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By
Gary W. Frasier
Raymond A. Evans

ESTABLISHING GRASSES BY IMPRINTING IN THE NORTHWESTERN UNITED STATES

M.R. Haferkamp[1], D.C. Ganskopp[1], R.F. Miller[2], F.A. Sneva[3], K.L. Marietta[4] and D. Couche[5]

ABSTRACT

Broadcasting seed and land imprinting was compared with broadcasting and chaining and drilling for establishing crested wheatgrass [Agropyron desertorum (Fisch. ex Link)] and bluebunch wheatgrass [Agropyron spicatum[6] (Pursh) Scribn. and Smith] in the northern Great Basin and Palouse Prairie. Land imprinting was most effective on loose or coarse textured soils.

INTRODUCTION

Drilling has conventionally been used to seed rangelands in the western United States. Planting with a drill provides uniform distribution of seed and proper depth of planting on firm seedbeds. On loose soils packing is usually required to achieve the degree of soil firmness needed for optimum control of planting depth, improved water holding capacity of the surface soil, enhanced capillary transfer of water to the seed, and optimum seed to soil contact (Hyder et al. 1955, Hyder and Sneva 1956, McGinnies 1962, Hyder and Bement 1969, Hyder and Bement 1970).

Broadcasting is employed where topography is too rough for drills to be used or where vast areas must be seeded, such as following large fires. Broadcast seeds are exposed to rapidly fluctuating moisture and temperature extremes and depredation by birds and rodents. Thus seed should be covered with soil when possible (Nelson et al. 1970, Goebel 1978). Chaining and other methods have been used to cover broadcast seeds (Vallentine 1980, Luke and Monsen 1984).

The land imprinter (Dixon and Simanton 1980, Anderson 1981) and the imprinting revegetation system (Dixon 1982) appear to be effective for covering broadcast seed and for creating microdepressions to reduce runoff. Results from imprinting have been variable in the southwestern United States, where much of the precipitation occurs as intense summer rains (Dixon 1980, Tye 1980, Dixon 1983, Dale 1985, Cox et al. 1986). In that environment, retention of water is critical to provide adequate moisture for seed germination and seedling establishment.

Prior to 1982, data comparing the imprinter to other commonly used equipment were lacking in the northwestern United States. One exception was a study initiated following a wildfire in Utah in October 1981 to compare the effectiveness of broadcasting seed and imprinting to drilling (Clary and Johnson 1983, Clary and Wagstaff 1987). To fill this information void a series of studies was initiated to compare effectiveness of broadcasting seed and land imprinting with broadcasting before chaining and drilling for fall planting cool-season grasses on a variety of seedbeds in the Palouse Prairie and northern Great Basin.

METHODS

Palouse Prairie

A study was initiated in 1982 to evaluate reestablishment of weeds and establishment of Nordan crested wheatgrass and Secar bluebunch wheatgrass following seedbed preparation on ash covered rangelands in the Palouse Prairie (Haferkamp et al. 1985). The study site located 43 km east of Ritzville, Washington, is representative of areas receiving a 5-cm deposition of ash of silt loam texture from the Mount St. Helens eruption occurring in 1980. Soils are in the Benge series, silt loam in texture, and occur on 0-15% slopes. Elevation is 560 m, and over 50% of the annual 31 cm of precipitation occurs during November through February. Vegetation consists mainly of annual grasses, forbs and bluegrasses (Poa spp.) with scattered plants of bluebunch wheatgrass and Thurber needlegrass (Stipa thurberiana Piper). Dominant annual grasses include downy brome (Bromus tectorum L.) and Ventenata dubia (Leers) Coss.& Dur.

Seedbeds were prepared by several techniques listed in Table 1. Crested wheatgrass seed was planted at 6.7 kg pure live seed (PLS)/ha with a rangeland drill equipped with single-disk openers and 25-mm depth bands or broadcast after plots were rolled with a water-filled land imprinter (2 m wide, 1-m diameter, 10-cm pattern depth, 4.1-Mg weight). Bluebunch wheatgrass seed was planted at 7.0 kg PLS/ha with the rangeland drill or by broadcasting before or after plots were rolled with the imprinter. All plantings were made in October 1982.

[1]Range Scientist, USDA-ARS, Eastern Oregon Agricultural Research Center, Squaw Butte Station, Star Rt. 1, 4.51 Hwy. 205, Burns, Oregon 97720.

[2]Associate Professor, Oregon State University, Eastern Oregon Agricultural Research Center, Squaw Butte Station, Star Rt. 1, 4.51 Hwy. 205, Burns, Oregon 97720.

[3]Range Scientist (retired), USDA-ARS, Eastern Oregon Agricultural Research Center, Squaw Butte Station, Star Rt. 1, 4.51 Hwy. 205, Burns, Oregon 97720.

[4]Research Assistant, Oregon State University, Eastern Oregon Agricultural Research Center, Squaw Butte Station, Star Rt. 1, 4.51 Hwy. 205, Burns, Oregon 97720.

[5]Range Conservationist, USDA-SCS, P.O. Box 195, Enterprise, Oregon 97828.

[6]Pseudoroegneria spicata (Pursh) A. Love has been proposed to replace the name Agropyron spicatum (Pursh) Scribn. and Smith (Barkworth et al. 1983)

Table 1. Seedbed preparation techniques applied on experimental range seeding plots in 1981 and 1982 east of Ritzville, Washington.

Undisturbed-Control
Herbicide
Spring applied
Glyphosate-1.12 kg/ha
Paraquat-0.56 kg/ha
12-month fallow
Atrazine-0.56 kg/ha
Disking
Spring
Fall
Burning
Summer
Fall
Summer Burning + Fall Applied Herbicide
Glyphosate-1.12 kg/ha
Paraquat-0.56 kg/ha

Treatments were replicated three times and arranged in a strip-plot design with seedbed preparation as main plots and planting method-species combinations as subplots. Each subplot measured 9 by 18 m. Success of treatments was evaluated by determining density of competing species in early May 1983 in 10, 15- by 15-cm quadrats per subplot and measuring frequency and density of crested and bluebunch wheatgrass seedlings in mid-June 1983 and plants in mid-June 1984 in 10, 30- by 60-cm quadrats per subplot. Analysis of variance was used to test the effect of seedbed preparation method and species-planting technique combinations. Mean separation tests were made using $LSD_{0.05}$.

Squaw Butte

A study was initiated in 1982 on a Wyoming big sagebrush (Artemisia tridentata wyomingensis Beetle)-Thurber needlegrass habitat type located on the Squaw Butte Experiment Station, 68 km west of Burns, Oregon (Haferkamp et al. 1987). Elevation is 1,372 m and the soils are mainly G..don Variant gravelly fine sandy loams (fine-loamy, mixed, frigid Orthidic Durixerolls) and some Ratto gravelly fine sandy loams (clayey, montmorillonitic, frigid, shallow Xerollic Durargids). The dominant shrubs, Wyoming big sagebrush and green rabbitbrush [Chrysothamnus viscidiflorus (Hook.) Nutt.], provide about 15% canopy cover (Doescher et al. 1984). Dominant grasses, squirreltail [Sitanion hystrix (Nutt.)J.G.Sm.], Sandberg bluegrass (Poa sandbergii Vasey), and Thurber needlegrass, provide 21.3% basal cover. Peak standing herbage production was 627 kg/ha in 1982, a wet year. Mean annual precipitation is 29 cm with peak accumula on occurring in the October to June period.

Seedbeds were either unprepared or prepared by mowing with a rotobeater (Vallentine 1980) or mowing plus disking. Mowing killed mature sagebrush plants and left a firm seedbed with live herbaceous and green rabbitbrush plants. Mowing plus disking killed most shrubs and herbaceous plants and provided a loose seedbed. Plot preparation in 1982 and 1984 included mowing and disking in August to destroy established plants, redisking in September after fall rains to destroy downy brome seedlings, and planting in October. Preparation by disking in 1984 followed a similar schedule but utilized plots that had been mowed in 1982. Soil water content at planting in the 0- to 5-cm depth on unprepared, brushbeat and brushbeat-disked seedbeds averaged 8.2, 9.9, and 8.1% of oven-dried weight in 1982; and 4.8, 4.2, and 6.2% in 1984, respectively. Soil water content at -1.5 MPa averaged 9.0%

Seeding methods included broadcasting in front of a water-filled imprinter, broadcasting after imprinting, drilling with a rangeland drill equipped with single-disk openers on 30-cm centers with 25-mm depth bands, and drilling with a rangeland drill equipped with deep-furrow openers on 60-cm centers. Nordan crested wheatgrass seed was planted at 6.7 kg PLS/ha in each plot planted by broadcasting or drilling with regular openers and 3.4 kg PLS/ha in plots planted by drilling with-deep furrow openers.

Four replications were arranged in a strip-plot design with years as main plots, seedbed preparation as subplots, and planting methods as sub-subplots. Each sub-subplot measured 15 by 30 m. Density and frequency of crested wheatgrass seedlings or plants were determined in 10, 30- by 60-cm quadrats per sub-subplot in September 1983 and August 1984 in the 1982 planting and in July 1985 and July 1986 in the 1984 planting. Canopy cover of shrubs and basal cover of other grasses were determined on both seedings by line intercept in 1985. Analysis of variance was used to test effect of years, methods of seedbed preparation, methods of planting and interactions. Mean separation tests were made using $LSD_{0.05}$.

Alkali Lake

A study was begun in 1983 following a wildfire in July, which removed most vegetative cover from a large area just south of Alkali Lake, Oregon (Ganskopp 1985). The soil is an Olson fine sandy loam (loamy mixed frigid shallow Xerollic Durargids). Wyoming big sagebrush and spiny hopsage [Grayia spinosa (Hook.) Moq.] dominate the overstory, with Indian ricegrass [Oryzopsis hymenoides (R.& S.) Ricker] and squirreltail as understory dominants. The annual precipitation is similar to Squaw Butte, with peak periods in fall, winter, and spring.

A helicopter broadcast a mixture of cereal rye (Secale cereale L.) at 15.7 kg/ha and Nordan crested wheatgrass at 7.8 kg/ha on the burned seedbed in October 1983. After broadcasting seed, three treatments were applied to the seedbed. These included: 1. Chaining, with a large anchor chain (22.7 to 31.8-kg links) stretched between two crawler tractors and pulled over the seedbed; 2. Imprinting with a land imprinter weighing 4.1 Mg; and 3. Untreated. Three replications were arranged in a randomized complete-block design. Each plot measured 50 by 100 m.

Success of treatments was evaluated in midsummer 1984 and 1985 by determining density of cereal rye, crested wheatgrass, and downy brome plants in 25, 30- by 60-cm quadrats per plot. Data were analyzed by analysis of variance and means were separated by $LSD_{0.05}$.

Fossil Beds and Diamond

Two studies were planted in fall 1985 to determine the effect of seeding rate on seedling and plant density for Nordan crested wheatgrass, Secar bluebunch wheatgrass, and T-2950 bluebunch wheatgrass. Plots were planted by broadcasting in front of a land imprinter or with a rangeland drill.

The Fossil Beds study site, a deteriorated Wyoming big sagebrush-bluebunch wheatgrass community, is located 11 km northwest of Dayville, Oregon. Soil is a Simas clay loam. Vegetation on the site prior to the study consisted of annual grasses and forbs including: downy brome, bur buttercup (Ranunculus testiculatus Crantz), wallflower mustard (Erysimum repandum L.), Jim Hill tumble mustard (Sisymbrium altissimum L.), and blue mustard [Chorispora tenella (Pall.) DC].

The seedbed was disked in April and again in June 1985. Secar bluebunch wheatgrass and T-2950, an experimental cultivar of bluebunch wheatgrass, obtained from the USDA Soil Conservation Service plant materials center, Aberdeen, Idaho, were planted in November 1985 by broadcasting seed on disked seedbeds and then rolling plots with an imprinter weighing 2.6 Mg. Secar was planted at 215, 430, and 645 PLS/m^2 (6.0, 11.9, and 17.9 kg PLS/ha), and T-2950 was planted at 215 PLS/m^2 (9.7 kg PLS/ha). Four replications were arranged in a randomized complete-block design. Each plot measured 17 by 22 m.

Bluebunch wheatgrass seedling density and frequency were determined in 10, 30- by 60-cm quadrats per main plot in early April 1986 and March 1987, weed seedling density was determined in 10, 30- by 60-cm quadrats per replication in late April 1986, and canopy cover of competing species was determined in May and June 1986. Weed standing crops were sampled in June 1986. Samples were harvested to ground level by clipping and oven-dried at 60°C for 24 hours before weighing. Data were analyzed by analysis of variance and means were separated by $LSD_{0.05}$.

An abandoned field located about 11.3 km northeast of Diamond, Oregon, was disked in May 1985, cultivated with a spike-tooth harrow (Vallentine 1980) in October 1985 to kill downy brome seedlings that had emerged following fall rains and planted in October 1985. The soil is an unclassified loam, and the annual precipitation averages 29.0 cm. Nordan crested wheatgrass was planted with a rangeland drill at 344 PLS/m^2 (9.5 kg PLS/ha) and broadcast in front of an imprinter at 172, 258, or 344 PLS/m^2 (4.7, 7.1, and 9.5 kg PLS/ha). The drill was equipped with single disk openers with depth bands, and the imprinter weighed 2.6 Mg. In an adjacent study, T-2950 bluebunch wheatgrass seed was broadcast in front of an imprinter at 215, 323, or 430 PLS/m^2 (8.8, 13.2, and 17.6 kg PLS/ha). In each study, four replications were arranged in a randomized complete block design. Each plot measured 20 by 30 m. Density of crested and bluebunch wheatgrass seedlings and plants were determined in 10, 15- by 30-cm quadrats per plot in mid-May 1986 and in late March 1987. In the Nordan study, data were analyzed by analysis of variance and means separated by $LSD_{0.05}$. T-2950 data were analyzed by regression analysis.

RESULTS AND DISCUSSION

Vallentine (1980) reported that on seeded foothill range in the Intermountain Region in the 28- to 33-cm precipitation zone, stands were evaluated based on the density of seeded plants. Stands were excellent when plant densities were greater than 8.0/m^2 and good if plant densities were between 5.5 and 8.0/m^2. These will be used as standards of comparisons in discussing the current studies.

Palouse Prairie

Precipitation for weather stations in the Palouse Prairie east of Ritzville, Washington, totaled 37 cm for October 1982 through June 1983 and 43 cm for July 1983 through June 1984. During both years precipitation was above average.

Burning seedbeds removed the dense layer of litter that was present on undisturbed seedbeds, while disking incorporated litter into the soil. Compared to control plots, density of annual forbs was significantly decreased by Atrazine fallow, fall disking, burning and summer burning + fall spraying (Table 2). Density of downy brome seedlings was significantly decreased by summer burning alone and summer burning combined with spraying. Summer burning was conducted when the majority of downy brome seeds were still held in the inflorescences, and fall spraying was conducted after downy brome seedlings had emerged. Density of other annual grasses, predominantly V. dubia, was increased significantly compared to control plots by most treatments except fall disking and burning. Past research has shown plantings of perennial forage species on downy brome ranges have often resulted in failures, mainly because of competition between seedlings and downy brome plants during the first growing season (Klomp and Hull 1972). Less is known about V. dubia, but phenologically it develops later

Table 2. Density of competing herbaceous species in 1983 on experimental seeding plots located east of Ritzville, Washington after seedbed preparation in 1981 and 1982.

		Seedbed Preparation Method								
		Herbicide			Disk		Burn		Summer Burn	
Species	Control	Gly.	Par.	Atr.	Spr.	Fall	Sum.	Fall	Gly.	Par.
	seedlings/m^2									
Annual forbs	879	959	787	611	757	441	603	464	403	583
Annual grasses	166	547	948	1224	611	271	602	296	527	509
Downy brome	240	172	255	321	255	202	90	205	37	36
Total	1285	1678	1990	2156	1623	914	1295	965	967	1128

$LSD_{0.05}$ = 237, for annual forbs.
$LSD_{0.05}$ = 359, for annual grasses.
$LSD_{0.05}$ = 126, for downy brome.

than downy brome, and thus may not compete as severely with emerging seedlings.

Emergence of Nordan seedlings was good the first summer after fall planting on a variety of seedbeds planted by drilling or broadcasting seed onto imprinted seedbeds (Table 3). Successful establishment of plants, however, occurred only from drilling on the burned and summer-burned + fall-sprayed seedbeds and from imprinting on the summer-burned + fall-sprayed seedbeds. Establishment from drilling on burned seedbeds was significantly better than on control, herbicide treated, or disked seedbeds, and when fall spraying was combined with summer burning, establishment was significantly increased over burning alone. Imprinting on summer-burned + Glyphosate-sprayed seedbeds resulted in significantly better establishment from broadcasting seed than occurred on other seedbeds. Establishment on summer-burned + Paraquat-sprayed seedbeds was significantly better than establishment on all but summer-disked seedbeds. Drilling resulted in significantly better establishment than imprinting on fall-burned and summer-burned + fall-sprayed seedbeds.

Table 3. Nordan crested wheatgrass seedling and plant density in 1983 and 1984 on experimental plots planted in fall 1982 east of Ritzville, Washington.

Year and Planting Method		Seedbed Preparation Method								
		Herbicide			Disk		Burn		Summer Burn	
	Control	Gly.	Par.	Atr.	Spr.	Fall	Sum.	Fall	Gly.	Par.
	seedlings/m^2									
1983										
Drill	1	5	8	3	7	7	19	22	41	46
Imprint	T[1]	1	1	1	5	12	17	3	23	20
	plants/m^2									
1984										
Drill	1	0	0	0	1	0	6	5	16	17
Imprint	0	0	1	0	1	2	3	1	10	5

$LSD_{0.05}$ = 12, between planting methods on same seedbed, 1983.
$LSD_{0.05}$ = 11, between seedbeds with same planting method, 1983.
$LSD_{0.05}$ = 4, between planting methods on same seedbed, 1984.
$LSD_{0.05}$ = 3, between seedbeds with same planting method, 1984.
1 T Less than 0.5

Secar seedling emergence and plant establishment followed a trend similar to Nordan with good emergence occurring on a variety of seedbeds planted by drilling or broadcasting and imprinting (Table 4). Successful establishment occurred with drilling on burned and summer-burned + fall-sprayed seedbeds. Imprinting resulted in establishment approaching good on fall-disked and summer-burned + Paraquat-sprayed seedbeds, but overall results were too variable to clearly determine the best seedbed-planting method combination for imprinting. Whether seeds were broadcast in front of the imprinter or onto imprinted seedbeds did not appear to affect success of establishment.

Plant densities usually decreased the second summer compared to seedling densities the first summer. This decrease in density was due in part to seedling mortality and the fact clustered seedlings counted as individuals in year one could not be identified as individuals in year two.

Drilled Nordan was more evenly distributed on fall-burned and summer-burned + fall- sprayed seedbeds and on disked seedbeds (Table 5). Frequency on imprinted seedbeds ranged from 40 to 73% with burning and burning + spraying and 47 to 77% with disking. Plants were less frequent the second summer. Nordan frequencies averaged 53 to 77% on fall-burned and burned + sprayed seedbeds planted by drilling and 50 to 70% on burned + sprayed seedbeds planted by imprinting. All other Nordan frequencies were less than 30%. Frequency of distribution of Secar seedlings and plants followed similar trends.

Table 4. Secar bluebunch wheatgrass seedling and plant density in 1983 and 1984 on experimental plots planted in fall 1982 east of Ritzville, Washington.

Year and Planting Method	Control	Herbicide Gly.	Par.	Atr.	Disk Spr.	Fall	Burn Sum.	Fall	Summer Burn Gly.	Par.
	seedlings/m^2									
1983										
Drill	2	6	6	2	8	4	30	28	37	44
Seed imprint	0	2	1	T[1]	4	13	9	5	12	8
Imprint seed	0	1	3	1	7	13	6	9	16	15
	plants/m^2									
1984										
Drill	0	0	T	0	T	1	7	6	10	14
Seed imprint	0	T	0	0	T	3	1	1	2	5
Imprint seed	T	T	0	T	T	5	1	1	4	3

$LSD_{0.05}$ = 12, between planting methods on same seedbed - 1983.
$LSD_{0.05}$ = 11, between seedbeds with same planting method - 1983.
$LSD_{0.05}$ = 4, between planting methods on same seedbed - 1984.
$LSD_{0.05}$ = 3, between seedbeds with same planting method - 1984.

Table 5. Frequency of distribution of Nordan crested wheatgrass and Secar bluebunch wheatgrass seedlings in July 1983 on experimental plots planted in October 1982 east of Ritzville, Washington.

Species and Planting Method	Control	Herbicide Gly.	Par.	Atr.	Disk Spr.	Fall	Burn Sum.	Fall	Summer Burn Gly.	Par.
	%									
Nordan										
Drill	13	50	70	43	60	53	67	90	100	97
Imprint	7	17	17	17	47	77	60	40	73	63
	%									
Secar										
Drill	20	43	40	37	53	43	83	87	100	100
Seed Imprint	0	23	13	7	37	53	57	50	77	60
Imprint Seed	0	17	20	17	60	77	37	73	90	83

These results demonstrate the well known positive relationship between successful plant establishment and planting seed into mineral soil on seedbeds where downy brome seedling density has been reduced. These conditions were met on the summer-burned and summer-burned + fall-sprayed seedbeds, where mineral soil was exposed by burning and downy brome seedling density was reduced to less than 90 seedlings/m^2 with summer burning and to less than 40/m^2 with burning combined with fall spraying.

The best explanation for increased establishment from drilling compared to broadcasting and imprinting on what appears to be the best prepared seedbed, summer-burned + fall-sprayed, is that drilling resulted in better seed distribution and seed to soil contact. When seed was planted by drilling on the firm-burned seedbed, planting depth was controlled by depth bands, and essentially all of the seed was planted into the furrows formed by the disk openers and covered with loose soil by pipes pulled behind each opener. In contrast, the water-filled imprinter was not heavy enough to allow full penetration and formation of 10-cm deep imprints. Instead only shallow grooves were formed by the outer edges of the angle iron welded to the outside of the metal cylinder. Thus, compared to drilling relatively more broadcast seeds were left exposed on the soil surface between the shallow grooves, and we speculate seed to soil contact was not optimum except possibly in grooves where seed was broadcast in front of the imprinter.

Squaw Butte

Fall precipitation was similar (8.6 and 8.0 cm) for the 2 planting years, but precipitation during winter, spring, and summer was 8.9, 10.8 and 4.9 cm in 1982-83 and 2.8, 5.5 and 2.0 cm in 1984-85. Basal cover of native grasses was significantly reduced from an average of 3.0% on unprepared and mowed seedbeds to less than 1.0% by disking after mowing. Canopy cover of shrubs was reduced from 13.0% on unprepared seedbeds to 4.0% with mowing and disking.

Significantly more seedlings emerged on mowed-disked compared to unprepared and mowed seedbeds planted by drilling with regular openers and broadcasting seed before or after imprinting (Table 6). On unprepared and mowed seedbeds, seedlings were more dense when seeds were planted by drilling with regular openers, but emergence on a per row basis was similar, 10/m^2, for the two drilling treatments since drilling with regular openers planted twice as many rows per plot as deep-furrow drilling (Table 6). Excellent stands of seedlings emerged on mowed-disked seedbeds planted by broadcasting seed in front of the imprinter. Broadcasting seed in front of the imprinter on this loose seedbed increased seedling emergence two and three times more than drilling with regular openers or broadcasting seeds onto the imprinted seedbed.

Averaged across years, significantly more plants were established by drilling with regular openers on mowed-disked compared to unprepared and mowed seedbeds (Table 6). As with seedling densities, plant densities/m^2 were greatest when seeds were planted by drilling with regular openers on unprepared and mowed seedbeds. In contrast to the first summer, plant densities were similar on mowed-disked seedbeds planted by broadcasting seed before imprinting and drilling with regular openers. Significantly more plants were established by these two techniques than by broadcasting after imprinting or deep-furrow drilling.

Seedlings were most evenly distributed on seedbeds prepared by mowing and disking and planted by regular drilling (88%) and broadcasting with imprinting (79-91%). Seedling distribution was intermediate on unprepared or mowed seedbeds planted by drilling (45-53%). Poorest seedling distribution occurred on unprepared and mowed seedbeds planted by imprinting (21-36%) and brushbeat-disked seedbeds planted by deep-furrow drilling (25%). Plant distribution the second summer was similar to seedling distribution the first summer. In general, plants were more evenly distributed in the 1982 seeding than the 1984 seeding, probably a result of more precipitation and better growing conditions in 1983 compared to 1985.

Table 6. Nordan crested wheatgrass seedling density the first summer after planting and plant density the second summer after planting on experimental range seeding plots planted in 1982 and 1984 on the Squaw Butte Experimental Range. Data are averaged across planting years.

Seedbed Preparation Method	Planting method: Regular Drill	Deep-furrow[1] Drill	Seed Imprint	Imprint Seed
	seedlings/m^2			
Unprepared	7	3	3	2
Mowed	8	5	3	1
Mowed-disked	16	1	30	10
	plants/m^2			
Unprepared	9	4	4	4
Mowed	9	5	5	4
Mowed-disked	19	2	18	11

$LSD_{0.05}$=7, between seedbeds with same planting method
$LSD_{0.05}$=6, between planting methods on same seedbed
$LSD_{0.05}$= 5, between seedbeds with same planting method
$LSD_{0.05}$= 6, between planting methods on same seedbed

The increase in seedling density with imprinting probably resulted from packing loose soil, improving seed to soil contact and planting more crested wheatgrass seeds at the proper depth. This supposition is supported by emergence of fewer seedlings on mowed-disked plots planted by drilling with regular openers and broadcasting seed after imprinting. More seedlings were also observed on ridges formed by the imprinter when seed was broadcast in front of the imprinter than when seed was broadcast onto the imprinted soil surface.

Reduced seedling emergence with imprinting compared to drilling on relatively firm seedbeds (no preparation and mowing) was due to poor penetration by the imprinter. On these seedbeds the imprinter was not heavy enough to form complete imprints. In contrast, furrow openers effectively removed competition in strips, and seed was planted into a firm seedbed and covered with loose soil. The requirement for reduction of competition for successful establishment of crested wheatgrass stands was obvious. Density of emerging seedlings was increased whether the reduction of competition resulted from furrow openers or disking.

Alkali Lake

High winds occurred on these plots, 5 days after seedbed treatments were applied, and blowing soil eliminated all visual evidence of imprinting or chaining. Precipitation from November 1983 through July 1984 totaled 23.4 cm, providing slightly less than normal moisture for developing seedlings. Seedling and plant densities of cereal rye and crested wheatgrass were about four times greater on imprinted areas than on chained and untreated areas in 1984 (Table 7). However, all stands were considered excellent.

Densities of cereal rye tended to decrease over time and by 1985 and 1986 were similar on all seedbeds. Crested wheatgrass plants were about three times more dense on imprinted areas than on untreated and chained areas in 1985 and 1986. Density of downy brome plants declined in 1986 on imprinted areas supporting the densest stands of crested wheatgrass.

In this study timing, soils, and precipitation patterns probably were ideal for broadcast seeding since seeding was accomplished just before fall rains. The improved emergence from the imprint treatment was probably related to compaction of the loose seedbed and retention of this compaction even though imprint depressions and seed were covered by blowing soil. The importance of compaction was also evident on chained areas where seedling emergence was most prevalent where tractor tracks compacted and indented the loose mineral soil. Clary (personal communication) also reported good seedling emergence on imprinted plots following wind erosion in Utah.

Fossil Beds and Diamond

Precipitation during the Fossil Beds study totaled 22.0 cm for September through May 1985-86 and 15.0 cm for September through March 1986-87. Seedling density of bluebunch wheatgrass growing near Dayville, Oregon, determined in April when seedlings were in the 2- to 5-leaf stage, was excellent for all treatments (Table 8). Increasing the seeding rate from 200 PLS/m^2 to 600 PLS/m^2 significantly increased seedling density of Secar bluebunch wheatgrass, but this increased density may or may not be beneficial to the subsequent stand. Plant distribution was good (90 to 100% frequency) in all plots. These stands developed with weedy competition from bur buttercup, Jim Hill mustard, blue mustard, and downy brome.

Table 7. Seeding and plant density of cereal rye, crested wheatgrass and downy brome growing on experimental range seeding plots planted in October 1983 near Alkali Lake in Oregon.

		Seedbed Preparation Method			$LSD_{0.05}$
Species	Year	Unprepared	Chained	Imprinted	
		number/m^2			
Cereal Rye	1984	3	4	17	6
	1985	3	4	6	-[1]
	1986	1	1	1	-
Crested Wheatgrass	1984	8	9	48	35
	1985	10	13	39	21
	1986	9	12	33	5
Downy Brome	1984	6	4	4	-
	1985	41	20	21	-
	1986	21	20	4	-

[1]Means are not significantly different.

Density of competing species was 115/m^2 in April and by June canopy cover was estimated at 86% and standing crop averaged 5170 kg/ha. Plant densities were excellent for all treatments in March 1987. Although plant density increased with increases in seeding rate, the lowest seeding rate appears adequate for both Secar and T-2950.

Seedling emergence of Nordan crested wheatgrass at Diamond was excellent for all seeding rates and planting methods (Table 9). Significantly more seedlings emerged on plots broadcast with 344 PLS/m^2 and then imprinted compared to other treatments. By March 1987, densities of established plants averaged 27/m^2, but densities were similar between treatments. An average of 25, 42, and 41, T-2950 seedlings/m^2 emerged from seeding rates of 215, 323, and 430 PLS/m^2. Although more seedlings emerged from the two highest rates, the increase was not significant. By March 1987, 18, 18 and 26 plants/m^2 were established in plots planted with 215, 323 and 430 PLS/m^2. The linear relationship ($Y = 8.35 + 0.04X$) was significant ($p = 0.05$) with $r^2 = 0.34$. Seedling and plant distribution were very even with frequencies ranging from 80 to 100%.

Table 8. Density of Secar and T-2950 bluebunch wheatgrass seedlings the first summer and plants the second summer growing on experimental plots planted in fall 1985 on the John Day Fossil Beds National Monument located north of Dayville, Oregon.

Year and Accession	Seeding Rate (PLS/m^2) 215	430	645
	- - - - - - -seedlings/m^2 - - - - - -		
1986			
Secar	33	53	99
T-2950	51	-	-
	LSD$_{0.05}$ = 63		
	- - - - - - -plants/m^2 - - - - - -		
1987			
Secar	20	30	47
T-2950	17		
	LSD$_{0.05}$ = 6		

Table 9. Density of Nordan crested wheatgrass seedlings in May 1986 and plants in March 1987 on experimental plots planted in October 1985 west of Diamond, Oregon.

Year and Planting Method	Seeding Rate (PLS/m^2) 172	258	344
	- - - - - - - seedlings/m^2 - - - - - -		
1986			
Imprint	61	66	120
Drill	-	-	78
	LSD$_{0.05}$ = 40		
	- - - - - - - -plants/m^2 - - - - - -		
1987			
Imprint	23	26	30
Drill	-	-	29

Dixon (1982) suggested seeding rates with imprinting should be 1.5 times the rate used with drilling when the land imprinter was used as the primary method of seedbed preparation and seeding. Results from prior studies at the Fossil Beds National Monument (M.R. Haferkamp, unpublished data) suggested seeding rates of Secar bluebunch wheatgrass needed to be increased to greater than 200/m^2, while preliminary results from the imprinting study at Squaw Butte suggested seeding rates for Nordan crested wheatgrass could be reduced.

Results from the current studies indicate excellent stands of Secar and T-2950 bluebunch wheatgrass and Nordan crested wheatgrass seedlings emerged on disked plots. These results suggest that good to excellent stands may be established with even lower seeding rates than evaluated. This question needs to be addressed in other studies with variable soils and climatic conditions.

CONCLUSIONS

The land imprinter appears to be a useful implement used in combination with broadcasting seed for planting loose or coarse textured soils in the northern Great Basin. With the imprinter as with other types of roller or press wheel seeders (Beutner and Anderson 1944, Hyder et al. 1961, Hyder and Bement 1969, Hyder and Bement 1970, Marlatt and Hyder 1970, Vallentine 1980), loose soil can be firmed prior to or during planting, thus, improving seed to soil contact. Possibly even more important seeds will be planted at a more optimum depth. When working on firm soils, other techniques, i.e. drilling appear better, since full 10-cm imprints are not formed and much of the broadcast seed is left uncovered on the soil surface. The major benefits of forming full imprints are more of the seed broadcast in front of the imprinter will be pressed into the soil, improving seed to soil contact; deeper imprints provide emerging seedlings some protection from wind; and the rougher surface occurring with deeper imprints should enhance snow catchment and water infiltration compared to a smoother surface.

At one time, the land imprinter was proposed as a primary implement for seedbed preparation (Larson 1980). It is doubtful the implement can be used effectively without some prior method of seedbed preparation, designed to control competing vegetation in the northern Great Basin or the Palouse Prairie. Without control of competition, i.e. annual grasses (downy brome and V. dubia), perennial grasses (Sandberg bluegrass), or sprouting shrubs (green rabbitbrush) seedlings of seeded species may emerge in years of above average precipitation, but they may not persist, and stand productivity may be poor in future years.

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