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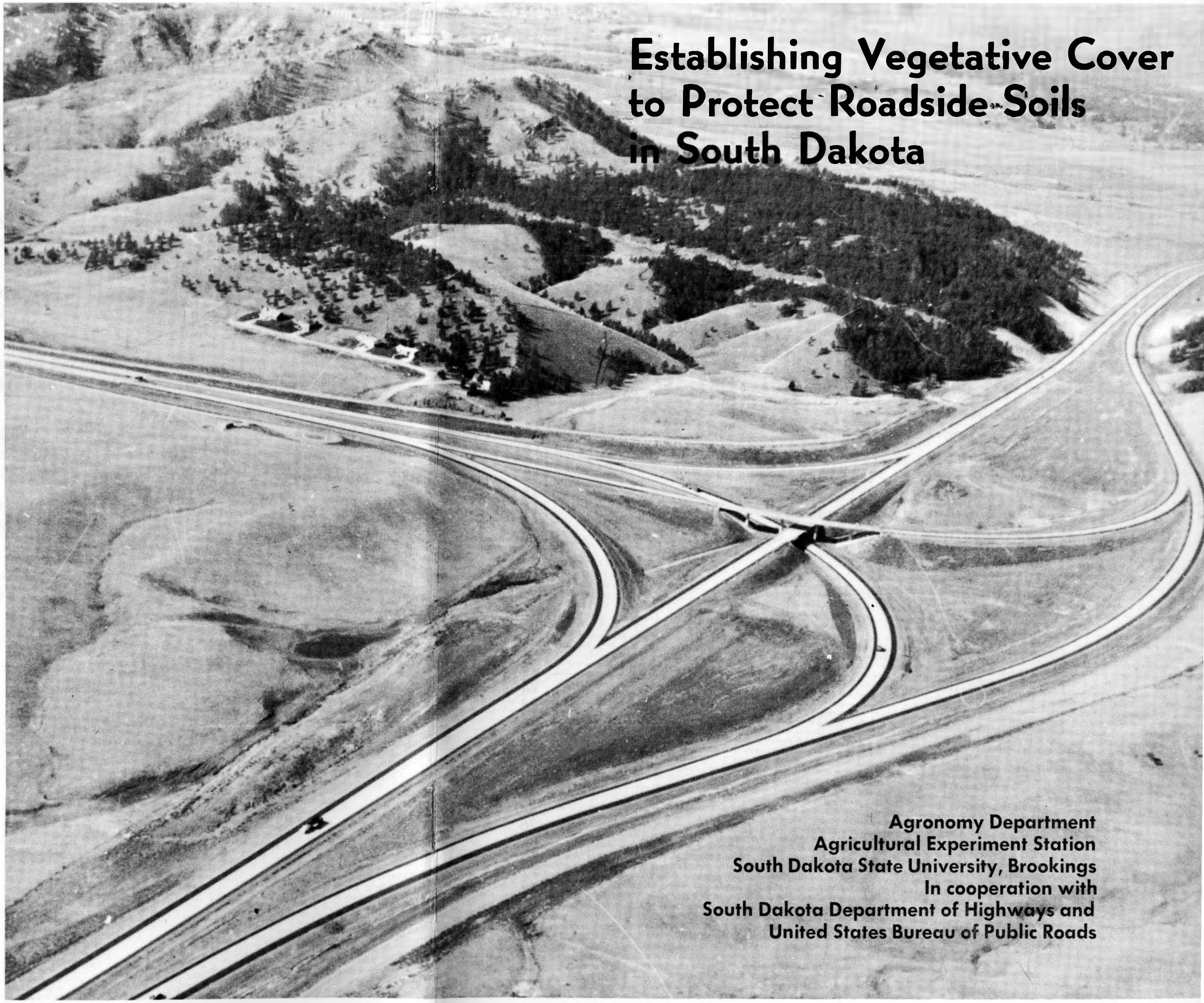

Three-level interchange on Route 90 near Rapid City, South Dakota.

Agronomy Department
Agricultural Experiment Station
South Dakota State University, Brookings
In cooperation with
South Dakota Department of Highways and
United States Bureau of Public Roads

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Establishing Vegetative Cover to Protect Roadside Soils in South Dakota

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SUMMARY

These factors of soil management in establishing vegetative cover to protect roadside soils were studied: (a) species of grasses and legumes, (b) date of seeding, (c) depth of seeding, (d) seedbed density, (e) companion crop, (f) fertilizer, and (g) straw mulch.

Of the grass and legume species individually tested on roadside soils at three locations, alfalfa and wheatgrass (particularly intermediate and pubescent) most consistently established stands. April seedings in field plots resulted in better grass stands than those in June, September, or October. In greenhouse pot studies the highest percentage of bluegrass seedlings emerged when seeds were planted ½ inch deep. Poor seedling establishment resulted from seeds placed on the soil surface. Intermediate wheatgrass emergence was greatest from ½-, ¾-, and 1-inch seeding depths; the 2-inch seeding depth and surface seedings produced inferior seedling stands. In other greenhouse studies, soil compaction in excessive amounts limited wheatgrass tillering and growth. However, the plants did not grow as well in loose soil as in firm or normal soil.

At two of three locations on roadside soils the use of a companion crop resulted in lower plant density and growth of perennial grasses. Perhaps the fast growing oats seedlings competed for the short supply of soil moisture to the disadvantage of the slow starting perennial grasses.

Both greenhouse tests and field studies showed a definite need for nitrogen and phosphorus fertilization of roadside soils in establishing vegetative cover. A reasonable

amount of fertilizer for subsoils seemed to be about 70 to 80 pounds per acre each of nitrogen and phosphorus. (An acre rate of 70 to 80 pounds of P is similar to 160 to 180 pounds of P_2O_5 per acre). Greenhouse studies suggested that smaller amounts of fertilizer were sufficient for topsoils.

Field use of straw mulch in establishing a stand of perennial grasses was not satisfactory. In all cases where cereal seedlings were allowed to develop from seeds contained in the straw mulch, perennial grasses were not established as well as on nonmulched areas. However, straw mulch maintained rate of water infiltration and decreased the amount of solids carried in runoff waters from steep, highly erodible subsoils.

A simple combination of soil management factors appeared satisfactory in establishing vegetative cover to protect subsoil materials along roadsides in South Dakota. That combination included: (a) soil loosened about 2 inches deep with a single pass of a cultivator with overlapping sweeps and (b) about 25 pounds of seed (including alfalfa and wheatgrasses, such as intermediate and pubescent) and 70 to 80 pounds each of nitrogen and phosphorus, e.g. 400 lbs. 18-46-0, applied per acre with a press drill with seed placed about ½ to 1 inch deep in the soil and the fertilizer dropped just ahead of the press wheel. Both the cultivator and press drill were operated along approximate contour lines. The seeding closely followed tillage and was completed in early spring.

INTRODUCTION

A vegetative cover has been the most practical protection against erosion of roadside soils. Since vegetation also has enhanced roads in safety and appearance, the establishment of a roadside cover has been a part of highway construction.

Topsoil has greater organic matter content, tilth development, fertility level, and seed content. As a result, it has been used more successfully than subsoil to produce a vegetative cover and stabilize roadsides from erosion. Costs of salvaging and spreading topsoil make it desirable to seek ways of satisfactorily establishing a vegetative cover on subsoil materials along roadsides.

Studies were conducted in 1962, 1963 and 1964 for the South Dakota Department of Highways by South Dakota State University. Included were laboratory, greenhouse, and field examinations of several representative South Dakota soils in respect to management requirements for establishing satisfactory plant cover on disturbed areas.

The scope of the study has been as outlined below.

A. Studied soil management requirements of disturbed areas to obtain satisfactory plant growth. Methods of approach:
   1. Investigated influence of straw mulch on establishing stands of some grasses and legumes.
   2. Compared various fertilizer treatments to determine soil fertility needs for optimum vegetative growth.
   3. Determined influence of seeding with and without a companion crop.
   4. Studied influence of seedbed density on seedling establishment after seeds were planted in soil materials of various levels of compaction.
   5. Determined optimum depths of planting various species after seeding at various depths in soil materials.
   6. Found influence of seeding date on seedling establishment by comparing results from seeding at various times of the year.

B. Studied performance of selected grasses and legumes to determine their relative effectiveness as ground cover for erosion control, considering ease of establishment and persistence.

BACKGROUND

Increased road construction and the resulting disturbed soil and newly exposed subsoil materials has aroused interest in improving methods of protection from erosion. A comprehensive bibliography (22) in 1960 showed most of this interest directed toward establishing vegetative cover on the soil materials.

Friday (9) pointed out that much of the available plant nutrient elements in soils were released primarily from the organic matter fractions and that only small amounts of organic matter were in roadside soils.

In establishing grass cover on subsoils as compared to topsoils, Schery (21) reported that well-fertilized subsoils usually did as well as topsoils. He recommended 20 pounds of 12-12-12 per thousand square feet for humid areas, but potassium was not recommended for drier areas such as parts of Kansas. Rose (19) demonstrated in Kansas that fertilizers were essential for establishing good stands of grass. He also showed the importance of using legumes to fix atmospheric nitrogen symbiotically so nitrogen would be supplied later for use by grass plants. In other work of reseeding eroded soils in Kansas, Launchbaugh (12) found that grasses responded to combinations of nitrogen and phosphorus. Peperzak (16) concluded that all backslope materials in Iowa were nutritionally poor and required adequate fertilization, usually nitrogen and phosphorus, in order to establish satisfactory vegetation. Both Ferguson (8) and Gibbs (10) reported soil fertility a most important factor in reducing erosion. Fertile soil allowed better growth of adapted vegetation and resulted in better cover and organic matter production.

Success in protecting highly erodible soils according to Astrup (1) and Blaser, *et al.* (3) depended upon use of adapted vegetative species. These reports indicated that indigenous grasses or mixtures of adapted grasses and legumes served best to stabilize slopes. Evidence by Dewey (6) and Rogers and Bailey (18) indicated pubescent wheatgrass and especially tall wheatgrass were tolerant to salt conditions such as in subsoils exposed during the road construction. Blaser, *et al.* (3) also suggested that the best times for seeding were during early spring or late summer. However, laboratory studies by McGinnies (14) showed that germination of six grass species was lower at high temperature, 30°C., than either moderate, 20° C., or low, 10° C. He also found that as moisture stress increased, germination was delayed and reduced and there was a strong interaction between temperature and moisture stress. Such results indicate that the best time to seed is in early spring when favorable soil temperature and moisture usually prevail.

In their survey of practices in most states, Butler and Yoerger (5) observed that machines which placed fertilizer 2 to 3 inches deep and seed ½ to 1 inch deep in the soil were more successful in establishing grass stands on roadside soils. They found that placing seed on the soil surface was not as satisfactory. This was substantiated by McWilliams (15) when best grass stands were obtained from seeding depths of ½ to 1 inch.

Blaser (4) suggested that a sparse stand of small grains was often desirable as it provided quick stabilization and protection against erosion while slower growing permanent grass seedlings became established. However, in another report Blaser and Ward (2) explained that temporary species with aggressive seedling development such as cereals and ryegrasses often crowded out the desirable permanent species with less aggressive seedlings;

immediately after seeding, the temporary species competed for light, nutrients, and moisture. This corresponded to an earlier statement by Schery (21). He recommended that when roadsides were seeded, nursegrasses (companion crops) not be used, for they always delayed establishment of the permanent grasses by robbing nutrients, water, and space. He concluded that in arid climates the vital ingredient in turf establishment was soil moisture and even a sparse stand of transpiring nursegrasses ruined establishment of permanent sod. This competition has been intensified with the use of fertilizer. In his study of establishing vegetative cover on backslopes in Iowa, Kulfinski (11) found oats, with increased fertility, to be inhibitory to legume cover. Application of 80 pounds each of nitrogen and phosphorus and 40 pounds of potassium per acre increased growth of oats and depressed initial legume cover.

There has been much discussion about the value of straw mulch. Since straw mulch usually should reflect more radiant energy than darker bare soil, the daily maximum soil temperature and evaporation rate of soil moisture should be lower under the straw mulch. Mannering and Meyer (13) found that straw mulching also: (a) reduced soil surface sealing or maintained a high rate of water infiltration and (b) decreased rainfall and runoff energy and thus reduced soil content in runoff waters. Steiner (23) and Diseker and Richardson (7) reported that the use of mulch over seedings often was the difference between success and failure and that mulch was necessary on steep slopes. Blaser (4) considered that mulches tended to assure succesful turf establishment. He stated that the more difficult the environment or moisture stress, the greater the benefits from surface mulching. Yet, he observed in some plots that much of the sod under straw mulch was made up of small grain seedlings. Too much small grain in the mulching material was harmful to the slower growing permanent sod species. Because of dense small grain stands in some straw mulches, desirable species were often exterminated.

The looseness or compactness of the seedbed in roadside soils has been considered to influence the establishment of grass cover. Few studies relating soil compaction to grass establishment have been reported. Using a silt loam material in 55 gallon drums Rosenberg and Willits (20) varied the bulk density from 1.07 to 1.35 $g./cm.^3$ They found that barley yields (forage and grain), oxygen diffusion, and hydraulic conductivity decreased with increased soil compaction. Revut *et al.* (17) found that compaction sharply decreased soil permeability to water and the rate of capillary saturation and these effects increased with increased clay content. They also showed in pot and field experiments that oat grain yield decreased with increased compaction (1.1 to 1.6 $g./cm.^3$) of fine textured soils but usually did not decrease in sandy loam.

MATERIALS AND METHODS

Soil sites were chosen as representative of the major soils of South Dakota. Number, site location, description, and tentative series name of the soil materials used in this study are recorded in table 1. Some of these soil materials were examined in the laboratory. Clay content, electrical conductance of saturation extract, cation exchange capacity, nitrogen content, water retention at various tensions, and specific surface were the properties determined for selected soils.

Straw Mulch

Field trials were conducted on soils 5, 8, 14, and 15 to determine the influence of straw mulch in establishing stands of some grasses and legumes. Plots with and without mulch were started June 11, 1963 on soils 14 and 15 at the Charles Mix County site. Individual plots were 7 feet wide and ran from top of backslope to road shoulder. Plots were randomized and repeated four times on both sides of the road, one side with an east aspect and the other a west-southwest aspect.

Seedbed preparation was one pass of a tractor-mounted, 7-foot cultivator set at a depth of about 2 inches. The cultivator had overlapping 12-inch sweeps.

A 7-foot press drill was used for seeding and fertilizing. The grass and legume seed mixture was placed in the grain box and fertilizer in the fertilizer box. The drill was adjusted to deliver about 100 pounds of 16-48-0 and 26 pounds of seed per acre. This rate of seeding supplied about 30 seeds per square yard each of white clover *(Trifolium repens)* and trefoil *(Lotus corniculatus)* and about 100 seeds per square yard each of intermediate wheatgrass *(Agropyron intermedium)*, western wheatgrass *(Agropyron smithii)*, Kentucky bluegrass *(Poa pratensis)*, creeping red fescue *(Festuca rubra)*, alta fescue *(Festuca elatior)*, brome *(Bromus inermis)*, and buffalo *(Buchloe dactyloides)* grasses. Seed was placed at a depth of about ¾ to 1 inch in the soil while fertilizer was dropped on top of the soil just in front of the press wheel.

On the mulch plots oat straw was spread at about 1½ tons per acre and a paper netting (Bemis-Mulchnet) was stapled over the straw.

Stand counts were made July 22, 1964. The number of grass, white clover, and trefoil plants were counted along 2 feet of four rows (4 square feet) at both top and middle of backslope for each plot. Rate of water infiltration and amount of solids in runoff water were measured during the summer of 1964 with a modified Purdue sprinkling infiltrometer. Observations* were made on nearly level topsoil above the backslope and on steep subsoil near the middle of the backslope, starting with both nearly dry soil and moist soil.

Some no-mulch plots were included in the 1964 field trials at both the Harding County and Lyman County sites.These plots were

*For detailed procedure see January 1966 *Agronomy Journal* for note by Dwight Hovland on "Sprinkling Infiltrometer, an Aid in Evaluating Roadside Plots."

prepared the same as treatment III plots (214 pounds 18-46-0 per acre) described under the fertilizer section except that the no-mulch plots were not covered with straw. Stand observations were made on these plots in June 1964 and during September or October 1964.

Fertilizer

Samples representing soils of South Dakota were studied in the greenhouse to determine which element essential for plant growth limited establishing and growing grass on these soils. Soils used were numbers 1, 2, 6, 9, 10, 11, 17, and 18, all listed in table 1.

Five-inch diameter, half-gallon pots of soil material were used to compare six treatments: (a) Complete Treatment, including Mo, B, Cu, Fe, Mn, Zn, Mg, S, K, P, and N-containing materials; (b) No N Treatment, similar to the complete treatment except no nitrogen material was included; (c) No P Treatment, similar to the complete treatment except no phosphorus material was included; (d) No K Treatment, similar to the complete treatment except no potassium material was included; (e) No Base Treatment, included only N, P, and K materials and included no Mo, B, Cu, Fe, Mn, Zn, Mg, and S materials; and (f) 0 Treatment, included no fertilizer materials. These treatments were repeated three times in individual pots on each of the eight soils, making a total of 144 pots.

Twenty-five intermediate wheat grass seeds were seeded in each pot and following seedling emergence the plants were thinned to 10 per pot. Individual pots were weighed and water was added to the soil about twice weekly. Plants were clipped, dried, and weighed three times at 6- to 7-week intervals. After each clipping the number of plants and tilllers were counted in each pot.

To separate the influences of fertilizer and clipping on grass tillering another small study was carried out in the greenhouse. Twelve pots of Soil 6, a Pierre-like material from Haakon County, were treated similar to the above experiment; six pots of soil received Complete Treatmentment of fertilizer (same as treatment "a" above) and six received 0 Treatment or no fertilizer (same as treatment "f" above). Twenty-five intermediate wheatgrass seeds were planted ¾ inches deep in each pot and soil moisture was maintained as described above. After seedling emergence they were thinned to 10 plants per pot; the grass in three fertilized and three nonfertilized pots of soil was periodically clipped back to the first green leaf. Four months after planting the grass, the number of tillers in each pot was observed and the grass in all 12 pots was clipped back to the first green leaf. Five weeks later the wheatgrass in all 12 pots was again clipped back to the first green leaf. Clippings were dried at 65° C. and weighed.

Three different fertilizer treatments were included in the field seeding at the Charles Mix County site June 11, 1963. One treatment was the same as the no-mulch plots at this site as described earlier un-

Table 1. Identification of Soil Used in This Study

No.	Site location	County	Series*	Topsoil or subsoil	Textural class
1	NE¼ sec. 16, T. 19 N., R. 18 E.	Perkins	Vebar	topsoil	sandy loam
2	NE¼ sec. 16, T. 19 N., R. 18 E.	Perkins	Vebar	subsoil	sandy loam
3	SW¼ sec. 30, T. 17 N., R. 5 E.	Harding	Vebar	topsoil	†
4	SW¼ sec. 30, T. 17 N., R. 5 E.	Harding	Vebar	deep subsoil	†
5	SW¼ sec. 8, T. 19 N., R. 5 E.	Harding	Vebar	deep subsoil	†
6	NE¼ sec. 26, T. 2 N., R. 20 E.	Haakon	Pierre	composite	clay
7	SE¼ sec. 24, T. 104 N., R. 76 W.	Lyman	Pierre	topsoil	†
8	SE¼ sec. 24, T. 104 N., R. 76 W.	Lyman	Pierre	deep subsoil	†
9	NE¼ sec. 36, T. 36 N., R. 36 W.	Bennett	Valentine	composite	†
10	SW¼ sec. 2, T. 113 N., R. 66 W.	Hand	Houdek	topsoil	loam
11	SW¼ sec. 2, T. 113 N., R. 66 W.	Hand	Houdek	subsoil	clay loam
12	NE¼ sec. 19, T. 107 N., R. 62 W.	Sanborn	Houdek	topsoil	†
13	NE¼ sec. 19, T. 107 N., R. 62 W.	Sanborn	Houdek	deep subsoil	†
14	SE¼ sec. 26, T. 95 N., R. 62 W.	Charles Mix	unnamed	topsoil	clay
15	SE¼ sec. 26, T. 95 N., R. 62 W.	Charles Mix	unnamed	deep subsoil	clay
16	SE¼ sec. 26, T. 95N., R. 62 W.	Charles Mix	unnamed	very deep subsoil	clay loam
17	NE¼ sec. 27, T. 105 N., R. 50 W.	Moody	Moody	topsoil	silt loam
18	NE¼ sec. 27, T. 105 N., R. 50 W.	Moody	Moody	subsoil	†
19	SW¼ sec. 24, T. 103 N., R. 50 W.	Minnehaha	Moody	topsoil	†
20	SW¼ sec. 24, T. 103 N., R. 50 W.	Minnehaha	Moody	deep subsoil	†

*Series name tentatively assigned to undisturbed soil.
†Textural class not determined but was similar to other members of same series; Valentine probably was sand.

der the straw mulch section; the fertilizer was spread on top of the soil just ahead of the press wheels. Another treatment was similar, however, the fertilizer was drilled with the seed (both fertilizer and seed were dropped into the double-disc openers of the press drill). A third treatment was also similar except that no fertilizer was used. Stand counts were made July 22, 1964, in the same way as for the straw mulch plots.

Field trials of application rates of 18-46-0 fertilizer were conducted on soils 5, 8, 13, and 20 in 1964. Tillage and seeding were done on the contour about midway between the top and bottom of the backslope with a north-northwest aspect at the Harding County site, south aspect at Sanborn County, and east aspects at each of the Lyman County and Minnehaha County sites. Individual plots were 2x10 feet; there were five rates of fertilizer application, two methods of fertilizer placement, and four replications for a total of 40 plots at each site.

Seedbed preparation was completed with a single pass of a 4-foot, tractor - mounted cultivator with overlapping sweeps and adjusted to loosen about 2 inches of soil material.

Seeding and fertilizing were done with a 4-foot pony press drill. Modifications of the drill allowed four rows (2 feet) to be seeded with the fertilizer spread on top of the soil just ahead of the press wheels, the remaining four rows were seeded with the fertilizer banded 1 inch below the seed. All the seed was planted 1 inch deep. About 27 pounds of a grass and alfalfa seed mixture were planted per acre (10 lb. bromegrass, 15 lb. intermediate wheatgrass, and 2 lb. alfalfa [*Medicago sativa*] per acre). Fertilizer rates used were, (I) no fertilizer, (II) 119, (III) 214, (IV) 387, and (V) 608 pounds of 18-46-0 per acre.

About 1½ tons of straw mulch per acre were stapled down with paper netting on all plots. Seeding dates were April 16 in Sanborn County, April 20 in Minnehaha County, April 22 in Harding County, and April 24 in Lyman County. Observations were made this first season wherever possible. By necessity (due to shortage of soil moisture and time for seedling development) some of these observations were not quantitative.

Companion Crop

Field plots at the Charles Mix County site were used to determine the effect of seeding grass and legumes with and without a companion crop. One treatment was similar to the no-mulch plots at this site described under the straw mulch section; the grass and legume seed mixture was used alone. Another treatment was the same as above except enough oats *(Avena sativa)* was added to the mixture so about ½ bushel per acre was seeded along with the grass and legume mixture. Stand counts were made July 22, 1964, in the same way as for the straw mulch plots.

Some companion plots were included in the 1964 field trials at both the Harding County and Lyman County sites. These plots were prepared similar to treatment III

plots (214 pounds of 18-46-0 per acre) described in the fertilizer section except that the companion plots were not covered with straw. Enough oats were included with the grass and alfalfa seed so about ½ bushel of oats per acre was planted. Stand observations were made on these plots in June 1964 and September or October 1964.

Soil Compaction

An examination of seedbed density was made under greenhouse conditions. Four - inch diameter, quart steel cans of soil were used to compare the various treatments. The necessary weight of soil was packed into the can to achieve the desired compaction or bulk density (volume-weight). The soils included were 1, 2, 6, 9, 10, 11, 17, and 18. The following soil materials and initial bulk densities were used to determine the influence of seedbed density on establishing a grass cover:

(a) Valentine 1.5g./cm.^{3}, (b) Vebar topsoil 1.2g./cm.^{3}, (c) Vebar topsoil 1.8g./cm.^{3}, (d) Vebar subsoil 1.2g./cm.^{3}, (e) Vebar subsoil 1.8g./cm.^{3}, (f) Pierre 1.1g./cm.^{3}, (g) Pierre 1.5g./cm.^{3}, (h) Pierre 1.8g./cm.^{3}, (i) Houdek topsoil 1.1g./cm.^{3}, (j) Houdek topsoil 1.5g./cm.^{3}, (k) Houdek topsoil 1.8g./cm.^{3}, (l) Houdek subsoil 1.1g./cm.^{3}, (m) Houdek subsoil 1.5g./cm.^{3}, (n) Houdek subsoil 1.8g./cm.^{3}, (o) Moody topsoil 1.0g./cm.^{3}, (p) Moody topsoil 1.5g./cm.^{3}, (q) Moody topsoil 1.8g./cm.^{3}, (r) Moody subsoil 1.0g./cm.^{3}, (s) Moody subsoil 1.5g./cm.^{3}, and (t) Moody subsoil 1.8g./cm.^{3}.

Each of these 20 treatments was repeated five times in individual cans for a total of 100 cans.

Twenty-five intermediate wheatgrass seeds were planted in each can of soil material. Cans were weighed individually about once every 2 days to maintain moist weight. Percentage emergence of intermediate wheatgrass seedlings was recorded 12, 15, 17, 19, 22, 24, and 29 days after seeding. Then the seedlings were thinned to five per can; 1 month later the grass was clipped, dried, and weighed. Three weeks after clipping the tillers were counted and following this the bulk density of each can of soil material was determined.

Depth of Seeding

Greenhouse and laboratory studies were used to determine optimum depth in soil for placing seeds. Soils used in this study were 6, 9, 11, and 18. They were put in 5-inch diameter, half-gallon pots. Six different depths of placing grass seed in soil were compared: (a) surface, (b) $\frac{1}{2}$-inch, (c) $\frac{3}{4}$-inch, (d) 1-inch, (e) $1\frac{1}{2}$- inch, and (f) 2-inch. These treatments were repeated three times, in individual pots for Kentucky bluegrass and for intermediate wheatgrass on four soils; this made a total of 144 pots.

Water was added to the soil material about twice weekly. Percent emergence of grass seedlings was recorded.

Seeds of the above Kentucky bluegrass and intermediate wheatgrass along with 10 other kinds of seed were germinated in the laboratory. Coleoptiles or hypocotyls were measured after maximum elongation. Average values of maximum elongation of bluegrass and wheatgrass coleoptiles were related to percent emergence of seedlings from different depths of seeding.

Date of Seeding

Field trials were conducted on soils 14 and 15 at the Charles Mix County site to determine the influence of seeding date on seedling establishment of some grasses and leggumes. Four dates of seeding were compared—April 16, 1963; June 11, 1963; September 6, 1963; and October 5, 1963. The June seeding was the same as the no-mulch plots at this site as described earlier under the straw mulch section. Other plots were seeded similarly on the other three dates. Stand counts were made July 22, 1964. Rate of water infiltration and amount of solids in runoff water were measured for the April and June seedings with a modified Purdue sprinkling infiltrometer during the summer of 1964. Observations were made on nearly level topsoil above the blackslope and on steep subsoil near the middle of the backslope both starting with nearly dry soil and starting with moist soil.

Species and Varieties

Selected grasses and legumes were compared as to ease of establishment under field conditions. On May 4, 1963, plots were started at the Charles Mix County site. Each of 17 plant species or varieties occurred three times in each of two blocks (one on each side of the road) for a total of 102 test plots. Individual plots were 18x18 inches. The plots were separated by 18-inch borders and were in single rows of 17 plots totaling 51 feet in length. One row of plots was above the backslope on the flat area, one near the center of the backslope, and the third at the bottom of the backslope. Soil material was excavated to the proper depth in each plot and 169 seeds were uniformly distributed over the pit bottom. The removed soil was uniformly spread over the seed and firmly packed. Fertilizer (16-48-0) was spread over the top of the plots.

Similar plots were started on soils 5 and 20 at the sites in Harding County and Minnehaha County in the spring of 1964. Twelve species and varieties were used with three replications for 36 plots in Minnehaha County and four replications for 48 plots in Harding County. At each site all plots were in one row just above the fertilizer plots near the center of the backslope. Planting procedure was similar to that used in 1963 except the fertilizer (18-46-0) was placed 1 inch below the seed.

Vegetative cover on all species and variety plots was observed during the summer of 1964.

RESULTS AND DISCUSSION

Some chemical and physical properties for selected soils are recorded in tables 2, 3, and 4. These properties helped in interpretation of other results. For example, when moisture contents of soils were plotted against moisture tensions, as in figure 1, it was appreciated how much these soils differed in amount of storage capacity for available water. Also, electrical conductance data indicated that deep subsoils derived from Pierre shale and glacial till were sufficiently saline to cause difficulty in establishing sensitive plants.

Straw Mulch

Stand counts of soil management plots in Charles Mix County are in table 5. Treatment F was compared with treatment D for observing the influence of straw mulch on establishing a vegetative stand. Plant density on the mulched plots was greater in all respects. There was almost twice as much vegetation on subsoil in the middle of the slope of the mulched plots when compared to nonmulched plots. These plots were seeded June 11, a late time for planting grass. Mulch may have helped by

Table 2. Clay Content, Specific Surface, Cation Exchange Capacity and Nitrogen Content of Selected Soils

Number	Description	Clay content	Specific surface*	Cation exchange capacity†	Nitrogen content
		%	$m.^2/g.$	me./100g.	%
1	Vebar topsoil	18	73	9.7	0.082
2	Vebar subsoil	11	77	9.7	0.043
6	Pierre composite	45	268	26	0.127
10	Houdek topsoil	24	166	16	0.173
11	Houdek subsoil	29	190	12	0.094
17	Moody topsoil	26	204	24	0.393

*Specific surface is the total amount of particle surface per unit mass of a substance. Bentonite from Belle Fourche, S. Dak. (A.P.I. Montmorillonite No. 27) has a specific surface of about 825 $m.^2/g.$

†Cation exchange capacity is a measure of the total amount of exchangeable cations that can be held by the soil. It is expressed in milliequivalents of cations per 100 grams of soil at neutrality (pH7). These exchangeable cations buffer or control soil pH, soil dispersion and availability of many plant essential elements. Values of 15 to 30 me./100g. are moderate. The abbreviation "me." is for milliequivalent which is the amount of a substance that will react with or replace 1.008 milligrams of hydrogen.

Table 3. Moisture Content of Selected Soils at Various Moisture Tensions

Number	Description	Moisture percentage at various moisture tensions (atmospheres)					
		0	1/20	1/3	1	3	15
1	Vebar topsoil	49	34	11	9.0	7.8	5.5
2	Vebar subsoil	48	32	10	8.4	7.5	5.4
3	Vebar topsoil	50	34	12	10	8.7	6.4
4	Vebar subsoil	49	25	10	....	8.5	6.6
7	Pierre topsoil	89	64	46	39	36	23
8	Pierre subsoil	85	56	40	31	....	21
10	Houdek topsoil	63	45	24	20	16	12
11	Houdek subsoil	68	42	21	19	16	11
12	Houdek topsoil	69	47	30	....	17	12
13	Houdek subsoil	55	34	23	20	13	8.9
19	Moody topsoil	65	49	34	20	17	11
20	Moody subsoil	57	42	32	18	15	10

Table 4. Electrical Conductance of Saturation Extract* from Selected Topsoils and Deep Subsoils

Tentative series name	Vebar		Pierre		Houdek		Unnamed		Moody	
Soil number	3	4†	7	8†	12	13†	14	15†	19	20†
Electrical conductance, mmho/cm.	0.3	0.6	1.1	3.3	1.1	3.4	0.8	4.5	0.4	0.4

*Electrical conductivity of saturation extract is a measure of soluble salts in soils. Usually conductivity values up to 2 mmho/cm. are negligible, however, sensitive plants do not grow well in soils with conductivity values greater than 4 mmho/cm. The mmho is a unit of electrical conductivity equal to conductivity of a body with resistance of one thousand ohms.
†Deep subsoils.

Table 5. Stand Counts of Plots in Charles Mix County

Treatment symbol	Seeding date	Special treatment	Plants* per 4 ft.² at top and middle of slope					
			Grass		Clover		Trefoil	
			Top	Mid	Top	Mid	Top	Mid
April 16	A	None	11.1	9.5	0.1	0.0	0.5	0.2
June 11	B	No fertilizer	9.4	8.0	0.0	0.0	1.2	0.0
June 11	C	Fertilizer drilled with seed	8.0	5.2	0.0	0.0	0.0	0.2
June 11	D	None	8.1	6.6	0.0	0.0	0.6	0.1
June 11	E	Companion crop	6.1	7.4	0.0	0.0	0.5	0.1
June 11	F	Straw mulch	10.9	12.0	0.1	0.2	1.2	0.4
Sept. 6	G	None	1.0	4.2	0.0	0.0	0.0	0.0
Oct. 5	H	None	0.2	1.7	0.0	0.0	0.1	0.0

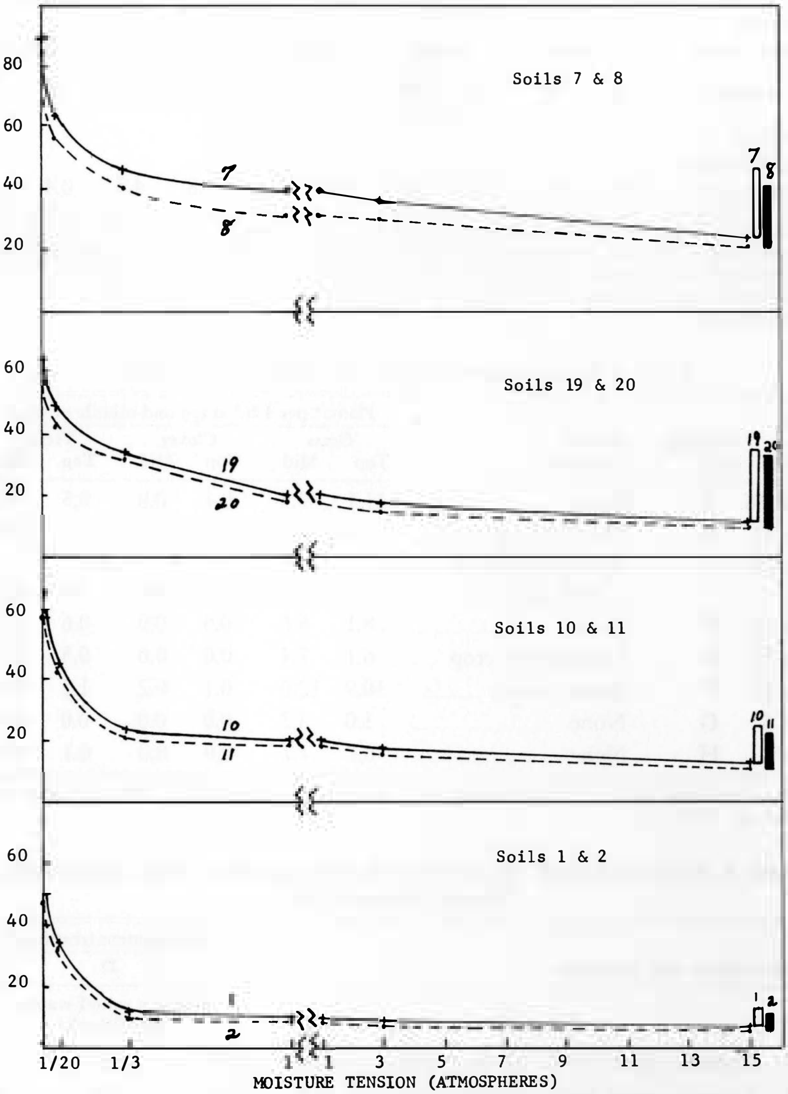
*Each value is the average of eight replications. Counts were made July 22, 1964, and plots were seeded in 1963.

Table 6. Solids in Runoff Water From Soil Management Plots, Charles Mix County, Summer 1964

Soil description and condition		Management treatments*		
		A	D	F
		Solids in runoff water, mg./50 ml.†		
I	Topsoil, nearly level, starting with dry soil	145	149	124
II	Topsoil, nearly level, starting with moist soil	145	160	127
III	Subsoil, mid-slope, starting with dry soil	246	267	143
IV	Subsoil, mid-slope, starting with moist soil	239	295	152

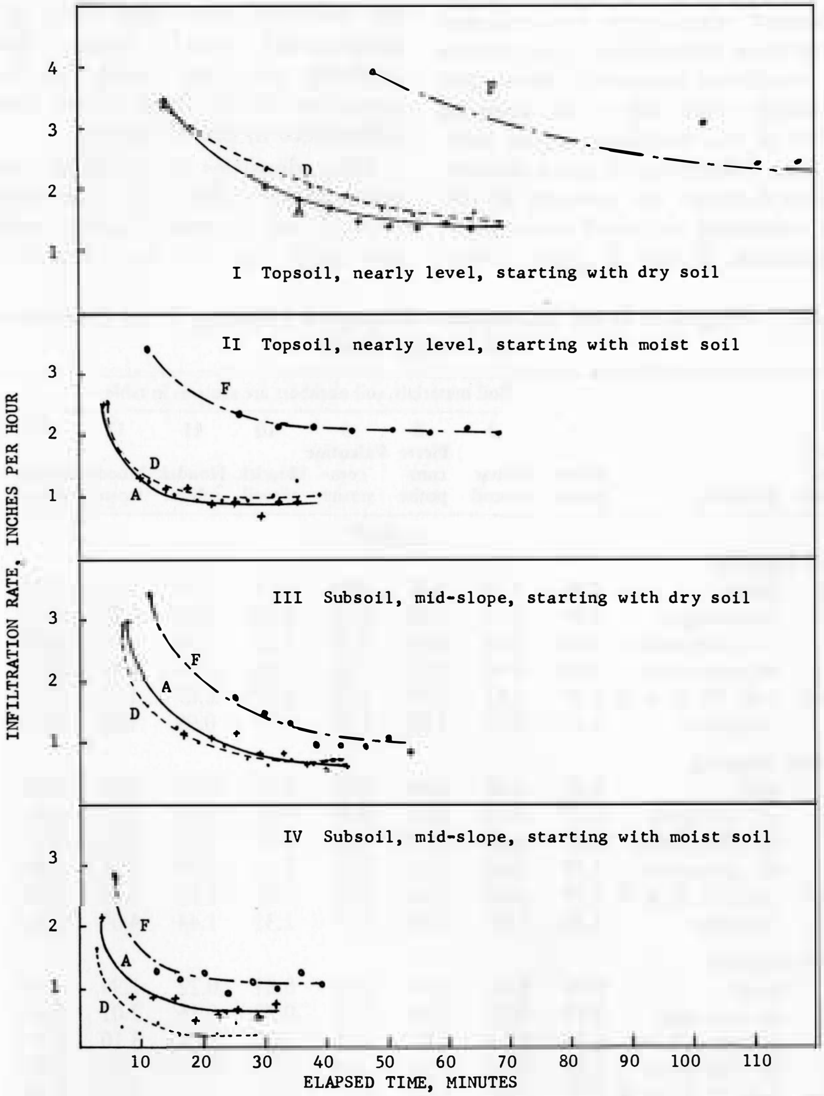
*Treatment code: A = April 1963 seeding, no mulch; D = June 1963 seeding, no mulch; and F = June 1963 seeding, straw mulch.
†Each value is the average of five replications.

Figure 1. Moisture retention* curves for selected soils. Bar graphs on right show available moisture range (⅓ to 15 atmospheres tension) for respective soils.



*Moisture retention on soil particle surface is by forces of adhesion, cohesion and surface tension. Moisture tension is equal to the amount of pressure required to just remove the outer part of the water film held to the soil particle surface. This moisture tension frequently is expressed in atmospheres with ⅓ atm. approximating moisture tensions when the soil is at field capacity of water retention and 15 atm. is similar to moisture tensions in soils at wilting coefficient. The amount of plant available water that a soil can hold is about the same as that amount of water held at tensions of between ⅓ and 15 atm.

Figure 2. Influence of three soil management treatments on the water infiltration rate* of roadside soils, Charles Mix Co., S. Dak., Summer 1964. (A = April 1963 seeding, no mulch; D = June 1963 seeding, no mulch; and F = June 1963 seeding, straw mulch)



*Water infiltration rate is the speed at which water enters surface soils. If this is lower than rainfall rate then runoff and erosion will result.

maintaining lower soil temperature, lower water evaporation and higher soil moisture content.

Water infiltration rates for treatments D and F are in figure 2. Infiltration was faster for mulched plots than nonmulched plots under all conditions measured; differences probably were due to the physical effect of the remaining straw rather than differences in plant density. Table 6 shows the amount of solids contained in runoff water from treatments D and F plots. These measurements were made at the same time and with the same apparatus as the infiltration determination. Under all conditions observed there was less erosion from the mulched plots than from the nonmulched plots. Again, this probably was due mostly to the protection of the straw rather than differences in plant density.

Plant densities in mulched and nonmulched plots in Harding County and Lyman County were low early in the first summer.

Table 7. Weights of Dried Intermediate Wheatgrass Clippings From Greenhouse Soil Fertility Study

		Soil materials, soil numbers are same as in table 1							
		1	2	6	9	10	11	17	18
Treatment symbol	Fertilizer	Vebar topsoil	Vebar subsoil	Pierre composite	Valentine composite	Houdek topsoil	Houdek subsoil	Moody topsoil	Moody subsoil
		g./pot*							
First clipping									
O	none	0.47	0.10	0.27	0.54	0.21	0.20	1.10	0.16
–N	no nitrogen	0.59	0.19	0.53	0.55	0.42	0.29	1.40	0.37
–P	no phosphorus	0.61	0.18	0.29	0.76	0.25	0.18	1.07	0.18
–K	no potassium	0.83	0.46	1.21	1.16	0.86	1.00	1.54	0.70
–base	only N, P, & K	0.85	0.52	1.12	1.16	0.73	0.87	1.43	0.71
C	complete†	0.82	0.55	1.32	1.29	0.72	0.99	1.68	0.79
Second clipping									
O	none	0.52	0.10	0.69	0.59	0.57	0.14	2.81	0.28
–N	no nitrogen	0.77	0.21	0.63	0.59	0.86	0.25	2.96	0.81
–P	no phosphorus	0.87	0.09	0.92	2.08	0.65	0.07	3.16	0.26
–K	no potassium	1.29	0.63	2.76	2.16	1.69	1.50	4.22	1.89
–base	only N, P, & K	1.59	0.69	2.56	1.66	1.51	1.72	4.25	2.33
C	complete	1.30	1.09	2.76	2.29	1.31	1.44	4.09	2.16
Third clipping									
O	none	0.56	0.16	0.37	0.36	0.84	0.22	1.94	0.48
–N	no nitrogen	0.45	0.11	0.30	0.33	0.77	0.16	2.01	0.43
–P	no phosphorus	1.25	0.14	1.07	2.31	1.22	0.18	3.10	0.49
–K	no potassium	1.78	0.73	2.59	2.39	2.52	2.17	3.47	1.87
–base	only N, P, & K	1.78	1.00	2.30	2.47	2.37	2.24	3.40	2.19
C	complete	1.79	1.46	2.26	2.64	2.03	1.88	3.74	2.28

*Each value is the average of three replications.
†Complete fertilizer included Mo, B, Cu, Fe, Mn, Zn, Mg, S, K, P, and N-containing materials.

There were fewer perennial grasses and alfalfa plants in mulched plots than in nonmulched plots. However, many cereal plants grew during the early part of the season in mulched plots. Straw contained the cereal seed. These fast starting cereals probably competed for soil moisture to the disadvantage of the slower starting perennials. Such results agreed with those reported by Blaser (4).

The soil in Lyman County was dry in the fall and very few seedlings remained green. Even after much difficulty with erosion and wildlife activity on the plots in Harding County the grass stand and vigor in the early fall appeared better on the nonmulched plots than on the mulched plots. In all cases where cereal seedlings were allowed to develop from seeds contained in the straw mulch, perennial grasses were not established as well as on nonmulched plots.

Fertilizer

Weights of dried intermediate wheatgrass clippings from the greenhouse soil fertility study are in table 7. On all soils, except perhaps Valentine (No. 9), wheatgrass yield was lower where no phosphorus fertilizer was used than where phosphorus was included in the fertilizer. Moody topsoil (No. 17), which was high in nitrogen content, was the only soil material that contained enough available nitrogen to satisfactorily supply the wheatgrass and this supply of available nitrogen in Moody topsoil became limiting after the first clipping. The data in table 7 showed no apparent shortage of soil potassium and plant nutrient elements other than nitrogen and phosphorus.

Table 8 shows the number of wheatgrass plants per pot in the greenhouse soil fertility study after three clippings. Throughout the growth period there was a substantial decrease in number of plants in individual pots for only one treatment on one soil material. This occurred with the Houdek subsoil (No. 11) which received no phosphorus in the fertilizer. In general, persistence of plants was good even with the severe clipping treatment.

The numbers of wheatgrass tillers per pot, in the greenhouse soil fertility study after three clippings, are recorded in table 9. With the exception of phosphorus on Valentine (No. 9) and nitrogen on Moody topsoil (No. 17), tillering of wheatgrass on all soils increased only when both nitrogen and phosphorus fertilizers were used. In general, vegetative cover of the soils became greater with the use of nitrogen and phosphorus fertilizers in combination. These findings corresponded to those reported by Peperzak (16) and Launchbaugh (12). Both showed the need for nitrogen and phosphorus fertilization for establishing grasses.

Since there was some question as to how much of the above tillering was due to clipping, another small greenhouse study was conducted. It was designed to separate influences of fertilizer and clipping on grass tillering. The results from this study are in table

10. Clipping had very little influence on tillering; however, with a complete fertilizer treatment, tillering increased by about four times. Dry weightes of the final clipping after the complete fertilizer treatment were about 12 times higher than where no fertilizer was used. Clipping appeared to decrease the vigor of the wheatgrass. During the final 5 weeks of the study, wheatgrass which had been clipped periodically produced less growth than wheatgrass which had been clipped only once.

Stand counts from the fertilizer plots (Treatments B, C, and D) at the Charles Mix County site are in table 5. There were no apparent differences in plant density due to this low amount of fertilizer and its method of placement except that poorer stands resulted where fertilizer was drilled with seed in saline subsoil in the middle of the slope (soil No. 15).

Table 8. Number of Intermediate Wheatgrass Plants Per Pot in Greenhouse Soil Fertility Study After Three Clippings

		Soil materials, soil numbers are same as in table 1							
		1	2	6	9	10	11	17	18
Treatment symbol	Fertilizer	Vebar topsoil	Vebar subsoil	Pierre composite	Valentine composite	Houdek topsoil	Houdek subsoil	Moody topsoil	Moody subsoil
		Plants per pot*							
After first clipping									
O	none	10.0	10.0	10.0	9.7	9.3	10.0	10.0	11.0
–N	no nitrogen	10.0	12.7	10.0	9.7	10.0	10.0	10.0	10.3
–P	no phosphorus	10.0	10.0	10.3	9.3	9.7	9.3	10.0	11.3
–K	no potassium	9.0	9.3	9.7	9.3	10.0	9.3	10.0	10.7
–base	only N, P, & K	9.7	9.7	10.0	9.3	10.0	10.0	10.0	11.0
C	complete†	10.0	10.3	10.0	9.3	10.0	10.0	10.0	10.3
After second clipping									
O	none	9.7	9.7	9.7	9.3	8.7	10.0	10.3	10.7
–N	no nitrogen	10.0	10.0	10.0	9.7	10.3	10.0	10.0	10.3
–P	no phosphorus	10.0	9.7	9.7	9.3	9.7	7.7	10.0	11.3
–K	no potassium	8.3	9.7	9.7	9.3	10.3	9.7	10.0	10.3
–base	only N, P, & K	9.7	9.0	10.0	8.3	9.7	10.0	9.7	10.7
C	complete	9.7	10.0	10.3	9.0	9.3	10.0	10.0	10.0
After third clipping									
O	none	9.7	9.7	10.0	9.7	8.7	9.7	10.3	11.3
–N	no nitrogen	9.7	9.7	9.0	10.0	10.0	9.3	10.3	10.3
–P	no phosphorus	10.0	9.7	9.7	9.3	9.0	7.3	9.3	11.0
–K	no potassium	8.7	9.3	9.7	9.3	10.0	9.0	10.3	11.0
–base	only N, P, & K	10.0	8.7	10.0	8.0	10.0	9.7	9.7	10.0
C	complete	9.7	10.0	10.3	8.7	9.0	9.3	10.3	10.3

*Each value is the average of three replications.
†Complete fertilizer included Mo, B, Cu, Fe, Mn, Zn, Mg, S, K, P, and N-containing materials.

Table 9. Number of Intermediate Wheatgrass Tillers Per Pot in Greenhouse Soil Fertility Study After Three Clippings

Treatment symbol	Fertilizer	1 Vebar topsoil	2 Vebar subsoil	6 Pierre composite	9 Valentine composite	10 Houdek topsoil	11 Houdek subsoil	17 Moody topsoil	18 Moody subsoil
		Soil materials, soil numbers are same as in table 1							
		Tillers per pot*							
After first clipping									
O	none	11.0	10.3	10.7	12.7	9.3	10.0	38.0	11.0
–N	no nitrogen	12.3	12.7	14.3	13.3	10.0	10.0	42.3	11.0
–P	no phosphorus	11.0	10.0	10.7	25.0	9.7	9.7	38.7	11.3
–K	no potassium	17.0	15.3	36.7	32.0	22.3	24.0	49.7	25.3
–base	only N, P, & K	23.7	16.7	39.0	31.0	18.0	25.3	48.3	25.7
C	complete†	17.7	20.7	40.3	35.3	15.7	28.3	50.7	25.3
After second clipping									
O	none	11.0	9.7	12.0	12.3	10.3	10.0	37.3	10.7
–N	no nitrogen	12.3	10.0	17.3	13.7	13.0	10.3	48.3	12.3
–P	no phosphorus	11.3	9.7	16.0	28.7	10.3	7.7	38.3	11.7
–K	no potassium	20.3	14.7	41.0	32.7	24.7	23.7	58.3	26.0
–base	only N, P, & K	26.7	13.3	42.3	29.3	21.7	27.0	50.7	30.0
C	complete	19.3	22.0	45.7	36.7	16.7	27.7	57.0	28.0
After third clipping									
O	none	11.3	9.7	12.7	12.3	13.3	9.7	37.7	12.0
–N	no nitrogen	12.0	9.7	15.3	12.7	13.0	9.3	46.7	12.3
–P	no phosphorus	17.3	9.7	18.7	32.3	18.0	8.0	41.3	12.7
–K	no potassium	30.7	19.7	46.7	36.7	37.0	31.3	56.7	31.3
–base	only N, P, & K	28.7	21.0	44.7	40.0	34.3	33.3	48.3	31.3
C	complete	24.7	30.7	49.7	42.0	27.3	29.7	55.7	29.0

*Each value is the average of three replications.
†Complete fertilizer included Mo, B, Cu, Fe, Mn, Zn, Mg, S, K, P, and N-containing materials.

Table 10. Influence of Fertilizer and Clipping on Tillering and Growth of Intermediate Wheatgrass on Pierre Soil (No. 6) in the Greenhouse

Treatment	Vegetative cover	Dry weights of final clipping
	tillers/pot*	g./pot*
No clipping and no fertilizer	11	0.24
Clipping and no fertilizer	12	0.19
No clipping and complete fertilizer†	47	3.07
Clipping and complete fertilizer	48	2.28

*Each value is the average of three replications.
†Complete fertilizer included Mo, B, Cu, Fe, Zn, Mg, S, K, P, and N-containing materials.

The 1964 field trials were conducted to better test grass response to rate of fertilization of roadside soils. When the Lyman County plots were observed there were very few perennial grasses and alfalfa plants growing in the mulched fertilizer plots. There was a very marked response of the cereal plants (seed from straw mulch) to the fertilizer. The soil (No. 8) at this site was dry during much of the growing season.

Even with adverse conditions at the Harding County site there was a definite response of perennial grasses to fertilizer. The numbers of plants and the growth and appearance of the plants were much better at the higher rates of fertilization. The 608 pounds per acre rate gave results similar to the 387 pounds.

At the Sanborn County site there appeared to be fewer perennial grasses where fertilizer was used. However, where the mulch did not completely cover the fertilizer plots, plant density was good. This undesirable effect of fertilizer might have been related to the vigorous competition of the cereal plants (seed from straw mulch) which responded markedly to the fertilizer. This was somewhat similar to Kulfinski's (11) observations where fertilizer increased oats growth and depressed initial legume cover. Later in the growing season (September 21, 1964) at the Sanborn County site vigor and growth of the perennials were much better after the high rates of fertilization than after the low rates. The 608 pounds per acre rate gave results similar to the 387 pounds.

Plant density and growth of pernial grasses at the Minnehaha County site improved with low rates of fertilization of the soil (No. 20). But the density and growth were less with high rates of fertilization than with the low rates. Where the mulch did not completely cover the plot there was more growth of perennials. Additional growth resulted from high rates of fertilization in the absence of mulch. Again, as at the Sanborn County site, this might have been related to competition of cereal plants (seed from straw mulch) which responded to the fertilizer.

Results comparing types of fertilizer placement were inconclusive.

Companion Crop

Stand counts from the companion plots at the Charles Mix County site were recorded in table 5. Treatment E with companion crop was compared to Treatment D, the control. There were no large differences between these two treatments in plant density of the perennials.

When companion plots were compared to no-companion plots at the Harding County and Lyman County site, plant density and growth of perennial grasses appeared better on the no-companion plots. The results at these two sites substantiated those experienced by several other investigators, including Blaser and Ward (2) and Kulfinski (11). Schery (21) suggested that in a dry climate the vital ingredient in starting the grass cover was soil moisture and even a sparse stand of the companion crop vigorously competed for the moisture

and the slow perennial grasses suffered.

Soil Compaction

Intermediate wheatgrass yield, cover (tillering), and rate of emergence from materials at different bulk densities in the greenhouse soil compaction study are given in table 11. As anticipated, it was difficult to establish or maintain any given bulk density for all soils. Soil moisture content and particle size distribution greatly influenced the closeness of fit of individual soil particles and thus to some extent controlled the variability of soil bulk density. Table 11 shows soil bulk densities established before seeding wheatgrass and bulk densities of the same soil materials after growing the wheatgrass. Bulk densities of fine textured soil materials decreased while maintained moist for plant growth. Bulk density of the compact Pierre soil (No. 6) decreased from 1.8g./cm.^{3} to 1.5g./cm.^{3}. This increase in volume (swelling) prob-

Table 11. Intermediate Wheatgrass Yield, Cover, and Rate of Emergence From Materials at Different Bulk Densities in the Greenhouse Soil Compaction Study

Soil materials				Percentage* emergence on days after seeding							Foliage yield	Plant cover
No.	Description	Bulk Density Initial	Bulk Density Final	12	15	17	19	22	24	29		
		g./cm.^{3}	g./cm.^{3}*								g./pot*	tillers/ pot*
1	Vebar topsoil	1.2	1.2	26	66	70	67	67	69	66	1.27	24
1	Vebar topsoil	1.8	1.7	30	64	66	66	66	70	67	1.25	25
2	Vebar subsoil	1.2	1.3	30	66	67	67	69	70	69	1.16	27
2	Vebar subsoil	1.8	1.7	29	67	66	65	66	67	66	0.65	19
9	Valentine composite	1.5	1.5	31	63	65	63	63	65	61	2.64	33
6	Pierre composite	1.1	1.0	0	35	46	61	69	67	70	2.55	32
6	Pierre composite	1.5	1.3	4	38	62	64	65	65	66	3.23	39
6	Pierre composite	1.8	1.5	2	41	69	62	63	63	62	2.02	34
10	Houdek topsoil	1.1	1.0	22	59	66	62	62	64	60	2.87	30
10	Houdek topsoil	1.5	1.5	30	57	64	65	64	65	62	3.07	32
10	Houdek topsoil	1.8	1.6	2	57	60	65	62	65	64	1.16	19
11	Houdek subsoil	1.1	1.1	6	53	58	59	62	63	62	2.36	33
11	Houdek subsoil	1.5	1.5	14	58	60	62	62	61	62	2.53	31
11	Houdek subsoil	1.8	1.7	13	53	54	53	54	55	56	0.95	23
17	Moody topsoil	1.0	0.9	18	50	54	58	66	63	65	2.85	47
17	Moody topsoil	1.5	1.4	21	63	63	66	65	65	65	3.08	45
17	Moody topsoil	1.8	1.5	2	66	69	69	63	68	68	0.72	18
18	Moody subsoil	1.0	1.0	8	38	49	48	53	54	53	2.31	30
18	Moody subsoil	1.5	1.4	2	31	38	39	41	42	51	2.37	29
18	Moody subsoil	1.8	1.7	6	41	45	46	47	47	48	0.95	15

*Each value is the average of five replications. Percentage emergence of 100 is equivalent to the development of 25 seedlings from the 25 seeds used per pot.

ably was associated with water adsorption on intercrystal faces of clay.

Soil compaction had very little influence on seedling emergence. Variations in soil density did not occur above the seed since soil was disturbed to plant the seed and soil placed over the seed was packed similarly in all pots. So, the wheatgrass coleoptiles were penetrating soils of similar compaction on all treatments. Planting grass with a press drill after simple tillage would produce like conditions.

Wheatgrass growth and yield of foliage were related to soil compaction. With most materials the greatest growth occurred on "normal" soils (bulk density of 1.3 to 1.5g./cm.^{3}) and the poorest growth on the "compact" soils (1.5 to 1.8 g./cm.^{3}). This was similar to results by Rosenberg and Willits (20) where they observed smaller forage yields of barley after compacting the soil.

On soils 2, 10, 11, 17, and 18 plant cover or number of tillers per pot was smaller on excessive compaction treatments (1.5 to 1.8 g/cm.^{3}) than on the "loose" (0.9 to 1.3 g./cm.^{3}) or on "normal" soils (1.3 to 1.5 g./cm.^{3}). All of these results supported the use of the press drill in the field; the drill press wheels restored a "loose," freshly prepared seedbed to firm or near "normal" conditions. As used in this report then, "loose" soil was similar to that in a freshly prepared seedbed; "compact" soil or excessive compaction compared to that resulting from repeated traffic or passage of machinery, particularly while soil was wet; and "normal" or firm soil was like undisturbed soil or soil following the passage of a drill press wheel over a seed row.

Depth of Seeding

Percentage emergence of Kentucky bluegrass and intermediate wheatgrass from six seeding depths in four soil materials are recorded in tables 12 and 13. Of the six depths (surface, ½, ¾, 1, 1½, and 2 inches) maximum number of bluegrass seedlings emerged from seed placed ½ inch deep in all soils. Emergence of wheatgrass was about the same from ½- and ¾-inch deep seedings and nearly as many seedlings emerged from 1-inch seeding. Seedling emergence from depths greater than 1 inch was less. Seedling production from surface seeding was much less than when seeds were placed in the soil at shallow depths.

These results agreed with coleoptile elongation measurements in the laboratory. Table 14 shows coleoptile or hypocotyl elongation determined for some grasses and legumes. As expected, seeding depths much greater than maximum coleoptile elongation resulted in low percentage of seedling emergence. Poor results from surface seeding probably was related to drying of surface soil between waterings. Deeper soil remained moist and allowed continuous supply of water to seeds and seedlings.

Date of Seeding

Stand counts from the date of seeding plots at the Charles Mix County site are in table 5. Treatments A (April), D (June), G (September), and H (October)

should be compared. Plant density was greatest after the April seeding. Very few plants developed from the September and October seedings. Figure 2 and table 6 include infiltration and erosion data from the April and June seedings. There appeared to be no differences in rate of water infiltration between the soils seeded those dates. However, the runoff water from the steep subsoil near the middle of the backslope carried slightly more solids after the June seeding than after the April seeding. The slightly denser grass stand after the April seeding probably gave more protection to this erodible soil material.

Species and Varieties

Vegetative cover on the Charles Mix County species and variety plots was observed July 22, 1964. On the soil (No. 14) above the backslope on the nearly level area excellent cover was made by Emerald crownvetch *(Coronilla varia)* and it spread rapidly. Plants that

Table 12. Kentucky Bluegrass Emergence From Six Seeding Depths in Four Soil Materials

Soil materials		Seed	Percentage* emergence on days after seeding							
No.	Description	depth	19	24	28	31	35	39	42	47
		inches								
6	Pierre composite	surface	12	16	15	18	17	18	18	20
6	Pierre composite	½	20	25	29	30	30	30	30	30
6	Pierre composite	¾	9	17	21	26	26	26	26	26
6	Pierre composite	1	5	13	16	17	22	20	20	19
6	Pierre composite	1½	0	0	1	1	2	2	2	2
6	Pierre composite	2	0	1	1	1	1	1	1	1
9	Valentine composite	surface	6	9	9	10	13	15	15	17
9	Valentine composite	½	16	22	26	27	28	28	28	29
9	Valentine composite	¾	5	16	18	21	22	23	23	22
9	Valentine composite	1	0	6	7	9	9	9	8	8
9	Valentine composite	1½	1	1	1	1	1	1	1	1
9	Valentine composite	2	0	0	0	0	1	1	1	1
11	Houdek subsoil	surface	1	4	4	6	7	8	9	9
11	Houdek subsoil	½	12	19	22	24	24	26	27	28
11	Houdek subsoil	¾	1	8	10	12	12	12	12	12
11	Houdek subsoil	1	3	8	9	11	11	11	11	12
11	Houdek subsoil	1½	0	0	0	0	0	0	0	0
11	Houdek subsoil	2	0	0	0	0	0	0	0	0
18	Moody subsoil	surface	5	7	10	12	15	15	16	18
18	Moody subsoil	½	11	16	19	21	22	23	22	23
18	Moody subsoil	¾	1	6	8	9	10	10	10	10
18	Moody subsoil	1	0	1	2	2	2	2	2	2
18	Moody subsoil	1½	0	0	0	0	0	0	0	0
18	Moody subsoil	2	0	0	0	0	0	0	0	0

*Each value is the average of three replications. Percentage emergence of 100 is equivalent to the development of 100 seedlings from the 100 seeds used per pot.

gave good cover were slender wheatgrass *(Agropyron trachycaulum)*, pubescent wheatgrass *(Agropyron trichophorum)*, Travois alfalfa and Rambler alfalfa. Fair cover was produced by crested wheatgrass *(Agropyron cristatum)*, and Penngift crownvetch. Slight cover was given by sand dropseed *(Sporobolus cryptandrus)* and no cover resulted from redtop *(Agrostis alba)*, blue grama *(Bouteloua gracilis)*, sand lovegrass *(Erogrostis trichodes)*, reed canarygrass *(Phalaris arundinacea)*, Kentucky bluegrass, or green needlegrass *(Stipa viridula)*. Hairy vetch *(Vicia villosa)* produced good cover in 1963 but there was no growth in 1964. Near the center of the backslope (soil No. 15) satisfactory cover resulted from only the wheatgrasses and alfalfas, particularly pubescent wheatgrass and Rambler alfalfa. Results at the bottom of the slope (soil No. 16) were similar except that Emerald crownvetch gave a fair cover. These soils were saline (see soil No. 15 in table

Table 13. Intermediate Wheatgrass Emergence From Six Seeding Depths in Four Soil Materials

Soil materials		Seed	Percentage* emergence on days after seeding						
No.	Description	depth	6	7	8	9	11	15	21
		inches							
6	Pierre composite	surface	11	19	21	35	43	50	71
6	Pierre composite	½	1	14	67	79	83	84	89
6	Pierre composite	¾	0	13	68	77	87	87	92
6	Pierre composite	1	0	4	59	79	79	79	91
6	Pierre composite	1½	0	0	10	37	47	57	52
6	Pierre composite	2	0	0	1	13	53	54	66
9	Valentine composite	surface	8	11	12	23	31	42	53
9	Valentine composite	½	2	31	67	71	83	86	89
9	Valentine composite	¾	0	23	55	73	80	83	85
9	Valentine composite	1	0	7	39	64	71	73	79
9	Valentine composite	1½	0	0	10	49	69	71	79
9	Valentine composite	2	0	0	0	26	41	45	58
11	Houdek subsoil	surface	5	11	13	17	21	36	65
11	Houdek subsoil	½	0	4	55	73	79	79	87
11	Houdek subsoil	¾	0	10	55	74	80	82	86
11	Houdek subsoil	1	0	3	45	69	73	76	81
11	Houdek subsoil	1½	0	0	7	38	55	58	68
11	Houdek subsoil	2	0	0	0	5	45	55	61
18	Moody subsoil	surface	11	21	23	31	37	46	66
18	Moody subsoil	½	2	21	67	76	82	84	86
18	Moody subsoil	¾	0	11	50	75	79	83	85
18	Moody subsoil	1	0	4	43	68	72	75	81
18	Moody subsoil	1½	0	0	3	45	64	65	78
18	Moody subsoil	2	0	0	0	1	21	35	43

*Each value is the average of three replications. Percentage emergence of 100 is equivalent to the development of 50 seedlings from the 50 seeds used per pot.

Table 14. Coleoptile* or Hypocotyl Elongation in a Dozen Grasses and Legumes

Kind of seed	Maximum elongation of coleoptile or hypocotyl		
	Range	Mean	
	mm.	mm.	in.
Kentucky bluegrass *(Poa pratensis)*	3-10	5.9	0.23
Redtop *(Agrostis alba)*	3-15	8.6	0.34
Sand lovegrass *(Eragrostis trichodes)*	9-24	15.5	0.61
Reed canarygrass *(Phalaris arundinacea)*	10-26	19.0	0.75
Green needlegrass *(Stipa viridula)*	11-28	19.4	0.76
Crested wheatgrass *(Agropyron cristatum)*	7-28	20.1	0.79
Crownvetch *(Coronilla varia)*	4-39	24.6	0.97
Pubescent wheatgrass *(Agropyron trichophorum)*	9-44	25.0	0.98
Intermediate wheatgrass *(Agropyron intermedium)*	15-36	26.4	1.04
Slender wheatgrass *(Agropyron trachycaulum)*	14-37	28.1	1.11
Alfalfa *(Medicago sativa)*	16-68	35.0	1.38
Hairy vetch *(Vicia villosa)*	24-99	56.2	2.21

*Coleoptile elongation refers to the lengthening of the first seedling leaf which grows pointed and strong and penetrates most soil crusts. Seedling depths much greater than maximum coleoptile elongation usually result in poor seedling emergence.

4) and the tolerance of pubescent wheatgrass under these conditions substantiated findings by Dewey (6) who observed that in saline soils tall wheatgrass *(Agropyron elongatum)*, and pubescent wheatgrass germinated and grew best of 25 strains of *Agropyron*. Unfortunately tall wheatgrass was not included in this study to demonstrate its tolerance to saline soils.

Following the planting of species and varieties at the Minnehaha County site the soil (No. 20) became and remained unusually dry far into the growing season. Plots at the Harding County site (soil No. 5) were subjected to much water erosion and wildlife grazing. Even under such severe conditions some of the plants produced a fair cover the first season. Fair cover was given at both sites by buffalo grass, pubescent wheatgrass, and intermediate wheatgrass; at Minnehaha County, Rambler and Teton alfalfa; and at Harding County, alta fescue and bromegrass. Hairy vetch completely covered its plots in Minnehaha County.

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