SEED- AND PLANT-SOIL RELATIONS AS AFFECTED BY SEEDBED FIRMNESS ON A SANDY LOAM RANGE LAND SOIL[1]

Donald N. Hyder and Forrest A. Sneva[2]

(Mimeograph of reprint from Soil Science Society of America Proceedings)
Vol. 20, No. 3, July 1956
Pages 416-419

ABSTRACT

Seed-soil and plant-soil relations were observed on a sandy loam soil given various mulching and firming treatments. Special emphasis was given to soil moisture trends.

The soil is sandy loam to a depth of about 12 inches where a semi-permeable B horizon is found. Plant roots penetrate the B horizon and extend through the underlying layer of sand to a depth of 3 feet where a caliche hardpan is encountered.

Rolling to firm the seedbed provided advantages in moisture retention, rate of seedling emergence, seedling growth, survival, lateral root distribution, and the occurrence of root hairs near the surface. Heavy rolling above the seed was undesirable in terms of mechanical restriction to emergence, soil aeration and subsequent restriction to germination under continued precipitation, number of primary roots, and lateral root distribution when cleavage lines were encountered.

A soil mulch above firm soil as obtained by rolling and shallow harrowing, and rolling in strips were especially beneficial in terms of moisture retention and grass survival.

---

[1]Technical Paper No. 925, Oregon Agr. Exp. Sta., Corvallis, Oreg. Presented before Div. V-A, Soil Science Society of America, Davis, Calif. Aug. 17, 1955. Received Sept. 2, 1955.

[2]Range Conservationists, Squaw Butte-Harney Exp. Sta., Burns, Oregon. Jointly operated and financed by the Bureau of Land Management, U.S. Dept. of the Int. and Oregon Agr. Exp. Sta.

Publications on range reseeding commonly state that a firm seedbed is essential, but offer few facts dealing with the application of that advice. Even though recommendations for rolling to firm the seedbed are found in the literature (1, 12, 13, 14), the practice is seldom used in range reseeding operations.

Range seeding failures are most often attributed to drought conditions; but site selection, elimination of competition, species and quality of seed, distribution and placement of seed, season of planting, and protection during establishment are critically important to seeding success. Attention has been given to the improvement of all phases of the seeding operation from site selection to protection during establishment. To reduce the risk of failure by drought, attention has been generally directed to elimination of competition, season of planting, and application of the preparatory crop method (3, 9).

The ideal seeding operation would plant the seed evenly at a uniform and proper depth immediately prior to the season when germination is desired. Practical considerations often justify late fall seeding in anticipation of spring emergence. Competition from other plants for moisture and nutrients would have been eliminated. For best germination, emergence, and growth, the optimum seed- and plant-soil relations would be attained. If moisture is abundant, a high macropore space is desirable, but if moisture is in short supply, attention must be directed to increasing the micropore space and the retention of moisture in the surface soil. Plowing increases macropore space, and is often the only operation employed in seedbed preparation for range seeding. It seems likely that soil firming operations could be devised to further reduce the risk of failure by drought.

Because of the need for clarification of the importance of a firm seedbed, research was initiated to find the value of rolling to seeding success as involved in seed- and plant-soil relations. The information should be of value in improving range reseeding operations on light textured soils, and in the development of seeding equipment more specifically suited to range conditions.

REVIEW OF LITERATURE

Among writers the relative importance attributed to seedbed firmness appears to vary greatly. Some writers omit the definition of practices deemed necessary to obtain soil firmness. Others advise that a plowed seedbed be given time for settling prior to seeding, but have not stated the degree of settling desired, or whether natural firming is adequate. Colbert[3] reported that settling for 18 months after plowing was not better than settling for 6 months, and on each of those seedbeds rolling increased grass density.

---

[3]Colbert, F. T. The effect of firming seedbeds on the emergence and establishment of four introduced species of *Agropyron*. M.S. thesis. Utah State Agr. College, Logan. Mimeo. (1950).

The preparatory crop method has been highly recommended because, among other things, the seedbed is firm.

In literature concerning the seeding of cultivated pastures, rolling to obtain seedbed firmness is commonly advised and practiced (4, 6, 8, 10). Nevertheless, the values to be gained are largely undefined.

Although largely empirical, it is known that the compactness of the soil can influence either directly or indirectly: depth of seeding, rate and uniformity of germination, seedling emergence, seedling establishment, root development and distribution, root-top ratio, yield of roots and tops, soil structure, moisture holding capacity, moisture transfer in the soil, evaporation, activity of soil micro-organisms, soil temperature, availability of nutrients, aeration, infiltration, and erosion. The sources of literature concerning those various topics are numerous, but they have been discussed with a thorough review of literature (Shaw *et al*. 11).

DESCRIPTION OF THE AREA

Squaw Butte Range is 40 miles west of Burns, Oregon, at an elevation of 4,600 feet. Average precipitation is about 11 inches, most of which falls in the form of snow.

The native vegetation is dominated by big sagebrush (*Artemisia tridentata*) with a variable understory of perennial bunchgrasses. Foremost among the bunchgrasses are Sandberg bluegrass (*Poa secunda*), squirreltail (*Sitanion hystrix*), Junegrass (*Koeleria cristata*), bluebunch wheatgrass (*Agropyron spicatum*), Thurber needlegrass (*Stipa thurberiana*), and Idaho fescue (*Festuca idahoensis*).

The soil is light textured (sandy loam by feel) to a depth of about 12 inches, where a semi-permeable B horizon is found. Even in the hardest portions, plant roots penetrate this zone of deposition, and extend through the underlying layer of sand to a depth of about 3 feet where a caliche hardpan is encountered.

The surface soil has essentially single-grain components. A composite sample of the surface soil taken after plowing had a wilting percentage (7) of 8.1% and a moisture equivalent (2) of 16.8% as shown in table 1.

Table 1. Moisture tension values in the surface 6 inches of soil.

Moisture tension (atmospheres)	Moisture content (percent)
0.05	37.7
0.1	26.2
(1/3)*	16.8
0.5	15.7
1	14.0
5	9.4
10	8.7
15 (wilting)	8.1

*Moisture equivalent.

EXPERIMENTAL PROCEDURE

A depleted sagebrush site was cleared 1 year prior to seeding on July 1, 1952 and June 2, 1953. The seedbed was firm underfoot and was harrowed about 2 inches deep to break the surface crust prior to seeding. Crested wheatgrass seed was broadcast from a grain drill box at a rate of 3 pounds per acre in 1952, and at 5 pounds per acre in 1953.

The time of seeding followed natural precipitation and when soil temperature was suitable for germination. Season of planting did not coincide with the common practice of late fall seeding.

Following broadcasting, the seed was covered by the following soil treatments: (a) harrowing to a depth of 2 inches or less, (b) light rolling with an 8-foot farm cultipacker weighing 1 ton, (c) heavy rolling with an 8-foot roller weighing 3 tons shown in fig.1[1/] left, (d) heavy rolling following by harrowing, and (e) strip rolling. In 1952 strip rolling was accomplished with the wheels of a pickup truck, and in 1953 was accomplished with equipment bearing concrete wheels 5 inches wide, 7 inches apart and weighing about 625 pounds per wheel as shown in figure 1[1/] right. Seed was dropped in front of the press wheels.

The 5 treatments were applied to plots 12 by 50 feet arranged in 4 randomized blocks. An area of undisturbed soil and vegetation was preserved adjacent to the plots for comparative study.

All sampling was conducted in the intervals between tractor tracks. On strip rolled plots, soil samples were taken in the pressed furrows.

Composite soil samples were taken from each plot for the determination of moisture content. In 1952 samples were taken from the surface 2 inches of soil from 8 to 10 a.m. In 1953 samples were taken from the surface inch of soil from 6:00 to 6:30 a.m. and 3:00 to 3:30 p.m.

[1/] Pictures in original reprint cannot be duplicated here.

Soil moisture samples were also takem periodically at 6 and 12 inches below the surface in 1953.

Samples of the surface 2 inches of soil were taken in 1953 for volume weight determinations. One random point was taken on each plot for a total of four samples per treatment. Four samples were taken on undisturbed soil.

A list count of emerged seedlings was obtained periodically on ten 5-square-foot permanent samples per plot. Due to surface soil temperatures in excess of 120°F. mortality was high in late July, 1952, and those plots were abandoned. Survival on 1953 plots was obtained in the spring 1954.

RESULTS

Soil Moisture

At seeding time on July 1, 1952, the soil was moist to field capacity below a depth of 2 inches. Rolling brought more moist soil to the surface 2 inches as shown in table 2. Differences among treatments remained fairly consistent throughout the period of study. Within 1 to 4 days, moisture levels had dropped below the wilting coefficient of 8.1%. It was believed that sampling at an earlier hour in the morning would have given better indications of seed-soil relations.

Table 2. Moisture trends in the upper 2 inches of soil during July 1952, as affected by treatments.

Time after seeding	Harrowed	Rolled lightly	Rolled heavily	Rolled heavily and harrowed	Strip rolled
(days)		(percent moisture)			
0	8.5	9.4	9.9	10.0	12.6
1	7.9	7.8	9.1	8.9	10.5
2	7.6	6.5	8.7	7.2	8.7
4	5.8	5.5	6.5	6.4	7.8
6	3.5	4.4	5.6	7.1	7.3
8	3.4	3.8	4.2	5.2	6.0
16	2.6	3.2	3.9	4.0	4.2
23	2.4	2.6	2.3	3.1	4.6

At seeding time on June 2, 1953, the soil was moist to field capacity throughout the top 2 feet or more. A composite sample of the surface inch of soil contained 12.2% moisture prior to seeding. Immediately after seeding, moisture levels were 10.5, 10.4, 12.2, 11.6, and 10.9% respectively for harrowed, lightly rolled, heavily rolled, heavily rolled and harrowed, and strip rolled soils. Precipitation interrupted the study of soil moisture trends in the first 16 days after seeding. On the 9th and 16th days after seeding, soil moisture samples were taken approximately 24 hours following cessation of rain. Differences in moisture content following those drainage periods were highly significant among treatments and the two dates gave similar results. The average moisture content retained in the surface inch of soil was 10.7, 11.1, 11.2, 12.8, and 13.5%, respectively for treatments in the order stated above. Harrowed soil held 2.6% of available moisture and strip rolled soil held 5.4%.

Moisture samples taken on and after the 16th day represent moisture trends without replacement by precipitation as shown in table 3. Strip rolled soil maintained the highest level of moisture; soil heavily rolled and harrowed maintained the second highest level. Within 6 days after precipitation (21st day after seeding), the harrowed soil was permanently below 7% moisture, and may have been permanently below the wilting coefficient within 4 days.

Although evaporation trends, as indicated by the changes in moisture from 6:00 a.m.to 3:00 p.m., appear different among treatments, with faster losses from harrowed soil, the differences in average daily losses were not significant. Those losses fluctuated directly with maximum daily temperatures and became of less magnitude as soil moisture decreased.

The amount of average gain in moisture overnight was highest for heavily rolled soil (2.5%), and lowest for the lightly rolled and the harrowed soil (1.9 and 2.0%, respectively). However, those differences were not significant at the 0.05 probability level.

When taken at 6 and 12 inches below the surface, differences in soil moisture among treatments were not significent at any time. Under the developing stands of grass, the moisture content at 6 inches dropped from an average of 18.9% on June 3 to 11.7% on August 4, and the moisture content at 12 inches dropped from 19.1 to 14.5%.

Table 3. Moisture trends in the upper 1 inch of soil during June 1953, as affected by treatments.

Time after seeding	Time of sample	Harrowed	Rolled lightly	Rolled heavily	Rolled heavily and harrowed	Strip rolled
(days)	(hour)		(percent moisture)			
9 & 16	*	10.7	11.1	11.2	12.8	13.5
16	3 p.m.	6.8	8.1	8.1	9.6	9.6
17	6 a.m.	9.7	10.4	11.4	11.8	12.3
17	3 p.m.	7.7	7.8	9.5	10.1	10.8
21	6 a.m.	6.8	8.6	9.0	9.9	11.1
21	3 p.m.	4.7	6.3	6.7	7.2	8.2
22	6 a.m.	6.8	9.2	10.0	10.6	10.5
22	3 p.m.	5.1	7.4	7.1	8.2	9.0
23	6 a.m.	6.5	7.3	8.2	10.1	10.0
27	3 p.m.	3.8	5.2	6.3	6.8	6.9
28	6 a.m.	5.1	7.8	8.5	8.4	9.3
28	3 p.m.	3.6	5.6	6.0	6.2	6.5

*Samples on the 9th and 16th days after seeding were obtained approximately 24 hours following cessation of rain.

Soil Density

In 1953 harrowed soil appeared to be well firmed by the unusually heavy precipitation, but was less dense than undisturbed soil. The weights of soils taken from the surface 2 inches were 1.13, 1.05, 1.08, 1.21, 1.19, and 1.07 g. per cubic cm., respectively, for soils undisturbed, harrowed, lightly rolled, heavily rolled, heavily rolled and harrowed, and strip rolled. The weight of 1.07 g. per cc. taken from pressed furrows of strip rolled soils is surprisingly light. Soil sloughing from ridges into pressed furrows is the most likely cause of the light soil weight with this treatment.

Volume weights were not significantly correlated with moisture values taken 24 hours after cessation of rain because the heavy rolling plus harrowing and strip rolling treatments provided gains in moisture retention that were not reflected by an increase in soil density. The effects of those treatments upon moisture exchange warrant more specific consideration than was given in this experiment.

Seedling Emergence and Initial Growth

In 1952 a greater number of seedlings emerged on soil heavily rolled and harrowed than on other soils as shown in table 4. Seedling stands were also satisfactory on heavily rolled soil, but other treatments were unsuccessful. The inadequacy of strip rolling was largely due to soil sloughing into pressed furrows as this covered the seed too deeply. Emergence appeared to be earlier on heavily rolled soil. Surface soil temperatures in excess of 120°F. caused rapid mortality of seedlings. Survival appeared stronger on strip rolled soil and heavily rolled and harrowed soil.

Table 4. Number of seedlings emerged in 1952 and 1953 as affected by treatments.

Time after seeding	Harrowed	Rolled lightly	Rolled heavily	Rolled heavily and harrowed	Strip rolled
(days)	(No. of seedlings/sq. ft. in 1952)				
7	0.1	0.1	0.3	0.3	0.1
9	0.4	0.3	0.9	2.8	0.2
12	0.6	0.3	1.3	3.9	0.3
18	0.7	0.3	1.7	4.3	0.5
18	L.S.D. among treatments = 0.4 seedling/sq. ft.				
	(No. of seedlings/sq. ft. in 1953)				
9	0.0	0.1	0.1	0.1	0.0
11	0.9	1.6	1.3	1.0	0.7
37	4.6	4.4	2.5	4.1	2.8
37	L.S.D. among treatments = 0.3 seedlings/sq. ft.				

All treatments resulted in good stands of grass under the favorable moisture conditions in 1953. Stands were least dense on heavily rolled and strip rolled soils. Emergence was later on harrowed and strip rolled plots than on those receiving other treatments. Seedlings on heavily rolled soil emerged from very shallow depths indicating the possibility of restricted germination due to poor soil aeration, and limited emergence due to mechanical restriction for those seeds planted deeper than 1/4 inch. Once again the weakness of strip rolling appeared to be due to soil sloughing which covered the seed too deeply.

As observed in August, 1953, the grasses growing in harrowed soil were decumbent with very few seed heads; whereas, those growing in soils heavily rolled and strip rolled were erect with an abundance of seed heads. Grasses growing in lightly rolled soil were decumbent like those in harrowed soil. Differences equally striking were found below the soil surface. Fewer main roots were found in heavily rolled soil than in harrowed soil, but the roots in heavily rolled soil were more widely distributed in the surface 6 inches. Hair roots occurred within the surface inch of heavily rolled soil, but were not prevalent above the 4-inch depth in harrowed soil. The heavy roller created occasional cleavage lines in the soil that were detrimental to root distribution.

Grass Survival in First Year

Differences among survived stands of grass seeded in 1953 were highly significant among treatments when adjusted by the density of seedling stands in analysis of covariance. Grass survival depended upon seedling density and soil treatment. Adjusted survival percentages were 39, 54, 52, 57, and 61%, respectively, for soil harrowed, lightly rolled, heavily rolled, heavily rolled and harrowed, and strip rolled. On harrowed and lightly rolled soils seedling density had less influence on survival rates than on soils given the other treatments.

Mean survived densities, as adjusted to the mean seedling density, are interpreted to represent the optimum grass densities under the conditions of this experiment. Adjusted mean survived densities were 1.41, 1.96, 1.91, 2.09, and 2.21 grasses per square foot, respectively, on soils treated in the order listed above.

Discussion and Conclusions

The most optimistic interpretation is that seeding failures caused by drought may be banned forever. However, the practical consideration of time required to complete seeding operations limits the choice of seeding time. For small area seedings, planting may be accomplished when soil moisture and temperature are satisfactory; with assurance of success even though subsequent precipitation does not occur.

Natural settling of the soil was not adequate even when an unusually high amount of precipitation fell. Soil firming operations improved seed-soil and plant-soil relations, but the effects noted were not all beneficial. In particular, firming above the seed was undesirable, and too much compaction created cleavage lines in the soil which affected root distribution. It is concluded that undisturbed soil represents near optimum soil density, and that a roller weight of 400 to 500 pounds per foot of axle will provide satisfactory firmness in a plowed seedbed.

Shallow harrowing to loosen the surface of firmed soils and strip rolling were especially beneficial in terms of moisture retention. Strip rolling seems especially applicable to range seeding conditions. Lighter wheel weights and wider treads than those used in this experiment would prevent soil sloughing and covering the seed too deeply. Attention is being given to the possibility of developing range seeding equipment which will plant the seed at a uniform depth in pressed furrows with firm soil below and loose soil above the seed. It is anticipated that as equipment development progresses seed-soil and plant-soil relations must be better defined; especially so with reference to moisture and nitrate availability.

Of special interest would be the definition of minimum moisture levels required for germination in soils receiving different degrees of compaction. In 1952 germination apparently occurred when moisture was available for less than 4 days. The mode of moisture transfer and its occurrence on other soils will be important in guiding equipment development and the application of the procedures defined. Moisture penetration was apparently restricted by the B horizon, and a reservoir was created from which moisture could rise by capillarity.

It is believed that stronger seedling vigor and decreased mortality found on firmed soils was an expression of improved nitrate availability resulting from the nature of moisture retention and root distribution. This phenomena warrants definition in its relation to grass establishment, yield, and the re-invasion of big sagebrush.

Literature Cited

1. Beutner, E. L., and Anderson, Darwin. A method of seedbed preparation and reseeding deteriorated range lands. Jour. Amer. Soc. Agron. 36:171-172 (1944).

2. Briggs, L. J., and McLane, J. W. The moisture equivalent of soils. U.S.D.A., Bur. of Soils Bul. 45:1-23 (1907).

3. Freidrich, C. A. Seeding crested wheatgrass on cheatgrass land. Montana Farmer. (March 1, 1945).

4. Hamilton, J. G., et al. Irrigated pastures for forage production and soil conservation. U.S.D.A., Farmers' Bul. 1973 (1945).

5. Hubbell, D. S., and Gardner, J. L. Effects of aeration, compaction, and waterlogging on soil structure and microflora. Jour. Amer. Soc. Agron. 40:832-840 (1948).

6. Klages, K. H. W., and Stark, R. H. Grass and grass seed production. Univ. Idaho Agr. Exp. Sta. Bul. 273 (1949).

7. Richards, L. A., and Weaver, L. R. Fifteen-atmosphere-percentages as related to the permanent wilting percentage. Soil Sci. 56:331-339 (1943).

8. Robertson, D. W., et al. Pasture and forage crops for irrigated areas in Colorado. Colorado Agr. Exp. Sta. Bul. 469 (1942).

9. Savage, D. A. Grass culture and range improvement in the central and southern Great Plains. U.S.D.A. Circ. 491 (1939).

10. Semple, A. T., and Hein, M. A. Good pastures. U.S.D.A. Farmers' Bul. 1942 (1943).

11. Shaw, B. T. et al. Soil physical conditions and plant growth. New York: Academic Press, Inc. (1952).

12. Sprague, H. B. Root development of Perennial grasses and its relation to soil conditions. Soil Sci. 36:189-209 (1933).

13. Stoddart, L. A. Grass plantings promise a new era on the range. Western Livestock Jour., Section 2 (Sept. 7, 1950).

14. Westover, H. L. Crested wheatgrass. U.S.D.A. Leaflet 104 (1934).