SOME FACTORS AFFECTING THE ESTABLISHMENT AND GROWTH OF IMPROVED FORAGE SPECIES ON LAUGHLIN-LIKE SOILS IN WESTERN OREGON

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SOME FACTORS AFFECTING THE ESTABLISHMENT AND GROWTH OF IMPROVED FORAGE SPECIES ON LAUGHLIN-LIKE SOILS IN WESTERN OREGON

INTRODUCTION

Approximately 1,400,000 acres of native foothill pastures surround the valleys of western Oregon (6, p.53). Many of these hill lands support a dense or open stand of white oak (*Quercus garryana* Dougl.), while some are denuded of tree cover because of burning practiced by Indians and early settlers (96). At present this type of agricultural land is considered to be marginal for crop production (92).

In the late years the number of productive and commercialized farms is decreasing in western Oregon. The causes for the decreasing agricultural land are: The increase of population; expansion in size of cities; for building sites, schools, industries; expansion and increase of communication and transportation means; increase of non-farming population in agricultural areas, etc.

The increasing of the population, the decreasing area of productive land, and the demand for more and better food supply in the future, all create the problem for more intensive use of less productive land. A large portion of this type of land in the area is suitable for growing timber and forage crops. Thus the pressure of the increasing population for food supply can be solved, partly, by bringing this marginal agricultural land under economic production.

The present investigation deals with one of the experiments started by the Oregon Agricultural Experiment Station in 1943 on Laughlin-like soils on the hill pasture area grazed by sheep near Corvallis. The purpose, of the original experiment, was to determine the establishment of 16 forage species under four different methods of preparing seedbeds.

In 1952 it was decided that in order to obtain a more thorough evaluation of the seeded species, data should be obtained on their abundance and production in relation to moisture and soil. Within this objective special attention was given to study:

1. Soil profile and some of the physical and chemical characteristics of it.

2. Moisture relationships and plant growth, that is, to find if the moisture of the soils especially during the summer period is critical in the establishment and growth of forage species.

3. Characteristics of the root development of the established species.

4. Forage composition and yield.

Based on the above findings, suggestions can then be made for future management practices for the most economical use of the area.

REVIEW OF LITERATURE

Ecology of the area. -- The Willamette Valley and the adjacent coast range foothills lie in the humid Pacific Coast division of the Transition Life Zone (64, p.4; 96) and within the cedar-hemlock climax of the Coast Forest (102, p.501). At the present time, the chief climax species, western cedar (Thuja plicata Donn.) and western hemlock (Tsuga heterophylla (Raf.) Sarg.), are not common in the area. Much of the region is covered by dense stands of Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) (64, p.4; 96).

Logging and forest fires favor the succession of fireweed (Epilobium augustifolium L.), bracken fern (Pteridium aquilinum L.) and blackberries (Rubus spp.). The next stage in succession is the investigation of the areas mainly by Oregon white oak and other hardwood trees. Douglas-fir gradually invades the hardwood stands and eventually supersedes the oak (64, p.6). The predominant shrubby species of the area is poison oak (Rhus diversiloba Tand. G.), while the common wild rose (Rose rubiginosa L.) invades the open grassland in advance of the tree growth (96).

Land use. -- The problem of returning these hill lands to a useful state has received much consideration from the standpoint of forage utilization, reforestation, and conservation (6). The climatic and soil factors of such areas are often well suited for grass establishment. However, because of the acid soil reaction, low organic matter and the loss of the essential soil nutritive elements, the areas become less advantageous for the establishment of improved forage species (20). To convert forest land to grassland, man works against nature and the prevention of the succession to oak and other trees and shrubs after some period of time, cannot be avoided (74).

Collins (25), working in the same general experimental area but on a different soil series, reports that such pastures are invaded by woody species. As Oregon white oak favors the establishment of Douglas-fir, he suggested that slashing and burning to clear the land before planting the improved species would help in their establishment.

Gorton (35) reports that pastures on the hill lands of the Willamette Valley were grazed principally by sheep, goats, and beef cattle. Pastures that had been seeded to mixtures of tame grasses produced more grazing than did the native pastures. Such pastures are used to some extent all year for they are usually well drained, and produce some forage even during the winter months (35, pp.5-13).

The Oregon Agricultural Experiment Station conducted a study of fifty-four hill pastures throughout the Willamette Valley in 1934-35 and found, on the average, about one third of the total acreage of pasture areas studied were waste land or covered with trees and brush (35, p.13).

Agronomists who have established pastures in such areas recommend bentgrasses (*Agrostis* spp.), fescues (*Festuca* spp.), velvet grasses (*Holcus* spp.), and others be seeded in mixtures with various leguminous forage species (90).

Other recommendations include mixtures of Alta fescue (Festuca elatior L. var. arundinacea (Schreb.) Wimm.), meadow foxtail (Alopecurus pratensis L.), orchardgrass (Dactylis glomerata L.), tall meadow oatgrass (Arrenatherum elatius L.), Tualatin oatgrass (Arrenatherum elatius var. Tualatin), chewings fescue (Festuca rubra L. var. commutata), red creeping fescue (Festuca rubra L. Illahee strain), perennial ryegrass (Lolium perenne L.); combined with these may be subterranean clover (Trifolium subterraneum L.), white clover (Trifolium repens L.), birdsfoot trefoil (Lotus corniculatus L.) (68) and on highly acid soils, lotus major (Lotus uliginosus) (46).

The final step of establishing improved species in such areas is the grazing practices and management to be used. Some grazing management studies have been made and others are still in progress (3, p.41). It is believed they will be helpful in the future. Avoiding heavy grazing in the first years, after the improved species have been established, will help in the permanent establishment of pastures (64, p.11).

Various studies on production, composition, fertilizer treatments, establishment, management, etc. of forage species for the same experimental area have been conducted since 1942. Because these studies have been made on a mosaic of soil types, topography, and ecological aspects, none of them has thrown much light on basic soil and vegetation relationships. Some of the earlier investigations were carried on by Livingston (58), Cooper (29), and Collins (25).

Others are conducting experiments that are still in progress. Miller (64) worked with cultivated hill pastures in King's Valley of western Oregon from the ecological viewpoint. It is believed that such investigations will increase, in the future, the knowledge of establishing forage species on non-irrigated hill areas in the Willamette Valley.

In a report (69) based on a forage inventory made in 1946 of the area under study, the following conclusions were made:

1. The upper land was lower in fertility than the lower land.
2. The plowed subplots were higher in moisture content than the remaining subplots.
3. Orchardgrass had been one of the predominant plant invaders on the majority of the plots.

In a report (69) made in 1951 it was stated that the species that were performing best were: Alta fescue; Tualatin oatgrass; tall meadow oatgrass; orchardgrass; chewings fescue; burnet; and subterranean clover.

In neither report is anything mentioned about the grazing of the area. Information obtained by interviews revealed that the area was grazed moderately in rotation from 1944 to 1949, and rather heavily for the years 1950 to 1952.

Some of the seeded species. -- According to Piper (76), tall meadow oatgrass is a grass that will withstand a longer season of heat but is easily injuried by prolonged winter cold. It is one of the most drought-resistant of cultivated grasses. It thrives best in deep loam and calcareous soils, but succeeds also on sandy and gravelly soils. It grows in poor soils but its yield can be increased by the use of fertilizers. It does not grow well in shade. It is a deep-rooted perennial and grows four to six feet in height (76, pp. 214-219).

Alta fescue, a deep-rooted perennial grass, has wide climatic adaptation. It performs well in the Willamette Valley. It is winter-hardy and adapted for forage production where the annual precipitation is 18 inches or more and grows in a diversity of soils (78, pp.6-7).

Orchardgrass is a typical bunch grass, strictly a temperate plant, which can withstand heat of the season but is injured in prolonged and severe low temperatures. It is better adapted to clay and clay loam soils with moderate amounts of moisture, and succeeds well in shady places. It develops a root system to a depth of three and one-half feet (76, pp.202-214).

Highland bentgrass (Agrostis tenuis Sibth.) is a grass growing native in the Willamette Valley. It is good for lawns (38), but not for forage (90). It develops root systems of three to four feet in depth with lateral extent of 10-14 inches (38) and performs best on low, level land.

Burnet (Sanguisorba minor Scop) is a deep-rooted perennial that withstands heavy pasturing. On good land burnet plants will grow two feet high and yield as much as six tons of green matter per acre (76, p.625).

<u>Root studies in Oregon</u>. -- Without the knowledge of root development of grasses, their extent, position, and activity, it is impossible to understand the plant establishment and development. Numerous investigations of root development of various grasses have been conducted almost in every part of the United States. Weaver and his co-workers (95 and 102) have conducted the most extensive studies of root development of grasses in the midwest. Many others, too, have made measurements and observations on the root development of crops growing in their respective localities. Because of local differences in soil fertility, structure, texture, and moisture conditions, in addition to regional and local climatic differences, etc., the root development studies conducted in the various parts of the United States cannot be compared directly with those existing in western Oregon even though the species are the same (31).

Gibson (34) conducted studies of root development of forage species in western Oregon on four soil types of which only one soil type (Melbourne clay) was derived from shale and sandstones as is the Laughlin-like soil in the present study. According to him, the soil properties that appeared to have the greatest effect on root development were structure and texture. He found variation in the root development on the various soil types and concluded that soil acidity was not responsible for such variation (34, p.101). Additional information on root development of forage species in western Oregon can be found in other studies (38 and 78).

Soil-moisture measurement in the field. -- Due to the importance of the water content in the soil for plant life and growth scientists have developed and applied various methods in determining soil moisture. The methods for soil-moisture measurements can be classified in the following categories: Gravimetric (52 and 106, p.11); volumetric (30, 57, 82, 104, and 105); gas evolved, heat evolved (4, p. 257); equilibrium tension (4, p.261) (79 and 80); heat conductivity (94); neutron scattering (9 and 33); electric (4, p.257; 32, 63, and 105); etc. Since the electrical method for soil-moisture measurements was used in the present study, a part of the literature is presented.

In 1897 Whitney, Gardner and Briggs (105) proposed an electrical conductivity method to be used directly in the field. Electrodes were placed in the soil, and the conductivity was measured and interpreted on the basis, that any changes in electrical conductivity were brought about by varying amounts of water between electrodes (105). It was soon observed, however, that small changes in the salt content of the soil solution affected the conductivity more than the amount of water that was present. In light of this fact, measuring soil moisture by means of electrical conductivity has never proved entirely successful (4, p.257).

In 1931 McCorkle (63) using multiple electrodes permanently set into the soil tried to measure soil-moisture content. While his method seemed to give promising results, it has not been proven entirely satisfactory.

Shaw and Baver (94) have attempted to measure the heat conductivity in the soils, to be used as an index of soil-moisture content. It was based on the principle of the increase in resistance of the wire conductor with increase in temperature, and on the ability of the soils to conduct heat away from the element which determines the temperature rise. It was found, later, that the relationships between heat conductivity and moisture content is distinct for each soil. This electrothermal method offers many possibilities to solve some of the soil-moisture problems.

Fletcher (32) has adapted the dielectric method to soils by using a special condenser in the soil for measuring soil moisture with a suitable capacitor.

Bouyoucos and Mick in 1940 (17) imbedded two electrodes in a porous gypsum block and buried the block in the soil to measure the moisture content of it. Any change in resistance is dependent upon changes in the moisture content when all other factors such as salt content, compaction, and texture of the soil are constant. In addition, the blocks must be uniform in every aspect. The blocks are calibrated in the laboratory and then buried in the field. The most sensitive range for the gypsum block lies between the moisture equivalent and the wilting point (18). The method can be used for a continuous record of soil-moisture changes, if the gypsum blocks do not dissolve. The same authors have suggested considerable improvements in making the gypsum blocks (18), and Bouyoucos (16) developed more durable plaster-of-Paris moisture blocks. There is some variation in the calibration of these blocks and they are not very sensitive to changes in high moisture content of the soil, whereas toward the dry end of the available range gypsum blocks are very responsive to moisture changes.

According to Baver (4, p.262) Kelley and his associates have the opinion that gypsum blocks are probably the most practical instruments available at the moment for measuring moisture changes at tensions above one atmosphere in soils that do not contain appreciable amounts of salt. On the other hand, according to Richards and Wadleigh (81) soil units of the electrical-resistance type are subject to disturbance from salts in the soil water. This should cause no trouble in leached soils, but the effect should be kept in mind if fertilizers are applied to the soil or if the units are used in saline soils.

Bouyoucos and Mick again (19) have described a fabric absorption moisture measurement unit, and Bouyoucos (13) a nylon electrical resistance unit for continuous measurement of soil moisture in the field. Colman (27), and Colman and Hendrix (28) have developed a fiberglass resistance unit.

Gypsum blocks were used in the present study because they can be made in a laboratory of uniform density and porosity by keeping the procedure and ingredients constant. In addition, they are used in practical field tests in large numbers (13). By using many gypsum-block locations it is possible to reduce the variability of the results. Economically speaking they are easily made in large quantities, and the cost is low.

The Southern Forest Experiment Station in New Orleans, Louisiana (22 and 73) conducted an experiment to check the performance of existing electrical resistance units. They found: 1. All of them, including the gypsum block, to be reasonably accurate; 2. The fiberglass and nylon are the most durable; 3. Where accuracy demands correction for temperature, the fiberglass unit is the most convenient (73, p.14).

DESCRIPTION OF THE EXPERIMENTAL AREA

Location. -- The Hill Pasture of the Oregon Agricultural Experiment Station was acquired in 1940 (25). The total hill pasture area was divided according to topography and vegetation into several pastures to be used for experimental purposes. The experimental plots under study are located in section 33, township 11 south, and range 5 west, Willamette Meridian (23). The total present experimental area occupies approximately 20 acres, and is designated as Field No. 106A.

The topography consists of one ridge running from north to south with a predominately west exposure and moderate slope. Views of the area from the west slope are shown in Figures 1 and 2.

Climate. -- The climate of Corvallis may be designated as a mild sub-coastal and equable type with moist, open winters; cool, dry summers; and a dry harvest period. Violent storms, hail, strong velocity winds, high relative humidity, and high summer temperatures occur rarely. Prevailing westerly winds bring the modifying effect of the Pacific Ocean, and the coldest winter weather or the hottest summer are associated with the advent of a continental air mass movement from north or east (77).

The average annual temperature is 52.4 degrees F. It ranges from 66.2 degrees F. in July and August to 39.3 degrees F. for January. The average minimum temperature ranges from 32.9 degrees F. for January to 51.3 degrees F. for August. The highest temperature

Figure 1. A view of the southwest corner of the experimental area.

White stakes mark the location of sampling units. Oregon oak is the prominent tree and common wild rose the dominant shrub in the foreground. The lighter portion to the right center is the highland bentgrass plot. The encroachment of tall meadow oatgrass is visible in this plot in the background. Notice the difference of height between the two species (May 21, 1954).

Figure 2. A view of the northwest portion of the experimental area.

Alta fescue is in the foreground and the tall meadow oatgrass under the oaks in the background. Notice the height of the species and the thickness of the oatgrass under the trees (May 21, 1954).

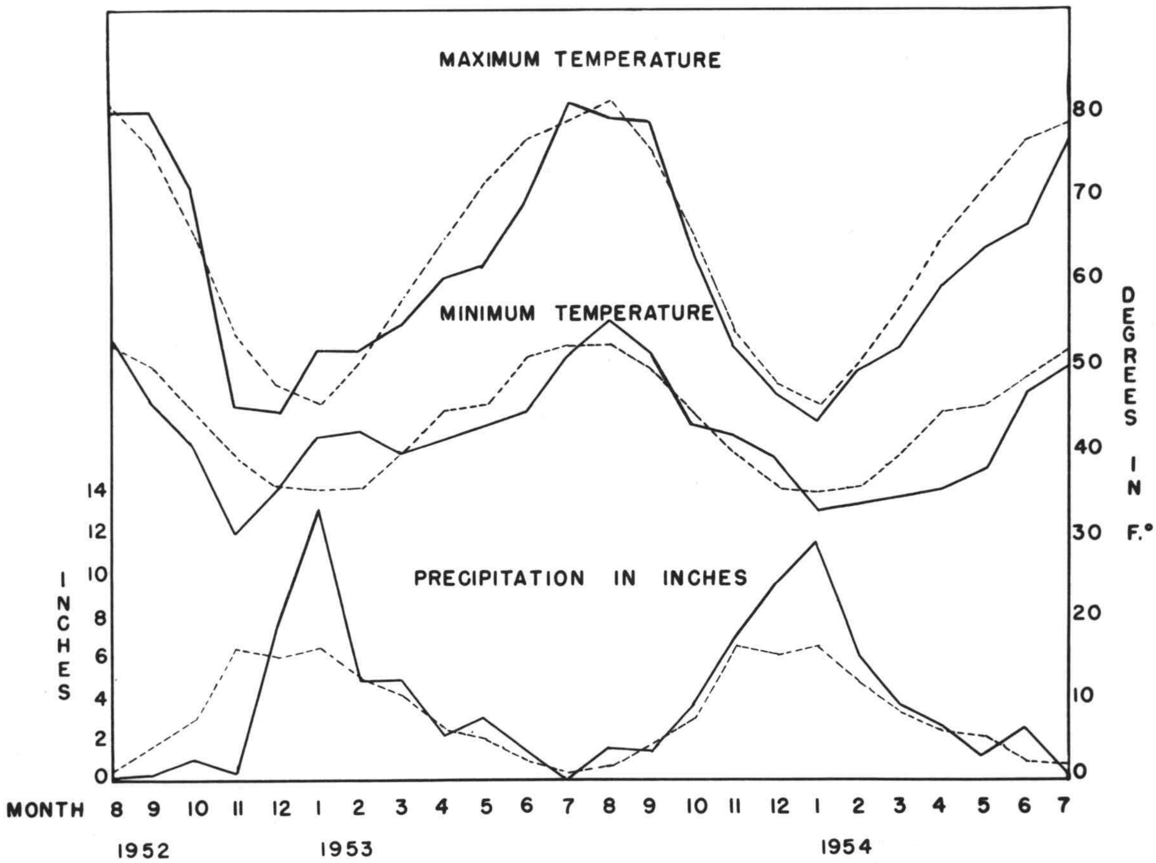

Figure 3. Monthly precipitation and mean temperatures.

Solid line indicates monthly precipitation and mean temperatures for the years 1952-1954 on the experimental area. Broken line shows sixty-year average monthly precipitation and temperatures for Corvallis, Oregon.

of 107 degrees F. was recorded on July 20, 1946, while the lowest of 14 degrees F. below zero occurred December 13, 1919. The temperature has dropped below zero four times, and exceeded 100 degrees F. sixteen times in the past sixty years. The average date of spring frost is April 12, and of the first frost in autumn is October 25. The average frost-free period is 195 days.

The average precipitation for the past 60 years is 39.06 inches. The wettest year was 1937 with 58.06 inches; the driest was 1944 with 22.99 inches of precipitation. The precipitation is seasonal, with very low rainfall during the summer months, June to September inclusive (less than 20 per cent), and proportionately heavy rainfall during the winter months, November to February inclusive. Precipitation and temperatures for the period of study are presented in Figure 3.

<u>Soils</u>. -- In the soil survey of Benton County, Oregon (23), the soils of the experimental area are designated as Cascade clay loam. Cascade soils, as described in that report, are residual soils derived from the coarser-grained, basic igneous rocks. The bedrock is reached at depths of four to six feet (23, pp.1449-1450).

The present investigation revealed that the soil is residual but derived from sedimentary rocks of shale and sandstone. Thus, according to the Soil Survey (23), the soils ought to be classified as Sites, Melbourne, or Carlton soil series, since these three series are mentioned as being derived from sandstone or shale (23, p.1441).

Field studies revealed that this profile did not fit any of the characteristics of the three above-named soil series derived from shale or sandstone parent material. Thus, through the help of Mr. R. C. Roberts (85) and his co-workers, the soils were considered as possibly belonging to the Laughlin series which had first been established as a soil series in Mendocino County, California, in 1948. The characteristics of the Laughlin series established in California have indistinct horizons; their color ranges from pale brown to yellowish to grayish brown; their reaction which is slightly acid in the surface becomes less acid with an increase of depth, etc. Complete descriptions of the Laughlin soils as they have been established in California and the soils on the study area are included in Appendix 1. Roberts (85) informed the writer that detailed information on the physical and chemical properties of the Laughlin soil series is lacking (Appendix 2).

Vegetation. -- The original vegetation consisted of dense stands of Oregon white oak. Burned oak stumps indicate that burning was practiced at intervals a long time ago (96). The oldest trees are estimated to be about 400 years old and range in age to one-year seedlings. An annual ring sample was not obtained. The diameter of the mature trees ranks from two to four feet. Some of the old trees had been cut down by the first settlers for fuel or lumber. The canopy of the oak trees of the experimental plots occupies the upper land and constitutes about one third of the area. Scattered bushes of the common wild rose and poison oak occur throughout the experimental area.

The following herbaceous plant species abound on the area. The most abundant are those designated with an asterisk.

Grasses (45)

Annuals

Soft chess (Bromus mollis L.)
Ripgut (Bromus rigidus Roth.)
Dog tail (Cynosurus echinatus L.)*
Medusa-head rye (Elymus caput-medusae L.)*
Annual fescue (Festuca myuros L.)
Briza (Briza minor L.)
Silver hairgrass (Aira caryophyllea L.)
Nitgrass (Gastridium ventricosum (Gouan) Schinz. and Thell.)

Perennials

Danthonia (Danthonia californica Boland)*
Velvet grass (Holcus lanatus L.)*
Orchardgrass (Dactylis glomerata L.)*
Blue wildrye (Elymus glaucus Buckl.)*
Highland bentgrass (Agrostis tenuis Scop.)
Canada bluegrass (Poa compressa L.)

Forbs

Plantain (Plantago lanceolata L.)*
Bracken fern (Pteridium aquilinium L. Kuhn var. pubescens Underw.)*
Wild strawberry (Fragaria chiloensis (L.) Duch.)*
Lilies (Lilium spp. L.)
Sedges (Carex spp. Rupp.)
Yarrow (Achillea millefolium L.)
Dandelion (Taraxacum officinale L.)*
Wild carrot (Daucus carota L.)*
Buttercup (Ranunculus occidentalis Nutt.)*
St. Johnswort (Hypericum perforatum L.)

Wildlife. — Gophers (Thomomys bulbivorus and Thomomys talpoides) seem to be very active in the open area. Field mice (Microtus Oregoni) and ground squirrels (Citellus beecheyi douglassi) have been seen during the period of the study. Red foxes (_Vuples fulva_) have been noticed and their dens are located in the experimental area. Snakes such as bullsnake (_Pituophis catenifer_) and blue racer (_Coluber constrictor_) and lizards (_Gerrhonotus multicarinatus_ and _Sceloporus occidentalis_) are plentiful. A covey of six to eight valley quail (_Lophortyx californicus_) was seen in late spring of 1954. The ring necked pheasants (_Phasianus colchicus torquatus_) are plentiful and permanent inhabitants of the experimental field. The black tailed deer (_Odocoileus hemionus columbianus_) is the only big game in the area throughout the year (72).

EXPERIMENTAL DESIGN

Original. -- In the spring of 1943 the experimental area was divided into 20 rectangular 60 x 1000-foot plots. They were laid out starting from south to north with the long axis running uphill from west to east. Four different seedbed preparation treatments were applied to all the plots during the spring of 1943. These treatments in order from bottom to the top of the slope, or west to east, were:

A. Plowed and summer fallowed.

B. Disked and summer fallowed.

C. No mechanical seedbed preparation; but closely grazed during the preceding spring and summer.

D. No mechanical seedbed preparation; no grazing that year; vegetation was burned in the fall of 1942 after slashing the brush.

Thus each plot was divided into four subplots in regard to the treatment. Each plot was seeded in the fall without any other treatment (69). The various seeded forage species are listed in Figure 4. Plots numbered 1 through 4, which were seeded in mixtures, have not been included in Figure 4.

Present. -- In order to study the establishment and growth of improved forage species in relation to some soil characteristics on the experimental area, a new design was superimposed over the 1943 treatment.

On April of 1953, the experimental field was fenced with woven wire to exclude any further grazing during the period of study. A number of pits was dug to expose the soil profile of the experimental area. The pit locations were chosen to represent every possible major change in topography and vegetation. These several pit locations enabled a study of the general soil profile and provided an opportunity to obtain representative samples for laboratory tests.

Of the 20 plots it was decided to study all that showed at least some establishment of the seeded species, plus one plot that had been a failure to use as a check. The following species were chosen:

Plot No.	Species Seeded
5	Highland bent (*Agrostis tenuis*)
6	Chewings fescue (*Festuca rubra* var. *commutata*), selected as a failure for use as a check
9	Alta fescue (*Festuca elatior* var. *arundinacea*)
11	Tall meadow oatgrass (*Arrhenatherum elatius*)
12	Tualatin oatgrass (*Arrhenatherum elatius* var. *Tualatin*)
16	Burnet (*Sanguisorba minor*)
17	Subterranean clover (*Trifolium subterraneum*)

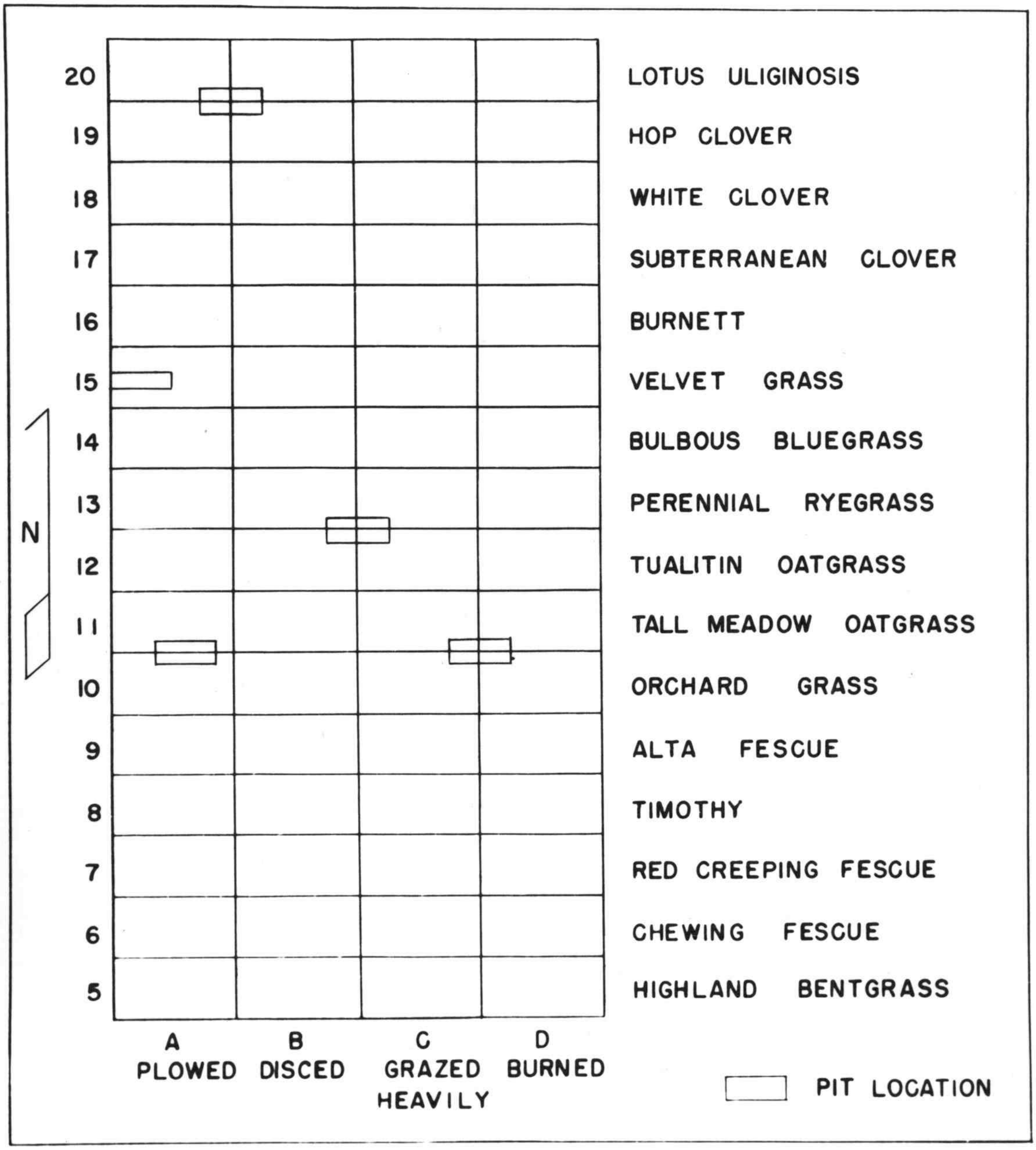

Figure 4. The 1943 original experimental design.

Lotus uliginosis should read *Lotus corniculatus*.

METHODS

A. Soils.

Data on various soil properties and characteristics are helpful in improving one's concept of a given soil as a natural body. According to Jenny, Joffe, Robinson, and others such properties are: 1. Physical and geological, such as: mechanical composition and the mineralogical type of clay (lattice), organic matter content, nature of parent material, horizons, eluviation and illuviation, erosion, infiltration, densities, heat capacity and conductivity, plasticity, etc. 2. Chemical, such as: soil solution, base exchange, soil reaction, chemical composition of mineral salts and organic matter, and generally the fertility of the soils (44, 47, 48, 87, 88, and 99). Before the study of any of the above-mentioned soil characteristics the soil profile of the study area must be exposed.

<u>Profile</u>. — Seven pits, 5 feet by 7 feet, were opened in April 1953 to study the soil profile. In all pits the parent material of the unconsolidated rock was cleared and exposed. The depths of the pits varied from three to four feet except for one which was deepened in 1954 to ten feet. Because the parent material was soft during the period of digging, no difficulties were involved. Locations of five of the pits are shown in Figure 4. Of the two pits not shown, one was dug in plot 4D and the other common to plots 1AB and 2AB. The exposed soil profile of the pits was studied and described twice (summer 1953, and May 1954) by Ray Roberts and his co-workers.

Samples for laboratory tests. -- Soil samples were obtained from all pits and kept separated. The soil samples from each pit were taken from six-inch layers in sequence to a 24-inch depth. One sample was obtained for the depth of 24-36 inches. The soils were air-dried, ground and sieved through a 2-mm. sieve; representative samples were kept in a natural cloddy condition.

Because of the similarity of the profile in some pits, soil samples from them were mixed by layers during the process of grinding and sieving. Each mixture had an equal amount by weight of the soil from each pit. The mixed soil samples were kept separately by six-inch layers. The following soil groups were made:

Group I consisted of mixed soil from three pits: 4D; common to plots 10A and 11A; and common to plots 12BC and 13BC.

Group II was made by mixing soil samples from two pits; common to plots 1AB and 2AB; and 15A.

Group III was from a single pit common to plots 19AB and 20AB.

Group IV represented the soils under oak canopy from a single pit common to plots 10CD and 11CD.

Group V was composed of a mixture from all seven pits.

Mineralogical analyses. -- Soil and parent material samples were sent to the Bureau of Mines, Albany, Oregon, for a complete mineralogical analysis, particularly to determine the type of clay minerals present as in general is suggested.

Texture. -- Of the numerous existing methods for mechanical analysis of the soil the Bouyoucos hydrometer method was chosen. A dispersing agent of 5 cc. of 1.1 N sodium hexametaphosphate $(NaPO_3)_6$ was used. All samples were stirred for thirty minutes. The organic matter of the soil samples was not digested (14 and 15).

Densities and porosity. -- For the true density the pycnometer method was applied (59). For the apparent or bulk density the paraffin method was used on natural air-dried clods and cores (59 and 106). From the two densities the total pore space of the soil was calculated for each six-inch layer of soil profile, using the equation $\frac{100\,(d - d_1)}{d}$ where d = the true or specific density of the soil; d_1 = the apparent density of it (87, p.38).

Wetting and drying phenomena. -- Soil cracking characteristics were only observed and not measured in the field by digging in locations where the most apparent cracks had developed. The following experiments were performed in the laboratory to determine the effects of wetting and drying on the soil:

1. Using the paraffin method, the bulk density of air-dried shale pieces were obtained. The same shale pieces were left to become saturated with water overnight, and their new bulk densities were determined. The difference of the two bulk densities was used to help explain their expansion by wetting.

2. Using 50 per cent of water based on weight of air-dried soil, a puddled paste of soil was made. Brass-rings of known volume were filled with the paste and left to be air-dried at laboratory

temperature for four months. The shrinkage of the puddled soil was used to give some explanation on swelling and expansion of soil saturated with water.

3. An attempt to explain the reason for the sponge-like appearance of the soil layer where small pieces of rotten shale and the soil are intermingled was carried on with the following test: Two graduate cylinders, 2000 ml. and 1000 ml., were filled with known volume of 2 mm. sieved soil sample from group V. The soil was compacted carefully by hitting the bottom of the graduate cylinders on a table covered with soft cardboard. The number of hits and the height the cylinder was let drop were kept constant. The top of the soil in the graduates was covered with filter paper above which were placed metallic heavy sheets. Fifty per cent of water on an air-dry basis was added to the top of the cylinders. The cylinders were left undisturbed for a period of six months, while observations of changes were recorded.

Laboratory moisture studies. --

1. Moisture equivalent or field capacity. The centrifuging method as described by Briggs and McLane (21) and the one-third atmosphere pressure devised by Colman (26) were both applied to determine the field moisture capacity of the soil.

2. Wilting point of the soil. Following the procedure described by Kramer (54, pp.87-93) sunflowers were seeded in 120 tin cans, each containing 500 grams of soil. The use of paraffin to cover the

surface soil of the cans for reducing moisture evaporation was avoided because the soil cracks easily and melted paraffin could fill the crevices. Barley was seeded with the sunflowers to reduce the rate of cracking and to more rapidly deplete the soil moisture for wilting.

Field moisture studies. —

1. Water table and capillary rise. An existing well in the experimental field afforded an opportunity to follow and measure the fluctuation of its surface water level. These fluctuations were recorded in 1953 and 1954.

On August 25, 1954, duplicate samples of the shale at intervals of every ten centimeters up from the water table were obtained for the determination of the capillary rise through the shale. The pit common to plots 19AB and 20AB developed a water table after it was deepened to ten feet during April 1954. The water was continuously in the pit during the summer. On the south wall of the pit the surface shale was cleared off to a horizontal depth of 5-8 inches. This was done to obtain samples not influenced by exposure to air or sun. The samples were taken starting from the surface of the water table to the height of the average level of root penetration of the improved seeded forage species. The surface of the water table in the pit at this date stood at 250 centimeters below the soil surface. The gravimetric determination of the shale moisture was obtained.

2. Soil-moisture measurements with the electrical resistance method. In the present study the Bouyoucos bridge was used to obtain

the electrical resistance readings of the gypsum blocks.

a. Manufacturing and setting the gypsum blocks in the field. In January of 1953 about one thousand (1000) gypsum blocks were made in the laboratory. The general specifications as suggested by Bouyoucos and Mick (17) were used in their manufacture. By trial and error it was found that four parts of gypsum mixed with five parts of water by weight gave the best blocks. Temperature of the water used for the mixture was kept constant at 25 degrees C. Uniform conditions in their manufacture resulted in blocks that gave electrical resistance readings of 350 $\pm$ 25 ohms when immersed in tap water for 12 hours. Before the blocks were inserted and buried in the soil, their locations were chosen as follows:

In each subplot six random locations were established and four-foot stakes were driven in the ground and painted with the appropriate characteristics, e.g., (16 A 4; 12 C 6; etc.). First number designates the number of the plot, the capital letter designates the type of the seedbed preparation, and the last number designates the number of the locations within the subplot. Thus, each subplot had six such stakes, or each plot had 24, or the seven plots under study had in all 168 locations. In other words, gypsum blocks were used in 168 locations. Each location or gypsum block set contained four blocks in a common hole at depths 0-6; 6-12; 12-18; and 18-24 inches. A total of 678 gypsum blocks were inserted in the experimental area. The gypsum blocks were inserted in a vertical position with their bottom surfaces laying at 6; 12; 18; and 24-inch depths.

The depths used for burying the gypsum blocks were not based on soil horizon thickness. Since it was difficult to distinguish the poorly differentiated horizons of this particular soil, it was arbitrarily decided to use the above mentioned depths.

To insert the gypsum blocks into the soil, a soil auger of one and one-quarter inches in diameter was used. The soil removed by the auger was laid in a pan. Soil from a certain depth was used to refill the hole at that depth after burying each block.

The gypsum blocks were inserted into the soil during April 15-30, 1953. A period of 15 days was allowed to elapse for the blocks to come into equilibrium with the surrounding soil moisture. First electrical resistance readings were obtained on May 15, 1953, but on these trials all blocks gave readings between 300-400 ohms. Actual recorded readings of the gypsum blocks started on May 28, 1953, and continued to May 15, 1954, at irregular intervals.

b. Calibration of gypsum blocks. Duplicate gravimetric samplings, corresponding to each gypsum block depth, were started on July 15 and continued to August 18, 1953. Soil samples of six-inch increments were taken at a distance of 12 to 40 inches from the gypsum block set, depending on the condition of the surface soil. Gopher action or large soil cracks were avoided. All gypsum block locations were samples gravimetrically once and only once for the above-mentioned period. Simultaneous with the soil samplings, the electrical resistance readings of the gypsum block sets were recorded. Duplicate gravimetric soil samplings were taken in 1953, too, for soil depths 24-30 and 30-36 inches.

For the year 1954, following the same procedure as in 1953, new sets of gypsum blocks were inserted into the soil profile on May 20 of two selected plots of the same experimental area. On June 8 and 9, twenty of them, or half of the total gypsum block sets, were irrigated to field capacity. On June 11, 1954, electrical resistance readings were obtained for all of them and duplicate gravimetric samples for only the irrigated ones. Irrigated blocks were sampled at 100-hour intervals until July 18, 1954. To obtain additional figures of the moisture content by both methods near the dry end of the curve, two additional samplings were made on August 18 and September 18, 1954. Gravimetric soil samples were taken at depths of 3-9, 9-15, 15-21, and 21-27 inches to correspond to the depths of the individual blocks set at 6, 12, 18, and 24 inches. The duplicate soil samples were taken in two concentric circles with 6 and 12-inch radii from the gypsum block set. No gravimetric soil samples were taken below the 27-inch depth for the year of 1954. The data of 1954 were used to obtain a calibration curve of gravimetric samplings and electrical resistance readings.

c. Checking gypsum block durability. Because of the rapid disintegration of the buried gypsum blocks, it was decided to test them and determine the causes of their breakdown. Three factors were assumed to affect their disintegration:

1. The effect of wetting and drying of the soil, 2. The soil acidity, and 3. The action of the plant roots. The experiments

were performed as follows:

1 (a) Gypsum blocks were continuously immersed in tap water and the water was changed every day.

(b) Blocks were immersed in tap water for 24 hours and then air-dried for the same length of time.

2 (a) The same two above procedures were carried on with aqueous solution of 0.5 N hydrochloric acid.

(b) The same procedures were performed with a buffer solution of pH 5.0 made of citric acid ($C_6H_8O_7$ H_2O) and dibasic sodium phosphate (Na_2HPO_4 12 H_2O) (24, p.1022).

3. Gypsum blocks were buried in cans filled with soil from the experimental area and seeded to barley. These cans were irrigated and allowed to drain and then dry. This procedure was repeated for a period of two months. All of the above named experiments were carried for the same two-month period.

<u>Chemical analyses</u>. -- The soils were analyzed for the following: Nitrogen, phosphorus, potassium, calcium, organic matter, and reaction or pH. Analyses were made in the Soil Testing Laboratory at Oregon State College. The following methods were used for the different tests:

For the nitrogen analysis the standard Kjeldahl method; for phosphorus, the $NaHCO_3$ of (0.5 N) method as developed by Olsen, *et* al. (67); for potassium and calcium, an extraction with ammonium acetate at pH 7.0 and run on flame photometer; for the organic matter, the Walkley (100), and Walkley and Black (101) methods as developed by them; and for soil reaction, a saturated soil paste with a glass electrode pH meter as suggested by Richards et al. (84).

B. Vegetation

Root studies. — The roots of individual isolated forage species were studied as follows. A monolith was dug around the individual plant. The depth of the trench of the monolith reached the shale layer. The monolith was cut horizontally at ten-inch layers of soil. The soil was put in sacks and then brought to the laboratory. Each sack was emptied onto a screen and the soil washed away from the roots with water by using a hose. The roots of the soil increments were arranged on a table in order by depths and air-dried. It was very difficult to obtain samples of roots penetrating into the shale, especially the fibrous ones.

Yield and composition. -- Forage yields on the experimental area were taken to determine: 1. Total production; 2. Relative production of the improved seeded forage species by season; and 3. The relative composition of the forage on the seven plots under study after one and two years protection from grazing. Of the various methods used to obtain composition and yield, the one-square-foot quadrat clippings were used at random to obtain data in this study (55, 75, 91, and 102). Seasonal clippings were obtained twice for

1953 and three times for 1954. The first or initial clippings were made at two heights. Part of the one-square-foot plots were clipped at ground level and the remainder at a two-inch stubble height. All succeeding seasonal clippings were made at ground level. At the second clipping the plots clipped initially at a two-inch height were reclipped at ground level to measure regrowth.

The point frame method was applied for 1953 in only two plots for comparison of the results with the clipping method (55).

Forage chemical analyses. — As the chemical composition of some forage species on the area have not been reported, samples were taken for analyses on July 20, 1954. Samples of green vegetative material of the two oatgrasses were obtained shortly after the seed was shattered. These samples represented plants growing in the open field and under oak canopy. Samples of plantain and burnet included both leaves and heads with seeds in the dough stage. The heads and stems of plantain were separated from the leaves before analyzing them. Plantain and burnet were obtained from the open field because no plants were found under the canopy. Thus, analyses were made to determine the nutritive quality of the above mentioned forage species and the crude protein and other constituents were run in the Animal Nutrition Laboratory at Oregon State College. Methods used in these analyses were those recommended by the Association of Official Agricultural Chemists (2).

RESULTS AND DISCUSSION

A. Soils

Classification. — The exposed profile in the pits dug in the experimental area was examined and described by Roberts (85). He states that they may belong to the Laughlin series. As was mentioned previously, the Laughlin series were first established in California in 1948. The present soils are residual being developed from tuffaceous and micaceous marine shale and sandstones, which include both marine and land fossils as shown in Figure 6. In general, they are rather shallow, ranging in depth of the weathered parent material or solum from 17 to 32 inches as indicated in Figure 5. They lack horizon C. Their profile color ranges from pale brown to dark-grayish brown, or brown, to dark brown, to reddish brown, to light gray, to white, to very pale brown. The structure for the horizon A_1O is weak, medium fine granular and hard when dry. It changes in the horizon B_1 to weak, medium, and fine subangular blocky, that is, hard when dry and friable when moist. In the horizon B_2 it is moderate fine subangular-blocky which is very hard when dry and plastic when wet. Between horizons B_2 and D_r the structure becomes granular and sponge-like in appearance. Finally, the horizon D_r exhibits a platy structure in the shale and sandstone. The geological age of the shale and sandstone has been established as Eocene. The complete description of the soil profile has been included in Appendix 3.

Figure 5. A soil profile of Laughlin-like soil.

The depth of the pit is 10 feet. Notice the water table which developed in 1954. The level on July 22, 1954, stood at 230 centimeters below the soil surface.

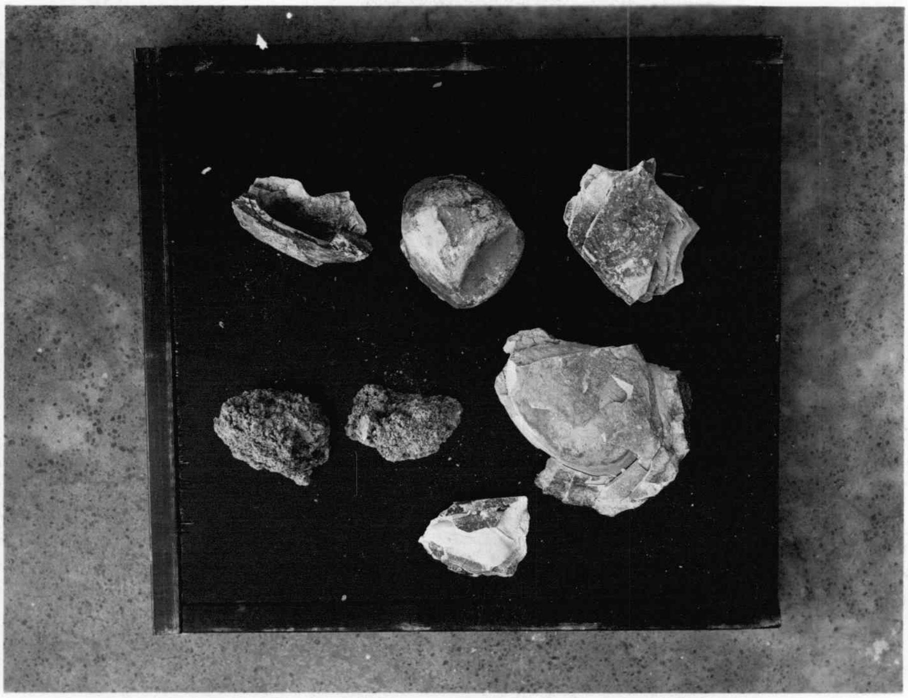

Figure 6. The soil parent material of the experimental area.

Parent material showing the spheroidal weathering formations. Pieces of plant fossils are plentiful. On the left in the second row, the two pieces show the sponge-like appearance of the soil layer just above the shale.

Comparing the description of the established Laughlin soil series in California and the description of the Laughlin-like soil in the study area, it is obvious that the two series exhibit similarities and differences in their characteristics. The two descriptions agree in the following points: topography and the main vegetative cover; the climate conditions; sedimentary parent material; general profile arrangement; and some similarity in color, texture, structure, and depth. However, they exhibit different soil reactions, possibly caused by the differences in kind of sedimentary material. These established in California as the Laughlin series are slightly acid in the surface soil and with progressing depth their reaction becomes less acid or neutral. In the present study it was found that the soils are rather acid in the soil surface (0 to 6-inch depth) having a range in pH from 5.6-5.7. With increasing depth they become more acid, ranging from a pH of 4.8-5.2, for the depth of 24-36 inches. Another minor disagreement is that the soils on the study area support an abundance of wild rose in addition to white oak.

A better comparison of the established Laughlin soil series in California and that of the study area could be made if more detailed information were available on the California series. The present tentative classification of the soils as belonging to the Laughlin series is accepted until further studies are undertaken on their classification. Therefore, the soils of the study area are named and classified as Laughlin-like.

The mere description of the soil profile, as it is presented here, is primarily of qualitative character. A functional analysis of the soil requires quantitative data. These are presented, whenever possible, as obtained by the various tests in this study. The number of experiments were necessarily limited, and further investigation for other soil properties are needed to better reveal the functional behavior of these soils.

By carefully studying the descriptions of the Laughlin-like soil series as they exist in the study area and the same series as they have been established in California (Appendices 1 and 3), the interested reader should be able to make a more thorough comparison of these two soils.

Mineralogical analyses. -- The mineralogical analyses of the soil samples sent to the Bureau of Mines in Albany, Oregon, is presented here as it was described by Hess (43).

> "The major clay mineral in shale and soil samples is illite rather than montmorillonite or bentonite. Very little or no swelling was observed in any of the materials. The microscopic identification of illite was confirmed by differential thermal analysis.
>
> The following are the over-all results of the mineralogical examination:
>
> The 'shale sample' contains quartz, altered feldspar, illite, some sericite, biotite, muscovite, small amounts of chlorite, graphite, and trace amounts of limonite and pyrite. Also present are small amounts of leaf fossils.
>
> The 'soil samples' are mineralogically similar. They contain illite, quartz, altered feldspar, organic matter,

fragments of shale, sericite, limonite, altered biotite, magnetite, ferromagnesian minerals, and ilmenite. These samples contain more organic matter and less illite and shale fragments as they grade to the surface. The samples labeled 24" plus contains a trace of graphite, apparently derived from the underlying shale.

The shale is comprised of mineral fragments that are less than 100-mesh in size and predominately less than 200-mesh. However, a great deal of the quartz and feldspar in the soil samples is much coarser. This observation, coupled with the fact that shale particles are present in the soil samples, would indicate that the soils were not formed entirely 'in situ' but were derived partly from the underlying shale and partly from some other source." (Appendix 4.)

On the basis of the mineralogical data, there is still a question about the type of the clay lattice. Hess found it to be principally illite, but he didn't state the proportion of it. In addition, he reported that there is very little swelling of the soil samples which is contrary to field observations and several laboratory tests which were performed. They both indicated marked swelling and expansion of the soil and the shale. Marshall (61) says that there is no information on the amount of swelling of illite (61, p.162). According to Shaw (93) it is known that illite has properties, in general, intermediate between those of kaolinite and montmorillonite, that is, illite will swell and shrink to some extent (93, p.15). Thus, it is believed that in addition to the illite there must be a portion of another clay of 2 to 1 lattice type that expands more than the illite. Another possible explanation for the swelling might be that it is a characteristic of macro- rather than microstructure. Tests on the base exchange capacity of the soil probably would give better information as to the proportion of illite in this soil.

Hess concludes that the soils were not formed entirely "in situ" but were derived partly from the underlying shale and partly from some other source. As both shale and basaltic parent materials are found in this general area, it would not be unreasonable to assume that the quartz and feldspar in the surface soil might be of igneous origin. However, this may be explained in another manner, as gophers bring a considerable amount of shale material to the upper layers. Furthermore, observations in the parent material indicate that burrowing animals are active in this layer as well as in the solum. This could account for the shale particles being present in the soil samples.

Texture. — Preliminary tests with the empirical hydrometer method as proposed by Bouyoucos revealed that stirring time should be carried on for 35 minutes (14 and 15) (Appendix 5).

A summary of the mechanical analysis of the soil by 6-inch layers is presented in Table 1. The textural classification of the soil profile as seen in Figure 7 is as follows: For depths 0-12 inches the soil is clay loam; for depths 12-24 inches the textural classification is clay; and for the depth 24-36 inches, it is clay loam again. All samples fall close to clay and clay loam divisions (Appendix 6).

The increase in percent of the clay fraction in the layers 12-18 inches and 18-24 inches (horizon B_{21}, B_{22}) may be attributed to the

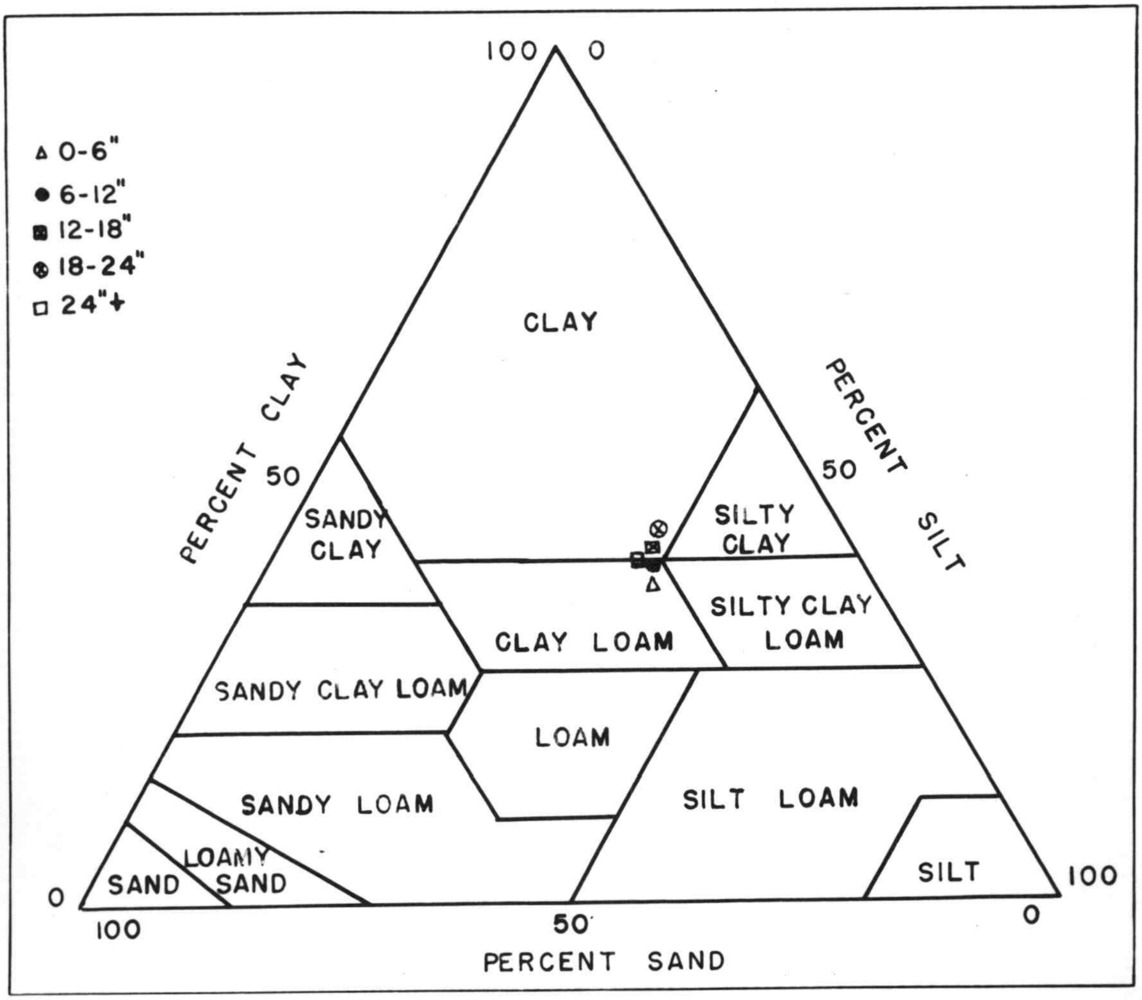

Figure 7. Texture of the profile of the Laughlin-like soil series from the study area.

Table 1. Average textural analysis by the hydrometer method of Laughlin-like soil series for five depths

Depth in inches	Per cent		
	Sand	Silt	Clay
0-6	21.80	40.60	37.60
6-12	20.38	40.01	39.60
12-18	20.00	38.78	41.23
18-24	19.86	37.29	42.84
24-36	20.51	40.01	39.48

mechanical eluviation that takes place in the upper A and B_1 horizons. Illuviation within horizon B results from the downward movement of the water from the top layer (87, p.79). In the present case eluviation of the upper soil layers and illuviation of the lower soil layers is accelerated by the cracks that develop in the soil. These cracks are vertical and horizontal. When the fall rains start, most of the water gets into the soil through the cracks and washes fine particles downward until the cracks are sealed by the expansion of the surface soil. Soil carried from the solum through the cracks by the downward movement of water and gravity was noticed in the shale layer at depths of 4 to 5 feet.

The clay fraction of this soil contributes materially to its structure which affects the water relationships. The peculiar subangular blocky structure of this soil is largely responsible for its porosity, especially the large size pores, which facilitates the deep development and penetration of root systems as well as to the movement of air and water within the root zone.

Porosity. — Porosity studies in a given soil may help explain some other physical properties of the soil which are important from the practical agricultural viewpoint.

In the equation used to calculate total porosity, a value of specific density of 2.60 grams/cm3 was used (Appendix 7). The average results of the apparent densities and the calculated total porosity are summarized and presented in Table 2 (Appendix 8).

Table 2. Average apparent density and total porosity of Laughlin-like soil series. (Each value is based on 42 samples.)

Soil depth (inches)	Apparent densities (gms/cm3)	Percent water*	Total porosity (percent)*
0-6	1.23	7.23	52.69
6-12	1.40	6.30	46.15
12-18	1.37	6.59	47.31
18-24	1.38	6.02	47.23
24-36	1.32	7.39	49.23

* Average moisture content of the soil clods corresponding to the apparent densities.

These values indicate that the total porosity decreases below the surface layer by 12.40, 10.20, 10.40, 6.60 per cent for the corresponding depth layers of 6-12, 12-18, 18-24, and 24-36 inches. The analysis of variance of the data of the apparent densities revealed a significant source of variation attributable to depth (Appendix 9).

It was noticed that the layer of 4-6 inches thick, which is found just above the shale at depths varying from 17-30 inches in all pits, exhibits a peculiar large porosity which makes it to resemble like a sponge in its appearance. The average porosity of this layer is only 6.60 per cent less than that of the surface 0-6 inches. It is believed that this visible large porosity may be created by two factors: The differential expansion and contraction under wetting and drying of the soil and parent material, and the entrapped air that lies between the upper layers when wetted by rains and the upward rise of capillary water from the water table below.

Agronomists are interested in an increased total soil porosity because the relative amounts of water and air in the soil are dependent upon it; especially with fine-textured soils they have the desire to increase the proportion of the macro-pore size distribution.

Wetting and drying phenomena. (Swelling and shrinking). — The shrinkage of drying soils which results in cracking is most marked in the heaviest clays. The fissures thus opened often extend several feet into the soil and result in a further intensification of the drying out process (11, 37, 51, and 87). Such old fissures extending to a depth of four or five feet within the shale layer were noticed in one of the pits of the experimental area. They are filled with soil and probably have occurred in periods of severe and prolonged droughts.

It seems that this soil has an inherent tendency to crack easily which is acquired from the parent material. In the experiment performed in the laboratory to determine the wilting point with sunflowers and barley, it was noticed that all the cans containing soil from various depths, including cans containing ground shale too, developed vertical cracks a few hours after watering. Further investigation might help to explain the reasons for this sudden cracking.

Field observations revealed that the soil under thick litter developed only slight surface cracks. Also, where the grass was thick or the canopy shaded the area for a considerable daylight period, the cracks were smaller in comparison with those developed under less dense grass cover or under annual plants.

Soil shrinkage and the development of the deep cracks started in the middle of May for both years of this study and became markedly wide and deep around the beginning of June. The vertical cracks of the soil profile were wider and more numerous than the horizontal ones. In the summer the horizontal cracks of surface soil found in 5-18 inches depth became smaller. In the late summer horizontal and vertical cracks were about the same in size but both were smaller than the corresponding cracks in June.

The phenomena of shrinkage and swelling or expansion and contraction of the soils have a two-fold meaning from the agricultural viewpoint. If the cracking is sudden and the cracks are large, roots of the plants can be broken and the plant suffers considerable damage. On the other hand, the cracks help to a considerable extent to increase water infiltration especially during torrential rains, thus protecting the soil from erosion, and supply the subsoil with organic matter that falls through the fissures from the surface into the deeper layers of the soil profile.

The alternation of shrinkage and expansion, and the action of burrowing animals produce a friable soil in the field, so that seedlings of late summer and fall can develop their roots and easily penetrate the soil profile.

It was observed, that for the two years during this study that the cracking had not greatly affected the soil profile below 14-18 inches. The intensity and frequency of cracking has undoubtedly been reduced by the cool, damp summers during the last two years.

Haines (37) distinguishes two types of shrinkages: First, the normal shrinkage during which the volume shrinkage is equal to the volume of water lost; and secondly, the residual shrinkage during which the volume shrinkage is less than the volume of water evaporated. Haines' classification of shrinkage coincides with the field and laboratory observations in this study. For example, it was noted that shrinkage is sudden and marked in the beginning of the warm season in the field observations or after the maximum expansion of saturated soil in the laboratory tests.

In contrast to the results of shrinkage and cracking as they occur in the field and in the laboratory with non-puddled soil, the experiment with puddled soil, as can be seen in Figure 8, resulted in considerable shrinkage without the development of cracks.

The absence of the cracks in the puddled soil coincides with the field observations where the soil under shade developed the smallest cracks. The puddled soil cores were left to dry slowly and away from

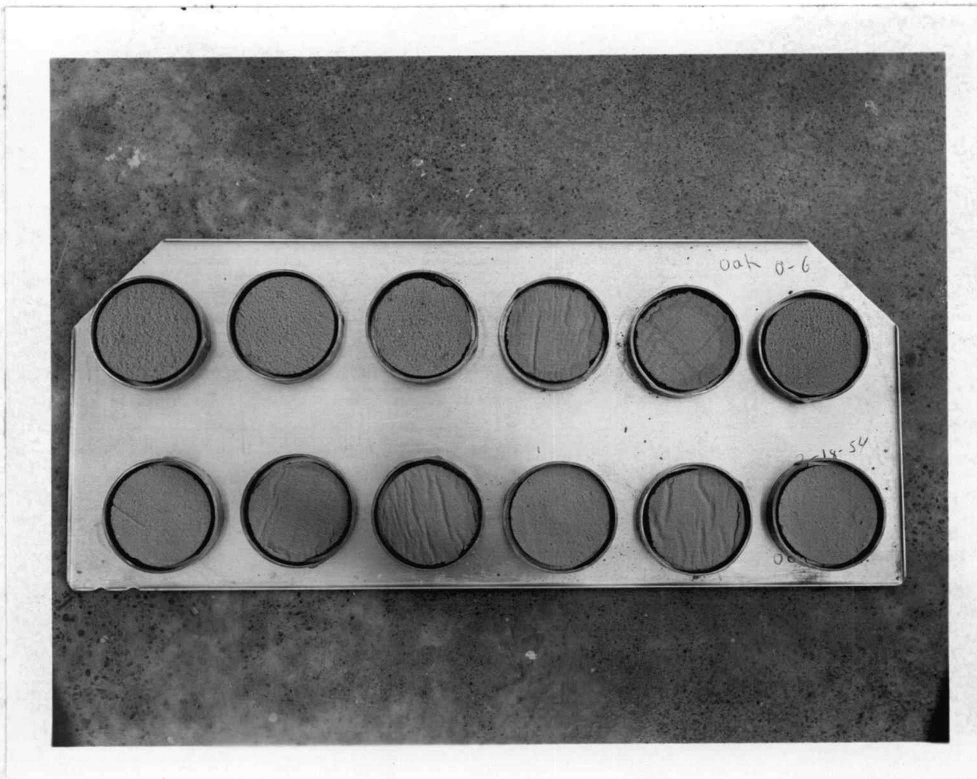

Figure 8. The expansion and shrinkage of saturated puddled soil.

Shrinkage of puddled soil without development of cracks. This surface soil was puddled with 50 per cent of water and shrank an average of 25.70 per cent.

Table 3. Percent of shrinkage and apparent density of surface 0 to 6-inch for a period of four months after the air-dried soil was puddled with 50 percent of water.

		Volume in cc.			
Pit	No.	Puddled Paste in brass cylinder	Dry soil cake core after 4 months	Percent shrinkage	Apparent density, gms/cm^3
10, 11	1	140.76	106.23	24.53	1.39
C D	2	137.99	103.15	25.25	1.38
	3	147.41	113.54	22.98	1.37
	4	142.98	110.78	22.52	1.37
12, 13	5	147.97	107.19	27.56	1.45
B C	6	141.32	101.58	28.12	1.45
	7	147.97	107.11	27.61	1.45
	8	141.87	103.65	26.94	1.45
		143.53	106.65	25.69	1.41

intensive light or high temperatures. As shown in Table 3 the total shrinkage of the puddled soil averaged 25.70 per cent for the 0-6 inch layer. In addition, there is an increase in the apparent density of the same layer of soil obtained from clods of 0 to 6-inch depth, as shown in Table 2. This increase in apparent density decreases the porosity by 13.20 per cent. This experiment suggests that during the winter when the soil is continually wet this type of land should not be grazed by heavy animals.

Figure 9 illustrates an experiment in which an attempt was made to determine one of the reasons for the development of the sponge-like layer just above the shale.

In the graduate cylinder, (Figure 9), which was filled with

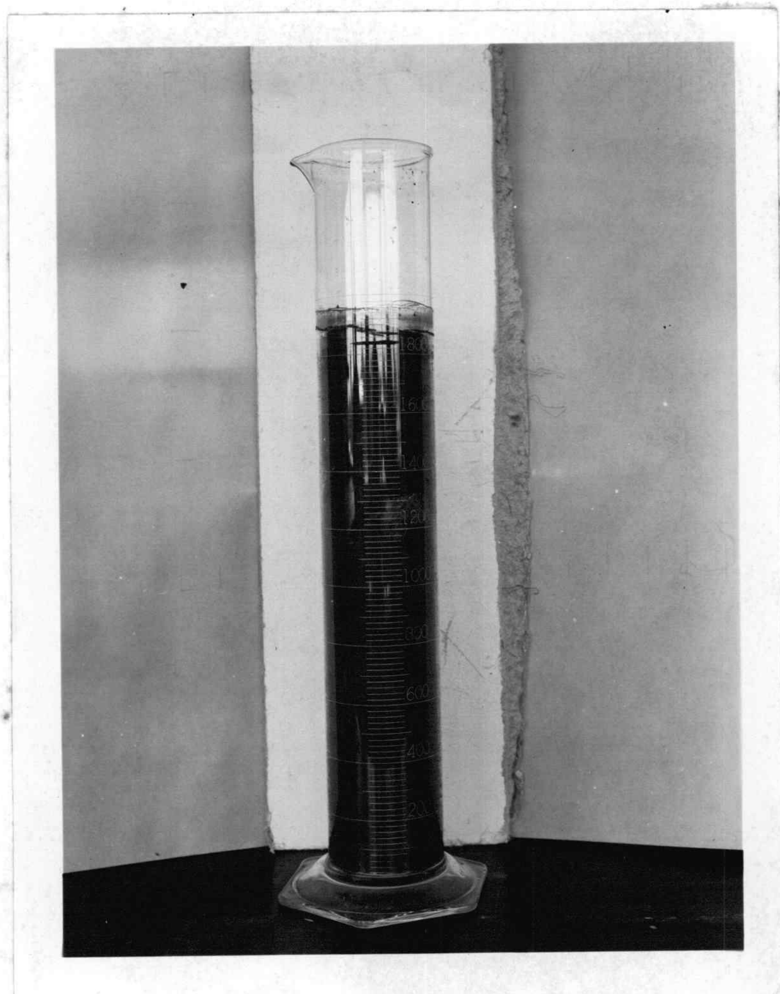

Figure 9. The expansion of air-dried soil saturated with 50 per cent water in a two-liter graduated cylinder.
1. The lower straight line is the original line of the compacted air-dried soil before saturation.
2. The next upper wavy line marks the point to which the soil shrank after drying.
3. The shadowy indistinct line shows the maximum expansion of the soil after saturation.
4. The top line is the point which the expelled water reached.

air-dried soil and saturated with 50 per cent of water by weight, the following observations which were not measured quantitatively were noted: The water front progressed downward evenly, indicating that the compaction of the soil was homogeneous. Some hours later the water reached the bottom of the graduates. There was no water left on the top of the soil because all of it was absorbed. In 3 to 4 days the volume of the soil increased to the line indicated in the same figure.

Four or five days later an excess of water was released which covered the top of the soil. This probably resulted from a higher temperature of the soil which caused an expansion of the entrapped air in the cylinders, under the laboratory temperature conditions, which expelled an amount of water (11 and 65). This excess water was evaporated and the cylinders left undisturbed in a corner of the laboratory for six months. The once expanded soil volume shrank slightly. Throughout the cylinders from bottom to top, horizontal air interspaces had been left, probably equal in volume to the volume of the permanently expanded soil after saturation. The soil in the cylinders never settled back to its original level.

This experiment suggests that the soil expands following saturation; then shrinks somewhat; and the soil does not return to its original compaction point, because interspaces that are left after the water evaporates fill with air. When the same experiment is carried on in beakers containing from 200 to 400 grams of soil the following is noticed: While the water front is moving towards the bottom of the beaker, as it reaches one half the depth of the soil, an explosion occurs and pushes up the wet soil. Thus is produced a permanent empty space visible in the middle of the soil mass. The compressed soil air by the water front is probably responsible for the explosion.

Another possible reason for the development of the sponge-like layer is given in the discussion of porosity, and under the discussion of water table. The fact that this layer is more pronounced where the solum is deeper, gives further support to the entrapped air theory. Further investigations should reveal a more satisfactory explanation.

An experiment was carried on to determine the amount of expansion of air-dried shale that occurs after wetting. The average results of ten shale samples are presented in Table 4. It was found that air-dried shale saturated overnight increased in volume for an average of 10.7 per cent with an absorption of water of 22.10 per cent above its initial water content of 11.09 per cent. Its apparent density was decreased by 11.5 per cent (22). Such a phenomenon indicates that there is pronounced expansion of the laminated shale after saturation (Appendix 10).

Table 4. Volume increase of shale rock after soaking in water overnight.

Before Soaking		After Soaking	
Mean apparent density of 10 air-dried samples		Mean apparent density of 10 samples	
gms/cm^3	Per cent water	gms/cm^3	Per cent water
1.34*	11.09	1.20*	33.21

$* \ \frac{1\ cm^3}{1.34} = .75\ cm^3$ per gram of shale

$* \ \frac{1\ cm^3}{1.20} = .83\ cm^3$ per gram of shale

$$\frac{.83}{.75} \times 100 = 110.67 - 100.00 = 10.67\%$$

increase in volume with an increase of 22.12 per cent of water content.

Laboratory moisture studies. -- The types of apparatus used in the laboratory for approximating the field moisture capacity of soil are not necessarily in close agreement. A satisfactory method for determining the field capacity for all soils is still lacking. The soil profile and the changes in structure of soil horizons are factors contributing to this lack of agreement.

Results of the laboratory methods used in this study to define approximate field capacities and wilting points are summarized in Table 5 (Appendices 11 and 12).

It is considered that centrifuging to determine moisture equivalent removes most of the water that is held in the large pores, and its value represents the moisture in the smaller capillary pores as well as that imbibed by the soil colloids (4, p.199). The moisture

Table 5. Summary of average moisture percentages at various depths for soil moisture equivalent, one-third atmosphere pressure, wilting point, and available water for plant growth of Laughlin-like soil series.

	Per cent water				
Depth in inches	M.E.	1/3 Atm.	Wilting point	Available moisture based on: M.E.	1/3 atm.
0-6	28.96	30.86	8.26	20.70	22.60
6-12	26.77	28.55	8.74	18.03	19.81
12-18	26.02	27.00	9.24	16.78	17.76
18-24	27.32	27.89	10.18	17.14	17.71
24-36	31.71	33.13	11.99	19.72	21.14

equivalent method is an empirical laboratory measure of water in the soil that approximates the field moisture capacity. The one-third atmosphere pressure is intended to measure the same moisture characteristic of the soil as moisture equivalent, but in this study the one-third atmosphere pressure gave a slightly higher figure for field capacity than those of the moisture equivalent.

The high field moisture contents of this soil are probably affected by a water table which results in moisture content above field capacity in the deeper layers.

Indeed, field gravimetric soil samples gave moisture contents in some cases of more than 40 per cent during August 1953. The figures of wilting point which increased with increasing depth obtained phytometrically may be too low. Growing barley with sunflowers may have been responsible for not catching the plants as soon as permanent wilting occurred. Whereas the sunflowers wilted readily, the barley plants did not show comparable evidence of wilting at the same time. A 15-atmosphere pressure test would, probably, give more reliable results for the wilting point of soil. Further investigations should throw more light on the range of available moisture in these soils.

<u>Field moisture studies</u>. —

1. Water table and capillary rise. The capacity of a soil to retain water cannot be defined without considering the nature of the deeper soil horizons. In order to better understand the moisture status of a soil, it is necessary to study the relationship of the water table or deep soil moisture to the entire soil profile. A water table, if it exists, usually follows the contours of the land but in a less accentuated manner (87). Owing to the predominance of rainfall over evaporation during the winter months in the Willamette Valley, the position of the water table fluctuates. Fluctuations in the water table on the study area are shown graphically in Figure 10. The water table for the study area reached a minimum on November 6, 1953, and a maximum on December 1, 1953. Depending on the rainfall in a particular year, the level of the water table generally continues to drop until the first killing frost in the fall hastens the leaf-fall of the oak trees and reduces the transpiration of deeper-rooted woody plants.

In order to study the possibility of the established improved forage species obtaining moisture from the water table, the following assumptions were made:

(a) A capillary water rise of 80 cm. or 31 inches above the water table can be attained (87, p.290; 4, p.234). (b) The average depth of the solum is 25 inches. (c) Capillary rise of water from the water table to the solum may be hindered by the sponge-like layer above the shale. (d) The average root depth of the improved seeded species is 42 inches. Thus, according to Keen (50) Figure 10 shows that the improved species could be supplied with water by capillary rise from the water table until the end of September of 1953. After this date soil moisture in the shale would reach a critical point for the growth of improved species. However, measurements taken, of shale moisture content at various levels above the water table in the deepest pit, as shown in Table 6, indicated that the capillary rise in these soils is about 160 centimeters or twice the distance given by Keen (50).

Table 6. Capillary rise of water in the shale layer above a water table. (August 25, 1954)

Height of shale samples above water table (cm.)	Average percent moisture content of two samples
0-10	31.34
10-20	30.79
20-30	30.28
30-40	33.18
40-50	38.02
50-60	37.35
60-70	35.33
70-80	32.12
80-90	35.26
90-100	30.42
100-110	29.61
110-120	31.85
120-130	33.40
130-140	34.06
140-150	39.95
150-160	26.54

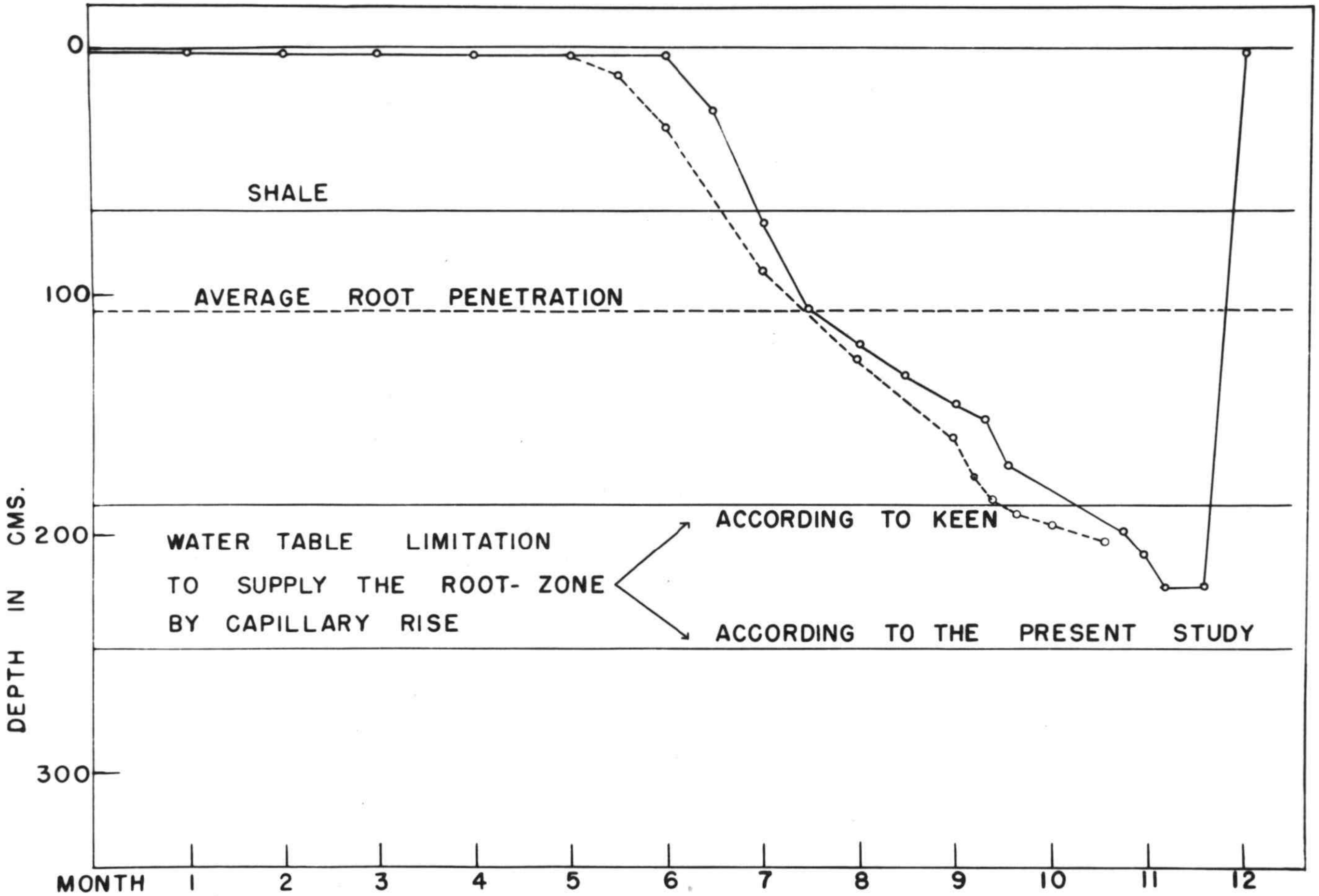

Figure 10. A water table fluctuation and its capillary rise.

Solid line represents 1953 and dotted line 1954 measurements.

It could be assumed that moisture values of shale samples, as indicated in Table 6, approximate field moisture capacity because of the low evapo-transpiration stress. Since in the sampled location there was a considerable number of deep-rooted woody species with roots extending as deep as 300 centimeters, they should have reduced the moisture content below field capacity by the end of August. Therefore, it is assumed that the capillary rise is 160 centimeters above the water table which saturates the shale to field capacity and not stored moisture left over from the rainy period of the year.

With the assumption of the capillary rise of 160 centimeters as indicated in this study in Table 6, the improved species could be supplied with water for a longer period. According to diagram in Figure 10, the water table can be lowered to the point of 250 centimeters below the soil surface and still provide moisture for deep-rooted species. This point was never reached in either year of this study.

The question, therefore, is if the water table will ever drop lower than 250 centimeters below the surface soil. The answer will be dependent on several conditions: (a) The amount of precipitation in a given year compared to normal precipitation; (b) summer temperatures; (c) date of the first heavy frost which prevents further lowering of the water table by transpiration of deep-rooted woody species; (d) the starting date of the rainy season for the year, etc.

Figure 11 gives a picture of the water table fluctuation due to

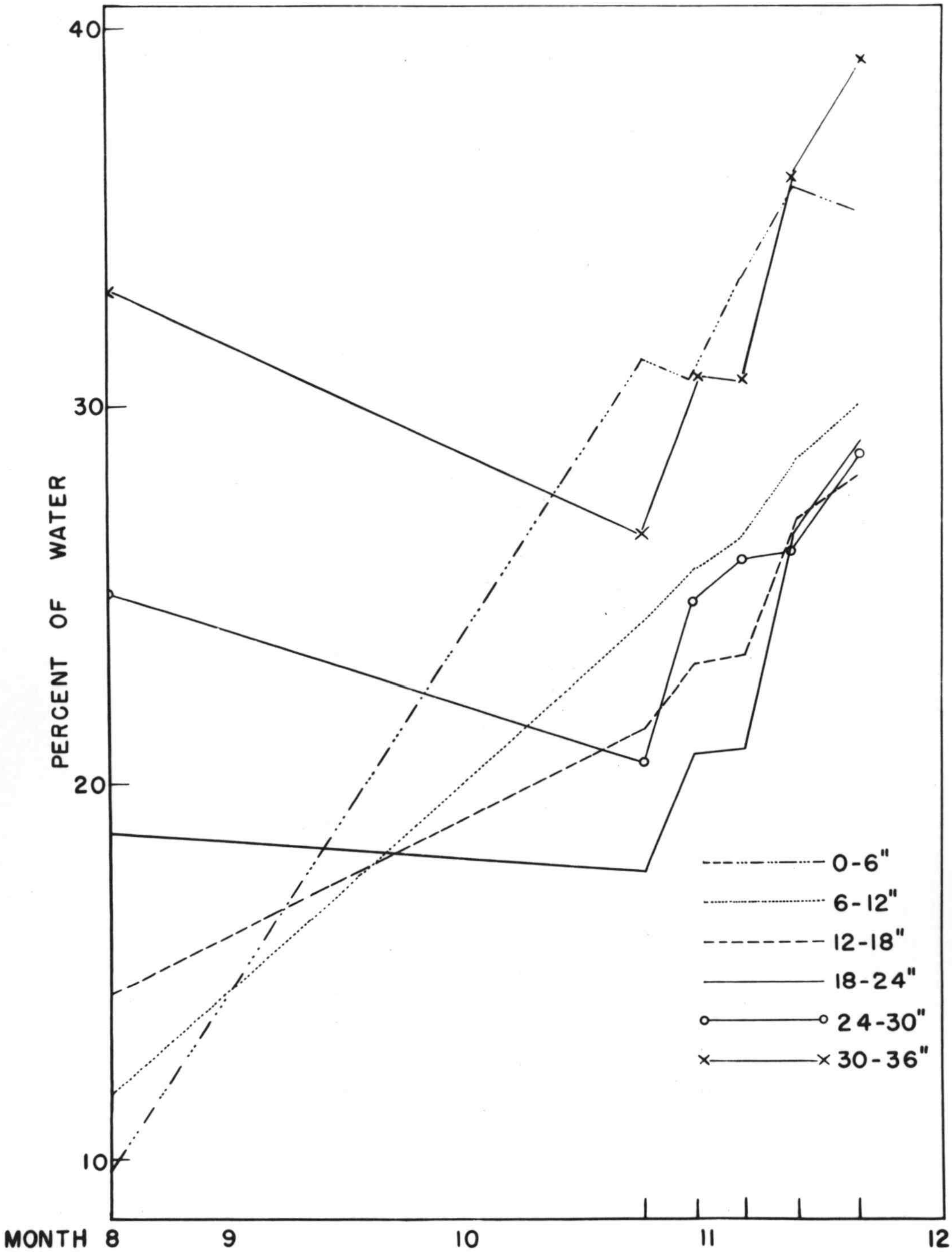

Figure 11. Wetting of the soil profile by precipitation and capillary rise of water table.

Note that the profile is simultaneously wetted from above directly by rainfall and from below by upward movement from the water table.

the transpiration of the deep-rooted plants. For the year 1953 after the fall rains started, the layers of the soil at 18 inches depth and below were further dried until October 22. On the other hand, the layers of the soil from 0-18 inches were becoming wetter because of the precipitation. Successive frosts in October and early November 1953 accelerated the fall of the oak leaves and transpiration by the oaks ceased. As a result, the water table started rising. Thus, the soil layer between 18-24 inches depth was saturated from both directions, that is, from the precipitation above and from the water table below by capillary rise. This dry zone between two advancing water fronts may play a role in the development of the sponge-like layer which lies just above the shale. Soil-air that is expelled from the upper and lower saturated layers is compressed and entrapped in this layer possibly creating the sponge-like structure. This possibility is considered, again, under the discussion of soil porosity, and wetting and drying phenomena.

One should remember that these studies of water table fluctuation presented in Figure 10 were followed by measuring the level of the water in an existing well and do not represent the average level of a water table for the whole experimental area. On the other hand, Figure 11 represents a diagram of successive gravimetric soil moisture samplings taken throughout the entire experimental area. However, in Table 7, the values of the gravimetric soil moisture taken after August 18, 1953 near the gypsum block sets show the same tendency, that is, the movement of two water fronts in the soil profile after October 22, 1953.

2. Gravimetric soil-moisture sampling. This method was used to try and calibrate the gypsum blocks directly in the field, and to obtain data on deep soil moisture. The only difficulty encountered was in sampling the shale. Data from gravimetric moisture sampling is summarized in Table 7.

Table 7. Average gravimetric moisture content of the soil from the experimental area at various depths and dates for 1953. (Underlined figures are the lowest ever obtained in 1953.)

Date	Depth of soil in inches					
	0-6	6-12	12-18	18-24	24-30	30-36
July 15	12.11	14.67	19.71	26.64	31.92	36.52
July 19	9.92	14.18	18.16	23.03	28.63	33.71
July 22	14.05	14.90	17.25	23.24	27.12	31.12
July 26	12.28	14.88	17.51	23.09	29.69	33.56
July 29	9.45	12.67	17.18	21.89	26.52	32.16
August 1	12.46	15.12	18.73	25.09	31.58	32.36
August 2	16.51	18.80	25.97	31.72	32.94	33.25
August 3	13.35	15.23	19.38	24.56	29.56	31.06
August 5	10.42	12.29	16.08	22.28	30.80	35.55
August 8	9.78	11.72	15.25	22.24	28.81	33.22
August 9	10.26	11.43	15.32	21.86	31.79	35.83
August 10	15.45	15.53	20.14	26.63	31.67	35.61
August 12	16.82	17.46	17.87	20.52	25.94	30.77
August 14	13.12	13.24	15.81	19.83	25.63	32.02
August 16	9.37	11.12	13.91	18.42	23.20	29.53
August 18	9.88	11.54	14.41	18.66	25.02	32.99
October 22	31.22	24.30	21.46	17.63	20.06	26.45
October 29	30.69	25.62	23.17	20.77	24.80	30.63
November 5	33.19	26.53	23.39	20.88	25.96	30.64
November 12	35.72	28.81	26.98	26.68	26.01	35.88
November 19	35.08	30.02	28.15	28.93	38.69	39.04

The lowest average soil moisture contents ever obtained by this method in 1953 were 9.37; 11.12; 13.91 per cent for the corresponding depths of 0-6; 6-12; and 12-18 inches on August 16. For the depths of 18-24; 24-30; and 30-36 inches, the lowest soil moisture content was 17.63; 20.06; and 26.45 per cent respectively, for August 18, 1953.

It must be kept in mind that the moisture contents of the various dates presented in Table 7 are not actually representative figures of the moisture content for the experimental area. Rather they give one a fair picture of the moisture content of the soil profile of selected locations. For example, the high moisture contents for the sampling dates of August 2; 3; 10; 12; 14 in 1953 represent soil sampling locations under the oak canopy. In such locations the evaporation of the soil moisture is lowered by the thick leafy oak litter and the shade of the trees. From the above obtained figures it can be said, in general, that the moisture content of the soil, checked gravimetrically, did not reach the wilting point in any layer of the soil profile below 18 inches before August 18, 1953. The diagram in Figure 12 indicates that, till August 18, 1953, the moisture content of the deep soil profile was adequate to support plant growth for deep-rooted species.

3. Electrical resistance readings of gypsum blocks. The following problem was noticed in burying the gypsum blocks. The soil taken off by the auger and then used in refilling the same hole containing the gypsum blocks was badly disturbed, especially, in its

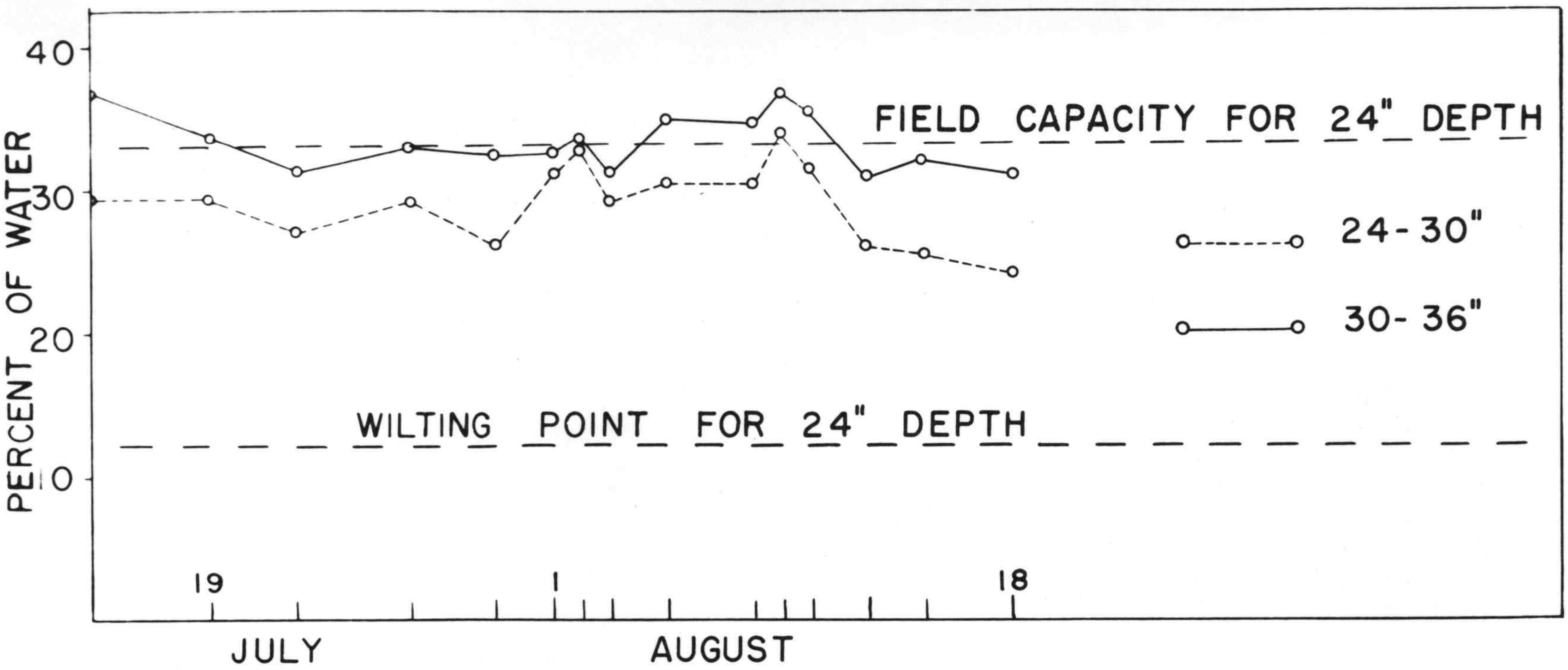

Figure 12. The gravimetric soil moisture content of depths 24 to 30 and 30 to 36 inches.

The average field capacity and wilting point are shown by the two horizontal dashed lines. The graph indicates that for the period of the growing season till August 18, 1953, these two soil layers never reached the wilting point.

natural structure. In many cases the soil was not enough to refill the hole regardless of the volume occupied by the four inserted gypsum blocks. Thus, to bring the soil level with the surrounding ground, additional soil had to be used. It is very difficult for a person to control and approach the same degree of compactness of the soil as it is under the natural conditions. Abd El-Samie (1), to overcome such difficulty in inserting plaster-of-Paris blocks, devised a metal tube containing the gypsum blocks at the desired depths. The principal advantages of his device were that the metal tube can be pulled up from one location and set in another easily, and this mounting provided better and greater surface contact of the gypsum blocks with undisturbed soil.

Another problem with the use of gypsum blocks is that of their durability, that is, the time they last when buried in the soil. Checking the durability of gypsum blocks in the laboratory revealed the following results: (a) Of those gypsum blocks continuously immersed in water and in the other aqueous solutions, only the buffer solution had a disintegrating effect and precipitated about the half of the gypsum. (b) The gypsum blocks that were under alternative immersion and drying for 24-hour periods in the water and hydrochloric acid broke in large pieces in about a week, while the gypsum blocks under the same procedure in the buffer solution of pH 5.0 disintegrated in shorter time and precipitated all of their gypsum. (c) The gypsum blocks buried in soil seeded to barley were surrounded by barley roots and when the cans were opened, slight disintegration of gypsum was visible, however, the gypsum blocks kept their shape and solidarity for the two-month period. Although Bouyoucos (16) attributes their short life to the wet soil, the above laboratory results indicated that a low pH of a buffer aqueous solution was one of the principal causes. Apparently the most rapid break and disintegration is brought about by a combination of wetting and drying (73), and high soil acidity. It was noticed, too, in the field and laboratory tests that fine roots of grasses surrounded the gypsum blocks and had a disintegrating effect upon them. Time is important as a contributing factor to the rate of disintegration. Further investigations about the durability of gypsum blocks are needed. Figures 13; 14; and 15 illustrate the condition of blocks taken from the field after January 1954 and blocks tested for durability in the laboratory.

The average electrical resistance readings for 1953, of the whole experimental area by dates and depths, are presented in Table 8. According to the readings obtained, the lowest water content in the soil was obtained on September 18. The readings for that date were the highest and are: 400,000; 350,000; 300,000; and 220,000-ohm for the corresponding depths of 0-6; 6-12; 12-18; and 18-24 inches. Figure 16 shows graphically the soil moisture depletion and saturation of the soil during rains. Until August 18, 1953, the average moisture obtained by the Bouyoucos bridge is normal for the four depths, that is, an increase of soil moisture with increase in depth. A rain at the end of August raised the moisture content of

Figure 13. Effect of root action on disintegration of gypsum block for a two-month period.

Notice the precipitated gypsum on the soil and the fine roots feeding on the blocks.

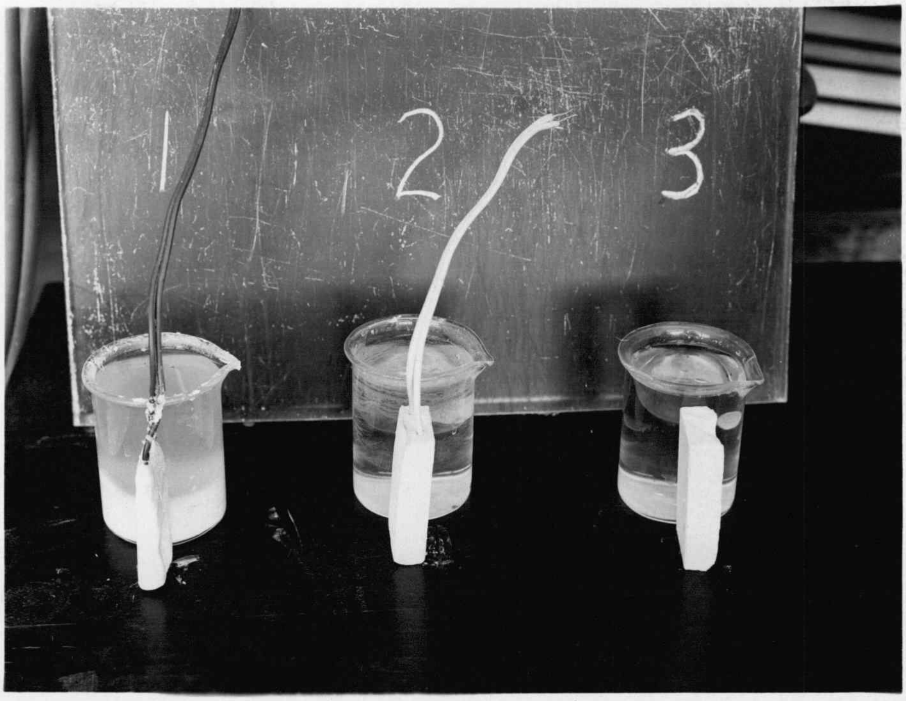

Figure 14. Laboratory tests for checking the causes of the disintegration of gypsum blocks.

No. 1. Gypsum block immersed in buffer solution of pH 5.0; notice the high precipitation of gypsum.

No. 2. Gypsum block immersed in water, no precipitation.

No. 3. Gypsum block immersed in 0.5 N hydrochloric acid, no precipitation.

All gypsum blocks were continuously immersed for a two-month period.

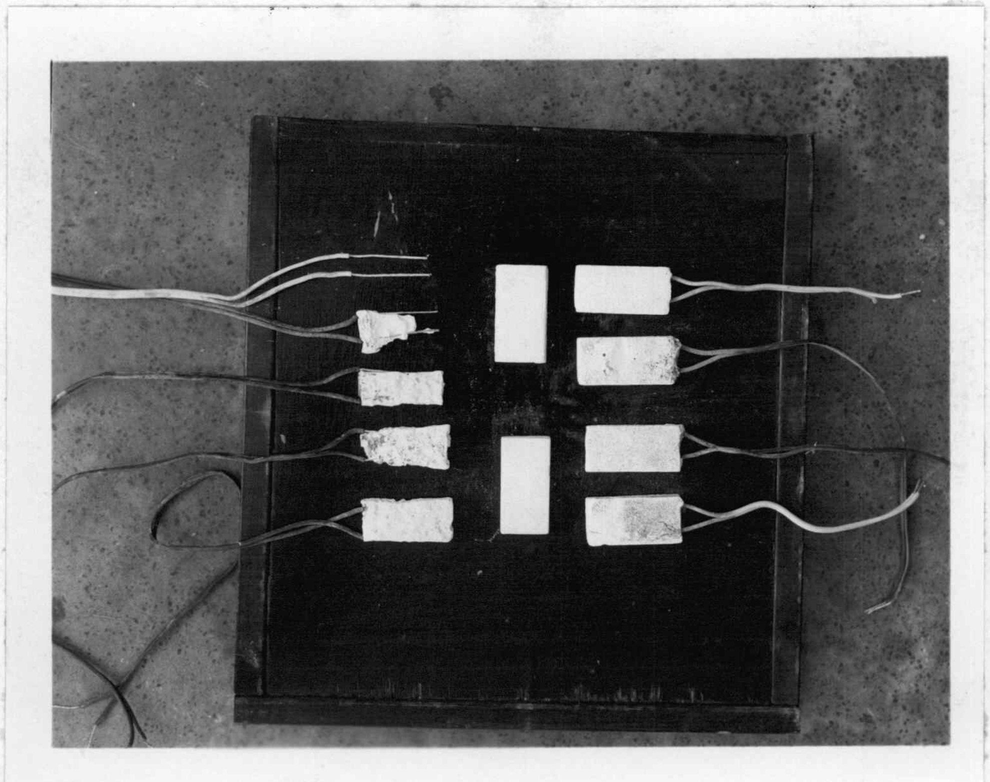

Figure 15. Disintegration of gypsum blocks used in the field and laboratory tests.

Left, as they come out from the field after eight months of use. Center, unused. Right, as they appear after the laboratory tests where they were subjected to root action and alternative wetting and drying for a two-month period.

Table 8. Mean of ohm-readings obtained by Bouyoucos bridge for the entire experimental area by depths at various dates for the year 1953.

Date	0-6	6-12	12-18	18-24
May 28	390	370	350	320
June 6	450	410	380	350
June 16	1,500	690	580	570
June 25	11,000	3,800	1,200	710
July 4	23,000	8,300	2,700	1,300
July 11	110,000	38,000	10,000	3,200
July 18	270,000	110,000	40,000	21,000
July 25	380,000	250,000	120,000	39,000
August 18	320,000	270,000	200,000	150,000
September 1	63,000	160,000	170,000	160,000
September 10	240,000	260,000	250,000	200,000
September 18	400,000	350,000	300,000	220,000
October 10	29,000	53,000	120,000	200,000
October 18	6,800	8,900	52,000	130,000
October 24	13,000	16,000	58,000	180,000
October 30	19,000	19,000	50,000	160,000
November 6	6,600	9,800	32,000	120,000
November 13	4,300	5,100	18,000	65,000
November 20	910	940	1,200	23,000
November 28	750	720	720	730
December 25	790	750	740	680

the three upper depths, but not that of 18-24 inches. The 18 to 24-inch depth continued to drop in moisture content until October 10. The actual gradual increase of the soil moisture, which means lower electrical resistance readings for the four depths without any reversal in trend toward the dry range, started on October 30. The

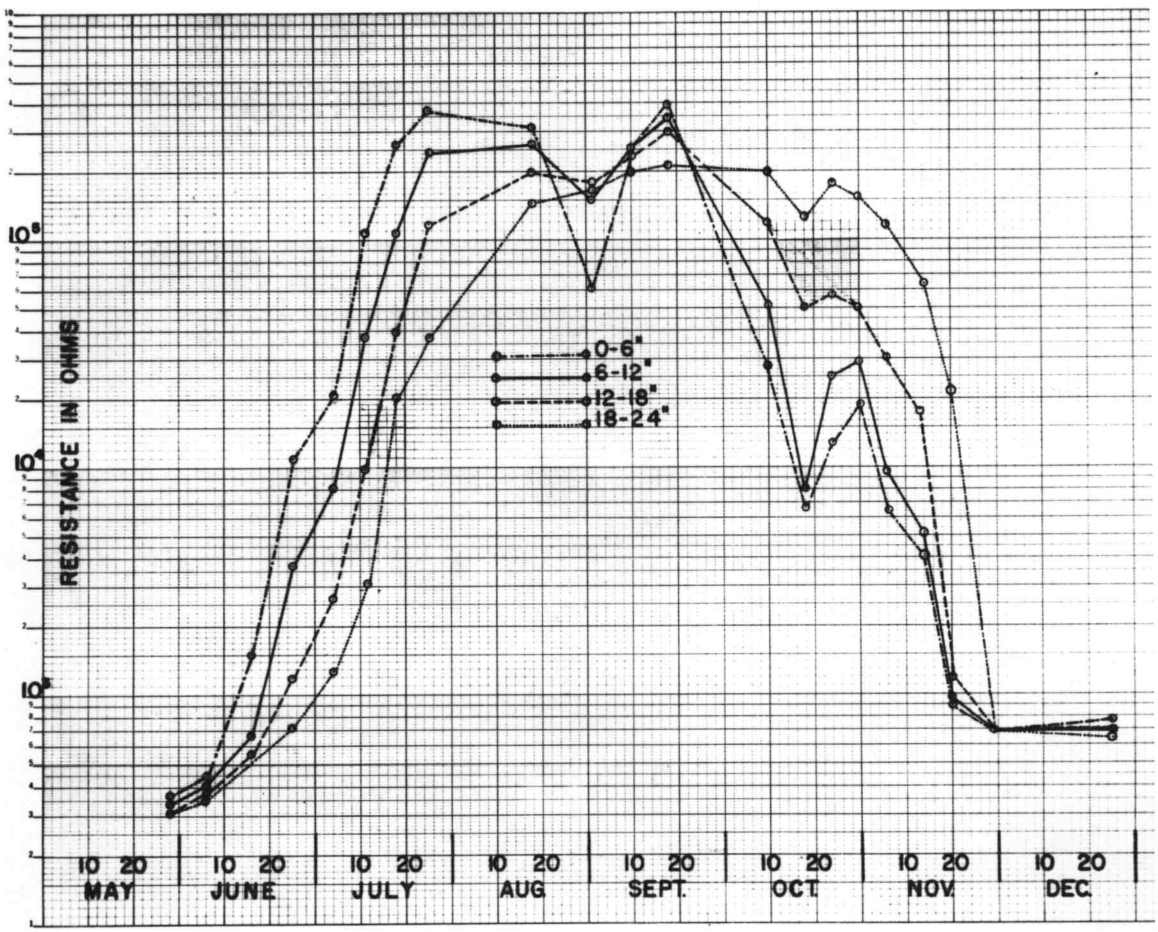

Figure 16. Average electrical resistance readings for the year 1953 for the entire experimental area.

same figure shows, too, that the readings of all depths reached the same point on November 28 (Appendix 13).

For the year 1954 electrical resistance readings, of the two experimental plots (highland bentgrass and tall meadow oatgrass), are presented in Table 9. Figure 17 shows graphically how the precipitation after the end of May and beginning of June in 1954 influenced the soil moisture content of the solum layers. During the period of June 11 to 24, the upper soil layer became wetter than all other layers. The next lower soil layer became wetter than all other layers. The next lower soil layer became wetter than that of 12 to 18 inch depth but it did not surpass the layer of 18 to 24 inches.

Table 9. Mean of ohm-readings obtained by Bouyoucos bridge for two experimental plots of non-irrigated gypsum block sets by depths at various dates for the year 1954.

	Depth in inches			
Date	0-6	6-12	12-18	18-24
June 11	3,800	24,000	13,000	9,200
June 17	2,200	9,500	12,000	5,700
June 21	2,700	7,300	11,000	6,300
June 25	8,800	12,000	13,000	7,600
June 29	28,000	19,000	14,000	9,500
July 3	89,000	33,000	22,000	13,000
July 7	130,000	56,000	28,000	18,000
July 11	210,000	80,000	43,000	25,000
July 18	380,000	180,000	87,000	61,000
August 18	3,000,000	2,100,000	1,100,000	960,000
September 18	170,000	390,000	320,000	340,000
October 27	860	15,400	138,000	280,000

By June 27 the moisture of all four layers started decreasing. On

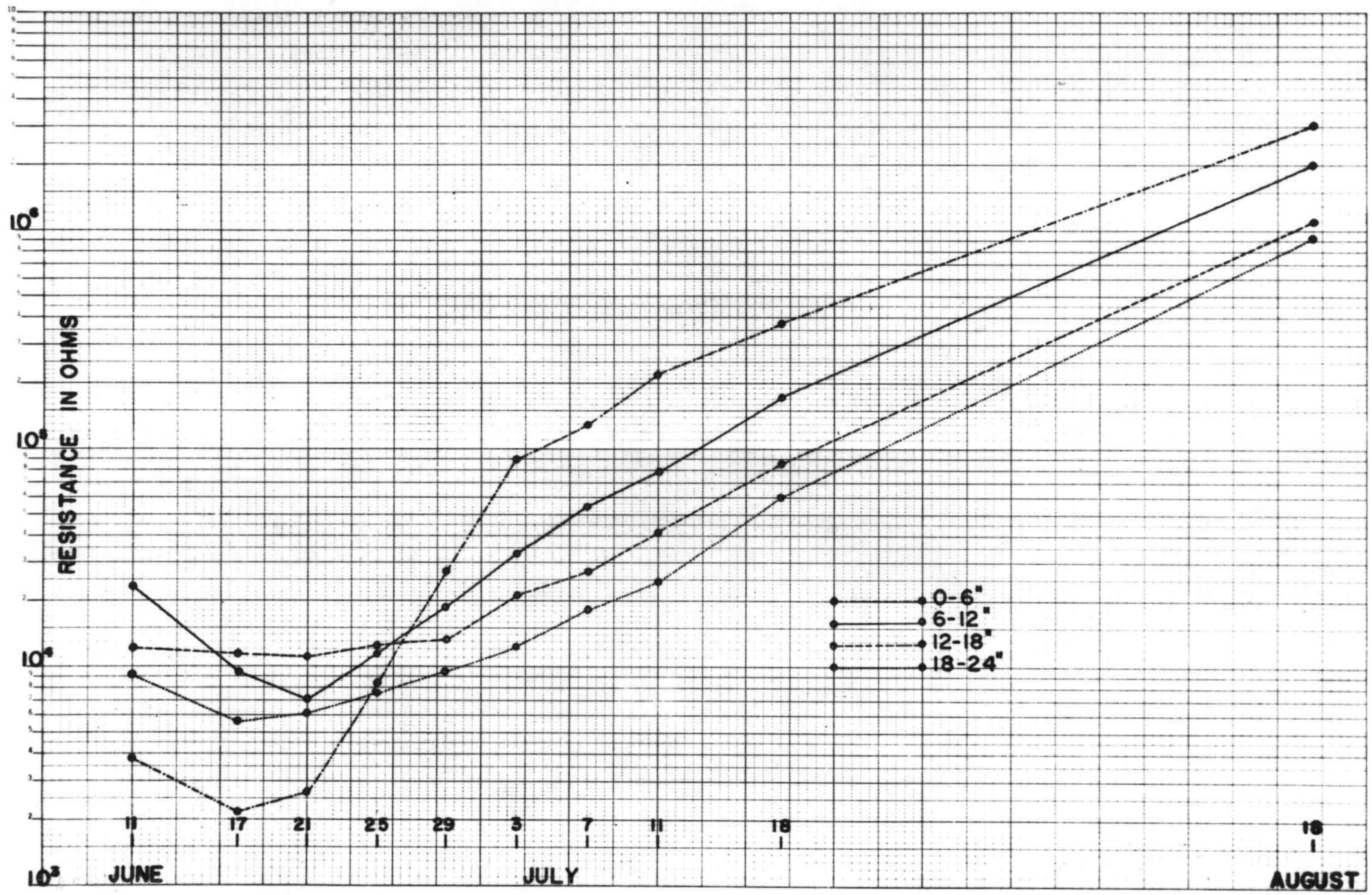

Figure 17. Average electrical resistance readings for the year 1954 for two experimental plots of non-irrigated gypsum block sets.

August 18, readings were 3,000,000; 2,100,000; 1,100,000; and 960,000 ohms for the gypsum blocks at depths of 0-6; 6-12; 12-18; and 18-24 inches respectively. On the other hand they dropped to 170,000; 390,000; 320,000; 340,000; and 860; 15,400; 138,000; 280,000 for the same depths on September 18, and October 27, 1954 respectively, because of precipitation. The high electrical resistance readings on August 18 might be due to the use of another Bouyoucos bridge for that date only (Appendix 14).

It should be pointed out that the year 1954 was wetter than the year 1953 but spring rains were heavier in 1953.

According to the field calibration curve of the blocks (Figure 18), the electrical resistance readings in Figures 16 and 17 did not reach in either year the permanent wilting point, as determined phytometrically.

4. Field calibration of gypsum blocks. As was pointed out previously, the decision of calibrating the blocks directly in the field was to overcome the objection of laboratory calibration (41; 22, p.41).

In 1953 simultaneous gravimetric sampling and electrical resistance readings were taken only one time in each location for the season. Consequently, points along the calibration curve depended upon the relative wetness of various gypsum block locations.

The data obtained did not cover a wide enough range of the soil moisture to establish the full calibration curve. In addition, the narrow range of the gravimetric moistures produced a great error in

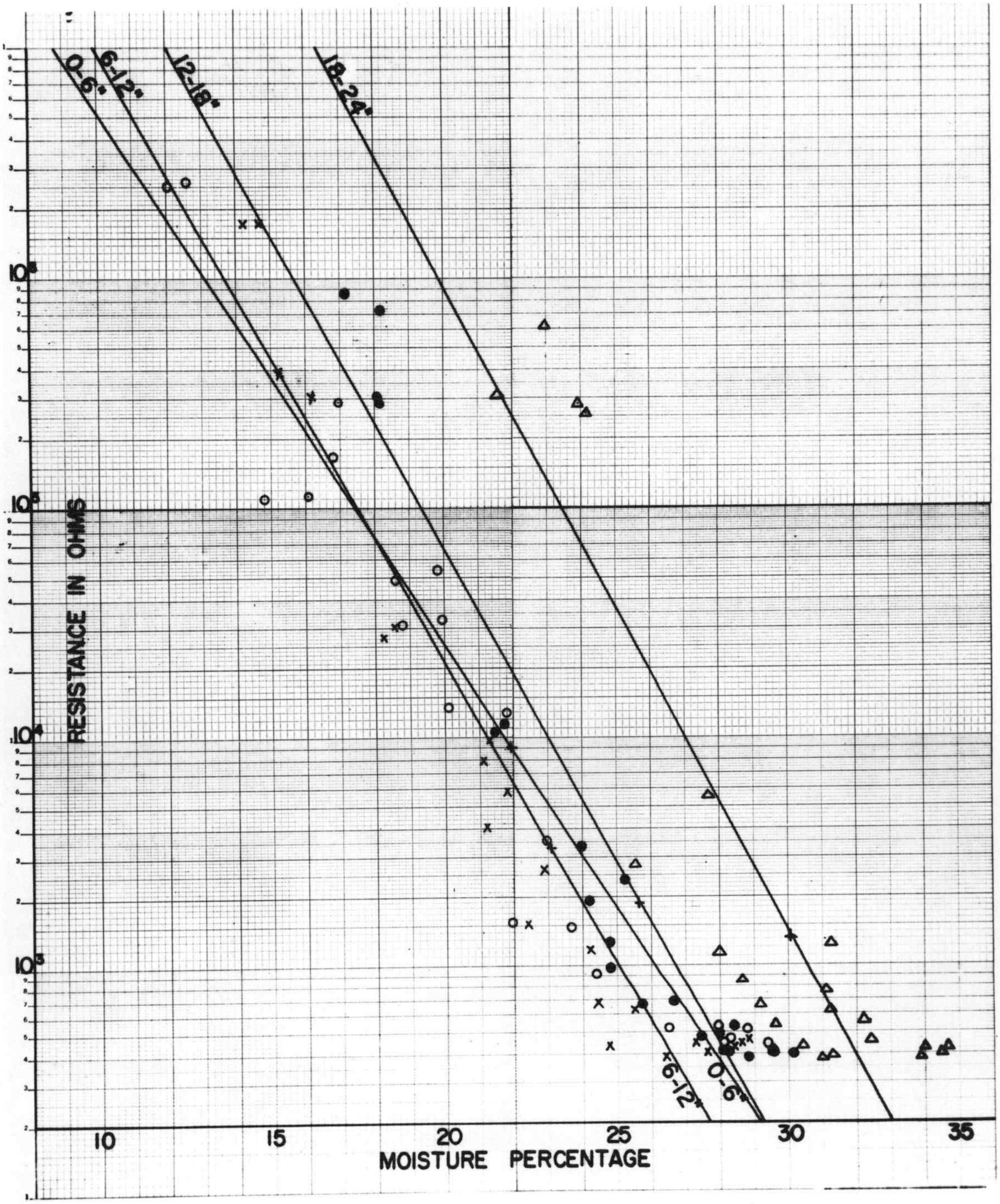

Figure 18. Field calibration curve of electrical resistance readings of gypsum blocks for four different depths corresponding to gravimetric moisture content of the soil profile. Open circles represent samples from 0 to 6-inch depth; crosses 6-12 inches; filled circles 12-18 inches; and triangles 18-24 inches.

the estimate of the slope of the curve. Hence, the data of simultaneous resistance readings and gravimetric soil moisture samplings with a greater spread of moisture of the year 1954 were used to establish the calibration curve in Figure 18. There is a decreasing of slope, or regression of gravimetric on resistance readings, with increase in depth. The average slope values were -4.30; -3.74; -3.61; -3.49 for the corresponding depths of 0-6; 6-12; 12-18; and 18-24 inches. Although these electrical resistance readings were not corrected for temperature, the great difference in the position of the curves, in Figure 18, between the three upper layers and the lowest one cannot be explained only by temperature. Changes in structure of these soil layers is probably a more important cause of these differences.

The analysis of variance of the regression coefficient of the gravimetric moisture average on logarithmic ohms for data of 1953 is presented in Table 10. In spite of the high error associated with the slope of the calibration curve, it is noticeable that species exert a highly significant effect upon the depletion of soil moisture.

Table 10. Analysis of variance of regression coefficients of gravimetric moisture means on log ohms for 1953.

Variation due to:	Sums of Squares	Degrees of Freedom	Mean Square	F
Total	797.30840476	55	--	--
Treatments	18.08307879	1	18.08307879	3.60
Depths	46.5925952	3	15.53084317	3.09
Species	357.31786985	6	59.55297831	11.87**
T x D	24.96639092	3	8.32213031	1.66
T x S	92.57532568	6	15.42922095	3.07*
D x S	167.44058002	18	9.30225445	1.85
Error (TxDxS)	90.33262998	18	5.01847944	--

Coefficient of variation $= \frac{\sqrt{5.01847944}}{.797968} = \frac{2.240196}{.797968} = 2.8074 = 280.7\%$

Fertility. -- Since the Laughlin-like soil series was being studied for the first time in the Willamette Valley, the results of the routine laboratory analysis for the major nutrients are presented in Table 11 (Appendix 15).

Table 11. Summary of the chemical analyses with ranges of soil reaction and average contents of some mineral nutrients and organic matter by depths for the Laughlin-like soil series.

Soil depth (inches)	Range of pH	Phosphorus (p.p.m.)	Potassium (p.p.m.)	Calcium (p.p.m.)	Nitrogen (percent)	Organic matter (percent)
0-6	5.5-5.7	4.7	372	1735	0.19	4.49
6-12	5.4-5.5	2.6	301	1604	0.12	2.60
12-18	5.2-5.4	2.6	280	1484	0.09	1.72
18-24	5.0-5.4	1.8	252	1478	0.06	1.03
24-36	4.8-5.2	2.1	235	1570	0.05	0.76

The average values, which are presented in Table 11 for contents of phosphorus, potassium, calcium, nitrogen, organic matter, and the range of pH values indicate that there is a decrease in chemical nutrients as well as in pH with an increase in depth. Thus, the 0 to 6-inch layer of the soil has pH values from 5.5 to 5.7 and average values for the nutrients as follows: 4.7 ppm for phosphorus; 372 ppm for potassium; 1735 ppm for calcium; 0.19 per cent for nitrogen; and 4.49 per cent for organic matter. The comparable values for the 24 to 36-inch depth decreased to 4.8 - 5.2; 2.1; 235; 1570; 0.05; and 0.76. According to the Soils Department of Oregon State College (70), the above values for phosphorus and calcium are considered as low; the potassium, nitrogen, and organic matter are adequate for pastures under western Oregon conditions.

It is known that nitrogen is an essential element for plants because it contributes to the formation of proteins (88, pp.30-36). Nitrogen is the most important element in increasing the forage yield for the Willamette Valley (29). Because of its rapid decrease in the soil in comparison with other nutrients, nitrogen has to be applied more often than other fertilizers (49 and 62). However, it is believed that productive pastures under western Oregon conditions must have a total amount of nitrogen greater than that found in this soil. Thus, the supply of available nitrogen, which is important for immediate forage production, increases after the application of nitrogen fertilizer.

Beeson (7) has identified the Pacific Northwest as being a soil-phosphorus deficient area. In such areas, phosphorus fertilizers generally increase phosphorus concentration in the forage species and have a beneficial effect upon the livestock production and functions (8 and 42). The low content of phosphorus in this soil may be one of the important factors limiting the growth of legumes. According to the Soils Department (70), samples containing less than 12 pounds per acre (6 p.p.m.) are considered low in available phosphorus for western Oregon.

One of the first steps in the improvement of soil fertility is to change its pH value and bring it up to the ideal soil reaction for plant growth, that is, around pH 6.5 (98). Again, according to the Soils Department (70), soils with pH 5.5 are considered to be distinctly acid and many crops will not grow well without adding lime. Low pH values in pastures result in an increase in acid tolerant plants that crowd out the more desirable species (88, pp.473-478). Calcium carbonate or lime application will increase the pH (5, pp.20-27), increase the yield (89 and 56), and reduce the toxicity, if any, of the soil (89). The addition of lime will improve root growth in depth and volume, so that the plant better utilizes the nutrients and moisture from the deeper soil. Calcium as a nutrient will enable the soil to support healthier plants and increases the activities of the soil microflora and microfauna (60 and 88, pp. 473-478). Failure in the establishment of many leguminous forage species may be attributed, also, to a lack of calcium and low pH which ties up available nutrients (70). The amount of limestone needed to be applied in the experimental area has not been calculated (71).

Better animal nutrition, especially mineral nutrition, advocates the application of phosphorus and lime in pastures. Animals commonly suffer mineral deficiencies when the soils are poor in these elements (42).

In general, it can be concluded that fertilization and liming of such areas, seeded to improved forage species, should pay. Their water supplying power is satisfactory to support plant growth and produce economical grazeable forage (86).

Further investigations in regard to the type, rate, and time of application of fertilizers to these soils, as well as investigation into their content of minor elements, will help to better understand the fertility status of Laughlin-like soils.

B. Vegetation

Root studies. -- Results of various observations and measurements of the root systems of some of the important species in the experimental area are as follows:

1. Highland bentgrass. This species was found to spread by rhizomes which root at the third and fourth nodes. A large number of roots originate from the crown, extending vertically to a depth of 3 to 3.5 feet with a lateral spread to a maximum of 12 inches. The most abundant volume of the root system was within a depth of 2 to 10 inches. The lower 10 to 18 inches of the vertical roots penetrated and were slightly branching within the shale.

2. Tall meadow oatgrass. Observations showed that the very

fine fibrous roots were abundant in the upper layer from 8 to 14 inches, while the main roots penetrated into the shale. The deep primary roots branched less in the shale. Some main roots of the species were traced to a depth of 3 to 3.5 feet having a considerable portion within the shale. Branching roots were from 3 to 12 inches long with many laterals.

3. Tualatin oatgrass. Roots of this variety are more fibrous and of finer texture than those of the tall meadow oatgrass. They completely occupy the upper 1 to 5-inch soil layers having decumbent stems which act as short rhizomes and root at the second and third nodes. Beyond the depth of 12 inches the fibrous roots extend in a parallel manner to the deeper soil layers. Their total depth has been traced to 4 feet, as it is seen in Figures 19 and 20, and at that depth the root volume seems to exceed that of the tall meadow oatgrass.

4. Alta fescue. The majority of the roots are present in the upper 2 to 7 inches and are densely branched. The few roots that penetrate deeper are less numerous and branching and reach a depth of at least 3 to 3.5 and more feet, penetrating the shale. The upper roots develop rhizomatic parts branching at the first and second nodes.

5. Chewings fescue. The main roots are densely branched to a depth of 4 to 6 inches. There were no roots of this species traced beyond a depth of 20 inches.

6. Orchard grass. The primary roots are the main penetrating

Figure 19. Shale samples, taken from a depth of four to five feet, showing the fibrous roots of Tualatin oatgrass.

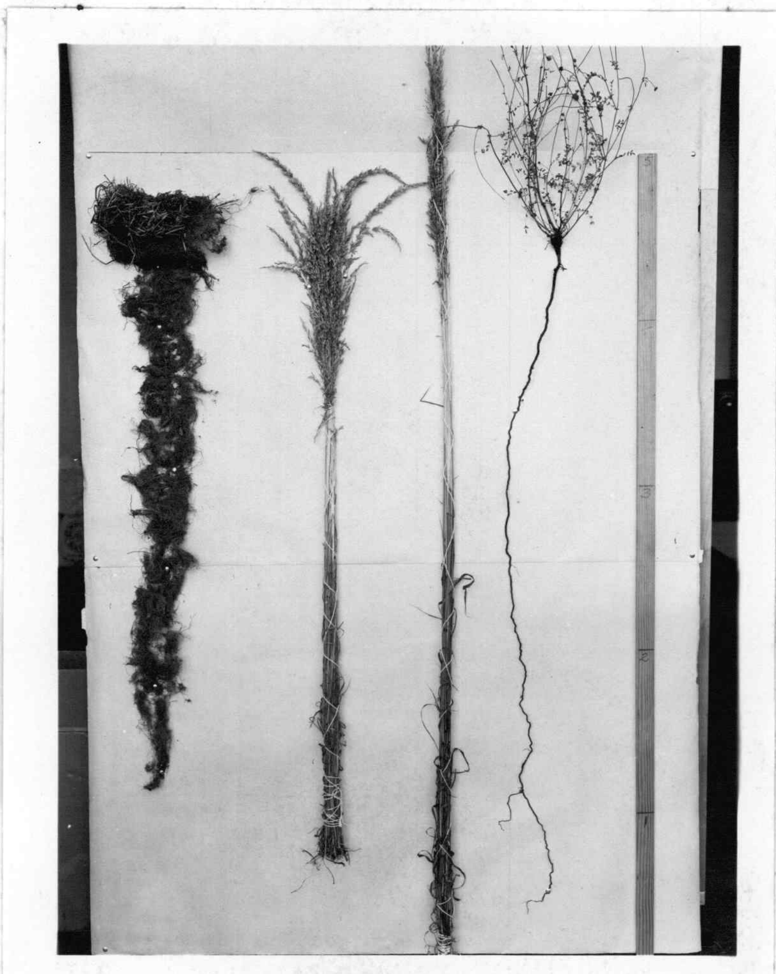

Figure 20. Root and top growth of some seeded forage species.

From left to right: Root system of a Tualatin oatgrass plant; the top of the same plant; top of a tall meadow oatgrass plant; an individual plant of burnet.

portion of the root system reaching to a depth of three and more feet. Branching of the primary root system was more abundant in the upper layer to ten-inch depth, while branching below that depth was slight. Of the main root, 15 to 20 inches penetrated into the shale layer. The orchardgrass roots were the coarsest in texture of all fibrous-rooted species investigated.

7. Timothy. The timothy which was found only under the oak canopy had abundant roots in the surface soil layer to a depth of ten inches. The greatest depth of penetration was 15 to 18 inches reached by only a few roots which branched very little. Roots did not extend to the shale layer.

8. Annual grasses. Most of the annual grass species develop an abundance of roots in the upper 1 to 6 inches. Very few roots of annuals were found to penetrate down to a depth beyond 15 inches.

9. Subterranean clover. No attempt was made to investigate the root system of subterranean clover.

10. Burnet. From the crown one main tap root penetrates vertically into the soil to a depth of 3.5 to 4 feet. A few fine laterals of one-half to 4 inches extend horizontally. About one-half of the total root length is found within the shale (Figure 20).

11. Plantain. This plant when matured develops deep taproots reaching to a depth of 30 to 36 inches, part of which penetrate the shale layer.

12. Fern. This is a rhizomatous species with their root system being most abundant between the 18 and 34-inch layer. Roots

of fern enter the large soil-filled crevices in the shale layer.

13. Oak trees, wild rose, and poison oak. Roots were found to extend their main roots into the deepest layers of the shale. Some of these roots were found at a depth of ten feet.

In general, investigations into the type, depth, and distribution of the root systems of plants for a given soil will help materially to understand the water supplying power of the soil. In addition, the knowledge of the behavior of the roots of the improved seeded species will help guide their entire manangement from selection of species through fertilizing and utilizing them. In obtaining root measurements several difficulties were encountered. In the first place, it was hard to dig the dry soil and obtain a monolith. The soil broke vertically and horizontally when dry. Furthermore, it is difficult to isolate the root system of a dense sod-forming grass species, such as bentgrass and oatgrasses.

The average root depth of the various improved species was found to be three and one-half feet. Some of the species might reach a greater depth (78), but no attempts were made to dig below 3.5 to 4 feet for all of the species. The main portion of the root volume of the improved seeded species, with the most fibrous roots that have become permanently established, tends to be in the upper 15 inches of the solum. Most of them had a portion of their root system that penetrated into the shale except for chewings fescue and timothy. No traces of the roots of these two species were found in the shale. The valuable forage species which developed taproot systems are burnet and plantain. Burnet readily penetrates the shale and almost the half of its root length is within the parent material. Plantain does not go as deep as burnet, but a good portion of its taproot is within the shale.

The bracken fern has the greatest volume of its roots between the layers of shale and solum.

Most roots of the woody species are within the shale layer and go beyond the zone occupied by the herbaceous species mentioned above. Therefore, there is no major competition for water and nutrients between deep-rooted forage species and the dominant woody species on this Laughlin-like soil.

The length and distribution of the development of the root systems examined suggest that the successfully established species in the area are able to utilize the soil moisture throughout the profile. It is of significance that their roots reach the shale layer and a portion of them penetrates into the shale crevices. The shale has been found to be supplied with an adequate water content for the growing season (Figure 12). Thus, once the roots of the plants have reached and entered the shale horizon, the moisture content of the soils did not become a critical point for plant life during the period of this study. In view of this fact, it seems reasonable to conclude that improved forage species like oatgrasses, bentgrass, Alta fescue, burnet and orchardgrass can become established and be maintained because of their deep rooting habits.

It was assumed previously that the sponge-like layer of the soil might hinder the capillary rise of the water table. If the roots in the solum cannot be supplied with water later in the season, it is necessary that plant roots be extended into a zone where continuous supply of water is available in late summer and early fall.

From the standpoint of root distribution in the soil profile, it appears that considerable competition for water, nutrients and light exists between annual and perennial species. Indeed, such competition is visible. In places where perennials are abundant, the annuals become dwarfed with small seed heads, while the annual species where perennials are less abundant become tall, thrifty, and produce larger seed heads. Similar competition seems to exist between perennial deep-rooted forage species and bracken fern. Under abundance of perennial grasses a great number of fern aerial parts die in the end of July and beginning of August, while in areas with sparse perennial grass species the aerial parts of bracken fern live until the end of September. Both oatgrass species seem to compete with bracken fern better than all other deep-rooted seeded grass species. Further investigation, based on the above observation, might help to control the bracken fern in native pastures.

Yield and composition. -- Comparison of the forage production and composition for the two years has to be made carefully because of the differences in the time of clippings. However, comparison of the total production based on September clippings for both years should give a clear picture of improvement after the exclusion of grazing for 18 months (103).

Table 12. Mean, in grams, of air-dried forage production, by species and total, of one square-foot quadrat clippings obtained for the growing season of 1953 from the seven seeded plots.

Date of clipping		June 5				September 5			
						New random locations		Same locations clipped June 5, at 2"	
Stubble height in inches		0	0	2	2	0	0	0	0
Plot no.	Seeded species	Sp.	Total	Sp.	Total	Sp.	Total	Sp.	Total
5	Highland bentgrass	15.6	31.1	4.8	9.6	—	55.4	—	27.3
		4.9*	3.6	0.9	1.1		5.6		3.4
6	Chewings fescue	3.2	21.3	0.6	8.6	—	41.1	—	20.8
		1.5	3.0	0.3	1.1		4.1		2.6
9	Alta fescue	2.9	17.1	0.6	5.8	—	34.0	—	16.2
		0.9	4.1	0.1	0.9		3.2		0.2
11	Tall meadow oatgrass	3.3	24.7	1.8	8.6	—	60.9	—	21.5
		0.5	4.0	0.1	1.1		5.3		2.7
12	Tualatin oatgrass	3.6	31.3	1.9	12.4	—	63.7	—	27.3
		0.5	3.5	0.4	1.5		5.9		1.4
16	Burnet	1.2	25.4	1.2	9.8	—	48.1	—	27.0
		0.3	2.3	0.3	1.2		3.0		2.2
17	Subterranean clover	0.8	29.8	0.2	9.3	—	52.7	—	26.8
		0.5	4.4	0.1	1.2		1.9		2.0

* Standard errors of means are directly below mean values.

Table 13. Mean, in grams, of air-dried forage production, by species and total, of one-square-foot quadrat clippings obtained for the growing season of 1954 from the seven seeded plots.

Date of clippings		May 1				July 15				Sept. 1	
						New random locations		Same locations clipped May 1, 2"		New random locations	
Height of clippings in inches		0	0	2	2	0	0	0	0	0	0
Plot no.	Seeded Species	Sp.	Total	Sp.	Total	Sp.	Total	Sp.	Total	Sp.	Total
5	Highland bentgrass	4.3	10.4	2.1	4.8	25.8	47.2	15.6	24.5	31.0	52.0
		0.9*	1.0	0.4	0.3	5.3	3.7	3.3	2.7	4.2	1.8
6	Chewings fescue	3.0	9.2	1.5	4.1	4.3	34.6	5.0	19.6	6.0	38.0
		0.9	0.5	0.5	0.4	1.6	2.1	1.4	1.8	1.9	1.6
9	Alta fescue	9.5	13.3	5.1	6.8	13.0	38.4	9.2	16.9	17.0	45.0
		1.3	0.9	0.5	0.5	1.7	3.5	1.2	2.3	2.1	1.5
11	Tall meadow oatgrass	15.1	16.7	8.6	9.5	37.3	46.7	19.9	25.0	50.9	70.2
		1.5	1.6	0.7	0.7	0.8	2.6	2.2	3.0	2.4	2.4
12	Tualatin oatgrass	10.6	22.4	6.7	7.3	45.3	51.8	25.6	31.7	60.5	82.5
		0.5	0.3	0.3	0.4	3.3	3.3	2.4	3.4	3.4	2.5
16	Burnet	1.4	8.3	0.7	4.8	5.0	28.4	4.1	15.4	9.0	45.0
		0.3	0.5	0.2	0.4	0.9	2.5	0.4	1.4	0.9	2.0
17	Subterranean clover	0.1	11.5	0.2	5.4	0.0	38.1	0.0	18.8	0.0	54.7
		0.06	2.3	0.1	0.4	0.0	2.4	0.0	1.7	0.0	2.0

* Standard errors of means are directly below mean values.

Summaries in grams per square foot of the mean total forage production, composition, and the growth among the various clipping intervals for 1953 and 1954 are presented in Tables 12 and 13 and in Figure 21 (Appendices 16-29).

In comparing the production in Figure 21 obtained in September for both years, the total yield differences among the plots of highland bentgrass, chewings fescue, burnet and subterranean clover are not significant. On the other hand, the total yield of the remaining plots of Alta fescue and both oatgrasses was greater for 1954 than the 1953 year. One should remember that the increased yield of some plots may be attributed to the greater precipitation for the year 1954 in addition to the exclusion of grazing.

Production from the first clippings for all plots in 1954 are lower than those obtained in 1953 because the yields were taken 35 days earlier in 1954.

The presentation of total production, obtained at zero-stubble height clippings, in Figure 21 (columns 1 and 2) is not particularly helpful in understanding the improvement that took place on the plots. However, when columns 3 and 4 of Figure 21 are compared, the changes in production of species are very interesting. For example, production of highland bentgrass and subterranean clover was less in the first clipping for 1954 than for 1953. On the other hand, the production of the species from the remaining plots was equal or greater despite the earlier date of clipping in 1954. Such a difference in seasonal production from various species suggests that chewings fescue, Alta fescue, both oatgrasses, and burnet produce more early forage, thus giving opportunity for early spring grazing by livestock.

The present study was primarily concerned with the composition and improvement of the seeded species rather than in the total forage yield. Percentage composition, as shown in Figure 22, of seeded species for the first clippings in both years gives a better picture of the improvement after one year's exclosure from grazing. The composition of the seeded forage species by weight varied in the plots depending on the time of clipping and the above-ground characteristics of the species. Thus, the following ratios were obtained for the clippings at ground level and two-inch height above ground on June 5, 1953, and May 1, 1954 as indicated in Table 14.

Table 14. Ratios of percentage composition of seeded forage species for the first clippings in 1953 and 1954.

Seeded species	Clipped at 0" stubble height	Clipped at 2" stubble height
Highland bentgrass	0.8	0.9
Chewings fescue	2.0	5.3
Alta fescue	4.4	7.6
Tall meadow oatgrass	6.9	4.4
Tualatin oatgrass	7.2	6.0
Burnet	3.4	1.6
Subterranean clover	0.3	2.0

$$\text{Ratio} = \frac{\text{Percent composition of seeded species for clippings, May 1, 1954}}{\text{Percent composition of seeded species for clippings, June 5, 1953}}$$

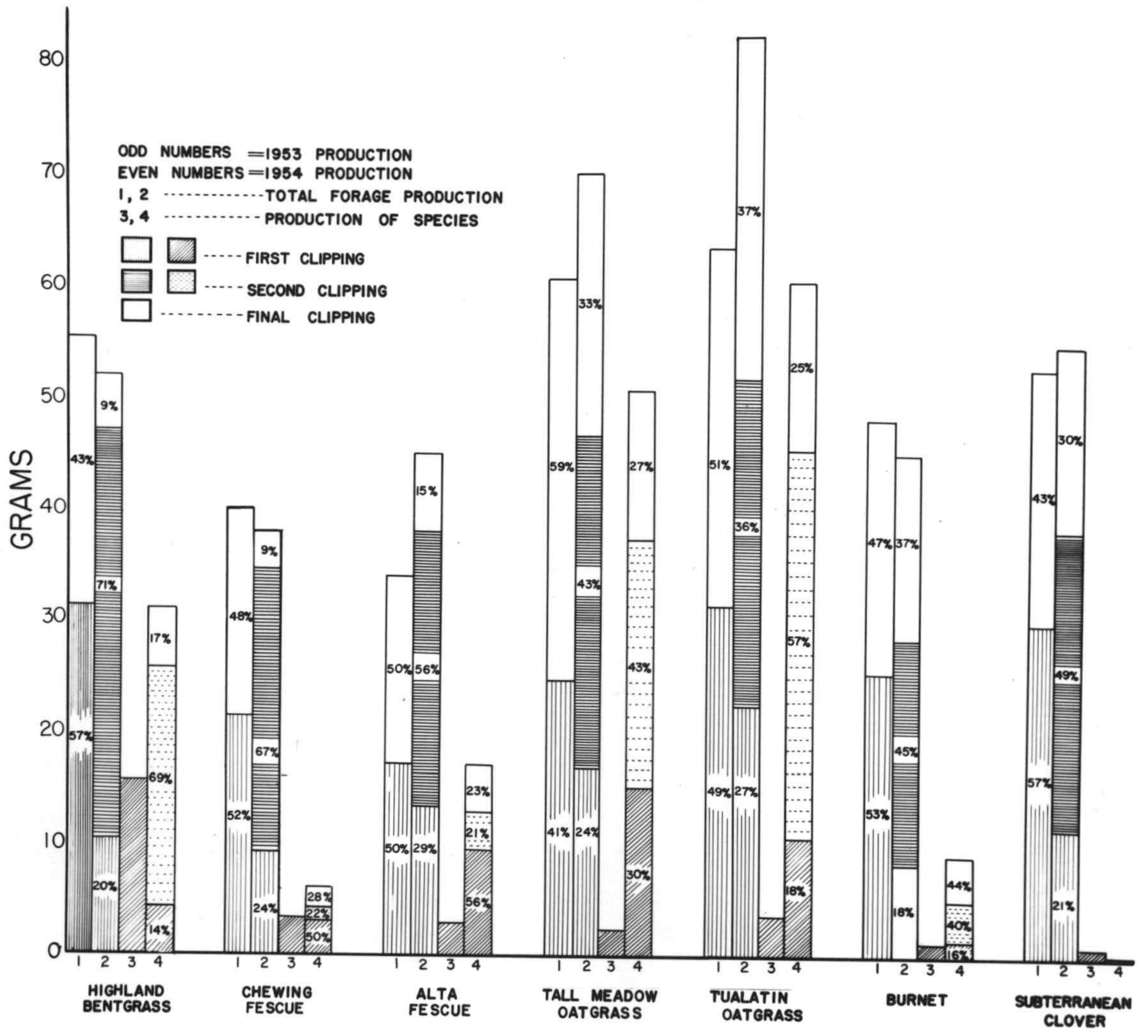

Figure 21. Total forage production obtained at zero-inch stubble height clippings for 1953 and 1954.

Two clippings were made in 1953 and three clippings in 1954. Per cent figures show the proportion of total and species production by season. Column no. 2 above burnet should have vertical hatch adjacent to the axis.

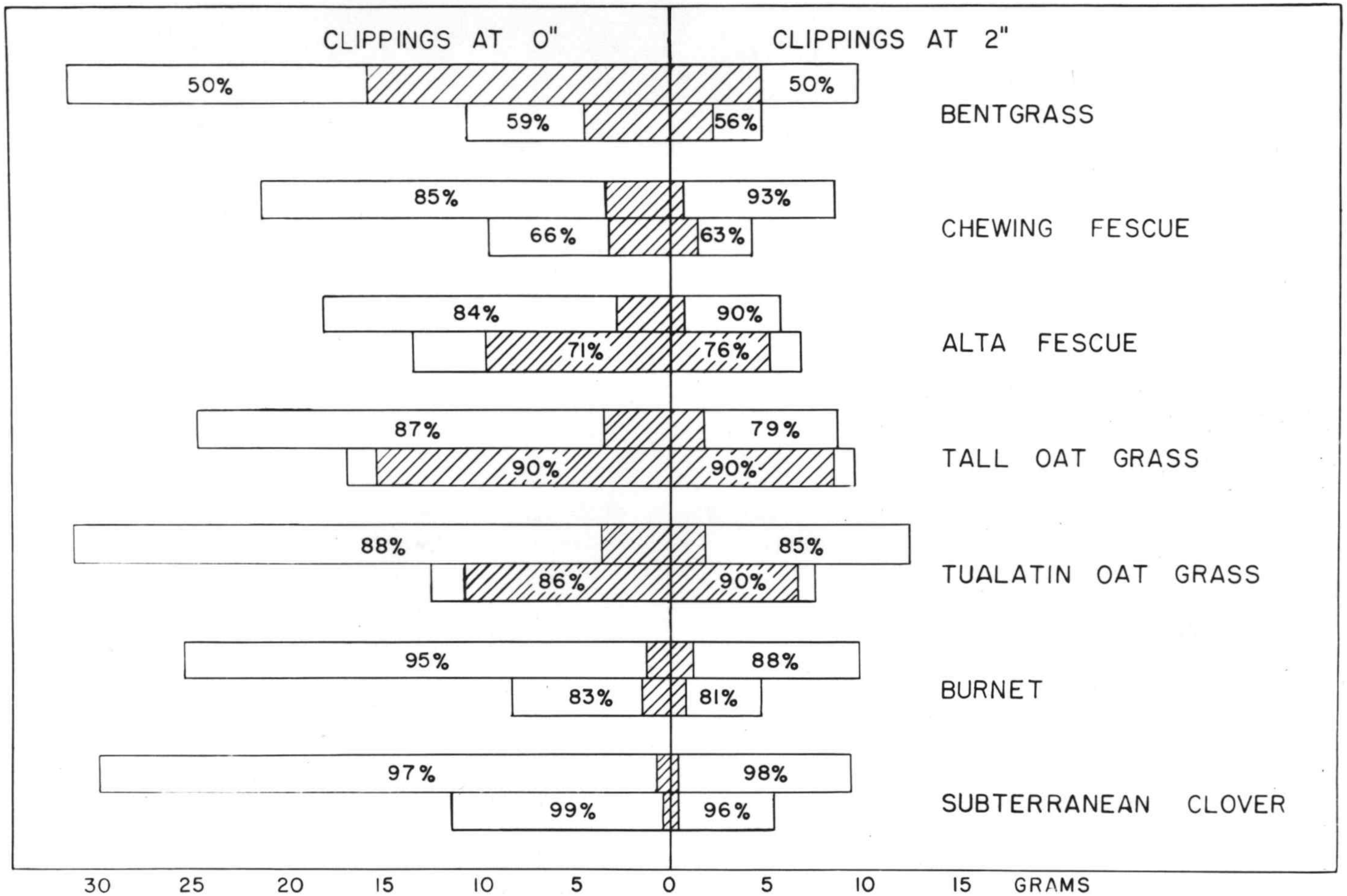

Figure 22. Per cent composition of seeded species at the first clipping for 1953 and 1954.

Upper and longer bars represent clippings obtained June 5, 1953; lower and shorter bars represent clippings obtained May 1, 1954. Shaded portion represents the per unit of seeded species.

The above obtained figures indicate that there was a pronounced increase in composition of seeded species from 1953 to 1954 after one year's exclosure from grazing. The low ratio of 0.80 for bentgrass can be attributed to the late growth start of the species rather than to the increase of other species. Growth of subclover was particularly poor in the 1954 growing season.

Composition obtained by the point-frame method for June and July of 1953 for the two species, highland bentgrass and chewings fescue, gave the following figures: Highland bentgrass from a total of 2400 hits composed 35.40 per cent of the composition, and 64.60 per cent of the composition was of other species; chewings fescue from a total of 1200 hits made up 5.25 per cent, with the remaining 94.75 per cent composed of other species. On the other hand, the per cent composition of the seeded species obtained by clippings on June 5, 1953, were 50 per cent for highland bentgrass, and 15 per cent for chewings fescue when clipped at ground level. Figures were 50 per cent for highland bentgrass and 7 per cent for chewings fescue at the 2-inch stubble height. Thus, there is not good agreement in the per cent composition between the point-frame and clippings methods. Such a disagreement can be attributed to: (a) The different sampling dates used. (b) The rapid rate of growth of the plants in height. However, the point-frame method revealed a significant abundance of litter and the absence of exposed bare ground. For example, in the highland bentgrass plot, about only one per cent of the total hits was for bare ground, whereas the litter made up 37 per cent, and vegetative cover the remaining 62 per cent. For the chewings fescue, it was about one per cent for bare ground, 35 per cent for litter, and 64 per cent for the vegetative cover. These data definitely suggest that the ground under the two seeded species is covered and well protected against erosion (Appendices 30 and 31). The figures of the inventory, of the experimental area in 1946, do not throw any light on the composition of the seeded species in relation to the other native species. However, it helps to understand that in 1946 most of the seeded forage species were thriving better under treatments A and B. (Appendices 32 and 33)

Unfortunately, the per cent composition by weight of seeded species for the last clippings of September 1953 could not be obtained because the forage was so dry that separation into species was impossible. The per cent composition for the production of the clippings for 1954 are presented in Table 15.

The decrease in the per cent composition of tall meadow oatgrass and Tualatin oatgrass between clippings obtained on September 1, in comparison to those clippings obtained on July 15, 1954, can be attributed to the loss in weight of the plant material upon drying. The percentage composition figures suggest that all seeded species, with the exception of subterranean clover, make up a good percentage of the stand.

The rate of growth, expressed in per cent, of most species was greater after May 1, 1954, except for the two fescues. It is surprising that both fescues gave above 50 per cent of their growth before May 1, 1954 (Figure 21). Both of these species are typical cool season plants but Alta fescue makes good summer growth, too. The most yield for both fescues was obtained in treatments C and D, where the forage was under the oak canopy (Appendices 24 and 25). It should be mentioned that both species spread vegetatively in 1953 and produced very little seed that year. In contrast, for the year 1954, fescue seed heads were produced in abundance and it is believed that for the next growing season of 1955 there will be a great increase in young seedlings of both species.

Table 15. Per cent composition by weight of air-dried forage production of seeded species and other grazeable species obtained for the entire growing season of 1954 from the seven plots clipped at height of ground level (zero-inch)

		Date					
		May 1		July 15		September 1	
Plot No.	Seeded Species	Seeded Sp.	Other Spp.	Seeded Sp.	Other Spp.	Seeded Sp.	Other Spp.
5	Highland bentgrass	41	59	55	45	60	40
6	Chewings fescue	33	67	12	88	16	84
9	Alta fescue	71	19	34	66	38	62
11	Tall meadow oatgrass	90	10	80	20	72	28
12	Tualatin oatgrass	47	53	87	13	73	27
16	Burnet	17	83	18	82	20	80
17	Subterranean clover	0	100	0	100	0	100

The disappearance of the seeded legumes (Lotus corniculatus, subterranean clover, and hop clover) from the seeded plots might be attributed first, to the lack of calcium and high soil acidity; and secondly, to the low fertility, especially the low phosphorus. In addition, the rate of their root development and dry summers combined with heavy grazing may have accelerated their disappearance. Subterranean and hop clover occur throughout the experimental area in the open, but nowhere in solid stands, while Lotus corniculatus exists in a very thin stand in its original seeded plot.

Once the acidity of the soil is corrected and the correct amount of phosphorus fertilizer is applied, one can expect to see a marked increase of leguminous forage plants. Further investigation on the establishment of leguminous forage plants is needed. Particularly, work needs to be done with deep-rooted legumes that will utilize the abundant moisture, and the nutrients existing in the deeper soil layers and shale.

From the present study it has been observed that the following species and varieties: tall meadow oatgrass, Tualatin oatgrass, Alta fescue, and orchardgrass, thrive under the shade of an oak canopy as well as in the open field. This is contrary to Piper's opinion for oatgrasses (76). Burnet thrives better in the open and highland bent, contrary to its name, thrives best in the low, open land. The oatgrasses as observed in Figures 23 and 24 thrive well under any type of seedbed preparation, whereas burnet requires a well prepared seedbed.

The vegetative composition of all plots, especially in the open field, showed an abundance of narrowleaf plantain. Agronomists usually consider it as a weedy forb and not as a valuable forage plant. The disadvantage of plantain, as forage species, is that it

Figure 23. Tualatin oatgrass under oak canopy. The photograph includes treatments C and D (July 22, 1954).

Figure 24. Tualatin oatgrass in the open field. Notice the thickness of the stand in the background. In the foreground the species is invading an area of bracken fern. The photograph includes treatments B and C (July 22, 1954).

dries readily after harvesting. It is difficult to handle and secure its yield because of the characteristic to disintegrate when dried. The same characteristic holds for burnet.

It was observed that when sheep enter a pasture for grazing where plantain grows, they do show a preference for it. They graze first the green heads of plantain and then the leaves. A chemical analysis of the plant was made and the results reveal that plantain is equally as nutritive as the improved seeded species of burnet and oatgrasses. It was observed, too, that plantain, when growing with tall grass species, develops longer and more vertical leaves so that they can be grazed easily. In addition, plantain is green throughout most of the year due to the continuous growth of the species under Willamette Valley climatic conditions. On this particular area its abundance may be an indicator of the acid reaction of the soil. Further investigations may reveal other reasons for its abundance. Furthermore, plantain in mixtures does not compete seriously with improved seeded species because its taproot system reach and penetrate the shale. It is palatable, nutritious, and makes a good protective vegetative cover against erosion.

Forage chemical analyses. — The values of the chemical analyses are presented in Table 16. The highest value of 73.00 per cent dry matter was obtained for the plantain heads and stems, whereas the lowest value of 55.10 per cent was for Tualatin oatgrass. The crude protein content from samples under the canopy was 7.25 per cent for

Table 16. Chemical composition of certain nutrients for some grazeable forage species.

Species	Dry matter (gms.)	per cent Crude protein	Ether extract	Ash	Crude fiber
Tall meadow oatgrass					
open field	56.34	5.95	--	--	--
under canopy	59.70	7.25	--	--	--
Tualatin oatgrass					
open field	55.10	6.45	--	--	--
under canopy	56.80	4.95	--	--	--
Burnet					
open field	60.10	6.15	4.075	5.768	20.05
Plantain					
open field					
heads and stems	57.40	6.15	3.648	4.050	26.29
leaves	73.00	7.05	2.775	8.162	13.28

the tall meadow oatgrass and 4.95 per cent for Tualatin oatgrass. No explanation is attempted for the differences in crude protein content of tall meadow and Tualatin oatgrasses growing under the canopy and in the open. More samples throughout the year would be needed to check the consistency of these results. Plantain leaves contain 7.05 per cent crude protein, which is higher than that of plantain heads and stems, and that of burnet. On the other hand, burnet has 4.075 per cent of ether extract, whereas plantain has a lower percentage. These chemical analyses of the three species indicates that all three of them are fairly high in nutritive value and should be encouraged as forage species (66, pp.953-993).

It is expected that fertilization of the study area would improve the forage quality of all grazeable species, which in turn should improve the quantitative and qualitative gains of the grazing livestock.

Grazing management. — According to information obtained on the past grazing management of the area, the grazing use by sheep had been rotated, but the rotation practiced was not based on the growth and propagation requirements of the improved seeded species. Consequently, the original stand of at least some of the species had deteriorated before the present study was begun. After 1950, sheep had access to the area during the whole year, and were left there to graze continually. Thus, there was not an opportunity for the stand to reproduce by seed. During the fall, winter, and beginning of spring of the 1952-53 period, the sheep grazed the study area until it was fenced. At the time of fencing, a few local stands of the improved species could be found and the plots, when inspected, were not impressive. Except for the bentgrass and the annuals, all other seeded species were grazed close to the ground. This indicated which seeded species were most palatable and relished by sheep. Furthermore, it was observed, too, that sheep during the cool months preferred to graze on the experimental area because of the sunny and well-drained slopes.

Livingston (58), working in the same general area but on a different soil type and exposure, found that when improved pastures are grazed in early spring there will be a reduction in the annual vegetation. This type of management has been demonstrated to be effective in removing part of the competition between annuals and improved species.

It was observed, in this study, that where annual species were clipped during their boot stage in 1953, they never came back into production in the same clipped plots for the growing season of 1953 and 1954. This observation is in agreement with Livingston's results.

The same author (58) suggests the removal of the livestock from the improved areas by May 1, in order to allow for growth and development of the desirable perennial forage species. The date set is rather arbitrary, and the best time to remove livestock will be as the annuals start developing their seed heads. At that time annuals become unpalatable.

The development of seed heads of the annual species indicates that livestock cannot keep pace with the rapidly maturing annuals. Therefore, to satisfy their grazing needs, they start to graze the palatable perennials more heavily. This period will fluctuate according to the current climatic conditions. It took an average of 60 days after May 1, 1954, for the improved seeded perennials to produce their seed heads, depending on the location of the stand. For example, tall meadow oatgrass seed had shattered in the open area the last fifteen days of June, while the same species retained its seed 15 days later under the canopy. Tualatin oatgrass seed develops and ripens, in both cases, 15 to 20 days later than tall meadow oatgrass. Alta fescue seed under the canopy ripens simultaneously with Tualatin oatgrass growing under the canopy. Burnet started developing seed from the middle of May 1954, and continued to produce seed heads throughout the summer.

Keeping in mind that reserves for plant regrowth are stored in stem bases and roots during the period of seed production suggests that livestock should be taken off for a period of 50-70 days for this particular area. This resting period for the improved pasture must start at the time the annuals develop their heads and lasts to the time when the majority of perennials ripen their seed. Depending on the year, this period will vary from two to two and one-half months. Thus, a dry spell will shorten the time needed for seed production, while a cool, wet season will lengthen it. After this period of resting it is believed that grazing can be continued until the time of lambing. Forage production of the seeded species, though at a slower rate, is continuous after seed production. A supplementary grazing area must be provided for this resting period, where it is possible. If only one pasture is available it should be cross-fenced so that each part could be protected during this critical period of seed production at least once every three or four years.

The highest grazing efficiency consists in producing the largest amount of forage from a pasture. Grazing a pasture to its maximum capacity year after year invariably results in a sharp decline in its carrying capacity (102, p.469). It is therefore suggested that complete exclosure of grazing for a year after 3 to 4 or 5 years of continuous grazing throughout the year will help the improvement of the pasture. Weaver and Hansen (103) found that a single full year of protection against grazing increased the quantity of vegetation of pastures. The same authors found that one year of protection more than doubled the amount of the better forage grasses utilized, and three years of protection increased the amount eight-fold (103, p.90).

The increased yields and composition of some species obtained in this study for the year 1954 after one year's exclosure from grazing agree with Weaver and Hansen (103) as shown in Tables 17 and 18 and Figures 23 and 24. However, because Willamette Valley conditions in Oregon are different from those of the midwest, recommendations for grazing have to be based on the local conditions and needs. Thus, management recommendations based on results of this study corroborate those of Livingston's; that is, heavy grazing in the spring (58) followed by a 50 to 70 day rest period for seed development of the improved species. Such a grazing management procedure should allow for stand improvement and at the same time enable the operator to graze during most of the year. Proper grazing, proper adjustment of animal units to the forage produced, and proper fertilization (10) should keep the pasture in excellent vigor for an indefinite period of years. The quality of forage production for 1954 after one year of exclosure is demonstrated in Figures 25 and 26.

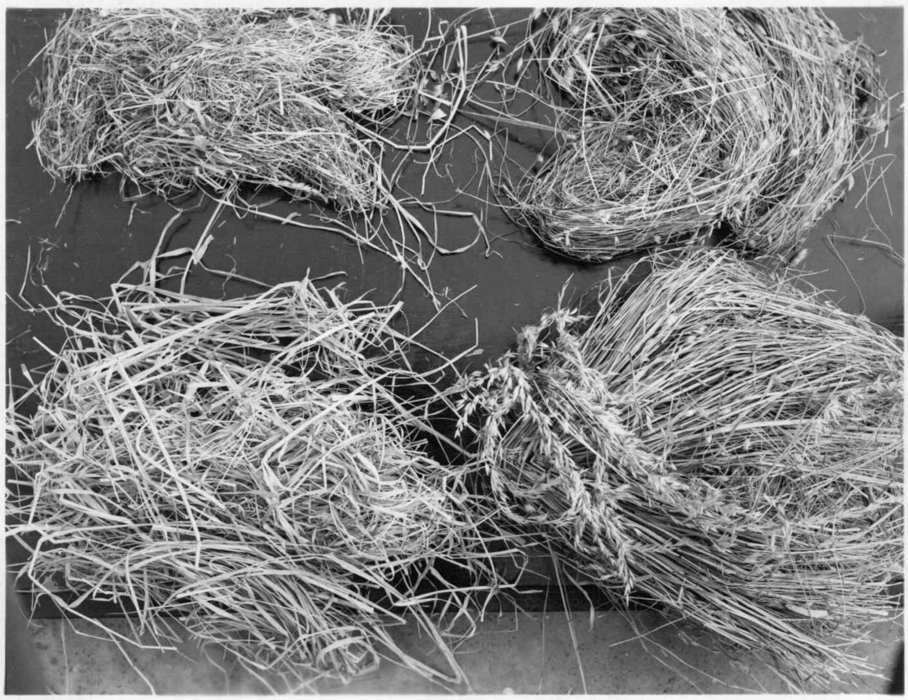

Figure 25. Forage samples clipped from one-square-foot plots in tall meadow oatgrass area in 1953 and 1954. Top left sample was clipped on June 5, 1953. Top right, September 1, 1953. Lower left was clipped May 1, 1954, and lower right, July 15, 1954.

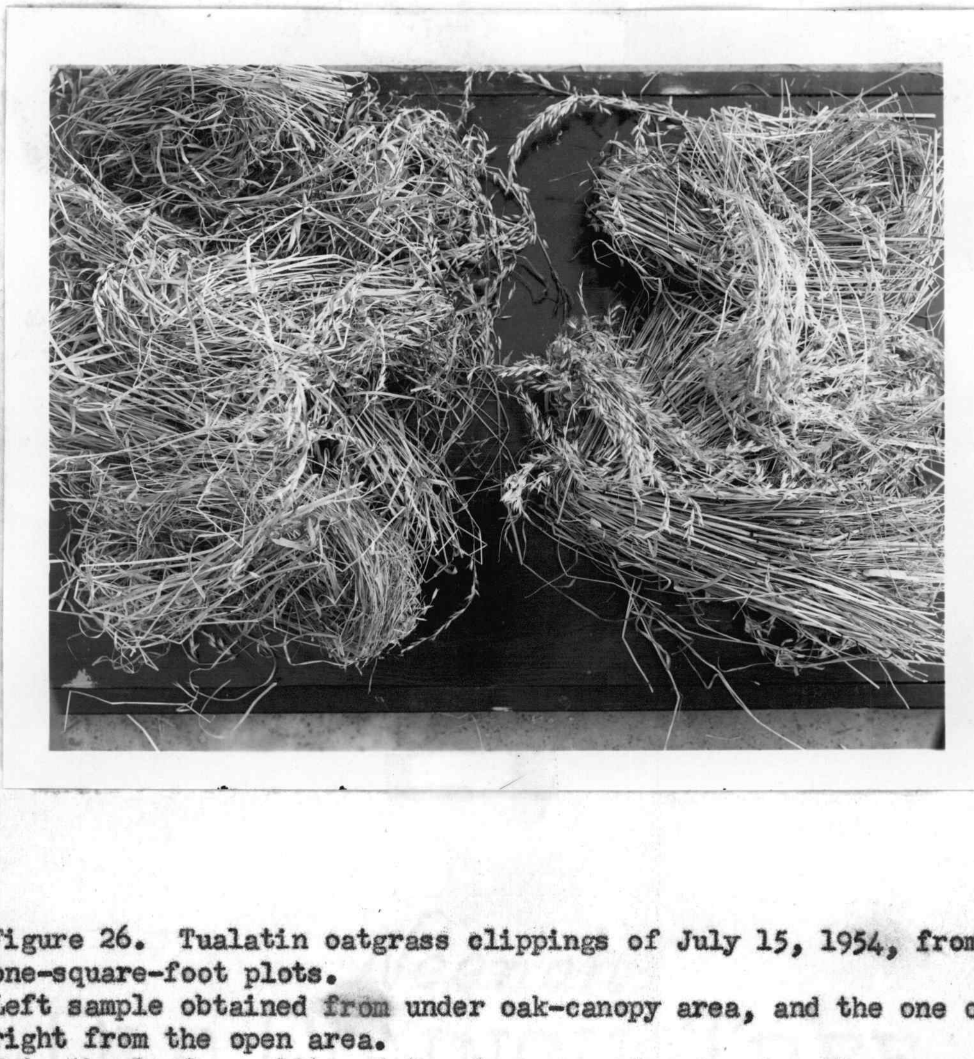

Figure 26. Tualatin oatgrass clippings of July 15, 1954, from one-square-foot plots.
Left sample obtained from under oak-canopy area, and the one on the right from the open area.
Note the leafy quality of the forage produced under the canopy.

Table 17. Average air-dried forage production in pounds per acre, by species and total, obtained from the two different height clippings for the year 1953.

Date of clipping	June 5		June 5		September 1		September 1	
Height of clipping in inches					New random locations		Same clipped June 5 at 2"	
	0	0	2	2	0	0	0	0
Species	Species	Total	Species	Total	Species	Total	Species	Total
Highland bentgrass	1500	3000	460	920	—	5300	—	2600
Chewings fescue	310	2000	60	830	—	3900	—	2000
Alta fescue	280	1700	60	560	--	3000	—	1600
Tall meadow oatgrass	320	2400	170	830	—	5800	--	2000
Tualatin oatgrass	350	3000	180	1200	—	6100	—	2300
Burnet	110	2400	110	940	—	4500	—	2600
Subterranean clover	80	3000	20	860	—	5000	—	2500

Multiplying the grams of a square-foot production by the factor 96 gives the yield in pounds per acre.

Table 18. Average air-dried forage productivity in pounds per acre, by species and total, obtained from the two different height clippings for the year 1954

Date of clipping	May 1, 1954				July 15, 1954				September 1, 1954	
Height of clipping in inches					New random locations		Same locations clipped May 1, 2"		New random locations	
	0	0	2	2	0	0	0	0	0	0
Species	Spec.	Total	Spec.	Total	Spec.	Total	Spec.	Total	Spec.	Total
Highland bentgrass	410	1000	190	460	2500	4500	1500	2300	3000	5000
Chewings fescue	300	880	140*	390	410	3300	330	1700	580	3600
Alta fescue	910*	1300	490*	640*	1200	3700*	860	1600*	1060	4300*
Tall meadow oatgrass	1400*	1600	820*	910*	3600	4500	1900	2400*	4900	6700*
Tualatin oatgrass	1000*	1200	640*	710	4100	4700	2400	3000*	5800	7900*
Burnet	130	800	90	480	480	2700	380	1500	860	4300
Subterranean clover	10	1100	20	520	0	3700	0	1800	0	5200*

* Indicates an equal or an increased yield in composition with that produced in 1953 despite the difference in time.

Multiplying the grams of a square-foot production by the factor 96 gives the yield in pounds per acre.

A mowing or slashing of the shrubs of oak, roses, and poison oak once every 5 to 10 years will help keep down their height. It is difficult to eradicate them, because they belong to the native plant communities. By keeping their height down, sheep can get better access to their leafage, tender twigs, and ripened berries. It was observed that sheep browse the above mentioned shrubs which contribute considerable variety to the grazeable material. As reported in other studies, particularly in California, these summer growing shrubby species contribute to the diet of grazing animals when predominately grassy vegetation may be low in Vitamin A and protein (39).

A major problem confronting livestock operators in this area is the adjustment of the number of animals to the forage production. Shall the number of animals be based upon the total forage production; or must it be adjusted to the seasonal production; or shall it be based upon the animal gains?

Tables 17 and 18 contain figures on forage production in pounds per acre in the various seasons and at the two heights of clipping by species and total. The question arises as to how accurate are the figures of yield per acre on which to based the adjustment in animal units on the area. Grazing habits of animals are not constant and they change according to the species, state of forage maturity, topography, and ecological aspect of the pasture, season, etc. (53). For example, it was observed during this study that at winter sheep graze the highland bentgrass close to the ground. On the other hand the same species in May - June is grazed only at the time when the panicles of the plants are still closed. They grasp the panicles which are 4 to 6-inch long and leave the greatest portion of the plants ungrazed. In contrast, both species of oatgrass are grazed in the early stages down to the crown. Sheep graze the same species when they begin to dry to a height of 10 to 12 inches above the ground. On the other hand, regrowth of both oatgrasses is grazed 6 to 8 inches above the ground. Wild carrots while not grazed during their young and succulent stage are relished by sheep at the time of bloom to a height of 4 to 5 inches above the ground, or at a height of 20 to 25 inches above ground while the mature seed heads are still green. Burnet is grazed down to the ground at any time.

Another striking observation in the grazing habits of sheep is the following: Sheep entered the experimental area after September 1, 1954. The best succulent forage was found under the oak canopy, but they avoided grazing this area and preferred to consume forage composed of new growth and dry material produced earlier in the season in the openings (40). It was found in Texas that the amount of forage eaten by cattle under an oak canopy was proportional to the amount of overstory deadened. This selective grazing emphasizes the importance of controlling brush over an entire pasture to prevent concentration of grazing animals in cleared areas. (53)

From the above observations the grazing management should not be based entirely upon the total yield at any of the height of clippings, or upon the seasonal growth. Clipping figures as they were obtained for forage production, do not correspond to the forage consumed influenced by the grazing habits of the livestock. At the present no conclusion can be made based on observations only. Further investigations for quantitative and qualitative data of the grazeable forage and that of the grazing habits of the various livestock types will enlighten this puzzling question.

The fundamental assumptions upon which the grazing management of the experimental area must be based are the following: 1. The area must provide a good pasturage throughout the grazing season; 2. Crowding out undesirable species by encouraging the growth and propagation of desirable ones will maintain a healthy pasture; 3. Adjusting the number of animals according to the seasonal production based not only on the total production by weight but on the healthy and good stand of the seeded species is necessary; 4. Fencing the area in lots to separate the canopy from the open area will provide for more even utilization of the forage production; 5. The best economical use of the area will be that which will improve and maintain a vigorous and dense stand of improved, adapted and desirable perennial species which in sequence will yield the highest and best gains to the proper number of animals; 6. The least possible input for greatest output must be applied to such types of lands for greater economic returns.

CONCLUSIONS

1. Soils of the experimental area cannot be definitely classified as Laughlin series but rather as Laughlin-like.

2. The soil's investigations and observations revealed favorable physical characteristics for the support of forage species in addition to the existing trees and shrubs. Among the desirable soil physical characteristics are: 1. Total porosity and structure favoring root penetration, water infiltration, and aeration; 2. A large water holding capacity; 3. Long period of water retention; 4. Water percolation; 5. The parent material consisting of shale and sandstone has been shown to be an adequate water storage tank. Thus, soil moisture has not been found to be a critical point, for the two years of investigations, in establishing and maintaining forage species.

3. The limiting factors in establishing and maintaining improved forage species are the soil's high acidity and low fertility status.

4. It should pay to fertilize and lime such soils because their water supplying power is satisfactory to support plant growth and produce economical grazeable forage.

5. The best time to apply phosphorus fertilizer and lime is during the period when the soil is cracked. Through the soil cracks

both elements will reach directly into the root zone of the forage species. Soluble nitrogen fertilizer can be applied at other periods in order to stimulate seasonal production.

6. Regardless of the shallowness of the soil the only plants to become established are those with deep root systems. In addition, species must be adapted to the climatic conditions of the area. The native forage species of California oatgrass, wild rye, and plantain should be encouraged because they are palatable and belong to the present climax vegetation. Investigations need to be undertaken on the establishment of deep-rooted leguminous forage species in mixture with successful grass species.

7. Ten years after seeding there is no observable difference among the four methods of seedbed preparation. However, the species become established more rapidly where good seedbeds are prepared, and broadcasting would require a greater amount of seed per acre without seedbed preparation.

8. Thinning a thick stand of oaks to increase the light under the canopy should help in the establishment and reproduction of improved species by seed and in obtaining more even utilization of the forage crop.

9. The density and production of the improved seeded species will depend mainly upon correcting the high soil acidity, and low fertility; resistance of the species to pests and diseases; the

weather conditions of the year; and grazing management practices.

10. The maintenance of the pasture will depend mostly upon the managerial skill of the operator.

11. In general, it is concluded that such type of lands, having the same soil series and ecology, can be converted to permanent grassland pastures. The cost of establishing them will be relatively low because it need consist only of: Purchase and application of seed, fertilizers, and fencing materials, and labor. The highest profit for the operator will depend, mainly, upon the wise practical commercial combination of all the factors contributing to the low cost of the final production.

12. Further investigation on similar hill land soils should result in: (a) Improved management of so-called marginal lands based on better knowledge of soil-plant relationships; (b) direct benefit to the farmers of western Oregon by increasing their forage production; and (c) relief in pressure on better agricultural lands by producing greater seasonal forage in fall and winter from hill grazing lands.

SUMMARY

Hilly, non-irrigated native pastures covered with Oregon white oak, occupy an extensive area in western Oregon. Such type of land, in general, is considered to be marginal for agricultural use.

An experiment, on the sheep hill pasture lands near Corvallis, Oregon, was started in 1943 by the Oregon Agricultural Experiment Station. In this study the choice of four seedbed treatments and several improved forage species were evaluated.

The present investigation on the same experimental area was started during the winter season of 1952-53, with the objective to define the reasons for the failure or success of the establishment of the seeded improved forage species. The investigation revealed that the soils of the area under study are of the Laughlin-like soil series not previously recognized in this locality of Oregon. Thus, an investigation was conducted to study some of the properties of these soils and the relationship of those properties in the establishment and growth of the improved seeded forage species.

It was found that the residual solum is shallow, ranging from 17 to 32 inches in depth, with an average depth of 24 inches. It has been developed from micaceous and tuffaceous marine shale and sandstone of the Eocene geological era. The solum lacks horizon C. The color of the profile from top to bottom changes from pale-brown, to brown, to light gray. The major clay mineral of the soil and parent material has been designated as illite, but shrinkage and

expansion characteristics support the opinion that the soils and the parent material contain in addition some other type of clay mineral of 2 to 1 lattice type. The textural mechanical analysis of the soil and parent material was determined to be clay and clay loam. The structure of the profile ranges from granular, to subangular; blocky, to granular with a sponge-like layer just above the shale.

The soil porosity decreases sharply below the upper soil layer of 6 to 12 inches and increases again in the porous layer just above the shale.

An inherent characteristic of soil and parent material is the sudden cracking under wetting and drying accompanied by shrinkage and expansion. It has been tentatively concluded that the properties of expansion and shrinkage under wetting and drying, and the entrapped air by two water fronts produce friable soil and cause the sponge-like soil layer above the shale.

Moisture content of the soil obtained by both electrical resistance readings and gravimetric methods did not, generally, reach the wilting point in either year for depths below 12 inches. The moisture content of the soil is not a limiting factor for the establishment and growth of deep-rooted species that penetrate the shale. The underlying shale is supplied with adequate moisture for plant growth, chiefly by capillarity from the water table. In an old well on the area the water table reached the lowest level of 220 cm. below the surface soil in November 1953. By capillarity, the water table water rises 160 cm within the shale, thus it supplies water to the average root-depth zone of the established improved forage species.

After the first heavy frost the soil may be saturated from two directions, downward by rainfall and upward by capillarity.

Deterioration of the gypsum blocks occurs in an average period of eight months after they are buried in this soil. This disintegration is probably brought about by the action of roots and the effect of the soil acidity, and the alternative drying and wetting of the soil.

While there is no significant difference in soil moisture content among treatments, in the analysis of variance of moisture readings the differences among the species is highly significant.

The chemical nutrients of the soil were found to be lower than the accepted standards for western Oregon, and the amounts of N, P, K, Ca, organic matter, and pH decrease with the increase in depth. In general, the physical characteristics of the soil favor, whereas, the low fertility and pH hinder, the establishment of improved forage species.

The plant species that succeeded in the experimental area were those that developed deep root systems. Such species were found to be: Highland bent, Alta fescue, both oatgrasses, orchardgrass, burnet, narrowleaf plantain, and all woody species. Both oatgrasses, Alta fescue, and orchardgrass all gave good stands and produced well in mixtures, both in the open and under the oak canopy.

There is no serious competition for soil-moisture and nutrients between woody species and improved forage species, because of the different root zone level occupied by them. However, there is noticeable competition between perennial forage species and bracken fern. Under a thriving stand of perennial grass species, especially oatgrasses, the bracken fern appears to be decreasing. Competition exists between annuals and improved forage species, but not between fibrous deep-rooted species and plantain, which is a palatable weedy forb.

For the ten-year period of establishment the seedbed preparation did not have any noticeable effect on the stand of the species, except for burnet which did better under plowing and disking. However, according to an inventory for three years after seeding, stands were better under the more intensive methods of seedbed preparation.

The forage production of seeded species was greater for the year 1954 than that of 1953. Most of the species, except for the fescues, produced their larger amount after May 1 of 1954. This suggests that exclosure of grazing, for a growing season after some years of continuous pasturing, helps the established species to thicken their stand.

The clipping method and the point frame method did not agree in the percent composition of forage species.

The forage chemical analysis showed that narrowleaf plantain and burnet are equally as nutritive as the improved species of oat grasses.

The greatest opportunity for encouraging the desirable forage species and discouraging the undesirable is through grazing management. It is concluded that grazing early in the spring, until the time the annual grasses start developing their seed heads, decreases their density and reduces their competition with perennials. Exclosure of grazing, starting at this period till the time the perennials scatter their seed, improves natural reseeding. This period, according to the year, might run from 50 to 70 days. Adjusting the number of annuals to the forage production, even utilization of open and wooded areas, and fertilizing and liming, will help maintain the pasture for an indefinite period. In addition, fertilization and liming will increase the carrying capacity, and will produce a higher quality and quantity of animal products.

Annual legumes for early spring forage production and deep-rooted perennial forage legumes for year-round production are needed in the area. Liming and phosphorus fertilization should encourage their establishment, while good grazing management will maintain the stand.

The results of forage production per acre, by species and total, suggests that such type of land can be reclaimed to a profitable grazing area with low costs and high economic returns.

It is the writer's belief that further investigations about the soils and adaptable seeded species, management, grazing, etc., should reveal that this type of area can become highly productive pasture land.

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APPENDIX

Appendix 1. Description of the established Laughlin soil series.

<u>Established series</u>

LAUGHLIN SERIES

The Laughlin series comprises pale-brown or grayish-brown, weakly developed, moderately shallow soils developed on hard sandstones and shales, in places partly metamorphosed, and typically supporting a cover of grass and scattered oaks. Climate is subhumid to humid mesothermal with warm, nearly rainless summers and cool, wet winters. Mean annual precipitation ranges from 25 to 45 inches, and mean temperature is about 57°F. Growing season averages about 210 days.

The Laughlin series is associated with the Los Osos soils, developed from similar type of rock and supporting a similar type of vegetation but browner and darker colored. In places the series is also associated with the timber-covered deeper Hugo soils, and with the brush-covered shallower Maymen soils (see Remarks). In some places the series is closely associated with the Yorkville series that has a dense clay subsoil.

<u>Soil Profile</u>: Laughlin loam.

0-10" Pale-brown, slightly acid loam of weak blocky structure. Friable when moist but hard during summer when very dry. Grass roots throughout but concentrated somewhat in upper part. Gradual change to: 5-12"

10-23" Light yellowish-brown, slightly acid, friable loam of weak blocky structure. Becomes somewhat browner with depth. Some rock fragments occur in lower part. Overlies rather abruptly: 8-18"

23" + Slightly weathered, hard but shattered, brown to yellowish-brown sandstone with some soil in cracks in the upper part. Many feet.

<u>Range in Characteristics</u>: The Laughlin soils characteristically have indistinct horizons, though commonly the surface soils are slightly paler or lighter colored than the subsoils. Surface color ranges from pale brown or lighter colored than the subsoils. Surface color ranges from pale brown to grayish brown, whereas subsoil color is light yellowish brown, yellowish brown, brown, or slightly darker grayish brown. The surface soil is slightly or moderately acid, and the soil commonly is less acid with depth, although in places there is very little change in reaction with depth. In some places the lower subsoil may be neutral, particularly where the parent rock

Appendix 1, continued

contains a few thin seams of calcite. Rock outcrops occasionally occur and small rock fragments (gravel size) may occur in the surface soil, the number ordinarily increasing with depth to parent rock.

Topography: Rolling, hilly, and steep uplands; ridge crests are generally well rounded.

Drainage: Surface runoff moderate to rapid; permeability moderate; not affected by high water table.

Vegetation: Woodland-grass; annual grasses, mainly brome grasses and wild oats, and associated herbs with scattered oaks, commonly blue oak or Oregon white oak, and scattered common manzanita. In places fairly dense stands of various oaks, make up the principal cover.

Use: Principal use is for range pasture, for which the soils in general are fairly well suited. A few places are cultivated, mainly for dry-farmed grain or grain hay. The soils erode readily where grazing is too intense.

Distribution: Coast Range Mountains, particularly bordering valleys, in northwestern California and southwestern Oregon.

Type location: SE 1/4 SW 1/4 sec. 20, T. 11 N., R. 11 W., Mendocino County, California

Series established: Mendocino County, California, 1948. State Cooperative Vegetation Survey (U. S. Forest Service). Series symbol 847.

Remarks: In earlier soil survey work the Laughlin soils were mapped in the Hugo series, as were also the Maymen soils. The Hugo series has been redefined and limited in characteristics to those associated with coniferous forest cover. The brush-covered soils formerly classed as shallow Hugo soils are now classed in the Maymen series, and those soils naturally supporting a woodland-grass cover and formerly classed as Hugo are now classed as Laughlin.

RAG
8-31-49

Division of Soil Survey
Bureau of Plant Industry, Soils, and Agricultural Engineering
Agricultural Research Administration
U. S. Department of Agriculture

Appendix 2. Letter from Ray C. Roberts regarding physical and chemical characteristics of Laughlin soil series.

UNITED STATES
DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Soil Survey
P. O. Box 520
Berkeley 1, California

January 8, 1954

Dr. D. W. Hedrick
Department of Animal Husbandry
Oregon State College
Corvallis, Oregon

Dear Dr. Hedrick:

I have just been snowed under with work and have had to go on several essential field trips since Miss Herrmann wrote to you and sent you a copy of the Laughlin series.

Unfortunately we do not have any chemical or physical data on the Laughlin soils. We will surely appreciate any information that you can send us on the results of the samples that Mr. Valassis is working on.

I have enclosed some notes that Mr. Leighty made when we visited the pits Mr. Valassis dug on your hill pasture lands. I hope to be in Corvallis sometime this spring and will be pleased to have an opportunity to discuss the Laughlin and related soils with you and Mr. Valassis in person.

Very truly yours,

/s/ Ray C. Roberts

Ray C. Roberts
Principal Soil Correlator
Far Western States

Enclosure

Appendix 3. Description of the Laughlin-like soil series found in the experimental area.

THE "LAUGHLIN LIKE" SOIL

The soils on the hillside pasture plots are pale brown, slightly developed, moderately shallow soils developed on light-gray acid tuffaceous sandstone. These soils are similar to the Laughlin series as mapped in California. They differ mainly in that they are derived from a more acid tuffaceous sandstone than the Laughlin soils and are, therefore, more acid in the lower part of the profile.

Soil Profile: "Laughlin like" loam

A_1O	0-6"	Pale brown (10YR 6/3; dark grayish-brown, 10YR 4/2, moist) weak, medium fine granular loam, that is hard when dry, friable when moist, and slightly plastic when wet. Grass roots throughout. pH 5.8; 4 to 8 inches thick.
B_1	6-13"	Pale brown (10YR 6/3; brown, 10YR 4/3, moist) fine textured loam which is weak, medium and fine subangular blocky that is hard when dry and friable when moist. Numerous fine and medium pores. pH 5.4; 4 to 8 inches thick.
B_2	13-22"	Brown (10YR 5/3; dark brown, 10YR 3/3, moist) moderate fine subangular-blocky light clay loam or heavy loam which is very hard when dry and plastic when wet. This horizon has some colloidal coated aggregates and in places it may be reddish-brown 5YR 4/4 when moist. pH 5.2; 8 to 12 inches thick and rests abruptly on bedrock.
Dr	32 "	White, 10YR 8/1, to very pale brown, 10YR 7/3, platy tuffaceous sandstone. pH 5.0.

Range in characteristics: Chiefly in depth to bedrock. On nearly flat hill tops the bedrock is usually below 30 inches and the B_2 horizon is finer in texture. The water holding capacity is also greater and trees generally dominate over grass in these sites. On some of the steeper south slopes, rocks may outcrop and the soil profile is shallow, 10 to 16 inches thick. In these sites the B_2 horizon may not be much finer in texture than the A_1 horizon.

Topography: Rolling, hilly, and steep uplands; ridge crests are generally well rounded.

Appendix 3, continued

Drainage: Surface runoff moderate to rapid; permeability moderate. In places may have moderately slow infiltration.

Vegetation: Woodland-grass; annual grasses, some roses and Oregon white oak. In places fairly dense stands of oak.

Use: Principal use is for range pastures for both sheep and cattle. A few places are cultivated, mainly for dry-farmed grain and grain hay. This soil erodes where grazing is too intense.

Distribution: Foothills adjacent to Willamette Valley in Oregon.

Type location: Oregon State Hillside Pasture Plots.

WJL & RCR
11-54

Appendix 4. Letter from H. D. Hess regarding mineralogical analyses of the Laughlin-like soil series.

UNITED STATES
DEPARTMENT OF THE INTERIOR
Bureau of Mines
Albany, Oregon

Region II April 12, 1954

Mr. Charles E. Poulton
Associate Professor of Range Management
Department of Animal Husbandry
Oregon State College
Corvallis, Oregon

Dear Professor Poulton:

Reference is made to the group of samples you recently left at this laboratory for a mineralogical examination.

The major clay mineral in your shale and soil samples is illite rather than montmorillonite or bentonite. Very little or no swelling was observed in any of the materials. The microscopic identification of illite was confirmed by differential thermal analysis.

The following are the over-all results of the mineralogical examination:

The "shale sample" essentially contains quartz, altered feldspar, illite, some sericite, biotite, muscovite, small amounts of chlorite, graphite, and trace amounts of limonite and pyrite. Also present are small amounts of leaf fossils.

The five "soil samples" are mineralogically similar. They contain illite, quartz, altered feldspar, organic matter, fragments of shale, sericite, limonite, altered biotite, magnetite, ferromagnesian minerals, and ilmenite. These samples contain more organic matter and less illite and shale fragments as they grade to the surface. The samples labeled "plus 24 inches" contain a trace of graphite, apparently derived from the underlying shale.

The shale is comprised of mineral fragments that are less than 100-mesh in size and predominantly less than 200-mesh. However, a great deal of the quartz and feldspar in the soil samples is much coarser. This observation, coupled with the fact that shale particles are present in the soil samples, would indicate that the soils were not formed entirely "in situ" but were derived partly from the underlying shale and partly from some other source.

Appendix 4, continued

It is hoped that the above information will prove to be of value to you. If you wish to retain the samples, please notify us within thirty days of the date of this report.

Very truly yours,

/s/ H. D. Hess

H. D. Hess
Petrographer

Appendix 5. Preliminary tests to define the stirring time needed for textural analysis of the Laughlin-like soil series.

Average values obtained from duplicate preliminary tests, for particle size distribution by the hydrometer method, to define the time needed for stirring with sodium hexametaphosphate $(NaPO_3)_6$ of the Laughlin-like soils. The soil sample used was a sandstone parent material ground and sieved through a 2 mm. sieve. The percentage of the clay fraction was considered as a guide.

Time of stirring in minutes	Per cent		
	Sand	Silt	Clay
0	63.92	24.50	11.58
5	41.67	36.75	21.58
10	36.92	39.00	24.08
15	33.27	40.25	26.48
20	32.82	41.20	25.98
25	29.57	42.95	27.48
30	28.82	43.20	27.98
35	29.07	42.43	28.50
40	28.32	43.18	28.50
45	27.57	43.93	28.50
50	27.92	43.78	28.40
55	28.07	43.43	28.50
60	29.02	42.20	28.78
120	28.10	43.40	28.50

Appendix 6. Average textural mechanical analysis obtained by the Bouyoucos hydrometer method of the Laughlin-like soil series by pit groups at five different depths. (Each group represents an average of seven soil samples, stirred for 35 minutes with sodium hexametaphosphate.)

Depth in inches	Pit groups	Per cent Sand	Silt	Clay
0-6"	I	20.47	42.35	37.18
	II	21.22	41.10	37.68
	III	26.02	38.70	35.28
	IV	19.47	40.25	40.28
Average		21.80	40.60	37.60
6-12"	I	20.22	40.10	39.68
	II	19.22	43.10	37.68
	III	24.22	36.50	39.28
	IV	17.87	40.35	41.78
Average		20.38	40.01	39.60
12-18"	I	20.72	37.60	41.68
	II	19.72	41.60	38.68
	III	24.47	35.25	40.28
	IV	15.07	40.65	44.28
Average		20.00	38.78	41.23
18-24"	I	19.72	37.60	42.62
	II	19.72	39.60	40.68
	III	23.97	35.25	40.78
	IV	16.02	36.70	47.28
Average		19.86	37.29	42.84
24-36"	I	21.22	39.10	39.68
	II	20.22	51.10	28.68
	III	23.72	36.00	40.28
	IV	16.87	33.85	49.28
Average		20.51	40.01	39.48

Appendix 7. Determination of particle density of the entire soil profile (0-36 inches depth) of the Laughlin-like soil series.

	No. of pycnometer 11	23	49	62	83	100
1. Mass of bottle full of water	34.760	34.960	34.770	35.710	35.335	35.065*
2. Mass of bottle partly full of water	18.190	19.400	18.450	19.050	18.750	19.375
3. Mass of bottle partly full of water plus oven-dried soil	25.340	26.270	25.690	26.500	25.700	26.475
4. Mass of soil used	7.150	6.870	7.240	7.450	6.950	7.100
5. Mass of bottle plus soil and filled with water	39.179	30.175	39.265	40.303	39.609	39.463
6. Mass (5) - (4)	32.029	32.305	32.025	32.853	32.659	32.363
7. Mass of water dislocated by soil	2.731	2.655	2.745	2.857	2.676	2.702
8. Particle density of soil = $\frac{(\text{mass } 4)}{\left(\frac{(\text{mass } 7)}{(\text{density of water})}\right)}$ =	2.61	2.58	2.63	2.60	2.59	2.62
Average particle density	2.60 ± 0.005 gms/cm^3					

* Temperature of water used (25°C.)
Density of water (.99707)

Appendix 8. Apparent densities of soil clods obtained by depths from the Laughlin-like soil series with the paraffin method.

Depth of soil layer in inches									
0-6		6-12		12-18		18-24		24-36	
Percent of water content	Apparent density gms/cm^3	Percent of water content	Apparent density gms/cm^3	Percent of water content	Apparent density gms/cm^3	Percent of water content	Apparent density gms/cm^3	Percent of water content	Apparent density gms/cm^3
6.45	1.22	4.58	1.38	4.62	1.49	3.90	1.42	5.05	1.44
10.49	1.14	3.58	1.35	4.84	1.39	6.22	1.32	6.38	1.44
9.44	1.19	4.47	1.42	5.69	1.34	6.07	1.47	7.83	1.34
4.01	1.15	3.98	1.43	4.77	1.33	5.50	1.46	6.56	1.38
9.24	1.25	3.94	1.27	4.68	1.39	6.16	1.22	5.62	1.45
5.82	1.19	3.74	1.25	5.20	1.43	6.34	1.41	7.88	1.26
5.19	1.20	4.54	1.52	5.70	1.24	5.57	1.26	6.86	1.32
12.76	1.17	4.61	1.52	7.02	1.28	6.10	1.24	7.52	1.26
7.34	1.24	3.49	1.50	4.77	1.31	6.35	1.45	3.71	1.38
11.88	1.16	4.78	1.46	5.95	1.32	8.05	1.41	5.29	1.26
4.70	1.22	4.18	1.49	5.33	1.43	6.28	1.26	4.00	1.40
11.15	1.20	5.07	1.34	16.17	1.32	7.07	1.46	4.90	1.34
7.12	1.29	4.71	1.46	9.44	1.25	7.20	1.20	8.47	1.23
4.90	1.17	4.57	1.44	9.95	1.10	5.80	1.50	4.21	1.44
14.14	1.18	3.84	1.44	6.48	1.23	6.34	1.43	8.29	1.39
5.10	1.23	4.91	1.44	4.44	1.46	5.08	1.49	7.54	1.19
5.34	1.15	5.12	1.44	13.78	1.30	5.69	1.34	5.34	1.38
3.83	1.21	4.49	1.31	5.67	1.50	8.64	1.31	6.29	1.49
3.51	1.31	5.04	1.46	9.67	1.36	4.09	1.26	6.05	1.26
5.12	1.22	5.72	1.99	6.70	1.40	3.98	1.34	7.71	1.21
3.98	1.43	4.94	1.52	7.63	1.40	3.96	1.35	7.52	1.35
4.76	1.22	5.66	1.30	9.39	1.21	4.01	1.45	6.48	1.33
3.85	1.24	14.04	1.37	6.76	1.31	4.86	1.29	7.70	1.20
3.60	1.30	5.30	1.33	4.37	1.47	3.73	1.38	6.71	1.16
2.73	1.21	9.55	1.37	4.58	1.48	6.00	1.46	7.30	1.24
4.34	1.25	13.79	1.25	3.79	1.39	4.59	1.43	6.35	1.31

Appendix 8, continued

Depth of soil layer in inches									
0-6		6-12		12-18		18-24		24-36	
Percent of water content	Apparent density gms/cm^3	Percent of water content	Apparent density gms/cm^3	Percent of water content	Apparent density gms/cm^3	Percent of water content	Apparent density gms/cm^3	Percent of water content	Apparent density gms/cm^3
3.86	1.27	5.01	1.29	3.56	1.45	7.33	1.26	5.84	1.31
4.89	1.28	5.30	1.29	4.69	1.46	3.62	1.32	5.38	1.38
6.95	1.26	9.42	1.40	4.86	1.42	5.61	1.43	8.66	1.28
4.57	1.15	6.58	1.39	4.93	1.47	3.55	1.46	7.88	1.26
4.50	1.38	7.47	1.34	5.21	1.40	4.86	1.45	10.22	1.24
4.58	1.26	7.79	1.38	5.93	1.34	4.65	1.41	6.91	1.30
6.54	1.20	9.58	1.45	5.59	1.40	3.96	1.40	7.35	1.34
4.43	1.32	5.29	1.28	3.54	1.42	3.56	1.43	5.07	1.24
6.90	1.17	4.94	1.30	3.77	1.36	5.07	1.46	4.21	1.41
4.15	1.37	7.18	1.33	3.64	1.41	4.57	1.43	4.74	1.45
9.52	1.27	9.55	1.36	7.76	1.32	12.58	1.37	12.52	1.25
21.17	1.22	8.16	1.36	9.52	1.35	9.49	1.39	12.68	1.30
14.68	1.26	13.12	1.28	8.92	1.38	8.68	1.36	13.93	1.29
15.50	1.21	7.67	1.34	8.58	1.32	8.52	1.34	12.08	1.31
8.19	1.22	7.42	1.34	11.60	1.43	7.45	1.38	12.43	1.30
12.34	1.16	7.29	1.35	7.23	1.44	12.06	1.38	12.98	1.32
7.23	1.23	6.30	1.40	6.59	1.37	6.02	1.38	7.39	1.32

Appendix 9. Analysis of variance of apparent densities of Laughlin-like soil series at various depths.

Variation due to:	Sums of squares	Degrees of freedom	Mean square	F
Total	2.3255	209		
Depth	.7244	4	.1811	23.19**
Error	1.6011	205	.00781	

Appendix 10. Apparent densities of parent material from Laughlin-like soil series obtained by the paraffin method.

Air-dried		Soaked overnight	
Percent of water content	Apparent density gms/cm^3	Percent of water content	Apparent density gms/cm^3
11.09	1.34	34.21	1.19
11.09	1.32	33.83	1.19
11.09	1.29	33.92	1.18
11.09	1.35	30.17	1.23
11.09	1.28	32.81	1.21
11.09	1.33	34.90	1.18
11.09	1.37	34.86	1.18
11.09	1.35	33.73	1.18
11.09	1.35	31.62	1.21
11.09	1.32	34.06	1.20
11.09	1.36	30.63	1.23
11.09	1.36	33.81	1.20
Average			
11.09	1.34	33.21	1.20

Appendix 11. Moisture equivalent and one-third atmosphere pressure of Laughlin-like soil series.

Depth of soil in inches: 0-6		6-12		12-18		18-24		24-36	
Percent of water content									
M.E.	1/3 Atm.	M.E.	1/3 Atm.	M.E.	1/3 Atm.	M.E.	1/3 Atm.	M.E.	1/3 Atm.
28.94	31.63	25.92	28.30	25.18	28.51	24.35	28.44	31.08	34.34
28.92	31.50	25.94	28.03	25.08	28.46	25.98	29.04	31.05	34.76
29.25	31.76	27.59	28.98	26.25	29.32	28.58	26.00	31.29	29.66
29.00	31.42	27.36	29.32	26.55	24.48	28.36	26.75	31.54	30.42
29.77	28.03	26.46	25.43	26.05	24.79	28.03	26.40	33.41	36.02
28.86	27.74	26.59	25.53	26.22	25.03	28.30	26.42	33.54	32.41
28.69	30.73	26.13	28.39	26.39	27.69	27.20	29.40	31.12	32.04
29.20	30.47	26.98	28.46	25.96	27.55	27.27	29.33	31.27	31.94
28.11	32.57	27.03	30.44	26.66	28.30	28.04	29.07	31.68	34.23
28.42	32.39	27.43	31.13	25.98	28.04	27.63	28.75	31.58	35.29
28.50	32.12	27.28	30.62	26.48	26.45	27.94	27.77	32.21	30.07
28.74	32.40	27.14	29.82	26.16	25.88	28.19	27.35	32.34	30.39
28.86	28.76	25.84	27.29	25.40	25.56	25.76	25.31	31.23	35.22
29.08	29.26	26.04	26.87	25.29	25.31	26.90	27.26	30.61	36.18
29.08	31.34	27.57	29.42	26.67	28.37		29.85		34.10
28.33	31.68	27.01	28.79	25.96	28.26		29.12		33.04
29.19									
29.22									
29.67									
29.42									
$\bar{x}$									
28.96	30.86	26.77	28.55	26.02	27.00	27.32	27.89	31.71	33.13

Appendix 12. Wilting point of Laughlin-like soil series obtained phytometrically by seeding sunflowers and barley seeds in cans containing 500 grams of soil.

Depth of soil				
0-6	6-12	12-18	18-24	24-36
7.44	8.62	9.72	10.03	13.47
7.64	8.43	8.58	10.24	13.16
8.40	8.54	10.19	10.58	12.93
8.10	8.65	8.72	11.40	12.71
8.62	8.95	9.85	10.17	12.47
8.28	10.07	9.66	11.17	11.77
8.39	9.17	11.03	10.11	12.02
7.75	8.15	9.18	10.18	12.60
8.27	8.07	10.01	9.55	11.04
8.92	8.02	8.49	10.15	10.11
8.88	9.72	9.57	11.22	11.11
7.98	10.10	9.24	9.71	10.82
8.01	8.49	8.64	9.53	10.52
8.45	9.02	8.49	10.24	11.70
8.11	7.96	8.92	9.73	11.55
8.47	9.38	9.04	8.90	12.34
8.59	8.93	9.32	9.16	11.88
7.91	7.92	8.33	9.98	11.58
8.26	8.02	9.85	9.43	11.80
7.97	8.66	10.36	10.42	11.95
8.56	8.30	9.67	10.26	12.36
7.76	8.23	9.25	10.04	12.39
8.49	9.79	9.08	11.25	13.20
8.93	8.66	10.49	10.79	12.24
$\bar{x}$				
8.26	8.74	9.24	10.18	11.99

Appendix 13. Means of electrical resistance readings for gypsum blocks in ohms by date, plot, and depth, obtained from May through December, 1953.

Each entry represents the mean reading of 24 gypsum blocks in each plot. The average represents the means of 168 gypsum blocks of the entire area. Readings after December 25, 1953, through May 15, 1954, have not been included because gypsum blocks in the field were dissolved.

Plot No.	Depth in inches 0-6	6-12	12-18	18-24
	May 28			
5	390	380	350	320
6	380	360	340	310
9	400	380	360	350
11	370	360	340	310
12	370	350	340	310
16	410	380	360	330
17	380	370	350	320
Average	386	369	348	321
	June 6			
5	470	440	410	380
6	420	390	380	360
9	420	400	380	350
11	400	380	370	330
12	390	370	350	320
16	600	450	410	370
17	470	410	390	350
Average	453	406	384	352
	June 16			
5	2600	1100	630	560
6	1500	750	580	550
9	1000	600	560	650
11	1200	610	610	560
12	1400	730	700	560
16	1400	520	480	550
17	1200	520	530	550
Average	1471	6900	584	568

Appendix 13, continued

Plot No.	Depth in inches 0-6	6-12	12-18	18-24
	June 25			
5	13000	5000	1200	700
6	8700	3500	990	660
9	6100	2700	1100	790
11	10000	3600	1400	840
12	14000	5400	1900	680
16	15000	3500	880	640
17	9100	2700	1100	660
Average	10843	3771	1224	710
	July 4			
5	33000	13000	3100	1200
6	19000	7800	2300	1800
9	14000	6600	2900	1500
11	19000	7900	3100	1600
12	20000	8400	2900	980
16	30000	7300	2100	1200
17	25000	7200	2400	850
Average	22857	8314	2686	1304
	July 11			
5	200000	68000	15000	4200
6	120000	29000	6500	2200
9	65000	22000	8700	3800
11	12000	33000	9300	4600
12	14000	38000	10000	2300
16	210000	41000	11000	2900
17	150000	38000	10000	2300
Average	110143	38428	10071	31867
	July 18			
5	330000	170000	56000	17000
6	210000	98000	29000	9700
9	130000	50000	19000	9100
11	240000	87000	51000	9800
12	300000	110000	36000	75000
16	330000	130000	48000	19000
17	320000	120000	40000	10000
Average	265714	109286	39857	21371

Appendix 13, continued

Plot No.	Depth in Inches 0-6	6-12	12-18	18-24
		July 25		
5	410000	290000	140000	51000
6	370000	220000	96000	33000
9	240000	110000	50000	21000
11	320000	220000	120000	38000
12	450000	260000	130000	29000
16	450000	350000	150000	58000
17	450000	280000	130000	45000
Average	384286	247143	116572	39286
		August 18		
5	320000	280000	210000	140000
6	380000	290000	220000	150000
9	260000	200000	150000	110000
11	290000	240000	190000	130000
12	340000	310000	210000	150000
16	340000	270000	210000	160000
17	330000	290000	230000	180000
Average	322857	268572	202857	145714
		September 1		
5	80000	180000	230000	180000
6	55000	150000	200000	150000
9	91000	130000	160000	130000
11	50000	150000	190000	150000
12	43000	130000	160000	130000
16	46000	200000	230000	180000
17	75000	200000	220000	180000
Average	62857	162857	174143	157143
		September 10		
5	250000	250000	250000	200000
6	240000	270000	260000	180000
9	260000	230000	200000	270000
11	220000	260000	270000	210000
12	220000	210000	240000	170000
16	260000	280000	280000	220000
17	230000	320000	270000	230000
Average	240000	260000	252857	197143

Appendix 13, continued

Plot No.	Depth in inches 0-6	6-12	12-18	18-24
	September 18			
5	420000	370000	320000	220000
6	410000	360000	310000	210000
9	400000	320000	280000	220000
11	370000	330000	290000	210000
12	400000	330000	290000	180000
16	400000	360000	290000	230000
17	380000	380000	290000	240000
Average	397143	350000	395713	215714
	October 10			
5	12000	36000	64000	160000
6	11000	7100	140000	210000
9	130000	120000	110000	170000
11	2200	59000	130000	230000
12	6400	3300	120000	140000
16	38000	110000	150000	270000
17	4500	36000	120000	220000
Average	29157	53057	119143	200000
	October 18			
5	5900	15000	42000	110000
6	1200	2900	54000	150000
9	37000	22000	32000	120000
11	790	680	53000	130000
12	710	700	44000	70000
16	1000	4700	77000	190000
17	980	10000	62000	170000
Average	6797	8871	52000	134286
	October 24			
5	6600	8900	44000	150000
6	1300	5800	41000	170000
9	60000	52000	62000	160000
11	4000	7900	84000	250000
12	1200	940	19000	110000
16	990	33000	100000	250000
17	1600	4100	59000	200000
Average	12615	16091	58428	184286

Appendix 13, continued

Plot No.	Depth in inches 0-6	6-12	12-18	18-24
	October 30			
5	8600	7900	24000	130000
6	4000	4400	25000	140000
9	73000	62000	74000	150000
11	31000	25000	94000	220000
12	6000	1800	9700	91000
16	4900	18000	78000	210000
17	5100	14000	44000	160000
Average	18943	19014	49814	157286
	November 6			
5	1600	2600	16000	100000
6	1300	2600	17000	99000
9	41000	49000	58000	140000
11	1000	12000	52000	170000
12	890	870	2500	64000
16	880	770	47000	140000
17	790	960	28000	130000
Average	6654	9828	31500	120428
	November 13			
5	1000	1400	5000	46000
6	880	1300	3900	65000
9	24000	22000	44000	110000
11	1500	8000	28000	100000
12	880	860	12000	27000
16	740	680	16000	51000
17	880	1400	29000	54000
Average	4268	5091	18271	64714
	November 20			
5	860	820	840	1900
6	800	740	790	3600
9	1500	1900	760	61000
11	790	840	3000	47000
12	770	750	1100	850
16	780	730	950	2500
17	840	770	1100	45000
Average	906	938	1220	23121

Appendix 13, continued

Plot No.	Depth in inches 0-6	6-12	12-18	18-24
	November 28			
5	800	780	690	690
6	780	790	680	680
9	740	690	720	820
11	730	720	720	710
12	720	750	840	750
16	730	690	680	720
17	720	650	690	720
Average	746	724	717	727
	December 25			
5	860	800	760	680
6	760	710	660	630
9	780	740	730	690
11	770	750	740	670
12	760	770	740	680
16	760	750	760	750
17	840	750	790	680
Average	790	753	740	683

Appendix 14. Means of electrical resistance readings for gypsum blocks in ohms by date, plot, and depth obtained for the nonirrigated gypsum block sets of two plots from June through October, 1954.

Each entry represents the mean reading of 10 gypsum blocks in each plot. The average represents the means of 20 gypsum blocks.

Plot No.	Depth in inches 0-6	6-12	12-18	18-24
		June 11		
5	990	18200	8100	2770
11	6580	29240	17670	15620
Average	3785	2372	12885	9195
		June 17		
5	420	3700	6610	3020
11	4050	15260	16630	8380
Average	2235	9480	11620	5700
		June 21		
5	620	3470	6180	3300
11	4700	11110	16120	9330
Average	2660	7290	11500	6315
		June 25		
5	5620	6920	7010	3690
11	11890	16280	18790	11450
Average	8755	11620	12900	7570
		June 29		
5	24680	14400	8850	4250
11	30820	23430	18720	14470
Average	27750	18915	13785	9495
		July 3		
5	102400	26170	12390	5830
11	76290	39170	30930	19520
Average	89345	32670	21660	12675
		July 7		
5	105300	45620	16850	8620
11	154700	66600	38870	27200
Average	132500	56110	27860	17940
		July 11		
5	227000	75600	30000	12080
11	197000	83400	55200	37400
Average	212000	79500	42600	24740

Appendix 14, continued

Plot No.	Depth in inches 0-6	6-12	12-18	18-24
	July 18			
5	359000	173000	73400	33600
11	213000	179000	101000	88500
Average	286000	176000	87200	61050
	August 18			
5	3200000	2500000	1180000	1060000
11	2800000	1700000	1030000	860000
Average	3000000	2100000	1105000	960000
	September 18			
5	150000	350000	280000	340000
11	190000	430000	360000	340000
Average	170000	390000	320000	340000
	October 27			
5	800	1800	70000	240000
11	920	29000	206000	320000
Average	860	15400	138000	280000

Appendix 15. Soil reaction and chemical analyses of some mineral nutrients, and organic matter by depths and groups for the Laughlin-like soil series.

OREGON STATE COLLEGE

Agricultural Experiment Station — Corvallis, Oregon

August 1953 — Soils — S-11

SOIL TEST REPORT FOR RESEARCH SAMPLES

Name Valassis Date April 21, 1954

Location Soils Department - Oregon State College

Project No. 160 Name of Project

Identification of Experiment Hill Pasture

Lab. No.	Plot or Treatment		Soil pH	P ppm	K ppm	Ca ppm	N %	O. M. %
R 2634	RM I	0 - 6	5.6	3.2	380	1600	.18	3.98
				4.2	385	1630	.18	3.98
R 2635		6 - 12	5.4	3.9	283	1520	.11	2.11
				3.5	285	1520	.11	2.17
R 2636		12 - 18	5.4	1.9	255	1420	.08	1.93
				1.9	260	1440	.08	1.93
R 2637		18 - 24	5.4	1.9	260	1470	.06	0.88
				2.0	255	1490	.06	0.94
R 2638		24 +	5.2	1.3	265	1690	.06	0.76
				1.5	270	1720	.05	0.82
R 2639	RM II	0 - 6	5.7	7.5	410	1810	.21	5.10
				7.2	405	1810	.21	5.27
R 2640		6 - 12	5.5	2.7	355	1630	.14	3.05
				2.9	350	1600	.14	2.99
R 2641		12 - 18	5.2	2.0	335	1520	.10	1.76
				2.3	330	1520	.10	1.82
R 2642		18 - 24	5.0	3.1	255	1420	.07	1.11
				2.7	245	1380	.07	1.23

Appendix 15, continued

Lab. No.	Plot or Treatment	Soil pH	P ppm	K ppm	Ca ppm	N %	O. M. %
R 2643	24 +	4.8	2.3	210	1420	.07	1.05
			2.7	220	1450	.07	1.11
R 2644	RM III 0 - 6	5.6	4.7	330	1800.19	.19	4.22
			4.2	337	1819	.19	4.34
R 2645	6 - 12	5.5	2.7	283	1740	.13	2.70
			2.7	260	1630	.13	2.64
R 2646	12 - 18	5.4	4.0	265	1540	.09	1.64
			4.0	265	1500	.09	1.70
R 2647	18 - 24	5.3	1.0	255	1565	.06	1.00
			1.0	250	1560	.06	1.05
R 2648	24 +	4.9	2.0	225	1565	.03	.41
			2.3	227	1560	.03	.47
R 2649	RM IV 0 - 6	5.6	3.2	360	1700	.19	4.51
			3.5	365	1720	.19	4.40
R 2650	6 - 12	5.4	1.0	295	1610	.12	2.58
			1.2	295	1580	.12	2.58
R 2651	12 - 18	5.3	2.3	265	1450	.09	1.52
			2.3	265	1480	.09	1.47
R 2652	18 - 24	5.1	1.5	250	1470	.07	1.00
			1.0	250	1470	.07	1.05
R 2653	24 +	4.8	2.0	230	1560	.05	0.70
			2.5	235	1600	.05	0.76

Appendix 16. Grams of air-dried forage production, by species and total, of one-square-foot quadrat clippings obtained for the year 1953 from the entire plot No. 5, seeded in highland bentgrass.

Date of clipping	June 5, 1953				September 5, 1953			
					New random locations		Same locations clipped June 5 at 2"	
Height of clipping in inches	0	0	2	2	0	0	0	0
Treatment	Species	Total	Species	Total	Species*	Total	Species*	Total
A	37.0	41.5	5.0	5.3		62.0		63.1
			8.2	8.7				51.7
	41.7	53.1	12.8	18.5		95.0		46.1
			13.0	14.1				25.4
	50.2	61.7	13.5	17.9		84.0		53.5
			11.4	11.7				44.9
B	7.8	15.8	6.5	14.3		73.0		27.6
			5.7	8.9				24.7
	8.3	22.3	1.8	13.8		50.0		30.1
			0.0	5.3				8.9
	6.9	31.9	5.6	12.4		41.0		40.8
			6.0	10.8				23.0
C	0.0	34.7	0.0	21.4		48.0		26.2
			6.4	9.5				18.3
	10.0	23.7	0.0	6.7		39.0		10.8
			3.2	12.1				26.2
	5.0	31.5	0.0	5.1		43.0		20.4
			0.7	8.7				15.3
D	0.0	8.7	0.0	5.9		40.0		23.0
			0.0	1.9				7.2
	7.0	19.2	3.0	3.5		35.0		15.5
			3.0	3.6				14.2
	13.0	29.5	4.2	4.2		55.0		16.1
			5.5	6.1				22.0

Appendix 16, continued

Date of clipping	June 5, 1953				September 5, 1953			
Height of clipping in inches					New random locations		Same locations clipped June 5 at 2"	
	0	0	2	2	0	0	0	0
Treatment	Species	Total	Species	Total	Species*	Total	Species*	Total
Total	186.9	373.6	115.5	230.4		665.0		655.0
Mean	15.6 ±4.9	31.1 ±3.6	4.8 ±0.9	9.6 ±1.1		55.4 ±5.6		27.3 ±3.4

* Species were not separated

Appendix 17. Grams of air-dried forage production, by species and total, of one-square-foot quadrat clippings obtained for the year 1953 from the entire plot No. 6, seeded in chewing fescue.

Date of clipping	June 5				September 5			
Height of clipping in inches					New random locations		Same locations clipped June 5 at 2"	
	0	0	2	2	0	0	0	0
Treatment	Species	Total	Species	Total	Species	Total	Species	Total
					*		*	
A	0.0	28.2	0.0	8.6		50.0		60.7
			0.0	9.6				44.8
	0.0	32.6	0.0	7.0		72.0		22.6
			0.0	15.2				33.5
	0.0	16.4	0.0	12.3		19.0		28.8
			0.0	13.6				33.2
B	0.0	42.2	0.0	5.7		40.0		17.2
			0.0	1.2				18.5
	0.0	28.3	0.0	13.9		44.0		22.5
			0.0	13.3				22.6
	0.0	18.9	0.0	15.2		26.0		19.5
			0.0	20.4				22.6
C	0.0	8.8	0.0	17.7		41.0		22.9
			0.0	10.0				22.9
	12.0	15.6	5.0	4.1		42.0		8.9
			0.5	10.4				15.7
	14.0	24.3	0.5	2.5		34.0		9.6
			2.0	2.2				9.1
D	0.0	7.0	1.0	2.6		25.0		6.7
			0.0	2.7				7.7
	5.0	13.6	4.0	3.9		52.0		13.2
			1.7	5.5				13.7
	8.0	19.5	0.0	6.7		48.0		14.8
			0.0	1.8				7.1

Appendix 17, continued

Date of clipping	June 5				September 5			
Height of clipping in inches					New random locations		Same locations clipped June 5 at 2"	
	0	0	2	2	0	0	0	0
Treatment	Species	Total	Species	Total	Species *	Total	Species *	Total
Total	39.0	255.4	14.7	206.1		493.0		498.8
Mean	3.2 ±1.5	21.3 ±3.0	0.6 ±0.3	8.6 ±1.1		41.1 ±4.1		20.8 ±2.6

* Species were not separated.

Appendix 18. Grams of air-dried forage production, by species and total, of one-square-foot quadrat clippings obtained for the year 1953 for the entire plot No. 9, seeded in Alta fescue.

Date of clipping	June 5				September 5			
Height of clipping in inches					New random locations		Same locations clipped June 5 at 2"	
	0	0	2	2	0	0	0	0
Treatment	Species	Total	Species	Total	Species	Total	Species	Total
					*		*	
A	5.0	32.0	0.0	14.0		50.0		40.7
			0.6	9.9				27.9
	3.0	47.6	0.0	14.5		39.0		29.4
			3.0	14.2				28.1
	0.0	36.7	0.0	14.2		55.0		24.7
			0.0	6.9				24.5
B	0.0	6.8	0.0	1.4		32.0		3.7
			0.0	2.4				12.5
	7.0	13.5	2.0	4.3		16.0		15.3
			0.0	5.0				14.5
	1.2	9.4	3.0	11.3		40.0		11.5
			0.0	2.0				12.5
C	0.0	5.8	0.6	4.6		33.0		8.3
			0.0	2.0				5.4
	2.0	8.2	0.0	3.1		20.0		6.1
			0.0	3.1				7.2
	1.3	5.0	0.0	1.8		26.0		5.1
			2.0	2.0				6.4
D	0.0	6.6	0.5	3.5		29.0		26.7
			0.0	2.5				19.0
	6.0	20.5	0.0	2.4		31.0		14.3
			0.0	2.2				23.5
	9.0	23.4	3.1	6.0		37.0		11.1
			0.6					10.9

Appendix 18, continued

Date of clipping	June 5				September 5			
Height of clipping in inches					New random locations		Same locations clipped June 5 at 2"	
	0	0	2	2	0	0	0	0
Treatment	Species	Total	Species	Total	Species *	Total	Species *	Total
Total	34.5	205.5	15.4	139.1		408.0		389.3
Mean	2.9 ±0.9	17.1 ±4.1	0.6 ±0.1	5.8 ±0.9		34.0 ±3.2		16.2 ±0.2

* Species were not separated.

Appendix 19. Grams of air-dried forage production, by species and total, of one-square-foot quadrat clippings obtained for the year 1953 from the entire plot No. 11, seeded in tall meadow oatgrass.

Date of clipping	June 5				September 5			
Height of clipping in inches					New random locations		Same locations clipped June 5 at 2"	
	0	0	2	2	0	0	0	0
Treatment	Species	Total	Species	Total	Species	Total	Species	Total
A	4.0	25.8	0.0	9.6	*	88.0	*	31.7
			1.5	15.5				38.1
	5.0	34.8	0.0	6.5		65.0		27.4
			2.0	13.4				26.9
	3.6	25.5	3.0	8.2		51.0		23.3
			3.1	15.2				31.2
B	3.0	30.6	0.0	7.0		58.0		44.2
			0.0	2.1				37.3
	4.0	44.4	1.0	3.7		90.0		12.0
			3.6	9.9				43.7
	6.6	53.5	5.8	25.1		80.0		43.1
			2.4	10.1				25.8
C	5.0	20.7	2.3	11.2		46.0		17.7
			4.1	15.5				20.8
	1.5	15.3	2.0	6.7		33.0		9.0
			3.7	8.7				15.7
	2.1	12.6	0.0	2.0		70.0		7.4
			0.0	2.3				9.4
D	1.0	7.4	0.0	5.0		50.0		10.2
			0.0	5.8				7.3
	3.0	17.6	3.0	7.6		40.0		12.1
			2.6	7.2				7.3
	0.6	8.3	0.6	3.4		60.0		8.4
			2.0	4.5				6.2

Appendix 19, continued

Date of clipping	June 5				September 5			
Height of clipping in inches					New random locations		Same locations clipped June 5 at 2"	
	0	0	2	2	0	0	0	0
Treatment	Species	Total	Species	Total	Species	Total	Species	Total
Total	39.4	296.5	42.7	206.2		731.0		516.2
Mean	3.3 ±0.5	24.7 ±4.0	1.8 ±0.1	8.6 ±1.1		60.9 ±5.3		21.5 ±2.7

* Species were not separated.

Appendix 20. Grams of air-dried forage production, by species and total of one-square-foot quadrat clippings obtained for the year 1953 from the entire plot No. 12, seeded in Tualatin oatgrass.

Date of clipping	June 5				September 5			
Height of clipping in inches					New random locations		Same locations clipped June 5 at 2"	
	0	0	2	2	0	0	0	0
Treatment	Species	Total	Species	Total	Species	Total	Species	Total
A	3.0	25.3	0.0	22.4	*	58.0	*	51.8
			3.0	23.8				30.8
	8.0	40.4	0.0	10.7		94.0		19.6
			1.8	17.8				19.7
	1.9	29.4	2.0	14.6		78.0		24.6
			0.0	6.2				23.6
B	9.0	44.3	0.0	16.0		84.0		32.0
			0.0	14.6				23.1
	5.4	57.4	5.0	19.3		92.0		20.0
			3.0	26.5				38.4
	2.0	34.7	7.0	15.2		78.0		23.3
			4.0	22.6				42.9
C	3.0	18.9	4.0	17.0		43.0		43.3
			0.4	4.4				24.4
	0.0	25.8	1.0	5.4		42.0		19.0
			2.2	12.7				42.1
	1.2	36.3	0.0	5.2		60.0		29.7
			0.0	4.3				26.6
D	0.0	13.5	2.0	4.1		42.0		31.0
			0.0	2.7				13.0
	3.5	27.7	3.0	9.9		43.0		26.7
			4.0	9.6				23.1
	6.0	21.5	1.2	8.2		50.0		18.0
			1.4	4.9				9.5

Appendix 20, continued

Date of clipping	June 5				September 5			
Height of clipping in inches					New random locations		Same locations clipped June 5 at 2"	
	0	0	2	2	0	0	0	0
Treatment	Species	Total	Species	Total	Species	Total	Species	Total
Total	43.0	375.2	45.0	298.1		764.0		656.2
Mean	3.6 ±0.5	31.3 ±3.5	1.9 ±0.4	12.4 ±1.5		63.7 ±5.9		27.3 ±1.4

* Species were not separated.

Appendix 21. Grams of air-dried forage production, by species and total, of one-square-foot quadrat clippings obtained for the year 1953 from the entire plot No. 16, seeded in burnet.

Date of clipping	June 5				September 5			
Height of clipping in inches					New random locations		Same locations clipped June 5 at 2"	
	0	0	2	2	0	0	0	0
Treatment	Species	Total	Species	Total	Species	Total	Species	Total
A	0.0	23.5	0.0	24.2	*	52.0	*	55.0
			0.0	17.6				29.2
	4.0	24.0	3.0	16.0		67.0		31.4
			2.1	14.1				23.6
	1.7	29.6	6.5	16.0		32.0		22.8
			3.0	9.6				26.6
B	0.0	17.7	0.0	9.7		44.0		28.8
			0.0	5.5				19.3
	0.5	17.2	0.0	3.4		42.0		17.9
			1.5	10.5				43.5
	2.0	21.6	0.0	3.6		36.0		19.7
			3.3	14.5				30.1
C	0.5	16.5	1.4	7.4		49.0		16.1
			2.0	14.8				18.9
	1.5	19.5	0.0	5.4		44.0		15.0
			0.0	3.9				12.5
	2.0	23.0	1.6	9.6		50.0		21.4
			0.0	7.1				10.3
D	0.0	35.1	0.0	10.1		40.0		46.0
			1.6	9.6				42.3
	1.0	38.8	1.0	6.0		60.0		28.7
			0.0	4.9				34.6
	1.2	38.2	0.3	6.3		61.0		27.9
			0.0	4.7				25.8

Appendix 21, continued

Date of clipping	June 5				September 5			
Height of clipping in inches					New random locations		Same locations clipped June 5 at 2"	
	0	0	2	2	0	0	0	0
Treatment	Species	Total	Species	Total	Species	Total	Species	Total
Total	14.4	304.7	27.3	234.5		577.0		647.4
Mean	1.2 ±0.3	25.4 ±2.3	1.2 ±0.3	9.8 ±1.2		48.1 ±3.0		27.0 ±2.2

* Species were not separated.

Appendix 22. Grams of air-dried forage production, by species and total, of one-square-foot quadrat clippings obtained for the year 1953 from the entire plot No. 17, seeded in subterranean clover.

Date of clipping	June 5				September 5			
Height of clipping in inches					New random locations		Same locations clipped June 5 at 2"	
	0	0	2	2	0	0	0	0
Treatment	Species	Total	Species	Total	Species	Total	Species	Total
A	0.0	51.0	0.0	14.2	*	48.0	*	37.1
			2.0	20.8				38.2
	6.0	64.3	0.5	21.0		65.0		33.2
			0.2	18.7				37.2
	1.5	36.4	0.0	13.1		62.0		37.8
			0.0	8.0				45.8
B	0.0	23.6	0.0	13.4		50.0		30.4
			0.0	6.6				15.9
	0.0	16.9	0.2	4.7		43.0		13.0
			0.4	5.4				17.4
	0.0	22.8	0.0	7.0		60.0		21.2
			0.0	14.6				13.8
C	0.0	14.4	0.6	8.6		47.0		23.6
			0.2	11.6				23.3
	0.0	16.2	0.0	3.2		50.0		11.7
			0.0	1.2				25.8
	0.0	17.1	0.0	6.8		48.0		19.0
			0.8	5.3				12.1
D	1.4	31.4	0.0	10.4		53.0		28.9
			0.0	12.7				41.1
	0.0	28.2	0.0	5.6		54.0		35.7
			0.0	3.3				31.1
	0.2	35.3	0.0	5.1		52.0		26.9
			0.0	2.1				27.6

Appendix 22, continued

Date of clipping	June 5				September 5			
Height of clipping in inches					New random locations		Same locations clipped June 5 at 2"	
	0	0	2	2	0	0	0	0
Treatment	Species	Total	Species	Total	Species	Total	Species	Total
Total	9.1	357.6	4.9	223.4		632.0		642.4
Mean	0.8 ±0.5	29.8 ±4.4	0.2 ±0.1	9.3 ±1.2		52.7 ±1.9		26.8 ±2.0

* Species were not separated.

Appendix 23. Grams of air-dried forage production, by species and total, of one-square-foot quadrat clippings obtained for the year 1954 from the entire plot No. 5, seeded in highland bentgrass.

Date of clipping	May 1				July 15				September 1	
Height of clipping in inches					New random locations		Same locations clipped May 1 at 2"		New random locations	
	0	0	2	2	0	0	0	0	0	0
Treatment	Species	Total	Species	Total	Species	Total	Species	Total	Species	Total
A	13.0	14.0	4.2	4.3	44.0	54.0	54.0	54.0	42.0	52.0
	12.5	13.0	8.0	8.0	48.0	52.0	40.0	46.0	40.0	49.0
	7.0	8.7	2.0	2.0	40.0	42.0	18.0	20.0	63.0	65.0
	8.6	10.6	2.8	3.0	70.0	72.0	20.0	25.0	53.0	60.0
	10.8	11.3	3.8	4.0	75.0	85.0	35.0	35.0	52.0	64.0
B	3.7	19.5	3.0	3.7	6.0	26.0	22.0	30.0	43.0	60.0
	1.5	6.6	2.1	5.1	20.0	40.0	5.0	15.0	44.0	51.0
	2.2	19.2	0.4	7.4	31.0	56.0	28.0	40.0	26.0	54.0
	4.6	16.8	0.4	4.4	67.0	77.0	25.0	27.0	27.0	46.0
	3.2	8.4	0.3	5.0	22.0	30.0	22.0	30.0	45.0	49.0
C	2.2	9.7	1.2	5.2	20.0	53.0	3.0	30.0	16.0	40.0
	1.8	6.4	0.5	3.6	11.0	31.0	5.0	16.0	34.0	46.0
	0.8	11.6	1.0	6.5	5.0	33.0	4.0	22.0	35.0	50.0
	0.0	10.0	0.0	6.3	17.0	37.0	0.0	18.0	45.0	61.0
	3.2	6.2	1.2	4.7	0.0	50.0	8.0	21.0	0.0	53.0
D	1.0	4.0	0.3	3.3	0.0	49.0	3.0	10.0	0.0	37.0
	3.0	5.6	1.8	4.3	10.0	44.0	5.0	11.0	25.0	39.0
	2.6	6.6	1.6	4.6	4.0	39.0	3.0	9.0	20.0	56.0
	2.0	12.8	4.5	6.3	15.0	50.0	9.0	17.0	10.0	50.0
	2.0	6.0	2.0	5.2	12.0	24.0	4.0	14.0	0.0	58.0
Total	85.7	207.0	41.1	96.9	517.0	944.0	313.0	490.0	620.0	1040.0
Mean	4.3 ±0.9	10.4 ±1.0	2.1 ±0.4	4.8 ±0.3	25.8 ±5.3	47.2 ±3.7	15.6 ±3.3	24.5 ±2.7	31.0 ±4.2	52.0 ±1.3

Appendix 24. Grams of air-dried forage production, by species and total, of one-square-foot quadrat clippings obtained for the year 1954 from the entire plot No. 6, seeded in chewings fescue.

Date of clipping	May 1				July 15				September 1	
Height of clipping in inches					New random locations		Same locations clipped May 1 at 2"		New random locations	
	0	0	2	2	0	0	0	0	0	0
Treatment	Species	Total	Species	Total	Species	Total	Species	Total	Species	Total
A	0.0	10.3	0.0	4.6	0.0	47.0	0.0	18.0	0.0	40.0
	0.0	7.8	0.0	2.2	0.0	43.0	0.0	42.0	0.0	58.0
	0.0	11.2	0.0	1.7	0.0	51.0	0.0	30.0	0.0	36.0
	0.0	10.0	0.0	5.0	0.0	40.0	0.0	28.0	0.0	51.0
	0.0	6.2	0.0	1.6	0.0	38.0	0.0	15.0	0.0	35.0
B	0.0	11.0	0.0	4.5	0.0	33.0	0.0	10.0	0.0	33.0
	0.0	5.3	1.0	3.0	0.0	45.0	7.0	17.5	0.0	31.0
	0.0	7.1	0.5	2.7	0.0	38.0	6.0	16.0	0.0	35.0
	0.0	11.0	0.0	6.2	0.0	25.0	0.0	26.0	0.0	40.0
	1.5	12.0	0.0	5.2	5.0	38.0	0.0	32.0	0.0	36.0
C	2.0	10.4	0.0	3.2	3.0	19.0	0.0	22.0	20.0	41.0
	0.0	7.2	0.4	2.0	6.0	26.0	3.0	15.0	10.0	43.0
	9.0	11.5	3.4	3.6	17.0	20.0	9.0	9.0	26.0	37.0
	5.9	6.9	2.5	2.8	5.0	35.0	10.0	18.0	9.0	36.0
	5.4	5.6	4.3	4.5	0.0	25.0	13.0	14.0	5.0	38.0
D	6.0	8.5	3.8	6.8	25.0	30.0	8.0	15.0	20.0	42.0
	9.0	10.0	8.0	8.3	0.0	20.0	13.5	13.5	3.0	33.0
	13.8	15.1	3.0	4.5	0.0	44.0	15.0	20.0	15.0	27.0
	5.0	8.5	3.8	5.9	13.0	40.0	13.0	15.0	12.0	31.0
	3.2	7.7	0.2	4.2	12.0	35.0	3.0	15.0	0.0	37.0
Total	60.8	183.3	30.9	82.5	86.0	692.0	100.5	391.0	120.0	760.0
Mean	3.0	9.2	1.5	4.1	4.3	34.6	5.0	19.6	6.0	38.0
	±0.9	±0.5	±0.5	±0.4	±1.6	±2.1	±1.4	±1.8	±1.9	±1.6

Appendix 25. Grams of air-dried forage production, by species and total, of one-square-foot quadrat clippings obtained for the year 1954 from the entire plot No. 9, seeded in Alta fescue.

Date of clipping	May 1				July 15				September 1	
Height of clipping in inches					New random locations		Same locations clipped May 1 at 2"		New random locations	
	[illegible]	0	2	2	0	0	0	0	0	0
Treatment	Species	Total	Species	Total	Species	Total	Species	Total	Species	Total
A	14.2	17.2	7.5	9.0	0.0	36.0	11.0	31.0	0.0	42.0
	2.0	10.0	2.0	6.0	10.0	50.0	2.0	42.0	20.0	58.0
	0.0	10.6	3.0	4.7	0.0	53.0	4.0	23.0	10.0	44.0
	0.0	8.8	0.5	4.1	0.0	50.0	4.0	33.0	0.0	42.0
	0.0	5.8	0.3	4.2	15.0	50.0	0.5	20.5	0.0	39.0
B	13.0	13.7	8.0	8.6	9.5	16.5	10.0	10.0	20.0	54.0
	9.0	10.1	6.7	7.2	7.5	27.0	20.0	25.0	10.0	35.0
	9.0	11.5	5.0	5.2	20.0	22.0	9.0	9.0	15.0	36.0
	4.7	7.6	4.0	5.6	14.0	28.0	5.0	10.0	20.0	37.0
	17.0	20.0	9.5	10.0	5.0	15.0	20.0	26.0	15.0	48.0
C	10.0	12.0	3.9	4.2	20.0	26.0	6.0	6.0	26.0	46.0
	12.7	14.0	5.4	5.6	10.0	55.0	18.0	18.0	25.0	40.0
	20.0	22.0	5.4	7.4	10.0	33.5	8.0	8.0	20.0	36.0
	10.3	14.8	6.5	8.0	20.0	33.0	10.0	10.0	20.0	43.0
	11.0	12.9	4.0	7.0	20.0	25.0	7.0	7.0	29.0	50.0
D	11.0	13.5	8.5	12.5	20.0	52.0	13.0	13.0	28.0	53.0
	15.0	18.5	4.0	5.5	20.0	80.0	8.0	10.0	14.0	46.0
	8.0	15.7	6.5	9.0	18.0	38.0	13.0	18.0	22.0	55.0
	10.0	13.0	4.8	5.0	20.0	38.0	5.0	8.0	16.0	44.0
	14.0	15.0	6.0	6.5	20.0	40.0	10.0	10.0	30.0	52.0
Total	190.0	266.7	101.5	135.3	259.0	768.0	183.5	337.5	340.0	900.0
Mean	9.5 ±1.3	13.3 ±0.9	5.1 ±0.5	6.8 ±0.5	13.0 ±1.7	38.4 ±3.5	9.2 ±1.2	16.9 ±2.3	17.0 ±2.1	45.0 ±1.5

Appendix 26. Grams of air-dried forage production, by species and total, of one-square-foot quadrat clippings obtained for the year 1954 from the entire plot No. 11, seeded in tall meadow oatgrass.

Date of clipping	May 1				July 15				September 1	
Height of clipping in inches					New random locations		Same locations clipped May 1 at 2"		New random locations	
	0	0	2	2	0	0	0	0	0	0
Treatment	Species	Total	Species	Total	Species	Total	Species	Total	Species	Total
A	25.0	26.6	11.0	12.0	60.0	64.0	30.0	46.0	50.0	62.0
	16.0	19.0	10.0	11.0	22.0	30.0	40.0	50.0	65.0	68.0
	31.0	35.0	19.5	21.0	46.0	50.0	40.0	45.0	64.0	85.0
	8.5	10.0	5.7	6.0	37.0	57.0	30.0	41.0	56.0	76.0
	12.0	12.5	7.8	7.8	58.0	73.0	9.0	23.0	35.0	59.0
B	7.0	8.8	6.0	6.5	20.0	35.0	8.0	10.0	66.0	88.0
	7.5	8.0	5.2	5.5	40.0	46.0	19.0	23.0	55.0	82.0
	12.0	13.7	7.5	8.0	40.0	45.0	19.0	24.0	47.0	84.0
	21.8	23.0	10.6	11.0	38.0	44.0	26.0	30.0	56.0	70.0
	16.0	16.5	10.5	11.0	45.0	50.0	25.0	27.0	44.0	76.0
C	17.0	19.0	9.0	10.0	14.0	34.0	19.0	34.0	35.0	62.0
	12.2	14.2	7.0	7.6	30.0	40.0	16.0	30.0	45.0	65.0
	9.0	9.3	6.0	7.4	40.0	44.5	10.0	10.0	50.0	52.0
	11.2	11.6	7.8	8.8	42.0	50.0	9.0	9.0	32.0	68.0
	10.0	12.0	6.0	8.0	39.0	48.0	8.0	10.0	38.0	57.0
D	9.8	10.2	7.0	7.5	44.0	48.0	10.0	12.0	60.0	76.0
	14.0	16.0	9.5	10.0	30.0	35.0	20.0	11.0	58.0	64.0
	22.5	25.5	5.5	6.0	39.0	39.0	12.0	12.0	44.0	56.0
	18.0	20.0	9.0	11.0	42.0	66.0	18.0	20.0	56.0	70.0
	21.3	24.0	11.0	13.5	20.0	35.0	20.0	32.0	62.0	84.0
Total	301.8	334.9	171.6	189.6	746.0	933.5	398.0	499.0	1018.0	1404.0
Mean	15.1 ±1.5	16.7 ±1.6	8.6 ±0.7	9.5 ±0.8	37.3 ±2.6	46.7 ±2.5	19.9 ±2.2	25.0 ±3.0	50.9 ±2.4	70.2 ±2.4

Appendix 27. Grams of air-dried forage production, by species and total, of one-square-foot quadrat clippings obtained for the year 1954 from the entire plot No. 12, seeded in Tualatin oatgrass.

Date of clipping	May 1				July 15				September 1	
Height of clipping in inches					New random locations		Same locations clipped May 1 at 2"		New random locations	
	0	0	2	2	0	0	0	0	0	0
Treatment	Species	Total	Species	Total	Species	Total	Species	Total	Species	Total
A	16.0	18.0	6.5	8.0	40.0	54.0	50.0	68.0	62.0	82.0
	7.8	8.2	6.0	7.0	40.0	45.0	16.0	36.0	73.0	88.0
	10.3	11.3	6.5	7.0	49.0	64.0	20.0	48.0	64.0	74.0
	8.7	9.1	6.0	6.0	19.0	39.0	24.0	24.0	51.0	68.0
	10.6	14.6	5.7	6.0	35.0	47.0	28.0	40.0	80.0	88.0
B	10.8	12.0	6.4	6.5	48.0	60.0	27.0	27.0	85.0	95.0
	7.0	10.0	4.0	4.5	46.0	49.0	23.0	26.0	74.0	90.0
	10.0	12.5	7.2	7.5	80.0	85.0	33.0	38.0	75.0	92.0
	12.0	13.0	6.7	7.2	75.0	85.0	40.0	47.0	86.0	98.0
	10.5	12.0	9.0	9.5	30.0	34.0	50.0	64.0	70.0	75.0
C	11.9	13.4	6.3	6.3	30.0	33.0	27.0	30.0	54.0	64.0
	8.0	9.8	4.0	4.3	62.0	66.0	15.0	17.0	65.0	72.0
	10.9	11.9	7.2	8.0	42.0	50.0	20.0	22.0	50.0	71.0
	10.0	10.7	6.0	6.5	45.0	45.0	22.0	22.0	60.0	78.0
	15.0	18.0	9.5	11.0	37.0	43.0	17.0	17.0	51.0	65.0
D	8.0	8.8	7.0	7.8	40.0	40.0	16.0	16.0	47.0	97.0
	9.5	12.5	6.4	8.2	42.0	42.0	16.0	16.0	40.0	93.0
	10.0	11.5	9.0	9.7	37.0	37.0	15.0	20.0	38.0	100.0
	12.0	14.0	8.2	8.8	59.0	59.0	20.0	21.0	43.0	78.0
	13.0	17.5	6.5	6.7	50.0	60.0	33.0	35.0	42.0	82.0
Total	212.0	248.8	134.1	146.5	906.0	1037.0	512.0	634.0	1210.0	1650.0
Mean	10.6 ±0.5	22.4 ±0.3	6.7 ±0.3	7.3 ±0.4	45.3 ±3.3	51.8 ±3.3	25.6 ±2.4	31.7 ±3.4	60.5 ±3.4	82.5 ±2.5

Appendix 28. Grams of air-dried forage production, by species and total, of one-square-foot quadrat clippings obtained for the year 1954 from the entire plot No. 16, seeded in burnet.

Date of clipping	May 1				July 15				September 1	
Height of clipping in inches					New random locations		Same locations clipped May 1 at 2"		New random locations	
	0	0	2	2	0	0	0	0	0	0
Treatment	Species	Total	Species	Total	Species	Total	Species	Total	Species	Total
A	3.4	10.4	1.5	5.5	8.0	28.0	9.0	23.0	12.0	58.0
	4.0	12.0	2.5	5.5	4.0	30.0	12.0	19.0	16.0	52.0
	3.2	9.6	1.3	8.0	15.0	39.0	8.0	22.0	10.0	45.0
	2.6	7.5	1.0	3.6	11.0	36.0	4.5	17.0	18.0	44.0
	3.0	12.0	2.3	5.4	14.0	33.0	5.0	11.0	14.0	51.0
B	0.8	4.6	0.2	3.2	2.0	18.0	2.0	10.0	4.0	45.0
	1.0	5.0	0.5	3.5	3.0	21.0	3.0	10.0	6.0	40.0
	2.5	7.5	1.1	6.0	4.0	21.0	5.0	12.0	10.0	34.0
	1.5	6.5	0.3	4.0	6.0	17.0	3.0	13.0	5.0	46.0
	1.0	5.0	0.3	3.3	2.0	33.0	2.0	7.0	5.0	35.0
C	0.7	9.6	0.3	8.3	3.0	20.0	5.0	15.5	6.0	42.0
	0.5	8.2	0.2	4.9	4.0	20.0	4.0	12.0	10.0	48.0
	0.3	7.2	0.4	2.6	4.0	24.0	3.5	10.0	12.0	32.0
	0.2	7.8	0.3	2.5	2.0	33.0	5.0	20.0	2.0	52.0
	0.5	7.5	0.4	6.0	3.0	21.0	3.0	16.0	5.0	26.0
D	0.5	10.5	0.2	3.9	0.0	35.0	1.0	33.0	9.0	57.0
	0.2	11.0	0.0	5.2	4.0	32.0	0.0	23.0	11.0	56.0
	0.4	7.7	0.5	6.6	3.0	64.0	4.0	17.0	7.0	42.0
	0.2	7.2	0.2	3.8	5.0	31.0	1.0	9.0	8.0	41.0
	0.5	8.5	0.3	5.0	2.0	12.0	2.0	8.0	10.0	54.0
Total	27.0	165.3	13.8	96.8	99.0	568.0	82.0	307.5	180.0	900.0
Mean	1.4 ±0.3	8.3 ±0.5	0.7 ±0.2	4.8 ±0.4	5.0 ±0.9	28.4 ±2.5	4.1 ±0.4	15.4 ±1.4	9.0 ±0.9	45.0 ±2.0

Appendix 29. Grams of air-dried forage production, by species and total, of one-square-foot quadrat clippings obtained for the year 1954 from the entire plot No. 17, seeded in subterranean clover.

Date of clippings	May 1				July 15				September 1	
Height of clipping in inches					New random locations		Same locations clipped May 1 at 2"		New random locations	
	0	0	2	2	0	0	0	0	0	0
Treatment	Species	Total	Species	Total	Species	Total	Species	Total	Species	Total
A	0.0	11.6	0.0	5.3	0.0	42.0	0.0	36.0	0.0	68.0
	0.0	12.5	0.0	3.8	0.0	53.0	0.0	31.0	0.0	64.0
	0.2	11.8	2.0	5.8	0.0	48.0	0.0	31.0	0.0	56.0
	0.3	14.2	0.0	9.6	0.0	47.0	0.0	11.0	0.0	70.0
	0.0	21.0	0.0	6.7	0.0	45.0	0.0	20.0	0.0	62.0
B	0.0	13.5	0.0	5.5	0.0	25.0	0.0	21.0	0.0	53.0
	1.2	7.2	0.4	4.3	0.0	27.0	0.0	10.0	0.0	37.0
	0.0	13.5	0.0	5.5	0.0	28.0	0.0	23.0	0.0	56.0
	0.0	12.0	0.0	4.3	0.0	36.0	0.0	11.0	0.0	44.0
	0.0	7.7	0.4	3.6	0.0	24.0	0.0	12.0	0.0	40.0
C	0.6	13.6	0.0	6.2	0.0	48.0	0.0	15.0	0.0	50.0
	0.0	9.8	0.0	4.5	0.0	25.0	0.0	15.0	0.0	48.0
	0.0	11.0	0.0	2.6	0.0	28.0	0.0	14.5	0.0	67.0
	0.0	13.0	0.0	6.0	0.0	43.0	0.0	8.0	0.0	57.0
	0.0	11.2	0.0	5.9	0.0	30.0	0.0	16.0	0.0	58.0
D	0.0	7.5	0.0	5.3	0.0	30.0	0.0	17.0	0.0	53.0
	0.0	6.0	0.5	2.5	0.0	41.0	0.0	20.0	0.0	57.0
	0.0	12.0	0.0	9.0	0.0	33.0	0.0	19.0	0.0	52.0
	0.0	10.0	0.0	5.5	0.0	48.0	0.0	17.0	0.0	55.0
	0.0	11.5	0.0	6.5	0.0	61.0	0.0	28.0	0.0	47.0
Total	2.3	230.6	3.3	108.4	0.0	762.0	0.0	375.5	0.0	1094.0
Mean	0.1 ±0.06	11.5 ±2.3	0.2 ±0.1	5.4 ±0.4	0.0	38.1 ±2.4	0.0	18.8 ±1.7	0.0	54.7 ±2.0

Appendix 30. Summary and percent of forage composition obtained in 1953 with the point-frame method for total of 2400 hits from plot No. 5, seeded in highland bentgrass.

	Number of hits			
	Bare ground	Litter	Seeded forage species	All other species
	--	100	130	42
	1	94	83	82
	--	97	102	76
	--	98	58	122
	1	99	98	38
	1	97	68	81
	--	90	60	156
	--	90	94	80
	--	91	79	106
	3	82	70	89
	--	92	97	120
	--	84	53	123
	1	84	21	182
	2	90	42	142
	6	70	16	81
	1	70	1	141
	7	88	25	59
	7	76	9	113
	4	98	15	63
	8	88	7	62
	1	98	27	87
	--	95	49	52
	2	100	41	103
	--	96	42	147
Total	45	2167	1287	2349
Percent of hits	0.77	37.06	22.01	40.17
Percent of vegetative composition			35.40	64.60

Appendix 31. Summary and percentages of forage composition obtained in 1953 with the point-frame method for total of 1200 hits from plot No. 6, seeded in chewing fescue.

	Number of hits			
	Bare ground	Litter	Seeded forage species	All other species
	—	81	—	222
	2	77	—	110
	2	95	—	185
	2	75	—	166
	8	85	4	118
	3	85	4	164
	1	86	22	88
	1	90	—	159
	4	78	9	131
	—	93	5	148
	3	89	21	137
	1	82	33	141
Total	27	1016	98	1769
Percent of hits	0.93	34.91	3.37	60.79
Percent of vegetative composition			5.25	94.75

Appendix 32. A letter regarding the inventory, of the seeded forage species in the experimental area, made in 1946.

August 15, 1946

Dr. H. A. Schoth
Ag 201
Campus

Dear Dr. Schoth:

Enclosed is a copy of the results of the seeding trial on the Hill Pasture Project.

Numbers under each method of seed bed treatment represent plants of the trial species found on a belt transect representing a random selected 50 square feet.

You may want to make comments on this material. We will appreciate having them.

Very truly yours,

R. G. Johnson, Head
Department of Animal Husbandry

RGJ/kls
Enc.

Dictated but not read

Appendix 33. The inventory, of the seeded forage species in the experimental area, made in 1946.

North
SEEDING TRIAL - HILL PASTURE PROJECT

	Plots	Plowed and Fallow	Disced and Fallow	Closely Grazed	No Grazing and Fall Burn
Lotus (corniculatus)	20	148	72	4	8
Hop clover	19	457	12	8	120
White clover	18	3	2	5	4
Sub clover	17	119	1	2	7
Burnett	16	272	139	81	45
Velvet grass	15	282	153	37	28
Bulbous blue	14	3	1	2	1
Perennial rye	13	435	261	11	116
Non shattering tall meadow oat	12	463	261	62	153
Tall meadow oat	11	207	208	166	141
Orchard	10	342	114	52	107
Alta fescue	9	538	236	86	119
Timothy	8	190	37	10	3
Red creeping fescue	7	604	37	87	4
Chewing fescue	6	553	369	9	108
Highland bent	5	303	44	0	35
	4	First			
	3		four		
	2			plots	
	1				not inventories