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permanent tape points.

The frame is placed over the tape near the first frame position, with the centered edge of the axial member next to the tape. Next, the frame is leveled and set to tape height by adjusting the legs. Then, holding the centered edge of the axial member flush with the tape, the back edge of the cross member is matched with the tape mark of the first frame position. With the frame thus alined, the loop shank is placed and plumbed in the desired notches, and ground cover within the loop is recorded. Frame alinement and recording of ground cover is repeated at each frame position, resulting in a grid of 50 loop readings on the plot (Figure 3). Although the 0.7-foot grid interval makes possible 52 loop positions per plot, only 50 are recorded. This facilitates analysis and transformation of data to percentiles. When the frame is alined on the first and eighth frame position of a plot, one loop position is omitted. In Figure 3, the third loop position has been omitted.

The recording form used for each plot is similar to that used in loop transect work[2] except that 8 instead of 10 rows and columns of recording blocks are used. The eight rows of blocks correspond to the eight frame positions on the plot. Also, each row has only the numbered blocks that correspond to the numbered loop positions read at that frame position. For example: the first row has blocks 4, 5, and 6 only; the second row, blocks 2 to 7; and the third row, blocks 1 to 8. This method of recording assures the operator of recording ground cover only at those loop positions desired at each frame position.

The height of the two reference points controls tape height; therefore, the tape occasionally lies below the minimum adjustable frame height. When this occurs, the tape side of the forward leg (at the end of the axial member) is positioned flush with the tape, and the frame is then alined along the tape line by using the loop shank as a plumb line. The tape mark designating a frame position is matched to the loop shank held plumb from the junction of the extended axial member and the back edge of the cross member (Figure 2).

Discussion

This equipment and method can yield any desired number of loop or similar measurements of ground cover in an areal distribution with accurate and easily maintained position control. When carefully used it also enables good accuracy in duplicating loop positions during remeasurements. Trials on eight grassland plots resulted in a plot average of 93.2 percent duplication of loop recordings with a standard error of 3.2 percent. More than three-fourths of the discrepancies noted in the remeasurement resulted from displacement of rock, litter, and moss by the operator during initial measurement.

The method is not well suited for sampling herbaceous vegetation in heavy timber nor among tall shrubs because of the rigidity and size of the frame. However, it has been used successfully since 1957 in open timber stands, in sparse cover of low shrubs, and in grasslands to supplement plot measurements obtained by other means and to relate these measurements to loop measurements.

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The Relative Rate of Root Development of Cheatgrass and Medusahead

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Cheatgrass *(Bromus tectorum)* is an annual grass well adapted to the Northern Intermountain Region. Since its introduction into southern Idaho, more than 50 years ago, cheatgrass has spread rapidly where the original native plant cover has been disturbed or destroyed by excessive grazing, burning, or land abandonment after cropping (Hull and Stewart, 1948). It is most abundant in the sagebrush-grass region, but it extends well into the salt-desert shrub type as well as into the ponderosa pine and Douglas-fir zones. Cheatgrass is currently dominant or an important component of the herbaceous vegetation on several million acres of rangeland in southern Idaho (Hull and Pechanec, 1947).

Cheatgrass is an important economic species because it provides the bulk of the forage for sheep and cattle on many spring-fall ranges. In recent years another introduced annual grass, medusahead *(Elymus caput-medusae)*, has been replacing cheatgrass and other annuals in Idaho, Oregon, Washington, and California. This newcomer is of great concern to land managers and livestock operators because of its low palatability and rapid increase.

Medusahead is an aggressive species. Within a period of about 15 years it has spread from a few

FIGURE 1. Individual plants were grown in tubes of nylon cloth. The tubes were recovered from the sidewall of trench dug adjacent to a row of tubes.

isolated patches to become the dominant on more than 750,000 acres of former cheatgrass range in Idaho. Reduction in livestock grazing capacity by as much as 50 to 80 percent has resulted in some areas within a period of a few years. Many additional hundreds of thousands of acres of annual grass range appear susceptible to invasion by medusahead in Idaho and adjacent states.

Both cheatgrass and medusahead are winter annuals and their life cycles are similar except in one major feature. Medusahead reaches maturity 2 to 3 weeks later than cheatgrass (Sharp *et al.,* 1957). The reason for the apparent ease with which medusahead has been able to displace cheatgrass is not understood. Outwardly, medusahead does not appear to have any distinct competitive advantage over cheatgrass, and yet the former has been able to replace the latter (Sharp and Tisdale, 1952). The possibility that an examination of the root system of the two species might help explain medusahead's superior competitive ability led to the present study, conducted during the period 1956 through 1958.

Location of Study

The study was conducted in Gem County, Idaho in a field where medusahead had supplanted cheatgrass several years previously. The soil type is Brent silt loam, a Chestnut soil. The soil developed on an old alluvial fan and has a relatively deep (43 inches) and well-developed profile. The land slopes 3 per cent to the west, and the elevation is approximately 2,600 feet above sea level. Precipitation at the study area was estimated to be slightly greater than at Emmett, located about 8 miles away. Emmett normally receives about 12 inches of precipitation annually, but about 15 inches of precipitation was recorded annually during the study period.

Methods

Prior knowledge of cheatgrass and medusahead root behavior played an important role in the decision as to what technique was to be employed in this study. Cheatgrass roots tend to penetrate the soil vertically (Hulbert, 1955) and preliminary study by the author indicated that medusahead roots behave similarly. This tendency toward vertical root penetration was found to be more pronounced in dense than in sparse stands.

In order to simulate natural stand condition as much as possible and simultaneously be able to follow rate of soil penetration by individual plants, roots of individuals were restricted to a narrow column of soil encased in 1-inch diameter tubes made from nylon cloth (Figure 1). The use of cloth, rather than a rigid container, permitted close contact between soil column and container wall during soil drying and allowed easy exchange of soil moisture with the adjacent soil outside the tube.

The cloth tubes were filled with soil extracted by an orchard-type soil sampler. The soil was placed in the tubes in the reverse order of extraction, i.e., soil from the bottom of the hole was placed in the bottom of the tube. A firmly packed tube was indicated when it became circular in cross section with repeated bouncing and tapping on the ground. The tubes were "planted" in holes from which the soil was obtained.

In October 1956 each tube was planted in a separate hole, but in the following year they were bundled in groups of four and firmly secured to a lath. The lath spine greatly facilitated later re-

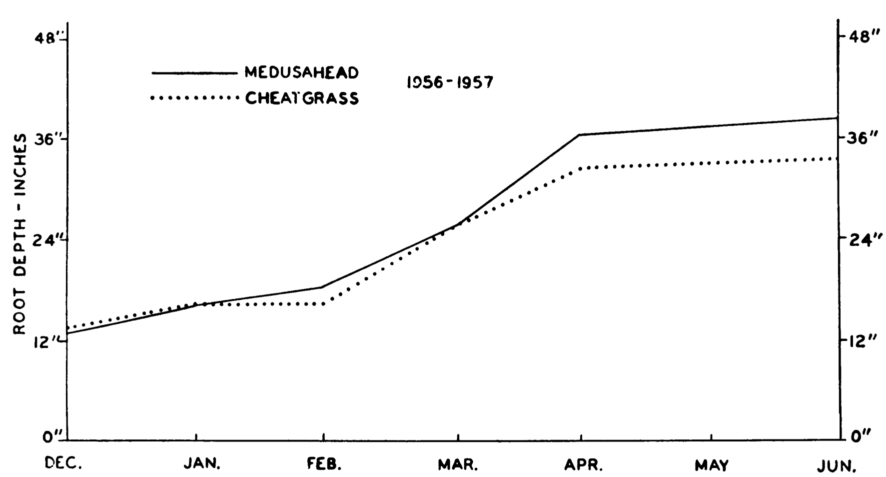

FIGURE 2. The cumulative growth curves of depths of root penetration for medusahead and cheatgrass during the 1956-57 study. Measurements were made during the middle of each month.

covery of the tubes. The length of the tubes to be recovered during the winter months was 2 feet or less. Those to be recovered after March were 3 feet long.

Only medusahead and cheatgrass were grown the first year. Each tube received two seeds and after germination and emergence one seedling was permitted to become established. When the experiment was repeated the following year (1957) each of the four tubes of a bundle was seeded to one of four species—medusahead, cheatgrass, desert wheatgrass *(Agropyron desertorum)*, or intermediate wheatgrass *(A. intermedium)*.

The tubes (or bundles of tubes) were planted 18 inches apart in seven rows in a dense stand of medusahead. The disturbance of the existing vegetation and soil was confined to a core 3 inches in diameter with a depth equal to the length of the "planted" tubes. The study area was mulched with a light cover of grain straw to reduce the chance of contamination of the seeded tubes by stray medusahead seed and also to lessen the effect of frost heaving. Each month, beginning in mid-December, one row of tubes (consisting of four replicates of each species) was recovered, taken to the laboratory, and soaked in water overnight. Each tube was then split carefully and the roots separated from the soil by washing with a fine jet of water. In no case did a root penetrate the nylon cloth, but in a few instances roots passed through the seams between stitches. Length measurements obtained were the maximum distance from root tip to seed and from seed to leaf tip with the plant laid out on a flat surface.

Results

The cumulative growth curves of roots of medusahead and cheatgrass for the 1956-57 study are presented in Figure 2. There was no significant difference in

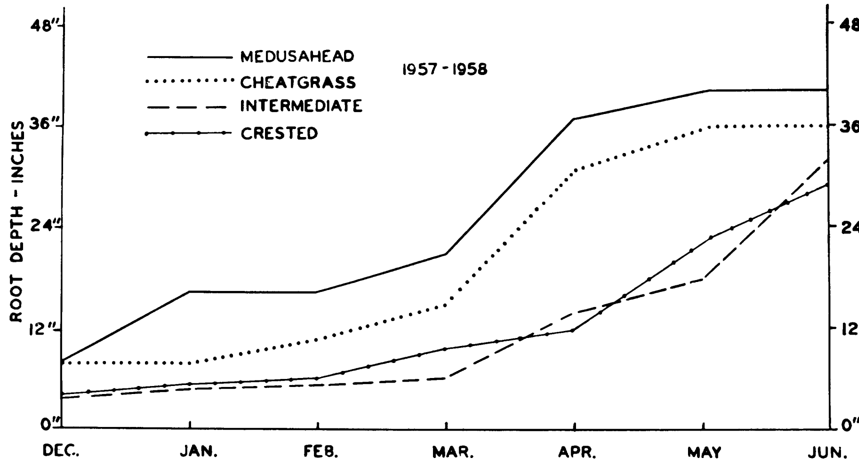

FIGURE 3. The cumulative growth curves of depths of root penetration for four species during the 1957-58 study. Measurements were obtained during the middle of each month.

root length between the two species during any period of the study. A significant increase in root length occurred for both species between mid-December and mid-March and between mid-March and mid-April. Little additional increase in overall root length occurred after mid-April for the two species.

Measurable increase in the aerial portion of the plants was not evident until after mid-March. Full emergence of the inflorescence of cheatgrass occurred during the third week of May, after which time no further increase in height was noted. Medusahead reached full flowering during the second week of June. Plants of both species developed only single culms during the first year of study.

The following year the experiment was repeated with the addition of desert wheatgrass and intermediate wheatgrass, two perennial grasses commonly used for range seeding purposes. Germination of these species occurred during the third week of October, about one week later than the annual grasses.

The cumulative growth curves for the four species are presented in Figure 3. Cheatgrass did not grow as well in 1958 as in the previous year, but medusahead behaved much as it had the year before. The roots of cheatgrass tended to be consistently shorter than those of medusahead, but because of the small number of replications a statistically significant difference ($P_{.05}$) could not be demonstrated between the two species. Because one or two plants were either missing or damaged at each recovery, the multiple range tests as described by Kramer (1956) were employed. The perennial species had a higher mortality percentage than the annuals.

Prior to April the root systems of the two annual grasses consisted primarily of a single main root with short laterals. About the time the aerial portion of the plants began to add conspicuous growth, much ramification and lateral development of the root systems were observed. It became increasingly difficult to determine which of the long roots was the original primary root. Multiculum plants tended to develop a more extensive root system than those with only a single culm. During the second year of study most of the annual plants developed more than one culm. Tillering became evident in April.

Cheatgrass developed a more fragile and fibrous root system than medusahead. This fragility increased as the roots became

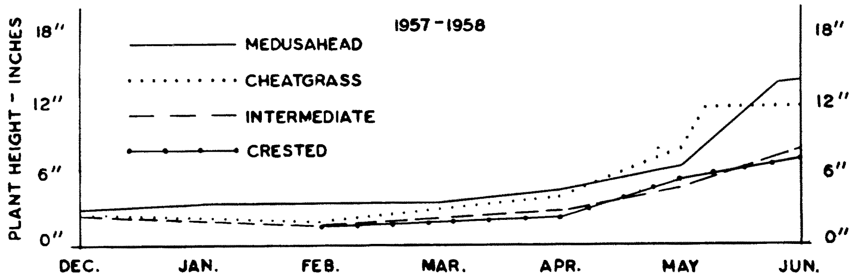

FIGURE 4. The cumulative growth curves of average maximum height of aerial portion for four species during the 1957-58 study. Measurements were obtained during the middle of each month. Cheatgrass reached its maximum height several days after the mid-May recovery was made.

older and appeared to be correlated with a change in color from white to brown. A noticeable increase in brittleness of roots occurred as full inflorescence was approached for both species.

The roots of the perennial grasses did not add any significant increment from mid-December to mid-March. After March, root increment was added at a fairly consistent rate until the termination of the study in mid-June. As in the case of the annual grasses, a significant increase in leaf length did not occur until April (Figure 4). This delay of aerial growth activity for all species was more apparent than real, however. The leaf blades that were present in the fall were gradually killed back from the leaf tip, and at the same time new leaf blades replaced the old during late winter and early spring. It was not noted whether this replacement occurred for all leaf blades that were present the previous fall, but it is probable that the coleoptile and the first and second true leaves were replaced in this manner.

Discussion

The root systems of cheatgrass and medusahead reached full development about the time full inflorescence occurred. After this stage of plant development a marked increase in brittleness of roots was noted. Nuttonson (1957) mentioned a similar phenomenon with annual rye, *Secale cereale,* and indicated that it was associated with a marked decrease in moisture uptake by the roots.

According to Piemeisel (1951), the annual species that ranks high in earliness of germination, earliness of maximum growth and maturity, capacity to withstand crowding, and high seed production possesses a decided advantage in occupying and holding a particular site over other annuals that rate lower in these characteristics. Cheatgrass is superior to medusahead in earliness of maximum growth and maturity. Both species are about equal in the remaining characteristics. It appears likely that a stand of cheatgrass would be able to resist invasion by medusahead in situations where soil moisture was sufficiently limiting that cheatgrass was able to utilize nearly all of the available moisture for its development, leaving an insufficient amount for medusahead to complete its life cycle.

In areas having a surplus of soil moisture after cheatgrass reaches maturity, medusahead would be able to complete its life cycle in spite of the presence of cheatgrass. This might explain how medusahead is able to invade cheatgrass stands when soil moisture is the only consideration. In southern Idaho there are many areas where a surplus of available moisture is present after cheatgrass matures. These areas are conspicuous by the presence of summer broadleaved annuals. Differential grazing preference by livestock may also favor invasion of medusahead into areas where it would not normally become established unless the cheatgrass cover were disturbed.

The above offers an explanation as to how it is possible for medusahead to invade cheatgrass stands. It does not, however, explain how medusahead is able to replace and become the dominant after initial invasion. In this respect, this study of the root system of the two species failed to yield a satisfactory answer. The mechanism of cheatgrass replacement by medusahead needs further study.

The performance of the perennial grasses in this study shows clearly why range seeding with perennial species is apt to be unsuccessful on lands dominated by cheatgrass or medusahead unless competition from the latter species is reduced.

Fall emergence of these annuals is a common occurrence, whereas fall emergence of seeded perennials is less frequent under the normal climatic conditions as well as under the present practice followed in seeding rangelands in the Intermountain Region. By the time spring emergence of the perennial species occurs, the annual grasses have their root systems well advanced towards full development. Even if the seeded species were to germinate and emerge in the fall, as in this study, the slower rate of root penetration places them at a disadvantage in competing for soil moisture in the spring.

Summary

The relative rate of root development of medusahead and cheatgrass was studied employing a new field technique. Individual plants were grown in nylon cloth tubes which were "planted" in the field. One row of tubes, consisting of four replicates of each species, was re-

covered monthly from mid-December through mid-June and the depth of root penetration and aerial growth measurements were obtained.

Rate of vertical root penetration of the two annual grasses was about equal, but cheatgrass reached maximum branching a few weeks earlier than medusahead. Maximum root development coincided closely with time of full inflorescence for the two species. Because medusahead matures later, its root system remains functional for a longer period than those of cheatgrass. When the two species are growing together the water requirement for cheatgrass must be satisfied before medusahead is able to complete its life cycle.

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Water Intake as Affected by Soil and Vegetation on Certain Western South Dakota Rangelands[1]

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The capacity of rangeland soils to absorb rainfall is of major importance in the production of forage and in the control of runoff and erosion on watersheds. Characteristics of the soil and past and present grazing use as they affect plant cover are some of the important factors determining water-intake. These and factors associated with climate govern the amount of precipitation that can be absorbed and stored by the soil. Improvements in water-intake are of extreme importance in range and watershed improvement programs.

Dyksterhuis and Schmutz (1947), in a comprehensive review of the literature, noted that with few exceptions mulches were a primary factor in determining total annual infiltration of rain water on ranges. Duley and Domingo (1949) found that when grass was clipped and mulch removed, water-intake rates were reduced because of loss of surface protection. The role of range cover in preventing splash erosion and surface sealing was quantified by Osborn (1954).

During the past several years, water-intake studies have been conducted on rangelands of the northern and central plains with a mobile infiltrometer (Figure 1). These tests were conducted over a seven-state area on different kinds of rangelands. Data were obtained by sampling contrasts in the condition of range plant covers along fence lines where soils were homogeneous. In general, these data reveal that the rate of water-intake increases appreciably with an increase in amount of standing vegetation and mulch (Rauzi and Zingg, 1956). Quantitative results, from three areas in the northern plains, emphasized the importance of vegetation and mulch material in increasing the amount of rainfall absorbed by range soils (Rauzi, 1960).

Questions remain on the degree to which results from the infiltrometer apparatus represent the infiltration and runoff to be expected from small watersheds under natural conditions. The purpose of this paper is to report on certain preliminary phases of broader studies designed to answer such questions.

In September 1956, a reconnaissance survey to locate suitable small watersheds was conducted in the general land area adjacent to the corners of Montana, the two Dakotas and Wyoming. Personnel of the Agricultural Research Service and the Soil Conservation Service selected a group of stockponds where useful hydrologic studies could be made and from which results could have wide application in surrounding areas.

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