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Title: ESTABLISHMENT OF SUBTERRANEAN CLOVER (*TRIFOLIUM SUBTERRANEUM* L.), ON MEDUSAHEAD, (*TAENIATHERUM ASPERUM* (SIM.) NEVSKI), INFESTED RANGES IN WESTERN OREGON

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Dr. William R. Furtick

An experiment was conducted to determine the best method to establish subterranean clover on medusahead infested ranges in Western Oregon. Secondary objectives of this study were to determind the effects of management treatments on (a) subterranean clover density, (b) density of medusahead and other vegetation, and (c) yield of subterranean clover.

Four treatments for establishing subterranean clover were compared including two seeding methods superimposed over six old treatments for controlling medusahead. The results of this experiment are as follows: Subterranean clover density was found to be significantly higher early in the season in the sod plus broadcast seeded area, in all but the chemically treated areas,

when compared with the sod seeded area. The number of subterranean clover plants per square foot in May was significantly higher in the sod plus broadcast seeded areas in all but the chemical treatment. There was a great loss of subterranean clover plants in both methods of seeding from March through April; this was due to poor nodulation.

Vegetation density was significantly lower in the chemical-mowed and sheep-grazed treatments in May. Medusahead density was lower in only the chemical-mowed treatment. It appears that removing the old vegetation before applying paraquat makes the chemical more effective in controlling medusahead and other vegetation.

The yield of vegetation other than subterranean clover ranged from 1,871 to 2,437 pounds per acre. The yield of vegetation in the chemical-mowed and sheep-grazed treatment was significantly lower than in the mechanical and control treatment.

Subterranean clover yields, which were highest in the sod plus broadcast seeded areas, ranged from 22 to 397 pounds per acre. The chemical-unmowed treatment along with a previous control treatment had the highest yield: the lowest yield was obtained in the mechanical treatment combined with a late grazed treatment. Low yields of subterranean clover were attributed to lack of nodulation which probably was caused by dessication of rhizobia prior to sowing (a

24 hour delay in broadcast inoculated seed), drying after seeding because of poor coverage in drill rows and lack of available phosphorus.

In establishing subterranean clover on similar sites, reduction of vegetation would be of prime importance. Prior grazing would be beneficial as shown, but because of the unpalatable and low nutritional value of annual grasses in summer and autumn, vegetation removal might depend on use of fire or mechanical means, with or without herbicides.

For stand establishment sod-seeding was more effective than broadcasting the seed. A higher rate of seeding is suggested when surface broadcasting seed onto undisturbed soil. Continued work on establishing of subterranean clover on medusahead infested sites should include the variables mentioned above.

Establishment of Subterranean Clover (<u>Trifolium Subterraneum</u> L.), on Medusahead, (<u>Taeniatherum Asperum</u> (Sim.) Nevski), Infested Ranges in Western Oregon

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INTRODUCTION

Medusahead (*Taeniatherum asperum* (sim.) Nevski), a winter-annual weed grass native to the Mediterranean region, is a serious problem on overgrazed foothill ranges of western Oregon.

Turner, Poulton and Gould (1963) state that half of Oregon's 36 counties are known to have medusahead infestations--five west of the Cascades in southwestern Oregon and 13 in eastern Oregon. Southwestern Oregon has the largest geographical area of medusahead with over 1,500,000 acres included within the periphery of known infestations. These are mainly in Lane, Douglas, Jackson and Josephine counties, with considerable amounts as far north as Polk and Linn counties.

The seeding of valuable forage species such as subterranean clover (*Trifolium subterraneum* L.) on medusahead weed infested range land in western Oregon is of prime importance if these lands are to contribute fully to the livestock economy.

Subterranean clover, a winter annual native to the Mediterranean region, has proved to be important as a range forage resource in western Oregon. It is currently being used in western Oregon counties to increase the forage potential of foothill ranges and pastures.

The primary objective of this study was to evaluate the establishment of subterranean clover under several experimental conditions on a hill pasture, in western Oregon, which is dominated by medusahead and California oat grass (*Danthonia californica* Boland).

Secondary objectives were to investigate: (a) the effects of sheep trampling on the establishment of subterranean clover; (b) methods of seeding--broadcast plus seeding directly into the sod vs. seeding directly into the sod for the establishment of subterranean clover, and (c) the effects of paraquat for controlling medusahead.

LITERATURE REVIEW

Medusahead

Medusahead, a winter-annual weedy grass native to the Mediterranean region, is currently one of the primary range weed problems in Oregon (Turner, Poulton and Gould, 1963). Medusahead is a serious threat to the range livestock industry because of its aggressiveness in competition with other vegetation. Torell, Erickson and Hass (1961) state that medusahead has invaded established stands of perennial grasses such as desert wheat grass (*Agropyron desertorum* (Fisch) Schult.), and intermediate wheat grass (*Agropyron intermedium* (Host) Beauv.).

Characteristics contributing to the competitive ability of medusahead are: the species is a prolific seed producer, its seeds are highly viable and germinate readily; its vigorous seedlings have a high survival rate; and its herbage is very unpalatable to livestock. Another attribute that contributes to medusahead's potential as a range weed is the fact that the species possesses a broad ecological amplitude (Turner *et al.*, 1963).

According to McKell, Robison and Major (1962) medusahead was introduced into the U. S. from the Mediterranean region of Eurasia. Specifically, the plant in the western U. S. appears to have originated in the area from Hungary to Apulia in southern

Italy east through northern Greece to the Bosporus region on the south and in the northeast through coastal Rumania, the Ukraine, the Crimea, the Caucasus and the Pamir-Alai region of Turkestan.

Geographic Distribution

Medusahead was first collected in the U. S. near Roseburg, Oregon on June 24, 1887, by Thomas Howell. In 1901, it was recorded from Steptoe Butte in eastern Washington by G. R. Vassey (McKell *et al.*, 1962).

It is assumed that all medusahead in the United States at the present time came from one original introduction which was first collected at Roseburg, Oregon and later at Steptoe Butte, Washington.

According to McKell *et al.* (1962) medusahead is at present distributed widely over the semi-arid regions in southeastern Washington, northeastern Oregon and adjacent Idaho, north of the Snake River in southwestern Idaho, with areas of infestation in western Oregon in summer dry climates. It also occurs in California through the coast ranges and on either side of the Sacramento Valley.

Rapid spread of medusahead is reported in all the states where infestation occurs. Hironaka (1961) reported medusahead has spread, in about 15 years, from a few isolate patches to more than 750,000 acres in Idaho.

East of the Cascades, the presently known extent of infestation is approximately 500,000 acres. The history of medusahead is obscure for this region, but alarm has been expressed by many ranchers and range administrators over the high rate of spread evident in recent years (Turner *et al.*, 1963).

There is no reason to believe medusahead has reached its ecological limits. It competes successfully and overlaps both in area and in local habitat ecology with two other exotic, annual range invaders, namely *Bromus mollis* L. and *Bromus tectorum* L. If the requirements of medusahead completely overlap those of *Bromus tectorum* L. it could spread widely in the Great Basin, where it now has a start on the northern, low altitude fringe of this physiographic province (McKell *et al.*, 1962).

There are several factors which appear to favor the rapid spread of medusahead. First, medusahead is an annual with a high reproductive capacity. Second, medusahead does not have to find a niche in an almost closed community as do seedlings of most, perennial plants. Third, medusahead was introduced into a biological near-vacuum, a range vegetation which was depleted or was actively being destroyed. Medusahead had almost unlimited opportunities for increase. Fourth, whatever biotic factors keep it in check in its homeland do not appear to operate in the western states. The biotic factors include not only diseases, insects, other plants, but also biotypes of medusahead itself (McKell *et al.*, 1962).

Description of Medusahead

Turner *et al.* (1963) list the following characteristics for identifying medusahead:

1. Wiry, slender stems contain but few short, narrow leaves. The leaves dry and wither soon after mature size is reached, giving the plant an unusually heavy-headed appearance.

2. Two (occasionally three) spikelets, each containing one seed, are located at each node.

3. The plant has two kinds of flat awns. The longest awns arise from the tip of a 1/4-inch seed and are from two to four inches long. The shorter awns, 1/4 to one inch in length, arise below the seed at the nodes of the central axis of the spike and remain attached after the seed scatters. These short awns represent the two glumes of each spikelet which arise below each seed.

4. The rachis is continuous rather than jointed, allowing the spike and its short, empty glumes to remain intact after the seed shatters. In addition, these plants are slow to decompose and identification of heads from the previous year's growth permits recognition of patches of medusahead at any time of the year, including early spring before the new heads emerge from the young plant.

5. The seed and its awn contain barbs which point upward and can be easily felt by rubbing the fingers backward down the awn and over the seed.

6. The seed head is disproportionately large in relation to the slender stems.

Growth of Medusahead

Medusahead seeds have an after-ripening dormancy during the hot, dry summer, which prevent premature germination even with rains (Major, McKell and Berry, 1960). Germination occurs as moisture becomes available from fall rains (Sharp, Hironaka and Tisdale, 1957). Young *et al.* (1968) investigating medusahead germination in relation to osmotic pressure; found that percent germination was lowered by increased levels of osmotic stress. The greatest percentage reduction in germination occurred between six and eight bars of tension. Other annual-grass species tested, except *Bromus tectorum* L., exceeded medusahead in germination at the higher osmotic stresses.

After seedlings are established, growth slows down markedly as temperatures become cooler during the winter. According to Brown (1966) medusahead must be exposed to periods of cold temperature if it is to complete its life cycle. This requirement can be met when the plant is in a very early stage of growth. Light does not appear to be involved in the floral induction of medusahead.

By spring, plants may be only a few inches tall and consist of a couple of thin leaves from slender sheaths. When most associated annual plants approach maturity and form seed, medusahead starts to send up a seed head and is still green. The earlier-maturing plants might be expected to dominate medusahead and suppress it by competition. They do not do so because medusahead is able to use moisture from late spring rains and moisture left in the soil after the associated plants have matured (Major et al. 1960).

Climate

According to Major (1959) medusahead grows where winter frost occurs but extended periods of great cold are lacking. Major *et al.* (1960) reported that the weed grows where annual precipitation is distributed over fall, winter and spring. There seems to be no upper limit on the precipitation where medusahead can grow, just so great amounts do not depress temperature too much. Medusahead can get along with 11 inches of precipitation in a cool climate such as in Idaho and 50 inches is not excessive if sufficiently unfavorably distributed and in a hot enough climate (Major, 1959).

In Oregon, medusahead has been observed growing within a mean annual precipitation range from a minimum of 11 inches to an upper limit of 40 inches (Turner *et al.*, 1963).

Root Development

Root development in medusahead may help explain how medusahead is able to compete successfully with other annuals and newly established perennial grasses.

Hironaka (1961) in studying the rate of root development of downy brome (_Bromus tectorum_ L.) and medusahead reports that: there is no significant difference in root length between the two species during any period of growth. 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.

The maximum depth of medusahead roots measured by Hironaka was 40 inches. Vertical development of the primary root was conspicuous during the winter, followed by much lateral development in the spring.

Harris (1967) in studying the rate of root development of downy brome and _Agropyron spicatum_ (Pursh) Scribr.-Smith, reports that: once seeds of downy brome and _Agropyron spicatum_ have germinated, downy brome has a distinct advantage in rate of root elongation. Downy brome roots grow to a greater depth due to their more rapid elongation immediately after germination. A possible explanation for the rapid elongation rate of downy brome roots may be found in their cell structure. Not only are these roots smaller in diameter, but the cells have only a small thickness of that observed in _Agropyron spicatum_.

Turner _et al._ (1963) state that in dense stands of medusahead growing on Oregon soils, roots are commonly abundant down to and below 30 inches, where soils are of such depths. In shallow or more stony soils, roots are abundant nearer the surface or concentrated in stoney pockets.

Seed Production and Viability

Medusahead being an annual is entirely dependent on seed production for each year's propagation. According to Murphy and Turner (1959) scattered plants will generally produce six or more seedheads per plant where in a dense stand one head per plant is the rule. Sharp, Tisdale and Hironaka (1957) noted 1,500 plants per square foot on valley bottom soils, and 500 per square foot on uplands. The average number of seeds per head for these two sites was 8.7 to 5.6, respectively.

Both seed production and germination of medusahead is high. Sharp et al. (1957) obtained fairly high germination percentages (74 to 78%) from seed samples collected while there was still a greenish appearance to the heads. The seed at this time was in mid-dough stage of maturity. At the late-dough stage germination percentages were more than 90 percent.

Hironaka and Tisdale (1957) showed that medusahead seed still retain their viability even after two years of burial in soil under field conditions. Sharp et al. (1957) noted that the amount of viable seed of medusahead carried over was related directly to the amount of medusahead litter. Accumulation of three to four inches of medusahead litter is not uncommon.

Seed Distribution

Medusahead seed is long-awned and can be carried for great distances by man, machinery, and animals. Seed can be transported in the coat or fleece of animals and also in the digestive tract. The ease with which the seeds can be transported poses a threat to additional acres (Sharp *et al*. 1957).

Type of Soil

Medusahead grows in a great variety of soils. In California, medusahead occurs in greatest abundance on dry-land soils that have a higher than average moisture capacity to a depth of a foot or more. It seldom grows on light-textured soils or sandy areas (Major *et al*., 1960). Sharp *et al*. (1957) indicate that medusahead grows in Idaho on a variety of soil types such as those high in clay content, well-developed loams and scabland. Growth occurs on soils of widely variable depth, subsoil characteristics, and profile development (Torell *et al*., 1961). Major *et al*. (1960) state that medusahead occurs mostly on soils low in fertility.

Turner *et al*. (1963) observed medusahead growing in Oregon on clay loams, and heavy clays which have a high water-holding capacity. These vary considerably in depth and some are exceedingly stony.

Medusahead Palatability

The low forage value of medusahead may be due to its chemical composition. Bovey et al. (1961) found that the moisture, crude protein, crude fat, crude fibre, and lignin contents of medusahead were comparable to that of downy brome and many other grasses. The ash of medusahead contained silica amounting to over 10 percent of the dry weight of the plant, as compared to only 4.4 percent in downy brome. The high silica content may be the possible explanation for the low palatability of medusahead to livestock and its slow rate of decomposition.

In an effort to increase medusahead palatability Lusk et al. (1961) applied 60 pounds of nitrogen and 75 pounds of phosphorus per acre. Fertilization increased consumption and quality of medusahead. According to Brown (1966) the application of nitrogen produced a decrease in the percent silica in the foliage of medusahead. The combination of reduced silica and increased crude protein, due to nitrogen application, may account for animal preference for the fertilized forage of medusahead.

Medusahead Impact on Range Economy

Bovey et al. (1961) indicate that in a decade medusahead has changed from a minor problem to one of major concern to the range livestock industry. This problem is three-fold: first, medusahead suppresses desirable vegetation due to its competitive ability; second, it is unpalatable to livestock at all stages of growth; and third, the dead vegetation decomposes slowly, thereby forming a persisting mulch layer on the surface which adds greatly to the fire hazard. In addition as the plant matures it develops long barbed awns which cause mechanical damage to the eye, nose, and mouth of grazing animals. The undecomposed litter adds greatly to the fire hazard on infested ranges.

Torell et al. (1961) state that the economic losses from medusahead due to forage losses in southwestern Idaho amounts to \$3,500,000 per year. Furthermore they state that if medusahead were to occupy the areas of downy brome range, the full impact would be reckoned in terms of the loss of spring and fall range use. The elimination of these seasons of range use would be catastrophic to range livestock operation as they are now practiced in Idaho.

Subterranean Clover

Subterranean clover (*Trifolium subterraneum* L.) has a short history as a cultivated plant. Its use in sown pastures began scarcely more than 60 years ago in the "Mediterranean" zone of southern Australia (Symon, 1961). It has become the most important pasture legume of the temperate region of southern and eastern Australia. In its native habitat, it received no recognition in agriculture, and its rise to first place as a pasture legume, over a wide area of Australia must be regarded as one of the outstanding examples of new plant utilization of this century (Subterranean clover, 1951).

The original habitat of subterranean clover is largely but not wholly Mediterranean in its distribution. The species is naturally distributed from the Azores and Canary Islands through North Africa, southern and middle Europe and the Mediterranean basin generally to the Balkans, the seaboard of Asia Minor and through the Caucasus to the Caspian Sea and northern Iraq. Its northerly limit is in southern and eastern Great Britain (Symon, 1961).

A combination of winter rainfall and summer drought with good spring-growing conditions is most favorable to growth, and subterranean clover has made most progress in areas where these conditions prevail. In areas of summer rainfall and winter drought the species has not been successfully grown. In the zone of good uniform rainfall, where summer as well as winter rains occur the species grows best on those soils which dry out in summer and which fail to support a full sward of perennial plants (Subterranean clover, 1951).

Subterranean clover was first planted in Oregon in 1922 at the Agricultural Experiment Station at Corvallis with seed supplied by the Division of Forage Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture. Subclover did not attract widespread attention in Oregon until 1937 when new Australian strains were tested. Since that time, its use for forage in pastures has increased rapidly in western Oregon (Rampton, 1945); until thousands of acres have been established and are now being maintained especially in Douglas County.

Description of the Plant

Subterranean clover is an annual species. It germinates from selfsown seed with the coming of autumn rains in late September or October, or may germinate later, lives through winter, grows vigorously in the spring, matures seeds and then dies before midsummer. The young plant usually attains a height of about one inch in the rosette stage in western Oregon and at this time consists of leaves and very short prostrate stems. With the coming of warm weather in March the growth of the plant proceeds rapidly, and by May prostrate branches on runners are thrown out, sometimes three to three and one-half feet long. It blooms in April and May and dies in June (Leidigh, 1925).

The subterranean clover plant is somewhat hairy; with prostrate, slightly thickened stems. The leaves are born on long, erect, slender stems above prostrate runners. There are three leaflets on each leaf stalk. The leaf is usually one to one and one-half inches across. The flower clusters are borne on short stalks originating from axils of the leaf stalks. There are usually four flowers in each cluster, but sometimes three or five. These are of a yellowish-white or an ivory-white color with a pink tinge. As the seeds develop, a head is formed, made up of a group of forked hairs equally spaced around the center at the end of the flower stalk and outside of the seed. The hairs of the head soon become thickened and tough, with sub-branches, and may be called bristles. The direction of slope of these bristiles from their point of attachment to the stem is such as to give a blunt pointed mass of turned-back bristles surrounding the seed pods. This is called the seed head. The head has an anchoring or holding function and serves not only to surround the seeds, but to retain them in the soil. There is one seed in a pod and usually three to five pods in a head. The pod is a soft tissue or fibrous covering about the seed, protected by the bristles. The ripening seed-heads tend to point downward, and many of these bury themselves in the earth by what is evidently a "pegging" action. Thus, many of the seed-heads are buried in the soil, and even with the removal of the dead growth when the plant ripens these heads remain in the soil, being held by the bristles and their forked structure. The seeds of subterranean clover are a brilliant dark purple in color, 1.5 to 2.5 millimeters long, two to three millimeters wide, and about 1.75 millimeters thick. The radicle is large and the appearance of the seed is round (Leidigh, 1925).

Soil Requirements

The soil requirements of subterranean clover have been described by officers of the Pasture Branch, Department of Agriculture, Victoria. Subterranean clover is adapted to a wide range of soils, and its continued use improves their fertility (Subterranean clover, 1951).

On sandy soils it makes quick germination and growth after favorable autumn rains, and can provide feed relatively early and well into the winter. The spring flush is very rapid, but it may be cut short by a dry spell, in which case the yield is severely reduced, and the seed becomes badly pinched, making the dry crop less nutritious. In sandy soils the plant easily buries its burrs, and, as rain penetrates such soils very readily, germination takes place quickly after the first autumn rains.

Loams are very suitable and are the most favorable soils. The plants buries its burrs freely, and, as rain percolates quickly into loamy ground, these soils allow establishment to take place rapidly after autumn rains, and growth is sustained well into winter. The crop is not so sensitive to temporary dry spells in spring as it is on sandy soils, and it usually makes heavy growth and fully matures.

Growth of subterranean clover on clay loams and clays is much slower. Owing to the physical characteristics of such soils, the burrs may not be buried, especially in a dry spring when the soil is hard, with the result that germination is slow in the following autumn and growth is delayed. If the burrs are lying on the surface, it often requires a fairly long period of cool moist weather to cause the seed to germinate. Therefore, on such soils, germination may not occur until late autumn, with the result that the plants remain closely appressed to the ground during the winter. They commence rapid growth later in the spring, but may sustain it longer than on sandy or loamy soils.

The great value of subterranean clover lies as much in its ability to grow in soils of relatively low fertility, and improve or restore them, as in its capacity to produce an abundance of nutritious fodder.

Natural Reestablishment

The competitive ability of subterranean clover depends in a great measure on a high seed yield and dense population of seedlings

(Donald, 1960).

The specific name subterraneum reflects the tendency for the young seeds at an early stage of development to be pushed below the ground, where the protective burr develops and seed maturation takes place (Yates, 1957). Seed-setting is influenced strongly by the microenvironment of the inflorescences and developing burrs. Burr burial is apparently a protective mechanism against unfavorable factors, probably low relative humidity and high temperature, of the atmospheric environment (Yates, 1958).

In favorable environments subterranean clover shows a very high regenerative capacity and in an established pasture may give an autumn germination of several hundred pounds of seed per acre, compared to the seed rate at establishment of about 3-6 pounds per acre (Donald, 1959).

Donald (1959) found that on the average 92 percent of the seed crop germinated in the year following its production, with 6.3 percent in the second year, 1.00 percent in the third, 0.52 percent in the fourth, and 0.07 percent in the fifth year. The "carry over" of seed into subsequent years is important since it enables the species to bridge a year of failure of seed production.

Hardseed and dormancy are two mechanisms which prevent the germination of subterranean clover seed, despite environmental conditions which favor the process (Donald, 1960). Aitken, quoted by Morley (1958) showed that intense hardseedness occur: a) where there are sustained environmental conditions favoring the full development and maturation of the seed; b) when the fully mature seed is strongly dehydrated by prolonged high temperature and low humidity; and c) when genotypic factors favour hardseededness.

Morley (1961) defines embryo dormancy as the inhibition of germination in viable, fully imbided seed. Loftus Hills (Morley, 1958) showed that dormancy may persist for as long as 12 months at 22^{o}C. He also showed that it is a relatively short-term phenomenon under field conditions.

The very high temperatures to which seeds are exposed at the soil surface leads to loss of dormancy in a few weeks or months. Thus, its main significance is as a mechanism which will prevent germination and subsequent death of seedlings when abnormal rains occur during the hot and arid summer. Even though these rains may lead to swelling or dormant seeds, the subsequent re-drying does not impair germination (Morley, 1958).

In tests with strains from the Mediterranean region, those from cool climates, showed greater dormancy than those from warm climates. A possible explanation of this is that summer rains are practically non-existent in the more arid part of the Mediterranean area, so that dormancy may not be as necessary in such region (Morley, 1958).

Weed Control

Subterranean clover has been observed to control undesirable weeds (Williams, Love and Berry, 1957). When used to control medusahead recommended steps are: (1) plowing or discing the sod before seed formation; (2) plant nutrients as needed should be applied just prior to (3) fall seeding of subclover; (4) the newly seeded area should be grazed heavily for a short period in the early spring while any new medusahead is in the young leaf stage (Williams *et al.*, 1957).

The ecological control of weeds by subterranean clover pastures is probably dependent on the fact that some weeds, such as medusahead, of pastures and range are able to compete, under conditions of depleted fertility, more aggressively than species adapted to high levels of fertility, such as perennial rye grasses, *Lolium* spp. In Douglas County perennial ryegrasses and other annual grasses are favored by subterranean clover and medusahead is eliminated from the sward naturally, through increased competition.

Nutritive Value

Subterranean clover provides an abundance of nutritious feed during the spring season and good dry feed during the summer and fall (Williams *et al.*, 1957).

Subterranean clover supplies its own nitrogen from the air in the presence of the proper legume bacteria. This is particularly desirable since most range soils do not contain enough nitrogen for abundant forage production. The nitrogen obtained from the air not only makes the clover productive but increases its protein content. It also improves the amount and quality of feed produced by other plants growing with them (Williams et al., 1957).

The chemical composition of subterranean clover at different stages of growth was determined by the Waite Agricultural Research Institute of South Australia (Subterranean clover, 1951). They are presented in the following tables.

Table 1. Nitrogen content and equivalent crude protein content at five different stages of growth in subterranean clover.

Stage of Growth	Nitrogen %	Equivalent Crude Protein %
Early tillering	4.74	29.6
Advanced tillering	4.26	26.6
Flowering	3.69	23.0
Seed setting	2.82	17.6
Maturity	2.50	15.6

It is not known what proportion of the crude protein is digestible, but it is higher in the succulent early stages than in the later more fibrous stages of growth. Subterranean clover has an extremely high protein content at the time of tillering and still retains about one-half of this amount at maturity.

Table 2. Phosphate and lime content of subterranean clover at various stages of growth.

Stage of Growth	Phosphate (P_2O_5) %	Lime (Ca_0) %
Early tillering	0.71	2.30
Advance tillering	0.70	2.60
Flowering	0.50	2.17
Seed setting	0.42	2.32
Maturity	0.39	2.31

The lime content is evidently maintained at a more or less constant level throughout the life of the plant, but the change in phosphate is similar to that for protein. The ratio of lime to phosphorus is regarded as higher than that needed by stock.

Establishment

According to Parish and Dillon (Morley, 1961) about 30 to 50 percent of the sown areas in Australia have been established by broadcast seeding. The chances of successful establishment are increased if subterranean clover is sown into prepared seed beds. Jackson and Mosher (1959) established subclover successfully by the following steps:

(1) Removing competition

(2) Proper seeding, seedbed preparation

(3) Fertilizers

(4) Grazing to remove grass competition

Rampton (1945) states that subterranean clover is adapted to early fall planting. Seeding in September and not later than mid-October is recommended. Early seedings will make maximum use of the season's moisture. Midwinter seedings have a chance of being moderately successful only during mild winters. In winters when frost heaving is a problem the early planted clovers with vigorous root systems are better able to withstand the strains developed by alternate freezing and thawing of the surface soil (Williams et al., 1957).

Subterranean clover may be established by broadcast seeding but a better method is drilling. The seeds should be drilled shallow and the discs or hoes of the drill should not penetrate to a greater depth than is necessary to cover the seed. Under these circumstances the clover seed has no difficulty in developing a hypocotyl capable of reaching the surface (Hudson, 1935).

Fertilization

The success of subterranean clover as a pasture plant and range forage depends on the provision of adequate nutrients. Early in its history it was realized that phosphorus was essential for good growth and for establishment (Symon, 1961).

Two fertilizer elements that improve range legume growth most frequently are phosphorus and sulfur. Single superphosphate is a good remedy for these since it contains substantial amounts of both (18-21% P_2O_5 and 10-12% S).

For the majority of range soils, from 200 to 500 pounds of single superphosphate per acre will aid the establishment of range clovers. In areas where sulfur is the principal nutrient lacking, 200 to 400 pounds of gypsum per acre will satisfy the requirements (Williams et al., 1957).

Although superphosphate is the all-important fertilizer for subterranean clover other fertilizers are sometimes required for the successful growth of the clover.

Lime in excess is harmful to subterranean clover, but a certain amount is necessary, and excessively-acid soils do not grow subterranean clover satisfactorily unless lime is applied in addition to superphosphate (Subterranean clover, 1951).

In soils with a pH 4.7-4.9, two ounches of molybdenum trioxide applied with 2 cwt. of lime per acre had the same effect as 8 cwt. of lime applied alone in promoting nitrogen fixation of subterranean clover (Anderson and Moye, 1952).

Rampton (1945) states that in established pastures, subterranean clover requires refertilization to maintain high production of forage and seed. A recommendation for western Oregon is a yearly application of superphosphate (16 percent) at 200 to 300 pounds per acre, or gypsum and treble phosphate (45 percent) at 100 to 150 pounds of each per acre in early March. Seedling growth may be encouraged on phosphate deficient soils by applying the phosphate fertilizer in the fall. Lime applied at one to two tons per acre may be beneficial on acid soils. According to Williams *et al.* (1957) range clover in California should be refertilized every two or three years.

Nodulation

Effective nodulation of subterranean clover soon after emergence is of great importance if plants are to be established and satisfactorily maintained. Three major problems in nodulation are:

(1) Provision of adequate mineral nutrition for the host plant

(2) Reduction of soil acidity

(3) Slowing of the death rate of the bacteria due to desiccation and ultra-violet light.

Nodulation in the field is uncertain despite the use of bacterial strains which are known to be effective. Several factors may be responsible. Although subterranean clover will grow in soils of relatively low pH, a low pH will reduce the survival and multiplication of the bacteria applied in the inoculum. It is not uncommon to drill the inoculated seed with single or triple superphosphate which creates temporarily a zone of reduced pH in which the seed lies. Drilling inoculated seeds in close contact with triple superphosphate will temporarily produce a zone of high acidity which can restrict nodulation and so reduce production.

Radcliffe (1964) showed that in soils of pH 4.9 to 5.4 almost 100 percent nodulation could be obtained by broadcasting two tons of lime per acre over the seedbed prior to sowing with banded superphosphate. Also, sowing the inoculated seeds directly in contact with a previously prepared 1:1 mixture of lime and single superphosphate drilled at the rate of 600 to 800 pounds per acre was as satisfactory as drilling the seed after application of two or three tons of lime per acre.

Rhizobia have a rapid mortality when exposed to desiccation (Vincent, Thompson and Donovan, 1962). The usual method of inoculating seeds is to place a coating of rhizobia, usually suspended in a peat medium, around the seeds before planting. Dessication is a major hazard in many regions where it is necessary to broadcast seed onto the surface of the soil. Unless rainfall occurs within a few hours, the likelihood of satisfactory nodules being formed is reduced. The presence of small amounts of moisture and an adequate covering of soil over the seeds will greatly increase nodulation.

Lime and phosphorus are important in nodulation and establishment. Liming increases the availability of phosphorus in acid lateritic soils. The nitrogen economy of Australian soils has been linked with their phosphate status, and without phosphate, nitrogen is seldom fixed in appreciable amounts in the higher rainfall districts (Vincent *et al.*, 1962). Willoughby (1954) suggested that two conditions must be met in order to fully exploit nitrogen fixation. First, an associated grass should be grown to acquire and store nitrogen, thereby lowering the level of nitrogen in the soil and thus reducing the inhibition of further nitrogen fixation. Second, the nitrogen status under the sward should be periodically reduced either by a harvest of hay or grazing.

Chemical Seedbed Preparation

In improvement of forage stands, special attention to seed placement and seed-soil contact is essential if germination and emergence are to be successful. Certain herbicides have been found to accomplish seedbed preparation as well or better than tillage alone. Herbicides are faster and cheaper and have a place in better forage production if used wisely (Spraque *et al.*, 1962).

Davis and Jones (1964) classified the uses of herbicides in chemical seedbed preparation into three categories:

(1) Selective control of one or more species

(2) Temporary suppression of some species to allow an increase of others

(3) Control of all species as a pretreatment to sowing a seed mixture.

The successful establishment of sown species in a chemically killed turf depends on the time interval between spraying and sowing. The herbicidal activity on a pasture has been phased as follows:

(1) The period of direct action by the herbicide

(2) The toxic residue period

(3) The period when the herbicide no longer directly influences the sward.

Seed should be sown so as to germinate at the end of the second phase. Sowing earlier carries risk of damage from herbicide residue in the soil; sowing later risks strong competition from germinating and recovering plants (Davis and Jones, 1964).

Sprague *et al*. (1962) states that in chemical seedbed preparation seed placement is easier because a dead sod is more friable than a live one; and that underground portions of the dead plants shrink as they decay, leaving many open channels in the soil layer as aid to water and fertilizer penetrations.

Paraquat for Chemical Seedbed Preparation

The use of paraquat (1,1'-dimethyl-4,4'-bipyridinium bis (methyl-sulfate) for chemical seedbed preparation on range lands has been reported by Kay (1964, 1966) in California. Paraquat has been used extensively in England in chemical seedbed preparation for renewal of grasslands (Allen, 1967 and Douglas, Lewis and McIlvenny, 1965).

Kay (1966) in establishment work in California sprayed paraquat in bands of various widths ahead of the drill opener to determine if a narrow weed-free band would provide adequate weed control for seeding establishment. Bands of 5.5, 11, and 22 inches were tested, in many cases the narrow bands were as good as the wide bands for seeding establishment. This would represent a 75 percent saving in herbicides cost, in all cases the 11 inch coverage gave satisfactory results. The unsprayed band represents a saving in forage and an excellent protection against erosion.

Douglas *et al.* (1965) used paraquat at two pounds per acre to kill weed infested swards and establish new seedlings. They state that paraquat is a particularly attractive compound for grassland improvement; it offers a rapid kill, lacks residual activity in the soil and gives consistent results under variable weather conditions.

The use of paraquat in the improvement of hill grazing can be considered from two aspects. First, there is the role of paraquat as a complete sward killer for the elimination of the old vegetation before sowing with grass and clover seed. Second, there is a slower approach, using paraquat at low doses in an attempt to alter the equilibrium of the indigenous grasses in favor of the most desirable species. This technique will require a critical approach, as the differential responses exhibited by the grass species will be conditioned by such factors as rate of application and stage of plant growth (Douglas *et al.*, 1965).

Properties of Paraquat

Paraquat, a heterocyclic organic herbicide, is a member of a much larger group of organic compounds, commonly referred to as dipyridylium (or bipyridylium) quaternary ammonium salts.

The most important properties of paraquat are as follows (Ortho Technical Information):

Stability: Paraquat is stable in aqueous, acid or neutral solutions.

Solubility: Paraquat is completely soluble in water, slightly soluble in alcohol; and insoluble in most organic solvents.

Volatility: Nonvolatile

Absorption: Paraquat is very rapidly absorbed by the sprayed plant. The rapid uptake by foliages minimizes the effect of rainfall soon after application.

Adsorbed: Paraquat is rapidly adsorbed by the soil and has no residual activity in soil at recommended rates.

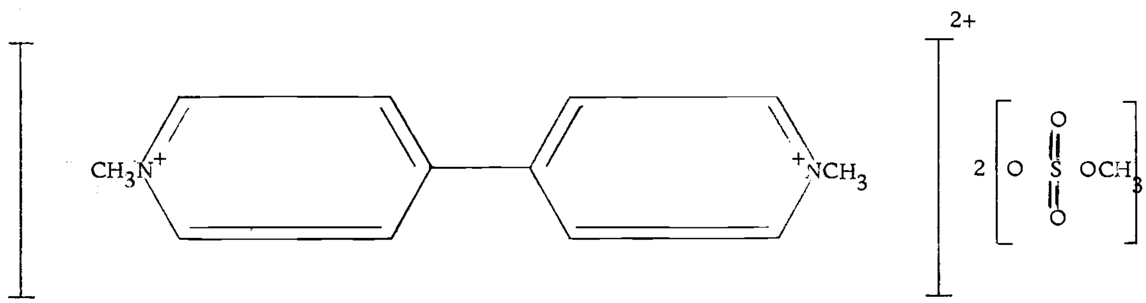

Figure 1. Chemical Composition of Paraquat: 1,1'-dimethyl-4,4'-bipyridinium bis (methyl sulfate).

Mode of Action of Paraquat

Several modes of action have been theorized for the herbicide paraquat. Two possible modes of action are presented by Boon (1965): First, paraquat, in the plant, is reduced to a free radical followed by reoxidation. This can be considered as shunting the energy generated in the primary stages of photosynthesis away from the production of end products; paraquat diverts the electron transport chain. Secondly: the free radical on reoxidation by molecular oxygen could be expected to lead to the formation of peroxide radicals or hydrogen peroxide by a series of chain reactions.

Calderbank (1964) explained the mode of action of paraquat as being dependent upon its reduction in plants to relatively stable, water soluble free radicals. The energy for the reduction may come from the primary photosynthetic process and to a lesser extent from respiration. Reduction to the free radical is freely reversible and it is believed that re-oxidation by molecular oxygen of the radicals results in the formation of peroxide radicals, or accumulation of hydrogen peroxide which destroys the plant cell.

A factor responsible for high activity seems to be that the molecules must be flat or be capable of assuming a planer configuration. Further requirements are the reduction of paraquat to a relatively stable, water soluble free radical formed by the addition of one electron to the diquaternary salt. The free radical formed contains an odd electron and this electron can occupy any of the nuclear carbon positions.

It is this delocalization of the odd electron over the whole structure which endows stability to the free radical, which being still a quaternary salt, is water soluble (Calderbank, 1964).

Black and Myers (1966) have proposed a theory on the mode of action of paraquat (Figure 2).

Photosynthesis is considered as involving two light reactions. The net result of this combination of two light reactions is the evolution of oxygen and the production of adenosine triphosphate (ATP) and reduced triphospopyridine nucleotide (TPNH). The ATP and TPNH subsequently may be utilized for the reduction of CO_2 (Black and Myers, 1966).

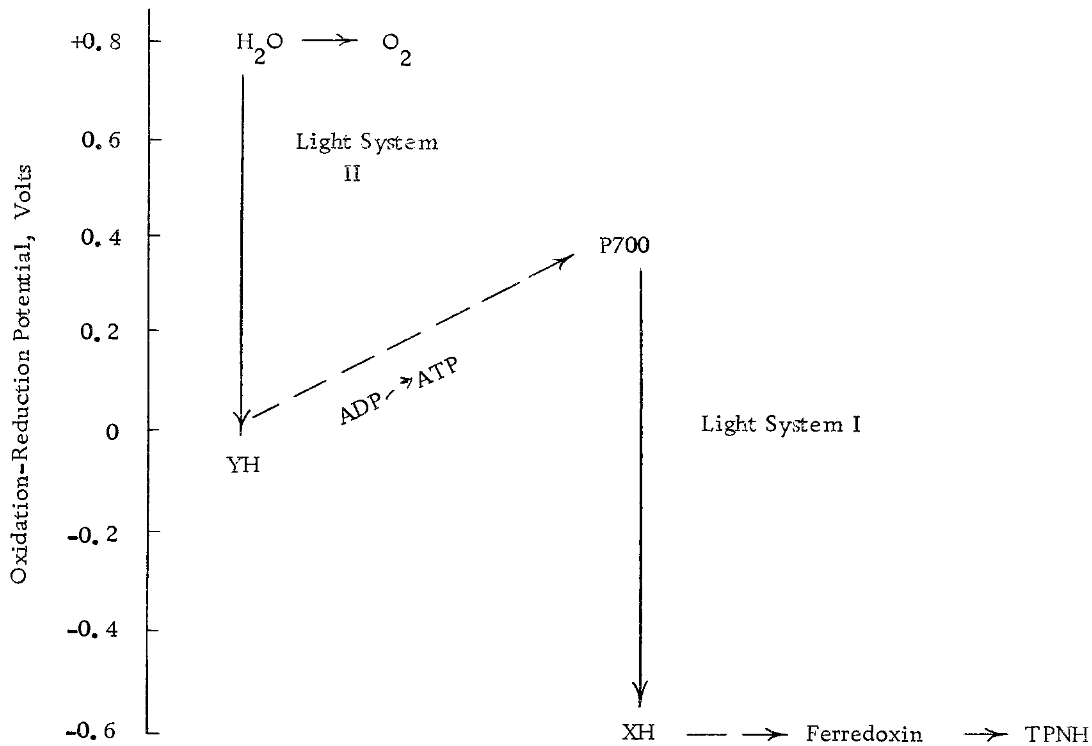

Figure 2. A Generalized Scheme for Photosynthesis Considered as Two Light Reactions (Black and Myers, 1966).

Paraquat seems to be active in light system 1. Oxidized paraquat can accept electrons from several sources, either from a reduced pyridine nucleotide or an electron produced during photosynthesis. Upon reduction, paraquat is quickly oxidized in the presence of oxygen to produce hydrogen peroxide.

A general scheme for the mechanism of the action of quaternary dipyridyls is given below.

$$\begin{array}{c}\text{Reducing}\\\text{Potential}\end{array} \xrightarrow{\bar{e}} \begin{array}{c}\text{Dipyridyl}\\\text{Reduced}\end{array} \xrightarrow{+O_2} H_2O_2 + \begin{array}{c}\text{Dipyridyl}\\\text{Oxidized}\end{array}$$

The reducing potential could arise from reduced pyridine nucleotides and/or photosynthesis. By this mechanism, plants lose a major energy supply, reduced pyridine nucleotides. The mechanism can account for toxicity both in light and darkness. Previous hypotheses based on the formation of a light-dependent free radical failed to account for the dark toxicity of the quaternary dipyridyl herbicides (Black and Myers, 1966).

Movement in Plants

Slade and Bell (1966) studied the uptake and movement of paraquat in plants. They found that paraquat moves in the xylem with the transpiration stream. The chemical is as well transported from young leaves as from mature ones.

When paraquat is applied during the day there is a general movement of the chemical through the treated plant, including some movement into the roots, with no apparent concentration in specific regions.

It is beleived that paraquat moves in the plant in the xylem with water which is pulled out of the cells in the paraquat--damaged tissue by the transpiration stream (Slade and Bell, 1966). A period of darkness after application increases uptake of paraquat; this shows that absorption takes place through the cuticle (Brian, 1967).

Adsorption and Degradation

Brian (1967) states that paraquat is strongly and rapidly adsorbed to leaf surfaces; adsorption is extremely rapid even from dilute solutions. Paraquat was shown to be adsorbed to leaf surface within 30 seconds of treatment.

Calderbank and Slade (1966) report that the maximum loss of paraquat takes place when the chemical remained largely on the surfaces of treated leaves, especially in sunlight, while minimum loss occurred when most of it was translocated away from the points of application. Under conditions of low light intensity, or in darkness, no degradation was observed. Degradation was photochemical, by ultraviolet rays, and no degradation by plant metabolism took place.

MATERIALS AND METHODS

Description of Experiment Area

The experiments were conducted on the hill pasture of Oregon State University, near Corvallis, Oregon. The area is similar to much of the hill pastures along the edge of the Willamette Valley. The vegetation is quite variable and represents a seral stage of succession. Medusahead and other annual grasses dominate the site. California oatgrass (*Danthonia californica*) was present throughout the study area; a few, small "seepy" micro-habitats contained *Carex* spp. and other more mesic species. The vigor of oatgrass was notably reduced, apparently from competition of the annual grasses and grazing. Detailed descriptions of the climate, soils and vegetation are described by Turner (1969).

The study area had received different treatments for medusahead control from 1963 to 1965. These treatments were:

(1) early mowed

(2) early-late mowed

(3) early grazed

(4) early-late grazed

(5) late grazed

(6) control

These treatments affected medusahead and California oat grass density and dominance in different ways. The early-late mowed treatment reduced the medusahead and increased California oat grass considerably. The grazed treatments did not affect medusahead, resulting in density similar to the control (Turner, 1967).

Each treatment was contained in a paddock having an area of 80' x 27.5', and running in a south to north direction. The early mowed and early-late mowed treatments were arranged in a split plot, each half plot having an area of 80' x 13.7'. The treatments were replicated in three blocks.

Turner (1967) found that block two was an ecotone between block one and three, it has areas which are like block one and three.

Experimental Methods

The primary objective of this study was to compare the establishment of subterranean clover on a medusahead and California oat grass range. The following treatments for establishing subterranean clover were randomly allotted in block one and three:

(1) Control, no seeding

(2) Seeding directly into the sod

(3) Chemical seedbed preparation and seeding into the sod

(4) Seeding into the sod, followed by grazing

Secondary objectives were how management treatments effected (a) subterranean clover density (b) density of vegetation and medusahead and (c) yield of subterranean clover.

Procedure

Each block was divided into plots of 20' x 136'. The treatments were then randomly located. The inside fences from the old study were taken down and new fences were made on the sheep grazing plots. The new plots ran in an east-west direction with each plot traversing a portion of the older treatments.

Paraquat treated plots were also split into two plots of 10' x 135'. One side was mowed and the litter was removed before applying the chemical. The chemical was sprayed directly on the litter on the unmowed side. The herbicide was applied, October 3, 1966, at the rate of 1/2 pound per acre when medusahead was in the second leaf stage. A surfactant X77, was added to paraquat at the rate of .5 percent by volume. Spraying was done with an experimental plot sprayer, bicycle-type, with a ten-foot boom. The volume of water used was equivalent to 35 gallons per acre.

The area was seeded on October 5, two days after the paraquat was applied. Subterranean clover, Mt. Barker variety, was seeded with an experimental sod-seeder, with Planter Junior seed boxes, into 18-inch rows at the rate of six pounds of inoculated seed per acre.

Inoculation was accomplished by wetting the seeds with sugarwater, adding the commercial inoculum, and mixing thoroughly by hand. All plots except the control were seeded with subterranean clover. Depth of seeding varied with the slope of the area but in no case exceeded one inch. One-half of the control was left untreated and borated superphosphate fertilizer was broadcasted on the remaining area at the rate of 300 pounds per acre.

On October 6, 1967, the grazing and mechanical treated plots were split in two and broadcast-seeded with subterranean clover at a rate of 18 pounds per acre on one side. The chemical treated plot was divided again into a ten-foot strip, five feet being on the mowed and five feet in the unmowed section, and broadcasted-seeded at a rate of 18 pounds per acre. The experimental design, along with the different old and new treatments are shown in Figure 3-4. Broadcast seeding was included to evaluate different seeding methods--sod plus broadcast vs. sod seeded only--on the establishment of subterranean clover and to evaluate the effects of sheep trampling on the establishment of subterranean clover. Five sheep were placed on each grazing treatment on October 20, 1966, and left to graze until October 25, 1966. During this time most of the medusahead and other vegetation was grazed close to the ground.

On January 28, 1967, sodium molybdate was sprayed on all seeded plots at a 1-pound per acre rate with an experimental plot sprayer, bicycle-type, with a ten-foot boom. The volume of water used was equivalent to 40 gallons per acre.

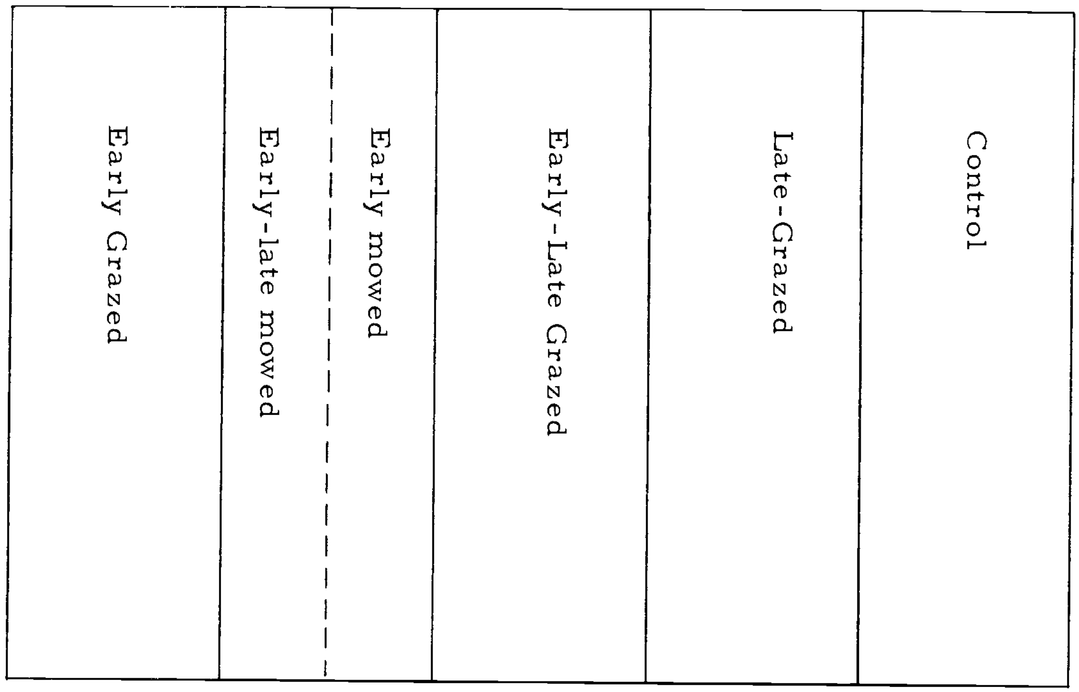

Figure 3. A Plan Showing Treatments for Medusahead Control 1963-1965.

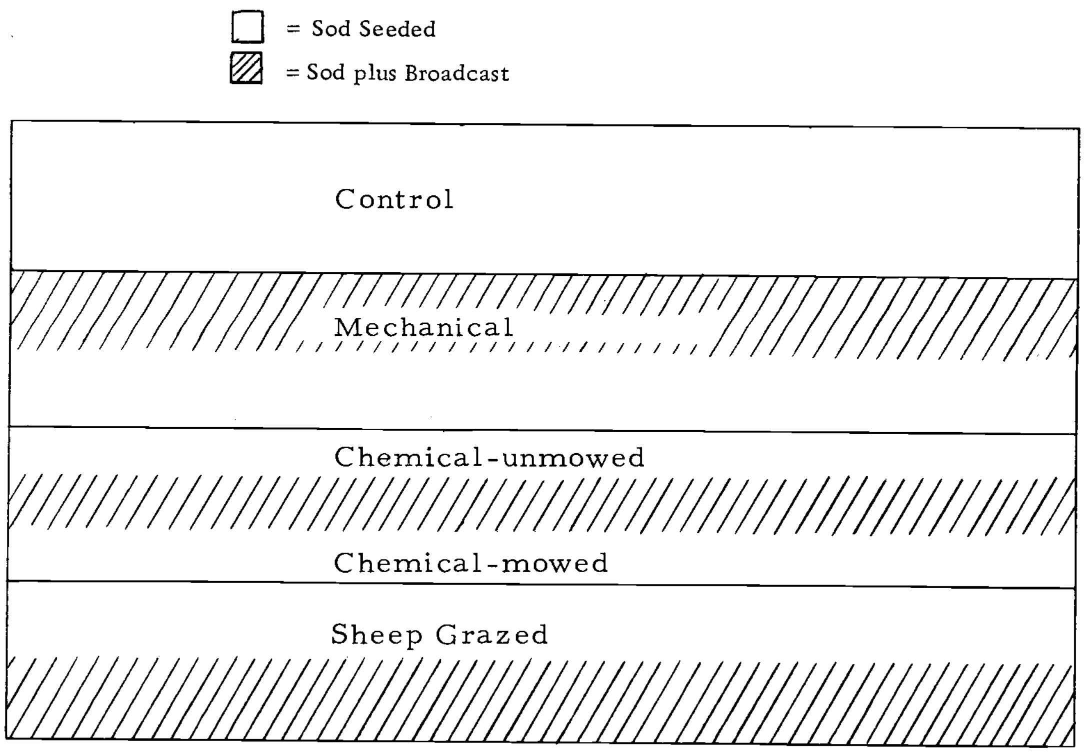

Figure 4. A Plan Showing Treatments for Establishing Subterranean Clover 1966.

Analysis of Soil

A representative sample of soil was obtained and sent to the Soils Department at Oregon State University for chemical analysis. The results ofthis analysis are shown in Appendix Table 1.

Climatic Data

Temperature and precipitation for the experimental period are summarized in Appendix Table 2.

Location of Line Transects

A randomly located but permanently marked line transect was established in each of the old treatments running north and south to traverse at right angles each new treatment.

Sampling

Sampling was done on the pre-determined line transects, these line transects were broken down into units of ten feet so that each new treatment was recorded as a separate unit in the overall sample. Total length of each line was 80 feet and three permanent points were established at 0.0, 40.0, and 80.0 feet, to expedite relocation.

One-square-foot observations were located by reading the line transects at four feet intervals, starting at 1, 5, 9, 13, ---, 77 feet. Those observations taken at 9, 29, 49, and 69 feet were in an area having sod seeded and sod seeded and sod plus broadcast seeding treatments. These were discarded thus leaving two observations per ten feet of new management treatments. The 1-ft^2 frame plot was subdivided into quarters. One-quarter was farther subdivided into quarters so that a total of 16 observations could be made in 1-ft^2 or 32 observations per treatment.

Data taken on each 1-ft^2 consisted of counts on subterranean clover per 1/16-ft^2, estimates of other vegetation density per 1/16-ft^2, and density of medusahead on four out of the 16 observations. Density ratings, based on the number of plants growing in each 1/16-ft^2, were as follows: 0 density rating = 0 plants, 1 density rating = 1-10 plants, 2 density rating = 11-50 plants, 3 density rating = 51-250 plants, 4 density rating = 251-500 plants.

Samples were taken on the two replications on December 22-26, 1966; March 19-23, 1967; and May 29-June 1, 1967. In addition block number 3 was sampled every two weeks, from the date of the first sample in December, in order to follow the fate of subterranean clover during the winter and spring growing season.

Clipping of Vegetation

Yield data were taken on the area from June 2-17, 1967. Four plots, each 2.4 square feet in area were harvested by hand in each treatment. These four plots were randomly located along seeded drill rows, clipped at ground level, separated into subterranean clover and other vegetation in the field, placed in paper bags, and dried for 24 hours at 180^{o}F. The dry weight in grams of subterranean clover and other vegetation was multiplied by ten to express the weight directly in pounds per acre (Brown, 1954).

Experimental Design

The experimental design consisted of a split-split-split block design with two replications, two seeding methods, six old and four new management treatments.

The treatments were as follows: two seeding methods (sod seeded only and sod plus broadcast seeded); six old management treatments (late grazed, early grazed, early-late grazed, early mowed, early-late mowed, and control); and four new treatments (chemical, sheep grazed, mechanical seeding, and control).

Data were analyzed according to requirements for a split-split-split block design. Duncan's Multiple Range Test was applied where applicable to locate significant differences. On all data tables lower case letters following compared means are the results of the multiple range test. Any two means not followed by the same letter are significantly different at the five percent probability level.

RESULTS AND DISCUSSION

Sampling data taken from December 1966 through January 1967 are presented in Tables 3-25. The primary objective of this sampling was to determine the effect of treatments on: (1) establishment of subterranean clover; (2) density of vegetation, and (3) density of medusahead.

Number of Subterranean Clover Plants

The statistical analysis for number of subterranean clover for December 1966 (Tables 3-4) shows a significant difference between sod seeded only and sod plus broadcast seeded. There are also significant differences between new treatments and between seeding methods and new treatments.

The statistical analysis for density of subterranean clover for March 1967 (Table 5-6), shows significant differences between sod seeded only and sod seeded plus broadcast seeded. There is also a significant interaction between the new treatments and seeding methods in both the December and June sampling.

The germination and fate of subterranean clover plants could be followed by observing plant density obtained throughout the growing season (Figure 5-10).

There was a high germination rate early in the season (Figure

Table 3. Analysis of variance. Subterranean clover density per 1-ft^2, December 1966.

Source of variation	SS	df	M. S.	F
Replications	88. 88	1	88. 88	24. 89
Seeding methods	12, 587. 55	1	12, 587. 55	3525. 9**
S. M. x R. (error A)	357	1	3. 57	
Old treatments	803. 83	5	160. 76	. 81
O. T. x R. (error B)	992. 95	5	198. 59	
O. T. x S. M.	1, 105. 28	5	221. 05	1. 86
O. T. x S. M. x R. (error C)	1, 045. 94	5	209. 19	
New treatments	3, 879. 75	2	1, 939. 87	50. 25*
N. T. x R. (error D)	77. 20	2	38. 60	
N. T. x S. M.	5, 105. 53	2	2, 552. 76	25. 29*
N. T. x S. M. x R. (error E)	201. 85	2	100. 92	
N. T. x O. T.	2, 269. 92	10	226. 99	2. 25
N. T. x O. T. x R. (error F)	1, 007. 47	10	100. 75	
N. T. x O. T. x S. M.	1, 154. 14	10	115. 41	1. 24
N. T. x O. T. x S. M. x R. (error G)	934. 14	10	93. 41	
Total	31, 258. 0	71		

*Significant at the .05 level of probability.
**Significant at the .01 level of probability.

Table 4. Mean number of subterranean clover plants per 1 sq. ft., December 1966.

Treatment	Mean no. of clover plants per 1 sq. ft.	Chemical	Grazed	Mechanical
Method of Seeding				
Sod seeding	2. 63a	3. 3b	1. 3b	3. 2b
Sod plus broadcast	15. 86b	4. 7b	22. 0a	20. 7a
New treatments		4. 06b	11. 7a	12. 0a

5). This germination was especially great early in areas with sod plus broadcast seeding. In the new treatments, only the chemical treatment showed no significant difference between sod seeded only and sod plus broadcast seeded. In March (Figure 6) the number of plants in each treatment had not changed greatly from those recorded in December. In June (Figure 7) there was a significant difference in seeding methods for subterranean clover establishment. The added advantage of more seed in the sod plus broadcast treatment was apparent at the end of the growing season, especially in the mechanical treatment (Figure 8-10). A large number of plants in the drilled and broadcast areas died from March through June.

A lack of nodulation appeared to be the principle cause of mortality between March and June. A pH of 6.00 on the experiment area indicates soil acidity was not important. The most probable explanations for poor nodulation include: dessication of rhizobia prior to sowing (a 24 hour delay in broadcasting inoculated seed), drying after seeding because of poor coverage in some drill rows and on most broadcast plots, lack of available phosphorus at time of drilling and delay in sheep grazing until three weeks after broadcasting. A higher plant population, through March, in the live vegetation between drill rows of the sod seeded areas, suggest a possibility of broadcast seeding range lands which are too steep to sod seeded. The live vegetation may create a microclimate which is more

Table 5. Analysis of variance. Subterranean clover density per 1-ft^2, March 1967.

Source of variation	SS	df	M. S.	F
Replications	183.68	1	183.68	12.14
Seeding method	9,964.01	1	9,964.01	658.55**
S.M. x R. (error A)	15.13	1	15.13	
Old treatments	731.24	5	146.25	1.97
O.T. x R. (error B)	370.90	5	74.18	
O.T. x S.M.	943.54	5	188.71	1.59
O.T. x S.M. x R. (error C)	592.49	5	118.49	
New treatments	2,870.86	2	1,435.43	143.39**
N.T. x R. (error D)	20.03	2	10.01	
N.T. x S.M.	4,084.03	2	2,042.01	29.58*
N.T. x S.M. x R. (error E)	138.05	2	69.02	
N.T. x O.T.	1,143.14	10	114.31	.89
N.T. x O.T. x R. (error F)	1,289.64	10	128.96	
N.T. x O.T. x S.M.	581.17	10	58.12	.69
N.T. x O.T. x S.M. x R. (error G)	843.08	10	84.31	
Total	23,770.99	71		

*Significant at the .05 level of probability.
**Significant at the .01 level of probability.

Table 6. Mean number of subterranean clover plants per 1 sq. ft., March 1967.

Treatment	Mean no. of clover plants per 1 sq. ft.	Chemical	Grazed	Mechanical
Method of Seeding				
Sod seeding	2.21a	2.9a	1.1a	2.6a
Sod plus broadcast	14.0b	4.3a	20.2b	17.4b
New treatments		3.6b	10.6a	10.0a

Table 7. Analysis of variance. Subterranean clover density per 1-ft^2, June 1967.

Source of variation	SS	df	M. S.	F
Replication	45. 13	1	45. 13	1. 471
Seeding method	300. 13	1	300. 13	9. 785
S. M. x R. (error A)	30. 67	1	30. 67	
Old treatment	156. 80	5	31. 36	1. 13
O. T. x R. (error B)	138. 45	5	27. 69	
O. T. x S. M.	113. 78	5	22. 75	. 96
O. T. x S. M. x R. (error C)	118. 92	5	23. 78	
New treatment	102. 26	2	51. 13	1. 45
N. T. x R. (error D)	70. 57	2	35. 28	
N. T. x S. M.	88. 58	2	44. 29	20. 22*
N. T. x S. M. x R. (error E)	4. 38	2	2. 19	
N. T. x O. T.	131. 07	10	13. 11	1. 20
N. T. x O. T. x R. (error F)	109. 10	10	10. 91	
N. T. x O. T. x S. M.	134. 76	10	13. 48	. 71
N. T. x O. T. x S. M. x R. (error G)	189. 28	10	18. 93	
Total	1, 733. 88	71		

*Significant at the . 05 level of probability.
**Significant at the . 01 level of probability.

Table 8. Mean number of subterranean clover plants per 1 sq. ft., June 1967.

	Number of clover plants per 1 sq. ft.		
Treatment	Chemical	Grazed	Mechanical
Sod seeded	. 8c	. 8c	. 98c
Sod plus broadcast	1. 6bc	2. 7ab	4. 4a

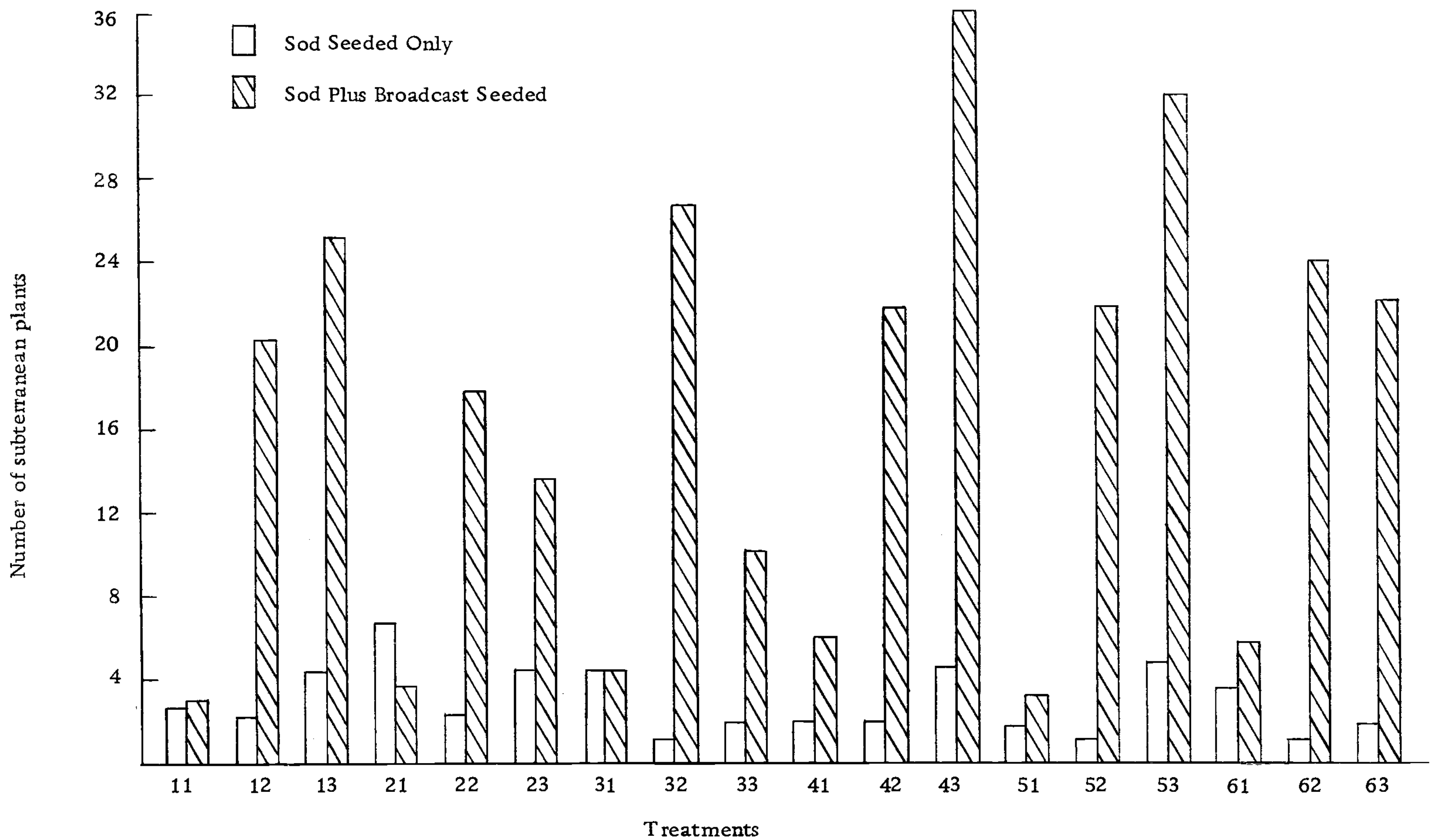

Figure 5. Mean Number of Subterranean Clover Plants Per Square Feet. December 1966. In numbering the old treatments are given first followed by new treatments.

Old Treatments

1 = Late grazed
2 = Early grazed
3 = Early-late grazed
4 = Early mowed
5 = Early-late grazed
6 = Control

New Treatments

1 = Chemical
2 = Grazed
3 = Mechanical

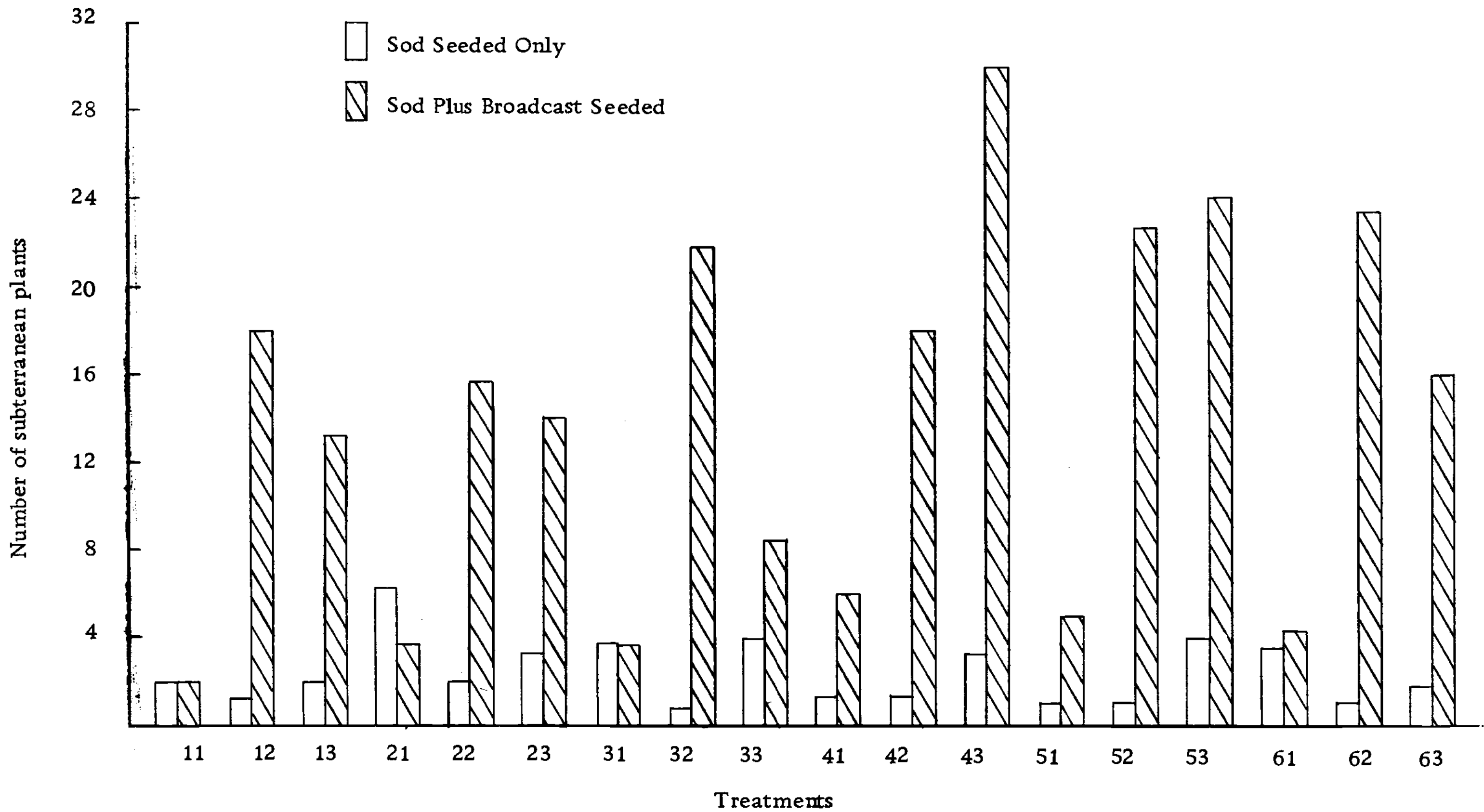

Figure 6. Mean Number of Subterranean Clover Plants Per Square Feet. March 1967. In treatment numbers the old treatments are given first followed by the new treatments.

Old Treatments		New Treatments
1 = Late grazed		1 = Chemical
2 = Early grazed		2 = Grazed
3 = Early-late grazed	6 = Control	3 = Mechanical
4 = Early mowed		
5 = Early-late mowed		

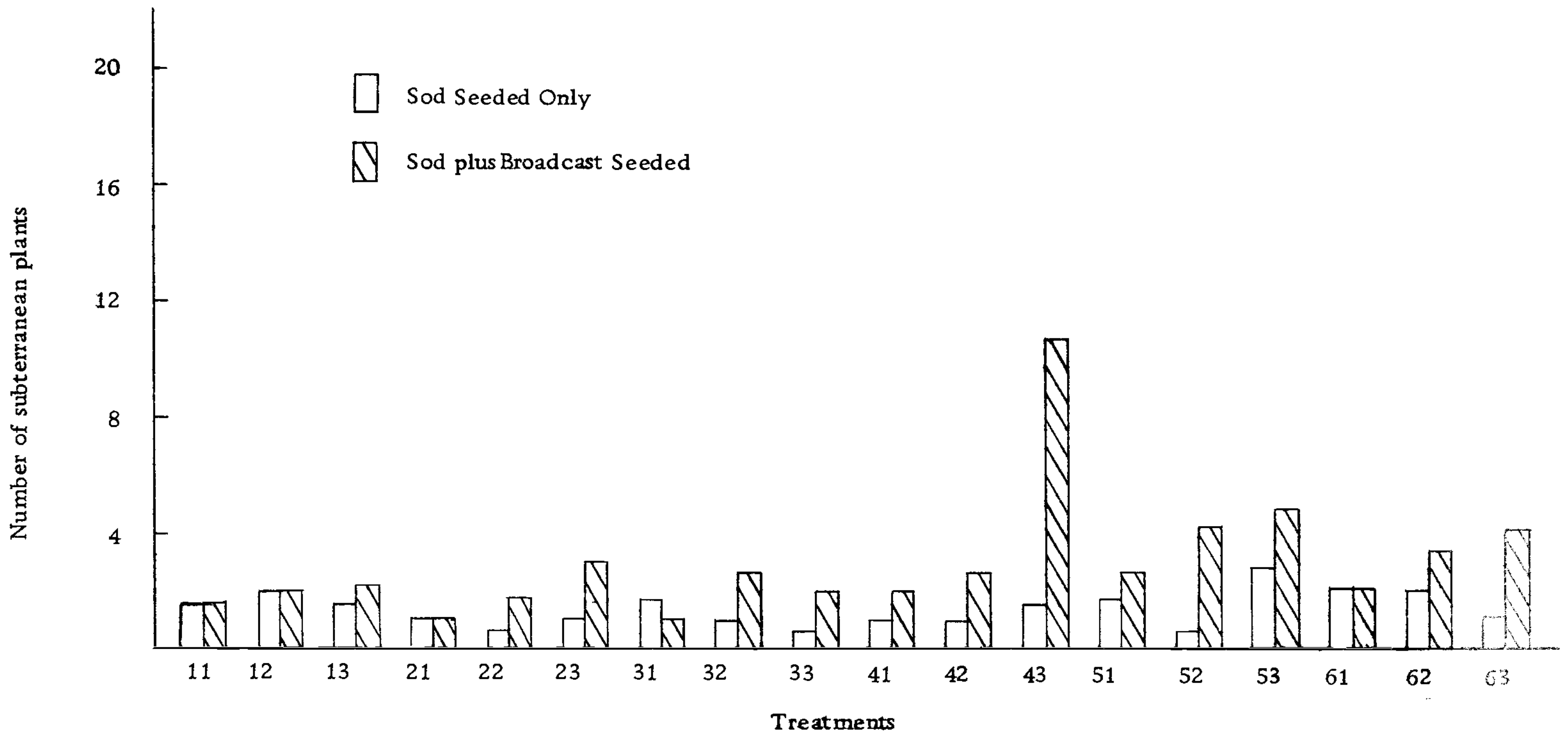

Figure 7. Mean Number of Subterranean Clover Plants Per Square Feet. June 1967. In treatment numbers the old treatments are given first followed by the new treatments.

Old Treatments
1 = Late grazed
2 = Early grazed
3 = Early-late grazed
4 = Early mowed
5 = Early-late mowed
6 = Control

New Treatments
1 = Chemical
2 = Grazed
3 = Mechanical

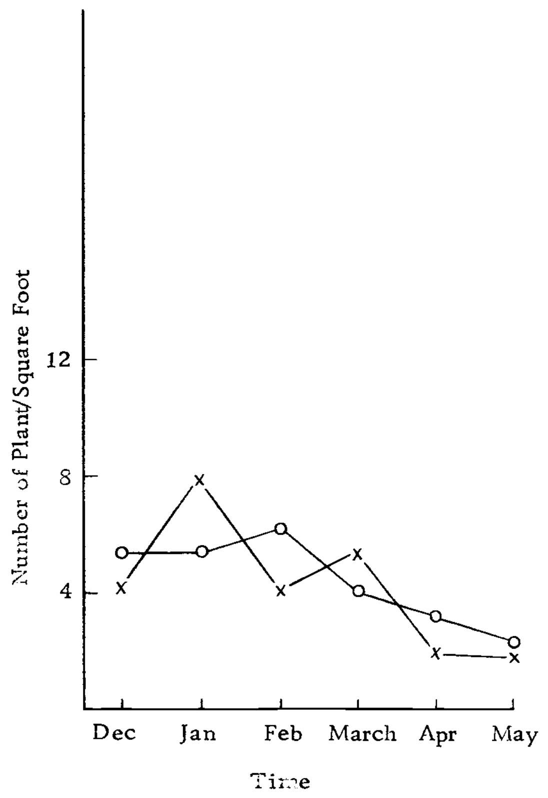

Figure 8. Chemical Treatment.

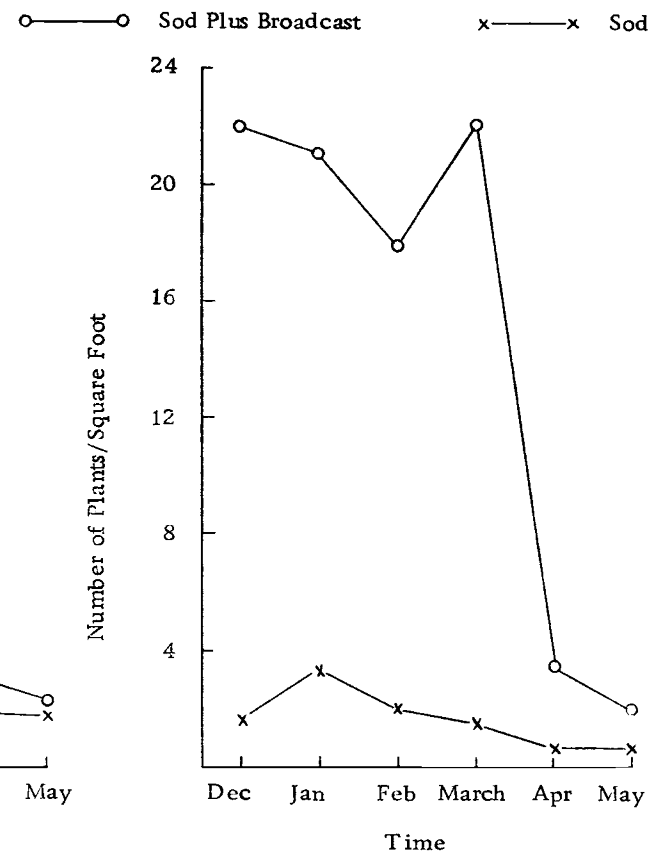

Figure 9. Grazed Treatment.

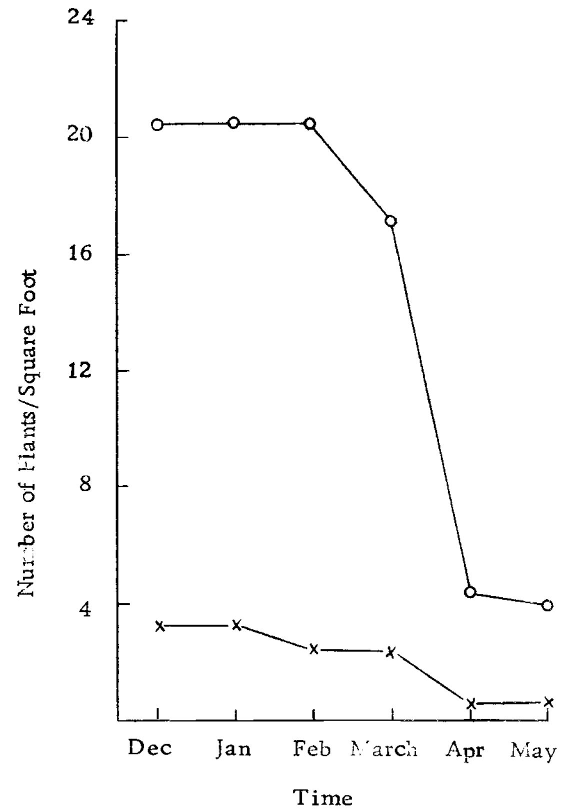

Figure 10. Mechanical Treatment.

Figures 8-10. Fate of Subterranean Clover Throughout Growing Season In Different Treatments.

favorable to the rhizobia thus allowing time to live longer and effectively nodulate the plant.

Vegetation Density Studies

Density of Vegetation

The purpose of these vegetation density studies was to find a combination of treatments which could reduce competition to a minimum in the establishment of subterranean clover.

The statistical analysis of vegetation density (Tables 9-10) in December 1966 shows significant differences between new treatments (vegetation density being greater in the control and mechanical treatments). Vegetation density in March 1967 (Tables 11-12) shows differences between new treatments, as in December, and the old treatments (density was lower in the early mowed treatments). Vegetation density in June 1967 (Tables 13-14) was greater in the control and mechanical treatment.

Density of Medusahead

An important objective of this experiment was to see how different treatments affected medusahead density.

The statistical analysis of medusahead density in December 1966 (Tables 15-16) shows significant differences in medusahead

Table 9. Analysis of variance. Vegetation density other than medusahead per 1/16 ft^2, December 1966.

Source of variation	SS	df	M. S.	F
Replication	.06	1	.06	.461
Seeding method	.01	1	.01	.077
S. M. x R. (error A)	.13	1	.13	
Old treatments	2.90	5	.58	2.52
O. T. x R. (error B)	1.15	5	.23	
O. T. x S. M.	.54	5	.11	1.37
O. T. x S. M. x R. (error C)	.41	5	.08	
New treatments	11.14	4	2.78	46.33*
N. T. x R. (error D)	.15	4	.06	
N. T. x S. M.	.29	4	.11	5.50
N. T. x S. M. x R. (error E)	.08	4	.02	
N. T. x O. T.	4.23	20	.21	1.40
N. T. x O. T. x R. (error F)	3.02	20	.15	
N. T. x O. T. x S. M.	1.76	20	.09	1.29
N. T. x O. T. x S. M. x R. (error G)	1.45	20	.07	
Total	27.32	119		

*Significant at the .05 level of probability.
**Significant at the .01 level of probability.

Table 10. Mean density vegetation other than medusahead per 1/16 sq. ft., December, 1966.

Treatment	Mean density rating
Paraquat unmowed	1.54 b
Paraquat mowed	1.58 b
Sheep grazed	1.79 b
Mechanical	2.25 a
Control	2.22 a

Table 11. Analysis of variance. Vegetation density other than medusahead per 1/16 ft^2, March 1967.

Source of variation	SS	df	M.S.	F
Replications	.02	1	.02	2.00
Seeding method	.00	1	.00	..00
S.M. x R. (error A)	.01	1	.01	
Old treatments	2.21	5	.44	15.71**
O.T. x R. (error B)	.14	5	.03	
O.T. x S.M.	.06	5	.01	.30
O.T. x S.M. x R. (error C)	.20	5	.04	
New treatments	2.78	4	.695	8.176*
N.T. x R. (error D)	.34	4	.085	
N.T. x S.M.	.07	4	.017	8.50**
N.T. x S.M. x R. (error E)	.01	4	.002	
N.T. x O.T.	.91	20	.045	1.023
N.T. x O.T. x R. (error F)	.88	20	.044	
N.T. x O.T. x S.M.	.73	20	.036	1.091
N.T. x O.T. x S.M. x R. (error G)	.66	20	.033	
Total	9.02	119		

*Significant at the .05 level of probability.
**Significant at the .01 level of probability.

Table 12. Mean density vegetation other than medusahead per 1/16 sq. ft., March 1967.

Treatment	Mean density rating	Chemical		Grazed	Mechanical	Control
		Unmowed	Mowed			
Old treatments						
Late grazed	2.25 a					
Early grazed	2.08 ab					
Early-late grazed	2.20 a					
Early mowed	1.89 b					
Early-late mowed	2.12 a					
Control	1.89 b					
New treatments						
Paraquat ummowed	1.96 ab					
Paraquat mowed	1.93 b					
Sheep grazed	1.95 ab					
Mechanical	2.27 a					
Control	2.24 a					
Sod seeded		1.97 b	1.94 b	1.92 b	2.32 a	2.25 a
Sod plus broadcast		1.95 b	1.93 b	1.98 b	2.23 a	2.23 a

Table 13. Analysis of variance. Vegetation density other than medusahead per 1/16 ft^2, June 1967.

Source of variation	SS	df	M. S.	F
Replications	.10	1	.10	5.00
Seeding method	.02	1	.02	1.00
S. M. x R. (error A)	.02	1	.02	
Old treatments	.84	5	.17	4.047
O. T. x R. (error B)	.21	5	.042	
O. T. x S. M.	.05	5	.01	.357
O. T. x S. M. x R. (error C)	.14	5	.028	
New treatments	1.10	4	.275	18.33*
N. T. x R. (error D)	.06	4	.015	
N. T. x S. M.	.22	4	.055	2.037
N. T. x S. M. x R. (error E)	.11	4	.027	
N. T. x O. T.	.55	20	.027	.964
N. T. x O. T. x R. (error F)	.58	20	.028	
N. T. x O. T. x S. M.	.18	20	.009	1.500
N. T. x O. T. x S. M. x R. (error G)	.11	20	.006	
Total	4.29	119		

*Significant at the .05 level of probability
**Significant at the .01 level of probability.

Table 14. Mean density vegetation other than medusahead per 1/16 sq. ft., June 1967.

Treatment	Mean density rating
Paraquat ummowed	2.05 b
Paraquat mowed	2.00 b
Sheep grazed	2.09 ab
Mechanical	2.25 a
Control	2.22 a

density in the new treatments (chemical and grazing treatments lowered medusahead density). Medusahead density in March 1967 (Tables 17-18) was similar to that of December. Density in June 1967 (Tables 19-20), indicate that chemical treatments were more successful in reducing medusahead density.

The chemical treatment initially reduced the density of the existing vegetation in the treated area, effectively reducing competition to subterranean clover during its early stages of growth. By December the vegetation in this area had recovered and there was no significant differences between the chemical and sheep grazed treatments, which were both significantly lower in vegetation density than the mechanical and control treatments.

The chemical mowed treatment was the most effective in reducing medusahead density. This was the only treatment which significantly reduced medusahead. It appears that paraquat was more effective in controlling medusahead when the old litter had been removed. In this study paraquat permitted favorable grasses, which germinated shortly after paraquat had been applied, such as soft cheat (*Bromus mollis* L.), six weeks fescue (*Festuca dertonensis* (All.) Asch. + Graeb.), and dogtail (*Cynosurus echinatus* L.) to increase in composition in the paraquat treated communities.

Sheep reduced medusahead and vegetation density by closely grazing the existing vegetation on the area. The reduction of

Table 15. Analysis of variance. Medusahead density per 1/16 sq. ft., December 1966.

Source of variation	SS	df	M. S.	F
Replications	.71	1	.71	35.5
Seeding method	.03	1	.03	1.50
S. M. x R. (error A)	.02	1	.02	
Old treatments	4.86	5	.972	2.292
O. T. x R. (error B)	2.12	5	.424	
O. T. x S. M.	.11	5	.022	..550
O. T. x S. M. x R. (error C)	.20	5	.040	
New treatments	12.89	4	3.22	21.18**
N. T. x R. (error D)	.61	4	.15	
N. T. x S. M.	.01	4	.002	..021
N. T. x S. M. x R. (error E)	.38	4	.095	
N. T. x O. T.	3.00	20	.150	1.00
N. T. x O. T. x R. (error F)	3.09	20	.150	
N. T. x O. T. x S. M.	2.30	20	.115	1.138
N. T. x O. T. x S. M. x R. (error G)	2.03	20	.101	
Total	32.36	119		

*Significant at the .05 level of probability.
**Significant at the .01 level of probability.

Table 16. Mean density medusahead per 1/16 sq. ft., December, 1966.

Treatment	Mean density rating
Paraquat unmowed	1.44 bc
Paraquat mowed	1.37 c
Sheep grazed	1.61 b
Mechanical	2.18 a
Control	2.08 a

Table 17. Analysis of variance. Medusahead density per 1/16 sq. ft., March 1967.

Source of variation	SS	df	M. S.	F
Replications	.04	1	.04	.2352
Seeding method	.00	1	.00	.00
S. M. x R. (error A)	.17	1	.17	
Old treatments	5.69	5	1.14	14.25**
O. T. x R. (error B)	.41	5	.08	
O. T. x S. M.	.09	5	.02	.286
O. T. x S. M. x R. (error C)	.34	5	.07	
New treatments	8.96	4	2.24	7.344*
N. T. x R. (error D)	1.22	4	.30	
N. T. x S. M.	.08	4	.02	.385
N. T. x O.T. x R. (error E)	.21	4	.05	
N. T. x O. T.	2.98	20	.15	1.364
N. T. x O. T. x R. (error F)	2.21	20	.11	
N. T. x O. T. x S. M.	1.97	20	.10	1.064
N. T. x O. T. x S. M. x R. (error G)	1.89	20	.09	
Total	26.26	119		

*Significant at the .05 level of probability.
**Significant at the .01 level of probability.

Table 18. Mean density medusahead per 1/16 sq. ft., March 1967.

Treatment	Mean density rating
Old treatments	
Late grazed	1.97 a
Early grazed	1.70 ab
Early-late grazed	2.04 a
Early mowed	1.60 b
Early-late mowed	1.82 a
Control	1.40 b
New treatments	
Paraquat unmowed	1.59 ab
Paraquat mowed	1.42 b
Sheep grazed	1.60 ab
Mechanical	2.09 a
Control	2.07 a

Table 19. Analysis of variance. Medusahead density per 1/16 sq. ft., June 1967.

Source of variation	SS	df	M. S.	F
Replications	12.01	1	12.01	171.57*
Seeding method	.02	1	.02	.286
S. M. x R. (error A)	.07	1	.07	
Old treatments	5.81	5	1.16	3.625
O. T. x R. (error B)	1.60	5	.32	
O. T. x S. M.	.41	5	.08	1.212
O. T. x S. M. x R. (error C)	.33	5	.07	
New treatments	6.41	4	1.60	17.412*
N. T. x R. (error D)	.37	4	.09	
N. T. x S. M.	.31	4	.08	1.10
N. T. x S. M. x R. (error E)	.28	4	.07	
N. T. x O. T.	3.06	20	.10	.644
N. T. x O. T. x R. (error F)	3.19	20	.16	
N. T. x O. T. x S. M.	1.38	20	.07	.812
N. T. x O. T. x S. M. x R. (error G)	1.71	20	.09	
Total	36.96	119		

*Significant at the .05 level of probability.
**Significant at the .01 level of probability.

Table 20. Mean density medusahead per 1/16 sq. ft., June 1967.

Treatment	Mean density rating
Paraquat unmowed	1.30 b
Paraquat mowed	1.15 b
Sheep grazed	1.40 ab
Mechanical	1.71 a
Control	1.74 a

vegetation was such that vegetation density was significantly different from the control and mechanical treatments and not significantly different from the chemical treated area in December. Competition to subterranean clover was therefore presumably reduced. Medusahead and other vegetation had recovered by June, so that no significant differences in medusahead or vegetation density were observed between the sheep grazing and control treatments.

The old treatments showed medusahead density to be significantly greater in the early-late grazed, late grazed, and early-late mowed treatments in March; by June these treatments were not significantly different from the early mowed, or control treatments.

The problem which was encountered in sampling medusahead was one of overestimated medusahead density especially during the December and March readings when the plants were in the vegetative stage. Six-week fescue was mistaken for medusahead in the vegetative stage.

Vegetation Yield Other than Subterranean Clover

Statistical analysis of vegetation yield other than subterranean clover (Table 21) shows a significant difference among the new treatment. Table 22 shows the mean vegetation yield on each new treatment and which treatments are significantly different.

There was no significant difference in yield between the

Table 21. Analysis of variance. Yield of vegetation, pounds per acre, dry weight, other than subterranean clover. June 1967.

Source of variation	SS	df	M. S.	F
Replications	2, 520. 83	1	2, 520. 83	8, 402. 7*
Seeding method	7, 712. 03	1	7, 712. 03	25, 706. 7*
S. M. x R. (error A)	. 30	1	. 30	
Old treatments	37, 209. 30	5	7, 441. 86	1. 79
O. T. x R. (error B)	20, 773. 17	5	4, 154. 63	
O. T. x S. M.	3, 585. 37	5	717. 07	1. 95
O. T. x S. M. x R. (error C)	1, 836. 70	5	367. 34	
New Treatments	71, 795. 00	4	17, 948. 75	11. 75*
N. T. x R. (error D)	6, 109. 53	4	1, 527. 38	
N. T. x S. M.	5, 891. 00	4	1, 472. 25	5. 38
N. T. x S. M. x R. (error E)	1, 095. 01	4	273. 75	
N. T. x O. T.	35, 718. 90	20	1, 785. 84	1. 77
N. T. x O. T. x R. (error F)	20, 118. 97	20	1, 005. 95	
N. T. x O. T. x S. M.	14, 875. 10	20	743. 75	. 81
N. T. x O. T. x S. M. x R. (error G)	18, 474. 49	20	923. 72	
Total	247, 715. 70	119		

*Significant at the . 05 level of probability.
**Significant at the . 01 level of probability.

Table 22. Mean yield vegetation, pounds per acre dry weight, other than subterranean clover, June 1967.

Treatment	Pounds per acre dry weight
Paraquat unmowed	2024. 5 abc
Paraquat mowed	1871. 2 c
Sheep grazed	1939. 2 bc
Mechanical	2388. 7 ab
Control	2473. 7 a

fertilized and unfertilized control treatment, indicating an unavailability of the fertilizer to the plants.

The chemical-mowed treatment was most effective in reducing vegetation growth, it was significantly different from the mechanical and control treatments. The chemical-mowed treatment was not significantly different from the chemical-unmowed or sheep grazed treatments.

In the chemical treated area California oat grass was severely damaged or killed. The plants did not recover fully by June. This damage to a valuable perennial grass may have been due to the fact that paraquat was applied in late afternoon, followed shortly afterwards by a period of darkness may have enhanced movement and uptake of paraquat into plants.

Subterranean Clover Yields

The yield of subterranean clover as well as its ability to re-establish during the following years are of prime importance in its establishment.

Statistical analysis of subterranean clover yields (Table 23) shows significant differences existing between the new and old treatment. No significant difference occurred within the old treatments, or the seeding methods (Table 24).

The differences in yields between old treatments and seeding

Table 23. Analysis of variance. Subterranean clover yield, pounds per acre dry weight, June 1967.

Source of variation	SS	df	M. S.	F
Replications	1,329.09	1	1,329.09	8.61
Seeding method	1,218.38	1	1,218.38	7.89
S. M. x R. (error A)	154.36	1	154.36	
Old treatments	813.42	5	162.68	1.03
O. T. x R. (error B)	785.10	5	157.02	
O. T. x S. M.	483.39	5	96.68	1.51
O. T. x S. M. x R. (error C)	321.09	5	64.21	
New treatments	478.82	3	159.61	1.07
N. T. x R. (error D)	447.40	3	149.13	
N. T. x S. M.	767.14	3	255.71	1.34
N. T. x S. M. x R. (error E)	573.45	3	191.15	
N. T. x O. T.	2,639.50	15	175.96	2.57*
N. T. x O. T. x R. (error F)	1,026.41	15	68.43	
N. T. x O. T. x S. M.	1,111.88	15	74.12	.764
N. T. x O. T. x S. M. x R. (error G)	1,454.51	15	96.97	
Total	13,603.94	95		

*Significant at the .05 level of probability.
**Significant at the .01 level of probability.

Table 24. Mean yield subterranean clover pounds per acre dry weight, June 1967.

Treatment	Pounds per acre dry weight			
	Chemical			
	Unmowed	Mowed	Grazed	Mechanical
Late grazed	126 abc	53 c	250.7 ab	45.2 c
Early grazed	99.7 bc	110.7 bc	89.7 bc	151.2 abc
Early-late grazed	143.7 abc	158 abc	211.5 abc	118.5 bc
Early mowed	131.7 bc	148 abc	172.5 abc	132.2 bc
Early-late mowed	109.2 bc	143.5 abc	191.0 abc	241.7 ab
Control	335.5 a	181.5 abc	189.2 abc	81.2 bc

methods are presented in Table 25 and Figure 11; these suggest that significant differences do exist between treatments. This difference may not have shown in the statistical analysis due to having a small number of observations per treatment and a small number of degrees of freedom.

Table 25. Mean yield subterranean clover pounds per acre dry weight,June 1967.

Treatment	Pounds per acre dry weight	
	Sod seeded	Sod plus broadcast
Late grazed	95.0	142
Early grazed	94.7	131
Early-late grazed	105	210.5
Early mowed	125	166
Early-late mowed	151	192
Control	118.5	275.2

The new and old treatment interaction (Table 26) shows that the chemical unmowed treatment with the old control treatment gave the highest yield of subterranean clover with 397 pounds per acre. Of the six highest yielding plots, four were where sheep grazing was used in establishing subterranean clover. In the sheep grazed treatment better yields were acquired when the area had prior grazing treatments; especially late grazed or early-late grazed treatments.

In areas where no previous treatments (old control) had been

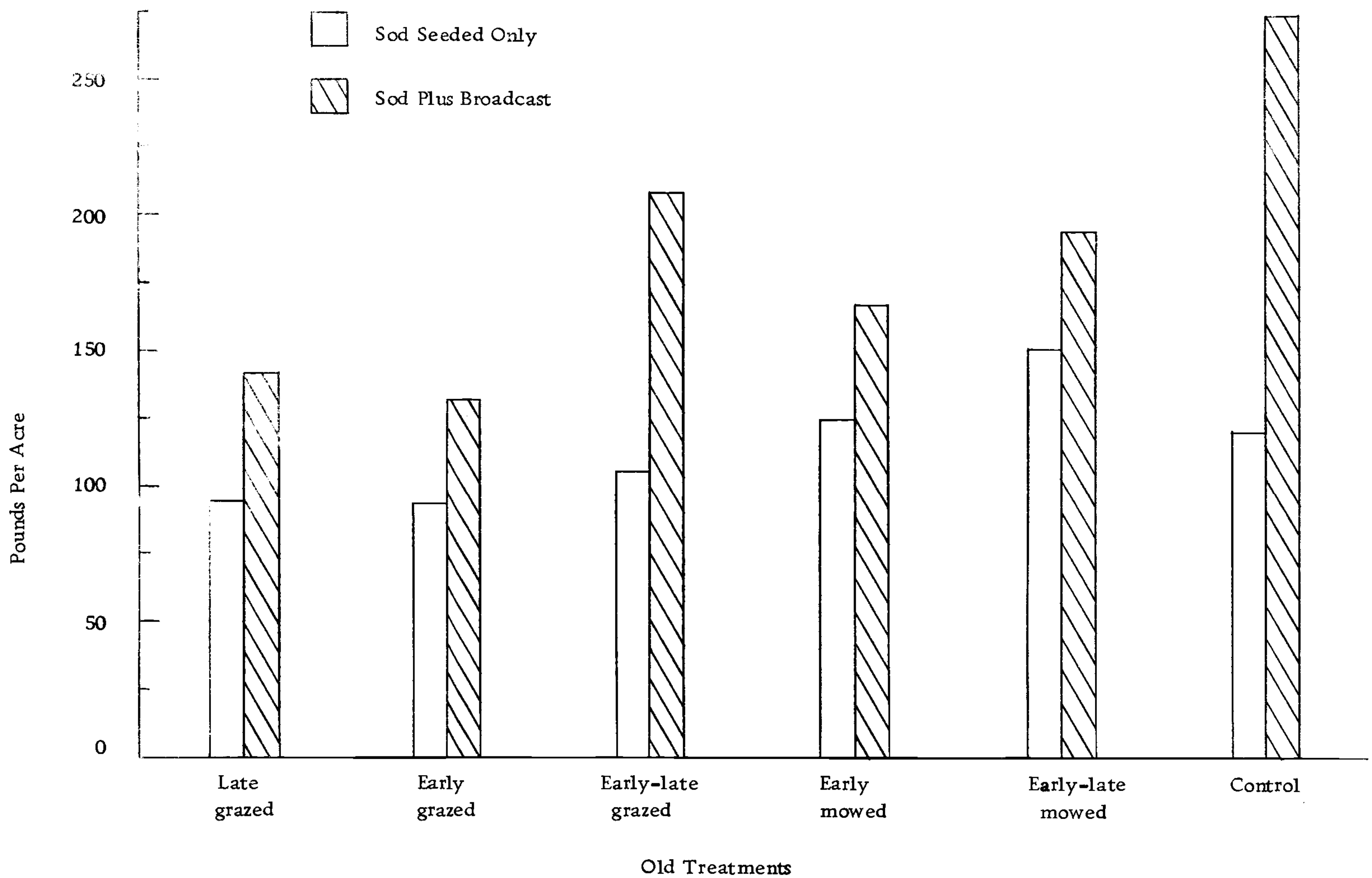

Figure 11. Mean Yield Subterranean Clover as Affected by Seeding Method and Old Treatments Interactions.

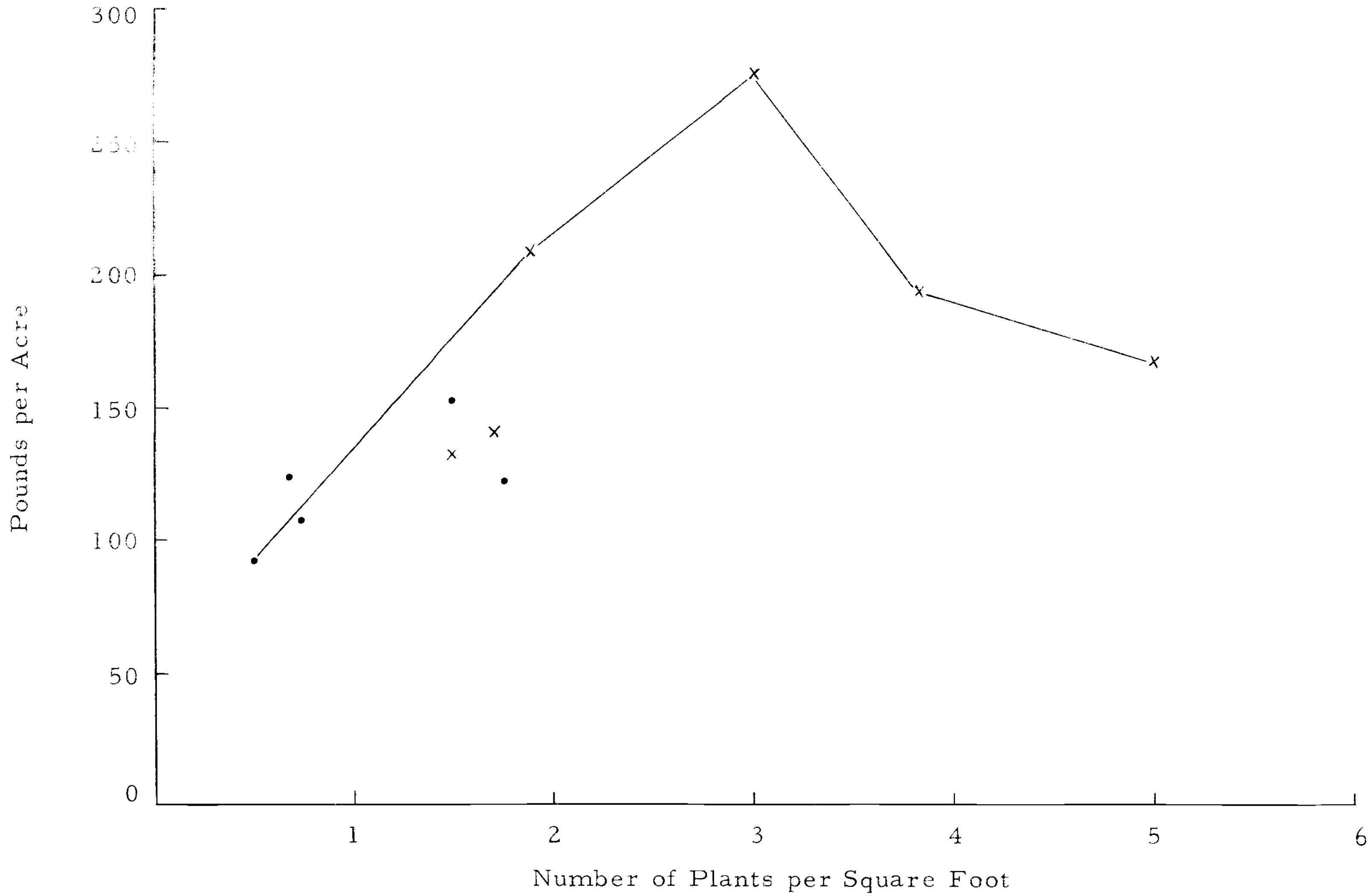

Figure 12. Mean Yield Subterranean Clover on Old Treatments and Seeding Methods Interactions. Comparing Number of Plants per Square Foot and Yield.

applied high yields were obtained in the chemical unmowed, chemical mowed, and sheep grazed treatments. These yields were not significantly different from the highest yield plot.

The lowest yields were obtained in the mechanical treated areas.

Table 26. Mean yield of subterranean clover pounds per acre dry weight, June 1967.

Treatment	Chemical		Grazed	Mechanical
	Unmowed	Mowed		
Sod Seeded				
Late grazed	109	23	206	22
Early grazed	99.5	125	122	32.5
Early-late grazed	112.5	148.5	104.5	56
Early mowed	172	158	113	60.5
Early-late mowed	124	155.5	143.5	180
Control	273.5	130.5	13.5	56.5
Sod plus Broadcast				
Late grazed	143	63	295.5	68.5
Early grazed	100	96.5	57.5	270
Early-late grazed	175	167.5	318.5	181
Early mowed	81.5	138	232	204.5
Early-late mowed	94.5	131.5	238.5	303.5
Control	397.5	232.5	365	106
Method of Seeding				
Sod seeded	148.4	126.7	117	67.9
Sod and broadcast	166.9	166.9	251.1	188.9

Figure 11 shows a difference in yield between the sod seeded only and sod plus broadcast seeded treatment. These differences were greater in the early-late grazed and old control treatments.

The differences in yield may be due to the fact that in the broadcast area the seeds and plants were not restricted to the drill rows but were scattered throughout the area; the plants were better able to utilize the available phosphorus fertilizer more extensively.

Figure 12 compares the relationship between yield and the number of subterranean clover plants per square foot in the old treatments and seeding methods interaction. Yield increases with plant density until there are three plants per square foot; above this density subterranean yield declines. This may be due to competition for moisture along with poor nodulation. The dry spring which was encountered may not have permitted newly established poorly nodulated stands to have a high plant density without a reduction in yields.

SUMMARY AND CONCLUSIONS

The establishment of subterranean clover on medusahead infested ranges in western Oregon was investigated. Four treatments for establishing subterranean clover were compared when superimposed over six old treatments for controlling medusahead. Two seeding methods were compared in the new treatments. The new treatments were (1) control, no seeding, (2) mechanical, seeding directly into the sod, (3) chemical seedbed preparation and seeding directly into the sod, (4) seeding into the sod, followed by grazing. The two seeding methods used were sod seeding only and sod plus broadcast seeding.

Secondary objectives of this study were to determine the effects of management treatments on (a) subterranean clover germination (b) density of medusahead and other vegetation and (c) yield of subterranean clover.

The conclusions of this study are as follows:

1. The germination and fate of subterranean clover plants could be followed by observing plant density obtained throughout the year (Figure 8-10). The number of subterranean clover plants germinating in the early season was high in the sod plus broadcast seeded areas and low in the sod seeded treatment. This was to be expected as

the broadcast seeded area had 24 pounds per acre seeding rate compared to six pounds per acre for the sod seeded. The difference in plant density was significantly greater between the methods of seeding when evaluated in May in all but the chemical treatment.

2. Subterranean clover density in the chemical treatment, sod seeded areas was greater than that in the sod seeded areas of the grazed or mechanical treatment throughout the year; this may have resulted by paraquat removing competition, thus allowing the plants in the drill rows to develop faster and enabling them to compete with other vegetation.
The chemical treatment was the only new treatment that did not have a significantly higher number of clover plants in the broadcast area as compared to the sod seeded areas. This may have been due to the microenvironment to which the broadcast seeds were exposed. Live vegetation may create a more favorable environment to the rhizobia. Transpiration, from live plants, may provide moisture, cooler and more favorable environment for seeds which are exposed to the environment. Transpiration would not occur in a paraquat treated area. Broadcast seeding of subterranean clover in areas which have a good litter cover on the ground may be practicable if nodulation

can be obtained on these plants. In both the grazed and mechanically treated areas the sod plus broadcast seeded area had high density of subterranean clover until March, when many plants started to die. This was the result of poor nodulation probably caused by dessication of seed prior to sowing (a 24 hour delay in broadcasting inoculated seed), drying after seeding because of poor coverage in drill rows, and lack of available phosphorus to clover plants.

3. The density of medusahead and other vegetation in the chemical-mowed, chemical-unmowed, and sheep grazed treatments was significantly lower in December than in the mechanical and control treatments. By June vegetation density was significantly lower only in the chemical treatments. Medusahead density was reduced significantly in the chemical-mowed treatment throughout the year.

4. The yield of vegetation other than subterranean clover ranged from 1,871 to 2,473 pounds per acre. The chemical-mowed and sheep-grazed treatments were significantly lower in vegetation yield than the control, mechanical, and the chemical-unmowed treatment.

5. The yield of subterranean clover ranged from 397 to 22 pounds per acre. There was a significant difference

between the new and old treatment interaction. The chemical-unmowed and old control treatment gave the highest yields of subterranean clover with 397 pounds per acre; the lowest was obtained in the mechanical treatment combined with a late grazed treatment with 22 pounds per acre. Four of the six highest yielding treatments were those where sheep grazing was used in establishing subterranean clover. There was a higher yield in the sod plus broadcast areas compared with the sod seeded only areas.

6. Paraquat may have a place in altering the composition of medusahead ranges in western Oregon. In this study paraquat permitted favorable grasses, such as soft cheat, six weeks fescue and dogtail, which germinated shortly after paraquat had been applied, to increase in composition in the community.

7. In establishing subterranean clover it is recommended that the area be grazed at least one season prior to seeding; seed should be drilled and the fertilizer banded below the seed. When drilling is not possible a higher rate of seed should be used to compensate for the loss from unfavorable environmental factors. In both cases the area should be grazed with sheep during the

establishment period to remove competition and recycle nutrients.

Studies need to be continued on the experimental area to determine on which treatment a satisfactory stand of subterranean clover can be maintained.

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APPENDICES

Appendix Table 1. Chemical analysis of soil sample obtained from the hill pasture.

Soil pH	6.0
Phosphorus	11.4 parts per million
Boron	2.52 parts per million
Potassium	0.37 milliequivalents per 100 grams
Calcium	20.5 milliequivalents per 100 grams
Magnesium	11.9 milliequivalents per 100 grams

Appendix Table 2. Mean rainfall and temperature during the growing season October, 1966-June 17, 1967.

Month	Rainfall (Inches)	Temperature (°F)	
		Maximum	Minimum
October	3.18	64.2	40.9
November	5.27	53.9	39.7
December	7.67	49.1	38.5
January	9.50	48.8	37.5
February	1.78	52.6	33.6
March	4.23	52.0	35.3
April	1.60	54.7	33.4
May	.85	68.2	41.8
June	.28	76.9	49.9

Appendix Table 3. Mean number of subterranean clover plants per 1 sq. ft., December, 1966.

Treatment	Chemical	Sheep Grazed	Mechanical
Sod seeded			
Late grazed	2.7	2.0	3.2
Early grazed	7.2	2.0	3.2
Early-late grazed	2.2	.8	1.5
Early mowed	1.5	1.5	4.2
Early-late mowed	1.5	.5	5.5
Control	3.7	1.2	1.7
Sod plus broadcast			
Late grazed	3.7	20.5	15.0
Early grazed	3.7	17.0	13.2
Early-late grazed	4.2	27.0	10.2
Early mowed	6.0	22.0	36.2
Early-late mowed	5.2	21.7	32.0
Control	5.7	24.0	17.7

Appendix Table 4. Mean number of subterranean clover plants per 1 sq. ft, December 1966.

Treatment	Chemical	Sheep grazed	Mechanical	Sod seeded	Sod plus broadcast	Number of plants
Old treatments						
Late grazed	3	11.2	9.1	2.6	1.3	7.8
Early grazed	5	9.5	8.2	3.8	11.3	7.6
Early-late grazed	4.2	13.8	5.9	2.1	13.8	8.0
Early mowed	3.7	11.7	20.2	2.4	21.4	11.9
Early-late mowed	3.3	11.1	18.7	2.5	19.6	11.1
Control	4.7	12.6	9.7	2.2	15.8	9.0

Appendix Table 5. Mean number of subterranean clover plants per 1 sq. ft., March 1967.

Treatment	Sod seeded	Sod plus broadcast	Number of plants
Old treatments			
Late grazed	1.8	11.4	6.6
Early grazed	3.5	10.4	6.9
Early-late grazed	2.0	10.9	6.4
Early mowed	2.1	1.9	10.6
Early-late mowed	3.0	17.6	9.3
Control	1.8	14.5	8.2

Appendix Table 6. Mean number of subterranean clover plants per 1 sq. ft, March 1967.

Treatment	Chemical	Sheep Grazing	Mechanical
Sod seeded			
Late grazed	1.7	1.2	3.0
Early grazed	6.2	1.7	2.5
Early-late grazed	3.5	.5	2.0
Early mowed	1.2	1.2	4.0
Early-late mowed	1.0	1.0	4.0
Control	3.7	.7	1.3
Sod plus broadcast			
Late grazed	2.2	18.5	13.5
Early grazed	3.7	15.5	12.0
Early-late grazed	3.5	20.7	8.5
Early mowed	7.2	19.7	30.0
Early-late mowed	5.2	23.2	24.5
Control	4.2	23.5	16.0
Old treatments			
Late grazed	2.2	9.8	7.8
Early grazed	5.0	8.6	7.7
Early-late grazed	3.5	10.6	5.2
Early mowed	4.8	10.5	22.0
Early-late mowed	2.6	12.1	14.2
Control	3.8	12.1	8.6

Appendix Table 7. Mean number of subterranean clover plants per 1 sq. ft., June 1967.

Treatment	Sod seeded	Sod plus broadcast	Number of plants
Old treatments			
Late grazed	.6	1.7	1.1
Early grazed	.6	1.6	1.1
Early-late grazed	.6	1.9	1.3
Early mowed	.6	5.2	2.9
Early-late mowed	1.5	3.9	2.7
Control	1.8	3.0	2.1
New treatments			
Chemical			1.2
Sheep grazing			1.7
Mechanical			2.7
Method of Seeding			
Sod seeded			.8
Sod plus broadcast			2.9

Appendix Table 8. Mean number of subterranean clover plants per 1 sq. ft., June 1967.

Treatment	Chemical	Sheep grazed	Mechanical	Sod seeded	Sod plus broadcast	Number of plants
Sod seeded						
Late grazed	0	1.5	.2			
Early grazed	.8	.2	.8			
Early-late grazed	1.2	.5	.2			
Early mowed	.5	.5	.7			
Early-late mowed	1.0	.5	3.0			
Control	1.7	1.5	.8			
Sod plus broadcast						
Late grazed	1.5	1.5	2.2			
Early grazed	.8	1.5	2.7			
Early-late grazed	.8	2.7	2.2			
Early mowed	2.2	3.0	10.5			
Early-late mowed	2.7	2.2	4.2			
Control	1.8	3.2	2.0			
Old treatments						
Late grazed	.8	1.5	1.2	.6	1.7	1.1
Early grazed	.8	.8	1.7	.6	1.6	1.1
Early-late grazed	1.0	1.6	1.2	.6	1.9	1.3
Early mowed	1.3	1.2	5.6	.6	5.2	2.9
Early-late mowed	1.8	2.2	3.8	1.5	3.9	2.7
Control	1.2	2.2	2.3	1.8	3.0	2.1
New treatment	1.2	1.7	2.7			
Method of Seeding						
Sod seeding						.8
Sod plus broadcast						2.9

Appendix Table 9. Mean yield, pounds per acre dry weight, subterranean clover, June 1967.

Treatment	Pounds per acre
Method of seeding	
Sod seeding	115.0
Sod plus broadcast	186.3
Old treatments	
Late grazed	118.7
Early grazed	112.8
Early-late grazed	158.0
Early mowed	146.2
Early-late mowed	171.4
Control	196.8
New treatments	
Paraquat unmowed	157.6
Paraquat mowed	132.4
Sheep grazed	184.1
Mechanical	128.4

Appendix Table 10. Mean yield, pounds per acre dry weight, vegetation other than subterranean clover, June 1967.

Treatment	Sod seeded	Sod plus broadcast	Pounds per acre
Old treatments			
Late grazed	2244	3160	2202
Early grazed	2227	2174	2200.5
Early-late grazed	2521	2281	2401
Early mowed	2112	1769	1940
Early-late mowed	1906	1861	1883.5
Control	2308	2111	2209.5
Method of Seeding			
Sod seeding			2219.6
Sod plus broadcast			2059.3

Appendix Table 11. Yield, pounds per acre dry weight, vegetation other than subterranean clover, June 1967.

Treatment	Chemical		Grazed	Mechanical	Control
	Unmowed	Mowed			
Sod seeded					
Late grazed	2050	2000	1745	2555	2870
Early grazed	2035	1915	1900	2550	2645
Early-late grazed	2235	2775	2395	2750	2955
Early mowed	1955	1820	2225	2590	2020
Early-late mowed	1935	1660	1795	2065	2075
Control	2025	2140	2575	2455	2255
Sod plus broadcast					
Late grazed	1840	1675	1530	2410	3345
Early grazed	2170	1805	2130	2275	2490
Early-late grazed	2180	1920	2240	2305	2760
Early mowed	1915	1645	1590	1805	1895
Early-late mowed	1860	1485	1380	2370	2210
Control	2145	2115	1685	2450	2165
Old treatments					
Late grazed	1945	1837	1637	2482	3107
Early grazed	2102	1860	2060	2412	2067
Early-late grazed	2207	2097	2315	2522	2857
Early mowed	1910	1733	1907	2145	1957
Early-late mowed	1897	1572	1587	2217	2142
Control	2085	2122	2127	2497	2210
Method of seeding					
Sod seeded	2038	1968	2120	2509	2470
Sod plus broadcast	2018	1774	1758	2268	2477