AN ECONOMIC AND ECOLOGICAL EVALUATION OF VELVETGRASS, *HOLCUS LANATUS* L.

by

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AN ECONOMIC AND ECOLOGICAL EVALUATION OF VELVETGRASS, *HOLCUS LANATUS* L.

INTRODUCTION

One of the more serious problems in the management of pastures in western Oregon is the invasion of the sward by weedy perennial grasses. These grasses are difficult to control, for they often are similar to the cultivated grasses in their responses to management practices or chemical control. They may be more resistant to grazing pressure than the desirable grasses, because of growth habit or lack of palatability, and will eventually replace them.

Velvetgrass, *Holcus lanatus* L., is one such weedy grass. It is a common invader of irrigated and nonirrigated pastures in the Willamette Valley and along the Oregon Coast, and in similar areas in western Washington. Velvetgrass, also called mesquite or fog, is a perennial bunchgrass, 30 to 100 cm. in height, with leaf blades four to eight millimeters wide. The entire plant is covered with a velvety pubescence, giving it a grayish appearance. The panicles, which appear in June in the Willamette Valley, are three to six inches long, contracted, and tinged with purple. The spikelets are two-flowered; the first floret is perfect and awnless, while the second is staminate with a short hooklike awn arising from the back of the lemma. The glumes are villous, while the lemmas are smooth. The species is described and illustrated by Hitchcock (21, p. 305).

Much of the earlier information about velvetgrass has been derived from informal observation, and its validity is questionable. This study was carried out to determine the conditions which favor or retard the establishment and increase of velvetgrass in pastures, and to provide an estimate of the value of velvetgrass for forage production.

A series of experiments evaluated the effects of light, temperature, and association with other plant species on the growth and survival of velvetgrass seedlings. Other tests examined the effects of fertilization on the amount of velvetgrass present in a pasture, and the effects of different systems of simulated grazing on the invasion of pastures by velvetgrass. The information from these studies was used to work out methods of control.

An estimate of the forage value of velvetgrass was needed, in order to determine the economic feasibility of controlling the species. Experiments were carried out to compare velvetgrass with several forage grasses on the basis of palatability, chemical composition, and digestibility.

REVIEW OF LITERATURE

Velvetgrass Investigations

The literature dealing with velvetgrass is quite limited, consisting mostly of material published in Europe, Australia, and New Zealand. In many cases, velvetgrass was not the primary object of study, but was part of the vegetation of the area under investigation, and its response to treatment was noted in passing.

Mitchell (30, p. 207-213), studying the effect of different levels of constant temperature on the growth of perennial ryegrass (*Lolium perenne*), orchardgrass (*Dactylis glomerata*), and velvetgrass, found that the growth rate of individual tillers was at a maximum at 57 degrees F. for ryegrass and at 62 degress for orchardgrass and velvetgrass. For the growth of the entire plant, optimum temperatures were 68 degrees for ryegrass and velvetgrass and 70 degrees for orchardgrass. It may be concluded that there is little difference in the optimum growth temperatures for the three grasses, although velvetgrass showed a more rapid decline in growth rate as temperatures rose above the optimum.

Ennik (14, p. 31-36), working in Holland, reported the effects of nitrogen fertilization and of continuous vs. rotational grazing on the amount of velvetgrass in a perennial ryegrass pasture. At the beginning of the study, velvetgrass contributed about five per cent of the total herbage. At the end of three years, the velvetgrass contents of the rotationally grazed and continuously grazed plots were five and twenty-five per cent, respectively. Ennik attributed the increase under continuous grazing to the failure of the cattle to consume the velvetgrass, while under rotational grazing more complete utilization of the forage was achieved and the velvetgrass was held in check. He also found that annual applications of forty pounds of nitrogen per acre caused a slight increase in the amount of velvetgrass, while applications of twenty-five or zero pounds of nitrogen caused no change.

Several authors have investigated the effects of trampling and soil compaction on velvetgrass and various cultivated pasture species. Lieth (28) recorded the plant species present and measured the soil pore-volume on 424 sites in Germany. The areas studied included pastures, cultivated fields, and roadsides. From his data, he developed a rating system, in which a value of one indicated a high tolerance to soil compaction and a value of seven indicated a low tolerance. The ratings which he assigned to some common pasture species (28, p. 456) were as follows: perennial ryegrass, 1.13; white clover (Trifolium repens), 1.85; orchardgrass, 3.26; velvetgrass, 5.00; red clover (T. pratense), 5.75; and tall oatgrass (Arrhenatherum elatius), 7.00. It can be seen that velvetgrass is less tolerant of soil compaction than some of the common pasture grasses. Davies (12, p. 40-42), an English worker, found that velvetgrass seldom occurred in heavily trampled habitats, such as the edges of roadways and pasture gateways, even though the surrounding grasslands contained as high as forty per cent velvetgrass. He listed the dominant grasses of such habitats as perennial ryegrass, annual bluegrass (*Poa annua*), and various species of *Agrostis* and *Festuca*. Edmond (13, p. 654-655) reported that both perennial and short-rotation ryegrass (*Lolium perenne* x *L. multiflorum* hybrid) were very resistant to trampling.

Reports of the response of velvetgrass to various fertilizers occur frequently in the literature. These must be regarded with caution, however, since the fertilizer response of a species is affected by the nutrient supply of the soil on which it is growing and by the response of associated species. Brenchley (6, p. 112-115), working with mixed grass pastures in England, reported that the application of potassium and lime resulted in a decrease in the amount of velvetgrass in the stand, while the application of high rates of nitrogen produced an increase. Hudson, Doak, and McPherson found that nitrogen applied alone favored the growth of velvetgrass in New Zealand pastures (23, p. 124, 152-154), but that the application of potassium plus phosphorus, with or without nitrogen, resulted in a reduction in velvetgrass (23, p. 87). Hugues, Denoy, and Ferret (24, p. 570-571, 641) published similar results, stating that the amount of velvetgrass in an irrigated pasture in France decreased when phosphorus plus potassium or a complete fertilizer were applied, but increased when only nitrogen was applied.

Norman (32, p. 164-165) studied the fertilizer response of a bentgrass-fescue pasture on a calcareous soil in England, and found that fertilization with nitrogen, potassium, and phosphorus produced little change in the amount of velvetgrass present; however, the stand contained only about three per cent velvetgrass.

McNaught, investigating potassium requirements, reported (29, p. 148) that the plant content of potassium necessary for maximum growth was approximately 1.8 per cent for white clover and 1.6 per cent for perennial ryegrass, orchardgrass, and velvetgrass. Jones and Elliott (25) found that velvetgrass had a lower copper requirement than sub clover (Trifolium subterraneum), but about the same requirement as big trefoil (Lotus uliginosus).

Chemical control of velvetgrass has been given some attention, and some promising results have been obtained. Goetze (17, p. 31 and 33) effectively controlled velvetgrass in Astoria bentgrass (Agrostis tenuis) with applications of diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea] in October, or CIPC [isopropyl-N-(3-chlorophenyl) carbamate] in December. Both materials were applied at the rate of four pounds per acre. Thompson (36, p. 96-98) was able to achieve over eighty per cent control of velvetgrass in perennial ryegrass by applying five pounds of dalapon (2,2-dichloropropionic acid) per acre in early spring; the ryegrass suffered only temporary damage. He was able to obtain only fifty per cent control of velvetgrass in orchardgrass, using two and one-half pounds of dalapon per acre, without damage to the orchardgrass.

Lee (27, p. 56-65) determined the effects of ten herbicides, applied at different rates and dates, on a number of weeds and forage grasses. Diuron, CIPC, and atrazine [2-chloro-4-(isopropylamino)-6-ethylamino-s-triazine] gave excellent control of velvetgrass when applied in January at the rate of three or four pounds per acre. None of these materials caused any damage to orchardgrass, and only CIPC had any undesirable effects on perennial ryegrass. In another trial (27, p. 47-52), the same herbicides were applied to several forage legumes. All three of the materials which controlled velvetgrass effectively caused slight to moderate damage to white clover, but none of the three damaged birdsfoot trefoil (*Lotus corniculatus*), red clover, or alfalfa (*Medicago sativa*).

Chemical control of velvetgrass may be only temporarily successful, however, because of the presence of large numbers of velvetgrass seeds in the soil. Foerster (15, p. 276) determined the number of viable seeds of various species in the upper five centimeters of the soil of two areas in Germany. In the first, in which velvetgrass made up twenty-five per cent of the vegetation and was the dominant species, there were 800 viable seeds of velvetgrass per square meter. In the second area, velvetgrass made up ten per cent of the vegetation, and there were 976 seeds per square meter. In addition to showing the large number of viable velvetgrass seeds which may be present in the soil, this study also illustrates that the number of velvetgrass plants present is not always a reliable indicator of the number of seeds in the soil.

Production of Phytotoxic Materials by Plant Species

It has been said that white clover will not grow in the presence of velvetgrass, and that velvetgrass may produce some substance that is toxic to the legume. No confirmation of this belief was found in the literature, but numerous reports of the production of phytotoxic materials by other species were encountered. Hamilton and Buchholtz (19, p. 305-306) stated that the presence of living or dead rhizomes of quackgrass (Agropyron repens) in the soil inhibited the growth of white clover and several weedy grasses and forbs. Gray and Bonner (18, p. 53-54) found that the application of leaves of Encelia farinosa to the soil inhibited the growth of tomatoes, peppers, and corn, but did not affect the growth of barley, oats, sunflower, or several species of Poa. Roots of Encelia had no detectable toxic effect.

Funke (16, p. 281-285) believed the secretion of the alkaloid absinthin by the leaves of Artemisia absinthium was responsible for the suppression of the growth of eighteen species of plants which were planted near an Artemisia hedge. Brooks (7, p. 17-27) reported that the growth of many plant species was inhibited in the vicinity of black walnut (Juglans nigra) trees, and that root contact was a necessary factor in this antagonism. Bonner (5, p.

343, 349-350) found that the roots of guayule (*Parthenium argentatum*), grown in gravel culture, produced transcinnamic acid, which inhibited the growth of guayule seedlings.

Benedict (4) noted that the growth of bromegrass (*Bromus inermis*) seedlings in sand was inhibited by the presence of oven-dried bromegrass roots in the substrate. Finally, Ahlgren and Aamodt (1) observed that, in the field, Kentucky bluegrass (*Poa pratensis*) soon eliminated redtop (*Agrostis alba*). However, greenhouse experiments failed to show that bluegrass inhibited the growth of redtop, or that harmful interactions existed among any of several other grass species.

Research Methods

Seed dormancy is often a problem when plants for experimental purposes are to be grown from freshly harvested seed. A number of methods of overcoming dormancy were suggested by Crocker and Barton (11, p. 119-126) and in the USDA publication, *Testing Agricultural and Vegetable Seeds* (37, p. 101-103), including pre-chilling, exposure to infra-red light, alternating temperatures during germination, and the use of potassium nitrate solution for moistening the substrate.

Investigations into methods of determining consumption of pasture forage and acceptability of forages to grazing animals are plentiful. Carter, Bolin, and Erickson reviewed the literature concerned with methods of estimating forage consumption (9, p. 5-7), and reported that the "difference" method overestimated forage intake from twenty-five to forty per cent, but was satisfactory for estimating differences between treatments or entries. They concluded this method was most applicable to short or rationed grazing periods, to minimize such sources of error as forage growth during the grazing period, unrecoverable reject, and the depressing effect of grazing on forage growth. Petersen, Weswig, and Cowan (33) employed both the difference method and an observation method when using grazing sheep to measure palatability differences among lines of tall fescue (Festuca arundinacea). Burton, Southwell, and Johnson (8) evaluated the effect of nitrogen level and age of stand on the palatability of Bermudagrass (Cynodon dactylon) by the difference method.

Recently, there has been a great deal of interest in the use of artificial rumen techniques, rather than expensive and time-consuming feeding trials, to determine the total digestible nutrients (TDN) content of feeds. Baumgardt, Cason, and Markley (3) used the artificial rumen to determine TDN values for three alfalfas and eight grasses, and found that correlation between their results and those obtained by conventional feeding trials was significant, with $r = 0.67$. Hershberger et al. (20) found a correlation coefficient of 0.92 between their in vitro digestion coefficients for thirty-five forages, and the values for digestible energy as obtained from feeding trials. Pigden and Bell obtained estimates of TDN and digestible crude protein that were "in close agreement" with those derived conventionally with sheep (34, p. 1239). Barnett (2, p. 468, 471) determined the *in vitro* digestibility of twenty-seven grass and grass-legume silages, and found that all his digestibility coefficients fell within six per cent of the *in vivo* values for sheep. Church and Petersen (10, p. 86-89) found that higher dry matter digestibility estimates were obtained when the rumen liquor/substrate ratio was increased, but little effect was noticed from changing the concentrations of mineral medium or the sources of rumen liquor. Fine grinding appeared to depress digestibility estimates in some cases. A pH in the vicinity of 6.5-7.0 was recommended for obtaining maximum digestibility estimates.

MATERIALS AND METHODS

General Information

In the course of this study, field experiments were carried out at the former Naval Air Station near Tillamook, Oregon, and on the South and Hyslop Agronomy Farms near Corvallis, Oregon. In addition, some work was done in the greenhouses on the Oregon State College campus at Corvallis.

The climate at Tillamook is marine, and that at Corvallis is modified marine. Precipitation and temperature data for both locations are given in Table 1, on the following page.

All trials at Corvallis were established on Willamette silty clay loam. This is a grayish-brown soil, well-drained and slightly acid, over a yellowish-brown subsoil. At Tillamook, the soil was Necanicum silt loam, a brown, well-drained, acid soil, high in organic matter, over a lighter brown subsoil. Since the Tillamook area was to be used for a fertility trial, a soil test was made by the Oregon State College Soil Testing Laboratory. Results were as follows:

Soil pH	4.80
Lime requirement, T./A.	6.00
Phosphorus, ppm	3.50
Potassium, meq./100 gm.	0.53
Calcium, meq./100 gm.	4.40

Table 1. Precipitation and mean temperatures at Corvallis and Tillamook.

		Precipitation in inches			Mean temperature, F.°		
Location	Period	Oct-Mar	Apr-Sep	Year	Oct-Mar	Apr-Sep	Year
Corvallis	1931-1955 average	30.25	6.86	37.21	45.3	61.2	53.2
"	Oct. 1, 1958-Sept. 30, 1959	34.25	6.27	40.52	45.6	59.2	52.4
"	Oct. 1, 1959-Sept. 30, 1960	26.55	8.59	35.14	43.2	59.3	51.2
Tillamook	1931-1955 average	70.81	18.72	89.53	----	----	----
"	Oct. 1, 1958-Sept. 30, 1959	70.64	27.15	97.79	47.2	54.6	50.9
"	Oct. 1, 1959-Sept. 30, 1960	61.49	22.13	83.62	45.8	54.2	50.0

Magnesium, meq./100 gm. 1.40

Nitrogen, per cent. 0.64

Two lots of velvetgrass seed were used. Lot A was hand-stripped from wild plants, most of which were growing along roadsides in the vicinity of Corvallis, in the summer of 1958. Lot B was acquired in 1959 from the Schrock Seed Company of Corvallis, where it had been removed from perennial ryegrass seed during the cleaning process. Seed in Lot B had undergone sufficient handling to remove most of the glumes and sterile florets, but most of this material was still present in Lot A, although bits of straw and other trash had been removed by hand screening. Lot A was used for all experiments except the management and velvetgrass invasion study.

Seed of the cultivated forage species used in this study was obtained from local seedhouses. Species and varieties used included Alta tall fescue, Oregon Perennial ryegrass, S-143 orchardgrass, New Zealand white clover, and common meadow foxtail. Mother Seed of white clover was used; all grass seed except that of meadow foxtail was Oregon Certified. All seed was sown and all fertilizer applied by hand broadcasting.

Germination and Dormancy

This experiment was a 2^4 factorial, in which velvetgrass seeds were submitted to the following treatments:

Glume removal; glumes were loosened by rubbing the florets between two boards faced with rubber, then removed by blowing with a Dakota Seed Blower.

Exposure to infra-red light; seeds were placed in a single layer in an aluminum pan, one and one-half inches below a 125-watt General Electric Industrial Infra-red bulb, and exposed for forty seconds.

Pre-chilling; seeds were held at five degrees C. for 139 hours before being placed in the germinating chamber.

Potassium nitrate solution; the substrate in the germinating dishes was saturated with a 0.2 per cent solution of potassium nitrate before the seeds were placed on it.

Seeds were germinated in four-inch Petri dishes on four layers of paper toweling, with 100 seeds per dish. The temperature cycle in the germinating cabinet was sixteen hours at twenty-five degrees C. and eight hours at fifteen degrees, with light provided during the warmer portion of the cycle. Four shelves in the cabinet were used, with each shelf representing a replication. The dishes were removed from the cabinet after seven days, and the number of germinated seeds counted. They were then returned to the cabinet for seven more days, but no further germination took place.

Shading and Seedling Growth

Four open-topped wooden boxes were constructed in the greenhouse, and each was divided into four compartments thirteen inches long, five inches wide, and twelve inches deep. Velvetgrass seeds were planted in thirteen by five inch metal loaf pans, twenty-four seeds per pan, and one pan placed in each compartment of each box. Light-intercepting screens were made of one-fourth inch plywood, in which holes had been drilled. One compartment in each box was left uncovered, and the other three were covered by screens which intercepted thirty-three, fifty-three, or seventy-eight per cent of the incoming light, as measured with a General Electric DW-68 exposure meter held two inches above the soil surface. The treatments were arranged within the boxes as a four by four Latin square. Twelve days after seeding and at seven-day intervals thereafter, height and number of leaves were recorded for four randomly-selected plants in each pan. Forty-two days after seeding, the four plants were cut off at ground level, oven-dried, and weighed to the nearest one-tenth of a milligram.

Fall and Winter Seedling Growth and Survival

On South Farm, in the fall of 1958, velvetgrass seed was planted in four-foot rows, 0.2 grams of seed per row, at approximately ten-day intervals. Seven plantings were made, with three replications arranged as a completely randomized block. The date of first emergence was recorded for each planting. Precipitation, amount of irrigation, and air and soil temperatures were recorded, the latter two on recording thermographs. A one-foot section of each row was harvested at the time of the first frost on November 18, 1958, and a second one-foot section was harvested March 12, 1959. Each time, the number of plants harvested and their total oven-dry weight were determined.

Seedling Growth and Competition

Seeds of velvetgrass, tall fescue, perennial ryegrass, orchardgrass, meadow foxtail, and white clover were sown in greenhouse flats on August 22, 1958. Three weeks later, seedlings were transplanted to six-inch pots. Four seedlings were placed in each pot, one at each corner of a two-inch square. When two species were placed in the same pot, there were two plants of each, with each species occupying a pair of diagonally opposite corners. The treatments used were as follows: (1) all species planted alone; (2) all cultivated species planted with velvetgrass; and (3) all cultivated species planted in pots in which three grams of oven-dried velvetgrass roots had been mixed into the upper two inches of soil. Three replications were used. After four weeks, the plants were cut off at ground level, oven-dried, and weighed. This experiment provided three types of information: (1) a comparison of the seedling growth rates of all the species involved; (2) an estimate of the effects of velvetgrass and dead velvetgrass roots on the growth of cultivated species; and (3) an estimate of the effects of cultivated species on the growth of velvetgrass.

Fertility and Competition

This study was established October 3, 1958, at Tillamook. Two weeks before planting, 200 pounds per acre of Mylone (3,5-dimethyltetrahydro-1,3,5,2H-thiadiazine-2-thione), a soil sterilant, was rototilled into the soil to control weeds. The area was seeded to orchardgrass, perennial ryegrass, tall fescue, and velvetgrass, at the rate of twenty-five viable seeds of each species per square foot. The area was then divided into three blocks of twelve plots each, each plot being seven by fifteen feet in size.

Levels of nitrogen, applied as ammonium nitrate, were (1) no nitrogen, (2) 100 pounds per acre, applied March 24, 1959, and (3) 100 pounds per acre, applied March 24, 1959, plus 100 pounds per acre, applied May 5, 1959. Superphosphate was applied March 24, 1959, at rates of 50 and 150 pounds of P_2O_5 per acre, and lime was applied October 3, 1958, at rates of two and six tons per acre. A factorial arrangement of treatments was used.

The plots were harvested three times in 1959 and in 1960, each time when approximately eight to ten inches high. A strip three feet wide was cut down the center of each plot, using a National small-plot mower adjusted to leave a three-inch stubble. Five or six grab samples, totalling about 150 grams of fresh material, were taken from the material in each plot as it lay in the swath. The samples from each plot were bulked and stored under refrigeration for later separation. The remainder of the material was weighed to the nearest one-tenth of a pound, mixed, and a sample of 600 to 800 grams taken for oven-drying, to determine the percentage of dry matter. Yield was recorded as dry matter per acre, expressed to the nearest one-hundredth of a ton.

The grab samples were separated by hand according to species; each component was oven-dried and weighed to the nearest decigram. For the first two cuttings in 1959, the material was separated into velvetgrass, cultivated grasses, and other species; thereafter, it was separated into velvetgrass, perennial ryegrass, orchardgrass, tall fescue, and other species. Botanical composition was recorded as percentages of the total forage production; any component contributing less than 0.5 per cent was recorded as a trace.

Simulated Grazing Management and Velvetgrass Invasion

This study was established May 25, 1959, at Hyslop Farm, using sod strips. The tall fescue, meadow foxtail, and orchardgrass were taken from a pasture test established in 1955, and the perennial ryegrass from an area seeded in September, 1958. The sod strips, one foot wide and two to four inches thick, were placed on a well-tilled soil surface, packed with a concrete roller, and irrigated daily for two weeks, until they were well rooted and top growth had resumed. At this time, ammonium nitrate and superphosphate were applied at the rates of 100 pounds of nitrogen and 50 pounds of P_2O_5 per acre. Broad-leaved weeds were removed by spraying with one pound of 2,4,5-T per acre on June 30, and weedy grasses were removed by hand weeding. No velvetgrass was present in the sod used. The plots were irrigated at approximately ten-day intervals during the summer.

The experiment was arranged as a split-split-plot, in a completely randomized block with four replications. The main plots were the different grass species, and were three by twelve feet in size. The two sub-plots in each main plot were clipped to different stubble heights, namely two and four inches. The sub-sub-plot treatments were different numbers of clippings during the season; one half of each sub-plot was clipped twice, on July 8 and September 18, while the other half was clipped on July 8, September 18, and October 27, for a total of three clippings. The clippings, intended to simulate different levels of grazing, were done with the National mower, with skids of appropriate height under the sickle bar. The clippings were removed from the plots and discarded.

On July 11, all plots were seeded with velvetgrass at the rate of approximately 250 seeds per square foot. The mean weight of 100 seeds had been determined by a series of weighings, so the amount of seed for each plot could be determined by weighing rather than by counting.

The test was harvested April 4, 5, 6, and 8, 1960. From an area one foot square in the center of each sub-sub-plot, all velvetgrass plants were cut at ground level, counted, oven-dried, and weighed to the nearest one-tenth of a milligram. All other vegetation was also harvested, dried, and weighed.

Palatability

Orchardgrass, perennial ryegrass, meadow foxtail, tall fescue, velvetgrass, and each of the cultivated grasses in a mixture with velvetgrass were seeded on South Farm on October 7, 1958. The seeding rate was 100 viable seeds per square foot for the pure stands, and 50 seeds per square foot for each component of the mixtures. Unfortunately, the mixture plots quickly became almost pure velvetgrass, so no useful information was derived from them. Plots were ten by fifteen feet, arranged in a completely randomized block design with four replications. No alleyways were left between the plots or around the edges, and the area was fenced to allow grazing by livestock.

Ammonium nitrate was applied at the rate of 200 pounds per acre on April 22, 1959, and 150 pounds of ammonium sulfate per acre was applied on June 30, 1960. Large amounts of white clover appeared in the stand during the winter of 1959-1960, but this was removed by spraying with two pounds of 2,4,5-T per acre on March 26, 1960. During the summer, the plots were irrigated at ten-day intervals.

The plots were grazed by livestock on four occasions, and consumption of the forage in each plot was estimated by observation and by the difference method. The animals were watched during a period of active grazing, and at five-minute intervals the number of animals grazing in each plot was recorded. Animals resting, ruminating, or travelling were not counted. The length of the observation period varied from grazing period to grazing period, as the amount of time which the animals spent in actual grazing was affected by temperature, growth stage of the grasses, and whether sheep or cattle were being used.

In evaluating consumption by the difference method, two quadrats, each one square foot in area, were clipped from each plot prior to grazing, and a second pair of quadrats was clipped after grazing. Material was cut at a height of one inch with large shears, oven-dried, and weighed. The difference in yield between the two clippings was taken as a measure of forage consumption. Consumption was calculated in kilograms of dry matter per plot.

On June 4, 1959, when all grasses were fully mature and flowering, the plots were grazed by twelve Hampshire ewes from 7:30 a.m. until 1:00 p.m. Observation data were recorded from 8:00 a.m. until 12 noon. The ewes, with an average weight of about 135 pounds, had been in dry lot for the week preceding the trial; before that, they had been on pasture.

The plots were grazed again July 30, 1959. At this time, all the grasses were six to eight inches tall, except perennial ryegrass, which was only about three or four inches tall. None of the species were headed. Twelve yearling crossbred rams, each weighing about 200 pounds, were turned onto the plots at 7:30 a.m., but the weather became very hot, and little grazing took place until evening. Therefore, the animals were left on the plots overnight and removed at 7:30 the next morning. Grazing was observed from 6:00 to 8:30 p.m. on July 30. The animals had been on good pasture for several weeks before being turned into the plots.

It had been planned to graze the plots on May 10, 1960, with six dry Hereford cows. Unfortunately, the gate into a nearby pasture was opened sometime during the night of the ninth, giving a herd of about fifteen cows, some with calves, free access to the plot area. As a result, the area had been well grazed and trampled by 7:00 a.m. on the tenth, when the situation was discovered. The cows were removed immediately, and the after-grazing clipping taken, as it was felt that sufficient grazing had already taken place. As a result of this nocturnal and unpremeditated grazing, no observation data are available for this trial. All the grasses were eight to ten inches tall, with no visible seed heads or flowering stems.

The last grazing trial took place on July 22, 1960, when five Hereford heifers, weighing about 1100 pounds each, grazed the plots from 5:30 a.m. until 1:00 p.m. The animals, which had been on pasture before the test, were observed from 6:00 to 7:30 a.m. All the grasses were mature and headed.

Composition and Digestibility

Samples of young, vegetative velvetgrass, orchardgrass, perennial ryegrass, tall fescue, and meadow foxtail were collected from an irrigated pasture trial at Hyslop Farm on August 12, 1960. The velvetgrass occurred as a weed in the plots; the other grasses were entries in the test. A sample of velvetgrass in the dough stage was collected from the palatability trial on July 20, 1960. These samples were oven-dried, ground with a Wiley mill, and analysed according to the procedures for feed analysis outlined in Horwitz (22, p. 283-296).

The samples were also subjected to artificial rumen fermentation in order to estimate the total digestible nutrient content. A quantity of material was removed from the rumen of a fistulated steer being fed a low-quality roughage diet. This material was strained through several layers of cheesecloth, then allowed to stand for a few minutes until all remaining particles had risen to the surface. With the aid of a water-tap aspirator, the clear rumen liquor was then drawn off into a flask. One gram of dried plant material was mixed with thirty milliliters of artificial saliva and five milliliters of rumen liquor in a wide-mouthed bottle, which was stoppered and placed in a water bath at a temperature of thirty-nine degrees C. The mixture was allowed to ferment for forty-eight hours, during which time carbon dioxide was bubbled through it. When fermentation was completed, the mixture was passed through a sintered glass filter, and the residue dried and weighed. The weight loss during fermentation was taken as an estimate of digestibility.

A check sample of tall fescue of known digestibility, as determined by conventional feeding trials, was fermented at the same time as the other samples. The actual digestibility was found to be 1.377 times as great as the estimated digestibility by the artificial rumen method, so all results were multiplied by the factor of 1.377. This adjustment would have been unnecessary if the animal from which the rumen fluid was obtained had been receiving a higher quality ration.

Statistical Analysis

The results of each experiment were subjected to the appropriate analysis of variance, and the F-test used to test for significant differences. Significance of mean squares is indicated in the usual manner; one asterisk (*) indicates significance at the five per cent level of probability, and two asterisks (**) indicate significance at the one per cent level. Where significant differences among means were found to exist, these were located by using Duncan's multiple range test. In tables of treatment means, differences are indicated by small letters placed after each mean value; those values followed by the same letter do not differ significantly at the five per cent level of probability.

RESULTS AND DISCUSSION

Germination and Dormancy

This experiment had two objectives; to determine the extent to which dormancy existed in dry, recently matured velvetgrass seed, and to find methods of breaking any dormancy which might be discovered. The main effects of the treatments applied to the seed are shown in Table 2, and an abbreviated analysis of variance is presented in Table 3. The interactions were summed in this table, as none of them were significant.

Apparently, little dormancy was present in the lot of seed used in this experiment. Small but significant increases in germination were produced by pre-chilling and by the addition of potassium nitrate solution to the substrate. Exposure to infra-red light had no effect.

The effect of removing the glumes was interesting. This treatment was included because it has been reported that the glumes of some species may contain substances which inhibit germination. If this were true in the case of velvetgrass, germination of seeds from which the glumes had been removed should have been increased. Instead, it was markedly decreased. This decrease was probably due to injuries suffered by the embryo during the process of glume removal. This seems a more likely explanation than any alternative, such as the presence of a growth-promoting substance in the glumes.

Table 2. The effect of various treatments on the germination of velvetgrass seed.

Treatment	Per cent germination Treated	Untreated	Difference
Removal of glumes	75.91	87.44	-11.53
Exposure to infra-red light	82.66	80.69	1.97
Pre-chilling	84.12	79.22	4.90
Potassium nitrate solution	83.62	79.72	3.90

Table 3. Analysis of variance of the effect of seed treatments on the germination of velvetgrass seed.

Source	d. f.		S. S.		M. S.
Replications	3		83.55		27.85
Treatments	15		2916.86		---
Glume removal		1		2127.52	2127.52**
Exposure to infra-red		1		62.02	62.02
Pre-chilling		1		385.15	385.15**
KNO_3 solution		1		244.14	244.14**
Interactions		11		98.04	---
Error	45		865.70		19.24
Total	63		3866.11		---

Conditions for establishment of velvetgrass are perhaps near optimum in irrigated pastures in mid- and late summer, just at the time when velvetgrass seeds are shattering from the head. High temperatures have slowed the growth of most pasture species, and grazing has removed much of the top growth, so that light may penetrate to the soil surface. Fertility may be reduced, as several months have passed since fertilizer was applied in the spring. Soil moisture is satisfactory because of irrigation. Therefore, light and moisture are adequate, fertility is lowered, and the ability of the desirable species to compete with the velvetgrass seedlings is reduced, just at the time when velvetgrass seeds are ready to germinate. The lack of seed dormancy, then, is of definite advantage to the species.

It seems likely, however, that a secondary seed dormancy may develop in velvetgrass. Foerster (15, p. 276) found large numbers of viable velvetgrass seeds in the soil of an area where little velvetgrass was growing, which would indicate that some of these seeds represented carry-over from previous seasons. Some of the results obtained from another experiment in this study indicate that cooler soil temperatures may increase the germination of velvetgrass, perhaps by breaking dormancy. Secondary dormancy would also have adaptive advantages, enabling velvetgrass to re-establish itself in the stand after a season which had been unfavorable for seed production, or after a season in which the velvetgrass plants were destroyed before seed was ripened.

Shading and Seedling Growth

Light readings were taken on the unshaded plots on several days during the course of this experiment, in order to obtain a rough estimate of the amount of light available. The readings obtained on the brightest and darkest days recorded are given in Table 4.

Table 4. Maximum and minimum light measurements on unshaded plots.

		Light in foot-candles		
Date	Weather	8 a. m.	12 noon	4 p. m.
September 3	Sunny	2000	2900	1000
October 15	Cloudy	400	1850	425

Shading had no significant effect on either the rate or percentage of emergence of the seedlings. No more plants emerged after September 9, six days after seeding. Mean emergence for each treatment was as follows: no shading, 39.6 per cent; thirty-three per cent shading, 40.6 per cent; fifty-three per cent shading, 42.7 per cent; and seventy-eight per cent shading, 37.5 per cent.

The effect of shading on the growth of the seedlings is summarized in Table 5, and the analysis of variance is given in Table 6. The leaf-height index shown in Table 5 is the product of

Table 5. The effect of shading on the growth of velvetgrass seedlings.

Per cent shading	Days after seeding	Average of sixteen seedlings: Leaf number	Height in mm.	Leaf-height index	Dry weight in mg.
0	12	1.00	43	43	--
"	19	1.94	71	137	--
"	26	2.50	144	359	--
"	33	3.00	176	529	--
"	42	3.81	225	859	9.18
33	12	1.00	38	38	--
"	19	1.31	73	95	--
"	26	1.94	93	180	--
"	33	2.31	155	359	--
"	42	3.06	183	560	3.76
53	12	1.00	43	43	--
"	19	1.06	70	74	--
"	26	1.88	80	151	--
"	33	2.00	121	242	--
"	42	2.69	152	408	2.49
78	12	1.00	39	39	--
"	19	1.00	59	59	--
"	26	1.25	71	89	--
"	33	1.69	76	129	--
"	42	1.75	86	151	1.89

Table 6. Analysis of variance of the effect of shading on the dry weight of velvetgrass seedlings, six weeks after seeding.

Source	d. f.		S. S.		M. S.
Replications (boxes)	3		55.81		18.60
Positions in box	3		118.58		39.53*
Shading	3		530.13		---
No shading vs. shading		1		501.17	501.17**
33% shading vs. heavier shading		1		26.14	26.14
53% shading vs. 78% shading		1		2.82	2.82
Error	6		40.14		6.69
Sampling	48		166.45		3.47
Total	63		911.11		---

the number of leaves on the plant and the height of the plant in millimeters. This is a fair estimate of seedling weight; the correlation between the leaf-height index at harvest and the dry weight at harvest was highly significant ($r = 0.81$).

Shading significantly reduced the growth of velvetgrass seedlings, as measured by dry weight at six weeks after seeding. Increasing the amount of light interception decreased the rate of growth, but there were no significant differences between the various degrees of shading. In addition to inhibiting the gain in weight of the seedlings, shading also inhibited growth in height and the production of new leaves.

These results were not unexpected, in view of the observed behavior of velvetgrass in the field. Velvetgrass infestations in lawns are less severe in areas shaded by trees or buildings. Velvetgrass may be removed from small areas in lawns by covering the ground with plastic sheeting or other opaque material for two or three days. Depriving velvetgrass of light for such a period will kill it, but will not permanently damage the lawn grasses. The failure of velvetgrass to become established in a heavy, vigorous stand of grass in a pasture must be due, at least in part, to the heavy shading of the soil surface which occurs under such conditions.

Fall and Winter Seedling Growth and Survival

In nonirrigated pastures, germination of velvetgrass seeds does not occur until the fall rains begin. Therefore, the rate of growth of velvetgrass seedlings during this fall period, and the effect of environmental conditions on seedling growth, are of interest. The experiment was also intended to evaluate the relationship between seedling size and winter survival.

The results of this experiment are presented in Table 7. Some of the observations are missing; by March 12, the plants from the September 8 and 15 seedings had grown so large that it was impossible to distinguish individual plants, and plant counts could not be made. As a result, there are no data for number of plants per foot of row and mean plant weight on March 12, or for percentage of survival, for these two plantings.

The number of days required for the emergence of the first plants was closely correlated with soil temperature, and slightly less closely correlated with air temperature. The single exception was the planting of September 26, when a lack of soil moisture delayed emergence. The results for the September 26 planting were omitted when calculating the values of the correlation coefficients. For the correlation between time required for emergence and soil temperature, $r = -0.88$; for the correlation with air temperature, $r = -0.86$. Both of these values were significant.

The number of plants emerging per foot of row showed a seasonal pattern. As soil temperature decreased and soil moisture increased, the number of seedlings emerging increased, reaching a maximum in October. Emergence then decreased as the soil temperature became much lower in November. An analysis of variance of the number of plants emerging per foot of row is presented in Table 8.

It is difficult to separate the effects of soil temperature and moisture on the number of plants emerging. The inhibiting effect of inadequate soil moisture on emergence is seen clearly in the data for the September 26 planting. The effect of high soil temperature is seen on the September 8 planting, which had the poorest emergence of the seven plantings. High temperatures seem not to slow emergence so much as to prevent it entirely in a

Table 7. Fall and winter emergence, growth, and survival of velvetgrass seedlings.

		Climatic data for period of emergence		Plants per foot of row			Mean plant weight	
Date planted	Days until emergence	Mean soil temperature	Precipitation	Nov. 18	Mar. 12	Per cent survival	Nov. 18	Mar. 12
		degrees F.	inches				mg.	mg.
Sept. 8	8	68.2	1.00	27.3 d[1]	----	----	146.5 a	----
Sept. 15	10	65.2	2.52[2]	32.3 cd	----	----	53.5 b	----
Sept. 26	18	68.8	0.33	28.7 d	26.7	95.6 a	9.2 c	314.4 a
Oct. 7	12	63.9	2.02	44.3 a	29.7	66.9 b	3.2 c	168.3 b
Oct. 16	16	56.5	2.76	38.7 ab	27.7	71.1 b	0.9 c	72.9 c
Oct. 25	12	57.5	2.25	40.0 ab	25.7	64.3 b	0.4 c	27.2 c
Nov. 8	27	51.8	6.44	36.7[3] bc	15.0	41.0 c	0.2[3] c	6.6 c

[1] Figures in the same column followed by the same letter do not differ significantly at the 5% level.

[2] Includes approximately two inches of water applied as irrigation.

[3] Observations made December 17, twelve days after emergence.

Table 8. Analysis of variance of emergence of velvetgrass seedlings, November 18.

Source	d. f.	S. S.	M. S.
Replications	2	24.00	12.00
Planting dates	6	699.14	116.52**
Error	12	124.01	10.33
Total	20	847.15	---

Table 9. Analysis of variance of weight of velvetgrass seedlings, November 18.

Source	d. f.	S. S.	M. S.
Replications	2	213.94	106.97
Planting dates	6	53647.59	8941.26**
Error	12	755.26	62.94
Total	20	54616.79	---

Table 10. Analysis of variance of survival of velvetgrass seedlings, November 18-March 12.

Source	d. f.	S. S.	M. S.
Replications	2	856.80	428.40
Planting dates	4	4545.33	1136.33**
Error	8	1191.64	148.96
Total	14	6593.77	---

Table 11. Analysis of variance of weight of velvetgrass seedlings, March 12.

Source	d. f.	S. S.	M. S.
Replications	2	5447.08	2723.54
Planting dates	4	191314.08	47828.52**
Error	8	17905.55	2238.19
Total	14	214666.71	---

fraction of the seed planted. Those seedlings which emerged from the soil at high soil temperatures did so very quickly. In view of the increased germination produced in the experiment on germination and dormancy by pre-chilling the seed, it was concluded that emergence increased at lower soil temperatures because the seed was chilled sufficiently to break the dormancy of some of the dormant seeds. This increase in emergence with a decrease in soil temperatures continued until soil temperatures became so low that germination of the non-dormant seed was inhibited.

The average weight per plant on November 18, the percentage of the plants which survived over the winter, and the average weight per plant on April 12, all decreased significantly from the earliest planting to the latest. Analyses of variance for these three sets of data are presented in Tables 9, 10, and 11.

The correlation between fall plant weights and winter survival is interesting, though not unexpected. The r value of .85 is significant. This correlation indicates that velvetgrass invasion might be prevented if the growth of velvetgrass seedlings could be retarded to the point that they would not become large enough to survive the winter.

Seedling Competition

This experiment was intended to provide three types of information. First, the seedling growth rates of velvetgrass and several pasture species were compared. Second, the growth rates of the pasture species were studied under competition with velvetgrass and in the presence of killed velvetgrass roots in the soil. Finally, the effect of competition with pasture species on the growth of velvetgrass was investigated.

Velvetgrass made the fastest seedling growth of the six species studied. This ability enables velvetgrass to become firmly established in a new pasture seeding. For this reason, it is probably better to control velvetgrass in the existing stand, rather than attempting to establish a new stand free of velvetgrass. The data comparing seedling growth rates are shown in Table 12, and the analysis of variance appears in Table 13.

Neither competition with velvetgrass nor the presence of killed velvetgrass roots in the soil had any effect on the growth of the pasture species. Similarly, none of the pasture species grown in association with velvetgrass had any effect on its growth. No indication was found for the existence of interspecific antagonisms, as have been believed to exist between meadow foxtail and velvetgrass and between white clover and velvetgrass. No evidence was found for the presence of phytotoxic materials in living or dead velvetgrass roots. These data are presented in Tables 14 and 16, and the analyses are given in Tables 15 and 17.

Table 12. Dry weights of seedlings of velvetgrass and five pasture species, fifty days after seeding.

Species	Weight in milligrams
Velvetgrass	184.3 a[1]
Perennial ryegrass	141.4 ab
Tall fescue	137.3 ab
Orchardgrass	121.2 abc
Meadow foxtail	71.8 bc
White clover	37.7 c

[1] Weights followed by the same letter do not differ significantly at the 5% level.

Table 13. Analysis of variance of seedling weights.

Source	d. f.	S. S.	M. S.
Replications	2	1457.31	728.66
Species	5	83138.16	16627.63*
Error	10	42930.07	4293.01
Sampling	18	26662.75	1481.26
Total	35	154188.29	---

Table 14. Effect of competition with velvetgrass and killed velvetgrass roots in the soil on the growth of pasture species.

Pasture species	Treatment: Grown alone	Grown with velvetgrass	Roots in soil
	Dry weight in milligrams at 50 days		
Perennial ryegrass	141.4	143.8	88.2
Tall fescue	137.3	146.1	108.1
Orchardgrass	121.2	92.0	99.2
Meadow foxtail	71.8	137.0	126.9
White clover	37.7	39.1	52.9

Table 15. Analysis of variance of the effect of competition with velvetgrass and killed velvetgrass roots in the soil on the growth of pasture species.

Source	d. f.		S. S.		M. S.
Replications	2		804.55		402.28
Pasture species	4		87583.96		---
Clover vs. grasses		1		79896.78	79896.78*
Among grasses		3		7687.18	2562.39
Error (a)	8		72002.98		9000.37
Treatments	2		4153.81		2076.90
Treatments x species	8		30813.48		3851.68
Error (b)	20		75818.03		3790.90
Sampling	45		59707.57		1326.83
Total	89		330884.38		---

Table 16. Growth of velvetgrass seedlings in association with pasture species and alone.

Associated species	Dry weight of velvetgrass plants in mgm., 50 days after seeding
Tall fescue	237.2
Meadow foxtail	221.4
White clover	212.5
Velvetgrass alone	184.3
Perennial ryegrass	145.5
Orchardgrass	114.8

Table 17. Analysis of variance of growth of velvetgrass seedlings in association with pasture species.

Source	d. f.	S. S.	M. S.
Replications	2	6726.72	3363.36
Associated species	5	67725.88	13545.18
Error	10	120435.69	12043.57
Sampling	18	41138.87	2285.49
Total	35	236027.16	---

Fertility and Competition

The effects of nitrogen, phosphorus, and lime on the botanical composition of the plots is shown in Table 18, and the effect of fertilization on the percentage of velvetgrass present is shown in more detail in Table 19. The analysis of variance for velvetgrass content is presented in Tables 20 and 21. Table 20 shows the combined analysis for both 1959 and 1960; Table 21 shows a separate analysis for each year.

Differences between cuttings were not considered of sufficient importance to be included in the analysis. The amount of velvetgrass harvested per plot per cutting was found by multiplying the plot yield by the per cent velvetgrass present in the harvested forage. The yields of velvetgrass for the three cuttings were then summed to find the total annual yield of velvetgrass from the plot. This sum was then divided by the total forage yield for the year, and the resulting figures, representing the percentage of the annual yield which was contributed by velvetgrass, were subjected to analysis.

The amount of velvetgrass present in the stand was not influenced by the application of phosphorus. The significant increase in yield obtained by supplying additional phosphorus indicates that a phosphorus deficiency existed, but velvetgrass and the cultivated grasses apparently responded equally to the added phosphorus.

Table 18. The effect of nitrogen, phosphorus, and lime on the botanical composition of a pasture stand, 1959 and 1960.

Fertilizer per acre			Per cent in 1959			Per cent in 1960				
Pounds nitrogen	Pounds P_2O_5	Tons lime	Velvet-grass	Cultivated grasses	Other[1]	Velvet-grass	Per. rye-grass	Orchard-grass	Tall fescue	Other
0	50	2	38.0	59.6	2.4	61.3	17.3	1.2	4.1	16.1
0	50	6	35.3	59.6	5.1	44.3	22.5	7.7	3.8	21.7
0	150	2	34.3	59.8	5.9	49.0	15.9	2.2	3.4	29.5
0	150	6	38.3	59.3	2.4	54.7	18.0	2.5	3.1	21.7
100	50	2	32.3	65.3	2.4	57.7	14.7	7.7	3.4	16.5
100	50	6	27.7	70.6	1.7	72.0	13.9	3.3	3.3	7.5
100	150	2	32.7	65.8	1.5	52.3	11.6	4.3	2.0	29.8
100	150	6	21.7	75.3	3.0	60.7	20.9	6.1	6.3	6.0
200	50	2	42.7	56.6	0.7	78.3	7.6	7.0	1.8	5.3
200	50	6	32.7	65.5	1.8	52.7	18.8	18.0	4.7	5.8
200	150	2	31.0	68.3	0.7	77.0	8.9	7.1	2.0	5.0
200	150	6	29.3	70.4	0.3	66.0	15.0	11.0	3.2	4.8

[1] Chiefly *Lotus uliginosus*, *Agrostis* spp., and *Anthoxanthum odoratum*, with small amounts of *Trifolium dubium*, *Trifolium procumbens*, and *Plantago* spp.

Table 19. The effect of nitrogen, phosphorus, and lime on the percentage of velvetgrass in the pasture stand, 1959 and 1960.

Fertilizer per acre			Per cent velvetgrass								
Pounds nitrogen	Pounds P_2O_5	Tons lime	5 May 1959	22 Jun 1959	6 Aug 1959	1959[1]	14 May 1960	19 Jul 1960	15 Sep 1960	1960[1]	1959-1960 Mean
0	50	2	23	46	50	38.0	56	71	49	61.3	49.7
0	50	6	19	40	42	35.3	43	49	36	44.3	39.8
0	150	2	14	46	41	34.3	58	49	35	49.0	41.7
0	150	6	15	42	40	38.3	52	60	46	54.7	46.5
100	50	2	20	37	36	32.3	54	62	50	57.7	45.0
100	50	6	17	37	35	27.7	62	84	65	72.0	49.8
100	150	2	23	36	45	32.7	54	53	44	52.3	42.5
100	150	6	11	28	28	21.7	49	77	51	60.7	41.2
200	50	2	23	51	41	42.7	64	90	71	78.3	60.5
200	50	6	19	40	23	32.7	48	60	52	52.7	42.7
200	150	2	16	37	36	31.0	67	87	67	77.0	54.0
200	150	6	15	37	28	29.3	55	82	59	66.0	47.7

[1] Per cent of total production for the year.

Table 20. Analysis of variance of the effect of nitrogen, phosphorus, and lime on the percentage of velvetgrass in the pasture stand, 1959-1960.

Source	d. f.		S. S.		M. S.
Replications	2		165.33		82.66
Years	1		13612.50		13612.50**
Error (a)	2		133.34		66.67
Treatments	11		2419.17		---
Nitrogen		2		716.08	358.04*
Phosphorus		1		98.00	98.00
Lime		1		329.39	329.39*
N x P		2		95.09	47.54
N x L		2		602.53	301.26*
P x L		1		200.00	200.00
N x P x L		2		378.08	189.04
Years x treatments	11		2519.83		---
Years x N		2		1243.75	621.88**
Years x P		1		26.89	26.89
Years x L		1		.05	.05
Years x N x P		2		292.52	146.26
Years x N x L		2		845.53	422.76**
Years x P x L		1		64.23	64.23
Years x N x P x L		2		46.86	23.43
Error (b)	43		3335.33		77.56
Total	71		22185.50		---

Table 21. Analyses of variance of the effect of nitrogen, phosphorus, and lime on the percentage of velvetgrass in the pasture stand, 1959 and 1960.

Source	d. f.	Mean squares 1959	Mean squares 1960
Replications	2	28.00	121.33
Treatments	11	---	---
Nitrogen	2	195.58*	784.34**
Linear	1	40.04	1568.17**
Quadratic	1	351.13**	0.50
Phosphorus	1	113.78	11.11
Lime	1	169.00[1]	160.44
N x P	2	36.69	154.11
N x L	2	59.25	664.78**
P x L	1	18.78	245.45
N x P x L	2	48.36	164.11
Error	22	40.12	116.03
Total	35	---	---

[1] Significant at .051 level.

The response of velvetgrass to nitrogen and lime is more difficult to interpret. In general, lime reduced the amount of velvetgrass in the stand. The application of nitrogen caused a slight decrease in the percentage of velvetgrass present in the first harvest year, but appeared to cause an increase in the second year. A puzzling nitrogen x lime interaction appeared in 1960 (see Table 21), in which the suppression of velvetgrass by the application of six tons of lime per acre seemed to be reversed at the 100-pound nitrogen level. The nature of this interaction is shown graphically in Figure 1.

When the amount of "other species" present in 1960 was examined, it was found that a high occurrence of these species was accompanied by a reduction in the amount of velvetgrass in the stand. It was therefore proposed that the reversed response of velvetgrass to lime in 1960 on the 100-pound nitrogen plots was not due to an increase in velvetgrass when six tons of lime was applied, but to a decrease in velvetgrass when two tons of lime was applied. This decrease resulted from increased competition from bentgrass (*Agrostis* spp.) and sweet vernalgrass (*Anthoxanthum odoratum*), which thrive under acid soil conditions and respond favorably to nitrogen application.

The apparent increase in velvetgrass at high nitrogen levels in 1960 has a similar explanation; at low nitrogen levels, bentgrass and sweet vernalgrass replace velvetgrass. If lime is added while nitrogen remains deficient, big trefoil (Lotus uliginosus) becomes an aggressive competitor, crowding out not only velvetgrass but bentgrass and sweet vernalgrass as well. The competitive nature of the response of velvetgrass and these other weedy species to nitrogen and lime may be seen by comparing Figures 1 and 2.

Figure 2 shows the response of the combined velvetgrass and "other species" fractions to nitrogen and lime. The application of higher rates of lime markedly reduced the total content of weedy species at all levels of nitrogen in both harvest years. The analysis of variance of total weed content in Table 22 shows that this reduction was highly significant; neither nitrogen nor phosphorus had any significant effect.

The effect of fertilization on yield is shown in Table 23, and the analysis of the data appears in Table 24. Significant responses to all three fertilizers were noted. Six tons of lime per acre produced .20 tons more dry matter per acre than two tons of lime. The response to phosphorus was smaller; the increase in yield between 50 and 150 pounds of P_2O_5 per acre was .13 tons of dry matter per acre.

The nature of the response to nitrogen is shown in Table 25. While each added increment of nitrogen produced a significant increase in yield in 1959, there were no differences among rates of nitrogen in 1960. Any nitrogen not used by the crop during the

FIGURE 1. THE EFFECT OF NITROGEN & LIME ON THE PER CENT OF VELVETGRASS IN THE PASTURE STAND, 1959 & 1960.

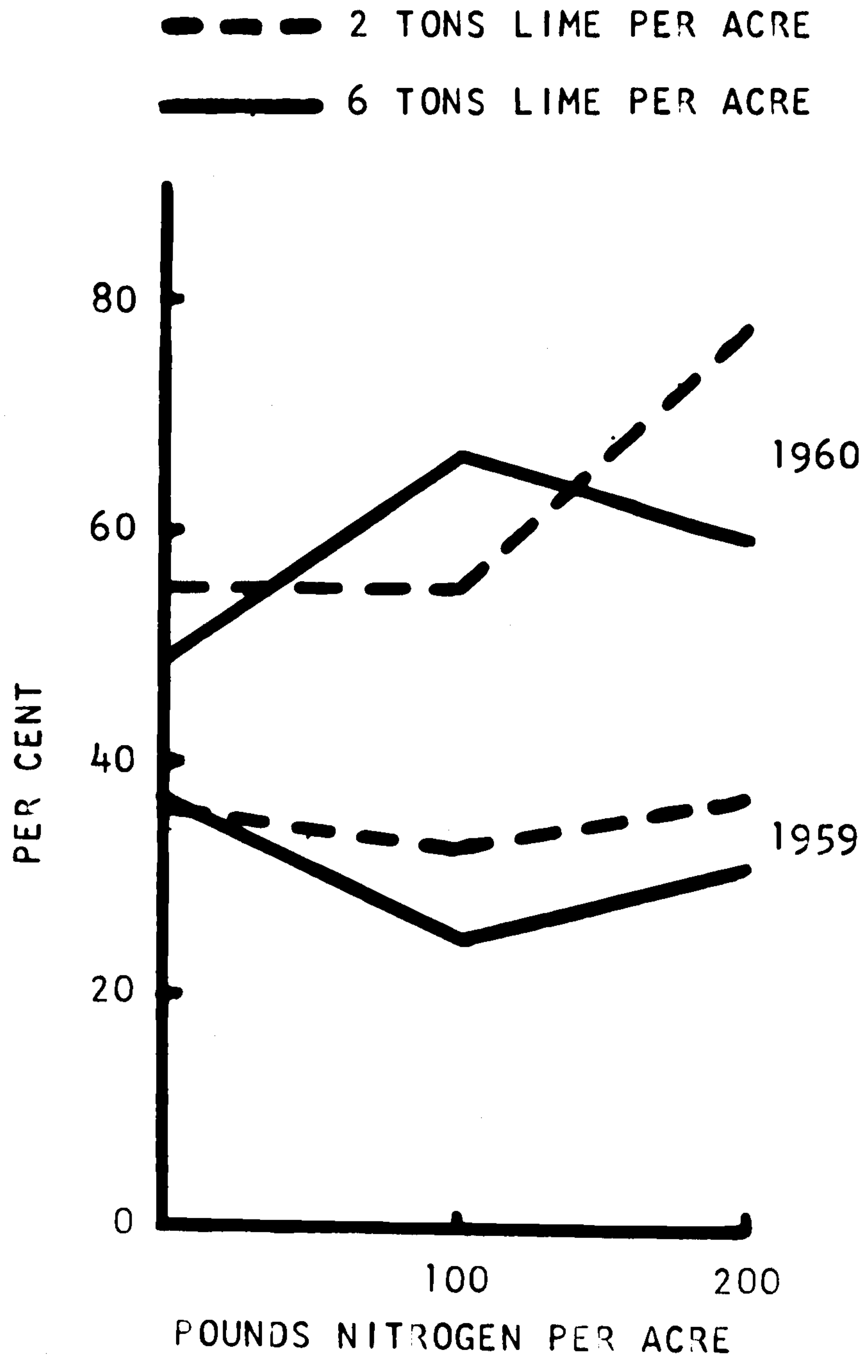

FIGURE 2. THE EFFECT OF NITROGEN & LIME ON THE PER CENT OF VELVETGRASS & OTHER WEEDY SPECIES IN THE PASTURE STAND, 1959 & 1960.

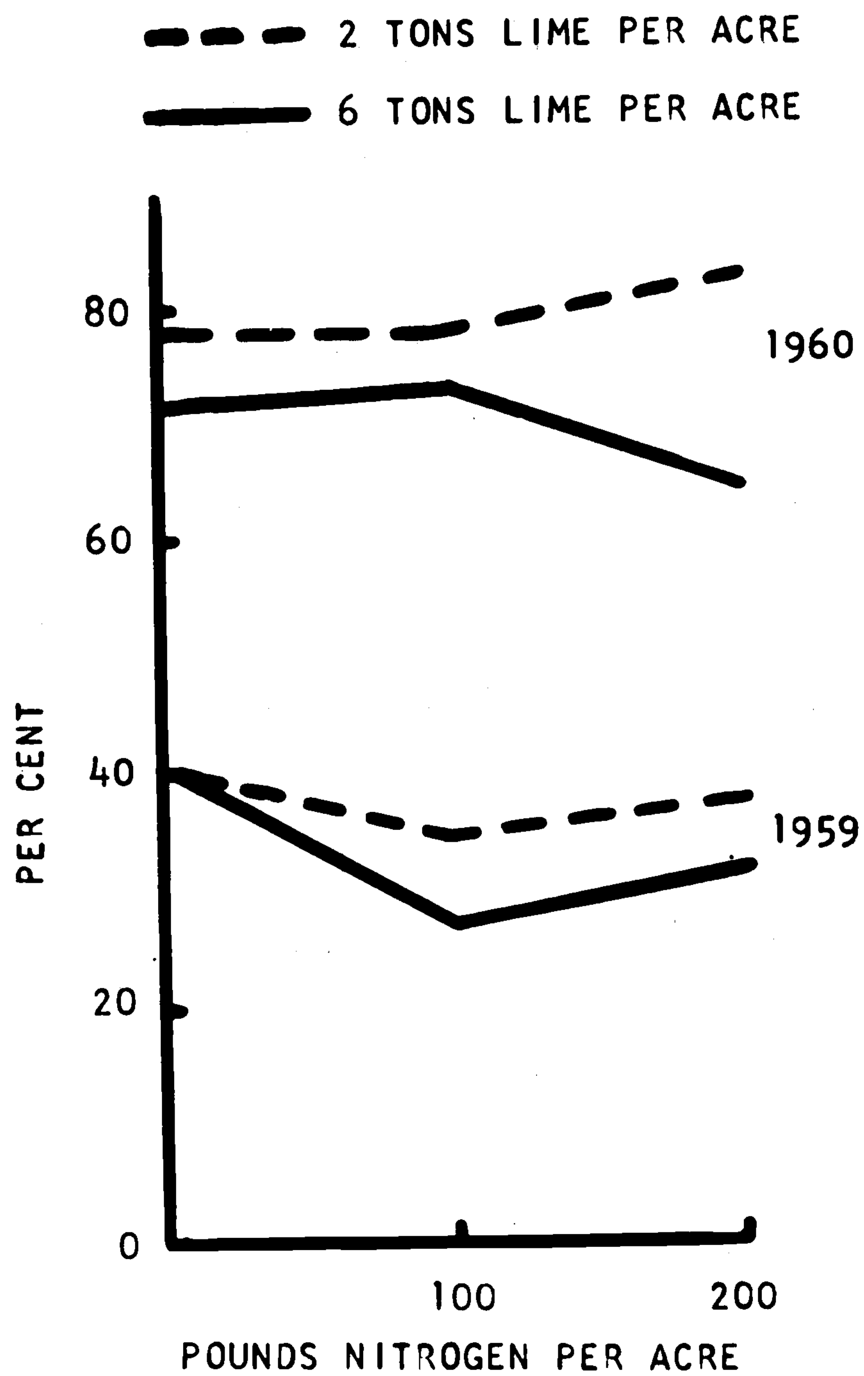

Table 22. Analysis of variance of the effect of nitrogen, phosphorus, and lime on the percentage of velvetgrass plus other weedy species in the pasture stand, 1959-1960.

Source	d. f.	S. S.	M. S.
Replications	2	259.75	129.88
Years	1	29282.00	29282.00**
Error (a)	2	350.08	175.04
Treatments	11	1803.00	---
Nitrogen	2	154.33	77.16
Phosphorus	1	4.50	4.50
Lime	1	1058.00	1058.00**
N x P	2	61.00	30.50
N x L	2	170.34	85.17
P x L	1	4.50	4.50
N x P x L	2	350.33	175.16
Years x treatments	11	1152.33	---
Years x N	2	273.00	136.50
Years x P	1	249.39	249.39
Years x L	1	107.56	107.56
Years x N x P	2	179.88	89.94
Years x N x L	2	134.77	67.38
Years x P x L	1	4.49	4.49
Years x N x P x L	2	203.24	101.62
Error (b)	43	3032.84	70.53
Total	71	34880.00	---

Table 23. The effect of nitrogen, phosphorus, and lime on the yield of the pasture stand, 1959 and 1960.

Fertilizer per acre			Yield in tons of dry matter per acre								
Pounds nitrogen	Pounds P_2O_5	Tons lime	5 May 1959	22 Jun 1959	6 Aug 1959	Total, 1959	14 May 1960	19 Jul 1960	15 Sep 1960	Total, 1960	1959-1960 Mean
0	50	2	.50	.69	.23	1.44	.45	.61	.24	1.29	1.36
0	50	6	.38	.99	.22	1.60	.55	.65	.27	1.46	1.53
0	150	2	.46	.69	.15	1.30	.43	.76	.29	1.49	1.40
0	150	6	.57	1.01	.23	1.82	.54	.88	.37	1.79	1.80
100	50	2	1.01	1.77	.14	2.92	.34	.57	.19	1.11	2.02
100	50	6	1.53	1.82	.17	3.51	.49	.56	.23	1.32	2.41
100	150	2	.98	1.86	.24	3.08	.44	.84	.30	1.58	2.33
100	150	6	1.24	2.01	.22	3.46	.61	.51	.24	1.36	2.41
200	50	2	.98	2.43	.48	3.90	.45	.68	.19	1.33	2.61
200	50	6	1.17	2.39	.45	4.01	.59	.55	.28	1.42	2.71
200	150	2	1.27	2.55	.41	4.23	.39	.62	.21	1.22	2.72
200	150	6	1.46	2.38	.42	4.26	.51	.50	.25	1.26	2.76

Table 24. Analysis of variance of the effect of nitrogen, phosphorus and lime on the yield of the pasture stand, 1959-1960.

Source	d. f.	S. S.	M. S.
Replications	2	.9589	.4794
Years	1	44.6827	44.6827**
Error (a)	2	.1912	.0956
Treatments	11	18.6049	---
Nitrogen	2	17.1670	8.5835**
Phosphorus	1	.2964	.2964*
Lime	1	.7160	.7160**
N x P	2	.0234	.0117
N x L	2	.1630	.0815
P x L	1	.0098	.0098
N x P x L	2	.2293	.1146
Years x treatments	11	24.6410	---
Years x N	2	23.8287	11.7774**
Years x P	1	.0001	.0001
Years x L	1	.1780	.1780
Years x N x P	2	.4022	.2011
Years x N x L	2	.1948	.0974
Years x P x L	1	.0213	.0213
Years x N x P x L	2	.0159	.0080
Error (b)	43	2.7121	.0631
Total	71	91.7908	---

Table 25. The effect of nitrogen on the yield of the pasture stand, 1959-1960.

Pounds nitrogen per acre	Yield, tons per acre	
	1959	1960
0	1.54 c[1]	1.51 cd
100	3.24 b	1.34 cd
200	4.10 a	1.30 d

[1] Yields followed by the same letter do not differ significantly at the 5% level.

1959 growing season was apparently leached from the soil profile by the winter rains.

Therefore, any effect of nitrogen on botanical composition in 1960 must have been a reflection of effects manifested in 1959, rather than a direct effect. "Other species" increased at low nitrogen levels in 1960 because they had become firmly established on the low-nitrogen plots in 1959. They could not invade the plots which received high rates of nitrogen in 1959, so were not present on these plots in significant amounts in 1960, although the low nitrogen supply was favorable for their growth. A second consequence of the complete depletion of applied nitrogen in 1959 is that at least part of the increase in velvetgrass from 1959 to 1960 can be considered as an effect of nitrogen deficiency.

In view of the complications introduced in 1960 by the absence of applied nitrogen and the invasion of "other species," any conclusions as to the effect of fertility on the ability of velvetgrass to compete in a pasture stand should be based largely on the 1959 results. On this basis, it was concluded that the application of lime could be expected to significantly suppress the growth of velvetgrass. The response of velvetgrass to nitrogen followed a quadratic pattern; there was significantly less velvetgrass on the plots receiving 100 pounds of nitrogen per acre than on those receiving no nitrogen, but the application of 200 pounds of nitrogen per acre caused a reversal of this trend. This may be explained by assuming that both velvetgrass and the cultivated grasses (nearly all perennial ryegrass in 1959) in this experiment responded favorably to nitrogen application, but the cultivated grasses showed a more rapid response than did velvetgrass. Thus at intermediate nitrogen levels, the growth of cultivated grasses would be favored over that of velvetgrass. If it is further assumed that the response of the cultivated grasses levels off more quickly than that of velvetgrass, then the competitive advantage of the cultivated grasses would be lost at higher nitrogen levels, and velvetgrass would no longer decrease.

Several additional pieces of information were uncovered in this experiment. The most important of these was the demonstration of the great competitive ability of velvetgrass. In a single year, the average percentage of velvetgrass over all plots nearly doubled, increasing from 33 per cent in 1959 to 60.5 per cent in 1960. This increase is presumably due to vegetative spread, since the velvetgrass was always harvested before seed was produced, and the application of the soil sterilant supposedly destroyed any seed present in the soil. Some velvetgrass seeds probably survived; certainly enough viable seeds of bentgrass, sweet vernalgrass, and big trefoil remained to make these species important constituents of the stand in 1960. However, most of the velvetgrass plants found in the plots in the spring of 1960 appeared to be large, year-old plants, rather than new seedlings.

This large increase in velvetgrass also indicated the futility of trying to control an established infestation of velvetgrass by fertilization alone. It would probably be necessary to destroy such an infestation with chemicals, and then try to prevent any reinfestation by a proper fertilization and management program. It has been suggested that frequent clipping of the stand to prevent seed production would result in the eventual disappearance of velvetgrass, but velvetgrass often persists on golf greens in spite of frequent close mowings over a long period of years.

The seasonal growth pattern of velvetgrass is indicated by the seasonal fluctuations in the amount present in the stand. This pattern follows the production pattern of the stand as a whole, but with a more pronounced peak in early summer (compare Tables 19 and 23). This uneven distribution of production makes velvetgrass a poor prospect as a pasture species.

Finally, the failure to obtain any yield response to nitrogen the year after application indicates that nitrogen should be applied at least every year at Tillamook, and probably twice during the year, on nonirrigated grass swards. This conclusion could be extrapolated to cover any area of heavy forage production and high annual precipitation.

Simulated Grazing Management and Velvetgrass Invasion

Three sets of measurements were taken on each plot at the time of the final harvest in April. The number of velvetgrass plants per square foot was determined to obtain an estimate of the survival of the velvetgrass plants. The average weight of the velvetgrass plants in each plot was found and used as a measure of vigor. Finally, the total forage yields were determined, and used as measures of the vigor and productivity of the forage grasses. The effects of the various treatments on these three measurements are summarized in Table 26, and the analyses of variance are shown in Table 27.

The number of velvetgrass plants in the stand was significantly higher in the plots which had been clipped to a two-inch height than in those clipped to four inches. On the plots clipped to a height of four inches, the additional clipping in the fall had no effect on the number of velvetgrass plants in the stand. On the plots clipped to a two-inch stubble, the additional clipping

Table 26. The effects of simulated grazing (clipping) treatments on the number and average weight of velvetgrass plants in the stands of four pasture grasses, and on the yields of the grasses.

Pasture grass	Clipping height	Date of last clip	Plants per square foot	Average plant weight in mg.	Yield in gm. per sq. ft.
Orchardgrass	2"	Oct. 15	15.00 a[1]	8.75 a	28.75 b
	2"	Sept. 27	4.25 b	0.98 b	40.75 b
	4"	Oct. 15	2.75 b	2.98 ab	32.75 b
	4"	Sept. 27	0.00 b	0.00 b	60.00 a
Perennial ryegrass	2"	Oct. 15	27.75 a	21.45 a	15.50 b
	2"	Sept. 27	22.50 a	19.82 a	20.75 ab
	4"	Oct. 15	0.50 b	1.10 b	23.25 ab
	4"	Sept. 27	0.00 b	0.00 b	32.50 a
Tall fescue	2"	Oct. 15	13.25 a	16.42 b	40.00 b
	2"	Sept. 27	10.75 ab	35.92 a	61.50 a
	4"	Oct. 15	4.25 b	8.10 b	53.25 a
	4"	Sept. 27	4.00 b	7.12 b	54.50 a
Meadow foxtail	2"	Oct. 15	31.00 a	42.00 a	23.25 b
	2"	Sept. 27	18.75 b	17.30 bc	28.00 ab
	4"	Oct. 15	6.50 c	26.50 b	30.00 ab
	4"	Sept. 27	1.25 c	6.82 c	37.50 a

[1] Figures in the same column, referring to the same grass, followed by the same letter, are not significantly different at the 5% level.

Table 27. Analyses of variance of the effects of simulated grazing (clipping) treatments on the number and average weight of velvetgrass plants in the stands of four pasture grasses, and on the yields of the grasses.

		Mean squares		
Source	d. f.	Plant number	Average weight	Yield
Replications	3	196.61*	584.40	199.14*
Grasses	3	268.11*	1186.06*	2640.81**
Error (a)	9	39.64	172.60	37.40
Clipping height	1	3844.00**	3053.94**	1064.40**
Height x grasses	3	305.12*	221.87	53.18
Error (b)	12	57.01	130.00	65.28
Date of last clipping	1	390.06**	376.84*	1969.15**
Date x grasses	3	46.35	682.66**	149.76
Date x height	1	121.00*	23.16	.75
Date x height x grasses	3	6.54	149.89	221.82*
Error (c)	24	25.84	84.37	61.37
Total	63	---	---	---

increased the number of velvetgrass plants in the stands of orchardgrass and meadow foxtail, but had no effect on the tall fescue and perennial ryegrass plots.

It appears that the survival of the velvetgrass plants was influenced much more strongly by the height of clipping than by the date of the last clipping in the fall. It might be argued that most plant growth had stopped by the time of the last cutting, so that no effect could be expected. However, the winter production of all grasses was significantly reduced by taking an additional clipping on October 15, so it appears that growth was still in progress at this time.

The difference in the magnitude of the effects of clipping height and fall clipping is largely a matter of timing in relation to the life cycle of velvetgrass. The height-of-clipping treatments were applied over a longer period, and at a time when the velvetgrass plants were particularly sensitive to environmental pressures. The detrimental effect of shading on the growth of velvetgrass seedlings was demonstrated in an experiment described earlier. In the stands clipped to a four-inch stubble height, it is probable that the growth of the velvetgrass plants was severely limited by low light intensity. Quite probably, many of the velvetgrass plants had already died by the time of the last clipping in the fall. Those plants that remained would be in poor condition to take advantage of the increased light intensity and reduced competition resulting from an additional clipping, and there would be no detectible difference in survival between the two dates of final clipping. On the other hand, the velvetgrass plants in the plots clipped to a two-inch stubble were apparently able to maintain a more nearly normal growth rate during the season. Therefore, they were more vigorous at the time of the last cutting, and could take advantage of the resulting improvement in environment. Therefore, when plots were clipped to a two-inch height, survival of velvetgrass plants was increased on the plots which were clipped on October 15, although this increase was significant only in the case of orchardgrass and meadow foxtail.

The pattern of the effects of clipping on the average weight of the velvetgrass plants is more complex. In general, the velvetgrass plants were larger on the plots which were clipped to a two-inch height and on those which were cut for the last time on October 15. However, there is an exception; among the tall fescue plots, the largest velvetgrass plants occurred in the plots which were clipped to two inches and received their last clipping September 27. The magnitude of the differences between the two clipping heights and the two dates of final clipping also differ among species.

The immediate effect of the clipping treatments is on the vigor of the forage grasses, as measured by their yield. As is shown in Table 26, the treatments which adversely affect the growth of the forage grasses are the same ones which encourage the growth of velvetgrass; clipping to a two-inch high stubble and taking a final cutting on October 15.

The effects of the clipping treatments on the three variables measured, and the interrelationships between the variables, can be understood if it is assumed that each velvetgrass plant must occupy an environmental niche or micro-site, in which environmental conditions are favorable for its growth. These niches occur in random fashion throughout the stand, wherever there is an opening in the vegetative cover which allows sufficient light for growth to penetrate to the level of the velvetgrass plant, and in which root competition for water and nutrients is reduced. Any treatment which increases the vigor of the forage grass will reduce the number of such niches in the stand, and will make conditions in the remaining niches less favorable for the growth of velvetgrass plants.

An examination of the correlations shown in Table 28 will show that the survival of velvetgrass plants (number of niches) is more closely correlated with vigor and yield of the pasture stand than is the growth of the velvetgrass plants (suitability of the niches for growth of velvetgrass). The poor correlation between yield of the stand and growth of the velvetgrass plants is due to two factors: the variability of the niches in which velvetgrass grows, and the impossibility of sampling those velvetgrass plants which make "zero growth." Microsites of different sizes and

Table 28. Correlations of yield of four pasture grasses with number and average weight of velvetgrass plants in the stand.

	Yield and number		Yield and weight	
Grass	r	P[1]	r	P
Perennial ryegrass	-.800	.001	-.619	.001-.005
Meadow foxtail	-.751	.001	-.508	.010-.025
Orchardgrass	-.418	.1-.2	-.228	.2-.4
Tall fescue	-.208	.4-.5	.016	.5+

[1] Probability of a larger r value in a population with no correlation.

suitabilities react differently to an increase in vigor in the pasture stand; a relatively large site may decrease considerably in size, but will still be adequate for the growth of a healthy velvetgrass plant, while a small site will disappear altogether. Also, although the latter niche has certainly become less suitable for the growth of velvetgrass, the decrease cannot be measured, because there is no plant there to measure; it has made "zero growth."

There are marked differences among the four grasses in respect to the degree of correlation between stand vigor as measured by yield, and the number and size of the velvetgrass plants in the stand. Both correlations are highly significant for meadow foxtail and perennial ryegrass. The stands of these grasses were quite uniform. Under the most severe clipping treatment, they were quite open and susceptible to invasion by velvetgrass, but under less severe treatment the stands gradually closed up and velvetgrass was excluded. The stands of tall fescue were quite bunchy and open; as a result, niches suitable for the growth of velvetgrass remained in even the heaviest stands, and correlations were poor. The poor correlations observed in the case of orchardgrass are due to its strong competitive ability; under all but the most severe clipping treatment, clipping to a two-inch stubble with the final clipping October 15, velvetgrass was almost completely excluded. As a result, there were no differences in the number or weight of velvetgrass plants among three of the treatments. However, there were differences in yield, so correlations were poor.

Palatability

To facilitate comparisons between the results of the four different grazing trials and the two different methods of estimating palatability, the estimated consumption and observation values were converted to relative consumption values. In each of the seven sets of estimates, the most palatable grass was assigned a value of 100; the value for each of the other grasses in the set is equal to the estimated consumption of that grass, expressed as a per cent of the consumption of the most palatable grass. These relative values are shown in Table 29.

The analyses of variance and multiple range tests were calculated from the original data, before conversion to relative consumption values. The analyses are shown in Table 30.

The grasses in this study appear to fall into three groups in respect to palatability. Orchardgrass is clearly the most palatable. Meadow foxtail and perennial ryegrass are somewhat less acceptable to grazing animals, but there appears to be little difference between them. Tall fescue and velvetgrass are still less palatable, with the latter probably the least acceptable of the five grasses.

Immature velvetgrass appears to be fairly palatable to livestock. When the grasses were grazed while completely vegetative and immature, no significant differences in palatability were detected among them. However, significant differences were found among the grasses in two of the four palatability estimates made on the mature grasses, and in each case, velvetgrass was the least palatable of the five grasses. In the remaining two estimates, velvetgrass likewise ranked low in palatability, but the differences among grasses were not significant.

Immature perennial ryegrass appeared in this test to be unpalatable to sheep, but this is probably not true. The ryegrass had been grazed very heavily during the previous trial, and had made a slow recovery. The amount of forage present at the time of grazing was quite small, and it was this low yield, rather than

Table 29. Relative consumption of five grasses by grazing animals, as estimated by the observation and difference methods.

Grazing animals	Sheep	Sheep	Sheep	Sheep	Cattle	Cattle	Cattle
Growth stage of grasses	Immature	Immature	Mature	Mature	Immature	Mature	Mature
Method	Obs.	Diff.	Obs.	Diff.	Diff.	Obs.	Diff.
Grass species							
Orchardgrass	81 a[1]	90 a	100 a	78 a	87 a	35 a	100 a
Meadow foxtail	100 a	100 a	27 b	54 a	15 a	100 a	84 ab
Perennial ryegrass	23 a	40 a	59 ab	100 a	100 a	85 a	53 b
Tall fescue	48 a	94 a	62 ab	33 a	15 a	25 a	60 ab
Velvetgrass	74 a	46 a	24 b	37 a	98 a	0 a	0[2] c
Coefficient of variation	76%	56%	58%	102%	108%	106%	90%

[1] Means in the same column followed by the same letter do not differ at the 5% level.

[2] Actual consumption estimate was negative.

Table 30. Analyses of variance of consumption of five grasses by grazing animals, as estimated by the observation and difference methods.

Grazing animals		Sheep	Sheep	Sheep	Sheep	Cattle	Cattle	Cattle
Growth stage of grasses		Immature	Immature	Mature	Mature	Immature	Mature	Mature
Method		Obs.	Diff.	Obs.	Diff.	Diff.	Obs.	Diff.
Source	d. f.	M. S.	M. S.	M. S.	M. S.	M. S.	M. S.	M. S.
Replications	3	12.98	.94	109.65	9.55	1.32	7.52	.97
Grasses	4	21.80	.62	349.30*	3.89	.41	17.68	4.18**
Error	12	14.73	.33	92.57	4.69	.86	6.81	.50
Total	19	---	---	---	---	---	---	---

a lack of palatability, which restricted consumption of the perennial ryegrass.

The experimental errors and coefficients of variation encountered in this study were very high. This is characteristic of such studies; Peterson, Weswig, and Cowan, in their study of palatability differences in tall fescue, reported coefficients of variation as large as 443% (33, p. 118). Much of the error is due to variations among the grazing preferences of the animals used, and to variations within the grazing plots. The sampling technique used in the difference method may also contribute to error. In this study, two quadrats per plot may not have been an adequate sample for determining plot yield. A third source of error is the inability of the observer to distinguish between animals which are merely nibbling at the forage and those which are actively grazing.

Composition and Digestibility

Neither Morrison (31) nor Schneider (35) have reported any data on the composition of velvetgrass, so a complete feed analysis was made. To provide a basis for comparison, samples of several forage grasses in a similar stage of maturity, grown under similar conditions, were analysed at the same time. The data thus obtained are more useful than data given in the above sources, since the

Table 31. Chemical composition and laboratory digestible nutrients (LDN) of velvetgrass and several forage grasses.

Species	Per cent dry matter	Per cent of dry matter					
		LDN	Crude protein	Crude fat	Crude fiber	Nitrogen-free extract	Ash
Perennial ryegrass	23.3	88.1 a[1]	17.8	3.9	23.5	42.5	12.3
Orchardgrass	21.5	83.3 ab	17.2	4.3	27.2	40.7	10.6
Tall fescue	23.7	75.7 b	17.8	3.3	23.9	43.6	11.4
Meadow foxtail	25.9	75.7 b	20.2	3.6	22.6	44.3	9.3
Velvetgrass, young	24.0	77.1 b	16.0	2.9	23.4	46.5	11.2
Velvetgrass, dough stage	----	58.5 c	11.8	3.1	27.2	47.0	10.9

[1]LDN estimates followed by the same letter do not differ significantly at the 5% level.

Table 32. Analysis of variance of LDN content of velvetgrass and several forage grasses.

Source	d. f.	S. S.	M. S.
Grasses	5	1015.25	203.05**
Error	6	100.55	16.76
Total	11	1115.80	---

stage of maturity and other factors affecting the latter are seldom adequately described.

The chemical composition and digestible nutrient content of the grasses, on a dry matter basis, are shown in Table 31. Laboratory digestible nutrients (LDN) is an estimate of TDN; it is probably an overestimation, but provides a picture of relative values.

The LDN content of velvetgrass is significantly lower than that of perennial ryegrass in a similar stage of maturity; the analysis of variance of LDN content appears in Table 32. Velvetgrass also has the lowest crude protein content of the five grasses. There do not appear to be any important differences among the immature grasses in regard to the other components. Velvetgrass in the dough stage, as would be expected, has a much lower LDN and crude protein content and a higher crude fiber content than young velvetgrass.

Control of Velvetgrass

Velvetgrass must be regarded as an undesirable constituent of pastures. Its seasonal pattern of growth is objectionable; maximum forage production is in spring and early summer, with almost no production after early July. The forage produced is only poorly utilized, because grazing animals find it unpalatable; this was shown by Ennik (14) as well as by the trials carried out in this study. From a nutritional standpoint, velvetgrass is certainly no better than the common forage grasses, and perhaps not as good as some.

Because of its low forage quality and undesirable production pattern, velvetgrass should be removed from pasture stands so that it may be replaced by better species. When large amounts of velvetgrass occur in the stand, control can be achieved only by the use of herbicides. The studies of Lee (27) and Goetze (17) have shown that a number of materials, including diuron, CIPC, and atrazine, will remove velvetgrass from a pasture without causing serious damage to the desirable species. Trials are now in progress at Oregon State College to determine the rates and dates of application which will give the most satisfactory control of velvetgrass under a variety of conditions.

Velvetgrass may also be controlled by managing the pasture in such a way that velvetgrass is unable to compete with the desirable species. Management can change the microenvironment so that velvetgrass cannot compete successfully for light, water, and mineral nutrients. Velvetgrass will then be unable to grow as rapidly or reproduce as readily as the other species present, and will eventually be replaced by them. Unfortunately, "eventually" may be quite a long time if there is a great deal of velvetgrass in the pasture. Controlling velvetgrass by pasture management practices is practical only if a relatively small proportion of the pasture vegetation consists of velvetgrass, or if the objective is to prevent velvetgrass from invading a pasture.

Velvetgrass is better adapted to acid soils than most of the forage grasses, so the application of lime will enable them to compete more successfully with velvetgrass. In this study and that of Brenchley (6), the application of lime definitely suppressed velvetgrass, and Norman (32) found that velvetgrass was no problem on calcareous soils.

Velvetgrass responds more slowly to nitrogen than the forage grasses, so moderate applications of nitrogenous fertilizers will reduce the amount of velvetgrass in the stand. However, as more nitrogen is applied, velvetgrass will continue to respond after the response of the forage grasses has leveled off, so the downward trend in velvetgrass content in the stand will be reversed. This type of response was observed in this study, and has been reported by a number of other workers. The point at which the reversal occurs varies widely, indicating that further work is necessary to determine what factors influence the response of velvetgrass to the application of nitrogen. It seems likely that the nitrogen content of the soil and the nitrogen requirements of the species growing in association with velvetgrass are important.

The potassium and phosphorus requirements of velvetgrass appear to be similar to those of the more desirable grasses. Some workers have reported changes in the amount of velvetgrass in a pasture stand, following applications of potassium and phosphorus fertilizers. Other workers have been unable to detect any response. The application of superphosphate had no effect on the amount of velvetgrass present in this study, even though yield increased, indicating that the soil was deficient in phosphorus.

The effect of soil fertility on the amount of velvetgrass in the stand is quite variable. In the absence of more basic information, it is probably best to adopt a fertilizer program designed to give maximum forage yields; this will assure a vigorous growth of the forage species, which should enable them to compete successfully with velvetgrass.

The response of velvetgrass to grazing varies with the stage of growth of the plants. Intensive grazing is necessary to control older plants, since they are not as palatable as the forage grasses, and animals will not eat them readily until they have achieved nearly complete utilization of the forage grasses. On the other hand, seedlings are best controlled by moderate grazing, which makes it possible to maintain the pasture stand in a vigorous condition. If the forage species are growing vigorously and producing enough top growth to keep the soil surface shaded at all times, the velvetgrass seedlings will not be able to get enough light or to compete for water and soil nutrients and they will not survive.

Ennik (14) found that rotational grazing prevented any increase in the amount of velvetgrass in the pasture, while continuous grazing permitted an increase. Under rotational grazing, it was possible to get such complete utilization that the velvetgrass was eaten along with the rest of the forage, preventing the velvetgrass plants from making seed and reducing their vigor and ability to compete.

In this study, it was found that velvetgrass seedlings could not survive in a stand where four inches of top growth were maintained at all times. Even harvesting late in the fall did not favor velvetgrass survival, although late fall harvesting stimulated invasion of stands which were periodically clipped to a two-inch height.

On the basis of the observed effects of grazing on velvetgrass, it seems probable that grazing management should change according to the season of the year. From the beginning of grazing in the spring until early summer, grazing pressure should be heavy to curtail seed production and reduce the vigor of the velvetgrass plants. For the remainder of the season, grazing pressure should be relaxed somewhat, so that a complete vegetative cover of vigorously-growing plants can be maintained to inhibit the growth of velvetgrass seedlings. To maintain this degree of control over grazing intensity will probably require the use of a rotational grazing system.

These recommendations have been based, for the most part, on the results of tests in which the forage has been harvested by clipping, rather than by grazing. Jones (26, p. 460-461) found that changes in botanical composition which occurred under clipping were not always repeated under grazing. In the case of velvetgrass, however, grazing should be more detrimental to it than clipping, because of its low resistance to trampling, which has been reported by several workers.

Velvetgrass control will be most successful as part of an integrated system of good pasture management. Proper management includes periodic applications of herbicides, a fertilizer program based on the nutrient status of the soil and the demands of the forage species being grown, and properly controlled grazing. Under such a system, velvetgrass and other weedy species will be excluded from the stand, and the production of forage and animal products will be increased.

SUMMARY AND CONCLUSIONS

Velvetgrass is a common weed in western Oregon pastures, but little was known about the conditions which favor or impede the establishment and increase of velvetgrass in pastures, or about the value of velvetgrass as a forage. In order to study these problems, a series of field and greenhouse experiments were carried out at Corvallis and Tillamook, Oregon, during the winter of 1958-59 and the 1959 and 1960 growing seasons.

Velvetgrass seeds were found to be capable of germinating immediately at maturity. However, some evidence was found for the development of a secondary dormancy in the soil.

Velvetgrass seeds will germinate over a wide range of soil temperatures, from those of midsummer to those of late fall. Emergence is more rapid at higher temperatures, but the percentage of emergence is greater at lower temperatures.

Shading strongly inhibits the growth of velvetgrass seedlings. However, it has no effect on germination and emergence.

The survival of velvetgrass seedlings over the winter is directly correlated with the weight of the seedlings. The value of r was 0.85, which was significant.

No evidence was found for the production of phytotoxic substances from living or dead velvetgrass roots, or for the existence of specific antagonisms between velvetgrass and any of several forage grasses. Velvetgrass was found to have the fastest seedling growth of any of the species tested, and this may account for the great competitive ability of velvetgrass seedlings.

The application of lime to pasture plots containing velvetgrass resulted in a significant decrease in the amount of velvetgrass present. The application of 100 pounds of nitrogen per acre also produced a significant decrease in the amount of velvetgrass, but applying 200 pounds of nitrogen per acre had no effect. It appears that the response of the cultivated grasses to nitrogen is more rapid than the response of velvetgrass, but that velvetgrass continues to respond to the application of additional nitrogen longer than the cultivated grasses. The application of superphosphate had no effect on the amount of velvetgrass in the stand. All three fertilizers significantly increased forage yields.

When pasture plots were clipped periodically to a height of two inches, they were more susceptible to velvetgrass invasion than when clipped to a height of four inches. Clipping in late fall increased the susceptibility of the plots to velvetgrass invasion if a two-inch stubble was left, but had no effect if a four-inch stubble was left. The increased susceptibility to velvetgrass invasion which resulted from short or late fall clipping was due to the opening up of the stand, which allowed light to penetrate and reduced the ability of the forage grasses to compete for water and mineral nutrients.

Mature velvetgrass was found to be less palatable to grazing animals than most of the common forage grasses. No differences were found among the grasses when they were grazed before maturity.

Velvetgrass was similar to the cultivated grasses in chemical composition, but it had the lowest protein content of the five grasses analysed. Velvetgrass was also low in digestible nutrients; however, only perennial ryegrass was significantly higher. In view of its low forage quality and undesirable production pattern, control of velvetgrass in pastures was discussed. The use of herbicides was recommended when the infestation was severe. A program of fertilization and controlled grazing, which would increase the ability of the desirable species to compete with velvetgrass, was recommended for controlling light infestations and preventing invasion of stands free from velvetgrass.

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