AN ABSTRACT OF THE THESIS OF

MATTHEW MULANAX for the MASTER OF SCIENCE in Farm Crops
(Name) (Degree) (Major)

presented on November 18, 1971
(Date)

Title: THE EFFECT OF DEFOLIATION AND NITROGEN APPLICATION ON THE SEED YIELD OF LINN PERENNIAL RYEGRASS (LOLIUM PERENNE L) AND MERION KENTUCKY BLUEGRASS (POA PRATENSIS L)

Abstract approved: Redacted for privacy
David O. Chilcote

The effect of clipping and supplemental nitrogen application on seed production of Linn perennial ryegrass and Merion Kentucky bluegrass was studied. Clipping and nitrogen treatments did not significantly affect the seed yield of Linn perennial ryegrass during the 1967 growing season. The seed yield of Merion Kentucky bluegrass was significantly increased by a combined winter-spring clipping regime when compared with the unclipped control. Application of 136 pounds of nitrogen in two equal spring applications significantly reduced the seed yield of Merion Kentucky bluegrass. Spring clipping tended to reduce the number of fertile tillers per unit area for both species. Supplemental nitrogen generally increased the number of fertile tillers per unit area for Linn perennial ryegrass. Application of 30 pounds of additional nitrogen delayed the period of head emergence for Linn perennial ryegrass. The time of pollen shed of Merion Kentucky bluegrass was delayed by all clipping regimes.

THE EFFECT OF DEFOLIATION AND NITROGEN APPLICATION ON THE SEED YIELD OF LINN PERENNIAL RYEGRASS (LOLIUM PERENNE L) AND MERION KENTUCKY BLUEGRASS (POA PRATENSIS L)

by

MATTHEW WILLIAM MULANAX

A THESIS

submitted to

OREGON STATE UNIVERSITY

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1973

APPROVED:

Redacted for privacy

Professor of Farm Crops
In Charge of Major

Redacted for privacy

Head of Department (Farm Crops)

Redacted for privacy

Dean of Graduate School

Date thesis is presented November 18 1971

Typed by Susan Toner

TABLE OF CONTENTS

LIST OF TABLES

THE EFFECT OF DEFOLIATION AND NITROGEN APPLICATION ON THE SEED YIELD OF LINN PERENNIAL RYEGRASS (LOLIUM PERENNE L) AND MERION KENTUCKY BLUEGRASS (POA PRATENSIS L)

INTRODUCTION

The Willamette Valley of Oregon is one of the major areas of seed production for cool season grass species because of its environment and geographic location. From an environmental standpoint, the winters are mild, the growing seasons are long, the summers are usually cool and dry. There is also an adequate supply of land which is most effectively utilized for annual and perennial grass seed production. The mild winters allow for survival and early regrowth of annual and perennial grasses.

A number of species and varieties are grown in the valley for use in lawns and turfs, pastures and conservation cropping throughout the world. In 1968 there were 92 varieties registered and 17 species for certified seed increase in the Willamette Valley. Nearly all of the perennial ryegrass and Merion Kentucky bluegrass produced in the United States is grown in the Willamette Valley.

The management practices followed by grass seed producers in the Willamette Valley are unique when compared with other grass seed producing areas. After harvest most of the annual and perennial seed fields are burned to remove the straw and stubble residue which harbors disease-causing microorganisms, insects and weed seeds. Burning incinerates some of the perennial grass crowns and tends to rejuvenate the stand. The subsequent regrowth of the perennial grasses after burning and the growth of newly established annual grass species is utilized for sheep and cattle pasture.

The fact that a grass seed production field can be grazed during the winter months offers the grower an additional source of revenue in the form of monthly pasture rental or the addition of a livestock enterprise to his farming system. The amount of herbage available and the carrying capacity of the pasture are determined by the individual grass species and the geographic location. Although the economic considerations of forage production are important to the grass seed grower, primary emphasis must be given to the management of the fields for their greatest production of quality seed.

This study was initiated to determine 1) the length of time a given species can be grazed without substantially reducing seed yield, 2) the amount of supplemental nitrogen required to maintain seed production and 3) the time of supplemental nitrogen application.

LITERATURE REVIEW

The utilization of grass seed stands for forage as well as seed production is practiced in many regions; however, there are only limited reports in the literature concerning the effects of grazing and supplemental nitrogen application on the subsequent seed yield. The information which is available indicates that species differ in their response to grazing and supplemental nitrogen application and presents conflicting reports on the benefits of such practices.

DEFOLIATION AND SEED PRODUCTION

Time of defoliation

Roberts (58) reported that winter grazing at different dates from October to January did not significantly reduce the seed yield of timothy and perennial ryegrass when extra nitrogen was applied. However, the seed yield of S. 50 timothy was reduced for three successive harvest years by spring grazing in April or May or winter plus spring grazing even though extra nitrogen was applied. On the other hand, S. 101 perennial ryegrass showed no reduction in seed yield after spring grazing or winter plus spring grazing when defoliation was no later than mid-April. When grazing was delayed until May and a drought occurred, there was a significant seed yield reduction. Winter defoliation was found to delay lodging until after anthesis. It was thought that normal pollination and seed set may be seriously affected if lodging occurred before anthesis. March and mid-April grazing of perennial ryegrass resulted in an extended period of panicle emergence and uneven seed ripening.

In a three year study Evans (22) found that autumn defoliation of S.24 perennial ryegrass delayed heading the first year, brought it on earlier the second year and had little influence the third year. The relative number of tillers was depressed the first year and increased the second year by autumn defoliation.

Work by Roberts (56) showed that October defoliation of perennial grasses reduced the over-wintering top growth, lessened the degree of winter burn and tended to enhance tillering. The total seed yield was not materially reduced by defoliation until two weeks before inflorescence formation, but was reduced by cutting at ear formation.

Peterson and Loomis (54) found that fall (September 30 to October 30) clipping of Kentucky bluegrass reduced the number of flowers to about one-tenth the number on unclipped plus nitrogen plants and essentially prevented flowering of unfertilized plants. The difference in flower numbers was considered to be due to reduced flower growth rate rather than differences in induction and differentiation.

Schwanbom and Froier (63) reported that orchardgrass and perennial ryegrass seed yields in Denmark were reduced by using regrowth after seed harvest for silage or grazing. Application of 100 to 150 kilograms of saltpeter per hectare (14.6 to 22.0 pounds of nitrogen per acre) was required to eliminate the seed yield reduction caused by grazing.

In studies involving S. 143 orchardgrass, S. 215 meadow fescue, S. 170 tall fescue, S. 59 red fescue and S. 23 perennial ryegrass, Green and Evans (32) found that October grazing in the seeding year reduced the first seed crop in all species except ryegrass. Grazing from December to late April reduced the seed yield in all species. Tall fescue and red fescue were the most seriously affected by grazing while meadow fescue and perennial ryegrass were the least affected.

Earlier work by Green and Evans (33) showed that October and April grazing stimulated the production of fertile tillers in orchardgrass, but reduced the weight of seed produced per tiller. As the age of the stand increased, the yield was maintained at a higher level than the no-grazing controls by extra tillers which were induced by grazing between October and April. In S. 215 meadow fescue, grazing did not stimulate tillering to the same extent as in orchardgrass. The net seed yield of orchardgrass was found to be reduced by April or May grazing but not by winter grazing in October or December. The aggregate seed yield of S. 215 meadow fescue was enhanced over a three year period by October and April grazing.

Lambert (39) could find no significant effect on orchardgrass seed yield from any cutting treatments when compared with no cutting. Nitrogen added after October defoliation did not increase the yield of seed when compared with plants which were cut at the same time but not fertilized. The production of tillers was not affected by cutting on any dates, but the weight of seed per ear was usually reduced by cutting.

Lambert (40) found that the majority of the tillers of timothy were produced in the autumn, but they are also produced continuously throughout the winter. Neither the pattern nor the amount of tiller production was affected by cutting treatments. Cutting was found to have little effect on the percent of fertile tillers except where floral primordia were removed by a cut in late May. In all treatments at least 90 percent of the ears at harvest were produced by tillers initiated the previous autumn.

Evans (28) reported that "autumn-winter" defoliation results in an increase in the number of fertile tillers in both orchardgrass and timothy. Over a three-year period defoliation reduced the weight of seed per 1,000 tillers in these two species.

Gardner and Wiggans (30) found that single clippings at the 4, 5, and 7 leaf stages reduced the grain yield of two mid-season spring oat varieties by 9, 28, and 98 percent, respectively. Clipping was found to retard floral development and reduce test weight per bushel.

In a series of experiments designed to compare grazing during the winter, spring, winter and spring and no grazing, Lambert (43) as well as Roberts (57) found that grazing orchardgrass increased the number of panicles but reduced the weight of 1,000 seeds, as well as the number and weight of viable seed per panicle.

Duration of defoliation

Huokuma (37) reported that the number of tillers in orchardgrass was reduced by four to eight cuttings to ground level with a tiller mortality of about 90 percent after eight cuttings.

Stechman and Lande (66) found that late and season-long clipping or grazing of wild oat, soft chess, rip gut brome and Mediterranean barley reduced the head height and number of spikelets per head. In the nursery clipping reduced the number of heads per plant and the weight of 100 seeds.

Grazing versus clipping

Rapid winter grazing by sheep had no affect on the seed yield of timothy the following summer as reported by Evans (29).

Similar results were reported by Roberts (57) who found that the seed yield of leafy orchardgrass does not appear to be reduced by winter grazing when extra nitrogen is applied. Grazing by sheep was found to be more detrimental to seed yield than defoliation by cutting because sheep tend to pull out tillers and give uneven defoliation.

DEFOLIATION AND FERTILIZER APPLICATION

There are frequent reports in the literature discussing fertilizer applications on cool season grass species grown for seed, but very few of these reports are concerned with the relationship between nitrogen fertilizer application and defoliation. Although contradictory reports appear in the literature, more often than not different species are involved.

Rate of application

Working with two levels of nitrogen (N and 6N), Wilson (68) found that the high level of nitrogen promoted earlier floral initiation, ear emergence and a greater percentage of fertile tillers in perennial ryegrass, Italian ryegrass and timothy.

Peterson and Loomis (54) showed that nitrogen applied to Kentucky bluegrass in the early fall stimulated vegetative growth and tillering and increased the number of flowers produced by about five times the number on the unfertilized plants.

Langer (45) found that variation in the level of nitrogen affected the number of tillers and leaves, leaf area and dry weight during the first year of timothy production. Differentiation and ear emergence occurred slightly earlier at high nitrogen levels. At high nitrogen levels ear length was increased as well as the percentage of fertile tillers among the total number produced after the first few weeks of tillering.

According to Lambert (44) the number of panicles in timothy was increased with nitrogen application. The number and weight of viable seed produced per panicle was found to increase with increasing nitrogen levels and spring applications.

Evans (29) reported that the application of ammonium sulfate does not influence the seed yield of S. 48 timothy, but stimulates leafy growth at the expense of seed bearing tillers and increases the weight of seed per tiller.

Work by Lambert (41) showed that orchardgrass seed yield may be reduced by nitrogen application due to subsequent winter injury.

Gardner and Wiggans (30) found that an application of nitrogen did not compensate for the deleterious effect of clipping spring oats. As mentioned earlier in this review, the deleterious effects of clipping were retarded floral development and reduced test weight per bushel.

Date of application

Evans (22) reported that a nitrogen application to perennial ryegrass as late as anthesis corrected a seed yield depression caused by autumn defoliation.

In studies of orchardgrass and meadow fescue, Green and Evans (33) found no significant seed yield differences between a single application of nitrogen in March and the same quantity split between March and May.

Evans (27) found nitrogen applications increased the seed yield, number of fertile tillers and weight of seed per fertile tiller during the first year of production in S. 23 perennial ryegrass when compared with the unfertilized controls. There was no difference due to nitrogen application dates.

According to Lambert (41, 42, 43) a spring or a split autumn and spring application of nitrogen was more effective than an autumn application on orchardgrass. However, an autumn nitrogen application gave the maximum number of panicles. Spring applications of nitrogen were found to produce the greatest weight of 1,000 seeds and the greatest number and weight of viable seed per panicle. Increased rates of nitrogen were found to increase the number of panicles, the number and weight of viable seeds per panicle and the number of seeds per unit area, but did not affect the weight of 1,000 seeds.

In S. 37 orchardgrass Evans (27) found no significant increase in the number of tillers due to nitrogen application or the time of application. There was, however, an increase in the weight of seed per fertile tiller due to nitrogen application. When 400 pounds of ammonium sulfate was applied to orchardgrass, the total seed yield was increased 200 to 400 pounds per acre. A single application in March was more effective than the same quantity in September. A split application in the spring gave no advantage over a single March application. An equal split between autumn and spring gave a smaller seed yield than a spring application and a larger seed yield than an autumn application. One-fourth of the nitrogen applied in the autumn and three-fourths in the spring was just as effective as the whole quantity applied in the spring.

METHODS AND MATERIALS

An experiment was designed to measure the effects of defoliation duration and the rate and date of nitrogen application on the seed yield components, inflorescence emergence and anthesis of two cool season grass species. Mowing to a height of one inch above the soil surface was used to simulate grazing.

Plots were established during the first week of October 1966 in pedigreed fields of Merion Kentucky bluegrass and Linn perennial ryegrass located on the Paul Pugh farm near Shedd, Oregon. A split plot experimental design with four replications was used with nitrogen treatments as the main plots and clipping treatments as the subplots. The main plots were 20 feet by 40 feet and the subplots were 10 feet by 20 feet.

The clipping regimes were as follows:

Winter clipping	October 15 through January 15
Spring clipping	January 15 through March 27
Winter-spring clipping	October 15 through March 27
No clipping	

Eight nitrogen treatments were selected for both grass species. These treatments are summarized in Tables 1 and 2.

Table 1. Rates and dates of nitrogen application for Linn perennial ryegrass.

Nitrogen treatments	Rate of nitrogen application in pounds per acre			
	October 15	February 1	March 31	Total N
Control	34	34	34	102
Equal split spring		50	50	100
15 pounds additional N	49	34	34	117
	34	49	34	117
	34	34	49	117
30 pounds additional N	64	34	34	132
	34	64	34	132
	34	34	64	132

Table 2. Rates and dates of nitrogen application for Merion Kentucky bluegrass.

Nitrogen treatments	Rate of nitrogen application in pounds per acre			
	October 15	February 1	March 31	Total N
Control	45	45	45	135
Equal split spring		68	68	136
15 pounds additional N	60	45	45	150
	45	60	45	150
	45	45	60	150
30 pounds additional N	75	45	45	165
	45	75	45	165
	45	45	75	165

The first 25 pounds of nitrogen in each treatment and species was applied as ammonium sulfate to supply approximately 25 pounds of sulfur per acre. The remaining nitrogen was applied as ammonium nitrate.

Phosphorous was supplied in a blanket application of superphosphate at the rate of 50 pounds of P_2O_5 per acre on March 20, 1967, with a Gandy hand spreader.

Standard weed control practices for perennial ryegrass and Kentucky bluegrass seed production were followed. During the third week of November, Karmex diuron was applied at the rate of three pounds per acre for weed control in Kentucky bluegrass. Weed control in perennial ryegrass was accomplished by spraying with one and one-fourth pounds of Atrazine per acre during the fourth week of November. Herbicide applications were made with a bicycle-type plot sprayer.

The clipping treatments were initiated in mid-October with a National Mower and repeated every two weeks for the first month and every three weeks thereafter. On March 24, 1967, the position of the floral primordia of each species was examined. The floral primordia of Kentucky bluegrass were one-fourth to one-half inch above the soil, while the perennial ryegrass was about an inch above the soil. Since the National mower cuts slightly more than one inch above the soil surface, clipping was discontinued after March 27, 1967.

Head emergence was recorded as the date when the inflorescence was first visible outside the leaf sheath while pollen shed was recorded as the date when pollen was visibly discharged from the extruded anthers. The number of fertile tillers per square foot was determined by harvesting a 6-inch by 24-inch sample from each subplot at seed maturity. The seed yield was determined from a nine-square-foot sample cut from the center of each subplot. Both grass species were threshed with a cylinder plot thresher. After threshing, the perennial ryegrass was cleaned with hand screens. The Kentucky bluegrass was first delinted and then cleaned with a miniature Clipper cleaner. Clean seed of each species was then weighed to the nearest gram.

Four lots of 100 seeds each were counted for each subplot of Merion Kentucky bluegrass and weighed to the nearest milligram. The combined weight of 400 seeds was then extrapolated to give the weight of 1,000 seeds which was then used in the analysis of variance.

Seed weight determinations for the Linn perennial ryegrass were handled in a somewhat different manner. Four lots of 100 were counted from each subplot of the first replication only. Each 100 seed lot was weighed to the nearest milligram and extropolated to give the weight of 1,000 seeds. The seed weights were then subjected to the analysis of variance as a completely randomized design with four observations.

All data were analyzed by the split plot analysis of variance method with the exception of the weight of 1,000 seeds for Linn perennial ryegrass.

The least significant difference at the five percent level of probability (LSD_{05}) was used to determine differences among treatments.

EXPERIMENTAL RESULTS

LINN PERENNIAL RYEGRASS

SEED YIELD

The effect of defoliation and nitrogen application on seed yield is summarized in Table 3. An analysis of variance showed no significant difference at the 5% level of probability due to treatment; however, certain trends are of interest.

Defoliation

Examination of Table 3 shows that the yield of clean seed tended to be reduced by the combined winter-spring clipping regime for a period of six months from October 15 through March 27. Clipping for three months either during the winter (October 15 through January 15) or the spring (January 15 through March 27) appeared to increase the seed yield when compared with the unclipped control.

Nitrogen application

As may be noted in Table 3, a spring application of additional nitrogen tended to give higher seed yields than a fall application of the same quantity of nitrogen. When mean values are compared, the application of 15 pounds of additional nitrogen per acre did not show a

Table 3. The mean seed yield of Linn perennial ryegrass in grams per nine square feet as influenced by defoliation and nitrogen application.

Nitrogen application	No clipping	Winter clipping	Winter and spring clipping	Spring clipping	Mean
Control	78.7	73.7	72.7	85.0	77.5
Additional N					
15 pounds per acre					
Fall	65.7	80.2	57.5	75.5	69.7
Early spring	87.0	81.0	67.7	74.0	77.4
Late spring	73.5	68.2	68.0	71.2	70.2
30 pounds per acre					
Fall	80.2	84.2	80.0	75.0	79.8
Early spring	70.5	85.5	77.7	88.7	80.6
Late spring	84.0	86.5	75.5	90.7	84.1
Equal split					
Two spring applications	80.5	84.0	81.0	80.5	81.5
Mean	77.5	80.4	72.5	80.0	

response in seed yield whereas 30 pounds of nitrogen did seem to show a trend toward higher yield.

The application of 30 pounds of additional nitrogen per acre regardless of the season of the year tended to increase the seed yield when compared with the control nitrogen treatment.

The application of all the nitrogen in two equal spring applications seemed to give higher seed yields than the control nitrogen treatment.

Even though the nitrogen treatments did not significantly influence the seed yield, there was a trend for higher seed yields when additional nitrogen was applied in the spring rather than in the fall. Nitrogen, whether applied in the fall or spring, is subject to losses through microorganisms in the soil, higher plants growing on the soil, leaching or washing in the drainage water and volatilization as a result of denitrification. Perennial ryegrass is commonly grown on the heavy clay Dayton-Amity soil association in the Willamette Valley and once the soil profile becomes saturated during the winter rains, a majority of the fall-applied nitrogen could be leached or lost through microbial denitrification.

FERTILE TILLERS PER UNIT AREA

The effect of defoliation and nitrogen application on the number of fertile tillers per square foot is summarized in Table 4. Although an analysis of variance showed no significant difference at the 5% level of probability due to treatment, certain trends may be noted.

Defoliation

The combined winter-spring clipping regime (October 15 through March 27) tended to increase the number of fertile tillers per unit area, while clipping for three months during the winter (October 15 through January 15) or three months during the spring (January 15 through March 27) tended to reduce the number of fertile tillers per unit area when compared with the unclipped control.

The combined winter-spring clipping regime seemed to increase the number of fertile tillers per unit area and decrease the seed yield when compared with the unclipped control. Although factors contributing to the decreased seed yield can not be accurately predicted from the data collected in this study, the combined winter-spring clipping regime could have either reduced the number of fertile florets per tiller or reduced the weight of seed per tiller.

Nitrogen application

There was a trend for spring-applied nitrogen to result in more fertile tillers per unit area than fall-applied nitrogen. In most cases both 117 and 130 pounds of nitrogen per acre produced more fertile tillers per unit area than the 102 pounds of nitrogen per acre of

Table 4. The mean number of fertil tillers per square foot for Linn perennial ryegrass as influenced by defoliation and nitrogen application.

Nitrogen application	No clipping	Winter clipping	Winter and spring clipping	Spring clipping	Mean
Control	255	245	190	195	226
Additional N					
15 pounds per acre					
Fall	236	225	253	202	229
Early spring	252	232	226	294	251
Late spring	200	190	280	253	231
30 pounds per acre					
Fall	297	271	287	272	281
Early spring	297	218	262	232	252
Late spring	225	311	380	261	294
Equal split					
Two spring applications	249	297	249	221	254
Mean	251	251	266	241	

the control. When the mean values are examined, all nitrogen treatments increased the number of fertile tillers per unit area when compared with the control.

There was a significant interaction between defoliation and nitrogen application at the 5% level of probability for the number of fertile tillers per unit area. When 15 pounds of additional nitrogen per acre was applied, the number of fertile tillers per unit area under the no-clipping and winter clipping regimes tended to decrease. The same nitrogen treatment tended to increase the number of fertile tillers per unit area with the combined winter-spring clipping as well as the spring clipping regime. When 100 pounds of nitrogen per acre were applied in two spring applications, the number of fertile tillers per unit area under the no-clipping and winter clipping regimes tended to be higher than the number of fertile tillers per unit area under the combined winter-spring clipping and spring clipping regimes.

The importance of the significant interaction between defoliation and nitrogen application is difficult to assess. In general, there was an increase in the number of fertile tillers per unit area when additional nitrogen was applied to the various clipping treatments.

WEIGHT OF 1,000 SEEDS

The effect of defoliation and nitrogen application on the weight of 1,000 seeds is summarized in Table 5. An analysis of variance showed no significant difference at the 5% level of probability due to treatment; however, certain trends may be observed.

Defoliation

There was a trend for both the combined winter-spring clipping and the spring clipping regimes to reduce the weight of 1,000 seeds when compared with the unclipped control. Winter clipping was the only treatment which tended to increase the weight of 1,000 seeds.

Nitrogen application

There seemed to be an increase in the weight of 1,000 seeds when additional nitrogen was applied at the rates of 15 pounds in the fall, 30 pounds in the fall as well as 30 pounds per acre in the early spring. The greatest weight of 1,000 seeds was obtained when all of the nitrogen was applied in two equal spring applications. Late spring applications of additional nitrogen tended to decrease the weight of 1,000 seeds.

HEAD EMERGENCE

The effect of defoliation and nitrogen application on the period of head emergence is summarized in Table 6. Although an analysis of variance did not show a significant difference due to treat-

Table 5. The mean weight of 1,000 seeds of Linn perennial ryegrass in grams as influenced by defoliation and nitrogen application.

Nitrogen application	No clipping	Winter clipping	Winter and spring clipping	Spring clipping	Mean
Control	2.134	2.112	2.057	2.073	2.094
Additional N					
15 pounds per acre					
Fall	2.146	2.156	2.144	2.167	2.152
Early spring	1.962	2.128	2.065	2.143	2.074
Late spring	2.082	2.046	2.094	2.049	2.062
30 pounds per acre					
Fall	2.156	2.217	2.037	2.138	2.135
Early spring	2.192	2.242	2.130	2.055	2.155
Late spring	2.118	2.081	2.005	1.980	2.046
Equal split					
Two spring applications	2.155	2.248	2.329	2.043	2.197
Mean	2.119	2.153	2.107	2.080	

Table 6. The period of head emergence for Linn perennial ryegrass expressed as the mean number of days from April 1, 1967 as influenced by defoliation and nitrogen application.

Nitrogen application	No clipping	Winter clipping	Winter and spring clipping	Spring clipping	Mean
Control	32.2	34.7	34.7	35.2	34.2
Additional N					
15 pounds per acre					
Fall	32.7	35.2	36.5	36.5	35.2
Early spring	34.0	37.7	33.5	34.2	34.9
Late spring	35.2	36.0	33.5	36.5	35.3
30 pounds per acre					
Fall	35.2	39.0 †	36.5	35.2	36.5*
Early spring	36.5 †	39.0 †	33.5	35.2	36.0*
Late spring	37.7 †	32.7	36.5	37.2	36.0*
Equal split					
Two spring applications	37.7 †	33.5	35.2	32.0	34.6
Mean	35.1	36.0	35.0	35.2	

*Significant at the 5% level
LSD_{05} for nitrogen 1.3

† LSD_{05} 2 N's at same clip 4.3

ment at the 5% level of probability, a significant difference due to nitrogen application was found as well as a significant interaction between defoliation and nitrogen application.

Defoliation

There was a slight delay in the period of head emergence for all clipping regimes when compared with the unclipped controls. The average increase was only one day and would not seem to be of practical significance.

Nitrogen application

The application of additional nitrogen delayed the period of head emergence for the unclipped plots when compared with the control nitrogen treatment. Two equal spring applications of 136 pounds of nitrogen per acre also delayed the period of head emergence for the unclipped plots when compared with the control nitrogen treatment.

There was a general trend for all nitrogen treatments to delay the period of head emergence when compared with the control nitrogen treatment for the winter clipping regime. Exceptions were 30 pounds of additional nitrogen in the late spring and an equal split of 100 pounds of nitrogen in two spring applications.

The application of additional nitrogen in the fall, regardless of the rate, as well as 30 pounds of additional nitrogen in the late spring, tended to delay the period of head emergence for the combined winter-spring clipping regime.

For the spring clipping regime, the application of 15 pounds of additional nitrogen per acre in the fall and late spring as well as 30 pounds per acre additional nitrogen in the late spring tended to delay the period of head emergence when compared with the control nitrogen treatment.

When the mean values for the period of head emergence are examined for each nitrogen treatment across all clipping regimes, the application of 30 pounds of additional nitrogen per acre, regardless of the time of application, significantly delayed the period of head emergence when compared with the control nitrogen treatment.

POLLEN SHED

The effect of defoliation and nitrogen application on the time of pollen shed is summarized in Table 7. An analysis of variance showed no significant difference due to treatments at the 5% level of probability.

Defoliation

The time of pollen shed was essentially the same for all clipping treatments.

Table 7. The time of pollen shed for Linn perennial ryegrass expressed as the mean number of days from May 1, 1967, as influenced by defoliation and nitrogen application.

Nitrogen application	No clipping	Winter clipping	Winter and spring clipping	Spring clipping	Mean
Control	24.0	25.0	24.5	25.0	24.6
Additional N					
15 pounds per acre					
Fall	24.5	24.0	24.5	24.5	24.3
Early spring	24.0	24.5	25.0	24.0	24.3
Late spring	24.5	25.0	25.0	24.5	24.7
30 pounds per acre					
Fall	25.0	24.5	24.5	24.5	24.6
Early spring	25.0	25.0	24.5	25.0	24.8
Late spring	25.0	24.0	24.0	25.0	24.5
Equal split					
Two spring applications	24.6	24.5	24.6	24.6	24.5
Mean	24.6	24.5	24.6	24.6	

Nitrogen application

No individual nitrogen treatment altered the time of pollen shed more than one day for any clipping regime.

MERION KENTUCKY BLUEGRASS

SEED YIELD

The effect of defoliation and nitrogen application on the seed yield is summarized in Table 8. An analysis of variance showed a significant difference at the 5% level of probability due to both defoliation and nitrogen application.

Defoliation

All clipping regimes were found to increase the seed yield when compared with the unclipped controls. The greatest increase in seed yield was found for the combined winter-spring clipping regimes.

Nitrogen application

The application of additional nitrogen in the late spring reduced the seed yield when compared with the control nitrogen treatment.

Similar results were noted for spring application of 136 pounds of nitrogen in two applications.

Table 8. The mean seed yield of Merion Kentucky bluegrass in grams per nine square feet as influenced by defoliation and nitrogen application.

Nitrogen application	No clipping	Winter clipping	Winter and spring clipping	Spring clipping	Mean
Control	70.0	86.7	91.7	74.2	80.6
Additional N					
15 pounds per acre					
Fall	83.7	86.0	104.0	78.0	87.9
Early spring	77.5	78.5	87.0	84.0	81.7
Late spring	77.7	73.5	80.7	81.0	78.2
30 pounds per acre					
Fall	78.8	92.0	86.5	80.7	84.5
Early spring	65.5	76.5	76.7	87.2	76.2
Late spring	70.2	71.2	77.7	43.8 ‡ †	74.0
Equal split					
Two spring applications	46.7 †	70.0	83.5 ‡	70.0	67.5*
Mean	71.4	79.3	86.0*	79.0	

*Significant at the 5% level
LSD_{05} for clipping 8.4
LSD_{05} for nitrogen 11.0
‡ LSD_{05} clip at same N 24.4
† LSD_{05} sN's at different clip or same clip 22.0

FERTILE TILLERS PER UNIT AREA

The effect of defoliation and nitrogen application on the number of fertile tillers per unit area is summarized in Table 9. Certain trends may be noted although an analysis of variance showed no significant difference due to treatments at the 5% level of probability.

Defoliation

Both the winter clipping and the combined winter-spring clipping regimes tended to increase the number of fertile tillers per unit area when compared with the unclipped control. In contrast spring clipping tended to reduce the number of fertile tillers per unit area.

Nitrogen application

The fall application of additional nitrogen seemed to reduce the number of fertile tillers per unit area when compared with the control nitrogen treatment. Conversely, spring nitrogen application tended to increase the number of fertile tillers per unit area when compared with the control nitrogen treatment.

WEIGHT OF 1,000 SEEDS

The effect of defoliation and nitrogen application on the weight of 1,000 seeds is summarized in Table 10. Although an analy-

Table 9. The mean number of fertile tillers per square foot for Merion Kentucky bluegrass as influenced by defoliation and nitrogen application.

Nitrogen application	No clipping	Winter clipping	Winter and spring clipping	Spring clipping	Mean
Control	547	626	637	629	610
Additional N					
15 pounds per acre					
Fall	687	640	560	531	604
Early spring	693	664	727	606	672
Late spring	588	675	692	588	636
30 pounds per acre					
Fall	623	506	629	586	586
Early spring	704	677	831	513	681
Late spring	623	685	658	713	670
Equal split					
Two spring applications	634	540	770	733	669
Mean	638	658	688	612	

Table 10. The mean weight of 1,000 seeds of Merion Kentucky bluegrass in milligrams as influenced by defoliation and nitrogen application.

Nitrogen application	No clipping	Winter clipping	Winter and spring clipping	Spring clipping	Mean
Control	335	325	316	325	325
Additional N					
15 pounds per acre					
Fall	331	324	334	338	331
Early spring	312	316	306	315	312
Late spring	335	340	365	324	341
30 pounds per acre					
Fall	322	329	322	328	325
Early spring	330	311	323	311	311
Late spring	312	317	315	317	315
Equal split					
Two spring applications	326	309	320	325	320
Mean	325	321	325	323	

sis of variance showed no significant difference due to treatment at the 5% level of probability, certain trends may be observed.

Defoliation

The combined winter-spring clipping regime had no influence on the mean weight of 1,000 seeds. Winter clipping or spring clipping tended to reduce the weight of 1,000 seeds.

Nitrogen application

The application of 15 pounds of additional nitrogen per acre in the early spring as well as 30 pounds of additional nitrogen per acre in the early and late spring tended to reduce the weight of 1,000 seeds when compared with the control nitrogen treatment. Two equal spring applications of nitrogen also appeared to reduce the weight of 1,000 seeds when compared with the nitrogen control. The application of 15 pounds of additional nitrogen per acre in the fall and late spring seemed to increase the weight of 1,000 seeds when compared with the control nitrogen treatment.

HEAD EMERGENCE

The effect of defoliation and nitrogen application on the period of head emergence is summarized in Table 11. An analysis of

Table 11. The period of head emergence for Merion Kentucky bluegrass expressed as the mean number of days from April 1, 1967, as influenced by defoliation and nitrogen application.

Nitrogen application	No clipping	Winter clipping	Winter and spring clipping	Spring clipping	Mean
Control	23.7	27.0 ‡	26.5 ‡	26.2 ‡	25.8
Additional N					
15 pounds per acre					
Fall	25.2	28.7 ‡	25.5	25.5	26.2
Early spring	28.2 †	25.2 ‡	28.0	25.5 ‡	26.8
Late spring	25.5	24.7	28.0	28.5 ‡†	26.6
30 pounds per acre					
Fall	26.2	25.5	28.0	25.5	26.3
Early spring	23.7	23.0 †	28.7 ‡	26.0	25.3
Late spring	25.7	28.5 ‡	24.7	26.0	26.2
Equal split					
Two spring application	28.7 ‡	24.2 ‡	27.0	29.5 †	27.3
Mean	25.9	25.9	27.0*	26.5	

*Significant at the 5% level
LSD_{05} for clipping 0.80
‡ LSD_{05} 2 clips at same N 2.4
† LSD_{05} 2 N's same clip 3.5

variance showed no significant difference due to nitrogen treatments at the 5% level of probability.

Defoliation

The combined winter-spring clipping regime significantly delayed the period of head emergence when compared with the unclipped control. Although results were not significant at the 5% level, the spring clipping regime also tended to delay the period of head emergence. Winter clipping was similar to the unclipped control in its effect on the time of head emergence.

Nitrogen application

In general the application of additional nitrogen delayed the period of head emergence when compared with the control nitrogen treatment. Two equal spring applications of 136 pounds of nitrogen also tended to delay the period of head emergence when compared with the control nitrogen treatment. The application of 30 pounds of additional nitrogen in the early spring seemed to shorten the time span for head emergence in the population.

POLLEN SHED

The effect of defoliation and nitrogen application on the time of pollen shed is summarized in Table 12. An analysis of variance

Table 12. The time of pollen shed for Merion Kentucky bluegrass expressed as the mean number of days from May 1, 1967, as influenced by defoliation and nitrogen application.

Nitrogen application	No clipping	Winter clipping	Winter and spring clipping	Spring clipping	Mean
Control	23.7	23.7	25.0	22.5	23.7
Additional N					
15 pounds per acre					
Fall	25.0	23.7	25.0	22.5 ‡	24.0
Early spring	22.5	25.0 ‡	23.7	21.2	23.1
Late spring	22.5	25.0 ‡	25.0 ‡	22.5	24.0
30 pounds per acre					
Fall	22.5	23.7	25.0 ‡	23.7	23.7
Early spring	22.5	23.7	25.0 ‡	25.0 ‡ †	24.0
Late spring	23.7	23.7	25.0	21.2 ‡	23.4
Equal split					
Two spring applications	21.2 †	21.2 †	22.5 †	25.0 ‡ †	22.5
Mean	22.9	23.7*	24.5*	23.1	

*Significant at the 5% level

LSD_{05} for clipping 0.80

‡ LSD_{05} 2 clips at same N 2.28 (2.3)

† LSD_{05} 2 N's same clip 2.5

showed significant differences due to defoliation treatments at the 5% level of probability. There were no significant differences due to nitrogen treatments at the 5% level of probability.

Defoliation

The time of pollen shed was delayed by all clipping regimes when compared with the unclipped control. Both winter clipping and the combined winter-spring clipping treatments significantly delayed the time of pollen shed when compared with the unclipped control.

Nitrogen application

There was a trend for the application of additional nitrogen to delay the time of pollen shed when compared with the control nitrogen treatment. Two equal spring applications of nitrogen generally reduced the time of pollen shed when compared with the control nitrogen treatment.

DISCUSSION

Seed growers in the Willamette Valley have grazed their fields of perennial ryegrass and Kentucky bluegrass in the fall and early spring for many years. In addition to the income from seed, grazing offers the growers an increment to the total source of revenue or an additional farm enterprise. The grass stands also are thought to benefit from grazing by rejuvenation through destruction of some old tillers and perhaps by other non-defined factors. No data on the effects of grazing on seed yield or the need for supplemental nitrogen to compensate for possible deleterous effects of grazing are available under Oregon conditions.

The hypothesis being tested in this study is that grazing perennial ryegrass and Kentucky bluegrass does not reduce the seed yield. A statistical analysis of the data shows that for the 1967 growing season there was no significant reduction in the seed yield of Linn perennial ryegrass and Merion Kentucky bluegrass due to the clipping treatments.

From a biological point of view the important finding of this study was the response of the two grasses to clipping and supplemental nitrogen application.

Although the seed yield of Linn perennial ryegrass was not significantly affected by the clipping treatments, there were trends indicating that seed yield increases were obtained under the winter or spring clipping regimes. There was a trend for the combined winter-spring clipping regime to result in lower seed yields than the unclipped control.

All clipping regimes were found to increase the seed yield of Merion Kentucky bluegrass regardless of the season or the duration. The combined winter-spring clipping regime gave a significantly higher seed yield than the unclipped control.

The observation that the seed yield of perennial ryegrass is reduced by the combined winter-spring clipping treatment while Kentucky bluegrass produced more clean seed under the same clipping regime is of biological interest. One possible explanation for the increased seed yield of the Kentucky bluegrass could be the amount of carbohydrate reserves in the rhizomes. Perennial ryegrass has a fiberous root system and the total volume of carbohydrate storage is probably not as great as in a rhizomatous root system. The photosynthetic efficiency of Kentucky bluegrass could also be higher than the perennial ryegrass.

The application of fifteen pounds of supplemental nitrogen generally reduced the seed yield of Linn perennial ryegrass. Either 15 pounds of additional nitrogen per acre is not sufficient to bring about a measurable increase in the seed yield or the existing crop plants do not get full benefit of the applied nitrogen. On the other hand thirty pounds of supplemental nitrogen tended to increase the seed yield when compared with the control. The data is interpreted to mean that although a perennial ryegrass field is grazed during the winter or early spring it is unnecessary to add supplemental nitrogen to the usual nitrogen fertilization program.

The response of Merion Kentucky bluegrass to supplemental nitrogen was also of interest. The application of supplemental nitrogen in the fall tended to increase seed yield while the supplemental nitrogen applied in the early or late spring tended to reduce the seed yield when compared with the control. When all of the nitrogen was applied in two equal spring applications, the yield was also reduced when compared with the control. The trends for a seed yield depression when all of the nitrogen or supplemental amounts was applied in the spring is contrary to reports in the literature (41, 42, 43). Peterson and Loomis (54) reported that the application of nitrogen to Kentucky bluegrass in the early fall stimulated vegetative growth and tillering and increased the number of flowers subsequently produced to about five times more than unfertilized plants. The induction of flowering in Kentucky bluegrass is brought about by the combined affect of low temperature and short photoperiods during the fall (54) and an application of nitrogen in the fall may influence the number of tillers which are physiologically sensitive to inductive conditions or may influence the number of florets which will be present on each inflorescence.

Although Merion Kentucky bluegrass is grazed during the winter and/or early spring, supplementary nitrogen has no significant effect on seed yield. According to the work of Langer and Lambert (47), the final seed yield of a given species is dependent upon the number of tillers which reach the reproductive state and the number of florets formed by each inflorescence. For Linn perennial ryegrass, the most tillers were produced by the combined winter-spring clipping regime and although not statistically significant this same clipping regime resulted in the lowest seed yield. The response of Merion Kentucky bluegrass was in accord with the work of Langer and Lambert (47) in that the combined winter-spring clipping regime produced the highest seed yield and the greatest number of fertile tillers per unit area.

One parameter that should be measured to more completely understand the effect of clipping and supplemental nitrogen application on seed yield is the number of seed per fertile tiller. A multiple regression and correlation analysis using seed yield, number of fertile tillers per unit area, weight of 1,000 seeds and the number of seeds per fertile tiller may show which factor is the most important factor contributing to seed yield.

The time of head emergence and pollen shed was recorded to determine if defoliation or supplemental nitrogen altered the pattern of development in Linn perennial ryegrass or Merion Kentucky bluegrass. In planning this study the combined winter-spring clipping and the spring clipping regimes were considered to be extreme treatments. A six-month clipping duration from October 1 through March 27 was felt to be an extreme pressure for a seed production field. Observations made prior to the final clipping indicated that spring defoliation as late as March 27, 1967 would not destroy any elongating inflorescences. In this particular year spring clipping as late as March 27 was not severe.

Extreme defoliation durations could extend the period of head emergence causing pollen shed to occur during periods of high temperature and low atmospheric humidity. Pollen shed during adverse environmental conditions could cause pollen viability to decline rapidly. Since perennial ryegrass lodges severely prior to harvest, an extreme defoliation duration could also delay pollen shed until after lodging. The result could be difficulty in pollen transfer from the anthers to the stigmas after lodging if a majority of the culms are horizontal, while only a few remained vertical.

There was a significant interaction effect between nitrogen and clipping on the time of head emergence for Linn perennial ryegrass. Although there was a trend for a delay in the time of head emergence for the clipping and nitrogen treatments, the trend was not consistant across all treatments. The delay in the time of head emergence may have been due to the plants being kept in a vegetative condition longer than the control plants; thereby delaying the period of initiation and subsequent head emergence.

The time of pollen shed for perennial ryegrass was not significantly influenced by the clipping or nitrogen treatments. Although there was a trend toward a delay in the time of pollen shed when supplemental nitrogen was applied the reduction was small and would not seem too important.

The application of supplemental nitrogen did not affect the period of head emergence or the time of pollen shed for Merion Kentucky bluegrass. However, the clipping treatments had a greater effect and did significantly affect the period of head emergence and the time of pollen shed for Merion Kentucky bluegrass. The combined winter-spring clipping regime significantly delayed the period of head emergence for Merion Kentucky bluegrass. Winter clipping as well as the combined winter-spring clipping regimes significantly delayed the time of pollen shed when compared with the unclipped control.

Although the time of pollen shed was delayed only two to three days, the ability to control the time of pollen shed may be a useful management tool. In a given area of grass seed production, such as the Willamette Valley, it is common to have different varieties of the same species planted in adjacent fields. A problem of contamination of pedigreed grass fields by foreign pollen may result from the adjacent planting of the same species. In order to prevent contamination of pedigreed seed and maintain genetic purity within seed lots certifying agencies have established minimum isolation distances for separation of closely related species and varieties of the same species as well as different generations of the same variety. If the time of head emergence and pollen shed can be accurately determined and controlled by management practices, the isolation distances and border areas required by certification standards can be replaced by time isolation or the difference in the date of flowering as discussed by Rampton (55).

In this study clipping was used to simulate grazing because of management problems involved with livestock. Although a mower offers more advantage than locating, transporting and managing livestock within the experimental area, certain differences between clipping and grazing must be recognized. Mowing non-selectively removes all plant material at a given level, while grazing animals select material more or less at random throughout the grazing area. Clipping does not subject the experimental area to the treading or trampling of livestock. Grazing by sheep is known to be more detrimental to the grass stands than mowing because sheep tend to pull out tillers and give uneven defoliation (57). This uneven defoliation by sheep may offer an advantage to certain tillers within the grazing area.

The data collected in this study represents but one year. In order to determine the response of Linn perennial ryegrass and Merion Kentucky bluegrass to clipping and supplemental nitrogen application, the study should be continued through a minimum of five years.

During the five-year period a complete range of environmental conditions would be involved instead of one selected year.

SUMMARY AND CONCLUSIONS

A study was initiated to determine the effects of the rate and date of nitrogen application and clipping on the seed yield of Linn perennial ryegrass and Merion Kentucky bluegrass. The results of this study are summarized:

1. Seed yield of Linn perennial ryegrass was not significantly increased or reduced by clipping or nitrogen treatments. The seed yield of Merion Kentucky bluegrass was significantly increased by combined winter-spring clipping for six months. Two applications of equal amounts of nitrogen in the spring significantly reduced the seed yield of Merion Kentucky bluegrass as compared to some fall nitrogen.

2. The number of fertile tillers per unit area was not significantly influenced by either clipping or supplemental nitrogen application. However, trends suggest that winter clipping or combined winter-spring clipping tends to increase the number of fertile tillers per unit area.

3. The weight of 1,000 seeds of both Linn perennial ryegrass and Merion Kentucky bluegrass was not significantly influenced by clipping or nitrogen application.

4. The inflorescence emergence of Linn perennial ryegrass and Merion Kentucky bluegrass was significantly delayed by high rates of supplemental nitrogen. A significant interaction was also found between clipping and nitrogen treatments for head emergence of Merion Kentucky bluegrass. Supplemental nitrogen plus clipping tended to delay inflorescence emergence for Merion Kentucky bluegrass.

5. The time of pollen shed for Linn perennial ryegrass was not significantly effected by clipping or nitrogen treatments. Nitrogen treatments did not

significantly influence the time of pollen shed for Merion Kentucky bluegrass. However winter clipping and the combined winter-spring clipping regimes significantly delayed the time of pollen shed.

BIBLIOGRAPHY

1. Aitken, Yvonne. Flower initiation in relation to maturity in crop plants. II. Internode lengthening in relation to grazing in oat varieties. Australian Journal of Agricultural Research 12(2):389-396. 1961.

2. Alberda, Th. The effects of cutting, light intensity and night temperature on growth and soluble carbohydrate content of Lolium perenne L. Plant and Soil 8(3):199-230. 1957.

3. Arnold. G. W. Selective grazing by sheep of two forage species at different stages of growth. Australian Journal of Agricultural Research 11(6):1026-1033. 1960.

4. Beard, James B. and William H. Daniel. Effect of temperature and cutting on the growth of creeping bentgrass (Agrostis palustris Huds.) roots. Agronomy Journal 57(3):249-250. 1965.

5. Bird, J. N. Stage of cutting studies: I. Grasses. Journal of the American Society of Agronomy 35(10):845-861. 1943.

6. Brougham, R. W. Effect of intensity of defoliation on regrowth of pasture. Australian Journal of Agricultural Research 7(5):377-387. 1956.

7. Brougham, R. W. The effects of season and weather on the growth rate of a ryegrass and clover pasture. New Zealand Journal of Agricultural Research 2(2):283-296. 1959.

8. Brougham, R. W. The rate of growth of short-rotation-ryegrass pastures in the late autumn, winter and early spring. New Zealand Journal of Science and Technology 38A(1):78-87. 1956.

9. Brougham, R. W. A study in rate of pasture growth. Australian Journal of Agricultural Research 6(6):804-812. 1955.

10. Brown, E. Marion. Seasonal variations in the growth and checmical composition of Kentucky bluegrass. Columbia, 1943. 56p. (Missouri. Agricultural Experiment Station, Research Bulletin 360.)

11. Calder, D. M. Environmental control of flowering in Dactylis glomerata L. Nature 197(4870):882-883. 1963.

12. Calder, D. M. and J. P. Cooper. Effect of spacing and nitrogen-level on floral initiation in cocksfoot (Dactylis glomerata L.) Nature 191(4784):195-196. 1961.

13. Cooper, J. P. Studies on growth and development in Lolium. I. Relation of the annual habit to head production under various systems of cutting. Journal of Ecology 37(2):233-259. 1949.

14. Davidson, J. L. and F. L. Milthorp. Leaf growth in Dactylis glomerata L. following defoliation. Annals of Botany 30(118): 173-184. 1966.

15. Dewey, Douglas R. Response of orchardgrass clones to clipping frequency. Crop Science 1(6):421-424. 1961.

16. Dexter, S. T. Response of quack grass to defoliation and fertilization. Plant Physiology 11(4):843-851. 1936.

17. Dibbern, John C. Vegetative responses of Bromis inermis to certain variations in environment. Botanical Gazette 109:44-58. 1947.

18. Donald, C. M. The interactiond competition for light and nutrients. Australian Journal of Agricultural Research 9(4):421-435. 1958.

19. Ehara, Kaoru and Satoshi Maeda. Physiological and ecological studies on the clipping of herbage plants. I. Relation between stubble, root starvation and shoot regrowth in Italian ryegrass. Proceedings of the Crop Science Society of Japan 29(2):307-309. 1962. (Abstracted in Biological Abstracts 36:no. 69772. 1961)

20. Ellett, W. B. and Lyman Carrier. The effect of frequent clipping on total yield and composition of grasses. Journal of the American Society of Agronomy 7(2):85-87. 1915.

21. Etter, Alfred Gordon. How Kentucky bluegrass grows. Annals of the Missouri Botanical Garden 38(3):293-375. 1951.

22. Evans, Gwilym. Defoliation and manuring of perennial ryegrass (S. 24) for seed production. Journal of the British Grassland Society 17(2):119-124. 1962.

23. Evans, Gwilym and R. A. Calder. Manuring pedigree grasses for seed production. Welsh Journal of Agriculture 7:195-208. 1931.

24. Evans, L. T. Inflorescence initiation in Lolium temulentum L. Australian Journal of Biological Science 13(2):123-131. 1960.

25. Evans, Marshall and C. P. Wilsie. The flowering of bromegrass, Bromus inermis, in the greenhouse as influenced by length of day, temperature and level of fertility. Journal of the American Society of Agronomy 38(10):923-932. 1946.

26. Evans, Morgan W. and J. E. Ely. The rhizomes of certain species of grasses. Journal of the American Society of Agronomy 27(10):791-797. 1935.

27. Evans, T. A. The effect of nitrogen applications at different dates on the seed yield of pedigree grass. Journal of the British Grassland Society 9(1):53-60. 1954.

28. Evans, T. A. Management and manuring for seed production in cocksfoot and timothy. Journal of the British Grassland Society 8(3):245-259. 1953.

29. Evans, T. A. Manuring and winter grazing for seed production in S. 48 timothy. Journal of the British Grassland Society 10(3): 254-262. 1955.

30. Gardner, F. P. and S. C. Wiggans. Effect of clipping and nitrogen fertilization on forage and grain yields of spring oats. Agronomy Journal 52(10):566-568. 1960.

31. Gardner, J. L. Studies on tillering. Ecology 23(1):162-174. 1942.

32. Green, J. O. and T. A. Evans. Grazing management for seed production in leafy strains of grasses. Journal of the British Grassland Society 12(1):4-9. 1957.

33. Green, J. O. and T. A. Evans. Manuring and grazing for seed production in S. 37 cocksfoot and S. 215 meadow fescue. Journal of the British Grassland Society. 11(3):165-173. 1956.

34. Haggar, R. J., W. Holmes and P. Innes. Wild white clover seed production. I. The effects of defoliation and fertilizer treatment on flowering and seed yields from ryegrass/white clover swards. Journalof the British Grassland Society. 18(2):97-103. 1963.

35. Harrison, C. M. and C. W. Hodgson. Response of certain perennial grasses to cutting treatments. Journal of the American Society of Agronomy. 31(5):418-430. 1939.

36. Harrison, Carter M. Responses of Kentucky bluegrass to variations in temperature, light, cutting and fertilizing. Plant Physiology 9(1):83-106. 1934.

37. Huokuna, E. The effect of frequency and height of cutting on cocksfoot swards. Annales Agriculturae Fenniae. 3(4):1-83. 1964. (Abstracted in Herbage Abstracts 35(2):no. 545. 1965.)

38. Knight, R. The relation between tillering and dry matter production in cocksfoot (Dactylis glomerata L.) grown under spaced and sward conditions. Australian Journal of Agricultural Research 12(4):566-577. 1961.

39. Lambert, D. A. The effect of cutting cocksfoot (Dactylis glomerata L.) Journal of the British Grassland Society 21(3):200-207. 1966.

40. Lambert, D. A. The effect of cutting timothy (Phleum pratense L.) for production of seed. Journal of the British Grassland Society 21(3):208-213. 1966.

41. Lambert, D. A. The effect of high levels of nitrogen on seed yield of cocksfoot (Dactylis glomerata L.) Journal of the British Grassland Society 20(3):164-167. 1965.

42. Lambert, J. P. Seed production studies. I. The effect of nitrogenous fertilizer, applied at different rates and dates on seed production in cocksfoot (Dactylis glomerata L.) New Zealand Journal of Science and Technology 37A(5):432-442. 1956.

43. Lambert, J. P. Seed production studies. II. The effect of grazing on seed production in cocksfoot (Dactylis glomerata L.) New Zealand Journal of Science and Technology 37A(5):443-450. 1956.

44. Lambert, J. P. Seed production studies. III. The effect of nitrogenous fertilizer, applied at different rates, and dates, on seed production in timothy (Phleum pratense L.) New Zealand Journal of Science and Technology 37A(6):367-377. 1956.

45. Langer, R. H. M. Growth and nutrition of timothy (Phleum pratense L.) V. Growth and flowering at different levels of nitrogen. Annals of Applied Biology 47(4):740-751. 1959.

46. Langer, R. H. M. A study of growth in swards of timothy and meadow fescue. II. The effects of cutting treatments. Journal

of Agricultural Science 52(3):273-281. 1959.

47. Langer, R. H. M. and D. A. Lambert. The physiological significance of population density in grass seed production. Journal of the British Grassland Society 18(3):177-180. 1963.

48. Leopold, A. C. The control of tillering in grasses by auxin. Plant Physiology 36(6):437-440. 1949.

49. Lovvorn, R. L. The effect of defoliation, soil fertility, temperature and length of day on the growth of some perennial grasses. Journal of the American Society of Agronomy 37(7):570-582. 1945.

50. Lucanns, Renate, K. J. Mitchell, G. G. Pritchard and D. M. Calder. Factors influencing survival of strains of ryegrass during the summer. New Zealand Journal of Agricultural Research 3(1):185-193. 1960.

51. Maeda, Satoshi and Kaoru Ehara. Physiological and ecological studies on clipping of herbage plants. III. Influence of clipping on the tiller number and regrowth in Italian ryegrass. Proceedings of the Crop Science Society of Japan 30(4):313-317. 1962. (Abstracted in Biological Abstracts 42:no. 11840. 1963.)

52. Mitchell, K. J. and S. T. J. Coles. Effects of defoliation and shading on short-rotation ryegrasses. New Zealand Journal of Science and Technology 36A(6):586-604. 1955.

53. Parks, W. L. and W. B. Fisher, Jr. Influence of soil temperature and nitrogen on ryegrass growth and chemical composition. Proceedings of the Soil Science Society of America 22(3):257-259. 1958.

54. Peterson, Maurice L. and W. E. Loomis. Effects of photoperiod and temperature on growth and flowering of Kentucky bluegrass. Plant Physiology 24(1):31-43. 1949.

55. Rampton, H. H. Time isolation as a safeguard to varietal purity in perennial ryegrass, annual ryegrass, and orchardgrass. Corvallis 1966. 12p. (Oregon. Agricultural Experiment Station. Circular of information 623.)

56. Robert, H. M. The effect of defoliation on the seed-producing capacity of bred varieties of grasses. Journal of the British Grassland Society 20(4):283-289. 1965.

57. Roberts, H. M. The effect of defoliation on the seed-producing capacity of bred strains of grasses. 2. Cocksfoot. Journal of the British Grassland Society 14(1):58-64. 1959.

58. Roberts, Humphrey M. The effect of defoliation on seed-producing capacity of bred strains of grasses. 1. Timothy and perennial ryegrass. Journal of the British Grassland Society 13(4): 255-261. 1958.

59. Roberts, R. Alun and I. V. Hunt. The effect of shoot cutting on the growth of root and shoot of perennial ryegrass (_Lolium perenne_ L.) and of timothy (_Phleum pratense_ L.) Welsh Journal of Agriculture 12:158-174. 1936.

60. Robertson, Joseph H. Effect of frequent clipping on the development of certain grass seedlings. Plant Physiology 8(3):425-447. 1933.

61. Sharman, B. C. The biology and developmental morphology of the shoot apex in the Gramineae. New Phytologist 46(1):20-34. 1947.

62. Sharman, B. C. Onset of reproductive phase in grasses and cereals. Nature 150(3798):208. 1942.

63. Schwanbom, N. and K. Froier. Methods of herbage seed production. Journal of the British Grassland Society 4(4):233-261. 1949.

64. Sprague, V. G. The relation of supplementary light and soil fertility to heading in the greenhouse of several perennial forage grasses. Journal of the American Society of Agronomy 40(2): 145-154. 1948.

65. Stapledon, R. G. and W. E. J. Milton. The effect of different cutting and manural treatments on the tiller and root development of cocksfoot. Welsh Journal of Agriculture 7:166-174. 1930.

66. Stechman, John V. and Horton M. Lande. Reproductive potential of four annual range grasses as influenced by season of clipping or grazing. Journal of Range Management 15(2):98-103. 1962.

67. Wilson, D. B. Effects of Light intensity and clipping on hergabe yields. Canadian Journal of Plant Science 42(2):270-275. 1962.

68. Wilson, J. R. The influence of time of tiller origin and nitrogen level on the floral initiation and ear emergence of four pasture grasses. New Zealand Journal of Agricultural Research 2(5): 915-932. 1959.

69. Zaleski, A. White clover investigations. I. Effect of seed rates and cutting treatments on flower formation and yield of seed. Journal of Agricultural Science 57(2):199-212. 1961.

APPENDIX

Appendix table 1. Computed F values for split plot analysis of variance for all characters measured for Linn perennial ryegrass.

Source of variation		Seed yield in grams per 9 square feet		Number of fertile tillers per square foot		Date of pollen shed		Head emergence	
	D.F.	M.S.	F.	M.S.	F.	M.S.	F.	M.S.	F.
Replication	3	238.7	1.25	8,902.7	1.66	0.73	2.28	2.40	0.77
Nitrogen	7	431.0	2.26	9,845.2	1.83	0.50	1.56	9.84	3.18*
Rep X N	21	189.9		5,358.7		0.32		3.09	
Clipping	3	426.2	3.23	3,357.6	0.78	0.06	0.62	6.13	0.58
Clip X Rep	9	131.9		4,274.6		1.06		10.44	
Clip X N	21	131.5	0.82	6,184.9	1.98*	0.58	0.85	16.36	2.53**
C X N X R	63	159.6		3,024.2		0.68		6.45	
Total	127								

*Significant at the 5% level
**Significant at the 1% level

Appendix table 2. Computed F value for the completely randomized analysis of variance for the weight of 1,000 seeds in grams of Linn perennial ryegrass.

Source of variation	D. F.	M. S.	F
Treatment	31	0.000251	0.000479 NS
Error	96	0.5236	
Total	127		

NS Not Significant

Appendix table 3. Computed F values for split plot analysis of variance for all characters measured for Merion Kentucky bluegrass.

Source of variation		Seed yield in grams per 9 square feet		Number of fertile tillers per square foot		Weight of 1,000 seeds in milligrams		Date of pollen shed		Head emergence	
	D.F.	M.S.	F.	M.S.	F.	M.S.	F.	M.S.	F.	M.S.	F.
Replication	3	937.7	4.17*	46,035.6	0.71	0.00033	0.33	9.90	1.73	18.30	1.20
Nitrogen	7	647.0	2.87*	21,919.0	0.35	0.00142	1.42	4.91	0.85	5.88	0.38
Rep X N	21	224.7		61,896.4		0.001		5.72		15.18	
Clipping	3	1,158.7	5.17*	34,644.1	3.34*	0.00033	3.00	16.13	7.75**	10.23	4.39*
Clip X Rep	9	223.8		10,522.1		0.00011		2.08		2.33	
Clip X N	21	191.9	0.81	17,289.1	0.86	0.00033	1.10	6.02	1.41	13.76	1.35
C X N X R	63	234.1		20,027.4		0.00030		4.26		10.19	
Total	127										

*Significant at the 5% level
**Significant at the 1% level