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Evaluation of Lolium Cultivars in Connecticut

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Eight species are listed in the genus *Lolium* (Terrell, 1968). Two of these species, perennial ryegrass (*L. perenne* L.) and annual or Italian ryegrass (*L. multiflorum* Lam.), have substantial importance as forage species in temperate regions. Both species have numerous desirable agronomic qualities. They establish rapidly, have a long growing season, are high yielding in a suitable environment when supplied with adequate nutrients, possess a high nutritive value, and can be used for pasture, hay, or silage. However, the ryegrasses do not possess the tolerance to prolonged cold weather that is desirable in forage grasses grown in the northeastern and northcentral United States. Further, their ability to be productive in hot, dry weather is also questioned. Consequently, the ryegrasses have found little use as forage grasses in the northeastern United States.

In the late 1930's and early 1940's a few tentative agronomic evaluations of ryegrasses were made at the United States Pasture Research Laboratory in Pennsylvania. In cooperation with the Pasture Research Laboratory a few of the state collaborators also made cursory studies. Presumably, management studies were discouraging since these initial investigations were discontinued. During this same period genetic studies were initiated and, indeed, are still underway at the Pasture Research Laboratory, and elsewhere, involving intergeneric crosses between *Lolium* and *Festuca* species. In 1968, studies were initiated at the Connecticut (Storrs) Agricultual Experiment Station to evaluate the potential of *Lolium* cultivars as forages for the New England area. This monograph summarizes the results that were obtained in the subsequent fifteen years.

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BOTANICAL DESCRIPTION

Relatively detailed descriptions of the *Lolium* genus and *L. perenne* and *L. multiflorum* have been given by Hitchcock (1951), Hubbard (1959), Beddows (1967), Terrell (1968), and Beddows (1973). The following descriptions are condensed from the above references. Where numerical values were given, the greatest value has been used in the descriptions presented below.

Genus Lolium

Species of this genus are widely distributed but they are indigenous to Europe, the North Atlantic Islands, temperate Asia, and North Africa. Considerable variation exists among species within the genus with respect to longevity and vegetative characteristics. Longevity varies from annual to perennial forms; culms may be few to many and may be erect to decumbent; auricles may be present or absent; ligules are usually short and membranous. The inflorescence is a spike and spikelets, usually containing several florets, are placed edgewise to the concavities of the rachis. The lower glume is usually present only in the terminal spikelet. Lemmas may or may not possess awns.

Although Hitchcock (1951) placed this genus in the tribe Hordeae, it is more frequently placed in the tribe Festuceae. The distribution of this latter tribe, and the subfamily Festucoideae, has been discussed in considerable detail by Hartley (1973). The greatest relative specific frequency of both the Festucoideae and Festuceae was observed in the high latitudes of the northern and southern hemispheres and at high altitudes in the subtropics and tropics. Summer temperatures appear to be closely related to the occurrence of species belonging to these taxa. Typically, the higher the midsummer temperature, the lower the specific frequency of species of the Festucoideae and Festuceae. Species belonging to the Festucoideae and Festuceae were reported in this study to have percentage frequency values of 49 and 17%, respectively, for the New England region.

Lolium perenne

Under suitable climatic conditions this species is a perennial, with culms 8-90 cm high, and with growth forms ranging from the erect to the prostrate. The basal leaf sheaths are pink to purplish. Leaf blades are glossy on the underside, folded in the young shoot, 3-20 cm long, and 1-6 mm wide. The upper surface of the blade is dull colored and has prominent ribs. The ligule is short, i.e., 2.5 mm; auricles may be present or absent but when present are small, i.e., up to 3 mm long. Slender spikes may be straight or slightly curved and are up to 31 cm long. They bear 5-37 spikelets that alternate on either side of the rachis. The spikelets have 4-14 florets. The caryopsis is usually awnless. The root system is fibrous and shallow. Neither rhizomes nor stolons are present.

Perennial ryegrass is considered indigenous to parts of Europe, and temperate Asia and North Africa. It has been introduced into most parts of the temperate world including higher elevations of the tropics. It is consistently found as an important component of pastures in areas with mediterranean, temperate-mild, temperate-cool-moist, and temperate-cold climates (Russell and Webb, 1976). Though widely used for pasture, perennial ryegrass is also used for hay and silage and it also finds use as a turfgrass.

Lolium multiflorum

Forms vary from annuals to short-lived perennials with culms erect to decumbent reaching a height of up to 127 cm. Basal leaf sheaths are often red or purple in color. Leaf blades are rolled in the shoot, may be 6-25 cm long and 1 cm wide; they are glossy below with a well marked venation above. The ligule is short, up to 4 mm long. Auricles are usually present, narrow or claw-like, and are up to 4 mm long. The spikes are slender to robust and usually are about one-third the height of the plants. Numerous spikelets, 6-42, occur alternately on either side of the rachis, in two rows, sometimes overlapping and containing many florets. Awns are typically present and may be up to 10 mm long.

This species is considered a native of central and southern Europe, northwestern Africa, and southwestern Asia. It is now widely distributed throughout the world. A cultivar of annual ryegrass is Westerwolds or Westerwolths ryegrass. It has been suggested that short-lived ryegrass originated from repeated harvesting of seed from annual ryegrass. This resulted in the development of an annual, early maturing form of annual ryegrass (de Haan, 1955).

Hybrids

Both annual and perennial ryegrasses are diploids with a chromosome number of 14. Terrell (1968) points out that (1) taxa of the *Lolium* genus are more or less interfertile, and (2) some species of the *Lolium* genus will cross with certain species of the *Festuca* genus. One such natural intergeneric hybrid is *Festulolium loliaceum* (Huds) P. Fourn. This sterile hybrid is the product of a *Festuca pratensis* Huds. x *L. perenne* cross and is found quite widely in western Europe (Hubbard, 1959). Other natural hybrids between these genera have also been recorded. The ability of these genera to cross has resulted in considerable effort being expended to produce a hybrid of agricultural worth. However, such hybrids are yet of little importance compared to the hybrids that have been produced between *L. perenne* and *L. multiflorum*.

At the present time there are commercially available cultivars of diploid and tetraploid perennial, annual, and Westerwolds ryegrass as well as tetraploid hybrids of perennial and annual ryegrass. These

cultivars have been subjected to considerable evaluation and have received much commercial attention in Europe and, indeed, elsewhere where the climate is moist and the winters mild. Such is not the case in New England.

MATERIALS AND METHODS

In the period of 1968-1983 several field experiments were conducted at the Plant Science Field Laboratory, The University of Connecticut, Storrs. The predominant soil at this location is a Paxton fine sandy loam (coarse-loamy, mixed, mesic Typic Dystrochrept) and, unless otherwise stated, the experiments were conducted on sites with this soil type. A summary of the weather experiences at this location during this period of time is provided in Appendix Table 1. Soil samples taken at each experimental site were analyzed in The University of Connecticut Soil Testing Laboratory. The laboratory extracts soil samples using the modified Morgan reagent (McIntosh, 1969).

Experiment 1

This study was initiated to compare ryegrass cultivars with other grass forages commonly used in New England. Soil tests taken at the experimental site indicated a pH of 6.2 and Ca, Mg, P, and K levels of 2464, 448, 12, and 224 kg ha^{-1}, respectively. Prior to seeding 2800, 45, 39, and 75 kg ha^{-1} of dolomitic limestone, N, P, and K, respectively, were broadcast and disked into the soil. 'Pennmead' orchardgrass (*Dactylis glomerata* L.), 'Ioreed' reed canarygrass (*Phalaris arundinacea* L.), 'Kentucky 31' tall fescue (*Festuca arundinacea* Schreb.), 'Lamora' perennial ryegrass, certified perennial ryegrass, and 'Tetrelite' ryegrass (*Lolium hybridum* Hausskn.) were drill-seeded on 19 April 1968. The ryegrass varieties and tall fescue were seeded at 13.4 kg ha^{-1}; the other species at a rate of 11.2 kg ha^{-1}. At the time of seeding a further 24 kg P ha^{-1} was banded with the seed. Three harvests were taken in 1968; the harvest dates were 2 July, 7 August, and 23 October. Following the first and second harvests, N was topdressed at a rate of 56 kg ha^{-1}. The experimental design was a randomized complete block with three replications. Plot size was 2.1 x 7.0 m.

Experiment 2

An experiment was initiated in the spring of 1968 to compare ryegrass growth at two N levels with that of other commonly used forage species. Soil tests of the experimental site indicated a pH of 6.2 and Ca, Mg, P, and K levels of 2016, 353, 6, and 179 kg ha^{-1}, respectively. Prior to seeding 2800, 45, and 67 kg ha^{-1} of dolomitic limestone, P, and K, respectively, were broadcast and disked into the seedbed. Five cropping

systems were established on 16 April. These were (a) 'Saranac' alfalfa (*Medicago sativa* L.) seeded at 13.4 kg ha^{-1} following an application of 4.5 kg ai ha^{-1} of EPTC, (b) 'Garry' oats (*Avena sativa* L.) seeded at 72 kg ha^{-1}, (c) a mixture of Saranac alfalfa and Garry oats seeded at the above rates, (d) Tetrelite ryegrass seeded at 13.4 kg ha^{-1} and fertilized with 448 kg N ha^{-1} and (e) Tetrelite ryegrass seeded as above but fertilized with 672 kg N ha^{-1}. The treatments of oats seeded alone and in combination with alfalfa received 56 kg N ha^{-1}. Timing of N applications, all of which were broadcast, as well as harvest schedules, are shown in Table 2. The experiment was set out in a randomized, complete block design with four replications. Plot size was 3.0 x 7.6 m.

Experiment 3

Fall seedings of Tetrelite ryegrass were made in 1969 in order to evaluate the winter survival of fall-seeded ryegrass as well as its production in the succeeding year. The experimental area had been plowed and disked. Tetrelite ryegrass, at 13.4 kg ha^{-1}, was seeded on 8, 15, and 25 August and 2 September. Phosphorus, at 39 kg ha^{-1}, was placed in the row at the time of seeding. Fall growth was excellent. One fall cutting, on either 10 or 24 October, was taken though yields were measured only for the first two seeding dates. The eight treatments were set out in complete blocks and replicated four times. However, due to incomplete randomization within blocks, data were not subjected to analysis of variance. Plot size was 2.1 x 3.5 m.

In the spring of 1970, 112, 44, and 168 kg ha^{-1} of N, P, and K were applied, respectively. Two N applications of 56 kg ha^{-1} each were applied after the first and second harvests. Harvests were taken on 4 June, 7 July, 5 August, and 9 October. Analyses of soil samples, taken in April 1971, indicated that the soil pH was 6.7, and Ca, Mg, P, and K levels were 2800, 560, 7, and 123 kg ha^{-1}, respectively.

Herbage samples were taken at the time of the fall harvests and also from the 1970 harvests. Following drying and grinding, samples were analyzed for *in vitro* dry matter disappearance (IVDMD) and concentrations of nitrate-nitrogen (NO_3^--N). In addition, herbage samples taken in the fall were subjected to analyses to determine cell wall constituents (CWC), acid-detergent fiber (ADF), acid-detergent lignin (ADL), and crude protein.

Experiment 4

Late-summer seedings of Tetrelite ryegrass were repeated in 1970 to evaluate (a) winter survival, (b) influence of fall cutting versus no fall cutting, and (c) response of ryegrass to high levels of N. The site was plowed and 45, 44, and 168 kg ha^{-1} of N, P, and K, respectively, were broadcast and disked in. Tetrelite ryegrass at 13.4 kg ha^{-1} was band seeded, with 45 kg P ha^{-1}, on 24 and 31 August and 8 September 1970. Plots receiving a fall cutting treatment were harvested on 28 October 1970. Analyses of soil samples, taken in April 1971, indicated a soil pH of 6.9

and Ca, Mg, P, and K levels of 2688, 560, 7, and 291 kg ha^{-1}, respectively. On 20 April 1971, a fertilizer application of 22 and 84 kg ha^{-1} of P and K, respectively, was made to all plots. Three N levels were then established: 224, 336, and 448 kg N ha^{-1}. Fifty percent of the total N was applied on 6 May while the remaining 50% was applied in thirds, each after the first, third, and fourth harvests. Five harvests were taken. Harvest dates were 1 June, 24 June, 16 July, 12 August, and 8 October. The factorial experiment was set out in a split-split-plot design with four replications. Dates of seeding were assigned to the main plots, fall cutting versus no fall cutting represented subplots, and N levels were sub-subplots. Treatment levels of each factor were arranged in a randomized, complete block design. Plot size for the sub-subplots was 1.5 x 7.0 m.

Herbage samples were taken from the 1970 fall harvest and from the harvests taken in 1971. Following drying and grinding samples were stored for analysis. All tissues were analyzed for IVDMD and NO_3^--N. Samples taken in the fall were found to be contaminated with soil and so results of analyses are reported on an organic matter basis. Fall samples were, in addition, subjected to analyses for crude protein and total nonstructural carbohydrates (TNC). In order to evaluate the influence of N level on the uptake of Ca, Mg, P, and K, samples of ryegrass obtained in 1971 from the 8 September 1970 seeding/no fall cutting treatment and each 1971 N level were subjected to elemental analysis. Concentrations of crude protein were also determined on these same samples.

Experiment 5.

Late-summer seedings of six ryegrass cultivars were made in 1971 to evaluate (a) winter survival, (b) influence of postestablishment harvesting on winter survival, and (c) productivity in 1972. Soil analyses indicated that the experimental site had a pH of 6.6 and Ca, Mg, P, and K levels of 3248, 560+, 7, and 426 kg ha^{-1}, respectively. Cultivars seeded were commercial perennial ryegrass, 'Epic', 'NK-200', and 'Petra' perennial ryegrass, 'Tetrone' Italian ryegrass, and Tetrelite ryegrass.[1] The former three cultivars are diploids while the latter three are tetraploids. Cultivars were hand broadcast on a conventionally prepared seedbed at a rate of 18 kg ha^{-1} on 31 August. A broadcast application of 39 kg P ha^{-1} was made simultaneously. The seedbed was then cultipacked. Plots were either harvested on 17 November or allowed to grow uncut throughout the fall and early-winter period. The experiment was set out in a split-block design in which cultivars were arranged in a randomized, complete block design (main plots) and cutting versus no fall cutting as strips across each block. Four replications were used; size of subplots was 2.1 x 3.5 m. On 2 May 1972 a general fertilizer application of 336, 44, and 168 kg ha^{-1} of N, P, and K, respectively, was broadcast over all plots.

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[1]*Seed of Epic, NK-200, Petra, and Tetrone ryegrass were provided by Northrup King Co., Minn.*

Harvests were taken on 6 June and 12 July 1972. After the second harvest 56 kg N ha $^{-1}$ was applied and a third harvest taken on 24 August 1972.

Experiment 6

This experiment, conducted in 1972-73, was designed to evaluate the influence of fall applications of N and varying fall cutting treatments on the carbohydrate reserves and winter survival of two cultivars of ryegrass. Analyses indicated that the soil had a pH of 6.2 and Ca, Mg, P, and K levels of 2352, 504, 7, and 134 kg ha $^{-1}$, respectively. The experimental site had been summer fallowed. Ground limestone was added and disked in on 21 August 1972 at a rate of 2.24 mt ha $^{-1}$.

The 2 x 2 x 3 factorial experiment used a split-split-plot design with four replications. Treatment levels of each factor were arranged in a randomized, complete block design. The size of each sub-subplot was 1.5 x 6.1 m. Main plots were cultivars: Tetrelite and commercial perennial ryegrass. Subplots were N levels: 0 and 56 kg N ha $^{-1}$. Sub-subplots were fall cutting frequencies. These were: (a) a no-cut system, (b) a one-cut system, and (c) a weekly-cutting system.

On 31 August 1972, the two cultivars at 18 kg ha $^{-1}$ plus 45 kg P ha $^{-1}$ were broadcast by hand and raked in. The area was then cultipacked. Nitrogen was broadcast on 5 September. The single cut of the one-cut system was taken on 27 October 1972. The weekly cuttings were initiated on 29 September and further cuts were taken until 3 November. All cuttings were made to a 5 cm height.

Stubble samples were initially collected on 30 November. Because of heavy rainfall, samples were collected over a period of time. However, at any given sampling time, all of the plots of one replication were sampled. Sampling consisted of harvesting tissues from the soil surface to a height of 5 cm above soil level. Hence, samples included pseudostems plus varying quantities of leaf lamina. Samples were dried at 100° C for 1 hour and then at 70° C until dry when they were ground through a 1-mm screen in a Wiley mill.

Tissue samples were analyzed for their TNC and nonfructosan carbohydrate concentrations. Since samples were found to be contaminated with soil they were ashed and organic matter calculated. Values for TNC, fructosan, and nonfructosan carbohydrates were then calculated on an organic matter basis.

Visual estimates of the percentage of winterkill sustained during the 1972-73 winter were made in late April 1973 by two observers. Estimates of each plot were made on the basis of percent ground cover.

Experiment 7

The purpose of this experiment, initiated in the late summer of 1973, was to further evaluate the response of ryegrass cultivars to fall applied N fertilizer and cutting treatments. The soil at the experimental site had a pH

of 6.2 and available Ca, Mg, P, and K levels of 2464, 504, 16, and 134 kg ha -1, respectively. During seedbed preparation 112 kg K ha -1 was incorporated. The cultivars were seeded at 18 kg ha -1 on 21 August 1973 using a modified grain drill.

The 2 x 2 x 3 factorial experiment was set out in a split-split-plot design and replicated four times. Treatment levels of each factor were arranged in a randomized complete block design. Size of the sub-subplots was 1.5 x 6.1 m. Main plots were ryegrass cultivars; Tetrelite and commercial perennial ryegrass. Subplots were cutting frequencies: a no-cut system and a one-cut system. The single cutting was taken on 26 October, at which time yield estimates were made. Sub-subplots were N levels: 0, 56, and 112 kg ha -1. All N applications were made in a single application on 2 October. Simultaneously, 112 kg K ha -1 was also applied.

Stubble samples were collected on 25 and 26 January 1974 after permanent soil freezing. Samples were rinsed free of soil, surface dried, and then oven dried, ground, stored, and analyzed for TNC. Concentrations of TNC are expressed on a dry matter basis. Samples taken on 26 October were used for IVDMD determinations.

On 30 April 1974, an application of 112, 49, and 93 kg ha -1 of N, P, and K was made to all plots, and on 3 June 1974 a further 76 kg N ha -1 was applied. Plots were harvested on 31 May and 17 July 1974.

Estimates of winterkill were made. Following establishment all plots were inspected and any gaps in excess of 5 cm were recorded. In the spring the plot rows were reexamined and ryegrass losses recorded. The difference between live rows in the fall and spring was considered winterkill.

Experiment 8

In order to evaluate the influence of location on the winter survival of ryegrass, a seeding similar to Experiment 7, but using only Tetrelite ryegrass, was established at the base of a protected slope. The experimental site had been summer fallowed. Tetrelite ryegrass at 18 kg ha -1 and P at 155 kg ha -1 were drilled on 22 August 1973.

The 2 x 3 factorial experiment was set out in a split-plot design replicated four times. Levels of each factor were arranged in a randomized, complete block design. The size of the subplots was 1.5 x 6.1 m. Main plots were fall cutting systems and subplots were fall applied N fertilizer levels. The cutting systems were a no-cut system and a one-cut system in which all plots were cut on 26 October 1973. Nitrogen levels of 0, 56, and 112 kg ha -1 were established. All N applications were made on 1 October.

Samples of ryegrass tissue were taken on 25 January 1974 and were analyzed for TNC and nonfructosan carbohydrates. Winterkill estimates and IVDMD analyses were also performed. Analyses of soil samples, taken from the experimental site on 25 April 1974, indicated soil

pH to be 6.2 and Ca, Mg, P, and K levels to be 1904, 347, 16, and 336 kg ha^{-1}, respectively. Dry matter yields were taken from the experimental plots on 31 May and 16 July 1974 as previously explained for Experiment 7.

In order to measure the changes that occurred in the concentration of nonstructural carbohydrates during winter dormancy, samples were collected from each block of both Experiment 7 and 8. They were collected from plots that had received no fall application of N fertilizer and which had not been cut during fall establishment. Collections were made on 26 January and 10 April 1974. The latter date was just prior to the initiation of active growth. Samples were handled and subjected to nonstructural carbohydrate analyses as previously described.

Experiment 9

The first of several cultivar trials was initiated in 1973. A listing of the cultivars is provided in Table 18. Cultivars were broadcast at 27 kg ha^{-1} into a conventionally prepared seedbed. During seedbed preparation limestone was incorporated at a rate of 1120 kg ha^{-1}; N, P, and K were also added at rates of 56, 90, and 112 kg ha^{-1}, respectively. The date of seeding was 30 April. Due to a heavy crabgrass (*Digitaria sanguinalis* (L.) Scop.) infestation yields were not taken during the establishment year. Plots were mowed, however, on 28 June, 19 July, and 28 September. Following the June mowing, plots were topdressed with N at 56 kg ha^{-1}. Following the September mowing a topdressing of N, P, and K at 50, 22, and 42 kg ha^{-1}, respectively, was made. Plots were evaluated in October 1973, and most cultivars had stands that were rated average to good.

Yield estimates were taken during the years 1974-1977. Fertilizer and harvest schedules for this period are provided in Table 17. In the fall of 1973 soil analyses indicated that the experimental site had a pH of 6.4 and Ca, Mg, P, and K levels were 2012, 448, 11, and 426 kg ha^{-1}, respectively. The experiment was set out using a randomized, complete block design with four replications. Individual plot size was 1.5 x 4.9 m. Pennmead orchardgrass was included in the trial for comparative purposes.

Experiment 10

Two cultivar trials were established in 1976. The first evaluated annual and short-rotation ryegrasses while the second trial evaluated perennial ryegrasses. In both trials Pennmead orchardgrass was included for comparative purposes. Both trials utilized a randomized, complete block design with three replications. Individual plot size was 1.5 x 4.9 m. Soil analyses indicated the soil pH to be 6.7 and Ca, Mg, P, and K levels to be 1904, 470, 10, and 179 kg ha^{-1}, respectively. Since both trials were established on the same site, field preparation and establishment procedures were identical.

The experimental site had been seeded to a rye cover crop in October, 1975. On 4 May 1976 applications of 45 and 112 kg ha $^{-1}$ of P and K, respectively, were made. The field was then disked and cultipacked. Seeding of all cultivars was initiated on 13 May and was completed by 17 May. Seeds were hand broadcast, lightly raked in, and the entire field cultipacked. All varieties were seeded at a rate of 22.4 kg ha $^{-1}$.

The cultivars used in the annual and short-rotation ryegrass trial are listed in Table 19. Those used in the perennial ryegrass trial are listed in Table 20.

On 15 July 1976 a broadcast application of 56 kg N ha $^{-1}$ was made. On 24 August 1976 an application of 56, 241, and 47 kg ha $^{-1}$ of N, P, and K, respectively, was made and on 26 October a second application of 22 and 84 kg ha $^{-1}$ of P and K, respectively, was applied.

Cutting schedules varied somewhat between the two trials. Yields were obtained from the annual and short-rotation ryegrass plots on 20 July, 12 August, and 7 October 1976. In the case of the perennial cultivars a field cutting was taken on 15 July. However, yields were not recorded since the plots were infested with weeds. Yields were obtained, however, from cuttings made on 12 August and 7 October 1976.

No harvests were taken from the annual and short-rotation ryegrass plots in 1977 since they were substantially winterkilled. The perennial ryegrass did survive the 1976-77 winter. Winter survival and vigor ratings were taken on 29 April and 1 May 1977, respectively. The perennial ryegrass plots were harvested for yield estimates on 1 June, 30 June, 1 August, 1 September, and 1 November 1977. Plots also received 56, 24, and 47 kg ha $^{-1}$ of N, P, and K, respectively, on 27 April, 9 June, 2 July, 2 August, and 5 September 1977. Harvests were not taken in 1978 since plots were severely winterkilled during the 1977-78 winter.

Experiment 11

In 1983 a cultivar trial was conducted to compare Westerwolds ryegrass production to that obtained from hybrid ryegrass. A factorial experiment, consisting of eight cultivars and three N fertility levels, was set out using a randomized, complete block design with three replications. The cultivars used are listed in Table 23. They included both diploid and tetraploid Westerwolds ryegrasses as well as the tetraploid hybrid cultivars Tetrelite and 'Bison'. Individual plot size was 4 x 2 m. Soil tests indicated that the soil pH was 6.4 while Ca, Mg, P, and K levels were 1982, 515, 2, and 90 kg ha $^{-1}$, respectively.

Cultivars were established using the no-tillage technique. Glyphosate was applied at 2.5 kg ai ha $^{-1}$, 5 days prior to seeding, to achieve vegetation suppression. On 10 May 1983 cultivars were seeded at 22.4 kg ha $^{-1}$ using a Tye 'Pasture Pleaser' no-till drill. At the time of seeding 44 kg P ha $^{-1}$ was banded with the seed. The day after seeding a broadcast application of 45 and 84 kg ha $^{-1}$ of N and K, respectively, was made.

Cultivars were harvested on 8 July and again on 8 August 1983. Following each harvest a broadcast application of 17 and 63 kg ha -1 of P and K, respectively, was made. Three N levels were established. These were 224, 336, and 448 kg N ha -1. The timing and distribution of the N applications were as follows:

Date	*Nitrogen treatment - kg ha^{-1}*		
	224	*336*	*448*
11 May	45	45	45
6 June	134	218	302
8 July	45	73	101

Experiment 12

In 1981 an experiment was initiated to compare the productivity of ryegrass grown in both pure and mixed stands. The 2 x 4 factorial experiment, replicated four times, was set out in a randomized, complete block design. Two ryegrass cultivars, Tetrelite and Bison, were used. These were grown as pure stands as well as in mixtures with either 'Iroquois' alfalfa, 'Arlington' red clover (*Trifolium pratense* L.), and 'Viking' birdsfoot trefoil (*Lotus corniculatus* L.). Individual plot size was 2 x 7 m.

The soil at the experimental site had a pH of 6.5 and Ca, Mg, P, and K levels of 1736, 308, 17, and 216 kg ha -1, respectively. Broadcast applications of 2240 kg ha -1 of dolomitic limestone plus 45, 39, and 75 kg ha -1 of N, P, and K, respectively, were made and disked in during conventional seedbed preparation. Plots were seeded on 23 April 1981 using a modified grain drill. A band placement of 45 kg P ha -1 accompanied all seedings. The ryegrass cultivars were seeded at a rate of 20 kg ha -1. The mixed seedings were made at a rate of 10 kg ha -1 of ryegrass and 10 kg ha -1 of legume.

The treatments were evaluated during the 1981-1983 period. Harvest dates and fertilization schedules during this period were as follows:

Year	*Harvest dates*	*Fertilization and dates applied*			
		N	*P*	*K*	
		kg ha^{-1}			
1981	25 June	67			25 June*
	3 Aug.	67	59	168	3 Aug.**
	30 Oct.				
1982	15 June	112	29	56	4 May*
	22 July	67	29	56	4 May+
		56	15	56	15 June*
		0	15	56	15 June+
		56	15	56	22 July*
		0	15	56	22 July+
1983	23 June	67	44	112	23 June**
	8 Aug.	0	44	112	8 Aug.**

*Ryegrass plots only. **All plots.
+Mixtures only.

Experiment 13

Two greenhouse-growth chamber experiments were conducted to evaluate the influence of photoperiod and growth interval on the accumulation of nonstructural carbohydrates in ryegrass. Tetrelite, certified perennial ryegrass, and annual ryegrass were seeded into 17 cm pots containing a well fertilized soil. The cultivars were allowed to establish from mid-October to the end of January. At this point all foliage was trimmed to a 5 cm height and the experimental treatments initiated.

In the first experiment four pots of each cultivar were placed in a growth chamber set to provide a 16-hour day and an 8-hour night cycle at 26.7° and 10°C, respectively. After 21 days of regrowth (20 February) two pots of each cultivar were again trimmed at 5 cm and then the stubble was harvested. The stubble was dried in a forced-draft oven as described by Smith (1969). After 43 days of regrowth the remaining pots of each uncut cultivar were harvested as described above.

An identical set of pots was placed in the greenhouse at the same time that the above pots were placed in the growth chamber. No additional lighting was provided so that the cultivars were growing under a short-day photoperiod. The experimental treatments were identical to those cultivars grown in the growth chamber and were initiated simultaneously.

After the second harvest, taken on 14 March, all cultivars in both greenhouse and growth chamber were fertilized with the equivalent of 50 and 112 kg ha^{-1} of N and K, respectively, in aqueous solution. On 15 April, all pots in both the growth chamber and greenhouse were harvested and stubble obtained as previously described. Consequently, those cultivars initially harvested on 20 February had had a regrowth period of 54 days, while those initially harvested on 14 March had a regrowth period of 32 days.

After drying, stubble samples were ground and concentrations of TNC and nonfructosan carbohydrates determined. In both greenhouse and growth chamber, the pots were set out in a completely random design.

In the second experiment Tetrelite, certified perennial, and annual ryegrass were established in 17 cm pots as previously described. Two replicates of each cultivar were cut at two heights: 7.6 cm and at the base. The pots were then placed in a completely random design in the greenhouse and allowed to grow until 22 April. At that time all cultivars were trimmed to a height of 5 cm and then the stubble harvested. The stubble was dried, ground, and analyzed for concentrations of carbohydrates as previously described. Stubble was also harvested from the beginning harvest and analyzed; the values so obtained represented initial carbohydrate concentrations for both experiments.

Analytical Procedures

A number of analyses were performed on herbage samples. Herbage was dried and ground to pass a 1-mm sieve and then stored in glass bottles. Dry matter was determined on the ground samples and all analyses are expressed on a dry matter basis, except where otherwise indicated.

In vitro dry matter disappearance was determined using the procedure of Tilley and Terry (1963), and ADF, ADL, and CWC using the techniques of Van Soest (1963, 1967). Nitrates (NO_3^--N) in aqueous tissue extracts were measured colorimetrically using the procedure of Kamphake et al. (1967); aqueous extracts were obtained using the procedure of Johnson and Ulrich (1950). Crude protein was determined as N x 6.25; N was determined using the macro-Kjeldahl method and the titration procedure of Meeker and Wagner (1933). Organic matter was determined after ashing at 600°C. Total nonstructural carbohydrate and fructosan concentrations were determined in samples of herbage after preparation and analysis according to the procedures outlined by Smith (1969).

Samples that were analyzed for Ca, Mg, P, and K were first digested in a mixture of nitric and perchloric acids (Hagstrom and Rubins, 1961). Phosphorus in the digestate was determined using the chlorostannous molybdophosphoric blue colorimetric method (Dickman and Bray, 1940). Potassium and Ca were determined using flame photometry while Mg was determined using atomic absorption spectrophotometry.

RESULTS AND DISCUSSION

Experiment 1

Initial growth and establishment, as measured by first harvest dry matter yields, were greatest for Tetrelite ryegrass (Table 1). The yield obtained from this cultivar was, with the exception of perennial ryegrass, significantly greater than that obtained from other species. The ryegrasses in general, i.e., Tetrelite, Lamora, and perennial, established more rapidly and gave greater first harvest yields than the remaining species. Aftermath growth in the period 2 July to 7 August was significantly greater for Pennmead orchardgrass than for Lamora and perennial ryegrass. However, in the same period there was no significant difference between yields of orchardgrass, tall fescue, or Tetrelite ryegrass. There were no significant differences among yields of harvested cultivars in the third harvest. Reed canarygrass did not produce a measurable yield of dry matter in the period 7 August to 23 October. Over the entire growing season there was no significant difference

in yield among the ryegrass, tall fescue, or orchardgrass cultivars.

Perennial ryegrass has a shallow root system. Garwood (1967) reported that approximately 80% of the root mass of perennial ryegrass was found in the upper 10.2 cm of soil. Despite this fact, regrowth of the ryegrass cultivars during the summer period was comparable to the orchardgrass and tall fescue.

The three ryegrass cultivars were completely winterkilled during the 1968-1969 winter. The other grass species survived this winter without noticeable damage.

Table 1. Dry matter yields of six grass cultivars obtained in the establishment year.

Cultivar	Harvest date			Total
	2 July	7 Aug.	23 Oct.	
	kg ha^{-1}			
Tetrelite ryegrass	2269[a*]	2972[abc]	2937	8178[a]
Pennmead orchardgrass	638[d]	3698[a]	2977	7314[a]
Kentucky 31 tall fescue	807[cd]	3283[ab]	3192	7282[a]
Perennial ryegrass	1975[ab]	2810[bc]	2194	6979[a]
Lamora ryegrass	1357[bc]	2480[c]	2730	6568[a]
Ioreed reed canarygrass	855[cd]	380[d]	-[†]	1235[b]
Significance (F test)	**	**	NS	**

**Significant at P<0.01.
*Means within a column followed by the same letter are not significantly (P<0.05) different according to Duncan's multiple range test.
NS Not significant.
†No harvest taken.

Experiment 2

Dry matter yields, totalled over the entire harvest period of 25 June to 23 October, were significantly greater for Tetrelite ryegrass than those obtained from the other cropping systems (Table 2). However, ryegrass was harvested four times during this period while the other species and mixtures were harvested only once or twice. If comparisons are restricted to the 25 June to 3 September period, the yields from the ryegrasses are significantly greater than those from alfalfa and oats grown in pure stands but were not different from these latter species grown as a mixture. Yields were greater for ryegrass fertilized with 672 kg N ha^{-1} compared to a level of 448 kg N ha^{-1}. Clearly, ryegrass was still responding to N applications even at these high rates. In Experiment 1, Tetrelite ryegrass produced 8178 kg ha^{-1} when fertilized with 157 kg N ha^{-1}.

Table 2. Dry matter yields of ryegrass, oats, alfalfa, and an oats-alfalfa mixture obtained in the establishment year.

Cultivar	N treatment		Harvest date				Total yields	
	Amount	Date	6/25	7/19	9/03	10/23	6/25-9/03	6/25-10/23
	$kg\ ha^{-1}$		$kg\ ha^{-1}$					
Tetrelite ryegrass	224	16-4	2640[b†]	2193	3541[a]	2134[‡]	8374[a]	10508[a]
	224	1-7						
	224	3-9						
Tetrelite ryegrass	224	16-4	2586[b]	1730	2288[b]	2670	6604[b]	9274[b]
	224	3-9						
Saranac alfalfa plus Garry oats	56	16-4	4926[a]		2669[ab]		7595[ab]	7595[c]
Garry oats	56	16-4	4453[a]				4453[c]	4453[d]
Saranac alfalfa				2316	2012[b]		4328[c]	4328[d]
F test			**	NS	*	*	**	**

**, *Significant at $P<0.01$ and 0.05, respectively.
†Means within a column followed by the same letter are not significantly ($P<0.05$) different according to Duncan's Multiple Range Test.
‡Significantly ($P<0.05$) different based on F test.
NS Not significant.

Yields of this same variety, grown on an adjacent site (Experiment 2) were enhanced by additional N. However, the economical aspect of these high rates of N during the establishment year would be debatable.

Yields obtained from the pure oats seeding were not significantly different from the oats-alfalfa mixture at the 25 June harvest. Recovery of the alfalfa, following the removal of the oat companion crop, was excellent and so the total seasonal production of the mixture was significantly greater than the pure alfalfa seeding.

Yields of ryegrass in the period 19 July-3 September were equal to or in excess of those obtained from the pure alfalfa seeding. In both this experiment, and the previous one, ryegrass cultivars at varying N levels produced satisfactory yields during the summer period.

Winterkill of ryegrass plots occurred in this experiment. However, the winterkill was not as complete as in the previous experiment, despite the higher N levels.

Experiment 3

The stands that developed from the August seedings of Tetrelite ryegrass were excellent. Harvests taken 24 October from the 8 August seeding produced 1609 kg ha^{-1} of dry matter with an IVDMD value of 82.2% (Table 3). The earlier seedings produced the greatest dry matter yields at both October harvests. Quality of forage, as indicated by IVDMD values was high. Of some interest was the relationship between age of the forage and its yield and IVDMD values. As expected, the forage with the longest period of time between seeding and harvest had the highest yields. As this time interval declined so also did yield. The reverse might be expected to occur insofar as quality is concerned. While this did occur when comparisons are made at each date of cutting, the reverse occurred when comparisons are made between cuttings. Hence, forage harvested 24 October, with calendar ages of 77 and 70 days, had a mean IVDMD value of 84.0% while that harvested on 10 October, with calendar age of 63 and 56 days, had a mean IVDMD value of 80.5%. Forage harvested 10 October was apparently depressed in IVDMD relative to that harvested 2 weeks later. Similarly, while concentrations of CWC and ADF had increased slightly in herbage harvested after 63 days growth, relative to that harvested after 56 days of growth, there was a depression in concentrations in subsequent growth, thus reflecting high IVDMD values. Concentration of crude protein declined from 24.5 to 19.7% over the harvest period. In general, the quality of the ryegrass herbage harvested after 56-77 days growth was very high. Concentrations of NO_3^--N in the forage were in excess of 1000 ppm. This was above the upper safe limit of 700 ppm NO_3^--N suggested by Garner (1958) but substantially below the lower safe limit of approximately 4500 ppm NO_3^--N cited by Davison et al. (1964).

Winter survival from the 1969 fall seedings, especially from those seedings made in August and harvested early in October, was good. Dry

Table 3. Dry matter yields and IVDMD, CWC, ADF, ADL, crude protein, and NO_3^--N concentrations of Tetrelite ryegrass obtained from 1969 fall harvests of 1969 summer seedings.

Date of harvest	Date of seeding	Days from seeding-harvest	Yield	IVDMD	CWC	ADF	ADL	CP*	NO_3^--N
			— kg ha^{-1} —			%			—ppm—
10 Oct.	8 Aug.	63	911	79.7	44.3	24.5	2.3	22.5	1336
	15 Aug.	56	522	81.3	43.0	23.1	1.6	24.5	1027
24 Oct.	8 Aug.	77	1609	82.2	41.5	21.6	2.3	19.7	1040
	15 Aug.	70	1002	85.9	41.3	18.9	1.7	23.0	1058

*Crude protein

matter yields obtained in 1970 from plots cut on 10 October 1969 were consistently greater than those from plots cut on 24 October (Table 4). Mean yields for the two dates of fall cutting, averaged over all dates of seeding, were 7.92 and 5.99 Mg ha^{-1}, respectively. Ryegrass seeded on 25 August 1969 gave consistently greater yields in 1970, compared to ryegrass seeded at other dates. The combination of early seeding and late fall harvest resulted in greater winterkill and, hence, lower yields in 1970. Averaged across all treatments 41, 36, 14, and 9% of the total seasonal yields were obtained at the first, second, third, and fourth harvests, respectively. However, no N fertilizer was applied after the third harvest on 5 August. At the time of the first harvest (4 June) the ryegrass was in the late-boot to early-heading stage of maturity. The mean dry matter content at this stage was only 12.6%.

Values for IVDMD were generally high throughout the entire season. Values were greatest for the first harvest and lowest for the second harvest. Consistent trends, relative to fall harvest or seeding date were not evident.

Concentrations of NO_3^--N were clearly greatest in first harvest tissues. Overall means for concentrations of NO_3^--N were 1237, 192, 653, and 136 ppm for the first through fourth harvests, respectively. These variations in concentrations of NO_3^--N undoubtedly reflect the pattern of N fertilization and time interval between harvests. Fifty percent of the applied N was broadcast in early spring, prior to the first harvest, with the remaining N applied after the first and second harvests. There was an approximate 1-month interval between the first and second harvests and between the second and third harvests. However, there was an approximate 2-month interval between the third and fourth harvests. The greater concentration of NO_3^--N in the third harvest tissues, relative to the second harvest tissues, is probably accounted for by a dilution effect since yields from the second harvest were approximately 2.6 times greater than those from the third harvest. The overall mean NO_3^--N concentration of 1237 ppm, obtained for the first harvest, was above the safe limit of 700 ppm cited by Garner (1958). However, George et al. (1972) indicated that steers grazing tall fescue, containing concentrations of NO_3^--N greater than commonly accepted critical levels, showed no detrimental effects.

Experiment 4

Fall growth of ryegrass from the 1970 seeding was excellent, as was the case the previous year. The earliest seedings gave the greatest yields at the 28 October harvest (Table 5). The 1560 kg ha^{-1} yield, produced after 65 days growth, was substantially higher than the 911 kg ha^{-1} yield obtained from 63 days growth the previous year. The older herbage was significantly ($P < 0.05$) higher in IVOMD compared to the youngest herbage. This same trend was observed for IVDMD the previous year. However, in 1970 the difference between IVOMD levels of the oldest and

Table 4. Dry matter yields, IVDMD, and NO_3^--N concentrations of Tetrelite ryegrass harvested in 1970 from 1969 seedings.

1969			IVDMD (1970)				NO_3^--N (1969)			
Date of harvest	Date of seeding	Total yield	6/4	7/7	8/5	10/9	6/4	7/7	8/5	10/9
		Mg ha^{-1}	%				ppm			
10 Oct.	8 Aug.	7.27	79.4	67.8	73.1	72.9	913	68	332	63
	15 Aug.	8.74	77.6	68.8	72.5	72.9	1191	171	429	65
	25 Aug.	8.89	78.3	68.3	69.2	67.9	1740	107	515	151
	2 Sept.	6.76	76.0	69.3	73.6	69.4	1390	295	262	103
24 Oct.	8 Aug.	3.97	-*	64.4	74.0	-*	-*	271	1175	-*
	15 Aug.	5.91	80.5	64.8	73.6	72.7	1152	301	1107	189
	25 Aug.	7.88	79.7	69.2	74.3	75.0	1170	230	787	163
	2 Sept.	6.19	79.8	71.0	75.0	73.9	1103	92	617	219
	Mean	6.95	78.8	68.0	73.2	72.1	1237	192	653	136

*Harvest not taken due to inadequate growth.

Table 5. Yields, IVOMD, and concentrations of crude protein (CP), total nonstructural carbohydrates (TNC), and nitrate-nitrogen (NO_3^--N) of Tetrelite ryegrass harvested 28 Oct. 1970 from late-summer seedings.

Date of seeding	Interval between seeding-harvest	Yield	IVOMD*	CP*	TNC*	NO_3^--N
	- days -	-kg ha^{-1}-		%		-ppm-
24 Aug.	65	1560	83.1	28.3	14.9	2224
31 Aug.	58	820	77.8	32.1	12.6	2749
8 Sept.	50	372	68.0	32.1	9.8	2537
LSD (5%)		486	9.3	NS	NS	NS

*Concentrations reported on an organic matter basis.
NS Not significant.

youngest herbage was much more pronounced, i.e., 83.1 versus 68.0% for 65 and 50 days growth, respectively. Had these data been expressed on a dry matter basis, rather than an organic matter basis, the difference would have been much greater since it was the youngest herbage that was most heavily contaminated by soil. That the oldest growth had the highest IVOMD levels may be related to the fact that this herbage also had the highest TNC concentrations. Data presented by Balasko (1977) indicated that tall fescue, harvested in early winter following uninterrupted fall growth, had varying IVDMD values. These variations were attributed to the length of the growing period, N fertilization, and climatic conditions. Concentrations of TNC also varied. Computation of a correlations coefficient provided an r value of 0.85 ($P<0.01$) indicating a high degree of association between TNC and IVDMD. Nitrate and protein concentrations in fall harvested herbage were somewhat higher than those observed the previous year. However, it must be remembered that these values are expressed on an organic matter basis and that N fertilizer was applied to the soil during seedbed preparation in 1970.

Analysis of variance of total yields obtained from the five harvests in 1971 indicated that N rates significantly ($P<0.05$) affected dry matter yields. As might be expected, yields increased significantly with successive increments of N fertilizer. Overall mean yields for the 224, 336, and 448 kg N ha^{-1} treatments were 9.14, 10.31, and 11.11 Mg ha^{-1}, respectively. Further analysis of the N response using orthogonal polynomials indicated that only the linear effect was significant

($P<0.01$). For each 112 kg N ha^{-1} increment there was a 1 Mg ha^{-1} increase in dry matter yield. The response also suggests that even at these relatively high rates of N application the maximum potential yield of Tetrelite ryegrass had not been attained.

Neither date of seeding in 1970 nor fall cutting influenced yields in 1971. Further, none of the first- or second-order interactions were of significance insofar as 1971 yields were concerned.

At the time of the first harvest (1 June) the ryegrass was in the boot stage, was somewhat lax, and exhibited some lodging. Dry matter content averaged 9.8%. Ryegrass continued to flower throughout the summer. The dry matter content averaged 12.5, 21.3, 18.0, and 18.3% for the second, third, fourth and fifth harvests, respectively. The distribution of the total season yield was not even; 34.4, 22,3, 8.9, 11.2, and 23.2% of the total yield was obtained at the first through fifth harvests, respectively.

Since IVDMD determinations had been performed on all tissues harvested throughout the 1971 growing season it was possible to calculate yield of digestible dry matter (yield x IVDMD). Analysis of variance of these data produced results similar to that for yield data. Only the N effect was significant. Mean yields of digestible dry matter were 6.97, 7.80, and 8.40 Mg ha^{-1} for the 224, 336, and 448 kg N ha^{-1} treatments, respectively. Use of orthogonal polynomials again only revealed a significant ($P<0.01$) linear response to N application.

The virtually identical response observed for yield of digestible dry matter and for yield of dry matter suggests that N fertilization had either (a) no effect on IVDMD or (b) the response of IVDMD to N fertilization was identical to that of yield. The data presented in Table 6 suggests that the former conjecture is the case. Nitrogen fertilization appeared to have only minor effects on the IVDMD of ryegrass when assessed on individual harvests and, where slight differences were evident, these were not consistent among harvests. Data reported by other investigators, working with a variety of forage grasses, have also indicated that N fertilization has negligible effect on digestibility (Calder and MacLeod, 1968; Niehaus, 1971; Lechtenberg et al., 1974). Even where significant statistical differences have been observed the magnitude of these differences has been very small.

However, differences in herbage IVDMD were evident among harvests. First and fifth harvest tissues had IVDMD values that were higher than those obtained for harvests taken during the summer months. These differences no doubt reflect, to a considerable degree, the differences in morphological development that had occurred at the time of each harvest. Even with the 10 unit variation that occurred among harvest means, the relative IVDMD values are indicative of forage possessing a high nutritive value.

Nitrogen fertilization had a pronounced impact on the NO_3^--N concentrations observed in ryegrass herbage. As N fertilizer rates increased so also did NO_3^--N concentrations. However, NO_3^--N con-

Table 6. Values of IVDMD and NO_3^--N obtained for Tetrelite ryegrass harvested five times in 1971 and fertilized at three N rates.

N rate	Harvest date 6/1	6/24	7/16	8/12	10/8	Mean
			IVDMD			
-kg ha^{-1}			%			
224	80.0*	75.4	69.2	69.5	76.2	74.1
336	80.6	74.5	70.2	69.7	75.6	74.1
448	80.4	73.6	70.4	70.3	75.8	74.1
Mean	80.3	74.5	69.9	69.8	75.9	
			NO_3^--N			
			ppm			
224	1196	301	67	617	64	449
336	4596	1218	133	1339	120	1481
448	7151	2805	256	2254	403	2574
Mean	4314	1441	152	1403	196	

*Values are means of 24 observations

centrations in herbage also reflected the timing of N fertilizer application. The greatest concentrations were obtained in first harvest herbage; this herbage had been fertilized with 50% of the total N rate. The lowest NO_3^--N concentrations were obtained in the third harvest herbage; in this instance no N fertilizer had been applied following the 24 June harvest.

At times, but particularly in first harvest tissues fertilized at the two highest N rates, the concentrations of NO_3^--N were high enough to be deemed dangerous. It has been pointed out that the "safe" concentration of NO_3^--N in herbage has not been clearly established. The early literature (Whitehead and Moxon, 1952; Case, 1957; Garner, 1958) established minimum lethal and toxic concentrations of NO_3^--N as being 2100 and 670 ppm, respectively. These concentrations essentially were used to differentiate between acute and chronic toxicities. Acute toxicity resulted in collapse and death of an animal while chronic toxicity, which might occur when an animal consumed forage having a NO_3^--N concentration greater than 670 ppm, resulted in lowered productivity, le-

sion formation, or abortions. More recent literature suggests that higher concentrations of NO_3^--N can be tolerated by livestock and questions the concept of chronic toxicity. In a lengthy review, Wright and Davison (1964) suggest that forage with NO_3^--N concentrations of 3400 to 4500 ppm should be considered potentially toxic. Davison et al. (1964) concluded that nitrate, consumed at less than 2% of the diet (approximately 4500 ppm NO_3^--N), did not cause abortions. Bryant and Ulyatt (1965) fed ryegrass, containing NO_3^--N at concentrations up to 7200 ppm, to sheep and did not observe any deleterious effects on health. Similarly, Large and Spedding (1966) did not observe any adverse effects on the health of early weaned lambs fed grass with NO_3^--N concentrations that exceeded 5000 ppm. In view of these findings the concentrations of NO_3^--N observed in Tetrelite herbage would appear to be high, but generally safe, with perhaps care being needed in the feeding of herbage fertilized with unusually high rates of N fertilizer within 3-4 weeks of harvest.

Concentrations of crude protein [determined as (total N - NO_3^--N) x 6.25] generally reflected rates of applied N (Table 7). Linear and quadratic regressions were significant for the first, second, and third harvests while the linear regression was also significant for the fifth

Table 7. Concentrations of crude protein in Tetrelite herbage harvested in 1971.

Nitrogen rate	Harvest date					Mean
	6/1	6/24	7/16	8/12	10/8	
-kg ha^{-1}	%					
224	19.3	16.8	14.3	19.3	14.7	16.9
336	23.8	20.0	15.8	19.8	16.0	19.1
448	23.0	19.8	15.9	20.2	17.5	19.3
Mean	22.0	18.9	15.3	19.8	16.1	
F tests						
N	**	**	**	NS	*	
Linear	**	**	**	NS	**	
Quadratic	*	*	*	NS	NS	

**, *Significant at P<0.01 and 0.05, respectively.
NS Not significant.

harvest. The significant effects observed in the third harvest indicated a N carry-over effect since no N fertilizer had been applied since early June and the second harvest occurred on 24 June. Nevertheless, concentrations of crude protein were the lowest in the third harvest, compared to the other four harvests, as also were concentrations of NO_3^--N (Table 6). Averaged over the entire harvest period the concentrations of crude protein ranged from 16.9-19.3%, depending upon the N fertilization rate.

The concentrations of Ca, Mg, K, and P found in the ryegrass tissues in 1971 are shown in Table 8. Concentrations of Ca were within the range normally reported for perennial grasses. Concentrations were consistently higher for ryegrass fertilized with the higher N fertilizer rates. The linear regression was significant ($P<0.05$) for the first, second, fourth, and fifth harvest herbage. Application of N fertilizer similarly increased concentrations of Mg in ryegrass herbage. Linear regressions were significant in the second, third, fifth ($P<0.05$), and fourth ($P<0.01$) harvests. The concentrations of Mg were relatively high throughout the growing season but were highest in the fourth and fifth harvests. Concentrations of K in harvested herbage, while within the range reported for perennial grasses, were high. This was particularly so for the first and second harvests when concentrations were consistently at 4.0% or greater. Nitrogen did not consistently affect herbage concentrations of K but when significance was obtained concentrations were depressed by increasing N rates. Reports in the literature suggest that the effect of N on the concentration of K in herbage varies with the availability of soil K; N fertilization increasing K concentration when soil K is high but depressing it when soil K availability is low (Whitehead, 1972). Concentrations of P in herbage were consistently in excess of 0.3% and, like K, were highest in the first two harvests. In the third through fifth harvests increasing N fertilization resulted in depressions of P concentrations. In each case the linear regression was significant ($P<0.01$) and in the fourth harvest the quadratic regression was also significant ($P<0.05$).

The high concentrations of herbage K suggested that consumption of such herbage could lead to incidences of hypomagnesemia. The K/Ca + Mg ratios were calculated and are presented in Table 9. Only in the first harvest at the 224 kg N ha^{-1} treatment did the ratio exceed the 2.2 value that is associated with grassy tetany (Kemp and 't Hart, 1957; Grunes et al., 1970). The low ratio values are clearly due partly to the relatively high concentrations of Ca and Mg in the herbage and also the differential influence of N. Nitrogen fertilizer tended to increase herbage concentrations of Ca and Mg but to decrease slightly the concentrations of K.

The combination of high dry matter yields plus high concentrations of K in the herbage resulted in substantial uptake. Over the five-harvest period 392, 391, and 424 kg K ha^{-1} were taken up by herbage fertilized with 224, 336, and 448 kg N ha^{-1}, respectively.

Table 8. Concentrations of calcium, magnesium, potassium, and phosphorus in Tetrelite herbage in 1971.

Nitrogen rate	Harvest date					Mean	Harvest date					Mean
	6/1	6/24	7/16	8/12	10/8		6/1	6/24	7/16	8/12	10/8	
-kg ha^{-1}-	%											
	Calcium						Magnesium					
224	0.52	0.63	0.52	0.58	0.60	0.57	0.28	0.36	0.34	0.45	0.39	0.36
336	0.67	0.72	0.60	0.63	0.61	0.65	0.36	0.40	0.38	0.48	0.41	0.41
448	0.68	0.75	0.59	0.68	0.72	0.68	0.33	0.40	0.38	0.52	0.46	0.42
Mean	0.62	0.70	0.57	0.63	0.64		0.32	0.39	0.37	0.48	0.42	
F tests												
N	*	NS	NS	*	*		*	NS	*	*	*	
Linear	*	*	NS	*	*		NS	*	*	**	*	
Quadratic	NS	NS	NS	NS	NS		*	NS	NS	NS	NS	
	Potassium						Phosphorus					
224	4.60	4.18	2.96	3.73	3.54	3.80	0.42	0.42	0.36	0.37	0.38	0.39
336	4.53	3.73	2.99	3.34	3.12	3.54	0.41	0.41	0.31	0.31	0.33	0.35
448	4.59	4.00	3.02	3.41	2.97	3.60	0.40	0.39	0.30	0.31	0.31	0.34
Mean	4.57	3.97	2.99	3.49	3.21		0.41	0.41	0.32	0.33	0.34	
F tests												
N	NS	*	NS	NS	*		NS	NS	*	**	**	
Linear	NS	NS	NS	NS	**		NS	NS	**	**	**	
Quadratic	NS	*	NS	NS	NS		NS	NS	NS	*	NS	

**, * Significant at P<0.01 and 0.05, respectively.
NS Not significant.

Table 9. K/Ca + Mg* ratios of Tetrelite herbage harvested in 1971.

Nitrogen rate	Harvest date				
	6/1	6/24	7/16	8/16	10/8
— kg ha^{-1} —					
224	2.40	1.75	1.40	1.45	1.46
336	1.84	1.39	1.25	1.20	1.24
448	1.92	1.46	1.27	1.14	1.03

*Calculated as mequiv kg^{-1}.

Stands thinned considerably over the 1971-72 winter and so no harvests were taken in 1972. Visual estimates indicated that 30% of the ryegrass had survived into 1972.

Experiment 5

All six ryegrass cultivars established from the late-August seeding. The harvest taken in November indicated that the tetraploid cultivars generally produced greater yields than did the diploid cultivars (Table 10). Tetrone, Petra, and Tetrelite produced 1714, 1655, and 1295 kg ha^{-1}, respectively, during the 78-day growth period. These values are similar to the 1609 kg ha^{-1} yield produced by Tetrelite during a 77-day growth period in 1969 (Experiment 3) and the 1560 kg ha^{-1} yield obtained from Tetrelite during a 65-day growth period in 1970 (Experiment 4). Of course, in 1971 the seeding and harvests were made later than the two previous experiments. Cultivars were differentially affected by the 1971-72 winter. Tetrone and Petra were completely winterkilled and Tetrelite had about 5% survival. In effect, the three tetraploids were lost. Commercial perennial ryegrass had about a 50% survival rate while Epic and NK 200 had approximately 85% survival. Winter survival was apparently inversely related to fall vigor and ploidy level.

Because of the differential survival only Epic and NK 200 were harvested on both 6 June and 12 July 1972. Analysis of variance of yields indicated that cultivars were significantly ($P<0.01$) different but fall cutting effects and the interaction between cultivars and cutting were both nonsignificant. The highest yielding cultivar was NK 200 which produced 4428 kg ha^{-1} over the two-harvest period. This is a relatively low yield. However, immediately after the spring fertilization with N, 5.9 cm of rain fell and, in the combined May-June period 39.0 cm of rain fell. Grass was generally chlorotic at the second harvest. Consequently, it is likely that much of the applied N fertilizer was lost.

After the second harvest, 56 kg N ha^{-1} was applied to plots of

Epic, NK 200, and perennial ryegrass. A further harvest of these three cultivars was taken on 24 August. Commercial perennial ryegrass produced the greatest yield (Table 10). The cultivar had shown gradual sward improvement since the early spring. Epic and NK 200 had been basically selected for turf purposes and had demonstrated winter hardiness under Minnesota and Canadian conditions (personal communication: Mr. H.E. Kaerwer, Northrup, King and Co., Minnesota).

Table 10. Production of six ryegrass cultivars, seeded in 1971, in both 1971 and 1972.

Cultivar	Yield			Winter Survival (1971-72)
	1971[1]	1972[2]	1972[3]	
	kg ha^{-1}			
Tetrone	1714[a]*	-	-	-†
Petra	1655[a]	-	-	-
Tetrelite	1295[ab]	-	-	-
Perennial ryegrass	896[b]	-	977[a]	±
Epic	328[c]	2929[b]	386[b]	+
NK-200	258[c]	4428[a]	504[b]	+

[1] Fall harvest, taken 17 Nov.
[2] Two harvests, 6 June and 12 July.
[3] Third harvest, 24 Aug.
* Means within a column followed by the same letter are not significantly ($P<0.05$) different according to Duncan's multiple range test (for 1971 and the third harvest of 1972) and the F test (combined 6 June and 12 July harvests, 1972).
† - Winterkill; + winter survival.

Experiment 6

CARBOHYDRATES

Analysis of variance of the concentrations of TNC found in late-fall harvested stubble indicated that both cutting and N effects were significant ($P<0.01$). One of the treatment interactions were significant. The weekly cutting system significantly ($P<0.01$) depressed concentrations of TNC compared to the other cutting systems (Table 11). The concentrations of TNC in ryegrass subjected to the 0– and 1-cut system were similar. Nitrogen application reduced the concentrations of TNC in both

Table 11. Concentrations of total nonstructural and fructosan carbohydrates in the stubble of two ryegrass cultivars treated with two nitrogen levels and three cutting regimes.+

Fall cutting system	Perennial ryegrass			Tetrelite ryegrass			Mean
	Nitrogen level kg ha^{-1}						
	0	56	Mean	0	56	Mean	
	%						
	TNC						
0	32.0*	29.4	30.7	36.0	33.5	34.8	32.7
1	32.0	31.4	31.7	34.2	34.0	34.1	32.9
Weekly	28.6	27.2	27.9	31.5	30.3	30.9	29.4
Mean	30.9	29.3	30.1	33.9	32.6	33.3	
LSD (P<0.05) for mean cutting systems: 0.9							
	Fructosan						
0	14.5*	12.2	13.4	17.7	12.6	15.2	14.2
1	15.0	14.0	14.5	15.4	14.1	14.8	14.6
Weekly	11.9	9.5	10.7	13.0	11.4	12.2	11.4
Mean	13.8	11.9	12.9	15.4	12.7	14.1	
LSD (P<0.05) for mean cutting systems: 0.8							

*Concentrations expressed on an organic matter basis.
+Treatments were applied in the fall; stubble sampling was initiated on 30 Nov.

cultivars, a finding in agreement with data reported elsewhere (Alberda, 1960; Jones et al., 1961; Nowakowski, 1962).

Analysis of variance of the nonfructosan fraction in the ryegrass tissues indicated that neither main effects nor their interactions were significant. However, as was the case for concentrations of TNC, the concentrations of nonfructosan in Tetrelite were consistently greater than those observed for perennial ryegrass, viz., 19.2 and 17.2%, respectively.

The analysis of variance of fructosan levels in ryegrass tissues indicated both cutting and N main effects to be significant ($P < 0.01$) (Table 11). The first-order interaction of cutting x N was also significant

($P < 0.05$). The trends observed for fructosan levels were similar to those observed for TNC levels. Concentrations of fructosan in ryegrass subjected to the 0 – and 1-cut system were similar, while ryegrass cut weekly had significantly ($P < 0.01$) reduced concentrations of fructosan. Sullivan and Sprague (1943) reported a significant drop in the concentration of fructosan in ryegrass resulting from a single cutting. However, they indicated that initial levels of fructosan were reestablished after 4 weeks of regrowth. In the study reported herein, approximately 4 weeks had elapsed between the time the single cutting was made and subsequent sampling.

Ryegrass treated with N at a rate of 56 kg ha^{-1} had significantly ($P < 0.01$) lower levels of fructosan (12.3%) than unfertilized ryegrass (14.6%). This finding was consistent in both cultivars. Alberda (1960) and Nowakowski (1962) reported similar changes in concentrations of fructosan in ryegrass as a result of N additions.

The interaction between cutting and N treatments indicated that in ryegrass, supplied with 56 kg N ha^{-1} and subjected to a single cutting, there was an increase in the concentration of fructosan compared to the 0 – and weekly-cutting systems (Table 12). With no N applied there was a consistent lowering in concentration of fructosan with increased cutting frequency.

Clearly, changes occurring with respect to carbohydrate concentrations are primarily reflective of fructosan changes rather than nonfructosan changes.

Table 12. Influence of cutting system and nitrogen rate on concentrations of fructosan in ryegrass stubble.[1]

Nitrogen rate	Cutting frequency 0	1	Weekly
— kg ha^{-1} —	%		
0	16.1*	15.2	12.4
56	12.4	14.0	10.5

LSD ($P<0.05$) to compare cuttings at the same nitrogen level: 1.1

*Concentrations expressed on an organic matter basis.
[1] Treatments were applied in the fall; stubble sampling was initiated on 30 Nov.

WINTERKILL ESTIMATES

Considerable winterkill was sustained over the 1972-73 winter. The mean winterkill estimates for the Tetrelite and perennial ryegrass were 82 and 40%, respectively. This difference in cultivars scontrasts with the report of Jung and Kocher (1974) in which similar winterkill was observed in commercial perennial ryegrass (82.8%) and a European tetraploid ryegrass (82.1%). However, the data is in agreement with that observed in Experiment 5.

The percent winterkill observed for the 0 – , 1 – , and weekly-cutting system was 34, 36, and 50%, respectively, for perennial ryegrass and 80, 81, and 85%, respectively, for Tetrelite ryegrass. The percent winterkill observed for the 0 and 56 kg N ha^{-1} treatments was 45 and 35%, respectively, for perennial ryegrass and 82 and 82%, respectively, for Tetrelite ryegrass.

In general, the differences in winterkill attributable to cutting and especially to N fertilizer application were not large enough to be considered conclusive. This is especially the case in attempting to relate winterkill to carbohydrate fractions. Heaving occurred on this site and so considerable winterkill occurred regardless of experimental treatment.

Experiment 7

NONSTRUCTURAL CARBOHYDRATES

Tetrelite ryegrass had significantly ($P < 0.01$) greater concentrations of TNC than did perennial ryegrass (Table 13). This response, though not as evident, was also observed in Experiment 6. Concentrations of TNC in fall herbage were depressed by applications of N fertilizer. Application of orthogonal polynomials to partition the N effects indicated only the linear component to be significant ($P < 0.01$). However, both N x cutting ($P < 0.01$) and N x cultivar ($P < 0.05$) interactions were significant. Analysis of the N x cutting interaction indicated that the linear component was significant ($P < 0.01$) for the 0-cut system but not for the 1-cut system (Table 14). Quadratic effects for both cutting frequencies were not significant. Analysis of the N x cultivar interaction revealed that the linear component was significant ($P < 0.01$) for both cultivars. However, the decline in TNC concentration associated with increasing N fertilization was much more immediate for Tetrelite than it was for perennial ryegrass. Consequently, while applying N to ryegrass in the fall resulted in a depression in the TNC in the herbage, particularly for Tetrelite, a single cutting had no appreciable impact.

Analysis of variance of fructosan concentrations in fall-harvested herbage indicated that both cultivar and N effects, as well as the first-order interaction of cutting x N, were significant ($P < 0.01$) (Table 13). The overall means for the fructosan concentrations in the Tetrelite and perennial ryegrass were 14.8 and 10.1%, respectively. Applied N reduced fructosan levels, i.e., 15.1, 12.0, and 10.2% for the 0, 56, and 112 kg N

Table 13. Concentrations of total nonstructural and fructosan carbohydrates in the stubble of two ryegrass cultivars subjected to two cutting regimes and three nitrogen levels.[1]

Nitrogen rate	Perennial ryegrass			Tetrelite ryegrass			Mean
	Cutting system						
	0	1	Mean	0	1	Mean	
— kg ha^{-1} —	%						
	TNC						
0	24.8	20.6	22.7	38.8	31.8	35.3	29.0
56	21.4	23.5	22.4	28.7	31.0	29.8	26.2
112	17.4	20.3	18.8	27.8	29.7	28.8	23.8
Mean	21.2	21.5	21.4	31.8	30.8	31.3	
	Fructosan						
0	13.5	10.8	12.2	20.7	15.5	18.1	15.1
56	9.7	10.7	10.2	12.5	15.0	13.8	12.0
112	7.2	8.7	8.0	11.5	13.4	12.4	10.2
Mean	10.1	10.1	10.1	14.9	14.6	14.8	

TNC:

F tests[2] N; L^{**}, Q^{NS}

N x cultivar; Perennial ryegrass, L^{**}, Q^{NS}
Tetrelite, L^{**}, Q^{NS}

Cultivar; **

Fructosan:

F tests N; L^{**}, Q^{NS}

N x cutting; 0-cut system, L^{**}, Q^{*}
1-cut system, L^{*}, Q^{NS}

Cultivar; **

**, * Significant at P<0.01 and 0.05, respectively.
[1] Treatments applied in the fall of 1973; stubble samples were obtained in Jan. 1974.
[2] L Linear regression; Q quadratic regression; NS not significant.

Table 14. Influence of nitrogen level and cutting system on the concentration of TNC in ryegrass.[1]

Fall cutting system	Nitrogen level kg ha^{-1}			F^2 tests
	0	56	112	
		%		
0	31.8	25.0	22.6	$L^{**}Q^{NS}$
1	26.2	27.2	25.0	$L^{NS}Q^{NS}$

**Significant at P<0.01.
[1]Treatments were applied in the fall of 1973; stubble samples were obtained in Jan. 1974.
[2]L Linear regression; Q quadratic regression; NS not significant.

ha^{-1} treatments, respectively. Partitioning the N effects indicated that the linear component was significant (P< 0.01) but the quadratic was not.

The N x cutting interaction was similar to that described for concentrations of TNC. With the 0-cut system, the fructosan concentrations were 17.1, 11.1, and 9.4% for the 0, 56, and 112 kg N ha^{-1} treatments, respectively. Linear (P<0.01) and quadratic (P<0.05) effects were significant. Under the 1-cut system, the equivalent values were 13.2, 12.8, and 11.1%, respectively, and in this case only the linear effect was significant (P<0.05).

Few trends were observed with respect to nonfructosan carbohydrates. There was a significant (P<0.01) difference between cultivars. The nonfructosan carbohydrate concentration of Tetrelite was 16.5% while that of perennial ryegrass was 11.2%.

DRY MATTER YIELDS, WINTERKILL, AND DIGESTIBILITY

The quality of the forage clipped on 26 October 1973 was very good.The IVDMD means for the Tetrelite and perennial ryegrass were 83.1 and 83.6%, respectively.

Both cultivars sustained little winterkill. The mean overall winterkill was 2.7%. Differences among treatments were very small. In comparing plots subjected to the same N and cutting treatments in Experiments 6 and 7, the winterkill estimates were 57 and 2%, respectively. While the method of estimating winterkill varied between the two experiments, much of the difference between winterkill must be assigned to environmental variation. Although the same site was utilized in both ex-

periments there was no evidence in Experiment 7 of the heaving that occurred in Experiment 6, further implicating environmental differences between 1972-73 and 1973-74.

Comparisons of the weather data for the respective years indicates some striking differences. In the fall of 1972, during the period of ryegrass development and hardening (September-December), only 27% of the days were clear. It was an especially wet fall. On the other hand, in 1973 during the same period, some 50% of the days were clear. Lawrence et al. (1973) showed that light conditions during the hardening and prehardening periods are important insofar as frost tolerance is concerned. They showed that reduced total light energy significantly reduced cold tolerance in ryegrass.

In 1972-73, during the period from January to the initiation of spring growth, 46% of the days were clear. In 1973-74, some 20% of the days were clear. Since snow cover was not apparently an important factor in either year, the greater preponderance of cloudy days in the early part of 1974 constituted milder winter conditions.

As was the case with other late-summer seedings, both ryegrass cultivars readily established. Yields obtained in late October 1973 were similar to those produced in other years. Tetrelite produced a significantly greater yield than perennial ryegrass, viz., 1409 versus 1069 kg ha^{-1}. There was a significant response to N fertilizer rates. Yields from the 0, 56, and 112 kg N ha^{-1} treatments were 759, 1399, and 1538 kg ha^{-1}, respectively. Use of orthogonal polynomials to partition the N effects indicated that the linear ($P < 0.01$) and quadratic ($P < 0.05$) effects were significant. These data would suggest that N fertilization in excess of 56 kg ha^{-1} would not be worthwhile.

Analysis of variance of the total yields obtained from two harvests in 1974 indicated that both 1973 fall cutting and N fertilization rates affected ($P < 0.01$) yields the following year. Plots cut in October 1973 produced 8.05 Mg ha^{-1} in 1974 while uncut plots produced 8.78 Mg ha^{-1}. This reduction in yield, however, was more than offset by the material harvested in the fall. Consequently, the practical implication of the reduced yield in 1974 is minimal. There was a carry-over effect due to fall fertilization. Yields in 1974 were 7.92, 8.48, and 8.84 Mg ha^{-1} from plots fertilized with 0, 56, and 112 kg N ha^{-1}, respectively, the previous fall.

Response to 1973 fall cuttings and fertilization varied with the two 1974 harvests. The reduced yields resulting from fall cutting were observed only in the first harvest; the carry-over effect from N fertilization was also observed only in the first harvest. Similarly, perennial ryegrass produced greater yields than Tetrelite in the first harvest but the reverse was true for the second harvest. The total yields from perennial and Tetrelite ryegrass were 8.07 and 8.76 Mg ha^{-1}, respectively.

Experiment 8

NONSTRUCTURAL CARBOHYDRATE FRACTIONS

Analysis of variance of TNC levels indicated that both cutting ($P < 0.05$) and N ($P < 0.01$) effects were significant (Table 15). Fall cutting and the application of N both reduced the concentration of TNC observed in ryegrass stubble in January. Analysis of variance of fructosan concentrations also indicated that both cutting and N effects were significant ($P < 0.01$). Again, as was the case for TNC concentrations, fall cutting and N application reduced fructosan concentrations. Application of orthogonal polynomials indicated that the depressions in TNC and fructosan concentrations that occurred as the result of N applications were linear ($P < 0.01$) in nature.

Comparing values obtained from Experiments 7 and 8 shows both similarities and differences. The TNC values obtained from the latter experiment were greater than those obtained from Tetrelite ryegrass in Experiment 7, viz., 36.1 and 31.3%, respectively. Application of N reduced

Table 15. Concentrations of nonstructural carbohydrate fractions in Tetrelite ryegrass subjected to three nitrogen and two cutting treatments.*

Nitrogen level	Cutting system		Mean
	0-cut	1-cut	
$kg\ ha^{-1}$	%		
	TNC		
0	41.3	37.4	39.4
56	38.8	33.4	36.1
112	34.4	31.3	32.8
Mean	38.2	34.0	
LSD (P<0.05) to compare overall N means: 4:1			
	Fructosan		
0	20.7	17.4	19.0
56	17.2	13.2	15.2
112	13.4	11.1	12.2
Mean	17.1	13.9	
LSD (P<0.05) to compare overall N means: 3:3			

*Treatments applied during the fall of 1973; stubble samples were obtained in Jan. 1974.

both TNC and fructosan fractions in both experiments. However, in Experiment 8, cutting reduced the concentrations of TNC and fructosan significantly while in Experiment 7 only minor reductions in these concentrations were observed.

IVDMD, WINTERKILL, AND DRY MATTER YIELDS

The quality of the fall grown Tetrelite ryegrass was very good; the overall mean IVDMD value was 83.8%. As was the case for Experiment 7, very little winterkill occurred (3.3%). Cutting in the fall had no influence on dry matter yields the following year. However, there was a significant ($P<0.01$) carry-over effect from the fall applied N. Yields in 1974 from the plots fertilized in the fall of 1973 with 0, 56, and 112 kg N ha $^{-1}$ were 8.33, 9.33, and 9.59 Mg ha $^{-1}$, respectively. The effect was primarily restricted to the first of the two harvests taken in 1974.

Dry matter yields obtained from Tetrelite ryegrass in Experiment 7 and 8 were relatively similar and, in view of the fact that the plots were only harvested twice, were quite high.

The concentration of nonstructural carbohydrate fractions, measured in ryegrass samples taken in January and April 1974, are shown in Table 16. At both dates Tetrelite ryegrass had higher concentrations of TNC, fructosan, and nonfructosan carbohydrates than did perennial ryegrass. In all cases, the levels of each fraction were lower in the April samples compared to the January samples. However, the pattern of carbohydrate reduction varied between cultivars. Tetrelite ryegrass had a greater percentage reductioh in TNC than did perennial ryegrass even though on 10 April 1974 Tetrelite had a greater remaining concentration of TNC than did perennial ryegrass. The higher rate of loss of TNC in Tetrelite ryegrass may indicate a higher rate of respiration. Barbour (1967) suggested that annual ryegrass might have a higher respiration

Table 16. Concentrations of nonstructural carbohydrates obtained in Tetrelite and perennial ryegrass during the winter-spring period of 1974.

Sample date	Cultivar	TNC	Fructosan	NFC[1]	Change TNC	Change Fructosan	Change NFC
		%					
26 Jan.	Perennial*	24.8	13.5	11.3	27	46	4
10 Apr.	Perennial*	18.1	7.3	10.8			
26 Jan.	Tetrelite**	40.0	20.7	19.4	32	41	23
10 Apr.	Tetrelite**	27.2	12.2	15.0			

*Perennial ryegrass samples obtained from Experiment 7.
**Tetrelite ryegrass samples obtained from Experiments 7 and 8.
[1]Nonfructosan carbohydrates.

rate than perennial; Tetrelite would be expected to have characteristics intermediate between the two species.

Both cultivars showed a major reduction in fructosan concentrations on 10 April. In addition, Tetrelite ryegrass exhibited a 23% reduction in nonfructosan carbohydrates. Baker (1957) also reported a greater reduction in the fructosan fraction compared to soluble sugars in ryegrass during a 79-day period from late November to early February. Perennial ryegrass showed only a negligible change in nonfructosan carbohydrates during this time period. These differences may be related to the differences in winter survival that have been observed between diploid and tetraploid ryegrass cultivars.

Table 17. Fertilizer and harvest schedules used in Experiment 9.

Harvest dates	Fertilizer applications: Date	Limestone	N	P	K
		$kg\ ha^{-1}$			
		1974			
28 May	2 Apr.		101	44	84
16 July	30 May		56		
11 Oct.	16 July		67	29	56
	28 Oct.			15	36
		1975			
3 June	6 May		224	22	84
11 July	9 June		56		
21 Aug.	15 July		56		
23 Oct.	28 Aug.	2240	56	45	168
		1976			
14 June	28 Apr.		112	23	56
26 July	16 June		56	24	47
3 Sept.	21 June	2240			
	2 Aug.		56	24	47
	26 Oct.	2240		22	84
		1977			
6 June	12 Apr.		101	44	84
6 July	15 Apr.	3360			
8 Aug.	9 June		56	24	47
2 Sept.	8 July		56	24	47
3 Nov.	9 Aug.		56	24	47
	5 Sept.		56	24	47

Experiment 9

The yearly total dry matter yields of the ryegrass varieties, obtained during the 1974-1977 period, are shown in Table 18. Harvest dates and fertilizer treatments are shown in Table 17. Significant differences occurred among ryegrass varieties in each of the years that yields were obtained. However, of some importance is the fact that in no year did any ryegrass cultivar exceed the yield obtained from Pennmead orchardgrass and only in 1977 did a ryegrass cultivar produce a yield that was comparable to that of Pennmead.

A few ryegrass cultivars consistently exhibited high yields and reasonable longevity. Tetrelite was the highest yielding ryegrass cultivar in 1974 and 1976 and ranked second in 1975. It also was one of only six cultivars that persisted in acceptable levels in 1977. By this time ryegrass was being lost in increasing degrees and so only those cultivars having stands with more than 50% ryegrass present were harvested.

The cultivar 'Valinge', a land variety obtained from Sweden, has long been considered extremely winter hardy but relatively low yielding

Table 18. Seasonal dry matter yields of perennial ryegrass cultivars during the 1974-1977 period.

Cultivar	Year			
	1974	1975	1976	1977
	Mg ha^{-1}			
Pennmead orchardgrass	12.59^{a*}	10.06^{a}	9.50^{a}	10.83^{a}
Tetrelite	10.18^{b}	8.83^{b}	8.18^{b}	8.08^{b}
Viva	9.98^{b}	7.34^{cde}	6.13^{cde}	8.23^{b}
Linn	9.74^{bc}	8.04^{bcd}	-	-
Perennial (commercial)	9.62^{bc}	8.23^{bc}	7.18^{bc}	9.34^{ab}
Vrm 01412	9.11^{bcd}	7.05^{de}	5.48^{def}	7.85^{b}
Reveille	8.79^{cde}	8.05^{bcd}	6.39^{cd}	8.13^{b}
K8 142	8.64^{cdef}	7.87^{bcd}	5.52^{def}	-
Valinge	8.18^{defg}	7.06^{de}	5.43^{def}	-
Pelo	8.00^{defg}	7.77^{bcd}	5.45^{def}	8.11^{b}
KO-13	7.81^{efg}	7.88^{bcd}	6.12^{cde}	-
KO-14	7.66^{efg}	8.05^{bcd}	6.00^{cde}	-
Petra	7.61^{efg}	8.88^{b}	-	-
KO-11	7.54^{fg}	8.23^{bc}	6.03^{cde}	-
Manhattan	7.35^{gh}	7.30^{cde}	5.07^{ef}	-
K9-124	6.38^{hi}	6.29^{e}	5.12^{ef}	-
Epic	6.31^{hi}	7.08^{cde}	6.26^{cde}	-
NK-200	5.93^{i}	6.30^{e}	4.69^{f}	-
Harvests	3	4	3	5
Total N - kg ha^{-1}	224	392	224	325

*Means within a column followed by the same letter are not significantly ($P<0.05$) different according to Duncan's multiple range test.

in that country. Though not actively being marketed, Valinge was used along with the variety 'Viktoria' — to produce the varieties 'Viva' and 'Vrm 01412' (personal communication, G. Julen, The Swedish Seed Association, Svalof, Sweden). Though not as high yielding as other varieties over the four-year period, Viva did persist throughout the trial, as did Vrm 01412.

As might be expected, there were differences in stages of maturity attained by the various cultivars at harvest time. At the first harvest in 1974, taken on 28 May, Pennmead orchardgrass was fully headed out. Commercial perennial, Tetrelite, Valinge, and Epic ryegrass had attained the early-head, late-boot to early-head, early-boot, and vegetative stages of maturity, respectively. Camlin (1981) indicated that in Northern Ireland the average dates at which 'Reveille' and 'Pelo' ryegrass were 50% headed out were 22 May and 14 June, respectively. At Storrs on 28 May 1974, Reveille was at the early-head stage while Pelo was in the late-boot stage. Reveille ryegrass is considered an early variety while Pelo is considered a late variety. On 14 June 1976 Reveille had completely headed out while Pelo was in the late-boot to early-head stage of maturity. These similarities suggest that the maturity groups delineated in Great Britain may well be applicable in New England.

Experiment 10

Cultivars in both trials established well. Precipitation in May 1976 was 8.92 cm. This was close to the expected long-term mean of 9.78 cm (Brumbach, 1965). However, only 28% of the May 1976 precipitation occurred after seeding. Further, the precipitation in June 1976 was only 4.90 cm. This was considerably less than the normal 8.84 cm. The mean maximum temperature for June was 25.5°C, slightly above the normal June mean maximum temperature of 24.4°C. Consequently, the combination of limited precipitation and warm weather resulted in slow growth of the varieties once initial establishment had occurred.

ANNUAL AND SHORT-ROTATION CULTIVARS

Analysis of variance indicated that yields of dry matter obtained at the first harvest varied significantly ($P<0.01$); 'NK-T4' produced 1.84 Mg ha^{-1} which was significantly greater than all other varieties (Table 19). 'Aubade', 'Barspectra', and 'Billion' produced 1.0 Mg ha^{-1} or more dry matter at the first cutting. As might be expected, orchardgrass established more slowly than the ryegrasses, producing only 0.23 Mg ha^{-1}. This was the lowest yield recorded at the first cutting.

The second harvest was taken some three weeks after the first. During the interval between the first and second harvests, 22.2 cm of precipitation occurred. Yields from cultivars were generally greater in the second harvest compared to the first. The mean cultivar yield for the second harvest was 1.76 Mg ha^{-1} compared to 0.67 Mg ha^{-1} observed for the first harvest. Analysis of variance indicated that yield differences among cultivars were not significant..However, the greatest

Table 19. *Yields of dry matter obtained from annual and short rotation ryegrasses in 1976.*

Cultivar	Harvest			Total
	1	2	3	
	Mg ha^{-1}			
Aubade	1.23^{b*}	1.85^{**}	1.93^{fgh}	5.01^{abcde}
Astor	0.30^{gh}	1.87	2.50^{bcde}	4.67^{bcde}
Augusta	0.32^{gh}	1.33	2.71^{abcd}	4.37^{cde}
Barmultra	0.53^{efgh}	2.24	2.78^{abc}	5.55^{abc}
Barspectra	1.09^{bc}	1.87	2.00^{efgh}	4.96^{abcde}
Billion	1.04^{bcd}	1.92	1.87^{gh}	4.82^{bcde}
Clipper	0.53^{efgh}	1.52	1.70^{h}	3.75^{e}
Imperial	0.54^{efgh}	1.56	2.66^{acd}	4.76^{bcde}
Lemtal	0.63^{defgh}	1.68	2.17^{defgh}	4.48^{cde}
Maris Ledger	0.57^{defgh}	1.84	3.14^{a}	5.55^{abc}
NK-T2	0.93^{bcde}	2.16	2.70^{abcd}	5.78^{ab}
NK-T3	0.83^{bcdef}	2.31	2.98^{ab}	6.12^{a}
NK-T4	1.84^{a}	1.60	1.89^{fgh}	5.33^{abcd}
Promenade	0.73^{cdefg}	1.68	2.22^{cdefgh}	4.63^{bcde}
SVO-2056	0.60^{defgh}	1.89	2.44^{bcdef}	4.93^{abcde}
Svita	0.40^{fgh}	1.53	2.44^{bcdef}	4.36^{cde}
Sabel	0.24^{h}	1.52	2.41^{bcdefg}	4.17^{de}
Sabrina	0.48^{efgh}	1.87	2.72^{abcd}	5.07^{abcd}
Tetrelite	0.71^{cdefgh}	1.79	3.09^{a}	5.59^{abc}
Tetrone	0.35^{fgh}	1.41	2.67^{abcd}	4.44^{cde}
Pennmead orchardgrass	0.23^{h}	1.55	2.41^{bcdefg}	4.19^{de}
Mean	0.67	1.76	2.45	4.88

*Values within a column followed by the same letter are not significantly ($P<0.05$) different according to Duncan's multiple range test.

**Differences among the second harvest yields were not significantly different (F test).

yields were obtained from 'NK-T3', 'Barmultra', 'NK-T2', and Billion. Orchardgrass, with a yield of 1.55 Mg ha^{-1}, gave 67% of the yield of NK-T3.

Third harvest yield differences among cultivars were significant ($P<0.01$). 'Maris Ledger' had the greatest yield, i.e., 3.14 Mg ha^{-1} while 'Clipper' had the lowest yield, i.e., 1.70 Mg ha^{-1}. Orchardgrass produced 2.41 Mg ha^{-1}, 77% that obtained from Maris Ledger. The mean cultivar yield of 2.45 Mg ha^{-1} was greater than that obtained in either of the previous two harvests.

Total dry matter yields obtained from all three harvests varied from 6.12 Mg ha^{-1} for NK-T3 to 3.75 Mg ha^{-1} for Clipper. Differences among cultivars were significant ($P<0.01$). Cultivars that yielded 90% or more dry matter, relative to NK-T3, were: NK-T2, Tetrelite, Barmultra, and Maris Ledger. These cultivars, as well as NK-T4, 'Sabrina', Aubade,

Barspectra, and 'SVO-2056', were not significantly ($P<0.05$) different from NK-T3.

The yields obtained from the highest yielding cultivar suggest that such forage grasses have potential in New England. An earlier date of seeding would have been desirable in view of the dry weather that occurred in late May and throughout June. Heavier applications of N fertilizer probably would also have resulted in greater yields.

PERENNIAL RYEGRASS CULTIVARS

Analysis of variance indicated that differences among first harvest yields were not significant (Table 20). The greatest yield was obtained from orchardgrass, i.e., 1.50 Mg ha^{-1} and the lowest yield obtained from 'Linn' perennial ryegrass, i.e., 0.72 Mg ha^{-1}. The first harvest of the perennial ryegrass cultivars may be compared to the second harvest of the annual and short-rotation ryegrasses since they were harvested at the same time and the growth interval was approximately the same. Overall, as might be expected, the perennial ryegrasses were lower yielding compared to the annual and short-rotation ryegrasses.

Differences among cultivars for second harvest yields were significant ($P<0.01$). Orchardgrass produced 2.43 Mg ha^{-1}. Ryegrass cultivars that produced significantly ($P<0.05$) greater yields were 'Massa', 'KO-14', and 'Barlatra'. These cultivars produced 2.89, 2.82, and 2.81 Mg ha^{-1}, respectively. The overall cultivar yield from the second harvest was 2.42 Mg ha^{-1}. This was substantially more than that obtained from the first harvest.

Differences among cultivars for total dry matter production were significant ($P<0.01$). Only Massa produced more dry matter than orchardgrass, though this difference was not significant. Fourteen ryegrass cultivars produced dry matter yields that were not significantly ($P<0.05$) different from Massa. Twelve of these cultivars produced yields that were at least 90% that of Massa. These latter cultivars were: 'Barenza', KO-14, Barlatra, 'Tove', Pelo, Petra, 'Talbot', Reveille, 'S-101', 'Barpastra', 'ID-66', and 'Taptoe'.

Analysis of soil samples, taken during the fall of 1976, indicated that the soil pH was 6.6 and Ca, Mg, P, and K levels were 1848, 448, 18, and 179 kg ha^{-1}, respectively, indicating that soil fertility levels had been maintained during 1976. The perennial ryegrass cultivars survived the 1976-77 winter, though there was considerable variation among cultivars both with respect to winter survival and spring vigor (Table 21). Orchardgrass was given a survival rating of 7.7. Only two ryegrass cultivars received superior ratings, viz., 'KO-15' and 'Svea'. However, cultivars 'Barvestra', ID-66, KO-14, Pelo, and Viva received ratings of 7.0 or better. Orchardgrass received a rating of 9.0 for spring vigor, a value not exceeded by any ryegrass cultivar. The ryegrass plots did not look vigorous early in the growing season. This visual observation is confirmed by the

Table 20. Yields of dry matter obtained from perennial ryegrass during the 1976 establishment year.

Cultivar	Harvest 1	Harvest 2	Total
	Mg ha^{-1}		
Common	0.84**	2.26 efg*	3.10 ghij
Barenza	1.13	2.73 abcd	3.86 abc
Barlatra	0.97	2.81 abc	3.78 abc
Barlenna	1.00	2.19 fg	3.19 fghi
Barpastra	1.08	2.53 abcdef	3.61 abcdef
Barstella	0.81	2.43 def	3.24 defghi
Barvestra	0.80	2.36 def	3.16 fghij
Eton	1.04	1.79 hi	2.83 ijk
ID-66	1.02	2.58 abcde	3.61 abcdef
KO-14	0.97	2.82 ab	3.79 abc
KO-15	0.80	1.57 ij	2.37 l
Linn	0.72	2.51 bcdef	3.23 efghi
Massa	1.12	2.89 a	4.01 a
NK-100	0.92	2.58 abcde	3.50 abcdefg
Norlea	1.18	1.39 j	2.57 kl
Pelo	1.12	2.62 abcde	3.74 abcd
Petra	1.27	2.44 cdef	3.71 abcde
Reveille	0.97	2.67 abcd	3.64 abcdef
S-23	0.81	2.62 abcde	3.43 bcdefgh
S-24	0.92	2.48 bcdef	3.40 cdefgh
S-101	1.06	2.57 abcde	3.63 abcdef
Svea	0.99	1.71 hi	2.71 jkl
Viva	0.97	2.01 gh	2.99 hijk
Talbot	1.06	2.64 abcd	3.70 abcde
Taptoe	0.96	2.64 abcd	3.60 abcdef
Tove	1.08	2.70 abcd	3.78 abc
Uri	0.97	2.56 abcde	3.53 abcdefg
Viris	0.93	2.52 abcdef	3.45 bcdefgh
Pennmead Orchardgrass	1.50	2.43 def	3.93 ab
Mean	1.00	2.42	3.42

*Values within a column followed by the same letter are not significantly ($P<0.05$) different according to Duncan's multiple range test.

**Differences among first harvest yields were not significantly different (F test).

first harvest yields in 1977 (Table 22). However, there was a remarkable recovery as the season progressed.

Yield differences among cultivars were significant for the first, second, third, and fifth harvests and for the total yield of dry matter produced in 1977 ($P<0.01$ level in each instance). Overall cultivar mean yields were lowest for the first harvest, i.e., 0.49 Mg ha^{-1} and greatest for the third harvest, i.e., 1.57 Mg ha^{-1}.

First harvest yields were low, except for orchardgrass. Usually, first harvest yields of forage grasses at this location are the greatest realized

Table 21. Winter survival and spring vigor ratings of perennial ryegrass.

Cultivar	Winter survival* 29 Apr. 1977	Vigor* 1 May 1977
Common	3.3	3.0
Barenza	6.3	5.3
Barlatra	4.7	5.3
Barlenna	5.3	4.3
Barpastra	2.3	2.3
Barstella	6.3	5.0
Barvestra	7.0	8.0
Eton	5.3	4.0
ID-66	7.3	6.0
KO-14	7.0	5.3
KO-15	9.0	7.3
Linn	3.7	3.7
Massa	5.3	6.3
NK-100	6.7	5.7
Norlea	4.3	4.0
Pelo	7.3	5.3
Petra	5.3	5.3
Reveille	4.3	4.3
S-23	4.0	3.0
S-24	4.0	4.3
S-101	4.0	3.0
Svea	8.7	8.0
Viva	7.3	6.3
Talbot	6.7	4.7
Taptoe	4.0	4.3
Tove	5.7	6.3
Uri	4.0	4.3
Viris	5.3	5.3
Orchardgrass	7.7	9.0
Mean	5.6	5.1

*Winter survival and vigor were both scored on a 0-10 scale with 10 representing complete winter survival and the greatest expected spring vigor.

over the season. The lowered yields observed in 1977 undoubtedly reflect the reduced vigor referred to earlier. The yield of the highest yielding ryegrass, i.e., Viva, was only 58% that of orchardgrass. However, even the yield of orchardgrass was substantially below normal.

Yields from the second harvest were much greater than those from the first harvest. Out of the 29 cultivars, orchardgrass now ranked eleventh, although only 'NK-100' yielded significantly ($P < 0.05$) more dry matter than did the orchardgrass. Conversely, only Barpastra yielded significantly less than orchardgrass.

Orchardgrass gave the highest yield in the third harvest. This harvest was made on 1 August 1977 and represented growth made during the period 30 June-1 August. This is a period of high temperatures, a

Table 22. Yields of dry matter obtained from perennial ryegrass during the 1977 postestablishment year.

Cultivar	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Harvest 5	Total
	Mg ha^{-1}					
Common	0.34^{bcde}*	1.17^{def}	2.07^{ab}	1.60**	0.71^{cde}	5.90^{abcde}
Barenza	0.40^{bcde}	1.21^{cdef}	1.61^{bcde}	1.36	1.74^{a}	6.33^{abcde}
Barlatra	0.47^{bcde}	1.51^{bcd}	1.61^{bcde}	1.50	1.36^{abc}	6.45^{abcde}
Barlenna	0.34^{bcde}	1.25^{cdef}	0.69^{fg}	0.83	0.85^{bcde}	3.96^{ef}
Barpastra	0.12^{e}	0.80^{f}	0.47^{g}	0.51	0.69^{cde}	2.59^{f}
Barstella	0.39^{bcde}	1.23^{cdef}	1.57^{bcdef}	1.47	1.21^{abcde}	5.86^{abcde}
Barvestra	0.77^{bc}	1.30^{bcde}	1.58^{bcde}	1.22	1.31^{abcd}	6.18^{abcde}
Eton	0.41^{bcde}	1.29^{bcdef}	0.92^{efg}	0.73	0.57^{de}	3.91^{ef}
ID-66	0.80^{b}	1.71^{abc}	1.68^{bcde}	1.75	1.68^{a}	7.63^{ab}
KO-14	0.46^{bcde}	1.38^{bcde}	1.37^{bcdef}	1.16	1.47^{abc}	5.83^{abcde}
KO-15	0.65^{bcd}	1.34^{bcde}	1.26^{bcdefg}	1.26	0.99^{abcde}	5.49^{bcde}
Linn	0.59^{bcde}	1.30^{bcde}	2.08^{ab}	1.95	1.07^{abcde}	6.98^{abcd}
Massa	0.44^{bcde}	1.26^{bcdef}	1.94^{bc}	1.77	1.19^{abcde}	6.61^{abcde}
NK-100	0.59^{bcde}	2.04^{a}	1.25^{bcdefg}	0.94	1.68^{a}	6.51^{abcde}
Norlea	0.36^{bcde}	1.44^{bcde}	1.04^{defg}	0.97	0.47^{e}	4.27^{def}
Pelo	0.45^{bcde}	1.49^{bcd}	1.64^{bcde}	1.38	1.62^{ab}	6.58^{abcde}
Petra	0.34^{bcde}	1.21^{cdef}	1.83^{bcd}	1.54	1.48^{abc}	6.39^{abcde}
Reveille	0.35^{bcde}	1.41^{bcde}	2.01^{abc}	1.64	1.19^{abcde}	6.61^{abcde}
S-23	0.17^{de}	1.24^{cdef}	1.93^{bcd}	1.80	1.44^{abc}	6.59^{abcde}
S-24	0.39^{bcde}	0.94^{ef}	1.15^{cdefg}	0.93	1.03^{abcde}	4.44^{cdef}
S-101	0.25^{cde}	1.27^{bcdef}	1.83^{bcd}	1.52	1.36^{abc}	6.23^{abcde}
Svea	0.79^{b}	1.59^{abcd}	1.31^{bcdefg}	1.26	1.36^{abc}	6.30^{abcde}
Viva	0.81^{b}	1.76^{ab}	1.53^{bcdef}	1.58	1.35^{abc}	7.04^{abc}
Talbot	0.46^{bcde}	1.42^{bcde}	1.38^{bcdef}	1.45	1.55^{ab}	6.25^{abcde}
Taptoe	0.30^{bcde}	1.32^{bcde}	1.85^{bcd}	1.89	1.03^{abcde}	6.39^{abcde}
Tove	0.57^{bcde}	1.52^{bcd}	1.58^{bcde}	1.78	1.43^{abc}	6.88^{abcd}
Uri	0.35^{bcde}	1.28^{bcdef}	2.12^{ab}	0.99	1.11^{abcde}	5.85^{abcde}
Viris	0.43^{bcde}	1.29^{bcdef}	1.43^{bcdef}	1.49	1.46^{abc}	6.10^{abcde}
Penmead Orchardgrass	1.39^{a}	1.40^{bcde}	2.81^{a}	1.70	1.00^{abcde}	8.30^{a}
Mean	0.49	1.36	1.57	1.38	1.22	6.02

*Values within a column followed by the same letter are not significantly ($P<0.05$) different according to Duncan's multiple range test.

**Differences among fourth harvest yields were not significantly different (F test).

condition not normally considered conducive for good ryegrass growth. Nevertheless, 'Uri', Linn, Common, and Reveille ryegrass produced yields that were not significantly different from that produced by the orchardgrass.

Though yield differences among cultivars in the fourth harvest were not significantly different, several ryegrass cultivars produced yields in excess of those obtained from orchardgrass. Significant yield differences were evident in the fifth harvest. Although many ryegrass cultivars produced yields greater than that produced by orchardgrass, these differences were not significant.

Over the entire 1977 growing season the greatest cultivar yield was obtained from orchardgrass, although this yield was not significantly ($P<0.05$) greater than that produced by 22 ryegrass cultivars. However, only cultivar ID-66 produced a yield that was greater than 90% of the orchardgrass yield. Ryegrass cultivars Viva, Linn, and Tove produced yields that were 90% or more of that produced by ID-66. Ryegrass cultivars KO-15, 'S-24', 'Norlea', 'Barlenna', 'Eton', and 'Barpastra' gave yields that were significantly ($P<0.05$) lower than the orchardgrass yield.

Yields were not taken from the perennial ryegrass trial in 1978 since widespread winterkill occurred during the 1977-78 winter. Orchardgrass survived this winter.

Experiment 11

Analysis of variance indicated that while significant ($P<0.01$) differences existed among cultivar yields, differences attributable to either the N rates or the cultivar x N interaction were not significant.

Yields obtained from the cultivars are listed in Table 23. Because of a very wet spring the seeding was made relatively late (10 May) and, since the second and final harvest was taken on 8 August, the effective

Table 23. Dry matter yields obtained in 1983 from cultivars of Westerwolds and hybrid ryegrasses.

Cultivar	Type	Yield
		— Mg ha^{-1} —
Caramba	Westerwolds 4n	4.20^{a*}
Torero	Westerwolds 4n	4.12^{ab}
Weldra	Westerwolds 2n	3.62^{abc}
ML 162	Westerwolds 2n	3.55^{abc}
Billion	Westerwolds 4n	3.45^{bc}
Tetrelite	Hybrid 4n	3.44^{bc}
Bison	Hybrid 4n	3.05^{c}
ML 454	Westerwolds 2n	2.92^{c}

*Means followed by the same letter are not significantly ($P<0.05$) different according to Duncan's multiple range test.

growing season was quite short, i.e., approximately 3 months. Consequently, cultivar yields were generally low. Nevertheless, the Westerwold ryegrasses did produce more dry matter than did the hybrid cultivars. Orthogonal contrasts indicated that this difference was significant ($P<0.05$). Similarly, tetraploid Westerwold cultivars had significantly ($P<0.01$) higher yields than the diploid forms. Yields obtained from Tetrelite and Bison were nonsignificantly different.

The lack of response to N fertilization suggests that the lowest rate was optimum or more than optimum to sustain grass production. In this experiment a seeding of 'Tyfon' (*Brassica rapa* L. x. *B. pekinensis* (Lour.) Rupr.) had been made into the ryegrass plots following the second harvest. This seeding was intended to evaluate the cropping sequence of ryegrass plus Tyfon and, hence, utilize the N remaining from the previous fertilization practices. However, the Tyfon seeding failed and so evaluation of this practice was not possible.

However, the yields obtained in this experiment may be compared to those obtained from Tetrelite ryegrass in Experiment 1. In the latter experiment a conventional seeding made on 19 April was followed by two harvests on 2 July and 7 August. The ryegrass, fertilized with approximately 100 kg N ha^{-1}, produced 5241 kg DMha^{-1} during this period. In Experiment 2, Tetrelite ryegrass produced only 3437 kg DMha^{-1} despite increased N fertilization. However, the growing period in the latter experiment was much shorter, viz., 89 days versus 109. Consequently, the delay in seeding had a substantial negative impact on growth for which increased N fertilization was unable to compensate.

Experiment 12

During the establishment year (1981) botanical separations were made on samples taken at each harvest. Hence, yields are expressed on a weed-free basis and, in addition, yields of ryegrass and legume can be presented.

Both ryegrass cultivars established readily in both pure stands and in the mixtures. However, legume establishment varied among species with red clover being superior to that of alfalfa and alfalfa superior to birdsfoot trefoil.

Analysis of variance of yields, obtained in the establishment year, indicated that significant ($P<0.01$) differences occurred among the four swards (pure ryegrass, ryegrass plus alfalfa, ryegrass plus red clover, and ryegrass plus birdsfoot trefoil). However, differences between the two ryegrass cultivars and the interaction of cultivar x sward were not significant. Yields are presented in Table 24. Ryegrass grown in a pure stand produced a significantly greater yield than the mean ryegrass-legume mixture. The 7.77 Mg ha^{-1} yield from the ryegrass was very similar to the 8.18 Mg ha^{-1} yield obtained from Tetrelite in 1968. In both years three harvests were taken, at approximately similar intervals, and

Table 24. *Yields of dry matter resulting from seedings of ryegrass in pure and mixed stands - 1981.*

Seeded species	Total yield	Ryegrass yield	Legume yield
	Mg ha^{-1}		
Ryegrass	7.77**	7.77**	—
Ryegrass and alfalfa	4.61a*	3.90	0.72b
Ryegrass and red clover	5.04a	3.81	1.23a
Ryegrass and birdsfoot trefoil	4.12b	3.99	0.27c

**F test indicated that the difference between the mean yield of the two ryegrass cultivars grown in pure stands was significantly ($P<0.01$) greater than the mean yield of the ryegrass-legume mixtures or of the ryegrass component grown in mixed stands (columns 1 and 2, respectively).

*Means within a column (mixed swards only) followed by the same letter are not significantly ($P<0.05$) different according to Duncan's multiple range test.

the quantity of N applied was similar. In 1981 the growth during the summer period was very good. The percentage of the total yield obtained at the first, second, and third harvests was 32, 46, and 22%, respectively. The period of time between the first and second harvests was 25 June to 3 August. This suggests, as was the case in 1968, that summer production from ryegrass is acceptable when seedings are made early.

Ryegrass made up the major component of the yields obtained from the three ryegrass-legume mixtures. Of the legumes, red clover produced significantly more dry matter than alfalfa, while alfalfa produced more than birdsfoot trefoil. However, there was not a significant difference between the ryegrass-alfalfa and ryegrass-red clover yields. Consequently, red clover contributed 24% of the ryegrass-red clover yield while alfalfa contributed 16% of the ryegrass-alfalfa yield.

Peters (1961) spring seeded alfalfa, ladino clover (*Trifolium repens* L.) birdsfoot trefoil, and red clover with an oats companion crop at the same site that the ryegrass-legume mixtures were established. Total yields obtained from the above legume-oat mixtures were 9.01, 7.79, 6.03, and 8.27 Mg ha^{-1}, respectively; the contributions obtained from the legumes were 29, 11, 6, and 26%, respectively. Both studies indicate that during the establishment year a rapidly growing grass will effectively reduce the productivity of the associated legume in the mixture. This is particularly so with a species that is slow to establish, such as birdsfoot trefoil. In the study reported by Peters (1961) only two cuttings were taken and these after lengthy intervals of growth. Hence, yields were greater than those reported herein.

Nevertheless, the ryegrass-alfalfa and ryegrass-red clover mixtures established successfully. The botanical composition of the swards at the

time of harvest is shown in Table 25. The pure ryegrass swards remained essentially weed-free throughout the growing season. However, where legumes were included, weeds made an ingress into the swards, particularly in the ryegrass-birdsfoot trefoil swards.

Yields obtained in 1982 and 1983 are shown in Table 26. Both ryegrass cultivars exhibited excellent winter survival over the 1981-1982 winter. In 1982, Bison produced a significantly ($P<0.05$) greater yield

Table 25. Botanical composition of swards resulting from seedings of ryegrass in pure and mixed stands - 1981.*

	Component and harvest								
	Ryegrass			Legume			Weeds		
Seeded species	1	2	3	1	2	3	1	2	3
	%								
Ryegrass	93	100	92	0	0	0	7	0	8
Ryegrass and alfalfa	73	58	72	12	15	7	15	28	21
Ryegrass and red clover	68	42	70	13	30	14	19	28	16
Ryegrass and birdsfoot trefoil	74	60	77	4	2	1	22	38	22

*Botanical composition is expressed as a percentage of each component and is based on the fresh weight of each component at each harvest.

Table 26. Yields of dry matter obtained in 1982 and 1983 from stands of ryegrass and ryegrass - legume mixtures.

Seeded species	*Total yield*	
	1982	*1983*
	Mg ha^{-1}	
Ryegrass	*7.91*[b*]	*7.71*[**]
Ryegrass and alfalfa	*8.51*[b]	*11.54*
Ryegrass and red clover	*9.23*[a]	*11.23*
Ryegrass and birdsfoot trefoil	*5.96*[c]	*10.28*

***F test indicated that the difference between the mean yield of the two ryegrass cultivars grown in pure stands was significantly ($P<0.01$) less than that of the ryegrass-legume mixtures (1983 only).*

**Means within a column followed by the same letter are not significantly ($P<0.05$) different according to Duncan's multiple range test).*

than that obtained from Tetrelite. Total seasonal yields were 8.17 and 7.64 Mg ha^{-1}, respectively. In addition, significant ($P<0.01$) differences occurred among the four swards. The ryegrass-red clover mixture produced the greatest yield followed by the ryegrass-alfalfa mixture.

Only two harvests were taken in 1982, the second of which occurred on 22 July. Regrowth following this harvest was excellent. However, the swards were subsequently and repeatedly grazed by wild deer which precluded an accurate harvest yield estimate in the fall.

In the spring of 1983 the stands looked rather poor. However, the ryegrasses, red clover, and alfalfa made a remarkable recovery. April and May were both cold and wet; the summer was hot and dry. Nevertheless, again from only two harvests, fairly substantial yields were obtained, particularly from the ryegrass-legume mixtures. In this year the pure ryegrass swards produced significantly ($P<0.01$) less than the mixed swards. There was no difference between the yields obtained from the ryegrass cultivars. During the 1983 growing season weeds began to invade the pure ryegrass and ryegrass-birdsfoot trefoil stands.

By 1984 the ryegrass, ryegrass-red clover, and ryegrass-birdsfoot trefoil swards were very poor. The ryegrass-alfalfa swards were excellent but consisted primarily of alfalfa. Consequently, yield estimates were not taken.

The use of ryegrass as an associate species with alfalfa and red clover appears promising. Certainly, during establishment, the ryegrass could replace oats as a companion species. In subsequent years, at least in the experiment reported herein, the yields from the ryegrass-alfalfa and ryegrass-red clover mixtures were equal or superior to the yields obtained from the pure ryegrass swards. Guillard (1983) reported that seeding ryegrass with legumes (alfalfa and red clover) increased yields in the seeding year compared to yields obtained from pure legume seedings.

Experiment 13

The initial concentrations of TNC and fructosan in the stubble of the three ryegrass cultivars are shown in Table 27. Concentrations of both fractions were greatest for annual ryegrass, lowest for perennial ryegrass, and intermediate for the hybrid Tetrelite. Of the TNC accumulated in the stubble of perennial ryegrass only 23% was in the form of fructosan. In the case of annual and Tetrelite ryegrass the fructosan fraction represented 49 and 41%, respectively, of the TNC fraction. Smith (1968a) indicated that those grass species that originated in temperate climates accumulated fructosan as their predominant reserve carbohydrate. In the data presented by Smith (1968a) fructosan represented 39% of the TNC accumulated in the lower 7.6 cm stubble of perennial ryegrass. Consequently, it would appear that in the experiment reported herein, either fructosan accumulation in perennial ryegrass lagged

Table 27. Concentrations of TNC and fructosan in ryegrass cultivars grown in the growth chamber.

Cultivar	Initial level	1 cycle 21-d	1 cycle 43-d	1 cycle Mean	2 cycle 32-d	2 cycle 54-d	2 cycle Mean
	%						
TNC							
Perennial	9.6[b†]	10.0	21.7	15.8[b]	9.9	7.8	8.8[b]
Annual	24.2[a]	11.6	12.8	12.2[b]	7.8	6.6	7.2[b]
Tetrelite	16.4[ab]	17.6	28.0	22.8[a]	19.4	16.7	18.0[a]
Mean	16.7	13.1	20.8		12.4	10.4	
F test	*	**		*	*		**
Fructosan							
Perennial	2.2	3.3	14.5	8.9[b]	1.4	1.6	1.5[b]
Annual	11.8	6.1	9.7	7.9[b]	0.9	1.4	1.2[b]
Tetrelite	6.8	9.6	20.4	15.0[a]	7.6	7.4	7.5[a]
Mean	6.9	6.3	14.9		3.3	3.5	
F test	NS	**		*	NS		**

**, *Significant at $P<0.01$ and 0.05, respectively.
†Values within a column followed by the same letter are not significantly ($P<0.05$) different according to Duncan's multiple range test.
NS Not significant.

behind that of the other cultivars or a smaller proportion of storage tissue was harvested in the 5 cm stubble of perennial ryegrass compared to the other cultivars.

GROWTH CHAMBER

After 21 days regrowth the concentrations of TNC in perennial and Tetrelite ryegrass were slightly greater than those at the initiation of the experiment (Table 27). After 43 days of regrowth the concentration of TNC in these cultivars was approximately double that of the initial concentrations. Alternately, the concentration of TNC in annual ryegrass was approximately half of the initial value. At the time of the 43-day harvest the annual ryegrass was at the anthesis stage of maturity, Tetrelite was at the early-head stage, while perennial ryegrass was still primarily vegetative. The emphasis on flower and stem development appeared to have inhibited TNC accumulation in annual ryegrass. This did not occur in Tetrelite, although this cultivar was not as advanced in maturity as was annual ryegrass.

After the 43-day regrowth period the concentration of fructosan in both perennial and Tetrelite ryegrass greatly exceeded the concentration measured at the initiation of the experiment. Again, annual ryegrass had a lower concentration of fructosan after this growth period than it did initially. However, for all three cultivars, after 43 days of regrowth the fructosan fraction represented 67-76% of the TNC fraction.

Analysis of variance indicated that significant ($P<0.05$) differences occurred among the ryegrass cultivars for concentration of both TNC and fructosan. In addition, concentrations of both fractions were significantly ($P<0.01$) greater in tissues harvested following the 43-day regrowth period compared to the 21-day period.

Concentrations of TNC and fructosan were generally lower in ryegrass tissues harvested in the second cycle compared to the first cycle. Further, especially for perennial and annual ryegrass, the percentage of TNC accumulated in the form of fructosan was also much less in the second cycle. The influence of flower initiation and development was undoubtedly of great importance. After 32 days of regrowth annual ryegrass had formed a number of flowering tillers — an average of 11 per replication. This cultivar exhibited the lowest concentration of TNC at this point and the fructosan fraction only contributed 12% of the TNC. The other two cultivars had not formed flowering tillers. After the 54-day regrowth period the annual ryegrass had produced many flowering tillers — 42 per replication, Tetrelite had 2 flowering tillers per replication, and perennial ryegrass was still primarily vegetative.

Analysis of variance indicated that, in the second cycle, the overall mean concentrations of both TNC and fructosan were significantly greater in Tetrelite than in the other two cultivars. Despite the heavy production of flowering tillers by annual ryegrass the concentration of both TNC and fructosan in this cultivar was essentially the same as that in the

vegetative perennial ryegrass. The mean concentration of TNC in tissues harvested after a regrowth period of 54 days was significantly (P 0.05) lower than that in tissues harvested after 32 days regrowth. This was the reverse of the trend observed in the first cycle and probably reflects, (a) the formation of reproductive tillers rather than photosynthetic pseudostems, plus (b) the removal of most of the accumulated carbohydrate reserves at the time of the first cycle harvest.

GREENHOUSE

Reproductive tillers were not formed by any of the cultivars when they were grown in the greenhouse. Since both growth cycles were completed during the period of 30 January to 15 April, the photoperiod was short but gradually increasing. Hence, light energy available for photosynthesis was greater during the second cycle than during the first cycle.

In the first cycle, annual ryegrass had a significantly greater concentration of TNC than either of the other cultivars (Table 28). In the second cycle, annual ryegrass and Tetrelite had significantly greater concentrations of TNC than perennial ryegrass. To a considerable degree, concentrations of fructosan in the three cultivars paralleled concentrations of TNC. These data indicate that when cultivars are compared at similar growth stages the annual and hybrid ryegrasses accumulated greater concentrations of reserve carbohydrates than perennial ryegrass. Analysis of ryegrass tissues in other experiments (Experiments 6, 7, and 8) also indicated that Tetrelite consistently had greater concentrations of TNC in its stubble than did perennial ryegrass.

The concentrations of both TNC and fructosan were much greater in all three cultivars grown in the greenhouse in the second cycle than they were when grown in the growth chamber. To a considerable degree this reflected the fact that no reproductive tillers were formed under the greenhouse conditions. Smith (1968b) demonstrated that timothy (*Phleum pratense* L.) accumulated greater concentrations of TNC and fructosan under cool rather than warm growing conditions. The varying temperatures existing in the growth chamber and greenhouse also probably influenced carbohydrate accumulations. Similarly, increasing light intensity is associated with increased carbohydrate accumulation. The period of the second growth cycle, 14 March to 15 April, was a period of increasing photoperiod with an associated potential for improved photosynthate accumulation.

In the first cycle concentrations of both TNC and fructosan were significantly ($P < 0.01$) greater after the 43-day regrowth period than they were after the 21-day regrowth period. Growth interval was not significant in the second cycle. Under the conditions of the second cycle, TNC and fructosan accumulation showed no increase after the 32-day regrowth period.

In the second experiment these same three cultivars were permitted to grow for a period of 81 days after being trimmed either at the base

Table 28. Concentrations of TNC and fructosan in ryegrass cultivars grown in the greenhouse.

Cultivar	Initial level	1 cycle 21-d	1 cycle 43-d	1 cycle Mean	2 cycle 32-d	2 cycle 54-d	2 cycle Mean
	——————	——————	——————	%	——————	——————	——————
				TNC			
Perennial	9.6[b†]	9.5	15.7	12.6[c]	20.2	24.4	22.2[b]
Annual	24.2[a]	18.4	26.6	22.5[a]	37.1	36.4	36.8[a]
Tetrelite	16.4[ab]	13.5	24.8	19.2[b]	36.6	36.9	36.8[a]
Mean	16.7	13.8	22.4		31.3	32.5	
F test	*	**		**	NS		**
				Fructosan			
Perennial	2.2	2.1	9.0	5.6[b]	8.8	12.6	10.7[b]
Annual	11.8	9.2	18.0	13.6[a]	23.4	22.0	22.7[a]
Tetrelite	6.8	5.9	16.8	11.4[a]	20.9	22.6	21.8[a]
Mean	6.9	5.7	14.6		17.7	19.1	
F test	NS	**		**	NS		**

**, *Significant at $P<0.01$ and 0.05, respectively.

†Values within a column followed by the same letter are not significantly ($P<0.05$) different according to Duncan's multiple range test.

NS Not significant.

or at a height of 7.6 cm. At the end of this period the stubble was taken for carbohydrate analysis. Concentrations of TNC and fructosan in the cultivars are shown in Table 29. Concentrations of both of these fractions were significantly greater in annual and Tetrelite ryegrass than they were in perennial ryegrass. The height of the initial cutting did not significantly influence subsequent carbohydrate accumulation. Fructosan represented 60% of the TNC in perennial ryegrass, 69% in annual ryegrass, and 75% in the case of Tetrelite.

Table 29. Concentrations of TNC and fructosan in ryegrass cultivars cut at two heights.

Cultivar	TNC			Fructosan		
	Base	7.6 cm	Mean	Base	7.6 cm	Mean
	%					
Perennial	19.8	20.9	20.4[b]*	12.0	12.1	12.1[b]
Annual	38.2	32.2	35.2[a]	26.2	22.6	24.4[a]
Tetrelite	39.6	34.8	37.2[a]	28.7	26.4	27.6[a]
Mean	32.5	29.3		22.3	20.4	
F	NS		**	NS		**

**Significant at $P<0.01$.

*Values within a column followed by the same letter are not significantly ($P<0.05$) different according to Duncan's multiple range test.

NS Not significant.

SUMMARY

During the 1968-1983 period a series of experiments were conducted to (a) evaluate the potential that various ryegrass species and cultivars have for forage use in this area, and (b) investigate the growth responses of ryegrass to varying managerial practices. The following conclusions and recommendations may be drawn.

1. Ryegrass was satisfactorily established in either the spring or the late-summer to early-fall period. Spring seedings should be made as early as possible. Delaying seeding until May increased weed invasion into the stands, particularly when perennial ryegrass was seeded, and resulted in lowered yields in the establishment year regardless of whether annual or perennial ryegrass was being grown (Experiments 9, 10, 11).
2. Seeding rates as low as 13.4 kg ha^{-1} proved satisfactory.
3. Stands were successfully established following conventional or no-till seedings (Experiments 1, 2, 3, 4, 11) and in pure and mixed seedings (Experiment 12).
4. Spring seedings, made in soils to which 45 kg N ha^{-1} had been added, produced approximately 2000-2500 kg DM ha^{-1} when harvested after approximately 10 weeks growth (Experiments 1, 12). Summer growth of both annual and perennial ryegrass in the establishment year was adequate and compared favorably to other forages (Experiments 1, 2). Adequately fertilized with N, i.e., 160-180 kg N ha^{-1}, productive cultivars produced approximately 8000 kg DM ha^{-1} during the seeding year (Experiments 1, 12). Higher N rates increased yields to some degree (Experiment 2).
5. Tetraploid ryegrass cultivars, seeded in August, produced between 1300-1700 kg DM ha^{-1} following 65 to 77-day growth periods. The nutritive value of this herbage, as indicated by laboratory techniques, was high. Concentrations of crude protein were 20% or higher and IVDMD values were in excess of 80% (Experiments, 3, 4, 5).
6. Winter survival of ryegrass cultivars was erratic. Many of the experiments reported herein were conducted with the tetraploid cultivar Tetrelite. In some instances this cultivar was winterkilled during the first winter after establishment (Experiments 1, 2, 5, 6) while in others it persisted for some years (Experiments 3, 4, 7, 9, 12). In one case there was evidence that winter survival was inversely related to fall vigor and to ploidy level (Experiments 5). Cultivar trials indicated that substantial variation existed among cultivars insofar as their production capacity was concerned in postestablishment years. Similarly, variation existed with respect to winter hardiness. The point should be made that all harvest schedules were

geared to a hay or silage management system. This undoubtedly placed some cultivars at a disadvantage since they may have been best suited for pasture or even turf use.

7. Tetrelite was capable of producing substantial herbage yields in postestablishment years (Experiments 3, 4, 7, 9, 12). Yields were influenced by N level. In Experiment 4 the mean yields of Tetrelite were 9.14, 10.31, and 11.11 Mg ha^{-1} when the cultivar was fertilized with 224, 336, and 448 kg N ha^{-1}, respectively.

8. The nutritive value of Tetrelite herbage remained high throughout the growing season. In Experiment 3 the mean IVDMD values of herbage at the various harvests ranged from 68.0 to 78.8%; in Experiment 4 overall means ranged from 69.8 to 80.3%. Values tended to be lower in the midsummer period compared to the early summer or fall periods. Concentrations of crude protein were influenced by N fertilization but overall means across N rates ranged from 15.3 to 22.0%.

9. Tetrelite ryegrass, fertilized with substantial rates of N fertilizer, accumulated nitrates. Fertilized with 448 kg N ha^{-1} the season mean concentration of NO_3^--N in harvested herbage was 2574 ppm; the greatest concentration occurred in first harvest herbage (1 June) and was 7151 ppm (Experiment 4). In this same experiment the concentration of K in the ryegrass herbage, while within the range reported for perennial grasses, was high. The overall mean concentrations of herbage K for the five consecutive harvests were 4.57, 3.97, 2.99, 3.49, and 3.21%. Despite these high concentrations the K/Ca + Mg ratios were generally well below 2.2. Nevertheless, ryegrass does have the capacity to remove substantial quantities of K from the soil, and so, in addition to N, ryegrass production will require substantial K fertilization.

10. Frequent defoliation and the application of N to late summer-seeded ryegrass reduced the accumulation of TNC and fructosan during fall growth. Tetrelite ryegrass consistently had greater concentrations of both TNC and fructosan than did perennial ryegrass. This difference was observed both at the beginning of the winter, in midwinter, and during initial spring growth. However, Tetrelite also had a greater utilization of TNC over the winter period. Despite the greater concentrations of stored carbohydrates observed in Tetrelite compared to perennial ryegrass, the former cultivar frequently had a higher incidence of winterkill (Experiments 6, 7, 8, 13). This suggests that carbohydrate accumulation may not be implicated in the winterkill process.

11. Finally, it may be concluded that ryegrass may be successfully used as a forage crop in New England. Certainly, yields from spring seedings of Tetrelite and Bison indicate that ryegrass may be suc-

cessfully used as an annual. In addition, mixtures of ryegrass with legumes such as red clover and alfalfa have promise. The development of a cultivar with greater winter hardiness than those cultivars evaluated in these studies is worthy of effort and is necessary before ryegrass can be unequivocally recommended as a perennial forage.

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Appendix Table 1. Mean monthly maximum and minimum temperatures and total monthly precipitation at Storrs, Connecticut during the 1968 - 1983 period.

Month		1968			1969			1970	
	Max.	Min.	Precip.	Max.	Min.	Precip.	Max.	Min.	Precip.
	°C		cm	°C		cm	°C		cm
Jan.	- 0.6	- 9.6	7.3	3.9	- 8.1	3.7	-3.2	-12.1	1.9
Feb.	0.2	- 4.7	1.8	0.4	- 6.1	4.3	2.4	- 8.3	13.4
Mar.	9.0	- 1.8	10.7	4.6	- 4.1	6.7	4.6	- 3.5	8.4
Apr.	17.3	3.4	5.3	15.1	3.2	14.5	13.2	2.1	11.0
May	19.2	7.2	13.6	19.6	7.6	10.0	19.6	8.4	12.0
June	23.8	12.7	17.9	24.2	13.3	3.4	23.0	12.6	7.2
July	27.2	15.8	4.0	24.8	15.7	16.7	26.6	16.5	2.0
Aug.	25.5	14.2	8.6	27.0	16.1	6.5	27.2	15.7	12.1
Sept.	23.1	11.2	6.5	22.3	11.4	17.2	21.7	11.2	8.3
Oct.	17.4	6.7	5.4	16.6	5.3	5.3	16.7	6.4	6.7
Nov.	8.1	0.1	13.3	9.2	0.9	15.2	10.0	2.1	11.1
Dec.	1.0	- 6.8	13.7	1.1	- 6.6	20.3	1.0	- 7.2	9.1
		1971			1972			1973	
Jan.	- 1.4	-11.7	4.6	2.4	- 7.2	5.2	3.3	- 6.2	11.8
Feb.	0.7	- 6.3	14.3	0.2	- 9.6	14.2	1.5	- 7.9	9.0
Mar.	5.2	- 3.1	6.8	5.3	- 4.3	17.9	10.3	0.4	8.1
Apr.	12.1	1.2	5.2	10.5	0.1	9.7	14.3	4.3	14.7
May	18.1	7.5	10.5	20.4	8.0	13.3	17.8	7.0	12.1
June	25.0	12.5	6.3	21.7	12.8	25.7	24.8	14.6	9.2
July	26.4	15.3	13.9	26.5	16.6	12.9	26.9	16.5	11.0
Aug.	26.0	15.2	8.4	25.1	14.6	8.4	27.1	17.3	11.8
Sept.	22.9	13.6	16.6	22.4	11.4	13.6	22.2	10.7	12.6
Oct.	19.5	8.1	9.1	14.1	2.9	10.9	17.5	5.9	12.2
Nov.	7.4	0.1	13.8	7.0	- 0.6	21.8	10.1	1.1	4.9
Dec.	5.4	- 4.1	7.4	3.4	- 4.2	20.4	6.6	- 3.6	25.3
		1974			1975			1976	
Jan.	0.1	- 7.2	13.1	3.2	- 5.4	12.7	- 0.7	-11.2	17.6
Feb.	1.0	- 8.6	7.6	2.0	- 6.5	8.4	6.1	- 5.4	9.2
Mar.	7.3	- 3.0	12.3	5.6	- 3.9	10.6	8.5	- 2.9	8.1
Apr.	14.8	3.8	9.3	10.9	0.2	8.3	16.0	4.5	9.0
May	18.2	7.3	7.1	22.0	8.7	8.9	18.9	7.3	8.9
June	23.2	13.6	5.8	22.6	13.1	10.7	25.5	14.5	4.9
July	26.5	16.5	7.7	26.5	16.2	10.5	25.5	15.3	10.2
Aug.	26.5	14.6	14.1	25.6	15.0	8.1	25.0	14.2	22.8
Sept.	21.0	11.0	21.5	19.5	9.0	25.3	20.9	10.5	6.3
Oct.	13.8	2.2	9.8	16.9	6.9	13.7	13.6	3.9	11.9
Nov.	10.6	1.4	5.1	12.6	3.4	13.8	7.2	- 1.6	2.0
Dec.	4.2	- 3.4	16.4	3.8	- 5.9	11.4	0.1	- 9.3	11.9

Appendix Table 1. continued

Month	1977 Max.	1977 Min.	1977 Precip.	1978 Max.	1978 Min.	1978 Precip.	1979 Max.	1979 Min.	1979 Precip.
	°C		cm	°C		cm	°C		cm
Jan.	- 3.9	-12.9	7.6	- 0.1	- 9.0	28.3	1.6	- 7.1	35.0
Feb.	0.7	- 7.4	6.1	- 1.8	-10.4	4.2	- 3.9	-12.0	9.0
Mar.	9.3	0.1	16.5	4.9	- 4.5	9.6	9.3	- 0.5	9.5
Apr.	15.3	2.6	11.3	12.4	1.6	6.6	13.0	2.8	13.8
May	21.2	8.4	12.3	18.9	8.2	10.5	20.2	10.1	13.2
June	22.4	11.8	12.0	24.7	11.8	5.8	23.6	12.1	2.8
July	26.5	15.2	9.1	25.8	14.3	13.6	27.1	16.5	9.3
Aug.	25.8	14.5	8.4	25.3	15.6	10.0	24.9	15.6	21.4
Sept.	20.8	10.9	19.4	20.9	8.8	5.9	22.1	10.3	10.7
Oct.	15.6	5.0	19.7	15.7	3.9	10.8	14.5	5.7	12.4
Nov.	10.1	2.2	8.6	10.4	0.4	6.2	12.7	3.2	11.6
Dec.	2.0	- 6.1	15.4	4.8	- 4.8	11.5	5.0	- 3.6	6.3
		1980			1981			1982	
Jan.	1.7	- 7.1	3.4	- 3.1	-12.6	1.6	- 3.1	-12.8	15.0
Feb.	0.4	- 9.4	2.6	5.9	- 4.8	20.0	2.1	- 5.9	9.7
Mar.	5.7	- 3.4	24.1	6.4	- 2.9	1.4	7.0	- 1.9	7.3
Apr.	13.8	3.4	13.3	14.6	3.8	10.5	12.4	2.1	13.3
May	21.1	8.4	4.6	20.8	9.1	8.3	21.3	8.5	6.4
June	23.2	10.5	8.7	24.6	13.3	6.8	21.9	11.8	32.5
July	27.5	15.9	22.8	27.5	16.3	8.4	27.2	15.6	5.4
Aug.	26.8	16.2	5.2	26.1	13.5	1.9	24.1	14.1	8.6
Sept.	22.9	11.2	3.3	20.2	9.4	9.8	21.8	10.8	7.9
Oct.	15.0	4.0	11.4	14.5	3.8	13.5	15.6	4.1	10.4
Nov.	8.1	- 1.2	12.3	9.4	0.9	6.7	11.6	1.5	11.9
Dec.	1.5	- 9.2	2.8	2.3	- 5.3	15.4	6.5	- 2.0	4.7
		1983							
Jan.	1.7	- 6.4	13.6						
Feb.	3.7	- 4.7	12.0						
Mar.	7.5	- 0.7	19.9						
Apr.	12.7	3.5	27.8						
May	17.8	7.3	14.5						
June	25.6	12.9	5.6						
July	28.0	15.8	3.9						
Aug.	26.6	14.9	7.6						
Sept.	24.9	12.4	3.6						
Oct.	16.0	7.1	17.4						
Nov.	10.9	1.1	19.6						
Dec.	2.5	- 6.4	16.8						