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RESEARCH REPORT 77, JANUARY 1983

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An Evaluation of Yield and Quality Components of Lolium X Festuca Hybrids

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FORAGE IMPROVEMENT has as its goal the development of highly nutritious and palatable cultivars which are high yielding, persistent, and tolerant of adverse growing conditions. As a means of extending the range of forage cultivars, as well as integrating desirable characteristics from different species into a new cultivar, forage breeders have for some time been making interspecific and intergeneric crosses. Of particular interest is the work involving attempts to hybridize ryegrasses *(Lolium* spp.) with fescues *(Festuca* spp.).

Interest in hybridization between *Lolium* and *Festuca* is not a recent development. There is in fact a natural hybrid classified as *Festulolium loliaceum* (Huds.) P. Fourn. (Hubbard, 1968). This

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sterile intergeneric hybrid is the product of a *Festuca pratensis* (Huds.) and *Lolium perenne* L. cross. While this hybrid is not common it is more prevalent than other natural *Lolium* x *Festuca* hybrids.

Ryegrasses are both nutritious and acceptable to all classes of livestock. They germinate and establish rapidly under favorable conditions. When adequately fertilized their yield potential is high. Perennial ryegrass *(L. perenne* L.) is widely used in many areas with temperate oceanic climates. However, its use in more temperate continental climates is limited by a lack of winter hardiness.

The most important forage fescue in the United States is tall fescue *(Festuca arundinacea* Schreb.). Tall fescue is a deep-rooted, long-lived perennial that is tolerant of adverse growing conditions. It will persist in both poorly drained and excessively drained sites (Smith, 1978). Though relatively slow to establish, tall fescue, like perennial ryegrass, is a high yielding species. The winter hardiness of tall fescue is superior to that of perennial ryegrass, being comparable to that of orchardgrass *(Dactylis glomerata* L.) (Smith, 1978). The intake of tall fescue may be variable due to poor palatability. The feeding quality of tall fescue is improved if it is kept rather closely grazed. Meadow fescue *(Festuca pratensis* Huds.) is a winter-hardy forage that begins growth early in the spring, will persist under moderate grazing intensity, and finds considerable use in Europe (Spedding and Diekmahns, 1972).

The aim in developing an intergeneric *Lolium* x *Festuca* hybrid is to produce a cultivar that combines the nutritional qualities of the ryegrass with the persistence and hardiness of the fescue. One of the severest problems in developing such a cultivar is overcoming the sterility of the resulting hybrid. One method of gaining fertility in the crosses is to pollinate *Lolium* (2n = 14) with tetraploid meadow fescue (2n = 28). The infertile triploid (2n = 21) is then treated with colchicine to produce a fertile autoallohexaploid (2n = 42). These plants are then pollinated with tall fescue. The resulting trispecies is then backcrossed to tall fescue (Berg and Hill, 1975).

The yield of *Lolium* x *Festuca* hybrids has generally been less than that of tall fescue cultivars (Webster and Buchner, 1971). Berg et al. (1979) reported that *Lolium* x *Festuca* hybrids had less

spring growth, were less vigorous, and provided significantly less estimated ground cover than commercially available tall fescue cultivars. However, *Lolium* x *Festuca* hybrids are reportedly higher in palatability than tall fescue, indicating that hybridization may lead to an improvement in its quality (Webster and Buchner, 1971).

The improvement of tall fescue via the introduction of *Lolium* genetic material seems promising. Since backcrossing to tall fescue is the best way to incorporate the necessary fertility levels, *Lolium* x *Festuca* cultivars will resemble tall fescue in appearance. However, as quality components of *Lolium* are heritable, some improvement in quality is possible.

In the present study thirteen *Lolium* x *Festuca* hybrids, two perennial ryegrass cultivars, and one tall fescue cultivar were assessed for dry matter yields and quality components. Quality components measured included *in vitro* dry matter digestibility, neutral-detergent fiber (cell wall constituents), acid-detergent fiber, acid-detergent lignin, and mineral levels.

MATERIALS AND METHODS

Plant Materials

Lolium x *Festuca* hybrids[2] were produced by pollinating perennial ryegrass (2n = 14) with induced tetraploid meadow fescue (2n = 28). The ensuing highly infertile triploid (2n = 21) was then treated with colchicine to produce a fertile autoallohexaploid (2n = 42). The plants were pollinated with tall fescue, and the resulting trispecies was then backcrossed to tall fescue (Berg and Hill, 1975). All hybrids evaluated in this study are denoted by a numerical code. The first number indicates the year that the parent

[2] ***Lolium* x *Festuca* hybrids were provided by Dr. C. C. Berg of the U.S. Regional Pasture Research Laboratory, University Park, Pennsylvania, as part of NE-106 Regional Research Project.**

clone was chosen. The second number identifies the female parent in the backcross to tall fescue. The last number identifies a specific plant resulting from the backcross.

In addition to the *Lolium* x *Festuca* hybrids, two cultivars of perennial ryegrass, 'Linn' and 'KO-14'[3], and one cultivar of tall fescue, 'Kenhy'[4], were included in the experiment. Kenhy tall fescue, a recently improved cultivar, is a synthetic of progenies of eleven 42-chromosome derivatives of annual ryegrass *(Lolium multiflorum* L.) x tall fescue hybrids (Buchner et al., 1977).

Field Experiment

The plant materials were evaluated during the 1977-1979 period. The experiment was conducted on a Paxton fine sandy loam (coarse-loamy, mixed, mesic Typic Dystrochrepts). Soil tests indicated that the soil had a pH of 6.1 and calcium, magnesium, phosphorus and potassium levels of 1588, 403, 6, and 168 kg/ha, respectively. On May 18, 1977, 4.48 metric tons of ground limestone and 896 kg/ha of 5-10-10 were broadcast per hectare and disked into the experimental site. Plots were hand seeded in rows on May 27, 1977 at the rate of 9 kg/ha. The entire area was then cultipacked. The experiment was laid out in a randomized complete block design with three replications. Each plot consisted of a 7.6m row.

Yields were obtained on August 8, 1977 from the center 6.1m of the row. The grasses were harvested with a sickle-bar mower at a height of 2.5 cm and yields recorded. Samples were collected for dry matter determination and subsequent analyses. The samples were dried at 65 C. The tissue was then ground through a 1-mm screen in a Wiley mill and stored in screw-top bottles.

After harvesting, urea and muriate of potash were broadcast at rates of 56 and 93 kg/ha of N and K, respectively. On September 6, 1977 a second harvest was taken. Samples were collected, dried, ground, and stored as before. After the second

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[3] Linn perennial ryegrass is a commercially available cultivar. KO-14 perennial ryegrass is an experimental cultivar, provided by Northrup King Seed Company, which displayed good winter survival in a variety trial at the Agronomy Research Farm, The University of Connecticut, Storrs, Connecticut.

[4] Kenhy tall fescue was provided by Dr. R. C. Buchner of the University of Kentucky, as part of NE-106 Regional Research Project.

harvest 2.4 metric tons/ha of ground limestone were applied in addition to 22, 59, and 112 kg/ha of N, P, and K, respectively. Fertilizers used were urea, triple superphosphate, and muriate of potash, respectively.

In 1978, harvests were taken on June 16, July 30, and August 26. The harvesting and sample preparation procedure was identical to that described for the 1977 harvests. Plots were fertilized as follows: May 7, 560 kg/ha of 10-10-10; June 17, 56 kg N/ha using urea plus 93 kg K/ha using muriate of potash; August 1, 22 kg N/ha using urea; August 29, 28 kg N/ha using urea.

In 1979, one harvest was taken on July 11. Again, harvesting procedures were identical to those previously described. All plots had been fertilized on May 5 with 560 kg/ha of 10-10-10.

Analyses

The samples collected in 1977 and 1978 were analyzed for *in vitro* dry matter digestibility (IVDMD) using the modified procedure of Tilley and Terry (1963). Determinations were also made for cell wall constituents (CWC) as described by Van Soest and Wine (1967), and acid-detergent fiber (ADF) and acid-detergent lignin (ADL) using the procedure of Van Soest (1963).

All samples were analyzed for concentrations of calcium, magnesium, phosphorus, and potassium after digestion in nitric and perchloric acids. Phosphorus was determined using the molybdophosphoric blue colorimetric method (Dickman and Bray, 1940). Calcium and potassium concentrations in the digestates of the 1977 samples were determined by flame photometry while magnesium was determined using atomic absorption spectrophotometry. The calcium, potassium, and magnesium concentrations in the 1978 samples were all determined via atomic absorption spectrophotometry.

RESULTS AND DISCUSSION

Dry Matter Yields

Dry matter yields for 1977, 1978, and 1979 are summarized in Table 1. The total dry matter production of the *Lolium* x *Festuca* hybrids in the seeding year was 15 to 60% of Linn perennial ryegrass and 17 to 70% of Kenhy tall fescue. The low dry matter yield of the hybrids in the first harvest reflects their slow establishment. They produced only 12 to 26% of their total yield in the first harvest.

In the first harvest of 1978 Kenhy tall fescue produced the greatest amount of dry matter. However, this was not significantly greater than seven of the hybrids. The hybrids produced yields that were between 64 to 95% of those produced by Kenhy tall fescue in the first harvest. The ryegrasses yielded significantly less than both tall fescue and the hybrids. Both ryegrass cultivars apparently had suffered considerable winter damage. Significant differences in yield were not obtained among the cultivars in either the second or third harvests in 1978. However, the ryegrasses produced the lowest yields in both harvests while yields from Kenhy were superior to most of the hybrids. The total dry matter production of Kenhy tall fescue in 1978 was not significantly greater than eight of the hybrids. Total dry matter production from the hybrids was 66 to 93% of the Kenhy yield.

For the single harvest taken in 1979, the hybrids produced 62 to 93% of the yield of Kenhy tall fescue. The yield of tall fescue was not significantly greater than hybrid 67-149-2. The ryegrasses produced very low yields due to severe winter injury.

In Vitro Dry Matter Digestibility

Data from the *in vitro* dry matter digestibility (IVDMD) analyses are summarized in Table 2. No significant differences in levels of IVDMD existed among cultivars in either harvest in 1977. In the first harvest the mean IVDMD value was 76.8%. Values ranged from 81.3% for hybrid 67-157-5 to 73.4% for Linn perennial ryegrass. The relatively low value obtained for Linn perennial

Table 1. Dry matter yield of Linn and KO-14 perennial ryegrasses, Kenhy tall fescue, and 13 Lolium x Festuca hybrids for the 1977, 1978, and 1979 harvests.

	Year and harvest							
	1977			1978				1979
Cultivar	1	2	Total	1	2	3	Total	1
	g/row							
Linn	341^{a*}	382^{ab}	723^{a}	1434^{f}	497	347	2278^{d}	114^{g}
KO-14	59^{cd}	167^{def}	226^{defg}	1910^{e}	448	389	2747^{cd}	281^{f}
Kenhy	208^{b}	411^{a}	620^{ab}	3736^{a}	788	618	5142^{a}	2402^{a}
67-135-6	39^{cd}	181^{cdef}	220^{defg}	3204^{abc}	731	553	4488^{ab}	1507^{e}
67-136-8	59^{cd}	238^{bcde}	298^{cdefg}	3331^{abc}	701	548	4580^{ab}	1725^{d}
67-136-16	41^{cd}	144^{def}	185^{efg}	2916^{c}	689	537	4142^{b}	1480^{e}
67-138-10	19^{d}	89^{f}	108^{g}	2398^{d}	519	466	3383^{c}	1494^{e}
67-149-1	110^{c}	323^{abc}	433^{bc}	3242^{abc}	692	510	4444^{ab}	1571de
67-149-2	72^{cd}	240^{bcde}	312^{cdef}	3407^{abc}	790	597	4794^{ab}	2234^{ab}
67-150-10	23^{d}	124^{ef}	146^{fg}	3087^{bc}	672	634	4394^{ab}	1598de
67-150-13	95^{cd}	285^{abcd}	379^{cd}	3547^{ab}	607	539	4693^{ab}	2107^{bc}
67-150-17	62^{cd}	208^{cdef}	270^{cdefg}	3241^{abc}	612	486	4339^{b}	1743^{d}
67-150-19	14^{d}	103^{ef}	117^{g}	3164^{bc}	785	597	4546^{ab}	1680^{d}
67-154-3	38^{cd}	167^{def}	205^{defg}	3164^{bc}	559	459	4181^{b}	1721^{d}
67-156-2	97^{cd}	276^{abcd}	373^{cde}	3260^{abc}	524	439	4223^{b}	1625de
67-157-5	39^{cd}	162^{def}	201^{defg}	3147^{bc}	688	581	4415^{ab}	2038^{c}
Mean	82	219	301	3012	644	519	4175	1583

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

ryegrass is probably attributable to its greater maturity at harvest compared to the other cultivars. In the second harvest the overall mean IVDMD value was 73.9% with the range being 69.4 to 76.6% for Linn perennial ryegrass and hybrid 67-135-6, respectively. Values were generally lower in the second harvest than in the first.

Significant differences existed in the first and third harvests of 1978, but not in the second harvest. In the first harvest the mean IVDMD value was 59.5% with a range of 55.6 to 74.3%. The two

Table 2. *In vitro* dry matter digestibility of Linn and KO-14 perennial ryegrasses, Kenhy tall fescue, and 13 *Lolium* x *Festuca* hybrids for the 1977 and 1978 harvests.

	Year and harvest				
	1977		1978		
Cultivar	1	2	1	2	3
	%				
Linn	73.4	69.4	65.7^{b*}	62.2	73.0^{abc}
KO-14	76.5	75.8	74.3^{a}	56.2	77.5^{a}
Kenhy	73.5	75.4	57.8^{cd}	52.9	74.4^{ab}
67-135-6	78.3	76.6	58.0^{cd}	59.4	76.4^{ab}
67-136-8	76.9	73.2	58.9^{cd}	56.3	77.2^{a}
67-136-16	75.8	75.8	59.1^{cd}	51.7	76.1^{ab}
67-138-10	79.5	71.4	57.7^{cd}	57.2	75.3^{ab}
67-149-1	75.8	73.7	61.0^{c}	52.0	72.5^{abc}
67-149-2	75.3	73.1	58.3^{cd}	48.4	74.4^{ab}
67-150-10	80.0	73.4	58.2^{cd}	55.5	71.8^{abc}
67-150-13	74.8	75.0	56.4^{d}	51.2	77.1^{a}
67-150-17	77.4	73.0	59.1^{cd}	55.0	68.2^{c}
67-150-19	75.4	73.2	58.4^{cd}	58.0	76.3^{ab}
67-154-3	78.2	74.0	56.7^{d}	54.6	71.0^{bc}
67-156-2	76.8	73.8	57.2^{cd}	57.4	75.4^{ab}
67-157-5	81.3	74.8	55.6^{d}	56.8	76.4^{ab}
Mean	76.8	73.9	59.5	55.3	74.5

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

ryegrass cultivars had significantly higher IVDMD values than tall fescue and all the hybrids. Kenhy tall fescue was intermediate in value among the hybrids. The mean IVDMD value in the second harvest was 55.3% with a range of 48.4 to 62.2% for hybrid 67-149-2 and Linn perennial ryegrass, respectively. As in the first harvest, tall fescue was intermediate in IVDMD value among the hybrids. The mean IVDMD value of 74.5% in the third harvest was higher than in the previous two harvests. Only two cultivars, hybrids 67-154-3 and 67-150-17, were significantly lower in IVD-

Table 3. Concentration of cell wall constituents (CWC) in Linn and KO-14 perennial ryegrasses, Kenhy tall fescue, and 13 Lolium x Festuca hybrids for the 1977 and 1978 harvests.

Cultivar	Year and harvest				
	1977		1978		
	1	2	1	2	3
	%				
Linn	45.5[a*]	50.2[a]	60.5[h]	58.7	54.0[bcde]
KO-14	41.0[bcde]	46.1[def]	59.1[i]	56.1	50.6[e]
Kenhy	44.6[ab]	49.9[ab]	66.4[bc]	59.0	53.6[cde]
67-135-6	44.4[ab]	46.8[bcdef]	65.1[cdef]	59.6	56.8[abcd]
67-136-8	41.5[bcde]	46.5[cdef]	63.3[g]	58.3	56.8[abcd]
67-136-16	43.5[abc]	46.5[cdef]	64.4[efg]	60.8	57.1[abcd]
67-138-10	39.0[e]	44.8[ef]	68.7[a]	60.3	58.0[ab]
67-149-1	45.6[a]	49.5[abc]	67.3[ab]	62.4	57.7[abc]
67-149-2	43.4[abc]	47.5[abcde]	65.8[bcde]	61.2	57.1[abcd]
67-150-10	39.5[de]	44.9[ef]	64.0[fg]	58.3	57.3[abc]
67-150-13	42.6[abcde]	48.1[abcd]	65.9[bcde]	57.9	53.0[de]
67-150-17	40.0[cde]	44.2[f]	64.0[fg]	58.0	58.4[a]
67-150-19	40.1[cde]	44.0[f]	65.1[cdef]	60.5	57.9[ab]
67-154-3	40.4[cde]	48.0[abcd]	65.4[cdef]	57.1	53.6[cde]
67-156-2	42.8[abcd]	46.6[cdef]	66.2[bcd]	58.6	56.1[abcd]
67-157-5	42.1[abcde]	46.3[def]	64.8[def]	58.4	54.6[abcd]
Mean	42.3	46.9	64.8	59.1	55.8

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

MD than KO-14 perennial ryegrass which had the highest IVDMD value (77.5%).

The IVDMD values for the first and second harvests were substantially lower than those obtained for the third harvest. The first harvest, taken on June 16, included flowering heads, and hence mature plant materials. The second harvest, taken on July 30, occurred following an aftermath growth period of 44 days which included the warmest part of the year. The third harvest was taken after a regrowth period of only 27 days. The range of IVD-

Table 4. Concentration of acid-detergent fiber (ADF) in Linn and KO-14 perennial ryegrasses, Kenhy tall fescue, and 13 Lolium x Festuca hybrids for the 1977 and 1978 harvests.

Cultivar	Year and harvest				
	1977		1978		
	1	2	1	2	3
	%				
Linn	29.7[a*]	30.8[a]	36.2[de]	32.2[d]	30.3[abcde]
KO-14	25.0[bcd]	26.8[bcde]	34.9[e]	33.2[d]	29.2[de]
Kenny	26.9[b]	27.9[bc]	39.8[abcd]	33.3[d]	29.5[cde]
67-135-6	25.4[bc]	26.2[bcde]	36.1[de]	34.6[abcd]	32.7[abc]
67-136-8	23.4[d]	26.4[bcde]	41.5[abc]	36.0[abcd]	33.1[ab]
67-136-16	25.0[bcd]	25.9[bcde]	37.6[bcde]	37.5[abc]	30.5[abcde]
67-138-10	23.8[cd]	24.9[de]	41.6[ab]	37.9[ab]	33.5[a]
67-149-1	26.7[b]	28.2[b]	37.7[bcde]	36.4[abcd]	32.3[abcd]
67-149-2	25.6[bc]	26.7[bcde]	37.5[cde]	34.8[abcd]	33.5[a]
67-150-10	24.0[cd]	25.6[cde]	42.3[a]	38.2[a]	32.0[abcd]
67-150-13	25.4[bc]	27.3[bcd]	39.0[abcd]	34.1[cd]	28.3[e]
67-150-17	24.3[cd]	25.4[cde]	39.1[abcd]	35.5[abcd]	29.9[bcde]
67-150-19	24.6[cd]	24.6[e]	42.6[a]	34.2[cd]	33.3[a]
67-154-3	24.6[cd]	26.4[bcde]	40.7[abc]	33.5[d]	29.8[cde]
67-156-2	25.6[bc]	26.0[bcde]	39.9[abcd]	34.4[bcd]	30.7[abcde]
67-157-5	24.6[cd]	25.9[bcde]	40.4[abc]	34.6[abcd]	30.7[abcde]
Mean	25.3	26.6	39.2	35.0	31.2

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

MD observed within harvests was greatest for the first harvest, followed by the second and third. However, if the IVDMD range of only the hybrids is examined, the greatest range was obtained in the second harvest, followed by the third and the first.

Fiber and Lignin

Concentrations of cell wall constituents (CWC), acid-detergent fiber (ADF), and acid-detergent lignin (ADL) determined in the cultivars from the 1977 and 1978 harvests are shown in Tables 3, 4, and 5, respectively.

Table 5. Concentration of acid-detergent lignin (ADL) in Linn and KO-14 perennial ryegrasses, Kenhy tall fescue, and 13 Lolium x Festuca hybrids for the 1977 and 1978 harvests.

	Year and harvest				
	1977		1978		
Cultivar	1	2	1	2	3
	%				
Linn	2.3	3.1^{a*}	4.0^{e}	3.1^{ab}	2.4^{b}
KO-14	2.3	2.8^{ab}	3.3^{f}	2.9^{ab}	2.2^{bcd}
Kenhy	2.1	2.2^{cd}	5.0^{bcd}	2.2^{d}	2.0^{cd}
67-135-6	1.9	2.2^{cd}	4.8^{d}	2.5^{cd}	2.2^{bcd}
67-136-8	2.2	2.3^{cd}	4.9^{cd}	3.1^{ab}	2.4^{b}
67-136-16	2.2	2.2^{cd}	4.8^{d}	3.2^{a}	2.3^{bc}
67-138-10	2.2	2.2^{cd}	4.9^{cd}	2.9^{ab}	2.0^{cd}
67-149-1	2.0	2.5^{bc}	4.9^{cd}	2.8^{bc}	2.0^{cd}
67-149-2	2.2	2.4^{c}	4.9^{cd}	2.3^{d}	2.2^{bcd}
67-150-10	2.1	2.3^{cd}	5.9^{a}	2.8^{bc}	3.0^{a}
67-150-13	1.9	2.1^{cd}	4.8^{d}	3.1^{ab}	2.1^{bcd}
67-150-17	2.1	2.0^{d}	5.4^{abc}	3.2^{a}	2.3^{bc}
67-150-19	2.5	2.2^{cd}	5.6^{a}	3.2^{a}	2.1^{bcd}
67-154-3	2.3	2.4^{c}	5.5^{ab}	2.8^{bc}	3.0^{a}
67-156-2	2.0	2.3^{cd}	4.7^{d}	3.1^{ab}	1.9^{d}
67-157-5	1.8	2.4^{c}	4.8^{d}	3.1^{ab}	2.2^{bcd}
Mean	2.1	2.4	4.9	2.9	2.3

*Means within a column followed by the same letter are not significantly different ($P \angle 0.05$) as determined by Duncan's new multiple range test.

Significant differences existed among CWC levels in both harvests in 1977 (Table 3). There was a tendency for high CWC concentrations to be associated with high yield. Indeed, the linear correlation between yield and CWC for the *Lolium* x *Festuca* hybrids was 0.65 ($P < 0.05$) and 0.72 ($P < 0.01$) for the first and second harvests, respectively.

In 1978, significant differences among CWC concentrations were observed in the first and third harvests. Significant correla-

tions between CWC and yield for the hybrids were not obtained. However, both ryegrass cultivars had CWC concentrations that were consistently low compared to the hybrids. The CWC values in the 1978 samples were substantially higher than those obtained for the 1977 samples, particularly for the first harvest.

Significant differences existed among cultivars for ADF concentrations in both harvests in 1977 (Table 4). In both harvests Linn perennial ryegrass had significantly greater ADF concentrations compared to all other cultivars. As was the case with CWC, linear correlations between yield and ADF concentrations were significant for the hybrids in both first and second harvests, i.e., 0.69 ($P < 0.01$) and 0.84 ($P < 0.01$), respectively.

Concentrations of ADF were greater in the 1978 samples than in those obtained in 1977. Significant differences occurred among cultivars in all three harvests. The ryegrass cultivars tended to have the lowest ADF concentrations with the *Lolium* x *Festuca* hybrids having the greatest concentrations.

Concentrations of ADL were generally low for all cultivars in both harvests in 1977 (Table 5). The mean ADL values for the first and second harvest samples were 2.1 and 2.4%, respectively. Values for ADL in the first harvest in 1978 were approximately twice those of the 1977 samples, a fact undoubtedly related to the maturity of the 1978 samples. Hybrid 67-150-10 had the highest ADL concentration in the first and third harvests in 1978. This hybrid also has consistently high ADF values.

Minerals

Concentrations of calcium, magnesium, phosphorus, and potassium determined for all cultivars in 1977 and 1978 are presented in Tables 6, 7, 8, and 9, respectively.

The calcium concentrations of all the cultivars in all harvests were medium to high. Significant differences among cultivars were observed in all harvests in both years. The calcium concentrations of the ryegrass and Kenhy tall fescue cultivars were consistently below each harvest mean while the calcium concentrations of the hybrids tended to be higher than each harvest mean. Hybrid 67-150-17 had the highest calcium concentration in all harvests.

Magnesium concentrations were also consistently high in all harvests. Soil analysis indicated available soil magnesium to be

Table 6. Concentration of calcium in Linn and KO-14 perennial ryegrasses, Kenhy tall fescue, and 13 Lolium x Festuca hybrids for the 1977 and 1978 harvests.

	Year and harvest				
	1977		1978		
Cultivar	1	2	1	2	3
	%				
Linn	0.48^{cd}	0.40^{d}	0.42^{c}	0.41^{c}	0.42^{c}
KO-14	0.43^{d}	0.45^{bcd}	0.41^{c}	0.41^{c}	0.41^{c}
Kenhy	0.47^{cd}	0.39^{d}	0.41^{c}	0.43^{c}	0.42^{c}
67-135-6	0.46^{cd}	0.44^{bcd}	0.42^{c}	0.42^{c}	0.43^{c}
67-136-8	0.52^{abcd}	0.47^{bcd}	0.45^{c}	0.44^{c}	0.43^{c}
67-136-16	0.51^{bcd}	0.52^{abc}	0.45^{c}	0.46^{bc}	0.45^{bc}
67-138-10	0.49^{bcd}	0.47^{bcd}	0.44^{c}	0.44^{c}	0.43^{c}
67-149-1	0.47^{cd}	0.44^{bcd}	0.43^{c}	0.44^{c}	0.42^{c}
67-149-2	0.56^{abc}	0.53^{ab}	0.47^{bc}	0.46^{bc}	0.47^{b}
67-150-10	0.46^{cd}	0.54^{ab}	0.42^{c}	0.43^{c}	0.46^{b}
67-150-13	0.52^{abcd}	0.48^{bcd}	0.44^{c}	0.43^{c}	0.44^{c}
67-150-17	0.62^{a}	0.62^{a}	0.55^{a}	0.52^{a}	0.53^{a}
67-150-19	0.59^{ab}	0.53^{ab}	0.50^{ab}	0.49^{ab}	0.49^{ab}
67-154-3	0.47^{cd}	0.41^{cd}	0.44^{c}	0.43^{c}	0.44^{c}
67-156-2	0.53^{abc}	0.45^{bcd}	0.46^{bc}	0.45^{bc}	0.42^{c}
67-157-5	0.47^{cd}	0.55^{ab}	0.43^{c}	0.44^{c}	0.43^{c}
Mean	0.50	0.48	0.45	0.44	0.44

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

high. General trends observed for magnesium concentrations were similar to those for calcium; that is, ryegrass and tall fescue cultivars were generally at the lower end of the magnesium range with the hybrids consistently at the upper end. Hybrid 67-150-17 again had the highest magnesium concentration of any cultivar in all five harvests.

Phosphorus concentrations were remarkably consistent over the two-year period. The concentration range was 0.18 - 0.27%. Despite this limited range significant differences were observed

Table 7. Concentration of magnesium in Linn and KO-14 perennial ryegrasses, Kenhy tall fescue, and 13 Lolium x Festuca hybrids for the 1977 and 1978 harvests.

Cultivar	Year and harvest				
	1977		1978		
	1	2	1	2	3
	%				
Linn	0.47^{def*}	0.41^{e}	0.42^{d}	0.44^{bc}	0.43^{c}
KO-14	0.41^{f}	0.42^{de}	0.43^{d}	0.41^{c}	0.41^{c}
Kenhy	0.43^{ef}	0.43^{cde}	0.44^{cd}	0.45^{bc}	0.44^{bc}
67-135-6	0.50^{cdef}	0.54^{abcd}	0.44^{cd}	0.44^{bc}	0.44^{bc}
67-136-8	0.53^{bcde}	0.54^{abcd}	0.46^{bcd}	0.43^{c}	0.43^{c}
67-136-16	0.53^{bcde}	0.56^{ab}	0.47^{bc}	0.48^{ab}	0.46^{bc}
67-138-10	0.51^{bcdef}	0.51^{bcde}	0.45^{cd}	0.42^{c}	0.47^{bc}
67-149-1	0.50^{cdef}	0.52^{bcde}	0.46^{bcd}	0.45^{bc}	0.42^{c}
67-149-2	0.60^{abc}	0.65^{a}	0.44^{cd}	0.45^{bc}	0.49^{abc}
67-150-10	0.60^{abc}	0.58^{ab}	0.43^{d}	0.46^{bc}	0.48^{bc}
67-150-13	0.59^{abc}	0.55^{abc}	0.52^{ab}	0.44^{bc}	0.47^{bc}
67-150-17	0.67^{a}	0.66^{a}	0.58^{a}	0.57^{a}	0.57^{a}
67-150-19	0.56^{abcd}	0.56^{ab}	0.51^{ab}	0.50^{ab}	0.50^{ab}
67-154-3	0.62^{ab}	0.55^{abc}	0.48^{bc}	0.43^{c}	0.46^{bc}
67-156-2	0.62^{abc}	0.54^{abcd}	0.49^{bc}	0.42^{c}	0.44^{bc}
67-157-5	0.56^{abcd}	0.57^{ab}	0.46^{bcd}	0.42^{c}	0.46^{bc}
Mean	0.54	0.54	0.47	0.45	0.46

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

among cultivars in all five harvests. Three cultivars: Linn perennial ryegrass and hybrids 67-149-2 and 67-150-17 were in the upper range of phosphorus concentrations in all five harvests, and in each harvest were not significantly different from each other.

Potassium concentrations were consistently high, approaching or exceeding 3% in all harvests. Analysis of variance indicated no significant differences among cultivars in any harvest.

In order to facilitate an examination for trends among the cultivars, some of the cultivars exhibiting extreme values are listed

Table 8. Concentration of phosphorus in Linn and KO-14 perennial ryegrasses, Kenhy tall fescue, and 13 Lolium x Festuca hybrids for the 1977 and 1978 harvests.

	Year and harvest				
	1977		1978		
Cultivar	1	2	1	2	3
	%				
Linn	0.27^{a*}	0.27^{a}	0.26^{a}	0.24^{ab}	0.23^{abc}
KO-14	0.25^{abc}	0.23^{bcd}	0.24^{abc}	0.22^{bc}	0.22^{bc}
Kenhy	0.21^{d}	0.21^{d}	0.21^{c}	0.18^{d}	0.24^{ab}
67-135-6	0.25^{abc}	0.24^{bc}	0.24^{abc}	0.24^{ab}	0.25^{ab}
67-136-8	0.25^{abc}	0.25^{ab}	0.25^{ab}	0.22^{bc}	0.24^{ab}
67-136-16	0.26^{ab}	0.24^{bc}	0.25^{ab}	0.25^{a}	0.26^{a}
67-138-10	0.23^{bcd}	0.22^{cd}	0.23^{bc}	0.22^{bc}	0.26^{a}
67-149-1	0.22^{cd}	0.22^{cd}	0.23^{bc}	0.22^{bc}	0.22^{bc}
67-149-2	0.24^{abcd}	0.25^{ab}	0.24^{abc}	0.24^{ab}	0.23^{abc}
67-150-10	0.23^{bcd}	0.24^{bc}	0.22^{bc}	0.21^{cd}	0.24^{ab}
67-150-13	0.22^{cd}	0.23^{bcd}	0.23^{bc}	0.21^{cd}	0.22^{bc}
67-150-17	0.25^{abc}	0.25^{ab}	0.24^{abc}	0.24^{ab}	0.23^{abc}
67-150-19	0.25^{abc}	0.25^{ab}	0.25^{ab}	0.22^{bc}	0.20^{c}
67-154-3	0.24^{abcd}	0.24^{bc}	0.24^{abc}	0.24^{ab}	0.21^{c}
67-156-2	0.24^{abcd}	0.24^{bc}	0.24^{abc}	0.23^{abc}	0.22^{bc}
67-157-5	0.25^{abc}	0.24^{bc}	0.24^{abc}	0.23^{abc}	0.20^{c}
Mean	0.24	0.24	0.24	0.23	0.23

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

in Table 10. In 1977 the greatest total dry matter yield was obtained from Linn perennial ryegrass while in 1978 the greatest total yield was obtained from Kenhy tall fescue. In terms of total dry matter production over the six harvests, the greatest yield was obtained from Kenhy tall fescue, although hybrid 67-149-2 produced yields that were not significantly different from Kenhy in both 1978 and 1979. Further, the IVDMD values for Kenhy and 67-149-2 over the 1977 and 1978 harvests did not differ significantly. In 1978 the yield of estimated digestible dry matter produced by

Table 9. Concentration of potassium in Linn and KO-14 perennial ryegrasses, Kenny tall fescue, and 13 Lolium x Festuca hybrids for the 1977 and 1978 harvests.

	Year and harvest				
	1977		1978		
Cultivar	1	2	1	2	3
	%				
Linn	3.07	3.01	2.92	3.02	2.98
KO-14	3.09	3.34	2.91	3.08	2.94
Kenhy	3.03	2.84	2.89	2.96	2.80
67-135-6	3.28	3.30	3.09	3.01	3.03
67-136-8	3.20	2.55	3.10	3.04	3.13
67-136-16	3.56	2.80	3.16	3.17	3.10
67-138-10	3.33	3.03	2.92	2.98	2.86
67-149-1	3.06	3.48	3.01	3.04	2.97
67-149-2	3.02	2.95	2.86	2.87	2.91
67-150-10	3.23	3.09	3.11	3.14	3.03
67-150-13	2.67	2.75	2.48	2.96	2.93
67-150-17	2.89	3.28	2.54	2.93	2.91
67-150-19	3.16	3.36	3.01	3.09	2.97
67-154-3	3.46	2.97	3.26	3.28	2.96
67-156-2	3.19	2.76	2.93	3.07	3.01
67-157-5	3.14	3.11	2.82	3.03	2.87
Mean	3.15	3.04	2.94	3.04	2.96

Kenhy was 3029 g/row while that produced from 67-149-2 was 2815 g/row, a nonsignificant difference. Clearly, however, none of the hybrids proved superior to Kenhy tall fescue in dry matter production.

In the seeding year IVDMD values for all cultivars were approximately 70 to 80% and no significant differences among cultivars were detected. In the second harvest year none of the hybrids were superior to either of the ryegrass cultivars insofar as IVDMD was concerned. Indeed, in the first harvest of the 1978

Table 10. Cultivars exhibiting extreme values for yield, IVDMD, CWC, calcium, magnesium, and phosphorus over the 1977-1978 period.

Parameter and extreme	Year and harvest					
	1977		1978			1979
	1	2	1	2	3	1
Yield - highest values	Linn Kenhy 67-149-1	Kenhy Linn 67-149-1	Kenhy 67-150-13 67-149-2	67-149-2 Kenhy 67-150-19	67-150-10 Kenhy 67-149-2 67-150-19	Kenhy 67-149-2 67-150-13
IVDMD - highest values	67-157-5 67-150-10 67-138-10	67-135-6 KO-14 67-136-16	KO-14 Linn 67-149-1	Linn 67-135-6 67-150-19	KO-14 67-136-8 67-150-13	
CWC - lowest values	67-138-10 67-150-10 67-150-17	67-150-19 67-150-17 67-138-10	KO-14 Linn 67-136-8	KO-14 67-154-3 67-150-13	KO-14 67-150-13 67-154-3 Kenny	
Calcium - highest values	67-150-17 67-150-19 67-149-2	67-150-17 67-157-5 67-150-10	67-150-17 67-150-19 67-149-2	67-150-17 67-150-19 67-149-2 67-136-16	67-150-17 67-150-19 67-149-2	
Magnesium - highest values	67-150-17 67-154-3 67-156-2	67-150-17 67-149-2 67-150-10	67-150-17 67-150-13 67-150-19	67-150-17 67-150-19 67-136-16	67-150-17 67-150-19 67-149-2	
Phosphorus - highest values	Linn 67-136-16	Linn 67-136-8 67-149-2 67-150-17 67-150-19	Linn 67-136-8 67-136-16 67-150-19	67-136-16 Linn 67-135-6 67-149-2 67-150-17 67-154-3	67-136-16 67-138-10 67-135-6	

year the IVDMD values of both ryegrass cultivars were significantly greater than all other cultivars in the trial. A number of the cultivars with the highest IVDMD values were also those with the lowest CWC values (Table 10).

Lolium x *Festuca* hybrid 67-150-17 had the highest concentration of calcium and magnesium in all five harvests. This same hybrid was also consistently high in phosphorus concentration. Hybrid 67-150-19 also had consistently high calcium, magnesium, and phosphorus concentrations.

SUMMARY

Kenhy tall fescue, Linn and KO-14 perennial ryegrasses, and 13 *Lolium* x *Festuca* hybrids were seeded in 7.6 m long rows in May, 1977 and grown under field conditions during the 1977-1979 period. The experimental design was a randomized complete block with three replications. Yield data were obtained from the center 6.1 m of each row. Laboratory analyses included IVDMD, CWC, ADF, ADL, and mineral concentrations.

The yield capacity of the *Lolium* x *Festuca* hybrids was less than that of Kenhy tall fescue. The difference in yield diminished in the postestablishment years. The two perennial ryegrass cultivars experienced severe winterkill and were the lowest yielding cultivars in 1978 and 1979.

No definite trends existed in the IVDMD values of the *Lolium* x *Festuca* hybrids as compared to the perennial ryegrass cultivars or Kenhy tall fescue. None of the hybrids proved to be superior to the ryegrass cultivars.

The CWC and ADF values for Linn perennial ryegrass and Kenhy tall fescue were generally higher than those of the hybrids in the seeding year. In the second harvest year these values for Linn and KO-14 perennial ryegrasses and Kenhy tall fescue were low to medium as compared to the hybrids. Mean CWC and ADF values declined over harvest dates in 1978.

The ADL values in the seeding year and in the second and third harvests of the second year remained relatively constant at 2.1 to 2.9%. In the first harvest of the second year the mean ADL value was 4.9%. In this harvest the two perennial ryegrass cultivars were in the lower range of values. Kenhy tall fescue was low to intermediate in value among the hybrids.

The concentration of both calcium and magnesium in all cultivars was high. In both harvest years the concentrations of these elements in the perennial ryegrasses and tall fescue were in the lower range of values. Hybrid 67-150-17 had the highest concentration of both calcium and magnesium in all harvests in both years. The phosphorus concentration of all cultivars was in the range that is considered normal. The variation in phosphorus con-

centration among cultivars was minimal, though Linn perennial ryegrass and hybrids 67-150-17 and 67-149-2 were consistently in the upper range of values. Potassium concentrations of all cultivars were in the range of 2.5 - 3.5%. No significant differences among cultivars were detected in any harvest.

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