Changes in continuous timothy production with time in a long-term dykeland experiment

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[1]*Agriculture Canada, Experimental Farm, Nappan, Nova Scotia, Canada B0L 1C0;* [2]*Acadia University, Biology Department, Wolfville, Nova Scotia, Canada B0P 1X0; and* [3]*Agriculture Canada, Research Station, P.O. Box 1210, Charlottetown, Prince Edward Island, Canada C1A 7M8.* *Received 20 Sept. 1990, accepted 21 Mar. 1991.*

Papadopoulos, Y. A., Reekie, E. G., Hunter, K. and Gupta, U. C. 1991. **Changes in continuous timothy production with time in a long-term dykeland experiment.** Can. J. Plant Sci. **71**: 761–769. The effects of 64 yr of various fertility strategies upon forage DM yield, botanical composition, and persistence of timothy (*Phleum pratense* L.) were evaluated on dykeland fields (Acadia soil) under a continuous (without plowing) hay production system. Fertility treatments during the first 41 yr of this study were: (1) no fertilizer, (2) 18 t manure ha^{-1} every 4 yr, and (3) 36 kg ha^{-1} of N and 11 kg ha^{-1} of P applied annually. The experiment was modified in the 42nd year by increasing the rate of nutrient application to 45 t manure ha^{-1} every 2 yr, and 153 kg ha^{-1} of N plus 25 kg ha^{-1} of P applied annually with one of four levels of K (0, 56, 169 and 282 kg ha^{-1}). The application of manure and commercial mineral fertilizer substantially increased yield over no fertilizer. Evidence of beneficial long-term effects was observed in the manure fertility treatment, while there appears to have been a gradual yield decline associated with commercial mineral fertilizers. Soil and foliar analyses suggest that the depletion of other nutrients not applied in this study and the decreased nutrient availability induced by lowering pH could be responsible for the observed yield decline. The application of potassium did not affect DM yield or the long-term persistence of timothy in this study. The application of manure and mineral fertilizers enhanced the long-term persistence of timothy.

Key words: Dykeland, manure, N, P, K, fertilization, yield, persistence, timothy

Papadopoulos, Y. A., Reekie, E. G., Hunter, K. et Gupta, U. C. 1991. **Évolution de la culture continue de phléole dans une expérience à long terme sur des polders.** Can. J. Plant Sci. **71**: 761–769. Les effets de diverses stratégies de fumure sur le rendement de MS du fourrage, la composition botanique et la persistance de la phléole (*Phleum pratense* L.) ont été évalués au bout de 64 ans dans des polders (sol Acadia) en régime du culture continue de foin (sans labour). Les traitements fertilisants au cours des 41 premières années de l'étude étaient les suivants: (1) aucune fumure, (2) 18 tonnes de fumier à l'hectare tous les quatre ans et (3) 36 kg de N ha^{-1} et 11 kg de P ha^{-1} appliqués chaque année. L'expérience a été modifiée au cours de la 42^{e} année en augmentant l'apport de substances fertilisantes à 45 tonnes de fumier à l'hectare tous les deux ans et en portant à 153 kg ha^{-1} et à 25 kg ha^{-1} les doses de N et de P appliquées chaque année, en plus de l'une des quatre concentrations suivantes de K (0, 56, 169 et 282 kg ha^{-1}). L'épandage de fumier et d'engrais minéraux du commerce augmentent substantiellement le rendement par rapport à l'absence d'engrais. Le traitement au fumier donne des effets bénéfiques à long terme, alors que les engrais minéraux du commerce semblent entraîner une baisse graduelle de rendement. Les analyses du sol et des feuilles donnent à penser que l'épuisement d'autres éléments nutritifs non appliqués dans le cadre de cette étude et que la disponibilité décroissante des substances nutritives provoquée par l'abaissement du pH pourraient être responsables de la baisse de rendement observée. L'application de K n'influe pas sur le rendement de MS ni sur le persistance à long terme de la phléole. Par contre, l'apport de fumier et d'engrais minéraux augmentent la persistance à long terme de la phléole.

Mots clés: Polders, fumier, N, P, K, fumure, rendement, persistance, phléole

Can. J. Plant Sci. 71: 761–769 (July 1991)

In the Maritime Provinces, "dykeland" is a term which refers to salt marshes that were drained at the beginning of the 17th century by early settlers and continue to be drained in modern times. There are 35 000 ha of dykeland soils in Nova Scotia and New Brunswick. These soils are deep, fertile, and can sustain good crop yields (Anonymous 1987). However, cultivating this type of soil is known to be a delicate procedure. Unfavorable weather conditions such as a rainstorm immediately following primary plowing can result in the soil forming hard clumps and a total failure of crop establishment. This has led farmers to rely on dykeland to produce hay crops continuously, without plowing for prolonged periods of time.

Fertility management of dykeland soils under a continuous hay production system depends primarily on surface application of fertilizer without incorporation. Information on responses to such fertility management on dykeland soils is lacking. In New Brunswick, Bélanger et al. (1989) reported the long-term effects of commercial N, P and K fertilizer applications on an acidic riverbank soil which was cropped continuously to timothy. In their study, an annual application of 160 kg N ha^{-1}, 44 kg P ha^{-1}, and 110 kg K ha^{-1} fertilizer maintained up to 8 t dry matter (DM) ha^{-1} yield (95% timothy) for 26 yr following stand establishment. Timothy persistance in their study was dependent only on the availability of K.

Long-term studies investigating various fertilizer practices indicated that unless high levels of fertilizer were applied annually, more P and K were removed than was added, and the inclusion of manure in conjunction with commercial fertilizer increased nutrient availability and produced superior yields (Royer et al. 1948; Brage et al. 1952; Cordukes et al. 1955). The above fertility studies considered only the effect of macronutrients on forage production. Micronutrients such as B, Mo, Zn, Mn, Cu, and Fe are generally lacking in the Atlantic region (Gupta 1979a; Gupta and Lipsett 1981; Gupta and Watkinson 1985). Specific studies on residual effects of micronutrients on plant growth, herbage yield and livestock production have been reviewed extensively (Gupta 1979a, b; Gupta and Lipsett 1981; Gupta and Cutcliffe 1982; Gupta and Watkinson 1985) but studies on long-term depletion of micronutrients have been few (Gupta et al. 1971; MacLeod et al. 1960).

A field experiment was initiated in 1925 at the Experimental Farm, Nappan, Nova Scotia, to examine the effect of surface applied manure or fertilizer N and P on forage yield from dykeland (Acadia) soils under a continuous (without plowing) hay production system. Results of other experiments at the Nappan Experimental Farm indicated that exchangeable K in dykeland soils decreased in response to surface application of P (Bishop et al. 1969). The experiment was modified in 1966 to reflect new N and P fertilizer recommendations in the region and assess the effect of various rates of K fertilization on herbage dry matter yield. No summary of yields of the test plots has been published since the initiation of the study.

The objective of this paper was to examine the effects of the above long-term fertility treatments (manure, N, P, and K fertilization) on forage yield and changes in species composition; however, this paper is not meant to report the accumulated evidence of the different requirements of plant nutrients for a permanent hay production system. Instead, it presents an attempt to assess and analyse the changes in yields and timothy persistence during the 65-yr experiment. Since no other long-term fertility study on dykelands has been recorded in this region, the results may be useful in formulating crop recommendations for continuous hay production on this unique soil type.

MATERIALS AND METHODS

A pure stand of timothy was established in 1925 on an Acadia silty clay loam. The experiment consisted of six 0.24-ha plots separated from each other by drainage ditches. Plots 1 and 4 received no application of fertilizer (NF), plots 2 and 5 received 18 t barnyard manure (MN) ha^{-1} every 4 yr, and plots 3 and 6 received commercial mineral fertilizer (225 kg $NaNO_3$ ha^{-1} and 130 kg 0-20-0 ha^{-1}) applied annually (F). Manure and fertilizer treatments were surface broadcast following first harvest.

The application of the above fertility treatments continued until the end of the 1965 growing season. Changes in sward composition were visually assessed in 1965 and it was concluded that timothy remained the dominant species in every plot of this study (L. P. Jackson 1990, personal communication). The experiment was modified in 1966 to increase the rate of nutrients applied and to include four levels of K application as outlined in Table 1. Herbage yield from 1929 to 1961 and from 1966 to 1989 was recorded by harvesting and weighing each plot at full bloom for the first cut and at the end of August for each year's regrowth (second cut). Height of cut was 6 cm above ground. The DM content was determined from duplicate 500-g chopped samples of each wagon load by measuring weight loss after drying at 80°C for 48 h. To estimate the range of variation in botanical composition during the 1988 growing season, each plot was subdivided into 10 equal subplots. Approximately 1 kg aboveground material clipped at 6 cm above soil surface was obtained from each of the five subplots chosen at random. The cut samples were placed in labeled plastic bags in a cold room at 4°C until separation by hand into species categories. A voucher specimen of each plant species was press-dried and mounted on herbarium paper to confirm the nomenclature of each species as outlined by Roland and Smith (1969). Materials from each species were dried at 80°C for 48 h to estimate the proportion of each species in the harvested sward.

Following the second harvest in 1988, five composite soil samples (15 borings/composite representing the top 30 cm) were taken at random from the area where forage yield was obtained. Soil pH was determined from a 1:1 soil to water ratio and percent organic matter (OM) content was determined by loss on ignition as outlined in the handbook of the Council on Soil Testing and Plant Analysis (1980). Soil phosphorous (P_2O_5), potassium (K_2O), calcium (Ca^{+2}), and magnesium (Mg^{+2}) were extracted with Mehlich I and determined by inductively coupled plasma (ICP) as outlined by the Association of Official Analytical Chemists (1990).

The source of manure applied throughout this study was obtained from straw-bedded beef animals raised at the Nappan Experimental Farm. As manure analysis prior to 1988 was not completed, the analysis of manure applied in 1988 was included to act as predictive of manure constituents applied over the years of this study. Composite samples of manure applied to the MN plot in 1988 were analyzed for Ca, P, Mg, K, Fe, Mn, Cu and Zn by dry ashing method and ICP detection as outlined by the Council on Soil Testing and Plant Analysis Handbook (1980), and The Association of Official Analytical Chemists (1990), and for N by automated combustion method using LECO FP-228 Nitrogen Analyzer as outlined by Sweeney (1989).

Five representative plant tissue samples were obtained from each plot at each harvest during the 1989 growing season, dried at 70°C for 3 d and ground to pass through a 1-mm sieve. The ground plant tissue samples were dry ashed and the extracts were used to estimate P, K, Ca, Mg, B, Zn, Mn and Fe as described by Isaac and Kerber (1971) and S as described by Wall et al. (1980).

Differences among plots in yield were analyzed by ANOVA using individual years as replications. In cases where there was a significant treatment effect, individual means were compared by means of multiple *t*-tests. Linear regression analysis was used to examine the effect of fertility treatment upon herbage yield over time. To determine if responses were indeed linear, a quadratic term was initially included in the regression model. In no case was the quadratic term significant.

RESULTS AND DISCUSSION

Average DM yields during the first 4-yr following planting were 4541 kg ha^{-1} for NF

Table 1. Fertilizer treatment applied on timothy stand during the years 1966–1989

Plot	Treatment identification	Fertility treatment
1	NF	Check — no fertilizer
2	MN	45 t barnyard manure ha^{-1} (fresh weight) every 2 yr
3	K0	153 kg ha^{-1} N and 25 kg ha^{-1} P applied annually
4[z]	K1	153 kg ha^{-1} N, 25 kg ha^{-1} P and 56 kg ha^{-1} K applied annually
5[z]	K3	153 kg ha^{-1} N, 25 kg ha^{-1} P and 169 kg ha^{-1} applied annually
6	K5	153 kg ha^{-1} N, 25 kg ha^{-1} P and 282 kg ha^{-1} K applied annually

[z] Note that plot 4 received no fertilizer and plot 5 received manure prior to 1966, and as a result of the modification in 1966, these plots are now receiving commercial mineral fertilizer.

plots, 5736 kg ha^{-1} for MN plots and 6552 kg ha^{-1} for F plots. Records of individual year data were not available during this period. Despite substantial environmental effects (year-to-year variation), there were observable forage DM yield differences from the years 1929–1961 and 1966–1989 among the various treatments (Figs. 1 and 2). As expected, the lowest yields (in all years) were obtained from the NF treatment. The application of 45 t ha^{-1} of manure every 2 yr resulted in a significant increase in yield compared to the NF treatment. However, the highest yields were obtained from the commercial mineral fertilizer treatments. With the application of N and P, the yields were close to double the yield of plots receiving manure treatments. The addition of various levels of K in the K1, K3 and K5 treatments did not increase forage yield (Table 2). Similar responses to surface applications of commercial mineral fertilizer were reported in another long-term study on Queens soil (MacLeod et al. 1960).

Linear regression with yield as the dependent variable and year as the independent variable indicated that in the absence of applied nutrition, there was no consistent change in yield over time; $P<0.70$ for the period 1929–1961 and $P<0.37$ for the period 1966–1989 (Figs. 1 and 2). The high CV of the NF plot (22 for the period 1929–1961 and 35.1 for the period 1966–1989) was the result of random, environmentally induced, year-to-year fluctuation in yield. There was no consistent change in yield over time in the MN treatment (18 t ha^{-1} every 4 yr) between 1929 and 1961 ($P<0.16$). A lower CV (17.8) was observed in the MN treatment during these years. However, the yield of the MN plots (45 t ha^{-1} every 2 yr) between 1966 and 1989 increased over time (slope = 77.4 kg ha^{-1} yr^{-1}, $P<0.01$). This treatment had the lowest random year-to-year fluctuation in yield (CV = 9.6). The lack of yield response over time between 1929 and 1961 is likely due to the low rate of manure application.

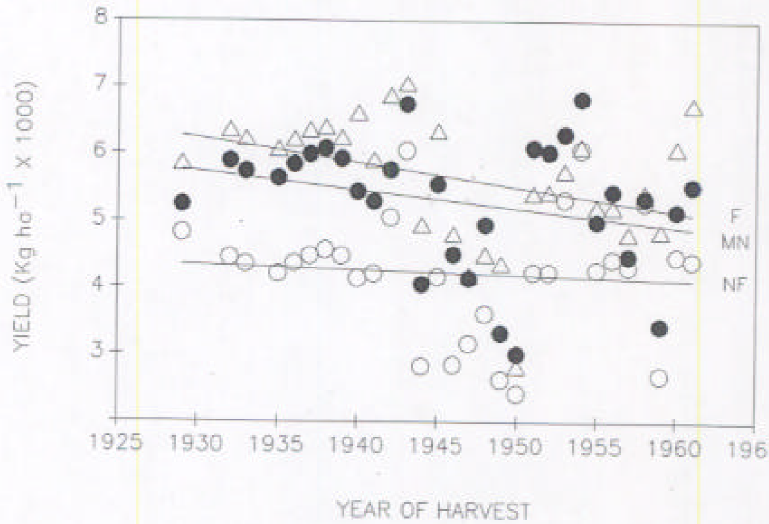

Fig. 1. Long-term forage DM yield from plots receiving no fertilizer (NF), manure (MN) and commercial mineral fertilizer (F). Lines were fitted by least squares regression. The equations for the lines and level of significance were as follows: NF yield = 18382 − 7.3 × year ($P<0.70$); MN yield = 58908 − 27.5 × year ($P<0.16$); and F yield = 76470 − 36.4 × year ($P<0.06$). Legend: NF (○), MN (●), F (△).

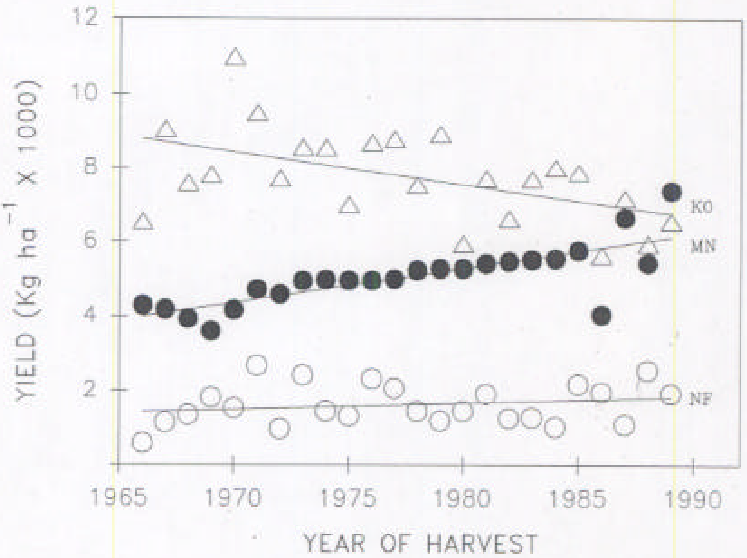

Fig. 2. Long-term forage DM yield from plots receiving various fertility treatments. See Table 1 for key to treatment designations. Yields K1 to K5 were similar to K0 and are not presented for the sake of clarity. Lines were fitted by least squares regression. The equations for the lines and level of significance were as follows: NF yield = −30398 + 16.2 year ($P<0.37$), MN yield = −148114 + 77.4 year ($P<0.01$); K0 yield = 180014 − 87.1 year ($P<0.02$). Legend: NF (○), MN (●), K0 (△).

Table 2. Soil nutrient status in 1989 (prior to fertility treatment application) and mean yield of plots receiving various fertility treatments applied on timothy stand during the years 1966 to 1989

Variable	Treatment[z]					
	NF	MN	K0	K1	K3	K5
Organic matter (%)	4.6±0.5[y]	7.3±1.1	5.6±1.4	5.6±0.6	5.9±1.1	6.4±0.8
pH	5.5±0.1	5.3±0.1	5.4±0.2	5.0±0.1	5.0±0.1	4.8±0.1
P_2O_5 (kg ha^{-1})	345±39	339±48	414±64	322±34	343±26	459±29
K_2O (kg ha^{-1})	128±25	163±14	114±23	149±26	200±48	475±53
Ca (kg ha^{-1})	1128±44	1705±186	1804±171	1223±117	1254±99	1470±106
Mg (kg ha^{-1})	605±58	601±36	552±43	469±71	443±17	380±54
Yield (kg ha^{-1})	1613±235	4955±292	7834±523	6081±424	6956±439	7040±488

[z] See Table 1 for key to treatment designations.
[y] Error values are twice the standard error and represent within-plot variation in the case of the nutrient parameters and among-year variation for yield.

The commercial mineral-fertilized plots also had low CVs (15.8, 14.5, 16.8, 13.8 and 15.4 for F, K0, K1, K3 and K5, respectively). However, yields decreased over time (F slope = −36.4 kg ha^{-1} yr^{-1}, $P<0.06$; K0 slope = −87.1 kg ha^{-1} yr^{-1}, $P<0.02$; K3 slope = −71.5 kg ha^{-1} yr^{-1}, $P<0.03$; K5 slope = −74.3 kg ha^{-1} yr^{-1}, $P<0.04$). The only exception to the pattern was K1 where there was no significant relationship between DM yield and time $P<0.39$).

A likely explanation for the long-term decrease in yield on commercial mineral-fertilized plots is the depletion of nutrients not applied in the fertilizers and the decreased nutrient availability induced by lowering pH.

Nutrient analyses of foliage harvested from these plots (Table 3) and soil analysis data (Table 2) support this suggestion. Continued surface application of manure and commercial fertilizers appear to produce significant soil acidity. Soil pH was highest in the NF plot. It decreased slightly in the MN and K0 plots but declined sharply in the K1, K3 and K5 plots (Table 2). Although effects of pH on plant nutrient levels in soils are complex, numerous studies were able to demonstrate that decreased nutrient availability and/or leaching can be induced by lowering the pH (Marschner et al. 1966; Bishop et al. 1969; Gupta et al. 1971; Chaiwanakupt and Robertson 1976). Regardless of time of harvest, levels of Mn and Fe in foliage were higher in the NF plot than in any of the other plots and levels of B and Zn were higher in the MN and NF than in the commercial mineral-fertilized plots. Depending upon the time of harvest, there was a tendency for levels of Ca, Mg, S and Cu to be higher in the MN and NF than in the mineral-fertilized plots.

Soil analysis indicates that the Mg level showed a decrease in most of the commercial mineral-fertilized plots (Table 2). The decrease in Mg levels was more severe in plots receiving K fertilization. The Mg concentration was also lower in forage harvested from these plots as compared with plots not receiving K commercial mineral-fertilizer (Table 3). It is unlikely such trends were induced by increased acidity, as MacLeod (1958) clearly demonstrated that the pH of dykeland soils receiving calcitic limestone increased from 5.0 to 6.5, while the Mg levels in the soil remained unchanged. It appears that the application of commercial mineral fertilizer had a positive effect upon yield but it also increased the removal of nutrients from the soil. Similar observations were reported by Langille and MacLean (1963) and MacKay et al. (1964). Gupta et al. (1971) showed that despite the increased removal of microutrients when high rates of mineral fertilizer were applied to forage fields, the micronutrient content of the forage tissue and soil were not

Table 3. Nutrient content (± 2 standard errors) of foliage harvested in 1989 at full bloom (first cut) or at the end of August (second cut) for plots receiving various fertility treatments

Nutrient	Treatment[z]					
	NF	MN	K0	K1	K3	K5
First cut						
P (%)	0.188±0.021	0.286±0.013	0.266±0.012	0.238±0.018	0.242±0.007	0.282±0.019
K (%)	1.76±0.18	2.27±0.15	1.51±0.06	1.97±0.08	2.66±0.12	3.10±0.35
Ca (%)	0.272±0.012	0.246±0.032	0.216±0.014	0.142±0.016	0.110±0.006	0.158±0.017
Mg (%)	0.190±0.016	0.190±0.018	0.188±0.008	0.140±0.014	0.092±0.008	0.136±0.008
S (%)	0.114±0.018	0.098±0.013	0.110±0.008	0.097±0.008	0.080±0.010	0.87±0.021
B (mg kg^{-1})	6.56±0.79	5.28±0.32	3.98±0.74	2.74±0.18	2.90±0.16	3.20±0.15
Cu (mg kg^{-1})	6.07±0.22	6.63±0.63	7.03±0.27	5.43±0.27	4.90±0.20	5.90±0.38
Zn (mg kg^{-1})	28.9±1.3	35.3±3.1	25.4±1.4	24.6±1.3	20.9±1.6	23.3±2.1
Mn (mg kg^{-1})	160±45	96±8	112±8	112±7	98±13	55±5
Fe (mg kg^{-1})	98.9±39.5	41.7±1.1	38.9±2.6	41.2±7.3	31.8±2.0	31.6±1.3
Second cut						
P (%)	0.192±0.021	0.298±0.012	0.194±0.015	0.168±0.007	0.162±0.018	0.168±0.007
K (%)	1.38±0.12	1.92±0.16	1.05±0.08	1.16±0.14	1.25±0.15	1.43±0.07
Ca (%)	0.402±0.056	0.576±0.091	0.332±0.062	0.230±0.017	0.236±0.050	0.186±0.008
Mg (%)	0.268±0.015	0.316±0.032	0.238±0.023	0.188±0.007	0.170±0.025	0.122±0.010
S (%)	0.165±0.015	0.149±0.015	0.110±0.008	0.092±0.006	0.099±0.012	0.090±0.010
B (mg kg^{-1})	12.92±1.32	13.48±1.62	9.89±2.38	8.01±0.43	9.76±1.97	5.77±0.63
Cu (mg kg^{-1})	4.00±0.49	5.94±0.63	3.82±0.40	3.40±0.37	—	—
Zn (mg kg^{-1})	23.5±2.3	39.7±3.7	16.8±2.9	18.0±1.5	19.6±2.5	19.3±1.2
Mn (mg kg^{-1})	444±43	190±26	162±40	212±58	200±81	143±16
Fe (mg kg^{-1})	203.1±67.8	89.6±11.4	63.4±23.1	53.2±3.7	56.6±4.5	51.0±3.1

[z]See Table 1 for key to treatment designations.

depleted in the short term (10 yrs). However, their data suggested that the continued removal of many micronutrients may lead to the appearance of deficiency symptoms in the long term. MacLeod et al. (1960) clearly demonstrated increased DM yields of permanent hayland when applied mineral fertilizers contained an essential secondary nutrient such as sulfur. Small but significant DM yield improvement was obtained in their study from plots which received nitrogen fertilizer in the form of ammonium sulphate rather than sodium nitrate or ammonium nitrate.

The long-term increase in yield on the MN treatment is probably due to two factors. First, the manure applications provide a wider range of nutrients (Table 4), decreasing the likelihood of nutrient depletion. Second, manure applications increased soil organic matter content. Soil organic matter level in the MN plot was significantly higher than NF, K0, and K1 plots, and arithmetically higher (but not statistically significant) than K3 and K5 plots (Table 2). This is likely to have beneficial effects on soil structure and nutrient holding capacity.

Data presented in Table 5 show the significant role which surface-applied manure or commercial fertilizer plays in long-term persistance of timothy. This is evident in the increased percentage of timothy from 17% in the NF plot to 39% or greater in the fertilized plots. There were no consistent differences in percentages of timothy between the MN plot and the mineral-fertilizer plots. The application of potassium in this study did not significantly affect the long-term persistence of timothy. This response was not consistent with the results reported by others. Bélanger et al. (1989) clearly demonstrated that surface-applied potassium fertilizer played a significant role in the long-term persistence of timothy. This discrepancy could be due to the fact that potassium treatments were not included during the first 40 yr following establishment of the stand.

In conclusion, the surface application of manure and commercial fertilizer in this experiment resulted in a substantial increase in timothy yield and persistence over the unfertilized control. Timothy yields increased with the initial application of manure and continued to increase progressively with subsequent applications over time. The application of mineral nitrogen, phosphorous and

Table 4. Nutrient content of manure applied to the MN plot in 1988

Nutrient	Nutrient content[z]	Rate of application (kg ha^{-1})
Dry matter (%)	17.6	
Ca (%)	2.23	177
P (%)	0.96	76
Mg (%)	0.50	40
K (%)	0.36	29
N (%)	2.19	174
Fe (mg kg^{-1})	674	53
Mn (mg kg^{-1})	217	17
Cu (mg kg^{-1})	16	1
Zn (mg kg^{-1})	91	7

[z]Reported nutrient analyses are based on dry matter content.

Table 5. Percent species composition (dry matter basis) of plots subjected to various fertility treatments

Species	Treatment[z]					
	NF	MN	K0	K1	K3	K5
Timothy	17.3*c*[y]	39.4*bc*	45.6*ab*	57.1*ab*	64.9*a*	45.5*ab*
Couch grass (*Elytrigia repens* L.)	21.0*a*	22.6*a*	30.0*a*	28.1*a*	22.2*a*	33.1*a*
Bent grass (Agrostis tenius L.)	36.1*a*	11.6*a*	7.3*b*	2.8*b*	4.4*b*	6.9*b*
Other grasses	13.0*a*	13.3*a*	4.2*a*	2.0*a*	0.9*a*	4.6*a*
Herbs	12.6*a*	12.9*a*	12.8*a*	10.0*a*	7.7*a*	9.8*a*

[z]See Table 1 for key to treatment designations.
[y]For a given species, means followed by the same letter were not significantly different from each other at the 0.05 level.

potassium resulted in a substantial yield increase, but the magnitude of this beneficial effect decreased over time. The decrease in the effectiveness of commercial mineral fertilizer applications is probably due to the depletion of other nutrients and the decreased nutrient availability induced by lowering pH.

Based on the findings of this work and other long-term fertility management studies (Bishop et al. 1969; Gupta et al. 1971; Bélanger et al. 1989), high timothy yield under a continuous hay production system on the dykeland of Atlantic Canada can be profitably sustained by adhering to the following fertility management regime: (1) fields should be top-dressed with 45 t ha^{-1} of barnyard manure immediately following the first cut once every 2 yr; (2) barnyard manure should be supplemented with approximately 2 t ha^{-1} of dolomitic limestone; (3) fields should be top-dressed early in the spring with an annual application of commercial fertilizer to elevate the levels of annual available nutrients to 160-44-110 kg ha^{-1} of N, P, and K, respectively.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the input of S. A. Hilton (1925–1947), C. D. Cameron (1948–1959) and L. P. Jackson (1960–1979) who took turns coordinating the study, and the technical assistance of S. R. Thompson, A. P. Emslie, B. L. Kyle and A. E. Foster. Thanks are also extended to J. E. Goodwin for word processing and B. Harnish of the Nova Scotia Department of Agriculture & Marketing for conducting the soil and manure chemical analysis. The authors also wish to acknowledge the assistance of the Farm Services Division of the Nappan Experimental Farm for maintaining, fertilizing and harvesting the plots of this study.

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