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Soil Fertility Investigations of Grass Seed Production in Northwestern Minnesota

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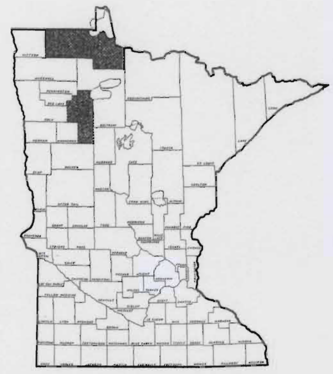

JOHN GRAVA, G. W. RANDALL, D. M. LARSEN, R. S. FARNHAM

Contents

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Seed production of turf and forage grasses is an important farm enterprise in northwestern Minnesota. Nearly $1 million in cash sales are realized annually by seed producers of Clearwater, eastern Polk, Lake of the Woods, and Roseau Counties. Growers who specialize in the production of grass seed derive most of their incomes from it.

Optimum yields of high-quality seed require sufficient plant nutrients. This is well recognized by the growers who invest up to $13 per acre each year for commercial fertilizers. Generally, about one-third of the total production cost is realized on fertilization practices. Thus, information on soil fertility problems, proper fertilization practices, and diagnostic techniques that can be used in evaluating plant nutrient needs are of utmost interest to the growers.

The main objective of this study is to investigate those soil fertility factors and fertilization practices most important in determining high seed yields of grasses. Another objective is to locate certain soils and fields on which future fertilizer trials could be conducted. The field investigations were conducted during the 1965 growing season. This report includes data on:

- chemical properties of major mineral and organic soils;
- production practices;
- seed yields of Kentucky bluegrass and timothy; and
- chemical composition of grasses on 51 fields in northwestern Minnesota.

MATERIALS AND METHODS

Kentucky bluegrass (*Poa pratensis* L.) and timothy (*Phleum pratense* L.) are grown for seed production in northwestern Minnesota on mineral and organic soils. Twenty-five of the surveyed fields were mineral and 26 organic soils. Of the 24 seed production fields in Roseau County, 18 fields were mineral and six organic soils. All seven fields in the Lake of the Woods County were mineral soils. In Clearwater County, 17 timothy fields and, in eastern Polk County, three timothy fields were studied on organic soils.

Most of the study area is in the outer basin of Glacial Lake Agassiz (1, 9). The mineral soils developed on calcareous, lake-laid (lacustrine) fine sands, silts, and clays under the influence of wet prairie vegetation. The organic soils developed from reeds, sedges, and grasses on the wetter areas of the lake plain. The soils are extremely variable in color and thickness of the dark surface soil. Soil textures range from sand to silty clay loam. Many peat (organic soil) areas are intermingled with mineral soils.

MINERAL SOILS

The predominant soils series on the fields studied were Bearden (nine fields), and Glyndon (eight fields). Other soil series studied include Colvin, Ulen and Rocksbury (two fields each) and Borup and Arveson (one field each). The following briefly describes the major characteristics of each series:

BEARDEN[1] silty clay loam and silt loam soils are dark colored, somewhat poorly to moderately well drained Aeric Calciaquolls[2] (calcium carbonate solonchak) developed on lacustrine deposits under prairie vegetation. The dark colored surface soil is calcareous, moderately thick, and high in organic matter. The subsoil has the same texture, but is more plastic. A layer of carbonate occurs about 10 inches below the surface. Calcareous lacustrine clay is commonly reached at depths of 3 to 4 feet or more. The water-holding capacity is high, and surface and internal drainage is often a problem because of the level topography.

GLYNDON very fine sandy loam and silt loam are dark colored, somewhat poorly to moderately well drained Aeric Calciaquolls which developed under grass vegetation on lake-laid silts and very fine sands. The surface soil is calcareous, high in organic matter, and moderately thick. The subsoil is a friable silt or very fine sandy loam, grading into very fine or fine sand at 24 to 36 inches. The water-holding capacity is moderate, and susceptibility to wind erosion is a major problem. Glyndon differs from Bearden in that its substratum is sandy rather than silty or clayey.

COLVIN silty clay loam is a dark colored, poorly drained Typic Calciaquoll (calcium carbonate solonchak) developed under prairie grass and/or swamp vegetation on calcareous lacustrine silts. These silts vary in thickness from 3 to 6 or more feet and are underlain by lacustrine clay. The surface soil is high in organic matter, moderately thick, and calcareous. The subsoil is either a silty clay loam or silt loam and calcareous. Gypsum crystals commonly are found in the subsoil or substratum. The water-holding capacity is high. The major management problem, other than alkalinity, is the lack of adequate drainage.

ULEN very fine sandy loam is a dark colored, moderately well drained Aeric Calciaquoll developed under prairie vegetation on light yellowish-brown, calcareous, very fine sands. It occurs in level lake plains with some microrelief. The surface soil is 10 to 15 inches thick and calcareous. The subsoil is a loose loamy fine or very fine sand and has a high concentration of calcium and/or magnesium carbonates, usually just below the dark surface layer. At depths of 20 to 40 inches, the sandy material becomes mottled and less calcareous. Clay loam till or lacustrine silts or clays may occur at 4 feet, but usually occur deeper than this. Droughtiness may occur in the surface of these soils on extremely "dry" years due to the low water-holding capacity of the fine sands. Wind erosion also may be a problem during such times.

BORUP silt loam and very fine sandy loam soils are dark colored, poorly drained Typic Calciaquolls. They developed from calcareous lacustrine silts or very fine sands under grasses and sedges in level to slightly depressed areas. The medium-textured material extends to a depth of 2 or more feet and overlies fine or very fine calcareous sand. The sandy material is usually at 3½ feet or less. The dark colored surface soil is thick, high in organic matter, and calcareous. The water-holding capacity is only moderate and the major management problems are the calcareous surface, susceptibility to wind erosion, and poor drainage.

ARVESON fine sandy loam and loam soils are dark colored, poorly drained Typic Calciaquolls developed from calcareous lake-laid sands. The original vegetation was prairie grass and sedges. The organic matter content is high, and the topography is nearly level. The surface

[1] Soil Survey Staff. Rev. 1964. Minnesota State Soil Survey Legend. Soil Conservation Service. U.S.D.A. St. Paul, Minnesota.

[2] Tentative Classification of Soil Series of Minnesota in the Comprehensive System. U.S.D.A. Soil Conservation Service. St. Paul, Minnesota. June 10, 1969.

soil is 12 to 16 inches thick; the subsoil is a loose, loamy, fine sand; and the underlying material is loose sand. The loose sand underlying the solum usually begins at 20 to 24 inches. The soil profile is calcareous throughout, and the water-holding capacity is moderate. Drainage is a major problem.

ROCKSBURY silty clay loam, Typic Haplaquoll (humic gley), is a dark colored, poorly to somewhat poorly drained soil developed in thin, lake-sorted material over glacial till. The original vegetation was prairie or swamp grasses. Originally some of this soil was covered by a thin layer of peat. The organic matter content is high, and the topography is level. The surface soil is 6 to 12 inches thick, and the subsoil is a firm, silty clay loam that is calcareous at 12 to 18 inches. The underlying material is a friable to firm, calcareous clay loam till. Evidence of stratification or modification of the till by water is often found. The water-holding capacity of this soil is high.

ORGANIC SOILS

The survey's organic soils were all developed from reeds, sedges, and grasses in the periodically water-saturated environment. They are all classified in the new comprehensive system as Typic Borohemists.[3] The surfaces of these deep peats are partially to well decomposed with some fine fiber still evident. Beginning at about 10 inches, the horizons are partially decomposed, fibrous, organic materials consisting of plant remains with some finely divided, decomposed organics between the fibers. The reaction is slightly acid throughout the profile although there is sufficient calcium for grass seed production. Underlying these organic soils at depths from 5 to 7 feet are calcareous silts and clays.

CLIMATIC FACTORS

The climate of northwestern Minnesota seems well suited for grass seed production. The following data (3) summarize the climate of Roseau County:

(a) Frost-free period averages from May 30 to September 12 (105 days).
(b) Mean temperature of 65° F. for June, July, and August.
(c) Extended daylight in the summer (as much as 18 hours, with an average of 14 hours during the entire growing season).
(d) Annual precipitation of 19.3 inches. Frequent heavy dews and light rains.
(e) Good snow cover with infrequent winter thaws.

Seed producers in the four-county area obtained relatively high yields and considered the 1965 harvest one of the best in recent years. Weather conditions may have contributed to this. The relatively cool and moist weather during the fall of 1964 and the growing season of 1965 appeared to be very favorable for seed production of the two cool-season grasses. Climatological data from the Roseau, and Fosston (eastern Polk County) Weather Stations are presented in table 1.

[3] Classification according to the Organic Soil Committee of the National Cooperative Soil Survey. Aug. 1968.

SPECIES AND VARIETIES

The principal bluegrass variety — Park — grown in northwestern Minnesota was developed by the Minnesota Agricultural Experiment Station. The main characteristics of this variety are quick germination, vigor, and rust resistance. Park Bluegrass is well suited for turf establishment for home lawns, parks, golf courses, and athletic fields throughout the northcentral and northeastern U.S.A. About 1.5 million pounds of Kentucky bluegrass seed are produced in Minnesota annually.[4] This seed is largely certified Park and is produced primarily in the four-county study area. Park Kentucky bluegrass was grown on all of the 22 fields in this study.

Over 13 million pounds of timothy seed were produced on 72,000 acres in Minnesota in 1967.[5] Nearly 70 percent of this total acreage was in the four-countly area, indicating the area's importance in timothy seed production. Of the 29 surveyed timothy fields, 20 were in certified Climax, one each in Essex and Itasca, and the remaining seven in Common.

In 1968, the following acreage was entered for certificaion by growers in the four-county area:[6]

Variety	Acres
Bluegrass:	
Park	7,997
Merion	150
C-1	55
Timothy:	
Climax	3,659
Itasca	740
Essex	240

Table 1. Precipitation and temperature data for the growing season of 1964-65 as measured at Roseau and Fosston U.S. Weather Stations.*

	Precipitation (inches)		Air temperature (°F)	
Period	Total	Departure from normal	Average	Departure from normal
	Roseau Weather Station			
August to October	7.11	+0.19	51.4	−3.5
November to March	2.76	−0.56	7.3	−5.2
April to July	11.94	+2.47	54.3	−1.4
Total	21.81	+2.10	...	....
Average	....	.....	34.0	−3.5
	Fosston Weather Station			
August to October	7.84	+1.23	55.6	−1.3
November to March	3.31	−0.79	11.8	−3.8
April to July	13.14	+1.30	56.8	−0.4
Total	24.29	+1.74	...	....
Average	....	.....	37.7	−2.0

* Calculated from climatological data, Minnesota, Vol. 70 and 71, 1964 and 1965, U. S. Weather Bureau.

[4] Crop and Livestock Reporting Service. March 1969. Minnesota Agricultural Statistics 1969. St. Paul, Minnesota.

[5] Ibid.

[6] Minnesota Crop Improvement Association. Minnesota Registered and Certified Seed Directory for 1969 Planting. St. Paul, Minnesota.

SELECTION OF FIELDS

Local county agents supplied a list of growers, who then assisted in the final selection of representative fields for this study. Information about cropping history, past seed yields, variety, date of seeding, rates of fertilizer applied, weed control, and other management practices was obtained from the seed growers.

COLLECTION OF PLANT AND SOIL SAMPLES

A representative area was selected in each field from which plant and soil samples were collected.

Samples of plant tissue were collected according to the method suggested by Chapman (4). During the emergence of heads or panicles, leaf tissue was collected at random along two 100-foot diagonal lines which formed an X. The center was marked with a lath for a reference point. Each sample, consisting of about 200 leaves, was placed in a number 10 paper bag and kept loose and aerated during transport to the laboratory for further processing and analysis.

During the 1st week of July, soil samples were taken near the lath marking the point of plant tissue collection in each field. A 2 x 24-inch slice was taken with a tiling spade from the face of a pit, then a knife was used to cut the soil slice into seven segments of 0-1, 1-2, 2-3, 3-6, 6-12, 12-18, and 18-24 inches. These samples were then placed in soil sample boxes and taken to the laboratory for analysis. Total depth of organic soils was determined with a bucket auger. Soil classification was also accomplished at the time of sampling.

HARVESTING

A wire frame, measuring 1 square yard, was placed at three random locations near the site of plant and soil sampling. Mature plants were clipped with hand shears from these measured areas and placed in number 10 paper bags. The harvested material was then dried at 105° F. for 1 week. After drying, the bluegrass was threshed with a Harmond thresher, the lint removed with a roller thresher and fan, and the seed finally cleaned with a Vogel seed cleaner. The timothy was passed through a spike-tooth cylinder and belt thresher, and the seed was cleaned with a Vogel seed cleaner. Seed weights were determined and converted to yields in pounds per acre.

LABORATORY PROCEDURES

Soil samples were air-dried for 7 days and analyzed at the University of Minnesota Soil Testing Laboratory.[7]

[7] Grava, J. 1962. Soil Analysis Methods as Used in the University of Minnesota Soil Testing Laboratory. Form 15-G. Institute of Agriculture. University of Minnesota.

SOIL pH — The pH was determined with a glass electrode pH meter on a 1:1, soil-to-water, suspension.

EXTRACTABLE PHOSPHORUS — P was extracted with Bray's No. 1 extracting solution (0.03N ammonium fluoride in 0.025N hydrochloric acid). One g of soil and 10 ml of extractant were shaken for 1 minute. After filtering, 5 ml of the filtrate were treated with ammonium molybdate and amino-naphthol-sulfonic acid solutions. The resulting blue color, which is related to P concentration, was read with an absorption spectrophotometer.

EXCHANGEABLE POTASSIUM — K was extracted with a solution of 1N neutral ammonium acetate, using a soil-to-solution ratio of 1:5. After being shaken for 1 minute and filtered, K was determined in the extract using a flame emission spectrophotometer.

ORGANIC MATTER was determined by the wet digestion method. One g of soil was treated with 10 ml of 2N potassium dichromate and 20 ml of concentrated sulfuric acid. Then 100 ml of tap water were added and the mixture allowed to stand overnight. The resulting green color is proportional to the organic matter content of the soil. An absorption spectrophotometer was used to give a light transmittancy reading of these solutions, calibrated to read as percent organic matter.

Additional chemical properties of the mineral soils were determined at the Department of Soil Science, University of Minnesota. *Cation exchange capacity* (CEC) was determined by the barium chloride-triethanolamine method (5). Because of the small size of the samples from 0-1, 1-2, and 2-3-inch depths, they were combined for this determination. *Electrical conductance* of a soil-water saturation extract was determined with a Solu-Bridge (12); *calcium carbonate equivalence* (CCE) by the acid neutralization method (8); and *sulfate* content in a 1:5, soil-to-water, extract by turbidimetric method using barium chloride and an absorption spectrophotometer (2).

GRASS TISSUE samples were dried at 150° F. in a forced-air oven for 72 hours, then ground in a Wiley mill with stainless steel blades and screen. Each sample was divided and placed in two plastic bags. One subsample was submitted for analysis to the Ohio Plant Analysis Laboratory. A spark emission spectrograph was used to determine the concentrations of 14 chemical elements in the dry matter. The nitrogen content was determined by the micro-Kjeldahl method at the Department of Soil Science, University of Minnesota.

EVALUATION OF DATA

For this study, the means, standard deviations, linear correlations, and multiple regression equations and coefficients were calculated at the University of Minnesota Numerical Analysis Center.

RESULTS AND DISCUSSION

CHEMICAL PROPERTIES OF SOILS

SOIL pH

Average pH values of soils at various sampling depths down to 2 feet are given in table 2. The mineral soils were strongly alkaline in reaction with an average pH of 8.0 in the top 6 inches and about 8.4 in the subsoil. The organic soils were slightly acid, with pH about 6.4 in the upper 3 inches gradually decreasing to 5.8 at the 18- to 24-inch level. The soils in these two groupings showed uniformity in pH values at various sampling depths. The coefficients of variability (CV) for the various sampling depths were less than 11 percent.

Table 2. Average pH values of mineral and organic soils at seven sampling depths on 51 grass seed production fields in northwestern Minnesota.

Sampling depth (inches)	Soils: Mineral	Soils: Organic
	soil pH	
0-1	7.9	6.3
1-2	8.0	6.4
2-3	8.0	6.4
3-6	8.0	6.3
6-12	8.2	6.0
12-18	8.4	5.9
18-24	8.4	5.8

CALCIUM CARBONATE EQUIVALENCE

Table 3 shows the calcareous nature of the 25 mineral soils. The CCE averaged 8.5 percent at the surface and increased downward through the profile to about 32 percent at the 18- to 24-inch depth. Slightly lower values of CCE were found in coarse-textured soils than in fine- and medium-textured soils.

Table 3. Average calcium carbonate equivalence (CCE) of 25 mineral soils at various sampling depths on grass seed production fields in northwestern Minnesota.

Sampling depth (inches)	Calcium carbonate equivalence	
	percent	CV*
0-1	8.5	109
1-2	8.5	106
2-3	8.0	101
3-6	7.6	90
6-12	18.1	78
12-18	27.3	46
18-24	32.1	30

* CV = coefficient of variability, defined as the sample standard deviation (s) expressed as a percentage of the sample mean (x), $CV = \frac{100s}{x}$.

ELECTRICAL CONDUCTANCE

Electrical conductance, which indicates soluble salt concentrations, of the saturation extract did not exceed 1.1 mmhos/cm at 25°C. These mineral soils, therefore, are classed as nonsaline (12).

SULFATES

Sulfate content of the mineral soils showed great variability and was highest in medium-textured soils. Averages ranged from 7 ppm in coarse-textured soils to 170 ppm in medium-textured soils. Most of the sulfates in the medium-textured soils were concentrated in the upper 6 inches; in both the coarse- and fine-textured soils, the highest sulfate contents were found below 12 inches.

ORGANIC MATTER, CATION EXCHANGE CAPACITY

The organic matter content for the mineral soils averaged about 5.2 percent in the upper 3 inches. It decreased to 4.9 percent at 3 to 6 inches and to 2.0 percent at 6 to 12 inches. The subsoils had less than 1 percent organic matter at depths of 12 or more inches.

A CEC of about 25 meq/100 g of soil was found for the medium- and fine-textured soils compared with 19 meq/100 g for the coarse-textured soils.

EXTRACTABLE PHOSPHORUS

A relatively low phosphorus availability in soils of northwestern Minnesota has been indicated by soil test summaries (7). It can be assumed that the great majority of samples submitted by farmers for testing was collected from the plow layer (0-6 inches) of cultivated land according to instructions. Some mixing of applied fertilizer with the soil of the plow layer obviously takes place through plowing and other seedbed preparation practices.

When phosphorus is applied by topdressing fertilizers to sod crops, it generally remains concentrated in the surface 3 inches of soil (6, 14). Movement of P seldom is noted below 6 inches. Figure 1 illustrates this high accumulation of P in the top soil. Bluegrass was seeded on this field in 1958, and the stand was renovated in 1962. The grower had used 40 + 20 + 20 pounds per acre of plant nutrients, expressed as N, P_2O_5, and K_2O, in the fall of 1964. The plant tissue contained 0.33 percent P.

Table 4 shows a relatively high concentration of extractable P in the top 1 inch of the mineral and organic

Table 4. Average extractable phosphorus content of 25 mineral and 26 organic soils at seven sampling depths on grass seed production fields in northwestern Minnesota.

Sampling depth (inches)	Mineral: Extr. P pp2m	Mineral: CV*	Organic: Extr. P pp2m	Organic: CV*
0-1	39	106	27	84
1-2	23	185	18	96
2-3	21	201	14	93
3-6	26	172	11	111
6-12	7	134	6	147
12-18	4	48	3	63
18-24	4	49	3	51

* CV = coefficient of variability, defined as the sample standard deviation (s) expressed as a percentage of the sample mean ($\bar{x}$), $CV = \frac{100s}{\bar{x}}$.

soils. The test values generally decreased with sampling depth. Occasionally values were slightly higher in the 3- to 6-inch zone than at depth intervals either immediately above or below it. Turning over the sod during renovation may have caused this concentration of P. Fertilization had little or no effect on soil tests below a depth of 6 inches. The P test levels found in the subsoil of the mineral and organic soils were classed as low (7).

EXCHANGEABLE POTASSIUM

The average contents of exchangeable K (table 5) fell into the medium category for the mineral soils, and low to very low categories for the organic soils (7). A gradual decrease in the K content at lower sampling depths also was found.

Table 5. Average exchangeable potassium content of 25 mineral and 26 organic soils at seven sampling depths on grass seed production fields in northwestern Minnesota.

Sampling depth (inches)	Soils			
	Mineral		Organic	
	Exch. K pp2m	CV*	Exch. K pp2m	CV*
0-1	182	72	94	53
1-2	132	83	57	52
2-3	124	98	48	58
3-6	133	93	41	91
6-12	102	112	25	105
12-18	107	114	16	42
18-24	103	84	17	44

* CV = coefficient of variability, defined as the sample standard deviation (s) expressed as a percentage of the sample mean ($\bar{x}$), $CV = \frac{100s}{\bar{x}}$.

FERTILIZATION PRACTICES

Table 6 shows the amount of commercial fertilizers used for seed production of the two grass species on mineral and organic soils. The growers apparently did not differentiate much between the two grass species when using fertilizers. The main difference in the use of fertilizers was between the soils — mineral soils received twice as much nitrogen as did the fields on organic soils. No obvious differences in fertilizer use were noted among the fine-, medium-, or coarse-textured soils.

The coefficients of variability (CV) for the amounts of nutrients used on various production fields ranged from 34 to 129 percent indicating considerable variability. Most commonly used fertilizers on mineral soils had nutrient ratios of 1:1:0, 2:1:0, or 2:1:1, and on organic soils ratios of 1:2:2 or 1:4:4. Some growers had applied fertilizers containing only nitrogen. No fertilizer had been used on three fields.

Growers spent from $8 to $13 per acre annually for commercial fertilizers. In most cases, commercial fertilizers were applied in the spring. On 38 of the 51 fields, fertilizer had been applied in the spring of 1965 and on 10 fields in the fall of 1964.

Table 6. Average amounts of plant nutrients applied annually for seed production of Kentucky bluegrass and timothy on mineral and organic soils in northwestern Minnesota.

Soils, Grass species	Plant nutrients applied		
	N	P_2O_5	K_2O
	(pounds per acre)		
Mineral soils			
Kentucky bluegrass	51	29	9
Timothy	58	21	18
Organic soils			
Kentucky bluegrass	21	43	43
Timothy	25	32	32

AGE OF STAND

The age of stand, in the case of timothy, means the number of years from seeding time. For bluegrass it means either the number of years from seeding or from the year of stand renovation.

The average age of the surveyed timothy fields was nearly 3 years, with most fields 1 to 3 years old. Six fields of common timothy in Clearwater County were 5 to 7 years old. The average age of bluegrass fields was about 2 years, ranging from 1 to 4 years.

YIELDS

Average yields of seed obtained on the surveyed fields were 417 pounds of bluegrass per acre and 234 pounds

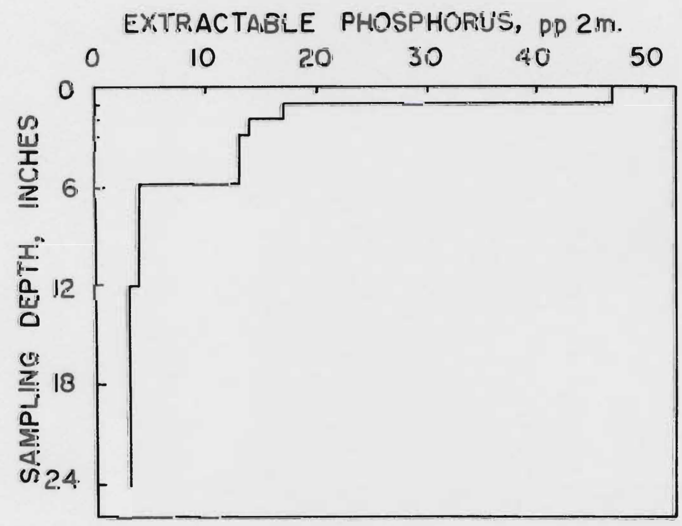

Figure 1. Vertical distribution of extractable phosphorus in a Bearden silty clay loam under Kentucky bluegrass sod.

of timothy per acre (table 7). Yields of three Lake of the Woods County timothy fields which had been heavily damaged by hail were excluded from calculations.

Generally, higher bluegrass yields were obtained on mineral soils than on organic soils. On the other hand, slightly higher average timothy yields were obtained on organic soils than on mineral soils. On mineral soils, by grouping the seed yields of both species together according to soil texture, the yields obtained on fine- and medium-textured soils were 75 to 100 pounds per acre higher than those obtained on coarse-textured soils.

Significant relationships between the seed yield of bluegrass grown on mineral soils and the rate of fertilizer applied were indicated by regression analysis. Figure 2 shows a linear relationship between the rate of nitrogen applied and the seed yield. The regression equations for the relationships between bluegrass seed yields and the rates of P and K, expressed as P_2O_5 and K_2O, are: Yield = 328.7 + 4.55 P, r = 0.740**[8], Yield = 413.7 + 5.27 K, r = 0.530*[9].

These linear relationships for bluegrass on mineral soils seem to indicate that a number of producers could have benefited from using a higher rate of fertilizer. However, excessive nitrogen rates may cause severe lodging and lower bluegrass yields. Carlson (3) reported that fertilizer rates containing 60 pounds or more of N caused moderate to severe lodging in years of above normal rainfall. In years of normal rainfall, 90 pounds of nitrogen appeared to be the maximum rate beyond which severe lodging occurred. In Oregon, only a slight yield increase was obtained from applying more than 90 pounds of nitrogen per acre to bluegrass (10). Our observations in northwestern Minnesota and studies in Oregon (11) indicate that residue management of bluegrass may influence considerably the effectiveness of fertilizer rates in determining seed yields.

Table 7. Average yields of Kentucky bluegrass and timothy seed produced on mineral and organic soils in northwestern Minnesota.

	Soils			
Grass species	Mineral	Organic	All soils	
	(seed yield, pounds per acre)			CV*
Kentucky bluegrass	465	289	417	41
Timothy	187	255	234	52

* CV = coefficient of variability, defined as the sample standard deviation (s) expressed as a percentage of the sample mean ($\bar{x}$), $CV = \frac{100s}{\bar{x}}$.

The two highest yields of bluegrass, 732 and 831 pounds of seed per acre, were obtained on production fields on mineral soils in Lake of the Woods County. The stands were 2 or 3 years old and had received, in one case, 75 + 75 + 0 and, in another case, 90 + 90 + 60 pounds per acre of plant nutrients. The growers had removed the stubble and excess vegetative regrowth by grazing with beef cattle and clipping. Other growers either left the stubble and regrowth or burned their fields.

[8] ** = highly significant.
[9] * = significant.

For the six bluegrass fields on organic soils, no significant relationship between the seed yields and the rate of fertilizer was found. This was probably due to the limited number of fields available for study and the relatively narrow range in the amounts of fertilizer used. The average yield for the six fields was 290 pounds per acre with a range of 180 to 435 pounds. These yields were obtained with an average amount of 21 pounds of N per acre, ranging from 15 to 25 pounds. An average of 42 pounds each of P_2O_5 and K_2O was used per acre.

Regression analysis indicated a highly significant curvilinear relationship between timothy seed yields and the amount of nitrogen applied in fertilizer on organic soils (figure 3). According to the regression equation, maximum seed yields were obtained with 40 pounds of nitrogen per acre. The depression of timothy seed yields with higher N rates may have been caused by excessive vegetative growth and lodging.

The average yield for the six timothy fields on mineral soils was 215 pounds of seed per acre. Yields ranged from 115 to 340 pounds. The growers used an average of 55

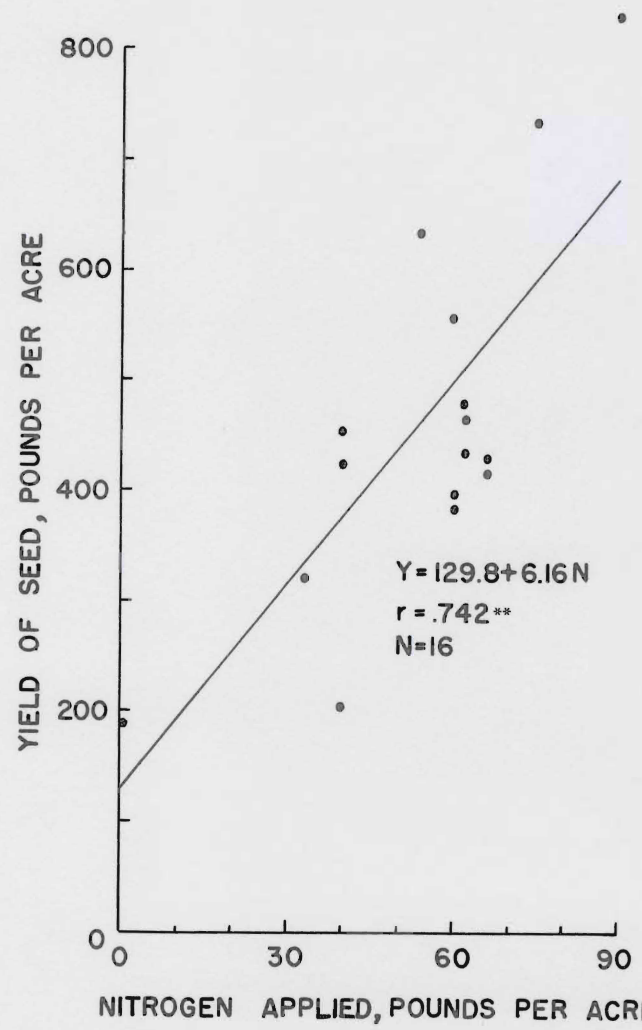

Figure 2. The relationship between fertilizer nitrogen and seed yield of Kentucky bluegrass on mineral soils in northwestern Minnesota.

pounds of N per acre, ranging from 30 to 73 pounds, and an average of 18 pounds of P_2O_5 and 13 pounds of K_2O per acre.

CHEMICAL COMPOSITION OF GRASS TISSUE

The concentration of chemical elements in plants is used as an index of their nutritional status. Plant analysis, a diagnostic method, is gaining rapidly in popularity. Several service laboratories in the U.S. are equipped with instruments to determine simultaneously as many as 16 elements within a few seconds. With plant analysis and soil tests, the seed grower has access to two valuable diagnostic tools to assist him in eliminating much of the fertilization guesswork.

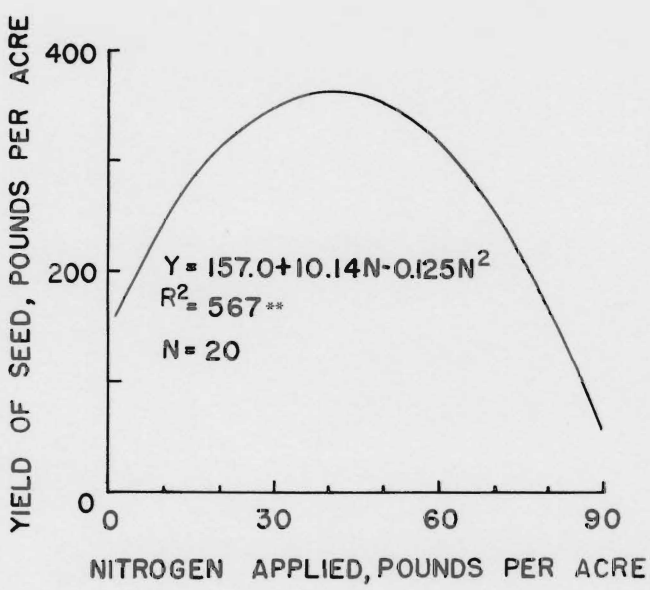

Figure 3. The relationship between fertilizer nitrogen and seed yield of timothy on organic soils in northwestern Minnesota.

The interpretation of plant analysis data, however, presents a serious problem. Most information on chemical composition of grasses refers to the nutritive value of grass forage. Some workers have reported on the composition of clippings from bluegrass sod (13). But information on chemical composition of grasses as related to the production of seed is scarce.

Tables 8 and 9 show average concentrations of 15 chemical elements in the dry matter of grasses grown on mineral and organic soils in northwestern Minnesota. These data provide reference points for the chemical composition of bluegrass and timothy tissue collected at the early heading stage.

Bluegrass tissue had slightly lower N, P, and K contents than did the timothy tissue. The tissue of both grasses collected from organic soils consistently showed slightly higher contents of the three major nutrients than did tissue from mineral soils. It is not known whether these trends were due to differences between the species or if the trends do reflect different nutrient availability in the two soils. Growers used higher average P and K rates on organic soils than on mineral soils (table 6). The differences found in contents of two trace elements, zinc and copper, may be significant. The zinc content in the tissue collected from organic soils was 6 to 8 ppm higher than the tissue from mineral soils. On the other hand, grass tissue from mineral soils had 2 to 4 ppm more copper than that collected from organic soils.

Table 8. Average chemical composition of Kentucky bluegrass tissue collected from 22 seed production fields in northwestern Minnesota.

Chemical element	Mineral soils (16)	Organic soils (6)	All soils	
	percent in dry matter			CV*
Nitrogen	2.49	2.55	2.50	21
Phosphorus	0.31	0.37	0.33	18
Potassium	2.12	2.38	2.19	17
Calcium	0.44	0.46	0.44	22
Magnesium	0.19	0.22	0.20	17
	parts per million in dry matter			
Boron	6	7	6	23
Manganese	44	53	47	30
Zinc	23	29	25	26
Copper	9	5	8	23
Iron	106	98	104	67
Aluminum	38	44	40	38
Molybdenum	0.7	0.8	0.7	36
Cobalt	1.4	1.2	1.3	22
Strontium	22	25	23	15
Barium	16	21	18	32

* CV = coefficient of variability, defined as the sample standard deviation (s) expressed as a percentage of the sample mean ($\bar{x}$), $CV = \frac{100s}{\bar{x}}$.

Table 9. Average chemical composition of timothy tissue collected from 29 seed production fields in northwestern Minnesota.

Chemical element	Mineral soils (9)	Organic soils (20)	All soils	
	percent in dry matter			CV*
Nitrogen	2.60	2.90	2.81	21
Phosphorus	0.32	0.40	0.37	20
Potassium	2.45	2.66	2.60	14
Calcium	0.38	0.38	0.38	18
Magnesium	0.18	0.14	0.16	20
	parts per million in dry matter			
Boron	7	5	5	25
Manganese	40	39	39	24
Zinc	26	34	32	17
Copper	8	6	7	22
Iron	69	75	73	24
Aluminum	21	21	21	50
Molybdenum	0.6	0.4	0.5	40
Cobalt	1.3	1.0	1.1	27
Strontium	22	19	20	18
Barium	8	7	8	34

* CV = coefficient of variability, defined as the sample standard deviation (s) expressed as a percentage of the sample mean ($\bar{x}$), $CV = \frac{100s}{\bar{x}}$.

To determine the degree of deficiency, sufficiency, or excess of plant nutrients, one must know how yield is related to the chemical composition of tissue.

Highly significant curvilinear relationships exist between the nitrogen content in tissue and the seed yields of bluegrass and timothy grown on both mineral and organic soils (figure 4). The peak of the parabolic curve for bluegrass was reached at 2.5 percent nitrogen (yielding 525 pounds of seed per acre). For timothy, the peak was reached at 3.0 percent nitrogen with a yield of 300 pounds of seed per acre. Additional nitrogen concentration beyond the peaks depressed the seed yields.

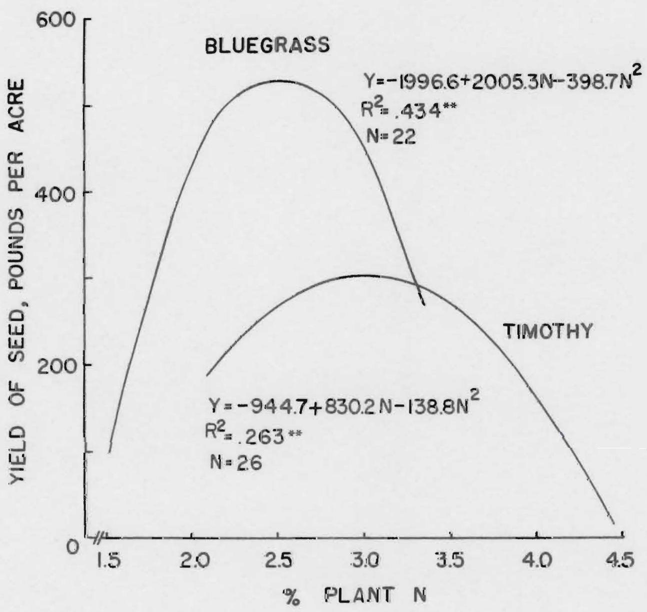

Figure 4. The relationship between nitrogen content of Kentucky bluegrass and timothy tissue and seed yield in northwestern Minnesota.

Another relationship between the seed yield and the chemical composition of bluegrass is shown in table 10. The content of N, P, and K was highest in plants from fields yielding 250-500 pounds of seed per acre. Slightly lower concentrations of these elements were found in tissue from fields yielding less than 250 pounds per acre or more than 500 pounds per acre. The increase in the contents of the three elements in tissue from the lower to the middle group was related to the use of higher fertilizer rates, particularly that of nitrogen, on the latter fields.

Table 10. Relationships between seed yields and chemical composition of plant tissue of Kentucky bluegrass.

Chemical element	Average seed yield, pounds per acre < 250	250-500	> 500
		number of fields	
	5	12	5
		percent in dry matter	
Nitrogen	2.04	2.74	2.40
Phosphorus	.31	.34	.32
Potassium	2.13	2.24	2.14

The reasons for the slightly lower N, P, and K contents in plant tissue from the highest yielding fields, however, are unknown. These fields had received, on the average, about 16 more pounds of N and 28 more pounds of P_2O_5 than had fields in the middle yield group. Perhaps it was due to a dilution effect on the concentration of chemical elements by the increased vegetative growth of bluegrass. Nutrition apparently did not limit the growth of plants, and some other factor(s) made possible such exceptionally high seed yields.

Relationships between seed yields and chemical composition, as observed in bluegrass, were not as pronounced in timothy because the seed yields of timothy were more uniform. Certain trends became apparent, however, when fields were divided into two yield classes: yields below 300 pounds per acre and yields above 300 pounds per acre. About the same rate of N had been used on fields from both groups. Fields with the highest average yields had received 11 more pounds of P_2O_5 and about 7 more pounds of K_2O than had fields yielding less than 300 pounds of seed per acre. Timothy tissue from the fields with the highest seed yields had a slightly lower N content, 2.79 percent compared with 2.88 percent, and a lower K content, 2.55 percent compared with 2.66 percent. Phosphorus in both cases averaged about 0.38 percent. These facts should be considered when using plant analysis as a diagnostic tool for advisory purposes.

Additional studies are needed to evaluate relationships between nutrient concentration in plant tissue and the availability of nutrients in soils. These studies help in establishing plant analysis as a diagnostic tool in grass seed production.

SUMMARY

- Seed production of turf and forage grasses is an important source of income to farmers in northwestern Minnesota. Since crop yields are affected greatly by soil fertility, a study was conducted to determine which of the various plant nutrients may limit seed production. Twenty-two Kentucky bluegrass and 29 timothy fields were studied in Clearwater, eastern Polk, Lake of the Woods, and Roseau Counties. Twenty-five fields were on mineral soils and 26 fields on organic soils.
- The climate of northwestern Minnesota is well suited for seed production of cool-season grasses. The relatively cool and moist weather during the fall of 1964 and the growing season of 1965 were favorable for seed production, and relatively high yields were obtained.
- Park Kentucky bluegrass and Climax timothy are the principal varieties grown in northwestern Minnesota.
- The soils in the area developed on calcareous lake-laid deposits under grass, sedge, or swamp vegetation. Surface and internal drainage is often a problem because of the generally level topography. Some fields occasionally flood in spring and early summer because of the flat terrain and the proximity to rivers. The two most prevalent series of

the mineral soils on surveyed fields were Bearden and Glyndon. All of the surveyed organic soils were deep peats.

• The mineral soils were strongly alkaline with an average pH of 8.0 in the upper 6 inches, and 8.4 in the subsoil. These soils were calcareous, having a calcium carbonate equivalence of 8.5 percent at the surface, which increased to 32 percent at the 18- to 24-inch depth. The soils had an electrical conductance of less than 1.1 mmhos and are classified as nonsaline. The cation exchange capacity for medium- and fine-textured soils was about 25 meq/100 g and for coarse-textured soils 19 meq/100 g. Sulfate content ranged from 7 ppm in coarse-textured soils to 170 ppm in medium-textured soils. The organic soils were slightly acid, with an average pH of 6.4 in the upper 3 inches which gradually decreased to 5.8 at the 18- to 24-inch level.

• Extractable P was highest in the 0- to 1-inch zone with slightly lower values in the 1- to 3-inch zone of the soil. Fertilization had little or no effect on soil tests below a depth of 6 inches. Exchangeable K content was slightly higher in the upper 1 inch of soil than at lower sampling depths. Since topdressed P and K remain close to the soil surface, soils from grass seed production fields should be sampled for testing purposes to a depth of 3 inches.

• Considerable variation was found in the use of commercial fertilizers. The growers did not differentiate greatly in the amounts of plant nutrients applied to the two grasses. The main difference in fertilizer use was between fields on mineral and organic soils. Twice as much N was applied to grasses grown on mineral soils than to those grown on organic soils. The most commonly used fertilizers on mineral soils had ratios of 1:1:0, 2:1:0, or 2:1:1; on organic soils, 1:2:2 or 1:4:4 ratios. Growers spent from $8 to $13 per acre annually for commercial fertilizers. Most fields were fertilized in the spring.

• Most of the timothy fields were 1 to 3 years old. The average age for bluegrass fields was 2 years.

• Average yields were 417 pounds for bluegrass and 234 pounds of seed per acre for timothy. Significant relationships exist between seed yields of both grasses and the rate of fertilizer used. Nitrogen affected the yields most decisively. A linear relationship was found between seed yields of bluegrass and N applied, with the top rate of 90 pounds per acre, to mineral soils. Residue management, however, appeared to be a deciding factor in determining the amount of N that can be used without causing lodging in bluegrass. A curvilinear relationship was found between timothy seed yields and the rate of N on organic soils. Maximum yields were obtained with 40 pounds of N per acre.

• The contents of 15 essential chemical elements found in tissue of bluegrass and timothy should serve as reference points. Significant curvilinear relationships between the N content of tissue and the seed yields were found for both grass species. The peak of the curve was reached at 2.5 percent N for bluegrass and at 3.0 percent N for timothy. Beyond these N concentrations, yield depressions occurred probably due to excessive vegetative growth and lodging.

• Grass tissue from fields on organic soils had a lower copper content than that from fields on mineral soils. In contrast, the zinc content was higher in tissue from organic soils than from mineral soils.

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