Station Bulletin 485 September 1966

a survey of Alfalfa Fields in Winona County Minnesota

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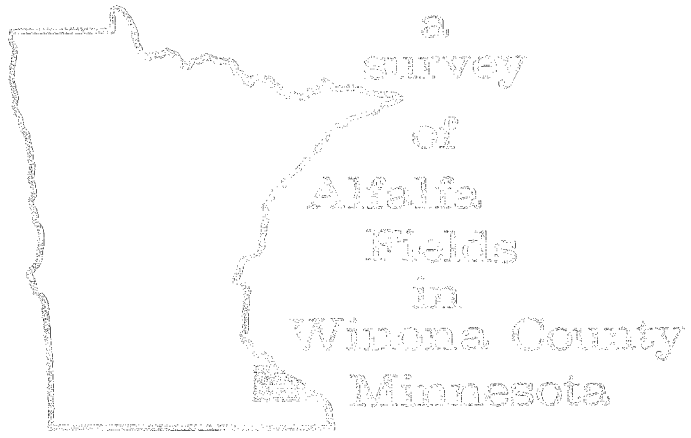

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Alfalfa is the most important forage crop grown in Winona County, Minnesota. Since 1935, when dairying assumed major importance in the county, alfalfa and alfalfa-grass mixtures have been economical sources of homegrown protein, vitamins, minerals, and energy. Of the total 1,267 commercial farms in the county, 72 percent are classed as dairy farms (19).[1]

Approximately one-third of the county's cropland acreage is harvested for hay. But the average yield of the 52,300 acres in alfalfa and alfalfa mixtures was only 2 tons per acre in 1965 (6). However, individual fields produced annual yields of 5-6 tons per acre on a three cutting basis (11). Average alfalfa production probably could be increased to about 4 tons per acre with good management practices. To increase yields and profits from this important crop, a study of the factors affecting alfalfa production was needed.

The main objective of this survey was to investigate which soil fertility factors were primarily responsible for the relatively low alfalfa yields. This report presents data on:

- Chemical properties of four major soil types.
- Production practices followed.
- Chemical composition of alfalfa on 82 fields in Winona County.

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[1] Numbers in parentheses refer to the literature cited, pages 15 and 16.

Materials and Methods

Soils

Most farms in the relatively rolling eastern and northern parts of Winona County are dairy enterprises and produce some alfalfa. The predominant soil associations in this area are Fayette-Dubuque-Rough Land, Fayette-Dubuque, and Fayette-Tama. In the southwestern quarter of the county, on the Tama-Downs and Racine-Ostrander soil associations, less dairy and alfalfa and more grain crop and meat livestock farms are in evidence.

For this study, four major soils on which alfalfa is grown extensively were selected: Fayette, Dubuque, Tama, and Bertrand. These soils occupy 210,313 acres—about 52 percent of the land area in Winona County (4).

FAYETTE SILT LOAM, the predominant soil type in the county, covers 113,118 acres or about 28 percent of the total land area. This soil developed under mixed hardwoods in deep, windblown Peorian loess that, in some places, may be 8-10 feet thick (20). Occurring on gently sloping to steep slopes, Fayette is a well-drained soil with little organic matter. While the surface layer of Fayette soil normally is slightly acid, the subsoil is strongly acid. The extractable phosphorus (P) content of the subsoil is relatively high (9). Erosion control is a serious problem.

DUBUQUE SILT LOAM (DEEP PHASE), a light colored, moderately deep, well-drained soil of the uplands, occupies 45,467 acres. It formed under hardwood forest cover in a thin mantle of loess over limestone residuum or bedrock. The average depth to limestone residuum and bedrock is 24-42 inches (20). The subsoil is strongly acid; erosion control is important.

TAMA SILT LOAM is a well-drained, dark colored soil which developed under grass vegetation on deep Peorian loess. Occurring principally on gently sloping uplands, this soil covers 45,008 acres. The slightly acid surface soil is 10-14 inches thick. The slightly acid subsoil is friable silty clay loam or silt loam. Free lime usually is reached at 5-6 feet. Erosion is slight except on rolling slopes where it is moderate.

BERTRAND SILT LOAM is a well-drained, light colored soil. It developed under forest vegetation from deep silty materials on stream terraces. The subsoil is a silty clay loam. Occupying 6,650 acres, this soil occurs in most valleys of the county.

Under good management, Fayette and associated soils are very productive (9). Soil tilth problems are minor and moisture generally does not limit crop yields. With high management practices, the esti-

mated yield potentials for the most productive soils are about 100 bushels of corn and 4 tons of alfalfa hay per acre (14).

Soil test summaries (8) of samples received from southeastern Minnesota (Fayette-Dubuque and Tama-Downs areas combined) indicated the following:

- 64 percent of the samples had less than a 3.1-percent organic matter content—a relatively low level.
- One-third showed lime deficiency.
- 65 percent showed high and very high P levels.
- 80 percent showed medium and low potassium (K) levels.

Alfalfa Varieties

In Winona County, Vernal and Ranger alfalfa are the principal varieties grown. These well adapted, winter-hardy, and disease resistant varieties have a high yield potential. Also grown are various commercial blends and several Flemish varieties.

Severely cold weather and heavy ice cover during winter 1964-65 winterkilled about 50 percent of the established alfalfa stands. Many killed stands were the moderately winter-hardy Flemish varieties and blends or had been heavily grazed or harvested late in the fall, resulting in a serious depletion of root reserves.

Selection of Fields

For this survey on 56 different farms, 82 alfalfa production fields were selected; 21 were on Fayette, 20 on Dubuque, 20 on Tama, and 21 on Bertrand soils. From July 18 through August 1, 1965, samples were taken from stands of second crop alfalfa at approximately the one-tenth bloom stage. The selected fields had survived the adverse weather conditions during the winter and had at least a 50-percent stand of alfalfa.

Estimation of Alfalfa Stand and Yield

Alfalfa stands were estimated by both visual evaluation and a count method adapted from Stivers and Ohlrogge (18). If five alfalfa plants were found per square foot, an adequate stand was assumed.

Yield estimations were made according to the method developed by Alexander et al. (2). A 25½-inch square of ¼-inch plyboard was dropped onto the sward from waist-high level. The height in inches from the plyboard to the ground was measured at the four midpoints along the sides of the square and then summed to give the value "H" (height) for each random location. The value "H" then was inserted in the equa-

tion, 85 × H-190 = pounds of dry matter per acre. After measurements were repeated at three random locations in each field, results were averaged to obtain the estimated forage yield per acre in pounds of dry matter for that field.

The reliability of the method was tested by harvesting the forage from three 25½-inch square quadrats (each representing 0.0001 acre) on three different fields, weighing and air-drying the forage, and then calculating the yield of dry matter. By actual measurement, the average dry matter yield for the three fields was 2,687 pounds per acre, compared to the estimated yield of 2,641 pounds per acre. Therefore, a relatively close relationship between estimated and actual yields was obtained.

In an effort to further check the reliability of the yield estimates, farmer-cooperators were asked to weigh and count bales of harvested hay on five fields. Again, estimated and measured yields closely agreed.

Collection of Soil and Plant Samples

The soil was sampled in each field at three different depths: 0-3, 3-6, and 6-12 inches. These samples were collected at 10 random locations from a 1-2 acre area within each field.

As suggested by Chapman (5), the top 6-inch portions of about 30 mature (one-tenth bloom) alfalfa plants were collected at random from each field. Plant material was kept in plastic bags in a home deep-freeze until further processing was done in the laboratory.

At the time of sampling, information was obtained from farmer-cooperators on the age of stand and the amounts of lime, barnyard manure, and commercial fertilizers applied during the last 3 years.

Laboratory Procedures

Soil samples were air-dried for 7 days and analyzed at the University of Minnesota Soil Testing Laboratory.[2]

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 0.03 normal ammonium fluoride in 0.025 normal hydrochloric acid, commonly referred to as Bray's No. 1 extractant. One gram of soil and 10 milliliters of extractant were shaken for 1 minute. After filtering, 5 milliliters of solution were treated with ammonium molybdate and amino-napthol-sulfonic acid solutions. The resulting blue color was read with an absorption spectrophotometer.

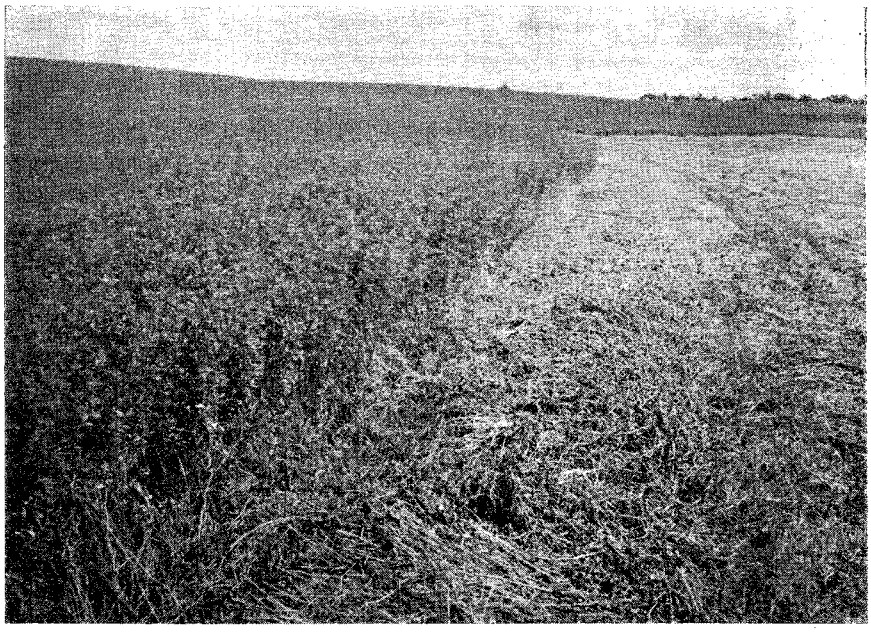
[2] See: J. Grava. Apr. 1962. *Soil Analysis Methods as Used in the University of Minnesota Soil Testing Laboratory.* Form 15-G. Institute of Agr. Univ. of Minn.

EXCHANGEABLE POTASSIUM—K was extracted with a solution of normal 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.

Alfalfa tissue samples were dried in an oven at 70° C. (158° F.) for 168 hours. Then the samples were ground in a Wiley mill with stainless steel blades and screen. Afterwards, the samples were submitted for analysis to the Ohio Plant Analysis Laboratory. A direct reading emission spectrograph was used to determine the concentrations of 16 elements in the dry matter of alfalfa (16). The sulfur (S) content in plant material was determined at the Department of Soil Science, University of Minnesota, by digestion with nitric and perchloric acid (3).

Evaluation of Data

For this study, the means and standard deviations and the analyses of variance were computed at the St. Paul Campus Computing Center. Linear and partial correlations and multiple regression equations and coefficients were calculated at the Minneapolis Campus Numerical Analysis Center.



Well managed alfalfa is an economical source of homegrown protein, vitamins, minerals, and energy for dairy enterprises in Winona County.

Results and Discussion

Soil pH and Liming Practices

Average pH values of soils at the 0-3, 3-6, and 6-12 inch sampling depths are given in table 1. The top 3 inches had an average pH of 6.6 for the 82 samples with no differences indicated between various soil types. A slight increase in the acidity—or decrease in pH values—was measured at the two lower sampling depths.

Soils on the 82 surveyed fields generally showed just slight acidity; liming was required in a few cases. No lime recommendations normally are made on soils having a pH of 6.3 or above. On 46 fields, the following acidity was found:

Sampling depth, inches	*Number of fields with pH less than 6.3*
0-3, 3-6, and 6-12	7
3-6 and 6-12 only	10
6-12 only	29

On the remaining 36 fields, pH values were above the 6.3 level at all three sampling depths.

The average field had received about 1.2 tons of agricultural limestone per acre during the last 3 years (see table 4). Actually, only 40 of the 82 fields had been limed; 38 fields had received 2-3 tons per acre of limestone and 2 fields had received 4 tons per acre.

Table 1. Average pH values of various soils at three sampling depths on 82 alfalfa fields in Winona County

Soil type	Sampling depth, inches		
	0-3	3-6	6-12
		soil pH	
Fayette sil	6.5	6.5	6.3
Dubuque sil	6.6	6.5	6.1
Bertrand sil	6.6	6.5	6.4
Tama sil	6.6	6.5	6.1
All soils	6.6	6.5	6.2
		C.V. percent*	
	4	5	6

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

Liming is accepted by many farmers in Winona County as a necessary prerequisite for alfalfa establishment. According to 1964 census data, 30,682 tons of liming materials were applied on 448 farms to 12,516 acres—an average of about 2.5 tons per acre (19). The federal cost-sharing program (ACP) probably can be credited for much of the lime used for alfalfa establishment.

Nevertheless, about 67 percent of the farmers are not following good liming practices. Since alfalfa draws many benefits from liming, the fields selected for this survey probably reflect better than average liming practices used in the county.

Even soil test summaries (8) sometimes fail to show the true liming needs of soils in an area since the most progressive farmers submit the most samples for testing. The extent of the subsoil acidity of the loess-derived soils in southeastern Minnesota was indicated by a regional investigation (13). The pH values in the profile, from 13 to 62 inches, of a Fayette silt loam in Winona County ranged from 5.1 to 5.4.

Extractable Phosphorus

Fayette and associated soils are relatively well supplied with P (8, 9). This condition was indicated by soil tests made on samples from the surveyed fields (see table 2). The average soil contained 39 parts per 2 million (pp2m) of extractable P in the upper 3 inches and 35 pp2m in the two lower layers. However, P test values of soils from different locations varied considerably, as indicated by the coefficient of variability (C. V.) of 106 percent. This variation probably was caused by the differences in fertilization practices.

Table 2. Average extractable phosphorus content of various soils at three sampling depths on 82 alfalfa fields in Winona County

Soil type	Sampling depth, inches		
	0-3	3-6	6-12
	extractable P, pp2m		
Fayette sil	48	43	47
Dubuque sil	19	18	30
Bertrand sil	39	32	33
Tama sil	48	45	29
All soils	39	35	35
	C.V. percent*		
	106	121	92

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

Table 3. Average exchangeable potassium content of various soils at three sampling depths on 82 alfalfa fields in Winona County

Soil type	Sampling depth, inches		
	0-3	3-6	6-12
	exchangeable K, pp2m		
Fayette sil	190	129	118
Dubuque sil	114	78	87
Bertrand sil	161	105	93
Tama sil	270	208	174
All soils	184	130	118
	C.V. percent*		
	69	84	76

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

The lowest extractable P contents—about 18-19 pp2m—were found in the 0-3 and 3-6 inch depths of Dubuque soils. However, the 6-12 inch depth averaged 30 pp2m. Soil tests showed slight decreases at the lower sampling depths in Tama and Bertrand soils. The average P content in Fayette soils was approximately the same throughout the upper 12 inches.

Exchangeable Potassium

The average content of exchangeable K in the upper 3 inches of the 82 soils was 184 pp2m, with a C. V. of 69 percent (table 3). While Tama soils had the highest K test levels, Dubuque soils had the lowest. Intermediate test levels were found in the Fayette and Bertrand soils.

Exchangeable K contents gradually decreased in the lower sampling depths, probably due to the relatively slow movement of topdressed K and P when applied to sod crops (7, 21). P remains mostly in the surface inch of soil with little or no movement below 3 inches. Although movement of K generally is slightly greater than that of P, most of it still remains concentrated in the upper 1 inch.

Fertilization Practices

Farmers of Winona County used some barnyard manure and commercial fertilizers to supply alfalfa with plant nutrients. The average field had received nearly 6 tons of manure per acre during a 3-year period (see table 4). However, the C. V. of 125 percent indicates that considerable variation existed in the use of manure. Actually, 41 fields

Table 4. Information on average stand, yield, liming, and fertilization of 82 alfalfa fields in Winona County

Variable	Soil type				All soils	
	Fayette sil	Dubuque sil	Bertrand sil	Tama sil		C.V. percent*
Age of stand, years	2.0	2.4	2.8	1.5	2.2	64
Stand, percent	78	77	75	78	77	20
Yield of second cutting hay, pounds per acre	2,234	2,504	2,664	2,507	2,477	27
Lime applied during a 3-year period, tons per acre	0.8	1.1	1.6	1.3	1.2	106
Manure applied during a 3-year period, tons per acre	7.6	3.4	7.6	4.9	5.9	125
Commercial fertilizer applied during a 3-year period, pounds per acre:						
N	7	2	3	8	5	158
P_2O_5	17	6	14	32	17	126
K_2O	26	5	12	37	20	138

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

had not received manure applications at all; rates varied from 6 to 20 tons per acre on fields receiving manure.

An average of 5 pounds N, 17 pounds P_2O_5, and 20 pounds K_2O per acre had been applied to soils during a 3-year period. However, only 37 of the 82 fields had received commercial fertilizer applications. Fertilizer had been used on 85 percent of the fields on Tama soils, 52 percent on Fayette, 29 percent on Bertrand, and only 15 percent on Dubuque.

Of the fertilized fields, 21 had received about 12, 48, and 48 pounds per acre of N, P_2O_5, and K_2O, respectively. The remaining 16 fields had received various amounts of plant nutrients, ranging from 120 pounds per acre of K_2O alone to 35 pounds per acre of each of the three major nutrients.

Of course, commercial fertilizers are mostly applied to cash crops such as corn. Of the 5,300 tons of commercial fertilizer used in Winona County in 1964, 85 percent was applied to corn and only 6 percent to hay and cropland pasture (19). Furthermore, of the 1,141 farms on

which alfalfa was grown, only 141 used commercial fertilizers for forage crops.

The relatively low usage of commercial fertilizers for alfalfa is alarming, especially in the light of the high amounts of nutrients removed by it. For example, 4 tons of alfalfa hay contain 18 pounds of P and 150 pounds of K (17). Since Fayette and associated soils contain relatively low amounts of exchangeable K (8, 9), and since little of this nutrient is supplied with commercial fertilizers, a K deficit probably exists in the alfalfa production on most Winona County farms.

Alfalfa Stand and Yield

The average alfalfa stand in the surveyed fields was 2.2 years old (table 4). The youngest stands were on Tama soils, averaging 1.5 years; the oldest were on Bertrand silt loam with an average of 2.8 years.

On the average, fields had 77 percent of alfalfa in the stand. According to correlation data, the percent of alfalfa in stands on Fayette soils decreased as the age of stand increased.

The average estimated yield of hay from second cutting alfalfa was nearly 2,500 pounds per acre (table 4). No significant relationships were found between yield and soil type. However, computations of multiple regression ($R^2 = 0.619$) indicated that 62 percent of the variation in alfalfa yields of the 82 fields was attributable to the combined effect of eight independent variables. The following multiple regression equation was obtained:

$$\text{Yield (pounds per acre)} = -4597.33 + 695.9X_1 + 1.26X_2 + 0.501X_3 + 52.3X_4 + 30.7X_5 - 3533X_6 + 211.5X_7 + 40.3X_8$$

Where X_1 = soil pH, 0-3 inch depth
X_2 = soil P (pp2m), 0-3 inch depth
X_3 = soil K (pp2m), 0-3 inch depth
X_4 = age of stand, years
X_5 = percent of alfalfa in stand
X_6 = plant P, percent
X_7 = plant K, percent
X_8 = plant B, ppm

Significant positive correlations (5-percent level) were indicated between the yield and soil pH, percent alfalfa in stand, and the boron (B) content in plant tissue. A significant negative correlation was obtained between plant P content and yield. No correlations were indicated between the yield and soil P, soil K, stand age, and plant K content.

Chemical Composition of Alfalfa

The chemical composition of plants is widely used as an index to their nutritional status; plant analysis is a useful diagnostic tool. Average

Table 5. Average chemical composition of alfalfa tissue collected from 82 fields in Winona County

Chemical element	Soil type: Fayette sil	Dubuque sil	Bertrand sil	Tama sil	All soils	C.V.
	percent in dry matter					percent*
Phosphorus	0.27	0.26	0.27	0.29	0.27	12
Potassium	1.47	1.39	1.18	1.53	1.39	24
Calcium	1.82	1.98	1.85	1.74	1.85	11
Magnesium	0.28	0.32	0.27	0.27	0.29	18
Sodium	0.03	0.03	0.02	0.03	0.03	68
Silicon	0.04	0.04	0.02	0.04	0.04	103
Sulfur	0.33	0.27	0.28	0.35	0.31	14
	parts per million in dry matter					
Boron	13	11	17	15	14	31
Manganese	46	53	43	40	45	21
Zinc	27	27	23	25	25	14
Copper	10	11	10	10	10	14
Iron	102	90	77	132	100	30
Aluminum	60	63	47	65	58	28
Molybdenum	0.94	1.40	0.94	0.80	1.02	50
Cobalt	0.51	0.68	0.60	0.53	0.58	24
Strontium	65	70	64	63	66	38
Barium	47	63	46	46	50	37

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

concentrations of 17 elements in the dry matter of alfalfa and the corresponding coefficients of variability are reported in table 5.

Compared to plants grown on other soil types, alfalfa grown on Dubuque silt loam showed significantly higher concentrations of these elements: calcium (Ca), magnesium (Mg), manganese (Mn), copper (Cu), molybdenum (Mo), cobalt (Co), and barium (Ba). Although the reasons for this occurrence are not known, differences in parent materials of the four soil types might be relevant. All four developed from loess. However, the loess mantle under the Dubuque soils is relatively thin, underlain by limestone or by cherty clay weathered from limestone. The clay or limestone usually is at a depth ranging from 2 to 3½ feet. Under the other three soils, limestone is either absent or found at considerably greater depths.

No significant relationships were indicated between the P content of alfalfa and soil type. But alfalfa grown on Bertrand silt loam had a significantly lower K content than plants from other soils.

The P content in alfalfa from the 82 fields was correlated with P soil test values for the three sampling depths. Similarly, K in plant tissue was closely related to the exchangeable K content of soils at all three sampling depths. The positive correlation which was found between the P and K contents of alfalfa apparently reflected the use of fertilizers containing both nutrients.

The B content of alfalfa from the 40 fields that had been limed during the 3-year period showed a significant decrease as the pH values of soils increased in the top 3 inches. Such a relationship between soil pH and plant B content was not found on the 42 unlimed fields.

To evaluate concentrations of these elements in alfalfa tissue from Winona County, comparisons had to be made with some established standards. Interpretation of plant analysis data of this survey was based on standards used currently at the Ohio Agricultural Experiment Station.[3] Data in table 6 show the percentage distribution of 82 alfalfa samples according to relative level of chemical elements.

Table 6. Percentage distribution of 82 alfalfa tissue samples from Winona County according to concentration and relative level of chemical elements

Chemical element	Relative level			
	Deficient	Low	Sufficient	High
Phosphorus (%)	<0.20*	0.20-0.25	0.26-1.00	>1.00
	0†	22	78	0
Potassium (%)	<1.75	1.75-2.00	2.01-4.50	>4.50
	88	7	5	0
Calcium (%)	<1.00	1.00-1.75	1.76-5.00	>5.00
	0	39	61	0
Magnesium (%)	<0.20	0.20-0.30	0.31-2.00	>2.00
	0	67	33	0
Boron (ppm)	< 20	20-30	31-80	> 80
	93	7	0	0
Molybdenum (ppm)	<0.5	0.5-0.9	1.0-10.0	>10.0
	7	45	48	0
Zinc (ppm)	< 11	11-20	21-70	> 70
	0	9	91	0
Manganese (ppm)	< 20	20-30	31-250	>250
	0	1	99	0

* Upper figure = nutrient concentration in plant tissue.

† Lower figure = percent of total samples.

[3] J. B. Jones, Jr. 1966. Standards used by the Plant Analysis Laboratory, Ohio State University. Personal communications.

In Summary

Alfalfa is the most important forage crop grown in Winona County. However, yields are relatively low; many fields produce less than 2 tons of hay per acre. Under proper management, average yields could be increased to about 4 tons per acre. Since crop yields are greatly affected by soil fertility, a survey was conducted to determine which of the various plant nutrients may limit alfalfa production. Eighty-two alfalfa fields, on four major soil types, were investigated. Because the fields were selected on the basis of winter survival and had at least 50 percent of the alfalfa in stand, they apparently represented above average production fields in Winona County.

The average alfalfa stand was 2.2 years old and had about 77 percent of alfalfa in stand. The average estimated yield of hay from the second cutting was approximately 2,500 pounds per acre. No significant relationships were found between yield and soil type. But yield was related to soil pH, percent alfalfa in stand, and the B content of plant tissue.

The average pH value of the upper 6 inches was 6.5; only seven fields had pH levels that required liming. A slight increase in soil acidity was measured at the 6-12 inch depth. Only half of the fields had received lime applications during a 3-year period; the most frequently used rates were 2-3 tons of limestone per acre. Soil acidity did not appear to be a serious problem on these fields. However, alfalfa most likely could benefit from liming on the numerous Winona County farms where lime is not used.

Fayette and associated soils of southeastern Minnesota are well supplied with P. The P content in alfalfa was related to P soil tests. Similarly, K in plant material was related to K soil tests.

The average content of exchangeable K in the upper 3 inches of soil was 184 pp2m. K test values gradually decreased at lower sampling depths, probably due to the relatively slow movement of top-dressed K. A serious K deficiency in alfalfa was indicated by plant analysis; 95 percent of the samples fell in the deficient and low categories.

Barnyard manure had been used on half of the fields at rates from 6 to 20 tons per acre. Thirty-seven fields had received commercial fertilizer applications. The most frequently used fertilizers added about 12, 48, and 48 pounds per acre of N, P_2O_5, and K_2O, respectively, over 3 years. According to 1964 census data, fertilizer was applied directly to alfalfa on only 12 percent of the farms in Winona County. Since alfalfa requires large amounts of K, and since the soils are not well supplied

with it, the low usage of commercial fertilizers for alfalfa production is alarming.

- Spectrographic analysis indicated relatively low concentrations of B in alfalfa tissue. Since 93 percent of the plant samples were classed as B deficient and 7 percent as low, B could be limiting alfalfa production on many fields. However, there is no experimental evidence of alfalfa yield increases from B applications on southeastern Minnesota soils (12, 15).

- Some deficiency in alfalfa of Ca, Mg, and Mo was indicated by plant analysis. These shortages can be eliminated by applications of dolomitic limestone. Although liming and molybdenum treatments in greenhouse studies with Fayette soils increased Mo concentration in alfalfa, they did not affect yield or protein content (1).

- No apparent lack of Zn, Mn, and S in alfalfa was indicated by plant analysis.

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