# A Report on Soils and Soil Fertility

(A compilation of recent experimental results by personnel of the Department of Soils and Extension Specialists and Agronomists at the Branch Stations at Crookston, Duluth, Grand Rapids, Lamberton, Morris, Rosemount, and Waseca).

Department of Soils
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February, 1961

Some of the results herein reported are from experiments carried on during 1960 only, and should not be regarded as the results obtained over a number of years. The investigations are those of a more practical nature, and do not include some of the more theoretical probelms presently under study in greenhouse and in the laboratory. Because these are largely one year results they should not be considered as conclusive and the results are not for publication.

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# The Weather of 1960

Donald G. Baker

The winter of 1959-60 (December, January, and February) was much milder than usual. The state-wide rains of December 27-28, 1959, brought the soil moisture up to a higher amount than is usual for soils to have over winter. These rains together with the mild temperatures and the fact that the cold periods were usually preceded by a snowfall decreased frost penetration to perhaps 50-75% of the usual depth.

Spring was characterized by cool temperatures and heavy rains. March, 1960, was the second coldest on record and April was too wet for field work, although it was dry enough in north-central Minnesota to create a fire hazard until this area received mid and late May rains. Excessive precipitation fell in south-central and southeastern Minnesota May 16-22 with a 24 hour record, 5.71 inches, occurring at Jordan on May 21. Planting was delayed over most of Minnesota due to the cool and wet season.

Summer weather continued to plague planting due to a wet and cool June. Many fields, particularly in south-central Minnesota, were flooded and had to be replanted. High temperatures occurred in the last half of July and during August together with an extended period during which little rain fell.

Normal September temperatures hastened the maturity of the late developing corn and by September 30 about 85% of the crop was safe from frost damage. In the west-central and central part of the state growing season precipitation was above normal, although much of it fell late in the season and was of little benefit to the crops. The northern protion of the state and even as far south as east-central Minnesota has less than normal precipitation during the growing season.

Except for the south-central and southeastern portions of the state the soil moisture content was lower than usual with the approach of winter 1960-1961. This fact together with the extremely low snowfall in fome areas of the state has resulted in the frost being deeper than usual.

Based upon the above situation we can make the following forecast

1. A late spring heavy snowfall followed by rapid melting will result in flooding with little of the meltwater entering the soil.
2. Without normal to above normal spring rains most areas, except the south-central and southeast, will be in precarious soil moisture condition.
3. A windy and dry spring will result in extensive wind erosion.
4. If spring rains are both sufficient in amount and low in intensity, the soils should soon be thawed, even though frost may be deeper than usual, since their relative dryness means less heat will have to be expended to thaw the soil. This does not include south-central and southeast Minnesota where soil moisture is normal to above normal.

(Source: Strub, J. H., Jr., 1960. Climatological Data, Minnesota)

# Soil Moisture Regime Under Corn in Southern Minnesota

Donald G. Baker and Lowell Hanson

Soil test correlation plots were again established in numerous counties for the 1960 season by Lowell Hanson and the Soils Extension staff with the cooperation of the county agents. In addition to the study of fertilizer rates and method of application the soil moisture regime of the corn crop during the course of the season was also considered.

Precipitation data were obtained from the record maintained by the farmer or the nearest observing station of the U.S. Weather Bureau. Soil moisture measurements at the beginning of the season were obtained through the cooperation of the Soil Conservation Service and at the end of the season by Donald Baker. The moisture status of the soil during the growing season was accomplished by calculation.

Results are shown in Table 1. The yields listed in Table 1 are those from the plots fertilized at the rate of 100# N, 100# $P_2O_5$ and 100# $K_2O$ per acre. The 100# $P_2O_5$ was applied broadcast at 70# per acre and 30# per acre now placed. The four rows of figures shown by month are as follows:

1. Precipitation: total rainfall that fell during each month.
2. Consumption: amount of water used by plants in transpiration and lost from the soil by evaporation.
3. Deficit: the amount of water required to bring the soil moisture up to field capacity. If soil moisture is maintained at field capacity it is believed that maximum plant growth will occur from the standpoint of soil moisture. The greater the deficit the more important becomes soil moisture as a growth factor.
4. Surplus: The amount of water in the soil in excess of field capacity content. This excess water reduces the volume occupied by air. This excess or surplus water is lost either through drainage or runoff. If it remains too long then plants suffer due to lack of sufficient air and especially oxygen.

Inspection of Table 1 indicates that in none of the counties shown was soil moisture seriously lacking or greatly in excess. Thus major differences in yield were essentially due to other climatic or soil fertility and soil physical factors than simply soil moisture.

Soil moisture may have played some part in yield differences, however, as shown in Table 2. June soil moisture did not appear to be critical at any of the plots (Table 1), except possibly in Rock county. The large June deficit at Rock county is a bit deceiving for there was still a large amount of water available to the plants due to the nature and depth of the Moody soil. The months of July and August may well be the most critical months during the growing season, for it is at this time that tasseling occurs and the ears are being filled. In Table 2 some relationship can be seen between yield and soil moisture deficit. However, it will pay to repeat that the data in Table 1, especially, indicate that soil moisture was not the major factor in corn yields this year in these counties.

Table 1. Yield, precipitation, and soil moisture regime in 1960 in six Minnesota counties, 1960

| Yield in Bu. per acre | County and Soil Type | Precipitation, moisture consumption and soil moisture deficit and surplus, in inches, during the season. | May | June | July | Aug. | Sept. | Oct. | Nov. | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 78.7 | Benton Co. Parent Loam | Precipitation | 1.15 | 4.27 | 1.77 | 4.52 | 1.74 | 0.48 | 0.05 | 13.98 |
| | | Consumption | 0.50 | 4.29 | 4.90 | 4.92 | 4.97 | 2.31 | 0.00 | 21.89 |
| | | Deficit | — | 0.02 | 3.13 | 0.40 | 0.40 | 1.83 | — | 8.61 |
| | | Surplus | 1.28 | — | — | — | — | — | 0.05 | 1.33 |
| 72.8 | Dakota Co. Ostrander Silt Loam | Precipitation | 0.35 | 4.75 | 1.00 | 3.60 | 5.45 | 0.60 | 0.00 | 15.75 |
| | | Consumption | 0.33 | 4.26 | 3.68 | 4.27 | 3.43 | 1.24 | 0.00 | 17.21 |
| | | Deficit | 3.18 | — | 2.68 | 0.67 | — | 0.64 | — | 7.17 |
| | | Surplus | — | 0.49 | — | — | 2.02 | — | — | 2.51 |
| 124.5 | Kandiyohi Co. | Precipitation | 0.00 | 2.91 | 3.10 | 8.10 | 1.80 | 0.93 | 0.00 | 16.84 |
| | | Consumption | 0.29 | 4.01 | 5.07 | 5.08 | 2.87 | 1.51 | 0.00 | 18.83 |
| | | Deficit | 2.54 | 1.10 | 1.97 | — | 1.07 | 0.58 | 0.00 | 7.26 |
| | | Surplus | — | — | — | 3.02 | — | — | — | 3.02 |
| 107.2 | Redwood Co. Nicollet Clay Loam | P | 0.60 | 5.20 | 5.20 | 5.90 | 3.75 | 0.62 | 0.00 | 21.27 |
| | | C | 0.55 | 4.64 | 5.85 | 5.40 | 3.43 | 1.71 | 0.00 | 21.58 |
| | | D | — | — | 0.65 | — | — | 1.09 | — | 1.74 |
| | | S | 0.71 | 0.56 | — | 0.50 | 0.32 | — | — | 2.09 |
| 96.2 | Rock Co. Moody Silt Loam | Precipitation | — | 3.10 | 2.30 | 5.09 | 2.60 | 0.86 | 0.10 | 14.05 |
| | | Consumption | — | 5.03 | 5.85 | 5.04 | 3.43 | 1.71 | 0.00 | 21.06 |
| | | Deficit | — | 6.01 | 3.55 | — | 0.83 | 0.85 | — | 11.24 |
| | | Surplus | — | — | — | 0.05 | — | — | 0.10 | 0.15 |
| 86.5 | Swift Co. Vallers | Precipitation | 2.00 | 3.30 | 2.40 | 7.60 | 2.50 | 1.49 | .T* | 19.29 |
| | | Consumption | 0.33 | 4.26 | 5.89 | 5.08 | 3.12 | 1.69 | 0.00 | 20.37 |
| | | Deficit | 0.89 | 0.96 | 3.49 | — | 0.62 | 0.20 | — | 6.06 |
| | | Surplus | — | — | — | 2.52 | — | — | — | 2.52 |

*T signifies trace of precipitation, i.e., less than 0.01 in.

Table 2. Yield and total soil moisture deficit of July and August.

| County | Yield | Total July and August deficit |
|---|---|---|
| Kandiyohi | 124.5 bu./A. | 1.97 in. |
| Redwood | 107.2 | 0.65 |
| Rock | 96.2 | 3.55 |
| Swift | 86.5 | 3.49 |
| Benton | 78.7 | 3.53 |
| Dakota | 72.8 | 3.35 |

## Soil Productivity Study

R. H. Rust

The soil productivity study which began in 1956 is an attempt to gain reliable estimates of the productivity of major soil types in Minnesota. This productivity is estimated for the major crops under several generally specified soil management programs. The estimates are incorporated in the soil survey reports published for the individual counties by the Soil Conservation Service, USDA, and The Experiment Station, cooperatively.

Since the project began 369 farm cooperators have furnished crop and soil management data on some 95 extensive soil types in the state. Currently 287 cooperators are enrolled in the project. The following kinds of data are recorded: date and rate of seeding; stand estimate; kind and amount of soil amendments used; moisture and temperature conditions during the growing season; weed and insect control measures; yields and losses of yield from harvesting or abnormal conditions; soil tests of pH, available P and K, organic matter.

Since it is planned that productivity estimates be based on multiple regression analysis and since there are a number of factors to be studied, a relatively large number of observations (generally more than 30) of each crop on each soil is necessary in order to establish reliability. In addition, the evaluation of yield variation associated with weather observations (chiefly rainfall and temperature) necessitates collection of data over several years.

In the following table the various soils included in the study are listed together with (1) number of fields, and (2) number of yields. Where 2 or more yields of a crop have been recorded, the crops, number of fields, and the average yields are given. The reader may establish the location of the listed soils by reference to Soils of Minnesota, Ext. Bul. 278, or to the appropriate county soil report.

It should be noted emphatically that the average yields listed do not necessarily reflect the relative productivity of the soils listed. They serve only to indicate the nature of yield levels attained in the last one to four years by farmers who are in general using above average management. Many of the yields also reflect very favorable weather patterns as well as very unfavorable seasons. For those personnel concerned the data may serve to indicate where additional effort is needed.

The results of a multiple regression analysis based on a study of corn yields on groups of somewhat similar soils will be presented in a forthcoming issue of Farm and Home Science.

Table 1. Soil series, number of fields, and number of yields included in soil productivity study to date. Average yields of selected crops given where two or more yields received.

* Number of fields on this series
** Number of yields of all crops

| | | |
|---|---|---|
| **Aastad** | (7) | (21) |
| Corn | 5 | 31 |
| Oats | 3 | 76 |
| Soybeans | 2 | 19 |
| Barley | 3 | 49 |
| **Afton** | (1) | (0) |
| **Anoka** | (1) | (1) |
| **Barnes** | (18) | (47) |
| Corn | 12 | 53 |
| Soybeans | 7 | 24 |
| Barley | 2 | 40 |
| Oats | 9 | 64 |
| Alfalfa | 4 | 2.0 |
| Alfalfa-Brome | 4 | 3.0 |
| Wheat | 2 | 27 |
| Flax | 4 | 14 |
| **Bearden** | (1) | (5) |
| **Beltrami** | (2) | (2) |
| **Blue Earth** | (2) | (5) |
| Corn | 2 | 85 |
| **Braham** | (1) | (0) |
| **Brainerd** | (1) | (4) |
| **Buse** | (2) | (6) |
| Alfalfa-Brome | 3 | 1.8 |
| **Central** | (2) | (4) |
| **Chilgren** | (3) | (7) |
| **Clarion** | (30) | (74) |
| Corn | 28 | 75 |
| Soybeans | 5 | 30 |
| Oats | 16 | 68 |
| Sp. Wheat | 3 | 35 |
| Alfalfa | 8 | 2.6 |
| Alfalfa-Brome | 9 | 3.0 |
| Corn Silage | 3 | 11.5 |
| **Colvin** | (2) | (7) |
| Alfalfa | 2 | 4.0 |
| Corn | 2 | 54 |
| **Comfrey** | (1) | (4) |
| Corn | 2 | 59 |
| **Cormant** | (2) | (8) |
| Wheat | 2 | 23 |
| Oats | 2 | 65 |
| **Dakota** | (1) | (2) |
| **Downs** | (2) | (5) |
| Corn | 2 | 131 |
| **Dubuque** | (1) | (1) |
| **Dundas** | (4) | (9) |
| Corn | 2 | 54 |
| Oats | 2 | 70 |
| Alfalfa | 2 | 1.7 |
| **Enstrom** | (1) | (4) |
| Alfalfa-Brome | 3 | 1.5 |
| **Estelline** | (1) | (4) |
| **Esterville** | (10) | (26) |
| Corn | 11 | 70 |
| Oats | 4 | 40 |
| Alfalfa-Brome | 7 | 1.8 |
| Corn Silage | 3 | 6.4 |
| **Fair Haven** | (3) | (8) |
| Corn | 5 | 75 |
| Oats | 2 | 70 |
| **Fargo** | (6) | (19) |
| Oats | 2 | 36 |
| Soybeans | 3 | 23 |
| Barley | 2 | 44 |
| Flax | 2 | 12 |
| Wheat | 2 | 38 |
| **Fayette** | (6) | (18) |
| Corn | 6 | 110 |
| Oats | 3 | 81 |
| Leg-Grass Mixt. | 2 | 3.6 |
| **Fielden** | (1) | (1) |
| **Flom** | (6) | (9) |
| Oats | 4 | 46 |
| Corn | 2 | 94 |

| | | |
|---|---|---|
| Floyd | (2) | (8) |
| Corn | 3 | 90 |
| Oats | 2 | 80 |
| Freer | (2) | (6) |
| Oats | 2 | 62 |
| Freon | (1) | (2) |
| Glenco | (1) | (1) |
| Greenbush | (1) | (1) |
| Grimstad | (4) | (12) |
| Oats | 2 | 70 |
| Barley | 3 | 43 |
| Grygla | (2) | (3) |
| Harpster | (1) | (1) |
| Hayden | (21) | (49) |
| Cprn | 19 | 94 |
| Oats | 10 | 60 |
| Alfalfa | 8 | 2.8 |
| Alfalfa-Brome | 5 | 3.2 |
| Hegne | (1) | (3) |
| Hubbard | (12) | (31) |
| Corn | 12 | 67 |
| Soybeans | 6 | 20 |
| Alfalfa | 4 | 2.7 |
| Oats | 6 | 50 |
| Kenyon | (1) | (3) |
| Corn | 2 | 87 |
| Kittson | (2) | (7) |
| Corn | 2 | 52 |
| Kranzburg | (4) | 9 |
| Corn | 2 | 65 |
| Flax | 4 | 12 |
| Alfalfa | 2 | 2.2 |
| Lamoure | (1) | (3) |
| Corn | 2 | 55 |
| Lester | (11) | (29) |
| Corn | 8 | 67 |
| Oats | 6 | 55 |
| Alfalfa | 3 | 4.5 |
| Alfalfa-Brome | 4 | 3.1 |
| Barley | 2 | 40 |
| LeSueur | (4) | (11) |
| Corn | 4 | 57 |
| Soybeans | 2 | 23 |
| Marna | (4) | (8) |
| Corn | 7 | 101 |
| McIntosh | (1) | (4) |
| Sp. Wheat | 3 | 30 |
| Menahga | (1) | (3) |
| Oats | 2 | 24 |
| Milaca | (3) | (9) |
| Mix. Leg-Grass | 5 | 1.8 |
| Moody | (1) | (3) |
| Corn | 3 | 67 |
| Nebish | (5) | (18) |
| Oats | 7 | 51 |
| Alfalfa | 5 | 1.3 |
| Alfalfa-Brome | 3 | 2.2 |
| Nicollet | (17) | (41) |
| Corn | 23 | 81 |
| Oats | 6 | 47 |
| Barley | 2 | 94 |
| Soybeans | 3 | 28 |
| Wheat | 2 | 48 |
| Nokay | (1) | (5) |
| Corn | 2 | 68 |
| Norwalk | (1) | (3) |
| Onamia | (2) | (8) |
| Corn | 4 | 68 |
| Oats | 2 | 68 |
| Alfalfa | 2 | 2.5 |
| Ostrander | (4) | (9) |
| Corn | 3 | 98 |
| Alfalfa | 2 | 3.2 |
| Parnell | (1) | (3) |
| Corn | 2 | 45 |
| Pierce | (1) | (1) |
| Rooksbury | (2) | (4) |
| Sweetclover-Brome | 2 | 1.6 |
| Shooks | (1) | (0) |
| Sioux | (1) | (3) |
| Oats | 2 | 20 |
| Sletten | (1) | (1) |
| Skyberg | (2) | (6) |
| Corn | 2 | 94 |
| Oats | 2 | 88 |
| Tama | (3) | (13) |
| Oats | 3 | 58 |
| Corn | 2 | 106 |
| Alfalfa-Brome | 2 | 4.8 |
| Mixed Leg-Grass | 3 | 3.1 |

| | | |
|---|---|---|
| Terril | (1) | (3) |
| Corn | 2 | 120 |
| Thurman | (1) | (1) |
| Todd | (1) | (0) |
| Truman | (2) | (6) |
| Corn | 4 | 93 |
| Ulen | (3) | (11) |
| Corn | 4 | 61 |
| Oats | 3 | 50 |
| Alfalfa | 2 | 2.6 |
| Varco | (1) | (3) |
| Corn | 2 | 27 |
| Alfalfa-Brome | 2 | 2.8 |
| Vienna | (1) | (2) |
| Corn | 1 | 60 |
| Wadena | (3) | (8) |
| Corn | 3 | 75 |
| Oats | 3 | 72 |
| Waukegan | (6) | (21) |
| Corn | 8 | 83 |
| Oats | 4 | 76 |
| Alfalfa-Brome | 2 | 3.5 |
| Soybeans | 2 | 31 |
| Waukon | (6) | (16) |
| Corn | 4 | 64 |
| Oats | 3 | 66 |
| Alfalfa | 6 | 2.5 |
| Barley | 2 | 56 |
| Webster | (28) | (67) |
| Corn | 34 | 78 |
| Soybeans | 9 | 23 |
| Oats | 10 | 68 |
| Alfalfa | 5 | 3.1 |
| Alfalfa-Brome | 6 | 2.4 |
| Corn Silage | 3 | 9.5 |
| Wildwood | (1) | (2) |
| Winger | (1) | (5) |
| Alfalfa | 2 | 1.1 |
| Barley | 2 | 42 |
| Zimmerman | (3) | (8) |
| Corn Silage | 2 | 11.5 |
| Corn | 2 | 80 |
| Mora | (2) | (5) |

| | | |
|---|---|---|
| Vallers | (5) | (9) |
| Corn | 3 | 53 |
| Soybeans | 4 | 20 |
| Litchfield | (1) | (3) |
| Lerdal | (2) | (9) |
| Corn | 4 | 80 |
| Alfalfa | 2 | 2.0 |
| Spooner | (1) | (0) |
| Buse-Barnes | (3) | (7) |
| Alfalfa | 2 | 2.0 |
| Alfalfa-Brome | 3 | 1.6 |
| Storden-Clarion | (1) | (2) |
| Oats | 2 | 80 |
| Webster Calc. Var. | (8) | (14) |
| Corn | 5 | 62 |
| Oats | 2 | 30 |
| Soybeans | 2 | 66 |
| Alfalfa | 2 | 2.2 |
| Colvin ALK phase | (1) | (2) |
| Corn | 2 | 54 |
| Comfrey Cal. Var. | (1) | (1) |
| Shallow Peat | (2) | (4) |
| Deep Peat | (3) | |
| Soybeans | 2 | 24 |
| Corn Silage | 3 | 9.7 |
| Wabash | (1) | (3) |
| Kingston | (3) | (7) |
| Corn | 5 | 91 |
| Kato Calc. Var. | (1) | (2) |
| Arlington | (1) | (2) |
| Hammerly | (1) | (1) |
| Indus | (1) | (0) |
| Misc. | (21) | (4) |
| | No. Fields | No. Yields |
| Grand Total as of January 10, 1961 | (358) | (850) |

## Soil Testing in Minnesota During 1960
By John Grava

Currently the University of Minnesota Soil Testing Laboratory tests about 36,000 samples annually. The following data show the number of various types of samples analyzed in 1960:

| | | |
|---|---|---|
| Regular farm, garden, and lawn samples | | 33,955 |
| Florist (Greenhouse) samples | | 1,247 |
| Limestone samples | | 144 |
| Departmental research samples | | 1,210 |
| | Total | 36,556 |

Because of adverse weather conditions during the spring of 1960, the prospects of exceeding or even reaching the number of 33,491 farm, lawn, and garden samples tested in 1959 seemed very remote indeed. Only 12,000 samples were received during the first eight months as compared to 21,000 for the same period in 1959. Fortunately, weather conditions during the last four months of the year were extremely favorable for sample collection. Consequently, the "Fall Soil Sample Round-Up" campaign organized by the Agricultural Extension Service, with participation of fertilizer and lime industries, bankers and Vocational Ag. Instructors, really paid off. Close to 22,000 samples were collected during this campaign. Figure 1 shows monthly distribution of samples received by the laboratory during 1960.

Generally 7 to 9 days are required for sample processing (Table 1). However, the unusual sample rush in October, when over 2500 samples were received in a single week, caused a certain delay in getting test results returned to county agents for recommendations. A sample rush in the fall, however, is preferable to one in the spring. Fall sampling and testing permits plenty of time for farmers to receive and use sound recommendations before spring planting.

Table 1. The number of days required for soil sample processing in 1960

| Month | Monthly Average Days |
|---|---|
| January | 7 |
| February | 7 |
| March | 9 |
| April | 7 |
| May | 8 |
| June | 11 |
| July | 10 |
| August | 8 |
| September | 9 |
| October, first half | 7 |
| second half | 15 |
| November | 24 |
| December | 21 |

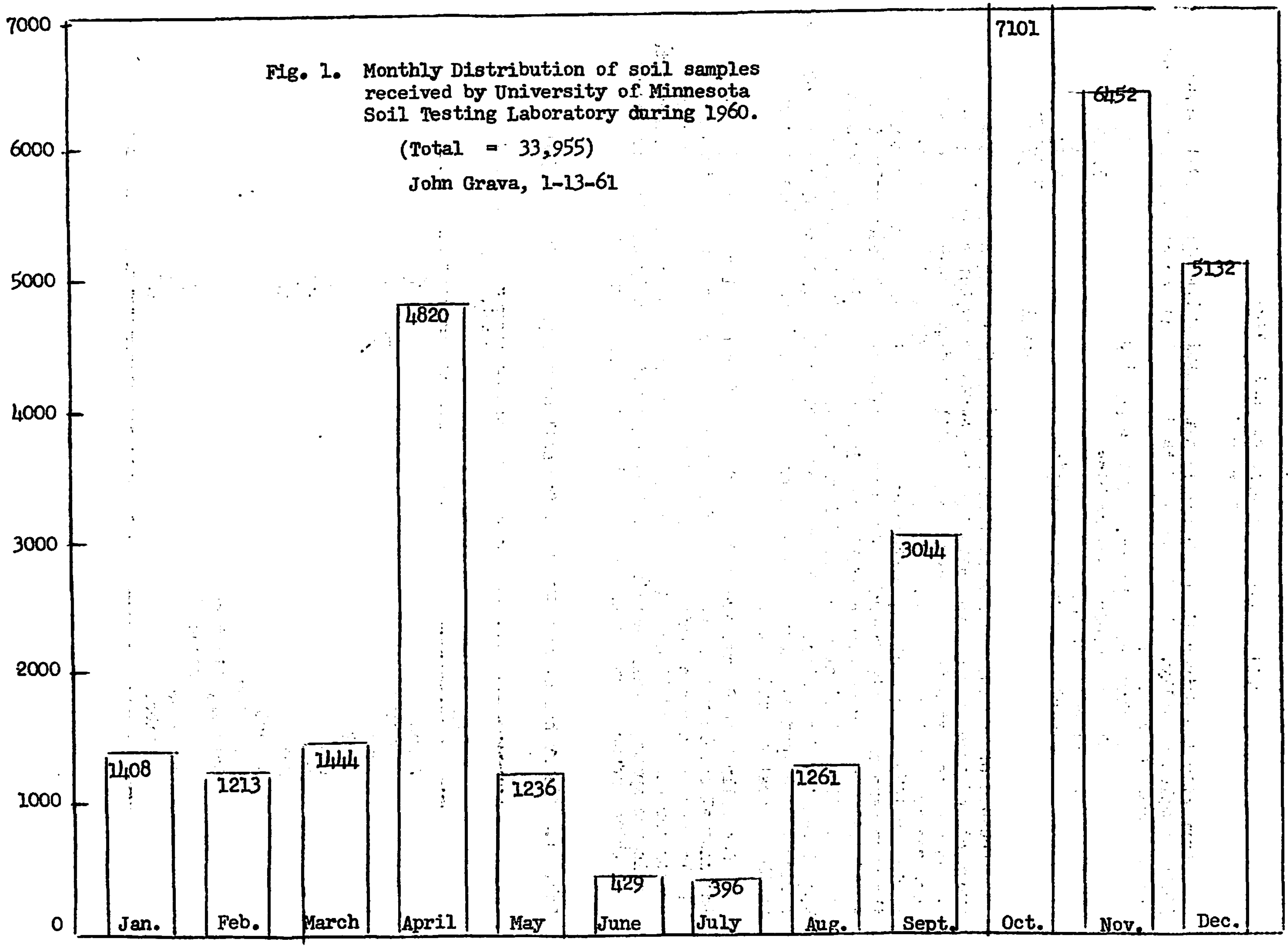


Fig. 1. Monthly Distribution of soil samples received by University of Minnesota Soil Testing Laboratory during 1960.

(Total = 33,955)

John Grava, 1-13-61

# Progress Report on N.C.-16 Nitrogen Projects

Minnesota Agricultural Experiment Station
December, 1960

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## Studies on Residual Nitrogen Effect.

Wheat was planted in the spring of 1960 on the two 1958-1959 $Ca(NO_3)_2$ -$(NH_4)_2SO_4$ fall-spring-summer treated corn fields. At Crookston, unusually heavy late June rains resulted in some flooding and a heavy growth of wild oats which essentially ruined the residual nitrogen effect study of spring wheat yield on the flat, fine-textured Hegne soil. The residual wheat crop on the Barnes silt loam at Morris showed marked residual nitrogen effect, and five of the six replicates were sampled for yield. Per acre yields of the 1960 wheat and of the 1959 corn of this Morris field are shown in Table 1. The 1959 corn yield was reduced by a late summer drowth.

Table 1. - Yields of 1960 Wheat and of Preceding 1959 Corn with Variable Nitrogen Fertilization in 1958-1959.

| Treatment Label | Treatment lbs. N/A[1] | 1960 Wheat (bu/A) | | 1959 Corn (bu/A) | |
|---|---|---|---|---|---|
| | | Yield | Increase | Yield | Increase |
| A | 80 N, $Ca(NO_3)_2$, May, 1959 | 35.1 | 20.7 | 40.5 | 3.3 |
| B | 80 N, $Ca(NO_3)_2$, Nov., 1958 | 30.0 | 15.6 | 44.5 | 7.3 |
| C | 80 N, $(NH_4)_2SO_4$, Summer, 1959 | 29.5 | 15.1 | 45.3 | 8.1 |
| D | 80 N, $Ca(NO_3)_2$, Summer, 1959 | 28.0 | 13.6 | 45.2 | 8.0 |
| E | 80 N, $(NH_4)_2SO_4$, Nov. 1958 | 27.2 | 12.8 | 40.6 | 3.4 |
| F | 40 N, $Ca(NO_3)_2$, May, 1959 | 26.4 | 12.0 | 40.0 | 2.8 |
| G | 40 N, $Ca(NO_3)_2$, Nov., 1958 | 26.2 | 11.8 | 44.2 | 7.0 |
| H | 40 N, $(NH_4)_2SO_4$, Nov. 1958 | 25.2 | 10.8 | 38.6 | 1.4 |
| I | 80 N, $(NH_4)_2SO_4$, May, 1959 | 24.5 | 10.1 | 51.8 | 14.6** |
| J | 40 N, $(NH_4)_2SO_4$, May, 1959 | 22.8 | 8.4 | 35.3 | 8.1 |
| K | 40 N, $(NH_4)_2SO_4$, Summer, 1959 | 19.1 | 4.7 | 37.4 | 0.2 |
| L | 40 N, $Ca(NO_3)_2$, Summer, 1959 | 17.4 | 3.0 | 45.6 | 8.4 |
| M | Check | 14.4 | -- | 37.2 | -- |

[1] Entire area received broadcast application of 0-20-20 at rate of 500#/A.

The only significant difference was in rate of N treatment on the residual wheat yields, but there was a trend toward slightly higher yields with the nitrate form of nitrogen.

Since several recently published investigations have emphasized gaseous losses of ammonia nitrogen from urea applied at different depths in soils of varying texture, pH, moisture, etc., both field and laboratory experiments have been used to study such losses and their effect on crop yield and composition. Two short term field experiments, (one on wheat and the other on corn), were established on the Hegne clay loam at Crookston in northwestern Minnesota, and one long term (10 year) experiment on Nicollet-Webster silty clay loam in southwestern Minnesota. The effect of urea and of ammonium nitrate nitrogen on crop yields were compared with different rates, times, and depths of application. A broadcast application of 0-20-20 at the rate of 500 pounds per acre was made over the entire experimental area and disked in before seeding. The boot stage nitrogen treatments were broadcast on July 6th, nearly two months after the first treatments were made. The resulting wheat yields and increases are shown in Table 2.

Table 2. The effect of N source, time of application, and disking in on yield and composition of 1960 wheat at Crookston (Hegne Clay Loam) and fertilizer N recovery.

| Treatment (N in lbs/A)[1] | bu/A | Sig. diff. (5%) | % Protein Grain | % N Straw | % N Recovery |
|---|---|---|---|---|---|
| 20 (urea) bdct. at boot stage | 6.7 | | 13.5 | 0.62 | -4 |
| 40 ($NH_4NO_3$) " " " " | 7.9 | | 15.0 | 0.65 | 12 |
| Check | 8.2 | | 13.0 | 0.47 | -- |
| 20 ($NH_4NO_3$) bdct. bef. seeding, disked | 11.7 | | 12.5 | 0.36 | 26 |
| 40 (urea) bdct. at boot stage | 11.9 | | 13.7 | 0.64 | 14 |
| 20 ($NH_4NO_3$) " " " " | 12.6 | | 13.1 | 0.56 | 33 |
| 20 (urea) bdct. bef. seeding, disked | 15.9 | | 12.5 | 0.42 | 50 |
| 20 (urea) bdct. after seeding, left on surface | 16.1 | | 12.8 | 0.36 | 56 |
| 20 ($NH_4NO_3$) " " " " " | 16.7 | | 12.8 | 0.43 | 73 |
| 40 (urea) bdct. bef. seeding, disked | 19.6 | | 9.2 | 0.38 | 37 |
| 40 (urea) bdct. after seeding, left on surface | 19.7 | | 12.6 | 0.42 | 39 |
| 40 ($NH_4NO_3$) bdct. " " " " | 21.3 | | 13.1 | 0.41 | 28 |
| 40 ($NH_4NO_3$) " bef. seeding, disked | 22.7 | | 13.2 | 0.41 | 50 |

Average N recovery from $NH_4NO_3$ = 37%
" " " " urea = 39%

[1]Entire area treated with 0-20-20 at 500 lb/A rate.

Using the Student-Newman-Keuls multiple range test, the first five fertilizer treatments do not differ significantly from the check. The 20 pound per acre nitrogen treatments are closely grouped, followed by the heavier treatments. There was no consistent difference for nitrogen source of disking in of one of the two earlier treatments, which does not coincide with some recently reported laboratory studies.

The Crookston corn plots were seriously damaged by flooding and runoff, during the 4.2 inch rain of June 27th. One set of treatments (40 pounds of N as urea applied in early spring and left on the surface) set few or no ears, and no yield was obtainable. The yields (with no statistical analysis attempted) are shown in Table 3.

Table 3. The effect of nitrogen source, time of application, and placement on the yield and composition of 1960 ear corn at Crookston and recovery of fertilizer nitrogen. (Hegne Clay Loam)

| Treatment (lbs N/A)[1] | Ear Corn | | Fodder | | % N Recovery |
|---|---|---|---|---|---|
| | bu/A | % Protein | T/A | % N | |
| Check | 52.9 | 8.5 | 1.18 | 0.95 | --- |
| 40 as $NH_4NO_3$-disked in early spring | 63.1 | 8.7 | 1.15 | 0.95 | 18 |
| 40 as urea " " " " | 67.8 | 9.3 | 1.15 | 0.94 | 32 |
| 80 as $NH_4NO_3$ " " " " | 67.6 | 9.1 | 1.70 | 0.94 | 27 |
| 80 as urea " " " " | 67.3 | 9.8 | 1.65 | 1.01 | 34 |
| 40 as $NH_4NO_3$-left on surf.-early spring | 66.2 | 10.1 | 1.58 | 1.13 | 74 |
| 40 as urea " " " " " | (no ear set) | | 1.12 | 1.12 | --- |
| 80 as $NH_4NO_3$ " " " " " | 66.4 | 8.7 | 1.68 | 1.01 | 27 |
| 80 as urea " " " " " | 60.7 | 9.4 | 1.25 | 1.04 | 16 |
| 40 as $NH_4NO_3$-sidedressed - July 6th | 63.8 | 9.5 | 1.55 | 1.04 | 61 |
| 40 as urea " " " " | 57.2 | 8.3 | 1.38 | 0.95 | 14 |
| 80 as $NH_4NO_3$ " " " " | 61.7 | 9.7 | 1.38 | 1.06 | 22 |
| 80 as urea " " " " | 60.4 | 9.9 | 1.45 | 0.97 | 21 |

[1]Entire area treated with 0-20-20 at rate of 500 lbs/A.

Average N recovery from $NH_4NO_3$ = 38%
" " " " urea = 23%

With the extensive water damage and yield variation in the four replicates, it is difficult to draw any valid conclusion, but the earlier applications appear to be somewhat better than those side-dressed in early July.

The South-West Experimental Station at Lamberton was activated early in 1960, and an urea-ammonium nitrate comparison experiment as to rate, time of application and covering on corn yield and composition was commenced. Of necessity, plowing and all fertilization was done in the spring of 1960. The results are shown in Table 4 and it should be emphasized that plots 2, 3, 4, 5, 6, 7, 8, and 9 were fertilized in the spring of 1960, and a wet spring resulted in delayed seeding and in immature crop.

Table 4. The effect of N source, rates and times of application on the yield and composition of 1960 corn at Lamberton and recovery of fertilizer nitrogen.

| Treatment lbs/A of N | Corn grain bu/A | Corn grain % Protein | Fodder T/A | Fodder % N | % N Recovery |
|---|---|---|---|---|---|
| 1. Check | 49.5 | 7.3 | 1.82 | 0.74 | --- |
| 2. 40 ($NH_4NO_3$) on stalks, plowed under in fall | 42.3 | 7.2 | 1.79 | 0.84 | 8 |
| 3. 40 (urea) " " " " " | 55.1 | 6.8 | 1.57 | 0.61 | -28 |
| 4. 40 ($NH_4NO_3$) left on top of plowing in fall | 49.0 | 7.9 | 1.87 | 0.84 | 16 |
| 5. 40 (urea) " " " " " | 62.3 | 7.5 | 1.87 | 0.76 | 13 |
| 6. 80 ($NH_4NO_3$) on stalks, plowed under in fall | 67.4 | 7.6 | 1.85 | 0.78 | 5 |
| 7. 80 (urea) " " " " | 61.7 | 7.8 | 1.87 | 0.88 | 7 |
| 8. 160 ($NH_4NO_3$) " " " " | 69.8 | 8.2 | 2.23 | 0.91 | 17 |
| 9. 160 (urea) " " " " | 79.4 | 7.6 | 2.18 | 0.85 | 12 |
| 10. 40 ($NH_4NO_3$) just bef. planting-Spring | 66.2 | 8.0 | 1.85 | 0.87 | 21 |
| 11. 40 (urea) " " " " | 45.4 | 7.6 | 2.12 | 0.85 | 47 |
| 12. 80 ($NH_4NO_3$) " " " " | 59.3 | 7.5 | 2.07 | 0.79 | 12 |
| 13. 80 (urea) " " " " | 57.7 | 7.9 | 2.26 | 0.82 | 21 |
| 14. 40 ($NH_4NO_3$) as a late sidedressing | 63.6 | 7.7 | 2.01 | 0.89 | 27 |
| 15. 40 (urea) " " " " " | 57.7 | 7.0 | 1.90 | 0.77 | 9 |
| 16. 80 ($NH_4NO_3$) " " " " " | 50.4 | 7.6 | 1.76 | 0.89 | 15 |
| 17. 80 (urea) " " " " " | 76.9 | 7.1 | 1.51 | 0.81 | -11 |
| 18. 160 ($NH_4NO_3$) " " " " " | 80.7 | 7.7 | 1.65 | 0.88 | 0 |
| 19. extra | 43.4 | | | | |
| 20. extra | | | | | |

Average N recovery from $NH_4NO_3$ - 14%
" " " " urea - 18%

Since treatments 2 to 9 were actually applied in the spring, and with the extreme yield variation, no statistical analyses were made. However, it is evident that the 40 and 80 pound per acre rates were not sufficient on this field, since the 160 pound rates were more effective.

## Laboratory Experiments

### (a) Ammonium fixation

The ammonium-fixing capacity of 36" profiles of four typical agricultural soils of southern Minnesota soils was determined. Two of the fields had been responsive to nitrogen fertilization, and the remaining two showed essentially no effect from nitrogen treatment on either the first crop of corn or residual effect on the following small grain crop.

The amounts of applied $NH_4$ fixed in the 36 inch profile depth varied from approximately 5 to 9 m.e.'s (1 to 2 tons of ammonium N per acre), with the most nitrogen responsive soil having the highest ammonia fixing capacity.

### (b) Ammonia N losses from urea or ammonium nitrate

Effect of fertilizer N source and depth of placement on loss of ammonia to the air has been studied on five soils, varying in texture from loamy sand to a clay loam. With N applications as $NH_4NO_3$ on the surface, 0.5 and 1.0 inches below the surface, at rates of 100 pounds of N per acre, there was no ammonia lost as Zimmerman loamy sand dried for one week from 7.0% moisture to 4.6%. Under the same conditions, the same amount of applied urea nitrogen lost 5.8% as ammonia where applied on the surface, 5.0% when urea was covered with one-half inch of soil, and 0.6% at the 1 inch depth.

On a Barnes loam drying for one week from 25% to 21.5% moisture, 100 pound rates of urea nitrogen per acre on the soil surface lost 4% of the N as $NH_3$, 1% as $NH_3$ where 1/2 inch below the surface, and none where placed 1 inch beneath the surface. There were no measurable losses as ammonia from urea placed on the surface of Tama silt loam and dried for a week.

Under laboratory conditions, there was usually some loss of ammonia when urea was left on the soil surface, except on the Tama silt loam. The maximum measured N loss was from a Zimmerman loamy sand over a one month period of approximately 6% of the 100 pound per acre rate applied. This is markedly less than the amounts reported by recent investigations in Kentucky and in Florida.

### (c) Gaseous losses of fertilizer N as $N_2$ and oxide forms

Using closed air-soil-fertilizer-moisture systems, gas samples were taken as the soil was dried for 2, 4, 7, and 14 day intervals, and analyzed for $N_2$, $N_2O$ and $NO_2$ derived from the added fertilizer nitrogen. These studies are designed to study possible fertilizer nitrogen losses as the soil is alternately wetted and dried.

# Nitrogen Fertilization Studies on Turf Grass

R. S. Farnham

Nitrogen fertilization studies on bluegrass turf were started in 1959 on plots located adjacent to the Soil Science Building. The objectives of these studies were as follows:

1. To evaluate the effect of various nitrogen fertilizer materials, both organic and inorganic, on the yield and color of Kentucky bluegrass turf.

2. To determine the optimum rate of nitrogen needed as a single application only and to make a comparison of the effectiveness of the different nitrogen sources.

3. To study the ability of several coated nitrogen materials in controlling the release of nitrogen applied on turfgrass.

## Materials and methods:

Nitrogen fertilizer materials included in the 1959 study were ammonium nitrate, uramite, nitroform, leached zone 14-7-7, ammoniated peat, calcium authroxillate, calcium-magnesium anthroxillate, and liquid humate obtained from peat. The plot size was 5 x 4 feet and there were two replications of randomized plots.

Nitrogen was applied at 4 and 8 pounds/1000 sq. ft. in late May all in one application. Phosphorus and potassium were applied as a blanket treatment with all plots receiving the equivalent of 4 lbs. of $P_2O_5$ and $K_2O$ per 1000 sq. ft.

All materials were applied broadcast and wet down thoroughly to prevent burning.

In 1960 the same fertilizers as in 1959 were used although the rates were increased to 5 and 10 lbs. of N per 1000 sq. ft. In addition some new experiments were begun using differently coated urea nitrogen (45-0-0).

Color ratings were made at time of clipping and plots were watered when necessary.

Table 1. 1959 Turf Plots (Soils Building) Total Clipping Yields and Color Ratings

| No. | Treatment (Rate, Analysis) | Grams dry wt/Plot | Grams dry wt/1000 sq. ft. | Ave. Color Rating |
|---|---|---|---|---|
| 14 | $NH_4NO_3$ + PK 8# N/1000 (14-7-7) | 212.5 | 20,230 | 9.75 |
| 1 | Ca Anthraxillate 2 tons/Ac + (14-7-7) | 197.0 | 18,754 | 5.62 |
| 9 | Allied Chemical's 4# N/1000 14-7-7 (A) | 195.5 | 18,610 | 6.38 |
| 12 | 16 ozs. liquid humate + NPK 4# N/1000 | 189.4 | 18,030 | 5.63 |
| 4 | Uramite 8# N/1000 + PK 14-7-7 | 175.4 | 16,698 | 6.25 |
| 2 | Ca/Mg Anthraxillate 2 tons/ac. + NPK | 170.1 | 16,184 | 5.25 |
| 6 | Nitroform 8# N/1000 + PK | 166.2 | 15,822 | 7.50 |
| 10 | Allied's 14-7-7 (B) 4# N/1000 | 159.1 | 15,136 | 4.63 |
| 5 | Nitroform 4# N/1000 + PK | 157.0 | 14,946 | 5.25 |
| 11 | Allied's 14-7-7 (C) 4# N/1000 | 155.3 | 14,784 | 5.13 |
| 13 | $NH_4NO_3$ + PK 4# N/1000 (14-7-7) | 153.8 | 14,641 | 6.00 |
| 8 | Allied's Ammoniated Peat 8# N/1000 + PK | 137.3 | 13,071 | 5.13 |
| 3 | Uramite 4# N/1000 + PK | 127.5 | 12,138 | 4.50 |
| 7 | Allied Ammoniated Peat 4# N/1000 + PK | 122.9 | 11,690 | 4.00 |

Table 2. 1960 Turf Plots (Soils Building) Total Clipping Yields and Color Ratings

| No. | Treatment | Grams dry wt/Plot | Grams dry wt/1000 sq. ft. | Average Color Rating |
|---|---|---|---|---|
| 20 | Urea Med. Coat 10# N/100 + PK | 544.9 | 51,874 | 9.38 |
| 17 | Urea Heavy Coat 5# N/1000 + PK | 512.1 | 48,751 | 8.88 |
| 18 | Urea " " 10# N/1000 + PK | 487.9 | 46,448 | 9.13 |
| 16 | Urea 10# N/1000 (uncoated) + PK | 465.5 | 44,315 | 9.06 |
| 1 | Ca Anthraxillate 2 tons/ac. + NPK 4# N/1000 | 459.8 | 43,772 | 7.94 |
| 15 | Urea 5# N/1000 (uncoated) + PK | 452.0 | 43,030 | 8.06 |
| 14 | $NH_4NO_3$ 10# N/1000 + PK | 449.2 | 42,763 | 9.13 |
| 12 | 16 ozs. liquid humate + NPK 4# N/1000 | 445.8 | 42,440 | 8.25 |
| 6 | Nitroform 10# N/1000 + PK | 436.0 | 41,507 | 8.06 |
| 19 | Urea Med. Coat 5# N/1000 + PK | 402.0 | 38,346 | 8.06 |
| 4 | Uramite 10# N/1000 + PK | 374.3 | 35,633 | 7.13 |
| 5 | Nitroform 5# N/1000 + PK | 374.0 | 35,604 | 6.75 |
| 2 | Ca Anthraxillate 4 tons/ac +NPK 4# N/1000 | 364.1 | 34,662 | 7.50 |
| 11 | Allied's 14-7-7 (C) 5# N/1000 | 361.2 | 34,386 | 6.19 |
| 8 | Allied's Ammoniated Peat 10# N/1000 + PK | 361.0 | 34,367 | 6.81 |
| 9 | Allied's 14-7-7 (a) 5# N/1000 | 351.1 | 33,424 | 7.25 |
| 13 | $NH_4NO_3$ 5# N/1000 + PK | 351.1 | 33,424 | 7.88 |
| 3 | Uramite 5# N/100 + PK | 305.1 | 29,045 | 6.56 |
| 10 | Allied's 14-7-7 (B) 5# N/1000 | 300.9 | 28,645 | 6.13 |
| 7 | Allied's Ammoniated Peat 5# N/1000 + PK | 276.2 | 26,294 | 5.75 |
| 21 | Check (No Fertilizer) | 241.9 | 23,028 | 3.13 |

# RATES AND SOURCES OF PHOSPHATE
## Northeast Experiment Station

Dale E. Baker, Wallace W. Nelson and A. C. Caldwell

The plots were started in 1958 on an area that had been in meadow for two years and had not been fertilized or limed for at least five years. The purpose of an experiment was to determine the amount of phosphate required to produce an oat-two year meadow rotation and the relative availability of different sources of phosphate.

The plots were plowed in the fall of 1957 and Dalapon applied at the rate of 7-8 pounds per acre on the plowed area for the control of quackgrass. In the spring of 1958, the entire area was limed at a rate 2-3 tons per acre using dolomitic limestone. Prior to seeding, all plots were fertilized with 20+0+180, using ammonium nitrate and muriate of potash. The area was seeded to minhafer oats, alfalfa and bromegrass on May 6. The randomized block design with four replications was used for the phosphate treatments. Each year after the first cutting of hay was removed the plots were treated with 0+0+80 per acre as muriate of potash.

All applications of phosphorus regardless of rate or source resulted in an increase in yields of oat silage and hay each year. There was some variation in the data that is difficult to explain, especially in the yields of silage. It is interesting to note that the application of 150 pounds of $P_2O_5$ as rock phosphate resulted in yields as high as those obtained from 200 pounds of $P_2O_5$ from triple superphosphate. Yet, there was no response to 1,000 pounds of rock phosphate over the 500 pound per acre application. By close observation of the relief of the area on which these plots are located, one finds that water drains off from the land above through the center and one end of each block in this experiment. The 1,000 pound rock phosphate plots were located at random, but in all four cases they were placed in one of these small depressions. These slight depressions running through all blocks are responsible probably for the large amount of variation in all forage yields.

Because of the large amount of variation in the data, it can be concluded only that:

1. There was a response to phosphate.
2. Applications of 400 pounds of $P_2O_5$ as triple superphosphate resulted in the highest yields.
3. The water soluble superphosphate might be more available to oats but not to alfalfa and bromegrass.

# RATES AND SOURCES OF PHOSPHATE (1960)
## Northeast Experiment Station

### Table I

Yields of forages in tons per acre as affected by different rates and sources of phosphate.

| Treatment | Oat Silage 1958 | 1st Yr. Hay 1959 | 2nd Yr. Hay 1960 | Average Hay Yields |
|---|---|---|---|---|
| Check | 5.88 | 2.22 | 1.35 | 1.79 |
| 50# $P_2O_5$/Ac. as Triple Super | 7.22 | 3.04 | 1.69 | 2.37 |
| 100# " " " " " | 7.17 | 3.15 | 1.81 | 2.48 |
| 200# " " " " " | 6.58 | 3.13 | 2.14 | 2.64 |
| 400# " " " " " | 7.94 | 3.69 | 2.24 | 2.99 |
| 50# $P_2O_5$/Ac. as Cal-Meta | 6.26 | 3.17 | 1.72 | 2.45 |
| 500# Rock Phos. | 6.60 | 3.20 | 1.93 | 2.56 |
| 1000# " " | 6.19 | 3.06 | 1.88 | 2.46 |
| Means for years | | 3.08 | 1.85 | |

Confidence Intervals ($D_{.05}$) for comparing:

1. Rates and sources of phosphate on silage yields = 1.90
2. Rates and sources of phosphate on average hay yields = 0.55
3. Average hay yields for different years = 0.18

# Phosphorus Source Experiment
## Rosemount, 1960

by A. C. Caldwell and J. B. Weber

A phosphorus source experiment was established at Rosemount in 1951. Twelve treatments of various phosphate materials were replicated four times across a regular rotation of corn, wheat, alfalfa, and alfalfa. Potassium fertilizer was supplied according to soil tests.

The crop rotation was changed in 1959 to corn, soybeans, wheat and alfalfa.

Yields of corn, soybeans, and wheat for 1960 were not significantly affected by the various phosphate sources. Experimental error amounted to a considerable portion of the variabion between treatments and hence masked those differences which did exist. A definite over all phosphorus response is evident as nearly all of the treatments had a higher yield than their respective controls. Alfalfa yields were significantly (.05) increased by the various phosphate sources. All sources increased the yield of alfalfa above the control by about 0.8 tons per acre. There were no significant differences between the phosphate sources, but the table indicates that the more available forms were somewhat superior to the less available forms.

Table 1. Effect of various phosphate treatments on the yield of corn, soybeans, wheat, and alfalfa in a rotation, 1960.

| Treatments | $P_2O_5$/A/yr lbs. | Corn[1] bu/A | Corn[1] Diff. | Soybeans Bu/A | Soybeans Diff. | Wheat bu/A | Wheat Diff. | Alfalfa[2] bu/A | Alfalfa[2] Diff. |
|---|---|---|---|---|---|---|---|---|---|
| 1. Check | ---- | 90.1 | --- | 22.4 | --- | 25.9 | --- | 3.17 | --- |
| 2. Ord. Superphos. | 40 | 90.7 | 0.6 | 21.9 | -0.5 | 26.5 | 0.6 | 4.01 | 0.84 |
| 3. Conc. Superphos. | 40 | 93.5 | 3.4 | 23.8 | 1.4 | 28.1 | 2.2 | 4.10 | 0.93 |
| 4. Ca. Metaphos. | 40 | 99.9 | 9.8 | 24.2 | 1.8 | 26.9 | 1.0 | 4.08 | 0.91 |
| 5. $H_3PO_4$ | 40 | 90.6 | 0.5 | 23.2 | 0.8 | 28.2 | 2.3 | 3.97 | 0.80 |
| 6. Fused Tri Ca. | 40 | 108.2 | 18.1 | 23.9 | 1.5 | 25.5 | -0.4 | 4.01 | 0.84 |
| 7. Fla. rock + Ord. Super. | 20 + 20 | 99.4 | 9.3 | 23.4 | 1.0 | 26.9 | 1.0 | 4.22 | 1.05 |
| 8. Fla. rock (lt.) | 100 | 94.2 | 3.1 | 23.6 | 1.2 | 26.8 | 0.9 | 3.63 | 0.46 |
| | lbs. material/A/4 years | | | | | | | | |
| 9. Fla. rock (hvy) | 1000 | 106.2 | 16.1 | 23.9 | 1.5 | 24.9 | -1.0 | 3.95 | 0.78 |
| 10. Western rock | 1000 | 98.0 | 7.9 | 25.3 | 2.9 | 28.0 | 2.1 | 3.45 | 0.28 |
| 11. Col. clay rock | 1000 | 94.4 | 4.3 | 24.2 | 1.8 | 28.5 | 2.6 | 3.77 | 0.60 |
| 12. Tunis. rock | 1000 | 84.8 | -5.3 | 25.0 | 2.6 | 26.2 | 0.3 | 3.98 | 0.81 |
| lsd (.05) = | | | N.S. | | N.S. | | N.S. | | 0.48 |
| hsd (.05) = | | | | | | | | | 0.98 |

[1] @ 15% moisture

[2] Dry weight

# Some Field Trials with Secondary and Minor Nutrient Elements on Corn

Merle Halverson and John Grava

In 1959, marked differences in corn leaf color attributable to the presence or absence of starter fertilizer were noted in a demonstration plot planted to corn on a Brainerd loamy sand in Crow Wing County. Untreated plant leaves bore the symptoms of pale-green color and mottling commonly associated with magnesium deficiency. Since the bulk of the phosphorus in the starter fertilizer was derived from ordinary superphosphate, the possibility of secondary or minor element deficiencies was indicated. Soil samples from the area and leaf time samples from all plots were collected and analyzed. The crop was subsequently damaged by drouth and the analysis of corn yields gave no evidence of yield differences. Results of the soil and leaf tissue analyses are listed in Table 1.

Two experiments with corn were established on the same soil in 1960.

In the first, five secondary or minor nutrient elements were individually compared with a check treatment in a randomized block replicated three times. The treatments were superimposed on an area treated with 80 lbs. N, 100 lbs. $P_2O_5$ and 150 lbs. $K_2O$ per acre applied broadcast and disced into the soil. The nitrogen and phosphate were applied as ammonium-phosphate-nitrate to eliminate possibility of contamination through use of ammoniated superphosphate materials. The area was machine planted by the farmer cooperator in late May using 47" between row and 40" within row spacings. Three kernels per hill were dropped, and no attempt was made to thin to a uniform stand. Yield samples consisting of 20 hills were harvested from each plot in mid-October, and moisture contents determined. Yields calculated on a basis of 15.5% moisture shelled corn are listed in Table 2.

In a second trial established in the same field, four treatments (3 metal ammonium phosphates and a check) were compared by application in the hill to recently emerged corn plants. Each treatment was replicated five times. The metal ammonium phosphates were physically blended with mono ammonium phosphate (11-48-2) and/or muriate of potash (0-0-60) to provide (1) common ratios of $N:P_2O_5:K_2O$ of 1:4.4:4.4 and (2) the desired level of each minor element. Check plots were treated identically except that no minor element was added. Each plot was a single row 20 hills long with 40" within row spacing, and the area was thinned to a uniform stand of three plants per hill. No broadcast applications of $P_2O_5$ or $K_2O$ were made. Nitrogen at 42 lbs/A was applied sidedress at the time of second cultivation. Yield samples consisting of 20 hills from each plot were harvested in mid-October and moisture contents determined by oven drying. Yields of 15.5% moisture ear corn are listed in Table 3.

The wide differences in over all yield between the two experiments are likely due to differences in the basic broadcast treatments, particularly of nitrogen and potash. Table 2 shows apparent but non-significant yield increases for several of the secondary and minor element treatments tested. No yield differences are suggested in Table 3 where the blended metal ammonium phosphates were applied in the hill to emerged corn.

Crops grown on this soil type are subject to frequent and severe drought damage. Further field trials should be conducted only after response to secondary and minor nutrient elements has been established in greenhouse testing.

Other contributors to this work include Messrs. Ray Norrgard and Glen Smith, County Agent and Assistant County Agent, respectively, who assisted in plot establishment and harvest; Mr. Gary Spalding, Chemist, Soil Testing Laboratory, who ran soil soil and plant tissue chemical analysis, and Mr. B. C. Wilkins, Crow Wing County farmer, who provided the location and equipment and labor for planting.

RESULTS OF CHEMICAL DETERMINATIONS
ON SOIL AND CORN LEAVES FROM
MR. B. C. WILKIN'S FARM, CROW WING COUNTY

(1) Results of Routine Soil Tests*

| pH | Lime Recommended Tons/A | Organic Matter, % | Phosphorus Lbs/A | Exch. Potassium Lbs/A | Soil Texture |
|---|---|---|---|---|---|
| 4.7 | 3 | 2.5 Low | 140 V High | 320 V. high | Loamy sand |

(2) Soil Chemical Properties

| Cation Exchange Capacity m.e./100 g. soil | | Exchangeable Cations | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ca | | | Mg | | | K | | H | |
| | | m.e. | Lbs/A | % | m.e. | Lbs/A | % | m.e. | Lbs/A | m.e. | % |
| 6.07 1) | (5.25) 2) | 3.64 | 1436 (1800) 3) | 60 | 0.43 | 103 (144) 3) | 7 | 0.29 | 226 (234) 3) | 1.76 | 29 |

(3) Percent Composition of Corn Leaves
Collected from Plots on Mr. Wilkin's Farm,
Crow Wing Co. (Date of sampling July 22, 1959)

| Treatment $P_2O_5$ Lbs/A | Phosphorus % | Calcium % | Magnesium % | Calcium + Magnesium % |
|---|---|---|---|---|
| 0 | 0.34 | 0.709 | 0.246 | 0.955 |
| 20 | 0.33 | 0.817 | 0.279 | 1.096 |
| 40 | 0.31 | 0.931 | 0.230 | 1.161 |
| 60 | 0.33 | 0.872 | 0.249 | 1.121 |
| 80 | 0.33 | 0.931 | 0.217 | 1.148 |
| 0 + starter | 0.32 | 0.963 | 0.252 | 1.214 |
| Striped leaves | 0.37 | 0.573 | 0.270 | 0.843 |
| Normal leaves | 0.30 | 1.012 | 0.319 | 1.331 |

* Sample from check plots, July 22, 1969.

1) By summation

2) Determined

3) Desired level, according to Missouri Experiment Station.
Basic application to all plots: 100 lbs N/Acre as ammonium nitrate
120 lbs $K_2O$/acre as KCl (0-0-60)

Starter: 170 lbs/acre of 4-12-24.

John Grava
Merle Halverson
Gary Spalding

Table 2

Effect of Some Secondary and Minor Nutrient Elements on Corn Yield Loamy Sand Soil - Crow Wing County 1960

(Basic treatment 80+100+150 applied broadcast to all plots, including check)

| Nutrient element(s) | Chemical applied Form | Chemical applied lb/A | Yield, bu/A 15.5% moisture shelled corn | decrease over check, bu/A | Increase over check necessary for significance at 0.95 level in variance analysis |
|---|---|---|---|---|---|
| Check | -- | -- | --- | --- | ----- |
| Ca# and/or S | $CuSO_4$ | 500 | 62.6 | 4.0 | 8.5 |
| Zn# | $ZnSO_4$ | 50 | 65.5 | 6.9 | 10.4 |
| Cu# | $CuSO_4$ | 25 | 66.0 | 7.4 | 11.7 |
| B | $Na_2B_4O_7$ | 25 | 66.9 | 8.3 | 12.5 |
| Mg# | $MgCO_3$ | 690 | 67.2 | 8.6 | 13.2 |

Table 3

Effect of 3 Micronutrients on Corn Yields - Loamy Sand Soil - Crow Wing County - 1960
(all treatments applied in the hill to recently-emerged corn)

40 lb. N/A as ammonium nitrate applied at second cultivation

| Treatments, lb/A | Yield, bu/A |
|---|---|
| N 10 + $P_2O_5$ 44 + $K_2O$ 44 | 40.6 |
| 10 + 44 + 44 * + MgO at 25 lb/A | 40.9 |
| 10 + 44 + 44 * + ZnO at 10 lb/A | 39.9 |
| 10 + 44 + 44 * + CuO at 3 lb/A | 40.6 |

* as magnesium ammonium phosphate
* as zinc ammonium phosphate
* as copper ammonium phosphate

# 1960 Trace Element Experiments on Soybeans and Corn

J. M. MacGregor and R. G. Burau

Three years of laboratory and field research had shown that the application of certain chelated iron compounds would effectively control iron chlorosis in soybeans and flax. However, the cost and trouble of such applications made it unsuitable for general farm practice and it was reasoned that direct applications of chelated iron to seeds might be effective, since only small amounts of iron are necessary to prevent chlorosis, and this is needed largely during the first few weeks of plant growth.

To test the feasibility of this approach, Sequestrene 138, a chelate having low phytotoxic properties, was adsorbed on soybean seeds by low vacuum, high vacuum, air saturated, and oxygen saturated solutions of commercial grade iron chelate. Seeds from each of these treatments were germinated and compared to untreated seeds. Only the oxygen saturated solutions were rejected by this test, all other treatments gave excellent germination.

A second experiment was designed with the following objectives:

1. To devise a method for assaying added iron on soybean seeds (sorbed iron) without destroying the seed.

2. To determine the specific activity of $Fe^{59}$ necessary to give adequate counting rates of all plant parts.

3. To determine the fate of sorbed iron.

4. To determine the efficiency of recovery of sorbed chelated iron as compared to soil treatment.

5. To determine the ability of sorbed iron to prevent chlorosis in soybeans.

To accomplish the first objective, 50 Ottawa Mandarin soybean seeds were treated with saturated Seq. 138 Fe plus 2% methyl cellulose for 4 minutes, while a second batch of 50 seeds were treated with the same solution, but under high vacuum for 4 minutes. After drying each seed was counted first on one side and then on the other side with Geiger Mueller scaler. The two counting rates were then averaged. Twelve seeds having a range of activities were selected from each lot and assayed for total added iron. Since a plot of the data did not show any curvilinear tendencies at moderate activities, a linear correlation was performed. The resulting equation was

$$Y = 1.58\ X + 11.3$$

where Y = counts per minute of assay disc and X = average surface counts per minute. The correlation coefficient for this relationship was $r = 0.9$ which indicates adequate accuracy.

Five soybeans from each treatment lot whose sorbed iron content was determined by the use of this equation were planted in individual greenhouse pots. As many untreated seeds were also planted. After emergence, the pots were placed in a cold water bath in an attempt to produce a chlorosis-inducing environment. Unfortunately the temperature in the bath remained about 20°C and no soybean plant developed chlorosis. When the second trifoliate leaf was mature, plant tops were cut off

1 cm. above the cotyledonary node; the rest of the plant was designated as root. Cotyledons were removed prior to the main harvest when they began to yellow and wither. Tops, roots and cotyledons were then analyzed for added iron content by a radio assay technique with results shown in Table 2.

Table 2. Distribution of sorbed iron in soybean plant parts.

| Seed 1 # | Treatment | ug. Fe. in seed before planting | Top ug. Fe % | Top Recovery Efficiency % | Cotyledons ug. Fe % | Cotyledons Recovery Efficiency % | Roots ug. Fe. % | Roots Recovery Efficiency % |
|---|---|---|---|---|---|---|---|---|
| 1 | No vacuum | 10.43 | 1.65 | 15.8 | 0.19 | 1.8 | 0.46 | 4.4 |
| 2 | " | 8.64 | 1.57 | 18.2 | 0.26 | 3.0 | 0.49 | 5.7 |
| 3 | " | 7.48 | 0.96 | 12.8 | 0.17 | 2.3 | NA* | NA |
| 4 | " | 6.86 | 1.20 | 17.5 | NA | NA | 0.37 | 5.4 |
| 5 | " | 7.41 | 0.75 | 10.1 | NA | NA | NA | NA |
| 6 | High Vacuum | 117.1 | 13.20 | 11.3 | NA | NA | NA | NA |
| 7 | " | 15.3 | 1.56 | 10.2 | NA | NA | NA | NA |
| 8 | " | 9.9 | 1.21 | 12.2 | NA | NA | NA | NA |
| 9 | " | 8.0 | 1.51 | 18.9 | NA | NA | NA | NA |
| 10 | " | 6.7 | 0.12 | 1.8 | NA | NA | NA | NA |

*NA - Not analyzed.

It should be noted and emphasized that 12 ug. Fe per seed is approximately equal to an iron chelate cost of $.25 per acre. Most of the quantities of sorbed iron are less 12 ug Fe/seed except for seed number 6 and 7 which are due to seed coat cracks sorbed very large quantities of iron chelate under high vacuum.

Largest quantities of iron were recovered in tops, smaller in roots, and smallest in cotyledons. Concentrations in tops will range from 1.5 to 26 ppm Fe in the plant with most concentrations around 2.5 ppm. This is especially significant when it is recalled that many plants which have recovered from iron deficiency chlorosis following the application of iron chelate contain 1 to 5 ppm Fe from added iron. This suggests that sorption quantities higher and lower than 12 ug. Fe/seed might be investigated.

Efficiencies of recovery by tops are very high. This is in line with prediction. Normal recovery efficiencies for soil applications range from 0.2% to 3%.

Seed numbers 6 and 7 were diseased, and although number 6 held its cotyledons full term, cotyledons from number 7 dropped off four days before the other cotyledons were harvested. The significant observation here is that recovery efficiency did not appear low. Possibly seed scarification prior to treatment will increase sorption.

Very low counting rates were observed on roots and cotyledons. If these are to be analyzed in future experiments specific activities of $Fe^{59}$ must be increased by a factor of 10 to 20 times.

Conclusions:

Further testing of this technique is warranted.

A second study was conducted during the summer of 1960 in McLeod County, and consisted of the addition of trace elements (including chelated iron) to the soil of two questionable corn fields. No radio-iron was used in these field experiments. In 1959, Soils Extension Specialists included a trace-element treatment in the experimental design of some statewide soil test-correlation studies. Two of these fields showed a significant yield increase due to trace-element treatments which included manganese, magnesium, zinc, copper, iron, boron, and sulfur (Es-min-el).

Two questions were raised by this study:

1. Is the conclusion a result of statistical error (rejection of the null hypothesis when it is actually true)?

2. If the conclusion is valid, which of the several elements applied was related to the yield increase?

To answer these questions, two experimental sites were selected in McLeod County. One of these sites was near a 1959 correlation experimental area on the John Lietz farm. The other site was on the Albert Schuft farm. In an effort to reduce soil variability within replicates, 578 soil samples were removed from the two fields for determinations of soil moisture, pH, and conductivity of the saturation extract. Sampling areas were located with respect to established reference points using a transit, which was also used for elevation measurements. Contour maps were then constructed and including information on pH, conductivity of the saturation extract, and soil moisture since these factors varied with depth as well as with horizontal displacement. The maps were used to select areas for replicates as homogeneous as possible with respect to these variables.

Treatments consisted of individual trace-element salts applied at rates which were judged to be sufficient to give yield increases if deficiencies existed. Each field included seven replicates of the treatments shown in Table 1.

Treatment did not affect yield on the Schuft location, where overall yield was undoubtedly reduced by soil moisture deficiency in mid-season. On the Lietz farm, iron chelate gave a nearly significant increase of yield over check. The hypothesis of iron deficiency in this soil cannot be firmly established with this one experiment. More important is the suggestion that copper and boron appear to be completely ineffective, which would eliminate these elements in further studies. Very possibly surface response experimental designs may give valuable information upon rates and combinations of the remaining elements with the objective of maximizing yields.

Table 6. Average yield of corn in McLeod County as affected by soil applications of various trace elements.

| Compound | Rate of application (lbs. salt/A.) | Schuft Farm | Lietz Farm |
|---|---|---|---|
| | | bu. ear corn/acre (15.5% moisture) | |
| Es-min-el | 108 | 71.6 | 97.1 |
| $MgSO_4$ | 100 | 71.6 | 108.7 |
| $MnSO_4$ | 75 | 70.8 | 103.8 |
| $Na_2B_4O_7$ | 30 | 74.4 | 99.4 |
| $CuSO_4$ | 20 | 73.7 | 102.2 |
| $ZnSO_4$ | 10 | 78.0 | 107.7 |
| Seq. 330 Fe | 10 (as Fe) | 73.2 | 115.1 |
| Check | | 75.2 | 97.7 |
| | H.S.D. 0.05 | N.S. | 18.2 |

Conclusions:

1. Previous year's conclusions are probably valid.
2. Iron treatment gave the largest yield increase which was nearly significant at the 5% level.
3. Magnesium and zinc should definitely be considered in future experiments and, if space permits, manganese and copper may also be included.

# TRACE ELEMENT EXPERIMENT (1960)
## Northeast Experiment Station

Dale E. Baker, Wallace W. Nelson, and A. C. Caldwell

The purpose of this experiment was to find if a response to trace elements could be expected from any crop in the oats-meadow rotation.

The trace element treatments were randomized with each of the (4) block being split. One-half of each block was limed at the rate of (3) tons of calcitic lime in the fall of 1957, while the other half was left without lime.

The different trace element treatments were applied in the spring of 1958. Prior to seeding the entire area was treated with 40+120+120 per acre. The plots were seeded to oats, alfalfa and brome grass in the spring of 1958.

The treatments with trace elements had no significant effects on any of the forage yields. The variation in hay yields were not so great as for the silage. The fact that there was a response to lime by all the crops with the difference being significant in the case of the first year hay; indicates that the precision in this experiment was good. It would seem, therefore, that a deficiency of any the trace and secondary elements included in this experiment does not exist in this area of Minnesota.

## TRACE ELEMENT EXPERIMENT

Forage yields in tons per acre as affected by different treatments with trace elements under limed and unlimed conditions.

| | Oat Silage - 1958 | | 1st Yr. Hay - 1959 | | 2nd Yr. Hay-1960 | |
|---|---|---|---|---|---|---|
| | Limed | Unlimed | Limed | Unlimed | Limed | Unlimed |
| Check | 7.86 | 7.36 | 3.54 | 2.95 | 2.56 | 2.64 |
| Trace Element Mixture | 7.15 | 7.07 | 3.58 | 2.89 | 2.61 | 2.23 |
| Molybdenum | 7.92 | 7.06 | 3.47 | 3.14 | 2.13 | 2.24 |
| Molybdenum and Mix | 8.51 | 7.08 | 3.40 | 3.14 | 2.58 | 2.54 |
| Average | 7.88 | 7.14 | 3.50 | 3.03 | 2.33 | 2.26 |

# BORON DEFICIENCY IN ALFALFA

A summary of observations made July 20 and 21, 1960
C. J. Overdahl

Visits were made in July to many of the 0-12-36 and 0-12-36B "quickie" topdressing plots established in northeastern and southeastern Minnesota in 1960. The 0-12-36 was applied at 250 pounds per acre, the boron plot received 25 pounds per acre of fertilizer borate or 3.25 pounds of boron. It was somewhat surprising to find evidences of boron deficiencies in almost all of the alfalfa fields visited. The following is a county-by-county report on observations. Plant tissue samples were taken and chemical analyses were made at Michigan State University.

Sherburne County - The 0-12-36 gave an apparent response, and where boron was applied in addition, the alfalfa was a darker green in color and had a slightly taller growth. No yellowing or purple cast typical of severe boron deficiency was apparent. The alfalfa growth on this field showed rather serious potash deficiency symptoms.

Mille Lacs County - The alfalfa on the Latcham field near Milaca had the most severe boron deficiency observed. Yellowing and purpling was apparent on most of the plants with the boron treated plot showing a healthy color. The 0-12-36 also gave a good response to topdressing (applied June 21). The major part of the field showed rather severe potash deficiency symptoms. Both color, and black and white pictures were taken. Plant tissue analysis for boron content showed the following: PK, 7.8 ppm boron, PKB, 23.6 ppm boron.

Aitkin County - The Otto Piispanen plot showed an interesting story. This was a very good field of alfalfa, but even with its excellent growth potash deficiency symptoms were common in addition to boron deficiency symptoms. The field had over 100 pounds per acre of $K_2O$ but the 90 pounds of $K_2O$ in the 0-12-36 plot gave an additional response and the plot receiving boron had greener leaves. Tissue tests of the alfalfa plants indicated 17.3 ppm boron on the PK plot and 62.4 ppm of boron on the PKB plot.

Crow Wing County - The Walt Schultz alfalfa field had visual boron deficiency symptoms with the boron treated plots showing a darker green.

Wadena County - Potash and boron deficiencies were obvious on an apparently good field of alfalfa. Drouth retarded growth on another field; hence no boron response was evident, although a PK response was obvious.

Todd County - Several fields along the road showed both boron and potash deficiencies. One excellent looking alfalfa field still showed a need for more potash. The Dale Foote field showed a slight boron response and boron deficient alfalfa plants were found throughout the field.

Morrison County - Boron and potash deficiencies were observed on alfalfa in several fields along Highway 10.

In addition to observations made by the extension specialists, county agents were contacted in 15 other counties. Those agents who responded reported no visual responses to boron in Pine, Beltrami, Washington, Wright, Koochiching, Chisago, Benton, Carlton, Houston, Wabash, Goodhue, Winona, and Dakota Counties. A visual response was reported both in Itasca and in Kanabec Counties.

There were 180 so-called "quickie" fertilizer kits mailed to county agents, who in turn established approximately 100 plots with assistance from SCS and vo-ag groups.

The boron response appeared to be confined to soils of low organic matter and soils of sandy loam or coarser texture.

Rainfall in the fall of 1959 and spring of 1960 was above average. Apparent boron deficiencies appeared in July following two weeks of very dry weather.

# The Effect of Molybdenum Fertilization on the Yield and Composition of Alfalfa Grown on Some Acid Minnesota Soils.

by Loren E. Ahlrichs, Roger Hanson, and J. M. MacGregor

Significant increases in yields of alfalfa, soybeans and Birdsfoot Trefoil have been obtained on some acid soil with the application of small amounts of molybdenum, in Wisconsin, Michigan, New York, Illinois and other states. In some field experiments soybean nodulation occurred only on the molybdenum treated plots.

## Objective of the experiment:

The primary purpose of this investigation was to determine if some acid soils in the state of Minnesota show a growth response in alfalfa with the addition of molybdenum.

## Materials and Methods:

The soils were selected on the basis of their possible deficiency in available molybdenum. In general there would be little response to molybdenum expected on soils with pH above 6.3. Michigan studies showed that some organic soils responded to applications of molybdenum.

Information provided by the Sub-Soil fertility studies showed the following Minnesota soils to be acid to slightly acid and these were selected for the experiment:

1. Ostrander silt loam
2. Kenyon loam
3. Tama silt loam
4. Estherville loam
5. Skyberg silt loam
6. LeSueur silt loam
7. LeSueur clay loam
8. Hayden silt loam
9. Fayette silt loam
10. Anoka loamy sand
11. Zimmerman loamy sand
12. Waukegan silt loam
13. Milica sandy loam
14. Hubbard sandy loam
15. Lester loam
16. Kasson clay loam
17. Peat-Aitkin Co.
18. Peat-Aitkin Co.
19. Peat-Anoka Co.
20. Peat-Anoka Co.

Bulk soil samples were taken from the field to the greenhouse and potted in one gallon metal cans with double plastic liners. They were maintained at approximately field moisture capacity levels prior to plantings. All were tested by the Minnesota Soil Testing Laboratory and the recommended applications of phosphate and potash made using reagent grade KCl and $CaH_2PO_4$. The recommended rate of reagent grade $CaCO_3$ was added to bring half the pots of each soil type up to a calculated pH of 7.0.

Molybdenum was applied at the rates of 0, 1, and 2 lbs/acre in the form of reagent grade $MoO_3$. The moisture equivalents for each soil were determined and the moisture level of all pots was brought to the moisture equivalent each week in addition to the watering during the week with deionized water.

The crop grown was Vernal alfalfa. Twenty-five inoculated seeds per pot were planted and, upon emergence, all pots were thinned to fifteen plants. Three cuttings of alfalfa were taken at the 1/3 to 1/10 bloom stage.

Nitrogen was determined by the Kjeldahl and molybdenum content by the orange colored molybdenum-thiocynate complex colormetric determination.

## Results and Conclusions:

At this time, alfalfa yields are available from six of the experimental soils and these are shown in Table 1. Yields obtained from one organic soil with minor elements added treatment instead of lime are shown in Table 2. A more complete report of alfalfa yields and levels of protein and molybdenum will be published later.

Table 1. Alfalfa yields in tons/acre (Average 3 Reps. - 3 cuttings - at 15% moisture)

| | | Molybdenum applied lbs/A | | | | Molybdenum applied lbs/A with lime | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Soil type | pH | 0 | 1 | 2 | T/A Lime | 0 | 1 | 2 | + H.S.D. (05) | Yield Difference |
| Fayette silt loam | 6.0 | 3.40 | 3.49 | 3.68 | 2.0 | 3.60 | + 4.12 | 3.54 | 0.69 | N.S. |
| Hayden silt loam | 6.4 | 2.33 | 2.29 | 2.33 | 1.0 | 2.56 | 2.44 | 2.29 | 0.60 | N.S. |
| Waukegan silt loam | 6.2 | 3.21 | 3.85 | 3.04 | 1.5 | 3.26 | 3.48 | 3.50 | 1.36 | N.S. |
| LeSueur clay loam | 6.1 | 3.62 | 3.88 | 3.33 | 1.5 | 3.76 | 3.60 | 3.97 | 0.82 | N.S. |
| Skyberg | 6.2 | 3.58 | 3.46 | 3.34 | 1.5 | 3.74 | 3.74 | 3.69 | 1.14 | N.S. |
| Ostrander silt loam | 6.4 | 3.02 | 2.97 | 2.84 | 1.0 | + 3.25 | 3.14 | + 3.18 | 0.43 | Significant at 5% level |

There was no significant difference in yield between treatments of lime, molybdenum on lime-molybdenum interaction on the Fayette silt loam. An honest significant difference at the 5% level was apparent between the unlimed no molybdenum and the limed 1 lb/A rate of molybdenum.

There was no significant difference in yield between treatments of lime and molybdenum or lime molybdenum interaction on the Hayden silt loam. No honest significant difference was evident.

No significant difference in yield resulted between treatments of lime and molybdenum or lime-molybdenum interaction on the Waukegan silt loam and there were no honest significant differences.

LeSueur clay loam showed no significant difference in yield between treatments of lime and molybdenum or a lime-molybdenum interaction, as well as no honest significant difference.

No significant difference in yield due to treatments of lime and molybdenum or lime-molybdenum interaction occurred on the Skyberg silt loam and there was no honest significant difference.

There was a significant increase in yield of alfalfa of the limed soil over the unlimed on the Ostrander silt loam. No significant differences in yield of alfalfa were shown by the molybdenum fertilization and there was no lime-molybdenum interaction. An honest significant difference of two of the limed treatments over the unlimed 2 lbs/A molybdenum application occurred on this soil.

Table 2. The effect of molybdenum and other trace elements on the yield of alfalfa growing on a reed and sedge peat from Anoka County. (Tons/A)

(Average 3 Reps. - 3 cuttings - at 15% moisture)

| | Molybdenum applied lbs/A | | | Molybdenum applied lbs/A with other trace elements* | | | | |
|---|---|---|---|---|---|---|---|---|
| pH | 0 | 1 | 2 | 0 | 1 | 2 | H.S.D.(0.5) | Yield Differences |
| 5.9 | 4.60 | 4.43 | 3.90 | + 5.28 | 4.82 | + 5.50 | 1.03 | Significant at 1% level |

*Trace element application consisted of:

| Compound | Rate/acre |
|---|---|
| $ZnSO_4 \cdot 7H_2O$ | 25 lbs. |
| $MgSO_4$ | 25 lbs. |
| $MnSO_4$ | 25 lbs. |
| $CuSO_4$ | 25 lbs. |
| Chelate 138 | 30 lbs. |
| Borax | 5 lbs. |

On the Anoka County decomposed Reed and Sedge Peat there was a significant difference in treatments at the 1% level. A significant increase in alfalfa yields on the minor element treatments over the pots receiving no minor elements at the 1% level was evident. No significant difference in yield with molybdenum treatments occurred but there was a significant difference due to the minor elements-molybdenum interaction at the 5% level. There was an honest significant difference at the 5% level between minor elements and the no molybdenum and minor elements 2#/A molybdenum and the 2#/A molybdenum only treatment. There was also an honest significant difference at the 5% level between the 1#/A molybdenum only treatment and the monor elements 2#/A molybdenum application.

It would appear that the increase in yield of alfalfa on this Anoka County Reed and Sedge peat increase probably due to one or more of the other minor elements rather than to the addition of molybdenum.

# RATES AND SOURCES OF LIME AT VARIOUS FERTILIZER LEVELS EXPERIMENT
## Northeast Experiment Station

Dale E. Baker, Wallace W. Nelson, and A. C. Caldwell

Procedure:

This experiment was initiated in 1957 for the purpose of determining the effect of different rates and sources of lime on the growth of oats and meadow when different amounts of phosphate and potash have been added. The plots were laid out in a split-split plot design. Each plot received two sources of lime at a given rate and different fertilizer treatments were applied across each limestone rate and source. The sources of lime were calcitic and dolomitic. Rates of limestone were 0, 3, 6, and 12 tons per acre. Also heavy liming plots, which were not replicated were included with lime application of (24) and (48) tons per acre. The various limestone treatments were applied by hand in the fall of 1957. The experimental area was then cultivated with a Graham-Homme and then plowed. After plowing, the entire area was sprayed with Dalapon at (8) pounds acid equivalent per acre on November 1. In the spring of 1958, before seeding, fertilizer was applied to sub-plots two and three. Sub-plot (2) received 20+120+120 and sub-plot (3) received 40+120+120. Sub-plots (1), (4), and (5) were left as checks for fertilizer.

The entire experimental area was seeded to Minhafer oats, (8) pounds Vernal alfalfa and (8) pounds bromegrass May 6, 1958. The oats crop was sampled for yields of silage July 29, 1958.

After the first cutting of hay was removed in 1959, sub-plot (2) was treated with 0+40+80 and (3) with 0+80+160. Yield samples were taken for each cutting in 1959 and again in 1960.

Soil samples were taken from the plots in 1957, (Table I), before the treatments for soil were made and again in 1959, (Table VI) for test correlation purposes. Before the second cutting was harvested in 1960, the stand of alfalfa was estimated for each sub-plot at each lime level.

Discussion of Results:

The yields of silage obtained in 1958, showed that oats in most cases did not respond to applications of limestone, (Table II). Calcitic limestone had no effect on yields regardless to the rate of application. Dolomitic limestone applications resulted in a decrease in yields of silage on all sub-plots except sub-plot number (3). The depression of yields from dolomitic limestone was statistically significant, (Table III). The small response to the magnesium from dolomitic in sub-plot (3), however, suggests an effect from cationic balance. Additions of calcium and magnesium might have decreased the potassium activity of the soil causing small yields from the unfertilized sub-plots. The application of ample amounts of phosphate and potash to sub-plot number (3), resulted in a small response to the magnesium from the dolomitic limestone over the calcitic form. The slower reaction rate for dolomitic limestone was suggested by the larger response to the higher rates in sub-plot (3). In all cases, the response of oats to limestone was negligible and economically of little importance.

Oats grown in the experiment responded significantly to applications of fertilizer, Tables (II and (III). This response was expected on the basis of soil test results obtained before the plots were treated, (Table I). The higher rate of fertilizer applied to sub-plot (3) resulted in higher yields than were obtained from the lower rate applied to sub-plot (2).

The yields of hay for 1959, (Table IV) and (V) showed the same trends as were obtained for oats in 1958. The results for soil tests made in 1959, (Table VI), for phosphorus and potassium did not indicate that the amounts available in the soil had been changed. Of course, a large amount of the initial application might have already been removed by crops. The results of the soil tests did not indicate that the calcitic lime reacted more rapidly than the Dolomitic. It is interesting to note that none, not even the (12) tons per acre, of the lime treatments had neutralized the soil by 1959. It will be interesting to note pH changes of these plots with time.

The response of hay yields to higher rates of limestone did not appear until 1960, (Table VII). Also, in 1960, the response to dolomitic limestone over calcitic limestone on sub-plots (3) was greater. The small response, however, was still not statistically significant, (Table VIII). The fact that yields of hay did not increase as a result of applications of limestone until three years after the area was treated, suggest that it might be advisable to lime and fertilize an area about two years before it is to be seeded to alfalfa. This would suggest the need for rotations that include corn, potatoes, or winter grain which could be grown for one year before the alfalfa is seeded.

The stand of alfalfa at the time of the second cutting in 1950 indicated that alfalfa had responded to both sources of limestone, especially where phosphate and potash had been applied, Table IX. The stand of alfalfa was not sufficient on any of the plots, however. The relatively poor stand of alfalfa on the treated plots may have resulted from the slow rate at which the soil reaction was corrected as was indicated above, or it might have been due to competition from the oats nurse crop of the bromegrass.

Yields of hay from the heavy liming plots when compared to those from replication (IV), show the same trends as those for the main experiment, (Table X). It does not appear that the very heavy rate of lime were either beneficial or detrimental to the growth of alfalfa and bromegrass.

Conclusions:

1. Applications of limestone regardless of source to acid topsoil in Northeast Minnesota do not increase yields of oats.

2. Alfalfa responds to applications of limestone, especially when the level of phosphate and potash are adequate.

3. Acotionic interaction between calcium, potassium and magnesium was indicated by the results of this experiment.

4. The delayed response of alfalfa to applications of limestone indicates that a crop management system should be such that basic lime and fertilizer treatments are made one or two years before the alfalfa is seeded.

RATES AND SOURCES OF LIME AT DIFFERENT RATES OF FERTILIZERS

Table I

Results of Soil Tests for samples taken prior to treatment with lime and fertilizers.

| Rep. | Surface pH | Subsoil | O.M. Surface | Subsoil | P Surface | Subsoil | K Surface | Subsoil |
|---|---|---|---|---|---|---|---|---|
| I | 5.8-6.0 | 5.5-5.8 | 3.8-4.5 | 1.4-2.1 | 9-25 | 7-11 | 55-90 | 45-60 |
| II | 5.6-5.9 | 5.7-5.8 | 3.9-4.4 | 1.4-1.9 | 18-28 | 14-26 | 55-80 | 30-65 |
| III | 5.7-6.0 | 5.7-5.9 | 3.9-4.4 | 1.6-2.1 | 18-29 | 14-21 | 60-85 | 45-65 |
| IV | 6.0-6.2 | 5.8-6.1 | 4.1-4.9 | 2.2-3.5 | 10-20 | 6-15 | 50-75 | 30-85 |

RATES AND SOURCES OF LIME AT DIFFERENT RATES OF FERTILIZERS (1958)

Table II

Yields of oat silage in tons per acre as affected by different rates and sources of lime and different rates of fertilizers

| Rates and Sources of Lime | Fertilizers 1 | 2 | 3 | 4 | 5 | Grand Means |
|---|---|---|---|---|---|---|
| Check | 4.62 | 7.04 | 7.34 | 4.92 | 5.07 | 5.800 |
| 3 T./Ac. Dolomitic | 4.44 | 5.09 | 7.39 | 5.29 | 4.15 | 5.282 |
| 3 " Calcitic | 6.31 | 7.07 | 7.39 | 5.36 | 4.88 | 6.203 |
| 6 " Dolomitic | 4.11 | 5.84 | 7.02 | 4.86 | 5.00 | 5.268 |
| 6 " Calcitic | 5.84 | 7.25 | 6.67 | 4.61 | 4.79 | 5.828 |
| 12 " Dolomitic | 4.24 | 6.62 | 7.50 | 4.98 | 4.95 | 5.661 |
| 12 " Calcitic | 4.78 | 6.96 | 7.32 | 5.31 | 4.88 | 5.852 |
| Grand Means | 4.908 | 6.555 | 7.233 | 5.050 | 4.821 | |
| *24 T/Ac. Dolomitic | 2.82 | 3.58 | 7.56 | 3.23 | | 4.30 |
| *24 T/Ac. Calcitic | 3.58 | 4.13 | 4.74 | 4.33 | | 4.20 |
| *48 " Dolomitic | 4.40 | 5.84 | 7.01 | 4.47 | | 5.43 |

*Heavy liming plots which were not replicated.

Confidence Intervals ($D_{.05}$) for comparing:

1. Grand means for rates and sources of lime = 0.510
2. Grand means for rates of fertilizers = 0.467

RATES AND SOURCES OF LIME AT DIFFERENT RATES OF FERTILIZERS (1958)

TABLE IV

YIELDS OF FIRST YEAR HAY IN TONS PER ACRE AS AFFECTED BY DIFFERENT RATES AND SOURCES OF LIME AND DIFFERENT RATES OF FERTILIZERS.

| Rates and Sources of Lime | Fertilizers 1 | 2 | 3 | 4 | 5 | Grand Means |
|---|---|---|---|---|---|---|
| Check | 1.91 | 3.18 | 3.23 | 2.17 | 2.39 | 2.576 |
| 3 T./Ac. Dolomitic | 2.02 | 2.03 | 3.54 | 1.70 | 1.84 | 2.426 |
| 3 T./Ac. Calcitic | 2.20 | 3.26 | 3.30 | 2.10 | 2.24 | 2.626 |
| 6 T./Ac. Dolomitic | 2.06 | 2.88 | 3.55 | 2.39 | 2.06 | 2.589 |
| 6 T./Ac. Calcitic | 2.24 | 3.52 | 3.29 | 2.60 | 2.35 | 2.800 |
| 12 T./Ac. Dolomitic | 2.03 | 3.39 | 3.54 | 1.92 | 2.42 | 2.660 |
| 12 T./Ac. Calcitic | 2.16 | 3.44 | 3.46 | 1.99 | 2.23 | 2.655 |
| Grand Means | 2.093 | 3.242 | 3.416 | 2.126 | 2.216 | |

Confidence Intervals ($D_{.05}$) for Comparing:

1. Grand Means for Rates and Sources of Lime = N.S.
2. Grand Means for Rates of Fertilizers = 0.403
3. Rates and Sources of Lime at a given rate of fertilizer = 0.400

RATES AND SOURCES OF LIME AT DIFFERENT RATES OF FERTILIZERS

TABLE VI

RESULTS OF SOIL TESTS FOR SAMPLES TAKEN IN 1959 TWO YEARS AFTER SOIL HAD BEEN TREATED WITH DIFFERENT RATES AND SOURCES OF LIME AND DIFFERENT RATES OF FERTILIZERS.

| Rep. Fert. | Determination | Check | 3T./A Dolo. | 3T./A. Calc. | 6T/A. Dolo. | 6 T/A. Calc. | 12 T/A Dolo. | 12 T/A Calc. |
|---|---|---|---|---|---|---|---|---|
| I - 2 | pH -0.7 | 5.4 | 5.5 | 5.8 | 6.0 | 6.3 | 6.0 | 5.8 |
| | " 7-12 | 5.4 | 5.5 | 5.4 | 5.9 | 5.4 | 5.1 | 5.2 |
| | % O.M. 0-7 | 4.0 | 4.4 | 3.9 | 4.0 | 4.4 | 4.1 | 4.2 |
| | % O.M. 7-12 | 2.1 | 2.7 | 1.8 | 2.7 | 2.2 | 1.6 | 2.7 |
| | P (lbs./Ac.) 0-7 | 18 | 14 | 14 | 14 | 37 | 49 | 31 |
| | " 7-12 | 10 | 12 | 9 | 11 | 12 | 28 | 17 |
| | K (lbs./Ac. 0-7 | 30 | 30 | 40 | 50 | 40 | 50 | 50 |
| | 7-12 | 30 | 50 | 30 | 30 | 20 | 55 | 40 |
| I - 3 | pH -0.7 | 5.4 | 5.9 | 5.8 | 6.0 | 6.1 | 5.4 | 6.6 |
| | " 7-12 | 5.5 | 5.6 | 5.6 | 6.4 | 5.5 | | 5.6 |
| | % O.M. 0-7 | 4.7 | 3.9 | 3.5 | 4.0 | 3.4 | 2.2 | 4.0 |
| | % O.M. 7-12 | 3.1 | 1.5 | 2.0 | 2.2 | 2.0 | | 2.2 |
| | P (lbs./Ac.) 0-7 | 20 | 23 | 23 | 39 | 19 | 17 | 28 |
| | " 7-12 | 10 | 7 | 9 | 200+ | 7 | | 10 |
| | K (lbs./Ac.) 0-7 | 30 | 50 | 50 | 50 | 50 | 40 | 40 |
| | K (lbs./Ac.) 7-12 | 30 | 30 | 40 | 40 | 30 | | 40 |
| I - 4 | pH 0-7 | 5.4 | 5.8 | 5.9 | 6.2 | 6.1 | 5.0 | 6.5 |
| | " 7-12 | 5.4 | 5.5 | 5.3 | 5.7 | 5.5 | 5.6 | 5.3 |
| | % O.M. 0-7 | 4.9 | 4.7 | 3.4 | 4.4 | 4.4 | 4.7 | 4.1 |
| | % O.M. 7-12 | 2.7 | 2.5 | 2.3 | 2.0 | 1.6 | 1.6 | 2.9 |
| | P (lbs./Ac) 0-7 | 22 | 21 | 77 | 23 | 12 | 28 | 19 |
| | P (lbs./Ac) 7-12 | 17 | 16 | 12 | 12 | 6 | 13 | 9 |
| | K lbs./Ac. 0-7 | 30 | 30 | 40 | 40 | 50 | 30 | 40 |
| | K " " 7-12 | 30 | 40 | 30 | 40 | 40 | 40 | 40 |

TABLE VI (Continued)

| Rep. | Fert. | Determination | Check | 3T./A Dolo. | 3T./A Calc. | 6T./A Dolo. | 6T/A Calc. | 12T/A Dolo. | 12T/A Calc. |
|---|---|---|---|---|---|---|---|---|---|
| III - 2 | | pH 0-7 | 5.3 | 6.2 | 6.0 | 5.8 | 5.6 | 6.3 | 6.7 |
| | | pH 7-12 | 5.3 | 5.6 | 5.6 | 5.2 | 5.4 | 4.8 | 5.6 |
| | | % O.M. 0-7 | 4.2 | 4.4 | 3.9 | 4.4 | 4.0 | 3.6 | 3.6 |
| | | % O.M. 7-12 | 1.8 | 1.6 | 2.0 | 2.3 | 1.9 | 2.2 | 2.1 |
| | | P (lbs./Ac.) 0-7 | 60 | 21 | 15 | 27 | 41 | 26 | 28 |
| | | P (lbs./Ac.) 7-12 | 34 | 10 | 9 | 20 | 18 | 23 | 15 |
| | | K (lbs./Ac.) 0-7 | 70 | 60 | 50 | 20 | 50 | 40 | 30 |
| | | K (lbs./Ac.) 7-12 | 40 | 20 | 30 | 20 | 40 | 60 | 30 |
| III - 3 | | pH 0-7 | 5.4 | 5.9 | 6.0 | 6.2 | 6.2 | 6.1 | 6.3 |
| | | pH 7-12 | 5.3 | 5.6 | 5.7 | 5.6 | 5.2 | 5.7 | 5.6 |
| | | % O.M. 0-7 | 5.3 | 4.4 | 4.4 | 4.4 | 4.5 | 4.4 | 4.4 |
| | | % O.M. 7-12 | 2.2 | 2.0 | 1.6 | 2.2 | 1.8 | 2.3 | 2.7 |
| | | P (lbs./Ac.) 0-7 | 40 | 20 | 37 | 48 | 42 | 51 | 51 |
| | | P (lbs./Ac.) 7-12 | 17 | 11 | 11 | 20 | 16 | 13 | 19 |
| | | K (lbs./Ac.) 0-7 | 60 | 40 | 60 | 50 | 70 | 40 | 40 |
| | | K (lbs./Ac.) 7-12 | 50 | 30 | 20 | 50 | 90 | 30 | 40 |
| III - 4 | | pH 0-7 | 5.4 | 5.9 | 6.2 | 5.9 | 6.0 | 6.4 | 6.2 |
| | | pH 7-12 | 5.4 | 5.4 | 5.6 | 5.5 | 5.4 | 5.5 | 5.5 |
| | | % O.M. 0-7 | 4.4 | 4.5 | 4.4 | 4.2 | 4.7 | 4.2 | 4.1 |
| | | % O.M. 7-12 | 1.7 | 2.7 | 2.2 | 2.3 | 1.8 | 2.2 | 2.1 |
| | | P (lbs./Ac.) 0-7 | 31 | 25 | 23 | 34 | 37 | 35 | 43 |
| | | P (lbs./Ac.) 7-12 | 12 | 16 | 15 | 20 | 14 | 28 | 24 |
| | | K (lbs./Ac.) 0-7 | 60 | 30 | 40 | 40 | 50 | 40 | 40 |
| | | K (lbs./Ac.) 7-12 | 40 | 20 | 20 | 60 | 60 | 30 | 40 |

RATES AND SOURCES OF LIME AT DIFFERENT RATES OF FERTILIZERS (1960)

TABLE VII

YIELDS OF SECOND YEAR HAY IN TONS PER ACRE AS AFFECTED BY DIFFERENT RATES AND SOURCES OF LIME AND DIFFERENT RATES OF FERTILIZERS:

| Rates and Sources of Lime | 1 | 2 | 3 | 4 | 5 | Grand Means |
|---|---|---|---|---|---|---|
| Check | 1.01 | 2.10 | 2.40 | 1.18 | 1.10 | 1.558 |
| 3 T/Ac. Dolomitic | 1.19 | 1.96 | 2.56 | 1.46 | 1.20 | 1.674 |
| 3 T/Ac. Calcitic | 1.17 | 2.18 | 2.46 | 1.36 | 1.29 | 1.689 |
| 6 T/Ac. Dolomitic | 1.18 | 2.07 | 2.61 | 1.45 | 1.17 | 1.694 |
| 6 T/Ac. Calcitic | 1.23 | 2.25 | 2.37 | 1.39 | 1.19 | 1.685 |
| 12 T/Ac. Dolomitic | 1.24 | 2.45 | 2.66 | 1.45 | 1.45 | 1.830 |
| 12 T/Ac. Calcitic | 1.40 | 2.20 | 2.47 | 1.29 | 1.39 | 1.750 |
| Grand Means | 1.202 | 2.173 | 2.504 | 1.366 | 1.241 | |

RATES AND SOURCES OF LIME AT DIFFERENT RATES OF FERTILIZERS (1960)

TABLE IX

PERCENTAGE STAND OF ALFALFA AFTER THREE YEARS IN PLOTS TREATED WITH DIFFERENT RATES AND SOURCES OF LIME AND DIFFERENT RATES OF FERTILIZER.

| Rates and Sources of Lime | Fertilizers 1 | 2 | 3 | 4 | 5 | Grand Means |
|---|---|---|---|---|---|---|
| Check | 7 | 22 | 22 | 8 | 5 | 12.8 |
| 3 T/Ac. Dolomitic | 9 | 32 | 42 | 6 | 13 | 20.0 |
| 3 T/Ac. Calcitic | 7 | 39 | 49 | 9 | 10 | 22.8 |
| 6 T/Ac. Dolomitic | 10 | 36 | 48 | 12 | 9 | 23.0 |
| 6 T/Ac. Calcitic | 6 | 35 | 42 | 9 | 6 | 19.6 |
| 12 T/Ac. Dolomitic | 10 | 32 | 34 | 5 | 11 | 18.4 |
| 12 T/Ac. Calcitic | 7 | 29 | 34 | 7 | 6 | 16.6 |
| Grand Means | 8.0 | 33.1 | 38.6 | 8.0 | 8.5 | |

RATES AND SOURCES OF LIME AT DIFFERENT RATES OF FERTILIZERS (1960)

TABLE X

YIELDS OF HAY IS TONS PER ACRE AS AFFECTED BY DIFFERENT RATES AND SOURCES OF LIME AT DIFFERENT RATES OF FERTILIZER

| | 1959 | | | | | 1960 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Check | 1 | 2 | 3 | 4 | Ave. | 1 | 2 | 3 | 4 | Ave. | Grand Ave. |
| Check | 2.25 | 3.09 | 3.55 | 2.30 | 2.80 | 1.05 | 1.76 | 2.23 | .85 | 1.47 | 2.12 |
| 3 T. Dolo. | 1.88 | 3.08 | 3.87 | 1.49 | 2.58 | 1.13 | 1.76 | 2.88 | 1.10 | 1.72 | 2.15 |
| 3 T. Calc. | 1.92 | 3.68 | 4.00 | 2.13 | 2.93 | .88 | 1.78 | 2.24 | .55 | 1.46 | 2.20 |
| 6 T. Dolo. | 1.73 | 2.75 | 3.77 | 2.80 | 2.76 | .88 | 1.95 | 2.53 | 1.44 | 1.70 | 2.23 |
| 6 T. Calc. | 1.59 | 3.10 | 2.84 | 3.11 | 2.66 | .74 | 1.77 | 2.55 | 1.34 | 1.60 | 2.13 |
| 12 T. Dolo. | 1.72 | 3.41 | 3.70 | 1.97 | 2.70 | .76 | 1.93 | 2.05 | .94 | 1.42 | 2.06 |
| 12 T. Calc. | 2.33 | 3.70 | 3.49 | 1.56 | 2.77 | 1.13 | 1.66 | 1.78 | .94 | 1.38 | 2.08 |
| 24 T. Dolo. | 1.94 | 2.54 | 3.70 | 1.71 | 2.47 | .83 | 1.45 | 1.78 | .82 | 1.22 | 1.84 |
| 24 T. Calc. | 2.35 | 3.92 | 3.82 | 2.35 | 3.11 | .95 | 1.41 | 1.39 | 1.16 | 1.23 | 2.17 |
| 48 T. Dolo. | 2.20 | 4.29 | 4.24 | 2.40 | 3.28 | 1.19 | 1.71 | 2.21 | 1.17 | 1.57 | 2.42 |
| 48 T. Calc. | 2.23 | 3.80 | 4.46 | 1.82 | 3.08 | 1.03 | 1.59 | 2.02 | .78 | 1.33 | 2.20 |
| Average | 2.01 | 3.42 | 3.77 | 2.15 | | .96 | 1.71 | 2.15 | 1.04 | | |

# Lime Experiment
## Rosemount, 1960

A. C. Caldwell and J. B. Weber

To study the long time effects of lime on the yields of some common crops and on the physical and chemical properties of the soil, a research project with lime was started at the Rosemount station in the fall of 1951. Plots were laid out consisting of four replications of five treatments. Treatments were 0, 3, 6, 12, and 24 tons of lime per acre. A regular rotation of corn, oats, alfalfa, and alfalfa was set up. Each year corn and grain have received 200 pounds of 5-20-20 per acre as a fertilizer treatment. Alfalfa has received phosphorus and potassium fertilizers as needed according to soil test.

In 1959, it was decided to also study the effect of lime on soybeans, so the rotation was changed to corn, soybeans, oats and alfalfa. The soybeans received 100 pounds of 5-20-20 per acre as a starter fertilizer.

In 1960, an application of 8.7 ounces of Mo per acre, as $(NH_4)_2MoO_4$, was made to one of the check plots in each replicate to study the effect of applied Mo on the yields of the various crops.

Yield results from the four crops for 1960 are included in Table 1. Corn yields were significantly (.05) higher than the control on all of the treatments. The various treatments are not significantly different from each other, however, and it appears that any one of the lime treatments or the molybdenum treatment would increase corn yields to about the same degree. Increased corn yields attributed to liming are most likely caused indirectly by added nitrogen from the previous alfalfa crop. Increased corn yields by the Mo application may be a direct response to Mo, or possibly the Mo improves the nitrogen fixing ability of the alfalfa nodules and is again an indirect affect. It will be noted that the Mo treatment also significantly increased the yield of alfalfa above the control.

Soybean yields were significantly (.05) increased above the control by the 12 and 24 tons of lime per acre treatment and by the Mo application. The treatments, other than the control, are not significantly different from each other but it appears as though the yields of soybeans did continue to increase with increased increments of lime applied.

Oat yields were not significantly affected by either the lime or Mo applications. It is interesting to note, however, that all treatments decreased the yield of oats below that of the control. Oats was equally as lacking to fertilizer response on the rate of seeding experiment in 1960.

Alfalfa yields were significantly (.05) increased by the lime and Mo applications. The 6 and 24 ton per acre rates produced the greatest yield increases above control being 1.39 and 1.45 tons per acre respectively. The 6 ton per acre rate has in the past years been the highest yielder of alfalfa and again seems to conform to that trend. The Mo application, although increasing the alfalfa yield significantly, is much lower than any of the lime treatments.

The included soil pH values are following the same trend as in previous years.

Table 1. The effect of lime and molybdenum on soil pH and the yields of corn, soybeans, oats, and alfalfa in a rotation, 1960.

| Treatment | Soil pH | Yields: Corn[1] bu/A | Diff. | Soybeans bu/A | Diff. | Oats bu/A | Diff. | Alfalfa Tons/A | Diff. |
|---|---|---|---|---|---|---|---|---|---|
| 0 tons lime/A | 6.1 | 132 | ---- | 25.4 | ---- | 75.4 | ---- | 2.67 | ---- |
| 3 tons lime/A | 6.5 | 146 | 14 | 24.0 | -1.4 | 66.0 | -9.4 | 3.91 | 1.24 |
| 6 tons lime/A | 6.9 | 147 | 15 | 27.1 | 1.7 | 70.2 | -5.2 | 4.06 | 1.39 |
| 12 tons lime/A | 7.2 | 141 | 9 | 27.8 | 2.4 | 71.6 | -3.8 | 3.80 | 1.13 |
| 24 tons lime/A | 7.5 | 152 | 20 | 28.7 | 3.3 | 73.3 | -2.1 | 4.12 | 1.45 |
| 8.7 oz. Mo/A | 6.1 | 143 | 11 | 27.4 | 2.0 | 72.1 | -3.3 | 3.30 | 0.63 |
| lsd (.05) = | | | 9.0 | | 1.9 | | N.S. | | 0.50 |
| hsd (.05) = | | | 15.6 | | 3.4 | | | | 0.94 |

1 @ 15% moisture

2 Dry weight

## The Nicollet County Plots

### Soil Fertility and Crop Production Studies on the Webster Soils of Southern Minnesota

W. P. Martin, Fred Wetherill and H. W. Kramer

### Yield Results - 1960

Re: 1959 results, "A Report on Soils and Soil Fertility", p. 74. Department of Soils, Mimeo, April, 1960.

Soils: Webster and closely related Nicollet silty clay loams: level topography, miminum erosion, drainage necessary.

Cropping systems established in 1948: (1) corn-oats, (2) corn-oats with clover as green manure, (3) 4-year rotation of oats-hay-corn-corn extended to 5-years in 1958 with soybeans between two corn years, and (4) continuous corn (established in 1954).

Fertilizer treatments: Multiple rates and materials including barnyard manure at regular and "extra" heavy fertilization levels; see tables for treatments and 1959 report for details on materials, rates and methods of applications. Four replications.

CONTINUOUS CORN (RATE AND TIME OF APPLICATION)

| Nitrogen: | | Yield results: | |
| --- | --- | --- | --- |
| Rate | Time* | Starter only** | +PK broadcast*** |
| None | 0-0-0 | 53 bu. | 54 bu. |
| 40 lbs | 1-0-0 | 89 | 86 |
| 80 | 1-1-0 | 89 | 96 |
| 120 | 1-1-1 | 96 | 105 |
| 80 | 1-0-1 | 86 | 96 |
| 80 | 0-1-1 | 83 | 100 |
| 40 | 0-0-1 | 80 | 93 |
| 40 | 0-1-0 | 79 | 90 |
| 80 | 2-0-0 | 86 | 94 |
| 120 | 3-0-0 | 91 | 100 |

*0-0-0 refers to time of application, i.e. planting time-first cultivation-second cultivation.

** 175 lbs. 6-24-12 starter in row at planting time.

***Starter plus 300 lbs. 0-20-20 braodcast.

## CORN-OATS (WITH AND WITHOUT LEGUME GREEN MANURE):

| | | CORN | (with legume) | OATS | (with legume) |
|---|---|---|---|---|---|
| 1. | Check | 57 bu. | 53 bu. | 31 bu. | 42 bu. |
| 2. | N on oats | 60 | 56 | 53 | 53 |
| 3. | NP on oats | 67 | 81 | 66 | 78 |
| 4. | NPK on oats | 68 | 82 | 63 | 69 |
| 5. | P plowdown | 71 | 72 | 33 | 53 |
| 6. | NPK in hill | 78 | 82 | 30 | 46 |
| 7. | N plowdown | 70* | 53* | 45* | 59* |
| 8. | N sidedress | 74* | 43* | 59* | 51* |
| | LSD (5%) | 11 | 14 | 11 | 14 |

One replication only

## Corn-Soybeans-Corn-Oats-Hay (with regular and extra-heavy fertilization levels):

| | Treatments (regular) | Corn (1) | | Soybeans | | Corn (2) | | Oats | | Hay | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Reg. | Extra* | Reg. | Extra* | Reg. | Extra* | Reg. | Extra* | Reg. | Extra* |
| 6. | Check | 73 bu. | 101 bu. | 34 bu. | 43 bu. | 70 bu. | 102 bu. | 58 bu. | 78 bu. | 1.8 tons | 4.7 tons |
| 1. | P for oats | 81 | 100 | 39 | 40 | 72 | 84 | 73 | 72 | 3.7 | 4.2 |
| 2. | PK for oats | 76 | 98 | 40 | 42 | 74 | 88 | 70 | 72 | 3.9 | 4.9 |
| 7. | NP for oats | 77 | 86 | 38 | 39 | 70 | 85 | 84 | 83 | 3.7 | 4.3 |
| 3. | NPK for oats | 78 | 99 | 37 | 40 | 73 | 87 | 87 | 90 | 3.4 | 4.4 |
| 10. | P for oats & corn | 91 | 102 | 38 | 42 | 82 | 86 | 81 | 106 | 4.1 | 4.5 |
| 9. | P for corn | 86 | 98 | 37 | 38 | 75 | 83 | 76 | 85 | 3.1 | 4.8 |
| 4. | Manure for corn | 96 | 103 | 43 | 46 | 89 | 87 | 66 | 76 | 3.1 | 4.7 |
| 8. | Manure & P for corn | 97 | 100 | 41 | 44 | 89 | 93 | 65 | 79 | 4.2 | 4.6 |
| 5. | Manure & NPK for corn | 107 | 102 | 42 | 41 | 89 | 107 | 72 | 72 | 3.5 | 4.7 |
| | LSD (5%) | 13 | 13 | 3 | 6 | 13 | 13 | 16 | 14 | 0.6 | 0.8 |

*Refers to extra-heavy fertilization treatments in addition to regular treatments.
Season very wet which delayed planting and early cultivation.

# Fertilizer Rotation Studies
(A report on 1960 fertilizer experiments)

## Introduction

The permanent fertilizer rotation plots which are established at the Waseca, Morris, and Crookston Branch Experiment Stations have now been in existence for 5 years. These plots were designed to evaluate the effects of the nutrients, nitrogen, phosphorus, and potash, on soil properties and crop response when crops are grown in typical rotations for an area. While all crops receive the three nutrients above and in all combinations with one another the rates of application are selected appropriately for the specific crops. All fertilizers are applied as a broadcast application in the spring with the exception of a small portion for corn which is applied as a starter at planting.

The crops at Morris and Waseca are in a five year rotation. Continuous corn is also grown at both stations. The rotations at the Waseca and Morris stations are as follows:

| Waseca | Morris |
|---|---|
| corn | corn |
| corn | corn |
| soybeans | soybeans |
| oats | flax |
| alfalfa | alfalfa |
| continuous corn* | continuous corn* |

The Crookston experiment consists of two rotations, a three and a four year rotation. The three year rotation consists of a sequence of sugar beets, wheat and sweet clover fallow. The four year rotation is a sequence of corn, soybeans, wheat and alfalfa.

Besides the regular fertilizer treatments an extra plot has been added to each experiment which receives a very heavy treatment of N, P, and K. These plots, which are known as NPK+ treatments are not analyzed statistically with the rest of the experiment but are used to make qualitative comparisons.

## Interpretation of Statistical Data

The data tables show the mean yields of the various crops for each fertilizer treatment, and the differences between these yields and those obtained from untreated plots. In addition each table has a column labled treatment effect. The treatment affects for N, P, or K alone are the best statistical estimates of the effect of these nutrients. The numbers tabulated in this column are the differences between all plots treated with a given nutrient and all plots not treated with that nutrient. This quantity is called the main effect of that nutrient. The main effect of nitrogen for instance is computed as follows:

$$\text{N main effect} = \frac{(N + NP + NK + NPK) - (P + K + PK + \text{check})}{12}$$

---

* Not in rotation

When significant treatment effects are shown for NP, NK, or PK treatments this fact indicates that interaction has occurred. This means that the two nutrients together produced some effect which was not due to either one of them alone. A hypothetical example of an NP interaction on corn would appear as follows:

| | No N | N |
|---|---|---|
| No P | 80 | 100 |
| P | 85 | 130 |

The first row shows that N increases yields from 80 to 100 bu/A when no P has been applied. The first column shows that P increases the yield from 80 to 85 bu/A when no N is applied. If there were no interaction it would be expected that the NP treatment would result in a yield of 105 bu/A (80 + 20 for N + 5 for P). A yield of 130 indicates that N and P combined produced a yield which is not attributable to either nutrient alone.

In certain cases treatment effects are found which are not significant at the usual 99 or 95 percent levels but nevertheless seem to be important. When this happens in this report the actual probability levels are tabulated after the treatment effect in parentheses.

## Waseca Yields

### Corn

Continuous corn yields in 1960 ranged from 85 to 125 bushels per acre. The corn at harvest was mature even though late spring rains caused a postponement of planting until June 2, 1960. This was the first year that a significant response to added nitrogen was found although this was the fifth year of continuous corn.

An unusual result was found on the first year corn in that a significant response to K application was obtained. The past five years of experience with these plots has shown no other instance of an increase in corn yields due to K application.

Significant yield increases were found on the second year corn for the applications on nitrogen.

All corn was planted at the rate of 20,000 stalks per acre. Due to the late planting date a 112-115 day variety was used instead of the usual 120 day maturity corn used in previous years. Soil insects were controlled by the use of a broadcast application of alderin and annual grasses were controlled by the use of a band spray application of Randox.

### Soybeans

Soybean yields were good, ranging from 29 to 33 bushels per acre. Soybeans in this and other locations respond only occassionally to added fertilizer but this year a small significant increase amounting to 1.5 bu/acre was found due to the application of phosphorus.

### Oats

Grain yields were increased slightly by N applications and decreased slightly by NP applications. As in recent years, significant lodging again occurred on plots treated with nitrogen.

Oats for forage were sampled in the dough stage when the average moisture content was 60%. Nitrogen and phosphate treatments both resulted in substantial increases in forage yield.

<u>Alfalfa</u>

Two cuttings of alfalfa were obtained from the Waseca plots, although total annual yield only is tabulated here. As is frequently the case, a significant increase in annual alfalfa yield was obtained due to phosphorus application.

## Fertilizer Rotation Experiment - Waseca

Table W-1. Continuous Corn (15% moisture)

| Treatment | lbs/ac $N-P_2O_5-K_2O$ | Average Yield bu/ac | Diff. | Treatment effect |
|---|---|---|---|---|
| None | 0-0-0 | 86.9 | | |
| N | 160-0-0 | 100.8 | 13.9 | 18.8** |
| P | 0-160-0 | 88.2 | 1.3 | 7.0 (90%) |
| K | 0-0-160 | 85.1 | -1.8 | |
| NP | 160-160-0 | 105.4 | 18.5 | |
| NK | 160-0-160 | 104.1 | 17.2 | |
| PK | 0-160-160 | 93.1 | 6.2 | |
| NPK | 160-160-160 | 118.3 | 31.4 | |
| NPK+ | 320-320-320 | 124.9 | 38.0 | |

Table W-2. First year corn.

| Treatment | lbs/ac $N-P_2O_5-K_2O$ | Average Yield bu/ac | Diff. | Treatment effect |
|---|---|---|---|---|
| None | 0-0-0 | 90.0 | | |
| N | 40-0-0 | 98.7 | 8.7 | |
| P | 0-80-0 | 100.2 | 10.2 | |
| K | 0-0-80 | 103.9 | 13.9 | 7.8(94%) |
| NP | 40-80-0 | 96.3 | 6.3 | |
| NK | 40-0-80 | 105.5 | 15.5 | |
| PK | 0-80-80 | 102.2 | 12.2 | |
| NPK | 40-80-80 | 104.6 | 14.6 | |
| NPK+ | 80-160-160 | 114.0 | 24.0 | |

* Significant at 95% level
** Significant at 99% level

Waseca

Table W-3. Second Year Corn

| Treatment | lbs/ac $N-P_2O_5-K_2O$ | Average Yield bu/ac | Diff. | Treatment effect |
|---|---|---|---|---|
| None | 0-0-0 | 91.9 | | |
| N | 80-0-0 | 103.4 | 11.5 | 17.5** |
| P | 0-80-0 | 86.4 | -5.5 | |
| K | 0-0-80 | 96.8 | 4.9 | |
| NP | 80-80-0 | 101.8 | 9.9 | |
| NK | 80-0-80 | 107.1 | 15.2 | |
| PK | 0-80-80 | 80.9 | -11.0 | |
| NPK | 80-80-80 | 113.7 | 21.8 | |
| NPK+ | 160-160-160 | 118.8 | 26.9 | |

Table W-4. Soybeans

| Treatment | lbs/ac $N-P_2O_5-K_2O$ | Average Yield bu/ac | Diff. | Treatment effect |
|---|---|---|---|---|
| None | 0-0-0 | 29.8 | | |
| N | 20-0-0 | 31.1 | 1.3 | |
| P | 0-40-0 | 31.4 | 1.6 | 1.5 (94%) |
| K | 0-0-40 | 28.9 | -0.9 | |
| NP | 20-40-0 | 31.5 | 1.7 | |
| NK | 20-0-40 | 31.3 | 1.5 | |
| PK | 0-40-40 | 31.7 | 1.9 | |
| NPK | 20-40-40 | 32.6 | 2.8 | |
| NPK+ | 40-80-80 | 32.5 | 2.7 | |

Waseca

Table W-5. Oats Forage[1]

| Treatment | lbs/ac $N-P_2O_5-K_2O$ | Average Yield T/ ac | Diff. | Treatment effect |
|---|---|---|---|---|
| None | 0-0-0 | 6.95 | | |
| N | 80-0-0 | 9.09 | 2.14 | 2.35** |
| P | 0-80-0 | 6.82 | -0.03 | 1.05* |
| K | 0-0-80 | 6.23 | -0.72 | |
| NP | 80-80-0 | 10.11 | 3.16 | |
| NK | 88-0-80 | 8.53 | 1.58 | |
| PK | 0-80-80 | 8.21 | 1.26 | |
| NPK | 80-80-80 | 9.88 | 2.93 | |
| NPK+ | 120-160-160 | 11.30 | 4.35 | |

[1]60% moisture

Table W-6. Oats Grain

| Treatment | lbs/ac $N-P_2O_5-K_2O$ | Average Yield bu/ac | Diff. | Treatment effect |
|---|---|---|---|---|
| None | 0-0-0 | 62.8 | | |
| N | 80-0-0 | 79.7 | 16.9 | 6.7 (90.3%) |
| P | 0-80-0 | 67.7 | 4.9 | |
| K | 0-0-80 | 69.7 | 6.9 | |
| NP | 88-80-0 | 72.3 | 9.5 | -7.5 (92.6%) |
| NK | 80-0-80 | 81.2 | 18.4 | |
| PK | 0-80-80 | 80.3 | 17.5 | |
| NPK | 80-80-80 | 74.3 | 11.5 | |
| NPK+ | 120-160-160 | 64.1 | 1.3 | |

Waseca

Table W-7. Alfalfa (Total of two cuttings)

| Treatment | lbs/ac $N-P_2O_5-K_2O$ | Average Yield T/ac | Diff. | Treatment effect |
|---|---|---|---|---|
| None | 0-0-0 | 2.17 | | |
| N | 20-0-0 | 2.89 | 0.72 | |
| P | 0-80-0 | 3.14 | 0.97 | 0.64* |
| K | 0-0-80 | 2.39 | 0.22 | |
| NP | 20-80-0 | 3.09 | 0.92 | |
| NK | 20-0-80 | 2.78 | 0.61 | |
| PK | 0-80-80 | 3.32 | 1.15 | |
| NPK | 20-80-80 | 3.22 | 1.05 | |
| NPK+ | 20-160-160 | 3.39 | 1.22 | |

## Morris Yields

### Corn

Yields of continuous corn were improved to the extent of 18 bushels per acre by the application of 160 pounds of N per acre. Neither first nor second year corn were similarly affected. It is significant to note that continuous corn at Morris yielded in general well below the levels of first and second year corn. The overall average yield of continuous corn amounted to 67 bushels per acre. First and second year corn on the other hand yielded an average of 79 and 82 bushels per acre respectively. The latter two yields were both significantly greater than the continuous corn yield at the 99% level of confidence.

The stand of corn at Morris amounted to 15,600 stalks per acre. Soil insects were controlled by the use of alderin and annual grasses were controlled by a band spray application of Randox.

An experimental application of amino triozole to thistles growing in the corn was tried. This was done with a small experimental sprayer which had guards installed to prevent any spray from touching the corn. It was hoped that if all thistles between rows were covered with spray, some of it would be translocated within roots and affect the thistles within rows. Three weeks after application, all thistles between rows showed characteristic amino triozole damage and an estimated 40% of the thistles within rows were similarly affected. None of the corn stalks showed any visible damage. This application was made June 18, 1960.

### Soybeans

Soybeans averaged about 20 bushels per acre but no treatment effect was noted.

### Flax

Flax yields ranged from 19 to about 24 bushels per acre. The nitrogen treated plots averaged slightly but significantly lower in yield than the non nitrogen treated plots.

### Alfalfa

Three cuttings of alfalfa were taken and the total annual yields computed. As has happened in every previous year of the experiment, the alfalfa yields were again improved significantly by phosphorus applications.

Alfalfa yields were slightly reduced on plots which have been treated with nitrogen. This occurrence is noted from time to time at all three branch stations considered in this report. It is not known if this is a direct effect of nitrogen or if it is an indirect effect of the heavier grain stand on nitrogen treated plots in the previous year.

# Fertilizer Rotation Experiment - Morris

Table M-1. Continuous Corn

| Treatment | lbs/ac $N-P_2O_5-K_2O$ | Average Yield bu/ac | Diff. | Treatment effect |
|---|---|---|---|---|
| None | 0-0-0 | 65.2 | | |
| N | 160-0-0 | 76.5 | 11.3 | 18.7** |
| P | 0-160-0 | 50.9 | -14.3 | |
| K | 0-0-40 | 53.9 | 11.3 | |
| NP | 160-160-0 | 74.9 | 9.7 | |
| NK | 160-0-40 | 84.5 | 19.3 | |
| PK | 0-160-40 | 65.4 | 0.2 | |
| NPK | 160-160-40 | 74.2 | 9.0 | |
| NPK+ | 320-320-80 | 58.2 | -7.0 | |

Table M-2. First year corn

| Treatment | lbs/ac $N-P_2O_5-K_2O$ | Average Yield bu/ac | Diff. | Treatment effect |
|---|---|---|---|---|
| None | 0-0-0 | 76.8 | | |
| N | 60-0-0 | 88.4 | 11.6 | |
| P | 0-40-0 | 85.5 | 8.7 | |
| K | 0-0-40 | 81.6 | 4.8 | |
| NP | 60-40-0 | 76.3 | -0.5 | |
| NK | 60-0-40 | 72.0 | -4.8 | |
| PK | 0-40-40 | 85.4 | 8.6 | |
| NPK | 60-40-40 | 76.9 | 0.1 | |
| NPK+ | 100-120-80 | 66.4 | -10.4 | |

Table M-3. Second year corn

| Treatment | lbs/ac $N-P_2O_5-K_2O$ | Average Yield bu/ac | Diff. | Treatment effect |
|---|---|---|---|---|
| None | 0-0-0 | 81.5 | | |
| N | 80-0-0 | 86.1 | 4.6 | |
| P | 0-80-0 | 94.6 | 13.1 | |
| K | 0-0-40 | 83.3 | 1.8 | -7.9 (90%) |
| NP | 80-80-0 | 82.8 | 1.3 | |
| NK | 80-0-40 | 81.1 | -0.4 | |
| PK | 0-80-40 | 77.3 | -4.2 | |
| NPK | 80-80-40 | 75.2 | -6.3 | |
| NPK+ | 120-120-80 | 78.5 | -3.0 | |

Table M-4. Soybeans

| Treatment | lbs/ac $N-P_2O_5-K_2O$ | Average Yield bu/ac | Diff. | Treatment effect |
|---|---|---|---|---|
| None | 0-0-0 | 20.5 | | |
| N | 20-0-0 | 19.8 | -0.7 | |
| P | 0-40-0 | 20.9 | 0.4 | |
| K | 0-0-40 | 16.7 | -3.8 | |
| NP | 20-40-0 | 20.9 | 0.4 | |
| NK | 20-0-40 | 19.3 | -1.2 | |
| PK | 0-40-40 | 19.0 | -1.5 | |
| NPK | 20-40-40 | 20.7 | 0.2 | |
| NPK+ | 40-80-80 | 18.9 | -1.4 | |

Table M-5. Flax

| Treatment | lbs/ac $N-P_2O_5-K_2O$ | Average Yield bu/ac | Diff. | Treatment effect |
|---|---|---|---|---|
| None | 0-0-0 | 23.9 | | |
| N | 60-0-0 | 21.2 | -2.7 | -2.0* |
| P | 0-40-0 | 23.6 | -0.3 | |
| K | 0-0-20 | 21.3 | -2.6 | |
| NP | 60-40-0 | 19.0 | -3.3 | |
| NK | 60-0-20 | 22.3 | -1.6 | |
| PK | 0-40-20 | 23.0 | -0.9 | |
| NPK | 60-40-20 | 21.2 | -2.7 | |
| NPK+ | 120-80-40 | 21.0 | -2.9 | |

Table M-6. Alfalfa

| Treatment | lbs/ac $N-P_2O_5-K_2O$ | Average Yield T/ac | Diff. | Treatment effect |
|---|---|---|---|---|
| None | 0-0-0 | 3.88 | | |
| N | 20-0-0 | 3.69 | -0.19 | -0.26 (93%) |
| P | 0-80-0 | 5.05 | 1.17 | 1.19** |
| K | 0-0-40 | 3.74 | -0.14 | |
| NP | 20-80-0 | 4.70 | 0.82 | |
| NK | 20-0-40 | 3.51 | -0.37 | |
| PK | 0-80-40 | 5.07 | 1.19 | |
| NPK | 20-80-40 | 4.78 | 0.90 | |
| NPK+ | 20-160-80 | 5.11 | 1.23 | |

# Crookston Yields

## Four Year Rotation

### Alfalfa

The average annual alfalfa yields ranged from about 1.3 to 3.8 tons per acre. Significant increases were found due to the application of 40 lbs. $P_2O_5$ per acre.

### Soybeans

Yields ranged from 11.3 to 18.1 bushels per acre with no significant treatment effects.

### Corn

Corn yields were better than those obtained in previous years ranging from 76 to 100 bushels per acre. As is usually the case at Crookstion station, yields were improved significantly by 40 pounds $P_2O_5$ per acre.

### Wheat

Wheat yields in the four year rotation were well above those in the three year rotation. The average yield of 4 year rotation wheat was 50.5 bushels per acre while that in the three year rotation amounted to only 29.6 bushels per acre. Yields of wheat in the 4 year rotation were significantly improved by the application of 40 pounds $P_2O_5$ per acre.

## Three Year Rotation

### Wheat

Yield data for wheat in the three year rotation tended to be quite variable in ranging from 18.3 to 49.9 bushels per acre. Some of this variation is probably due to early season plot damage by heavy rains. Nevertheless, significant increases in yield were found due to the application of both phosphorus and nitrogen.

### Sugar Beets

Sugar beet yields ranged from 14.7 to 20.9 tons per acre and were significantly improved by the application of 120 pounds $P_2O_5$ per acre.

## Soil Testing Results

Soil samples were taken from both the three and four year rotations in 1960. Surface samples (0-6") were taken from the summer fallow plots in the three year rotation and the alfalfa plots in the four year rotation. Soil testing laboratory results were well correlated with previous treatment on the P and K tests while soil pH was shown to be not influenced by fertilizer treatment. (Table C-7 and C-8)

Fertilizer Rotation Experiment - Crookston

Table C-1. Hay - four year rotation

| Treatment | lbs/ac $N-P_2O_5-K_2O$ | Average Yield T/ac | Diff. | Treatment effect |
|---|---|---|---|---|
| None | 0-0-0 | 1.62 | | |
| N | 20-0-0 | 1.27 | -0.35 | |
| P | 0-40-0 | 3.59 | 1.97 | 1.25** |
| K | 0-0-20 | 1.77 | 0.15 | |
| NP | 20-40-0 | 3.39 | 1.77 | |
| NK | 20-0-20 | 1.69 | 0.07 | |
| PK | 0-40-20 | 3.58 | 1.96 | |
| NPK | 20-40-20 | 3.31 | 1.69 | |
| NPK+ | 20-160-80 | 3.83 | 2.21 | |

Table C-2. Soybeans - 4 year rotation

| Treatment | lbs/ac $N-P_2O_5-K_2O$ | Average Yield bu/ac | Diff. | Treatment effect |
|---|---|---|---|---|
| None | 0-0-0 | 11.3 | | |
| N | 40-0-0 | 16.2 | 4.9 | |
| P | 0-40-0 | 16.4 | 5.1 | |
| K | 0-0-20 | 15.3 | 4.0 | |
| NP | 40-40-0 | 13.1 | 1.8 | |
| NK | 40-0-20 | 12.5 | 1.2 | |
| PK | 0-40-20 | 14.9 | 3.6 | |
| NPK | 40-40-20 | 17.1 | 5.8 | |
| NPK+ | 40-120-40 | 18.1 | 6.8 | |

Crookston

Table C-3. Corn - 4 year rotation

| Treatment | lbs/ac $N-P_2O_5-K_2O$ | Average Yield bu/ac | Diff. | Treatment effect |
|---|---|---|---|---|
| None | 0-0-0 | 76.3 | | |
| N | 40-0-0 | 80.8 | 4.5 | |
| P | 0-40-0 | 96.5 | 20.2 | 8.3* |
| K | 0-0-20 | 83.7 | 7.4 | |
| NP | 40-40-0 | 100.6 | 24.3 | |
| NK | 40-0-20 | 92.0 | 15.7 | |
| PK | 0-40-20 | 93.7 | 17.4 | |
| NPK | 40-40-20 | 92.0 | 15.7 | |
| NPK+ | 80-120-40 | 96.7 | 20.4 | |

Table C-4. Wheat - 4 year rotation

| Treatment | lbs/ac $N-P_2O_5-K_2O$ | Average Yield bu/ac | Diff. | Treatment effect |
|---|---|---|---|---|
| None | 0-0-0 | 41.8 | | |
| N | 40-0-0 | 43.8 | 2.0 | |
| P | 0-40-0 | 54.7 | 12.9 | 14.2** |
| K | 0-0-20 | 40.1 | -1.7 | |
| NP | 40-40-0 | 54.5 | 12.7 | |
| NK | 40-0-20 | 44.0 | 2.2 | |
| PK | 0-40-20 | 61.6 | 19.8 | |
| NPK | 40-40-20 | 55.9 | 14.1 | |
| NPK+ | 40-120-40 | 58.2 | 16.4 | |

Crookston

Table C-5. Wheat - 3 year rotation

| Treatment | lbs/ac $N-P_2O_5-N_2O$ | Average Yield bu/ac | Diff. | Treatment effect |
|---|---|---|---|---|
| None | 0-0-0 | 18.3 | | |
| N | 20-0-0 | 22.9 | 4.6 | 12.8** |
| P | 0-40-0 | 16.4 | -1.9 | 7.4* |
| K | 0-0-20 | 20.5 | 2.2 | |
| NP | 20-40-0 | 39.1 | 20.8 | |
| NK | 20-0-20 | 31.4 | 13.1 | |
| PK | 0-40-20 | 27.8 | 9.5 | |
| NPK | 20-40-20 | 39.7 | 21.4 | |
| NPK+ | 40-80-40 | 49.9 | 31.6 | |

Table C-6. Sugar Beets

| Treatment | lbs/ac $N-P_2O_5-K_2O$ | Average Yield T/ac | Diff. | Treatment effect |
|---|---|---|---|---|
| None | 0-0-0 | 14.7 | | |
| N | 40-0-0 | 15.9 | 1.2 | |
| P | 0-120-0 | 15.7 | 1.0 | 3.46** |
| K | 0-0-40 | 14.9 | 0.2 | |
| NP | 40-120-0 | 20.0 | 5.3 | |
| NK | 40-0-40 | 16.9 | 2.2 | |
| PK | 0-120-40 | 20.9 | 6.2 | |
| NPK | 40-120-40 | 19.7 | 5.0 | |
| NPK+ | 80-240-80 | 16.9 | 2.2 | |

Crookston

Table C-7. Soil test results on three year rotation

| Treatment | Total 5 year Fertilizer Application | lbs. P/A | lbs. K/A | pH |
|---|---|---|---|---|
| Check | 0-0-0 | 12.7 | 473 | 8.0 |
| N | 280-0-0 | 14.0 | 437 | 8.0 |
| P | 0-440-0 | 64.7 | 460 | 7.8 |
| K | 0-0-160 | 11.3 | 587 | 8.0 |
| NP | 280-440-0 | 56.0 | 427 | 8.0 |
| NK | 280-0-160 | 15.0 | 427 | 7.9 |
| PK | 0-440-160 | 66.0 | 577 | 7.9 |
| NPK | 280-440-160 | 72.3 | 430 | 7.8 |
| NPK+ | 360-880-320 | 134.7 | 510 | 7.9 |

Table C-8. Soil test results on four year rotation

| Treatment | Total 5 year Fertilizer Application | lbs. P/A | lbs. K/A | pH |
|---|---|---|---|---|
| Check | 0-0-0 | 6.3 | 357 | 7.8 |
| N | 160-0-0 | 8.0 | 270 | 7.9 |
| P | 0-200-0 | 22.0 | 357 | 7.9 |
| K | 0-0-100 | 7.3 | 403 | 7.9 |
| NP | 160-200-0 | 23.7 | 423 | 7.9 |
| NK | 160-0-100 | 6.3 | 437 | 7.8 |
| PK | 0-200-100 | 25.7 | 400 | 7.9 |
| NPK | 160-200-100 | 17.3 | 363 | 7.9 |
| NPK+ | 200-680-280 | 84.0 | 473 | 7.7 |

## Manuring, Liming and Fertilizing Experiment (1960)

Northeast Experiment Station

Dale E. Baker and A. C. Caldwell

Potatoes:

Because of poor drainage, the yields from these plots were quite variable. The effect of applying manure over a period of years is reflected in the yields of potatoes. Although applications of lime alone resulted in somewhat higher yields, the highest yields were obtained where both lime and fertilizer were applied.

Oats:

Yields of oats showed the same trends as those for potatoes with one important exception. The response to lime and commercial fertilizer was very small, especially where manure had been applied in the rotation. This is disturbing, and indicates that more than nitrogen, phosphate and potash is needed by this soil.

Hay:

As with oats, hay responded to applications of manure and also some to lime. The response to fertilizer, however, was small for first year hay where the crop was depending on residual fertility from the oat crop. The response to fertilizer applied to the second year hay was more encouraging.

MANURING, LIMING, AND FERTILIZING EXPERIMENT

YIELDS OF 1 ST. YEAR HAY IN 1960

| Plot Nos. | Manure Treatments | Lime and Fertilizer Treatments Check T./Ac. | Lime T./Ac. | Lime & Fert. T./Ac. | Ave. Yield |
|---|---|---|---|---|---|
| 7 & 13 | Check | 1.16 | 1.41 | 2.02 | 1.53 |
| 8 & 14 | 5 T/A on Stubble | 1.76 | 2.08 | 2.05 | 1.96 |
| 9 & 15 | 10 " " " | 2.06 | 1.89 | 2.16 | 2.04 |
| 10 & 16 | 20 " " " | 2.16 | 2.20 | 2.59 | 2.32 |
| 11 & 17 | 10 " " Sod | 1.40 | 2.73 | 2.21 | 2.11 |
| 12 & 18 | 5 " " " | 1.95 | 2.32 | 2.40 | 2.22 |
| | Average | 1.75 | 2.10 | 2.22 | |

MANURING, LIMING, AND FERTILIZING EXPERIMENT

YIELD OF 2 ND. YEAR HAY IN 1960

| Plot Nos. | Manure Treatments | Lime and Fertilizer Treatments Check T./Ac. | Lime T./Ac. | Lime & Fert. T./Ac. | Ave. Yield |
|---|---|---|---|---|---|
| 7 & 13 | Check | 1.15 | 1.55 | 1.77 | 1.49 |
| 8 & 14 | 5 T./Ac. on Stubble | 1.90 | 1.78 | 2.60 | 2.09 |
| 9 & 15 | 10 " " " | 2.10 | 2.19 | 2.68 | 2.32 |
| 10 & 16 | 20 " " " | 2.50 | 2.29 | 2.92 | 2.57 |
| 11 & 17 | 10 " " Sod | 1.69 | 1.68 | 2.61 | 1.99 |
| 12 & 18 | 5 " " " | 1.55 | 1.52 | 2.20 | 1.76 |
| | Average | 1.81 | 1.84 | 2.49 | |

## MANURING, LIMING, AND FERTILIZING EXPERIMENT (1960)

### Yields of Oats in Bushels per Acre from Series 12

| Plot Nos. | Manure Treatments | Lime and Fertilizer Treatments: Check | Lime | Lime & Fertilizer | One Yield |
|---|---|---|---|---|---|
| 7 & 13 | Check | 56.4 | 52.9 | 65.6 | 58.3 |
| 8 & 14 | 5 T/A. on Strubble | 64.3* | 58.0* | 63.6* | 61.6 |
| 9 & 15 | 10 " " " | 70.2 | 58.5* | 58.6 | 62.4 |
| 10 & 16 | 20 " " " | 72.2 | 80.0* | 80.5 | 77.6 |
| 11 & 17 | 10 " " " | 80.8 | 77.5 | 62.5* | 73.6 |
| 12 & 18 | 5 " " " | 62.5 | 64.7 | 61.2 | 62.8 |
| | Average | 67.7 | 65.3 | 65.3 | |

## MANURING, LIMING AND FERTILIZING EXPERIMENT

### YIELDS OF POTATOES (Bu./Ac.) in 1960

| Plot Nos. | Manure Treatments | Check | Lime | Lime & Fertilizer | Ave. |
|---|---|---|---|---|---|
| 7 & 13 | Check | 48 | 79 | 108 | 78.3 |
| 8 & 14 | 5 T./Ac. on Strubble | 47 | 60 | 130 | 79.0 |
| 9 & 15 | 10 " " " | 88 | 64 | 96 | 82.7 |
| 10 & 16 | 20 " " " | 97 | 102 | 111 | 103.3 |
| 11 & 17 | 10 " " Sod | 48 | 91 | 114 | 84.3 |
| 12 & 18 | 5 " " " | 80 | 72 | 117 | 89.7 |
| | Average | 68.0 | 78 | 113 | |

# RATES AND SYSTEMS OF FERTILIZATION EXPERIMENT

Dale E. Baker, Wallace W. Nelson and A. C. Caldwell

**Purpose:**

This experiment was initiated in 1955 for the purpose of determining the most economical rate of fertilizer and the best system for applying phosphorus and potash to a small grain-meadow rotation.

**Procedure:**

All plots received 40 pounds of nitrogen per acre when the grain was seeded. The rates of phosphorus and potash applied during the rotation of oats and four years of meadow were as follows:

1. 100# $P_2O_5$ and 100# $K_2O$ per acre.
2. 200# " " " " " "
3. 400# " " " " " "

The systems of fertilization were as follows:

1. All fertilizer on grain.
2. 1/5 $P_2O_5$ and $K_2O$ each year.
3. 1/2 $P_2O_5$ and $K_2O$ on grain and 1/2 on 2nd. year hay.
4. All $P_2O_5$ on grain and 1/5 $K_2O$ each year.
5. 1/5 $P_2O_5$ on $K_2O$ each year plus 40 lbs. N/Ac. after 1st hay cutting.
6. 1/2 $P_2O_5$ on grain and 1/2 on 2nd year hay with 1/5 $K_2O$ being applied each year.
7. Check (No fertilizer).

The experiment consisted of 21 plots replicated four times. The plots within each replication were randomized. The entire area was limed to correct the soil reaction prior to seeding.

The phosphorus and potash were applied as 0-30-30 where amounts applied were equal, and 0-47-0 and 0-0-60 were applied where amounts of $P_2O_5$ and $K_2O$ were unequal. The plots were seeded to a grass-legume mixture of 7# alfalfa, 2# timothy and 5# brome, with oats as a nurse crop.

The meadow seeding failed on all plots in the 1955 seeding. The same experiment was repeated on a different area in 1956 and the meadow seeding was established more successfully.

The yields of oats in 1955 (Table I) and also in 1956 (Table II) indicate a response to all rates of phosphate and potash, although the greatest response was to the 0-100-100 treatment over the unfertilized plots. System No. 4 in which all the phosphate was applied on the grain and 1/5 of the potash was applied each year resulted in the highest yields of oats in both years. System No. 1 also received all the phosphate on grain. System (1) might have been inferior to No. 4 for production of oats because of too much muriate of potash. However, one must not overlook the fact that the phosphate applied in system No. 4 was water soluble superphosphate; whereas that applied in system No. (1) was water insoluble calcium meta-phosphate. A comparison between systems two and six also indicates that the superphosphate was superior to calcium meta-phosphate as a source of phosphorus for oats.

The high yields of oats obtained from system (4) where all the phosphate was applied as superphosphate had a depressing effect on hay yields for the next four years, Table III. The yields of hay were higher each year where the larger amounts of fertilizer had been applied. Yields of hay the 1st year were higher for system (1) where all the phosphate and potash had been applied to the grain. However, over a five year period system No. 6, in which 1/2 the phosphate was applied to the nurse crop and 1/2 to the 2nd. year meadow with 1/5 of the potash being applied each year, was the most profitable method of applying phosphate and potash. Applications of 40 pounds of nitrogen per acre after the first cutting increased hay yields over the four year period but not enough to make the practice economical, Table IV. However, the response to the nitrogen on the 4th year hay was almost enough to pay the cost of the fertilizer, Table VI.

Calculations of the value of the increase in oats and hay as a result of fertilizer applications, Table IV, show that the largest hay and grain increase were obtained where 400 pounds of both $P_2O_5$ and $K_2O$ were applied over the five year period. With the high fixed cost for seeding and harvesting this would result in the most profitable fertilizer level. However, the calculations also show that application of 200 pounds of both $P_2O_5$ and $K_2O$ resulted in the most return for each dollar spent for fertilizer.

Conclusions:

1. Water solubility of phosphate might be a factor affecting the yield of oats.
2. Establishment of grass-meadow seeding with an oat nurse crop was most successful and economical when the nurse crop was fertilized with 40+200+80.
3. Maintenance of hay yields was successful when 80 pounds of $K_2O$ was applied annually and 200 pounds of $P_2O_5$ was applied to the 2nd year per meadow.
4. Annual applications of nitrogen to meadows where the stand of alfalfa was good was not profitable.

Further Consideration of Experiment:

Quality of forage as affected by the different treatments has not been evaluated. It would probably be worthwhile to determine the botanical and chemical composition of forage produced on these plots next year, which will be the fifth year for the meadow. I would suggest that only one replication be sampled. Since the stand of alfalfa will vary, the vegetation for each plot sampled should be sorted by hand so the yield and composition of alfalfa and grass can be determined separately.

RATES AND SYSTEMS OF FERTILIZATION EXPERIMENT (1955)

Table I

YIELDS OF OATS IN BUSHELS PER ACRE AS AFFECTED DIFFERENT RATES OF FERTILIZERS AND DIFFERENT SYSTEMS OF APPLYING FERTILIZERS:

| SYSTEMS OF FERTILIZING | Fertilizer Treatments 0-100-100 | 0-200-200 | 0-400-400 | Grand Means |
|---|---|---|---|---|
| All Fertilizer on Grain | 62.1 | 64.0 | 61.7 | 62.6 |
| 1/5 $P_2O_5$ & $K_2O$ Each Year | 60.4 | 50.9 | 66.6 | 59.3 |
| 1/2 $P_2O_5$ & $K_2O$ on Grain & 1/2 on 2nd. Year Hay | 59.2 | 67.6 | 65.6 | 64.1 |
| All $P_2O_5$ on Grain & 1/5 $K_2O$ Each Year | 61.0 | 67.7 | 66.4 | 65.0 |
| 1/5 $P_2O_5$ & $K_2O$ Each Year Plus 40 Lbs. N/Ac. after 1st Cut. | 62.0 | 57.4 | 64.8 | 61.4 |
| 1/2 $P_2O_5$ on Grain & 1/2 on 2nd. Yr. Hay; 1/5 $K_2O$ Each Year | 55.3 | 60.8 | 57.7 | 57.9 |
| Unfertilized | 45.5 | 44.3 | 51.2 | |
| GRAND MEANS | 60.0 | 61.4 | 63.8 | |

RATES AND SYSTEMS OF FERTILIZATION (1956)

Table II

YIELDS OF OATS IN BUSHELS PER ACRE AS AFFECTED BY DIFFERENT RATES OF FERTILIZERS AND DIFFERENT SYSTEMS OF APPLYING FERTILIZERS:

| Systems of Fertilizing | FERTILIZER TREATMENTS 0-100-100 | 0-200-200 | 0-400-400 | Grand Means |
|---|---|---|---|---|
| All Fertilizer on Grain | 57.6 | 62.8 | 75.7 | 65.4 |
| 1/5 $P_2O_5$ & $K_2O$ Each Year | 56.3 | 53.8 | 55.1 | 55.0 |
| 1/2 $P_2O_5$ & $K_2O$ on Grain & 1/2 on 2nd Year Hay | 55.0 | 62.4 | 69.5 | 62.3 |
| All $P_2O_5$ on Grain & 1/5 $K_2O$ Each Year | 68.4 | 63.0 | 78.4 | 69.9 |
| 1/5 $P_2O_5$ & $K_2O$ Each Year Plus 40 Lbs. N/Ac. after 1st. Cut. | 58.6 | 55.8 | 66.8 | 60.4 |
| 1/2 $P_2O_5$ on Grain & 1/2 on 2nd Yr. Hay; 1/5 $K_2O$ Each Year | 69.3 | 51.6 | 72.1 | 64.3 |
| Check | 60.9 | 51.6 | 56.9 | 56.4 |
| GRAND MEANS | 60.9 | 58.2 | 69.6 | |

RATES AND SYSTEMS OF FERTILIZATION EXPERIMENT

TABLE III

DIFFERENT YIELDS OF HAY IN TONS PER ACRE OVER A FOUR YEAR PERIOD AS AFFECTED RATES OF FERTILIZERS AND DIFFERENT SYSTEMS OF APPLYING FERTILIZERS.

| System No. | 1st Year Hay (1957) Lbs./Ac. of $P_2O_5$ & $K_2O$ Applied | | | | 2nd. Year Hay (1958) Lbs./Ac. of $P_2O_5$ & $K_2O$ Applied | | | |
|---|---|---|---|---|---|---|---|---|
| | 100 | 200 | 400 | Means | 100 | 200 | 400 | Means |
| 1 | 1.89 | 2.10 | 2.35 | 2.18 | 2.38 | 2.78 | 2.74 | 2.63 |
| 2 | 1.62 | 1.67 | 2.17 | 1.82 | 2.47 | 2.49 | 3.20 | 2.72 |
| 3 | 1.78 | 1.92 | 2.47 | 2.06 | 2.24 | 2.84 | 2.98 | 2.69 |
| 4 | 1.67 | 1.68 | 1.90 | 1.75 | 2.22 | 2.32 | 2.99 | 2.51 |
| 5 | 1.65 | 1.87 | 2.19 | 1.90 | 2.63 | 3.14 | 3.56 | 3.11 |
| 6 | 1.94 | 2.07 | 2.34 | 2.12 | 2.62 | 2.54 | 2.95 | 2.70 |
| 7* | 1.55 | 1.18 | 1.47 | 1.40 | 2.32 | 1.95 | 2.65 | 2.31 |
| Means | 1.77 | 1.89 | 2.24 | 1.965 | 2.43 | 2.69 | 3.14 | 2.730 |

| System No. | 3rd. Year Hay (1959 Lbs./Ac. of $P_2O_5$ & $K_2O$ Applied | | | | 4th. Year Hay (1960) Lbs./Ac. of $P_2O_5$ & $K_2O$ Applied | | | |
|---|---|---|---|---|---|---|---|---|
| | 100 | 200 | 400 | Means | 100 | 200 | 400 | Means |
| 1 | 2.14 | 2.24 | 2.84 | 2.41 | 0.98 | 1.09 | 1.32 | 1.13 |
| 2 | 2.46 | 2.55 | 3.41 | 2.81 | 1.04 | 1.11 | 1.68 | 1.28 |
| 3 | 2.25 | 2.59 | 2.99 | 2.61 | 1.02 | 1.23 | 1.57 | 1.27 |
| 4 | 2.34 | 2.56 | 2.80 | 2.57 | 1.09 | 1.24 | 1.83 | 1.39 |
| 5 | 2.44 | 2.43 | 3.14 | 2.67 | 1.14 | 1.38 | 1.83 | 1.45 |
| 6 | 2.62 | 2.68 | 3.12 | 2.81 | 1.10 | 1.21 | 1.57 | 1.29 |
| 7* | 2.02 | 1.89 | 2.15 | 2.02 | 0.90 | 0.82 | 1.02 | 0.93 |
| Means | 2.33 | 2.51 | 3.10 | 2.644 | 1.06 | 1.21 | 1.66 | 1.302 |

* System No. 7 was not used in statistical calculations.

Confidence Intervals ($D_{.05}$) for comparing means:

1. Systems within each year = 0.35
2. Rates Within each year = N.S. Interaction
3. Yields for different years = 0.091

RATES AND SYSTEMS OF FERTILIZATION EXPERIMENT

TABLE IV

AVERAGE YIELDS OF HAY IN TONS PER ACRE OVER A FOUR YEAR PERIOD AS AFFECTED BY DIFFERENT RATES OF FERTILIZATION AND DIFFERENT SYSTEMS OF APPLYING FERTILIZERS.

| System No. | Systems of Fertilizing | Lbs./Ac. of $P_2O_5$ & $K_2O$ Applied 100 | 200 | 400 | Grand Means |
|---|---|---|---|---|---|
| 1 | All Fertilizer on Grain | 1.87 | 2.05 | 2.31 | 2.082 |
| 2 | 1/5 $P_2O_5$ & $K_2O$ Each Year | 1.90 | 1.96 | 2.62 | 2.156 |
| 3 | 1/2 $P_2O_5$ & $K_2O$ on Grain & 1/2 on 2nd. Year Hay | 1.82 | 2.14 | 2.50 | 2.157 |
| 4 | All $P_2O_5$ on Grain & 1/5 $K_2O$ Each Year | 1.83 | 1.95 | 2.38 | 2.053 |
| 5 | 1/5 $P_2O_5$ & $K_2O$ each year plus 40 Lbs. N/Ac. After 1st Cut. | 1.97 | 2.20 | 2.68 | 2.283 |
| 6 | 1/2 $P_2O_5$ on Grain & 1/2 on 2nd Yr. Hay; 1/5 $K_2O$ Each Year | 2.07 | 2.12 | 2.50 | 2.230 |
| 7 | Unfertilized* | 1.70 | 1.46 | 1.82 | 1.660 |
| | Grand Means | 1.909 | 2.072 | 2.498 | |
| | Cost of Fertilizer | $12.90 | $25.80 | $51.60 | |
| | Value of Grain Increase | 0.00 | 5.28 | 10.16 | |
| | Value of Hay Increase | 16.80 | 48.96 | 54.40 | |
| | Increased Returns over Fertilizer Costs | 3.90 | 28.44 | 12.96 | |

*Data for System No. 7 was not used in statistical calculations.

Confidence Intervals ($D_{.05}$) for comparing Means:

Grand Means for Systems = 0.149
Grand Means for Rates = 0.068
Rates within Systems = 0.296

RATES AND SYSTEMS OF FERTILIZATION EXPERIMENT (1960)

TABLE VI

YIELDS OF FOURTH YEAR HAY IN TONS PER ACRE AS AFFECTED BY DIFFERENT RATES OF FERTILIZERS AND DIFFERENT SYSTEMS OF APPLYING FERTILIZERS:

| SYSTEMS OF FERTILIZING | Fertilizer Treatments* 0-100-100 | 0-200-200 | 0-400-400 | Grand Means |
|---|---|---|---|---|
| All Fertilizer on Grain | 0.98 | 1.09 | 1.32 | 1.130 |
| 1/5 $P_2O_5$ & $K_2O$ Each Year | 1.04 | 1.11 | 1.68 | 1.274 |
| 1/2 $P_2O_5$ & $K_2O$ on Grain & 1/2 on 2nd Year Hay | 1.02 | 1.23 | 1.57 | 1.272 |
| All $P_2O_5$ on Grain & 1/5 $K_2O$ Each Year | 1.09 | 1.24 | 1.83 | 1.387 |
| 1/5 $P_2O_5$ of $K_2O$ Each Year Plus 40 Lbs. N/Ac. after 1st. Cut. | 1.14 | 1.38 | 1.83 | 1.452 |
| 1/2 $P_2O_5$ on Grain & 1/2 on 2nd. Year Hay; 1/5 $K_2O$ Each Year | 1.10 | 1.21 | 1.57 | 1.334 |
| Unfertilized** | 0.90 | 0.82 | 1.02 | |
| GRAND MEANS | 1.081 | 1.211 | 1.632 | |

Confidence interval ($D_{.05}$) for comparing grand means for fertilizer Treatments = 0.131

Confidence interval ($D_{.05}$) for comparing grand means for systems of Fertilization = 0.227

* All plots received 40 pounds of nitrogen per acre on grain.

** Data for the unfertilized plots were not used in the statistical analysis.

## Complete Fertilization Experiment (1960)

Dale E. Baker and A. C. Caldwell

Potatoes:

During the third week in August the tops of potato plants growing on plots that had received no potassium were dying prematurely. Early symptoms present on the leaves of deficient plants appeared as a purplish-green or bronzing appearance followed by scorched tips and margins. The premature withering collapsing of the haulms or main tops of the plants was the plants was the symptom of a severe deficiency. I think we should get some publicity out on this about the first week in August, so potato growers will watch for the deficiency symptoms.

The yields of potatoes reflected the potassium deficiency. Addition of potassium was more beneficial than additions of nitrogen and phosphorus in increasing yields.

The potato yields were quite variable this year so small differences don't mean much. It does seem, however, that there was a response to lime, especially where no manure had been applied. There was a very good response to manure on unlimed plots. A (70) bushel per acre potato increase from (10) tons of manure is quite significant and should be checked for over a period of years.

Oats:

In all cases the yields of oats were too low to be very profitable. There was a small yield response to phosphorus, potash and nitrogen. The most significant results obtained this year was from the effect of the treatments on the stand of alfalfa remaining at oat harvesting time. The nitrogen only plots had much better stands of alfalfa than plots treated with phosphate and potash. This is difficult to explain because it does not seem that a 50 bushel oat crop should completely eliminate the alfalfa seeding regardless of the fertilizer treatments. It would seem a cropping sequence study is needed for this area.

Hay:

A good response was obtained from phosphate, potash and lime on both first and second year meadow. However, addition of nitrogen, alone or with phosphate and potash, to small grain had very little effect on hay yields the following years.

## COMPLETE FERTILIZATION EXPERIMENT (1960)

### Yields of Potatoes (bu./Ac.) from Series 15-S.

| Fertilizer Treatments | Lime Treatments | | |
|---|---|---|---|
| | East (Limed) | West Unlimed | Average |
| Check | 88 | 64 | 76 |
| K | 138 | 55 | 96 |
| PK | 152 | 105 | 128 |
| P | 68 | 63 | 66 |
| Urea | 78 | 52 | 65 |
| $NH_4NO_3$ | 88 | 67 | 78 |
| NK | 167 | 82 | 124 |
| NPK | 172 | 117 | 144 |
| NP | 104 | 95 | 100 |
| NPK & 10 T./A. Manure | 110 | 187 | 148 |
| Average | 116.5 | 88.7 | |

## COMPLETE FERTILIZATION EXPERIMENT (1960)

**Yields of Oats in Tons per Acre and % stand of Alfalfa at harvest time as affected by different NPK treatments.**

| No. | Fertilizer Treatments | East (Limed) | | West (Unlimed) | | Average | |
|---|---|---|---|---|---|---|---|
| | | Bu/Ac. | % Alf. | Bu/Ac. | % Alf. | Bu/Ac. | % Alf. |
| 1 | Check | 41.2 | 5 | 40.8 | 5 | 41.0 | 5 |
| 2 | K | 45.6 | 0 | 42.8 | 5 | 44.2 | 2.5 |
| 3 | PK | 48.2 | 5 | 49.4 | 5 | 48.8 | 5 |
| 4 | P | 53.6 | 5 | 48.0 | 5 | 50.8 | 5 |
| 5 | Urea | 43.4 | 50 | 46.4 | 35 | 44.9 | 42.5 |
| 6 | $NH_4NO_3$ | 40.8 | 65 | 43.6 | 30 | 42.2 | 47.5 |
| 7 | NK | 50.0 | 0 | 47.5 | 5 | 48.8 | 2.5 |
| 8 | NPK | 52.8 | 5 | 55.6 | 0 | 54.2 | 2.5 |
| 9 | NP | 55.5 | 0 | 46.6 | 0 | 51.0 | 0.0 |
| 10 | NPK + 10T./A. Manure | 54.6 | 0 | 53.5 | 0 | 54.0 | 0.0 |
| | Average | 48.57 | 13.5 | 47.42 | 9.0 | | |

## COMPLETE FERTILIZATION EXPERIMENT (1960)

### Yields of Hay (Tons/Acre) from 1 St. year meadow on Series 17-S

| Fertilizer Treatments | Lime Treatments | | |
|---|---|---|---|
| | East (Limed) | West (Unlimed) | Average |
| Check | 1.73 | 1.32 | 1.52 |
| K | 2.48 | 2.07 | 2.28 |
| PK | 2.99 | 2.58 | 2.78 |
| P | 1.74 | 1.76 | 1.75 |
| Urea | 1.78 | 1.72 | 1.75 |
| $NH_4NO_3$ | 1.44 | 1.58 | 1.51 |
| NK | 2.04 | 1.89 | 1.96 |
| NPK | 2.78 | 2.08 | 2.43 |
| NP | 1.87 | 1.70 | 1.78 |
| NPK & 10 T./A. Manure | 2.61 | 2.42 | 2.52 |
| Average | 2.15 | 2.01 | 2.08 |

# COMPLETE FERTILIZATION EXPERIMENT (1960)

## Yields of Hay (Tons/Acre) from 2 Nd. Year Meadow on Series 16-S

| Fertilizer Treatments | Lime Treatments East (Limed) | West (Unlimed) | Average |
|---|---|---|---|
| Check | 1.50 | 1.43 | 1.46 |
| K | 2.40 | 2.11 | 2.26 |
| PK | 2.84 | 2.20 | 2.52 |
| P | 1.88 | 1.76 | 1.82 |
| Urea | 1.39 | 1.26 | 1.32 |
| $NH_4NO_3$ | 1.44 | 1.22 | 1.33 |
| NK | 2.30 | 1.82 | 1.56 |
| NPK | 2.52 | 1.94 | 2.23 |
| NP | 1.95 | 1.64 | 1.80 |
| NPK & 10 T./Ac. Manure | 2.85 | 2.18 | 2.52 |
| Average | 2.11 | 1.76 | 1.94 |

# N, P, and K Experiment on Continuous Corn
## Rosemount, 1960

A. C. Caldwell and J. B. Weber

This experiment was designed to st dy the effects of different combinations and rates of N, P, and K on the yields of continuous corn. Twenty-two treatments were laid out in t replicates, of five blocks each, in the spring of 1957.

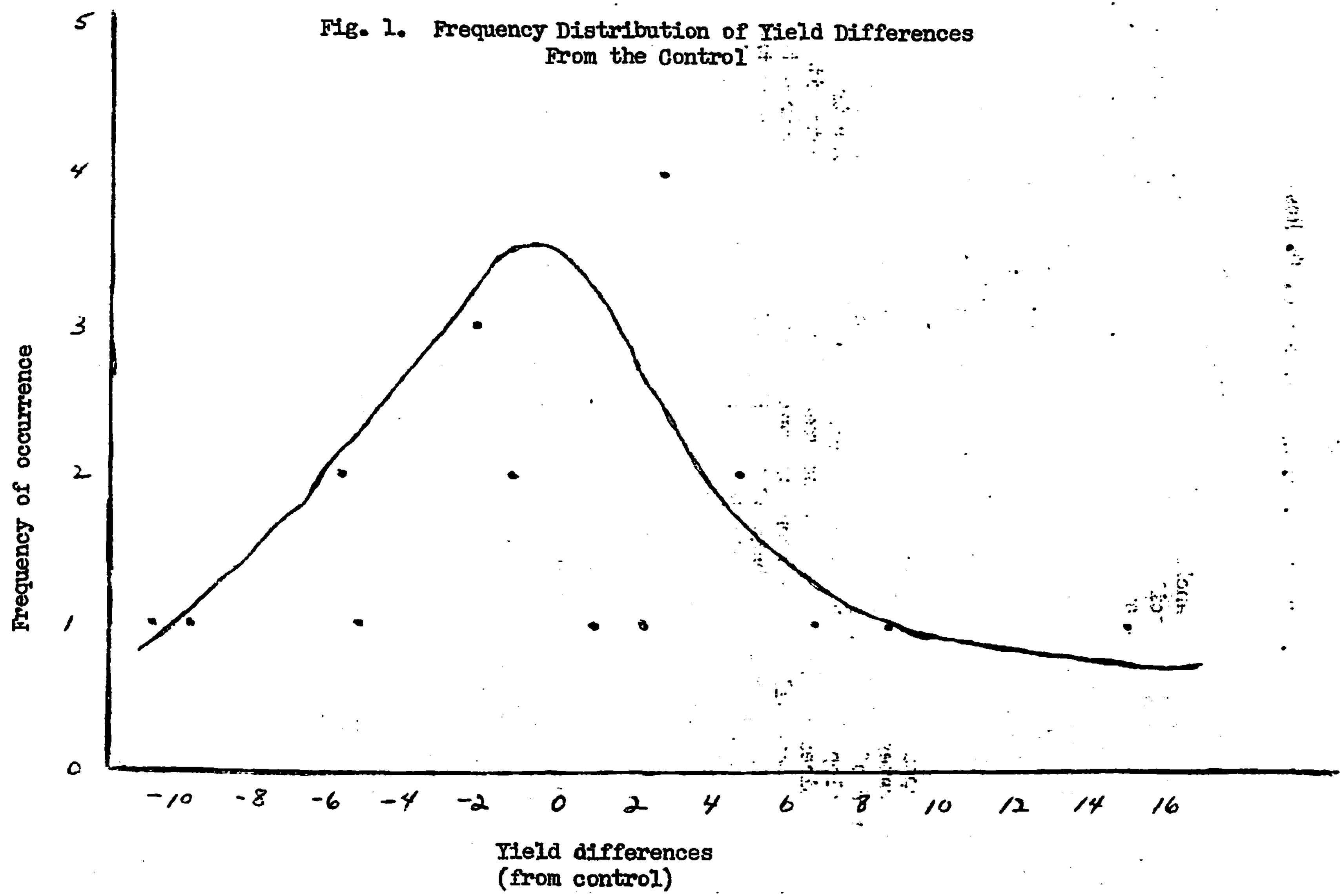
In 1958 through 1960, no fertilizer was applied in order to study the residual effects of the previously applied fertilizer.

Corn yields for 1960 are included in Table 1. No significant differences were found. A plot of the frequency distribution of yield differences, figure 1, indicates that as many increases or decreases in yields resulted. This would tend to indicate that the residual fertilizer effect has vanished and the yields on all treatments are approaching that of the control.

Table 1. The effect of residual N, P, and K fertilizers on the yields of continuous corn, 1960.

| Fertilizer $N-P_2O_5-K_2O$ lbs/A. | Yield bu/A. | Diff. |
|---|---|---|
| 0-0-0 | 69.3 | --- |
| 0-60-37 | 84.5 | 15.2 |
| 0-60-83 | 58.5 | -10.8 |
| 37-0-60 | 68.0 | -1.3 |
| 37-120-60 | 67.0 | -2.3 |
| 60-37-0 | 72.0 | 2.7 |
| 60-37-120 | 78.0 | 8.7 |
| 60-60-60 | 70.2 | 0.9 |
| 60-83-0 | 59.5 | -9.8 |
| 60-83-120 | 64.0 | -5.3 |
| 83-0-60 | 67.0 | -2.3 |
| 83-120-60 | 72.0 | 2.7 |
| 120-60-37 | 63.5 | -5.8 |
| 120-60-83 | 71.5 | 2.2 |
| 23-23-23 | 74.0 | 4.7 |
| 23-23-97 | 76.0 | 6.7 |
| 23-97-23 | 68.0 | -1.3 |
| 23-97-97 | 67.0 | -2.3 |
| 97-23-23 | 72.0 | 2.7 |
| 97-23-97 | 74.0 | 4.7 |
| 97-97-23 | 63.5 | -5.8 |
| 97-97-97 | 72.0 | 2.7 |

Fig. 1. Frequency Distribution of Yield Differences From the Control



# The Effect of Fertilizer Placement on Root Development, Maturity, Quality and Yield of Corn.

By

Paul M. Burson, R. D. Curley, and C. O. Rost*

In 1960 a study was conducted in cooperation with the Tennessee Valley Authority on root development with different fertilizers, methods of application, time of application, root anchorage, and different nitrogen:phosphate:potash ratios. On the basis of soil tests all plots received a total of 120 lbs. of N, a maximum of 40 lbs. $P_2O_5$ and a total of 120 lbs. of $K_2O$. All phosphorus was applied as starter but the N was applied all as a starter or as a starter-sidedressing combination. In the case of potash, a part was applied as starter while the remainder was broadcast and plowed under. The starter was applied in ratios of 1:1:0, 1:1:1, 1:4:0 and 3:1:0. In the 3:1:0 all the N for the season was applied in the band as starter. Soil tests showed a medium to high in organic matter, medium in phosphorus and potassium and a pH of 6.0 to 6.4.

The purpose of these trials was to observe the effects of various N:P:K ratios and rates of fertilizer that could be applied in a band as a starter, the response of potash applied as starter and broadcast and the difference in root development with the different combinations of fertilizer treatments. The most noticeable difference was the great mass of fibrous roots with the 3:1:0 ratio where all the nitrogen was applied as starter as compared to limited fibrous roots in the band of the 1:3:0 and 1:4:0 ratios where the nitrogen was applied later as sidedressing. With the 3:1:0 ratio and the 1:1:1 ratio, containing potash, practically all proliferated roots were concentrated in the single fertilizer band.

From the results with potash contained in the starter it appears that at least 40 lbs. of N should be present to get the maximum root proliferation. Adding 40 lbs. of N in the starter with a 1:1:1 ratio was better than adding greater amounts of N with no potash in the starter. With the 1959 and 1960 work it appears certain that the higher levels of N with phosphate controls the development of the corn roots systems with maximum development of roots in the fertilizer band. For this reason if the corn is to obtain sufficient potash for optimum growth and crop yield, adequate amounts of potash must also be included in the starter fertilizer band.

The following tables give the effect of fertilizer on yield, lodging, maturity, quality and anchorage of corn for 1960. Similar results were obtained in 1959 but will not be reported at this time.

The Effect of Fertilizer Treatments on Yield, Lodging, Maturity and Quality of Corn

| | Check | 40-40-40 starter +80# N side-dressed | 40-40-0 starter +80# N side-dressed | 120-40-0 starter + No N side-dressed | 60-20-0 starter +60# N side-dressed | 10-40-0 starter +110# N side-dressed |
|---|---|---|---|---|---|---|
| | Fertilizer Treatments in lbs. per acre | | | | | |
| I. Yields per acre | 88.2 | 124.0 | 112.0 | 122.7 | 113.3 | 106.2 |
| II. Lodging (%) (1) | Trace | 0 | 45 | 15 | 65 | 5 |

(1) Stalks were bowed and leaned at least 45 degrees. All showed potash deficiency on the leaves during the growing season.

Percent in each maturity class

| III. Maturity Class (2) | | | | | | |
|---|---|---|---|---|---|---|
| | | | Sept. 8, 1960 | | | |
| Milk | 50 | 2 | 30 | 20 | 40 | 20 |
| Late Dent | 48 | 8 | 5 | 35 | 5 | 50 |
| Early Dent | 2 | 90 | 65 | 45 | 55 | 30 |
| | | | Oct. 12, 1960 | | | |
| Milk | 0 | 0 | 0 | 0 | 0 | 0 |
| Late Dent | 25 | 0 | 10 | 0 | 15 | 0 |
| Early Dent | 75 | 100 | 90 | 100 | 85 | 100 |

(2) Milk - 100% would be damaged by early frost.
Late Dent - At least 50% would be damaged by frost. Started to dent.
Early Dent - 100% would not be damaged by early frost.
Killing frost date Oct. 4.

Ear Size (Percent in each class)

| IV. Ear Class | | | | | | |
|---|---|---|---|---|---|---|
| 8" + (3) | 44.0 | 63.7 | 48.0 | 69.8 | 52.7 | 57.8 |
| 5 to 7" (4) | 47.5 | 32.7 | 49.6 | 27.0 | 37.5 | 36.4 |
| Nubbins (5) | 11.5 | 3.6 | 3.4 | 3.2 | 3.8 | 5.8 |

(3) Marketable, well filled, uniform ears
(4) Low grade marketable, poorly filled, variable size and chaffy ears.
(5) Nonmarketable, very short, curved, partially filled tips and sides and chaffy ears.

The Effect of Fertilizer Treatments on Root Anchorage

| V. | No. stalks Pulled | Average (6) pull per single stalk |
|---|---|---|
| Check | 16 | 179 |
| All fertilizer treatments | 58 | 259 |
| No potash in starter | 28 | 217 |
| Potash in starter | 35 | 251 |
| **Rates of Nitrogen per Acre in Starter Fertilizer** | | |
| Under 10 lbs. N | 10 | 200 |
| 11 to 20 lbs. N | 15 | 252 |
| 21 to 40 lbs. N | 15 | 262 |
| Over 40 lbs. N | 18 | 250 |

(6) Pounds of vertical pull on one stalk of corn at the time the roots released from the soil.

## Summary

1. Nitrogen and phosphate in the starter markedly control root proliferation and intensity of root growth.

2. If high rates of nitrogen and phosphate are used in the starter, potash should be included.

3. All three nutrients of nitrogen, phosphate and potash should be included in the starter.

4. High rates of starter fertilizer will not injure germination and stand if placed in a band to the side and below the seed.

5. All fertilizer nitrogen can be applied in the starter fertilizer if desired provided the fertilizer is placed in a band to the side and below the seed.

6. Fertilizer in proper balance and in sufficient amounts speeds up maturity, reduces moisture content and increases quality of corn grain and improves size and uniformity of ears.

7. Nitrogen, to be most effective, should be applied not later than late spring whether the season is wet or dry.

8. July and August, 1960, was extremely dry (1.6 inches of rain). No more drought injury was noticeable on corn with all the fertilizer in the band as compared to split applications of starter and sidedressing combined and with lower rates in the starter band.

# Continuous Corn - High Fertility Experiment

## Rosemount Experiment Station
## Soils

W. P. Martin and H. W. Kramer

Yield Results - 1960

Re: 1959 results, "A Report on Soils and Soil Fertility", p. 97, Department of Soils, Mimeo., April, 1960.

Experiment Started: 1953

Soil type: Port Byron silty clay loam

Object: To determine profitable rates of fertilization for continuous corn.

Site: Fairly level with minimum erosion hazard; protected from hill pastures with terrace; tile drained.

Past results: Yields have varied from 45 bushels to 133 bushels (as an average of the treatments) from 1953-1960. Highest yields were obtained in 1954 and lowest in 1957 (excessive precipitation). Yields have consistently reflected fertilizer responses.

| | | 16,000 plants | 20,000 plants |
|---|---|---|---|
| 1. | Check | 69 Bu./acre | 86 Bu./acre |
| 2. | H* | 92 | 104 |
| 3. | $HS_1$ | 92 | 108 |
| 4. | $HS_2$ | 94 | 118 |
| 5. | $B_1H$ | 90 | 106 |
| 6. | $B_1HS_1$ | 103 | 110 |
| 7. | $B_1HS_2$ | 96 | 116 |
| 8. | $B_2H$ | 94 | 113 |
| 9. | $B_2HS_1$ | 97 | 114 |
| 10. | $B_2HS_2$ | 99 | 116 |
| | LSD (5%) | 9.8 | 10.7 |

*H = 200 lbs. 10-20-20 hill drop
$S_1$ = 100 lbs. 33-0-0 sidedress
$S_2$ = 200 lbs. 33-0-0 sidedress
$B_1$ = 400 lbs. 6-24-12 broadcast
$B_2$ = 800 lbs. 6-24-12 broadcast

# Continuous Corn - High Fertility Experiment

Rosemount Experiment Station
Soils

John Grava

Soil Test Results 1956, 1958 and 1960

| Treatment No. and Replication No. | Annual Application of N P$_2$O$_5$ K$_2$O Lbs/Acre | Soil pH | Extractable Phosphorus (P) Lbs/Acre | Exchangeable Potassium (K) Lbs/Acre |
|---|---|---|---|---|
| **1) Sampling Date: July 5, 1956** | | | | |
| 1 - IV | 0 + 0 + 0 | 5.9 | 13 M | 90 L |
| 4 - III | 82 + 32 + 32 | 6.0 | 9 L | 80 L |
| 6 - IV | 73 + 128 + 80 | 5.5 | 58 VH | 145 M |
| 9 - III | 97 + 224 + 128 | 5.7 | 115 VH | 185 M |
| **2) Sampling Date: July 18, 1958** | | | | |
| 1 - (4 Replications) | 0 + 0 + 0 | 5.8 | 17 M | 105 M |
| 4 - (4 Replications) | 82 + 32 + 32 | 5.8 | 27 H | 135 M |
| 6 - (4 Replications) | 69 + 112 + 112 | 5.7 | 91 VH | 218 M |
| 9 - (4 Replications) | 89 + 192 + 192 | 5.4 | 143 VH | 278 VH |
| **3) Sampling Date: August 1, 1960** | | | | |
| 1 - IV | 0 + 0 + 0 | 5.9 | 13 M | 120 M |
| 4 - III | 82 + 32 + 32 | 6.1 | 21 H | 160 M |
| 6 - IV | 69 + 112 + 112 | 5.7 | 90 VH | 210 M |
| 9 - III | 89 + 192 + 192 | 6.0 | 95 VH | 210 M |

Organic Matter = 3.7% Med.

# Fertilizer Experiment on Continuous Soybeans
## Rosemount, 1960

by A. C. Caldwell and J. B. Weber

An experiment was set up in 1957 to study the effects of P, K and barnyard manure on the yields and plant composition of soybeans. Plots were laid out considting of four replications and fifteen treatments.

In 1958 through 1960, no fertilizer was applied in order to study the residual effects of the 1957 applied fertilizer.

Yield results for 1960 are shown in Table 1. Significant increases in yields occurred only on the plots which had received the relatively high rates of P and K. The increases of about 4 bushels per acre above the control are in agreement with the 1959 data.

Selected soil samples were analyzed in 1960 to determine the relative changes in available P and in exchangeable K. Table 2 shows a comparison of the levels of these nutrients for the years 1957 through 1960 for selected samples. The levels of P and K are relatively similar for the control plots, but have decreased substantially on the plots that received fertilizer in 1957. The largest decrease occurred from 1957 to 1958, and seems to be leveling off to a point where it will decrease at a much slower rate. The levels of both nutrients are still considerably higher on the plots that received fertilizer when compared to the control plots. The P level on the control plots has remained relatively constant over the period 1957 to 1960, while the K level has decreased slightly.

Table 1. Effect of residual fertilizer on yield of continuous soybeans, 1960

| Treatment $N-P_2O_5-K_2O$ lbs/A | Yield bu/A | Diff. |
|---|---|---|
| 0-0-0 | 19.8 | ---- |
| 0-0-20 | 18.3 | -1.5 |
| 0-0-80 | 18.9 | -0.9 |
| 0-0-400 | 20.7 | 0.9 |
| 0-20-20 | 19.5 | -0.3 |
| 0-40-40 | 21.0 | 1.2 |
| 0-60-60 | 21.6 | 1.8 |
| 0-80-80 | 21.4 | 1.6 |
| 0-400-400 | 24.1 | 4.3 |
| 0-400-400 + *6T | 24.0 | 4.2 |
| 0-20-0 | 18.6 | -1.2 |
| 0-80-0 | 19.6 | -0.2 |
| 0-400-0 | 19.1 | -0.7 |
| 0-20-0 + 6T | 20.1 | 0.3 |
| * 6T | 19.7 | -0.1 |

* 6T refers to 6 tons manure/A.
lsd (.05) = 3.3

Table 2. Effect of fertilizers on exchangeable K and available P in the soil.

| Treatment $N-P_2O_5-K_2O$ LBS/A. | 1957 P | 1957 K | 1958 P | 1958 K | 1959 P | 1959 K | 1960 P | 1960 K |
|---|---|---|---|---|---|---|---|---|
| | lbs/A. | | | | | | | |
| 0-0-0 | 9 | 115 | 11 | 108 | 9 | 100 | 11.5 | 85.0 |
| 0-80-0 | 21 | 100 | 14 | 110 | 13 | 95 | 15.8 | 87.5 |
| 0-0-80 | 8 | 106 | 9 | 108 | 8 | 93 | 11.0 | 87.5 |
| 0-80-80 | 15 | 143 | 12 | 103 | 10 | 98 | 12.0 | 90.0 |
| 0-400-0 | 106 | 113 | 33 | 115 | 26 | 105 | 27.3 | 77.5 |
| 0-0-400 | 9 | 305 | 9 | 145 | 9 | 148 | 10.8 | 117.5 |
| 0-400-400 | 84 | 365 | 39 | 170 | 29 | 163 | 33.8 | 127.5 |

The Effect of Phosphate and Phosphate-Potash Fertilization on the Ten Year Yield of a Ranger Alfalfa at Rosemount.

J. M. MacGregor and R. G. Hanson

In the fall of 1949, a fertilizer experiment with Ranger alfalfa was commenced on the Port Byron silt loam of the Soils Unit of the Rosemount Experiment Station. The project was designed by Dr. C. O. Rost, and over the eleven year period, the study has been continued by W. W. Nelson, later by J. R. Brownell, and presently by R. G. Hanson. The primary object was to determine whether alfalfa stands could be satisfactorily maintained by good soil fertility over many years, and what kind, rate, and time of fertilization would most economically accomplish a desirable longevity of a satisfactory alfalfa stand. The initially acid loess soil was limed at the rate of 6 tons per acre before the experiment was commenced late in 1949.

The following table indicates the effect of the various treatments on the ten year yields obtained from these annual cuttings, the treatments being arranged in decreasing effectiveness of the total ten year yield obtained. The initial 1951 and the final 1960 hay yields are also shown to give a more complete outline over the ten years. The most effective fertility treatments have produced an average of nearly 1.5 tons more alfalfa hay annually than was obtained from the unfertilized areas, an increase of approximately 50%. Using 1961 fertilizer prices, the fertilizer treatment most effective for increasing alfalfa yield, (300#/A of 0-20-20 annually plus 200#/A topdressing annually) now represents an investment of $75 per acre - or $5 for each additional ton of hay produced. Several detailed publications on various phases of this study are available.

TOTAL YIELDS - ROSEMOUNT ALFALFA - 1951-1960
AVERAGE OF SEVEN REPLICATIONS - THREE CUTTINGS

| 10 year yield rank | Treatment | (Tons/Acre at 15% moisture) 1951 | 1960 | Ten year total yield | Increase |
|---|---|---|---|---|---|
| 30 | Check | 3.10 | 2.33 | 29.06 | - |
| 1 | 300# 0-20-20 SBS+ 200#AS | 3.96 | 3.90 | 44.02 | 14.96 |
| 2 | 300# 0-20-20 FBS+ 200#AF | 3.89 | 3.77 | 43.20 | 14.14 |
| 3 | 300# 5-20-20 SBS+ 200AS | 4.03 | 3.47 | 42.86 | 13.80 |
| 4 | 1000# 0-20-20 SBS+ 200#AS | 4.42 | 3.86 | 42.53 | 13.47 |
| 5 | 1000# 0-20-0 SBS+ 100# KCl A 1st cut. | 4.26 | 3.85 | 42.12 | 13.06 |
| 6 | 1000# 0-20-20 SBS+ 200# 5-20-20BS | 4.34 | 3.53 | 42.10 | 13.04 |
| 7 | 200# 0-20-20 AS | 3.25 | 3.73 | 41.79 | 12.73 |
| 8 | 1000# 0-20-0AS+ 200# 0-20-20 AS | 4.14 | 2.97 | 41.00 | 11.94 |
| 9 | 300# 0-20-20FBS+ 200# BF | 3.51 | 3.62 | 39.70 | 10.64 |
| 10 | 200# 0-20-20 AF | 3.60 | 3.53 | 39.60 | 10.54 |
| 11 | 100# 0-20-20 SBS+ 200# BS | 4.30 | 2.87 | 37.62 | 8.56 |
| 12 | 300# 0-20-20 SBS+ 200# BS | 3.79 | 3.06 | 37.40 | 8.34 |
| 13 | 100# 0-20-0 SBS+ 200# 0-20-20 BS | 3.95 | 3.37 | 36.01 | 6.95 |
| 14 | 300# 0-20-0 SBS+ 200# AS | 3.77 | 2.58 | 35.44 | 6.38 |
| 15 | 300# 0-20-20 SBS | 3.90 | 2.98 | 34.27 | 5.21 |
| 16 | 1000# 0-20-20 SBS | 4.09 | 2.62 | 34.06 | 5.00 |
| 17 | 200# 0-20-0 AS | 3.64 | 2.47 | 33.45 | 4.34 |
| 18 | 200# 0-20-0 AF | 3.84 | 2.35 | 33.32 | 4.26 |
| 19 | 1000# 0-20-0 SBS+ 200# AS | 4.04 | 2.57 | 33.24 | 4.18 |
| 20 | 300# 0-20-0 FBS+ 200# BF | 3.68 | 2.54 | 32.79 | 3.73 |
| 21 | 300# 0-20-0 FBS+ 200# AF | 3.77 | 2.51 | 32.49 | 3.43 |
| 22 | 300# 0-20-20+ Trace elements SBS | 3.88 | 2.28 | 32.18 | 3.12 |
| 23 | 300# 0-20-0 SBS+ 200# BS | 3.64 | 2.41 | 31.55 | 2.49 |
| 24 | 300# 5-20-20 SBS+ 20# N AS | 3.75 | 2.28 | 31.53 | 2.47 |
| 25 | 300# 0-20-0 FBS | 3.61 | 2.48 | 31.25 | 2.19 |
| 26 | 300# 0-20-20 SBS+ 20# B SBS | 3.84 | 2.02 | 30.04 | 0.98 |
| 27 | 1000# 0-20-0 SBS | 4.01 | 2.22 | 29.71 | 0.65 |
| 28 | 300# 5-20-20 SBS | 3.82 | 2.26 | 29.49 | 0.43 |
| 29 | 300# 0-20-20 FBS | 3.78 | 2.22 | 29.09 | 0.03 |
| 31 | 300# 0-20-0 SBS | 3.59 | 2.12 | 28.49 | -0.55 |

SBS - Spring before seeding
FBS - Fall Before seeding
AS - Annual Spring
Trace elements - $CuSO_4$ 25#/A; $ZnSO_4$ 25#/A
$MnSO_4$ 25#/A; $FeSO_4$ 25#/A
Boron 20#/A

BS - Biennial Spring
AF - Annual Fall
BF - Biennial Fall
N - Nitrogen
B - Boron

## Conclusions

Some of the better fertilizer treatments have maintained alfalfa stands very well over the ten year period, whereas others have been badly invaded by grasses (largely Kentucky bluegrass) and weed growth, and alfalfa stands are now comparatimely poor. Many important comparisons may be made from the results in the table, but the following are some of the more important findings:

1. Potassium fertilization is essential along with the phosphorus for the maintenance of alfalfa stands over many years. This is evident from the fact that the thirteen most productive fertilizer treatments all included potassium.

2. The addition of nitrogen to alfalfa was not profitable. By the end of the 1960 growing season, the third highest yielding treatment (300 pounds of 5-20-20 spring before seeding and 200 pounds topdressed each spring) produced 13.80 tons alfalfa per acre more than the unfertilized check yields. This nitrogen application over the eleven years cost approximately twelve dollars per acre and resulted in somewhat lower alfalfa production than fertilization with the same amounts of phosphorus and potassium with no nitrogen present (14.96 tons per acre).

3. Annual topdressing of the established alfalfa stand was very beneficial, and much more effective than where applied in alternate years. The additional fertilizer used in the annual applications (1200 pounds of 0-20-20) would cost a total of 35 more, but produce an extra half ton of hay each year.

4. Moderate amounts of starter fertilizer in addition to the later topdressings are effective. Starter fertilizer plus annual topdressings produced 2.9 tons more hay per acre over the 10 year period than did the topdressings alone.

5. High initial rates of fertilization alone were not economical. Initial application of 1000 pounds per acre increased yields during the first few years, but these declined rapidly.

6. Initial trace element applications (copper, boron, zinc, manganese, and iron) did not increase alfalfa yields and apparently were not essential to good alfalfa production.

7. Fall topdressing produced a slightly lower increase in alfalfa yields compared to the same fertilizer applied in the spring.

8. Alfalfa should be topdressed at least every second year, as the beneficial fertilizer effect will otherwise largely disappear, even though large amounts of fertilizer were originally applied.

Good soil fertility management is an essential for efficient alfalfa production irrespective of the soil on which it is grown. Such management is especially true where the more steeply sloping lands are to be utilized, since lower fertility levels frequently ends in the loss of good alfalfa stands, and in serious soil erosion. One of the first steps in making better use of our more marginal sloping areas must be a thorough soil testing program, and a strict adherence to the best fertility and general soil management practices.

# Fertilized Legumes for Seed Production Increase Yields of Succeeding Crops

Paul M. Burson and Henry W. Kramer*

The forage legumes are the basis for a sound permanent agriculture. They are the most important livestock feeds and are essential in a sound soil fertility, management and landuse program. Their varied uses are being increasingly recognized and utilized. Therefore, the acreage being planted to these legumes is increasing, and hence greater quantities of seed are required.

In the past Minnesota had a flourishing legume seed industry of alfalfa, alsike clover, sweet clover and red clover. At various times the state has held first place in the production of alfalfa, alsike clover and sweet clover. Today it is outranked by all other legume seed producing states in the production of alfalfa and red clover, whiel the total seed produced of all four crops has decreased to the point where farmers have gone out of the business. This decrease is the result of the decreased yields per acre of all four crops so the acreage devoted to seed production is low.

Today the most important problems facing the seed producer are those concerned with soil type selection, fertilization, adequate pollination and the control of injurious insects.

Research work and observations by the Department of Soils have indicated that soil type, drainage, and proper fertilization are the important basic soil factors in legume seed production. A certain soil type may be suitable for one legume crop but not suitable for another. Determination of the proper soil type suitable to the various legume seed crops is basic. It goes without saying, that a legume plant will not produce seed abundantly unless it has an adequate and balanced nutrient supply on properly selected soil conditions. Results show a relationship between soil type conditions for different legume crops, proper fertilization and seed production. Observations further suggest a possible relationship between soil conditinns, fertilization and the attractiveness of the plant to pollinators. The information reported here will give the results of the response to fertilizer used in legume seed production and the residual response on succeeding crops that are grown in the rotation system.

Since 1952 over 40 different fields of all four legume seed crops have been studied. In the years 1952 through 1955 phosphate and phosphate + potash fertilizers were applied at the rates shown in Table i, to insure adequate amounts of both phosphate and potash.

Table 1. Fertilizer used in the experimental fields.

| Grade | Pounds per acre |
|---|---|
| 0-0-0 | (check) |
| 0-20-0 | 500 |
| 0-20-0 | 1000 |
| 0-20-20 | 500 |
| 0-20-20 | 1000 |
| 0-20-40 | 500 |
| 0-20-40 | 1000 |

*Professor and Experimental Plot Supervisor respectively, Department of Soils, University of Minnesota.

Since 1956 the same grades of fertilizer have been used but the rates per acre have been at 300 and 500 lbs. instead of 500 and 1000 lbs. Each of the seven fertilizer treatments were repeated four times in each field. All fertilizer was applied broadcast either at the time of seeding or topdressed in early spring of the year that the crop was to produce seed. No difference was noted as to the time of fertilization. The legume stands were equally good in all cases except where the legume was not adapted to the soil conditions such as too wet or too dry for the particular crop in a certain year.

The phosphate and phosphate + potash treatments were made on the basis of soil test. All plots were sprayed with DDT emulsion spray at 1 1/2 to 2 lbs. per acre at the onset of flowering. Adequate pollination was provided in all fields.

Minor nutrients of boron, manganese, copper, zinc and sulphur were studied but no responses were obtained from any of these treatments.

In Table 2 the acreage yields of the four seed crops are given for the best fertilizer treatments in those fields where the legume crop was definitely adapted to the soil type conditions, as compared to the average yield of these seed crops for Minnesota over the 10 year period of 1942-51.

Table 2. Average yield of seed from the best treatments and soil conditions in experimental fields compared with average seed yield of each crop for the state.

| Crop | Average yield Minnesota, 1942-51* | Average yield, best treatment experimental fields |
|---|---|---|
| | (pounds per acre) | |
| Alsike clover | 114 | 808 |
| Red clover | 59 | 761 |
| Alfalfa | 49 | 740 |
| Sweetclover | 180 | 1,438 |

*"Acreage, yield, and production of field seed crops. Revised estimates 1939-51 by States." USDA Bureau of Agricultural Economics, June, 1952.

Table 3 shows what seed yields are possible when the crops are grown on adaptable soil conditions, sufficient fertilization, adequate pollination and injurious insects are controlled.

Table 3. A summary of seed yields from fertilizers on representative fields with proper selection of soil, adequate pollination and control of injurious insects.*

| Crop | Year | Yields in lbs. per acre: No fertilizer | With fertilizer | Increase from fertilizer | Fertilizer Rate per acre |
|---|---|---|---|---|---|
| Alsike clover | 1952 | 154 | 691 | 537 | 0-20-20 (1000 lbs) |
| Alsike clover | 1953 | 236 | 685 | 449 | 0-20-20 (1000 lbs) |
| Alsike clover | 1953 | 368 | 808 | 440 | 0-20-40 (1000 lbs) |
| Red clover | 1953 | 387 | 662 | 175 | 0-20-40 (500 lbs) |
| Red clover | 1954 | 397 | 761 | 364 | 0-20-20 (500 lbs) |
| Alsike clover | 1954 | 297 | 691 | 394 | 0-20-40 (1000 lbs) |
| Alfalfa | 1954 | 322 | 740 | 418 | 0-20-20 (1000 lbs) |
| Sweet clover | 1955 | 1078 | 1438 | 360 | 0-20-0 (1000 lbs) |
| Alsike clover | 1956 | 54 | 308 | 254 | 0-20-40 (300 lbs) |
| Alsike clover | 1957 | 188 | 427 | 239 | 0-20-20 (300 lbs) |
| Alsike clover | 1958** | 181 | 710 | 529 | 0-20-20 (500 lbs) |
| Sweet clover | 1958** | 674 | 1032 | 358 | 0-20-20 (500 lbs) |

* Most of the pollination was by honey bees located near the experimental fields.
** In 1958 the entire plot areas were sprayed to control injurious insects.

Under the usual farming operations the seed fields are plowed following the harvest and then other crops such as small grains or flax are grown for one or more years and then the land is reseeded to one of the legumes. These experiments were carried out in the northern one-third of the state since the climate there is most favorable for legume seed production.

The residual yields of the experiments are shown in Table 4. It will be noticed the increase in yield of the succeeding crop was generally higher on the higher rates of fertilization than when the lower rates were used.

The results obtained on field No. 5 deserves special consideration because of the longer yield records. On this field the fertilizer was applied for alsike clover. Yields were increased from 154 lbs. to 691 lbs. per acre on the 1000 lbs. of 0-20-40. Two crops of barley followed and the residual effect was pronounced.

In the fourth year the land was in fallow and this was followed again by barley. Yields were not determined on the barley that year although very definite effects from the fertilizer were observed.

Alsike clover again was seeded with the barley and a crop of seed taken in the following year which was the sixth crop following the application of the fertilizer. Yields of alsike clover seed were still increased from 145 lbs. to 381 lbs. per acre on the 1000 lbs. of 0-20-20 per acre.

Using present day prices the annual increase from the crops clearly show that the residual carry-over effect on the crops which followed the alsike clover seed more than paid for the fertilizer.

Furthermore, these data show that higher rates of fertilization produce greater carry-over effects. This emphasizes the importance of making fertilizer applications heavy enough to supply all the nutrients needed to produce maximum crop yields under prevailing soil and weather conditions.

Table 4. Residual or Carry-over Effect of Fertilizer Applied for Legume Seed. All the fertilizer applied for 1st year crop. Yields per acre for each treatment.

| Field No. | Year | Crop | Check | 0-20-0 500 lb. | 0-20-0 1000 lb. | 0-20-20 500 lb. | 0-20-20 1000 lb. | 0-20-40 500 lb. | 0-20-40 1000 lb. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1st | Red clover seed* | 84 lbs. | 80 | 78 | 93 | 108 | 94 | 94 |
| | 2nd | Corn | 52.9 bu. | 56.3 | 60.8 | 84.4 | 83.6 | 86.3 | 89.1 |
| 2 | 1st | Red clover seed | 129 lbs. | 135 | 159 | 129 | 128 | 166 | 157 |
| | 2nd | Corn silage | 20 tons | 23 | 23 | 26 | 26 | 23 | 24 |
| 3 | 1st | Red clover seed** | 166 lbs. | 235 | 222 | 240 | 267 | 216 | 211 |
| | 2nd | Flax | 16 bu. | 21 | 22 | 22 | 24 | 22 | 23 |
| 4 | 1st | Red clover seed | 387 lbs. | 670 | 653 | 654 | 637 | 662 | 622 |
| | 2nd | Red clover seed | 151 lbs. | 245 | 287 | 281 | 271 | 302 | 280 |
| 5 | 1st | Alsike clover seed | 154 lbs. | 570 | 620 | 641 | 657 | 614 | 691 |
| | 2nd | Barley | 32 bu. | 51.5 | 57.8 | 59.0 | 62.5 | 60.4 | 60.7 |
| | 3rd | Barley | 37.4 | 51.6 | 52.7 | 51.0 | 50.3 | 44.4 | 50.5 |
| | 4th | Fallow | --- | --- | --- | --- | --- | --- | --- |
| | 5th | Barley*** | visible increase in yield from fertilizer. | | | | | | |
| | 6th | Alsike clover seed | 145 lbs. | 267 | 330 | 264 | 381 | 278 | 352 |
| 6 | 1st | Sunflowers | 79.8 bu. | 100.9 | 101.9 | 105.2 | 96.0 | 97.6 | 91.9 |

* Inadequate pollination and first crop clipped too late for good seed set.
** Fertilizer rates at 300 and 500 lbs. per acre instead of 500 and 1000 lbs. per acre.
***Not sampled for yield.

Table 5. Residual or Carry-over Effect of Fertilizer Applied for Legume Seed, 1959 and 1960*

| Crop | Check | 0-20-0 300 lb. | 0-20-0 500 lb. | 0-20-20 300 lb. | 0-20-20 500 lb. | 0-20-40 300 lb. | 0-20-40 500 lb. |
|---|---|---|---|---|---|---|---|
| | | | | 1959 | | | |
| Barley | 20.8 bu. | 58.5 bu. | 54.9 bu. | 52.8 bu. | 62.0 bu. | 56.6 bu. | 63.1 bu. |
| Oats | 40.3 | 56.5 | 62.3 | 68.1 | 72.2 | 63.3 | 69.5 |
| Oats | 87.3 | 124.0 | 126.9 | 123.9 | 132.1 | 123.9 | 120.1 |
| Flax | 20.4 | 21.3 | 21.5 | 22.2 | 19.7 | 23.1 | 22.4 |
| Alsike Clover | 72.0 lb. | 192.0 lb. | 207.0 lb. | 181.0 lb. | 191.0 lb. | 174.0 lb. | 194.0 lb. |
| | | | | 1960 | | | |
| Wheat | 27.7 bu. | 29.1 bu. | 27.7 bu. | 30.9 bu. | 28.5 bu. | 28.0 bu. | 26.9 bu. |
| Oats | 76.8 | 82.9 | 80.8 | 80.8 | 77.0 | 82.3 | 83.4 |
| Oats | 43.6 | 45.8 | 47.9 | 51.1 | 49.2 | 50.5 | 47.4 |
| Oats | 65.6 | 76.0 | 88.0 | 71.7 | 82.8 | 82.2 | 84.0 |
| Wheat | 47.4 | 52.7 | 51.9 | 51.9 | 51.5 | 52.6 | 51.7 |
| Wheat | 45.2 | 52.8 | 53.0 | 54.1 | 52.8 | 52.1 | 53.9 |

* All fertilizer applied previous years on legume seed crop.
** Individual fields

These consistent residual yield increases can be expected to carry through anywhere from 2 to 6 years or possibly more, after the initial fertilizer application.

The question now being asked by farmers in the legume seed producing areas of northern Minnesota as to what this fertilization program can mean to me on my farm in economic returns?

This residual response indicates that such a fertility program can apply to any type of farming regardless of the crops grown in the different agricultural areas of Minnesota.

In all the residual yield responses reported above on the 5 fields, the dollar return for fertilizer over fertilizer cost ranged from $3.00 for each $1.00 spent for the year of application up to as high as $9.00 return for a 6 year residual response. To illustrate what these dollar returns over fertilizer cost would mean field no. 5 is an excellent example.

On the basis of the 0-20-20 fertilizer, which gave the most consistent increase in all crop yields for the 6 years, when applied at two rates, 500 and 1000 pounds per acre, it would cost $17.00 and $34.00 per acre respectively. The acre return over fertilizer cost would be $164.00 for the 500 pound rate and $211.50 for the 1000 pound rate. The second 500 lbs. of fertilizer returned $47.40 per acre for $17.00 per acre additional investment in fertilizer. Crop prices were figured on the current farm price.

If a typical 50 acre Minnesota field was cropped in the same way as field no. 5, the return over fertilizer cost would amount to $8,205.00 for the 500 pound rate as compared to $10,575.00 for the 1000 pound rate for the 6 year residual period.

The difference in the return over fertilizer cost between the two rates of application per acre then is $2,370.00 in favor of the 1000 pound rate. This means that the second 500 pounds per acre of fertilizer added to the 50 acre field brought this additional return.

How much longer these residual responses may continue beyond the 6 years is not known, but such a fertility program is now in progress on the other 5 fields. These fields are being cropped with different kinds of crops and in a different sequence than field no. 5, but all are showing similar yield increases and similar ratios of dollar returns over fertilizer costs for the different crops.

There is no substitute for good soil fertility and management. It is the best insurance and investment a farmer can make, no matter how large or how small his scale of farming operations may be. Proper fertilization means efficiency of production and greater economic return in any farming operation.

# PASTURE FERTILITY AND BEEF PRODUCTION

P.M. Burson, Soils; A.R. Schmid, Agronomy
A.L. Harvey and O.E. Kolari, Animal Husbandry

On May 16, 1960, steers from the winter feeding experiment were lotted and turned onto pasture. One-half of each of the three pastures was fertilized and the other one-half unfertilized. Each pasture received an annual topdressing of 200 lbs. per acre of 0-20-20 and 200 lbs. of 33-0-0, ammonium nitrate (66 lbs. of nitrogen). The 0-20-20 was applied in early spring while the nitrogen was applied at different times during the spring and summer as shown in table 2. Pastures B and F are mainly brome grass and bluegrass. Pastures A and C are a mixture of alfalfa, brome and orchard grass, while pastures B and F are brome and orchard grass. Table 1 shows the production of beef for 1960. The total production of beef per acre ranged from 134 lbs. on the unfertilized B and F pastures to 280 lbs. on the fertilized renovated A and C pastures. It should be noted that the greatest beef production per acre was from the fertilized renovated pastures which also gave the greatest beef return per acre over seed, tillage and fertilizer costs. The carrying capacity as shown by steer-clays per acre ranged from 86 on the unfertilized grass to 132 on the fertilized grass to a top of 181 on the fertilized renovated pastures. The average pounds gained per steer for the 113 days of grazing ranged from 155 on the unfertilized to 175 on the fertilized renovated to 187 lbs. on the fertilized grass.

As shown in table 2, the application of nitrogen fertilizer on pastured B, D, F and G was made at two different times in the spring. This was compared with a split application with one-half put on in the spring and one-half during mid-summer. The effect of nitrogen fertilizer on the yield of forage produced per acre was determined. The difference in time of application or the use of split applications had no major effect on the amount of forage produced per acre over a single application all applied in early or late spring. In some areas where rainfall is sufficient and well distributed during the summer months, the split application of nitrogen may boost pasture yields during mid-summer. A split application may be important where the soils are eroded to the extent that no topsoil remains. Where no topsoil remains higher rates of nitrogen should be used at the spring application along with the mid-summer application. The application of nitrogen fertilizer did boost pasture yields from .31 ton per acre on the unfertilized B1 pasture to 2.70 tons on the nitrogen fertilized D1 pasture. The percentage of grass in the pasturage was increased by nitrogen fertilizer. However, no difference in the percentage of grass could be noted as to the time of nitrogen application.

Table 1. Beef produced with yearling steers on unfertilized and fertilized pastures grazed in rotation. May 16, 1960 to September 6, 1960. (113 days)

| | Unfertilized | Fertilized [a] | |
|---|---|---|---|
| | Grass<br>$B_3$, $B_4$, $F_1$<br>5.65 acres | 60# N on Grass<br>$B_1$, $B_2$, $F_1$<br>5.65 acres | Renovated [b]<br>$A_2$, $A_3$, $C_1$<br>7.50 acres |
| No. steers at start | 6 [c] | 10 [d] | 12 |
| Initial weight, lb. | 636 | 634 | 628 |
| Final weight, lb. | 791 | 821 | 803 |
| Gain/steer, lb. | 155 | 187 | 175 |
| Daily gain, lb. | 1.56 | 1.59 | 1.55 |
| Steer days/acre | 86 | 132 | 181 |
| Beef produced/acre, lb. | 134 | 210 | 280 |
| Value beef produced/acre @ 21.00 cwt. | 28.14 | 44.10 | 58.80 |
| Fertilizer and lime cost/acre | ___ | 15.00 | 8.00 |
| Tillage and seed cost/acre | ___ | ___ | 6.00 |
| Value beef produced/acre less seed, tillage and fertilizer cost | 28.14 | 29.10 | 44.80 |

[a] 200#/acre 0-20-20 annual

[b] Renovation - three workings with deep tiller and once with disk. Seeded to alfalfa 5#, alsike 1#, Lincoln brome 6#, and orchard grass 2# per acre.

[c] 2 steers removed 6/2/60

[d] 4 steers removed 6/2/60

Table 2. Clipping yields from fertilized pastures B, D, E, F, and G comparing nitrogen fertilization as to time of application and split versus one application.

P.M. Burson, Soils; A.R. Schmid, Agronomy
A.L. Harvey, Animal Husbandry [a]

| Treatments Lbs. N/acre [b] | Total tons and average per acre for each pasture at 15% moisture [c] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | B1 | B2 | D1 | E1 | F | G2 | G5 | Av. |
| No fertilizer | .31 | 1.30 | 1.55 | 1.21 | 1.28 | .63 | .54 | .97 |
| 66#April 22 | .56 | 1.43 | 2.30 | 1.27 | 2.17 | 1.00 | 1.42 | 1.45 |
| 33# April 22 - 33# July 13 | .52 | 1.32 | 2.50 | 1.25 | 1.33 | .95 | 1.44 | 1.34 |
| 66# June 13 | .40 | 1.27 | 2.31 | 1.11 | 1.94 | .89 | 1.69 | 1.37 |
| 33# June 13 - 33# July 13 | .67 | 1.49 | 2.70 | 1.39 | 1.36 | .82 | 1.44 | 1.41 |

[a] Acknowledgement is due Ed. Bonnell and Lawrence Olson who harvested the sample.

[b] Annual application - 200# per acre 0-20-20, April 22, 1960

[c]

| Pastures | Number of Clippings |
|---|---|
| D1, B2, and G5 | 3 |
| F and G2 | 2 |
| B1 and E1 | 1 |

Pastures D1 and E1 legume-grass mixture

# BEEF PRODUCTION FROM RENOVATED AND FERTILIZED GRASS PASTURES

A. R. Schmid, Agronomy; P. M. Burson, Soils;
A. L. Harvey and O. E. Kolari, Animal Husbandry

Four types of pasture were compared on "G" for the third successive year. The four types were renovated, grass with no fertilizer, grass with nitrogen and grass with manure. All pastures were limed in the fall of 1956 with 3 tons of ground limestone per acre. The area for renovation was cultivated three times in the fall and one time in the spring with a Deep Tiller. Then it was disced, packed and seeded to flax and a mixture of Ranger alfalfa, 5 pounds per acre; alsike clover, 1; Lincoln bromegrass, 6; and orchard grass, 2.

For the manure treatment on grass, applications were made each fall. Commercial fertilizer used on the various treatments was applied in the spring. The rates of fertilization, manure and lime are shown in Table 1.

Results - In 1958 the beef produced per acre was 251 pounds from the check (grass with no fertilizer), 272 pounds from manure (6 tons per acre), 265 from nitrogen (80 pounds N per acre), and 394 pounds from the renovation (fertilizer-legume-grass).

In 1959 the manure treatment was increased from 6 to 8 tons of manure per acre and because of an error the nitrogen treatment was reduced from 80 pounds to 60 pounds per acre. The beef produced per acre was 146 pounds from the control; 216 pounds from the manured; 233 pounds from the nitrogen and 263 pounds from the renovated. Returns above costs for both years plus the 1960 data are shown in Table 1.

In 1960 the beef produced per acre was 172, 247, 289, and 240 pounds respectively from the check, manure, nitrogen and renovated. In returns per acre above costs no spectacular differences were obtained. Steers on the pasture treated with nitrogen returned $5.22 more per acre than the control, the manure $3.60 less and the renovated $8.75 less per acre than the control. The legume in the renovated pastures had pretty well disappeared and the stand was not the best to begin with.

The three year averages of returns per acre over costs show the removated to be $10.29 per acre better than the control. The manure and nitrogen treatments although not showing any important advantage over the control in returns did have a higher carrying capacity. At times during the three year period the lack of moisture did not allow for maximum yields from the manure and nitrogen treatments.

Table 1. Beef produced from brome-timothy and renovated pastures (2 pasture rotation-G). May 16, 1960 - August 16, 1960. (79 days)[a]

| | | Control (G4,G6) | Manure[b] (G1,G7) | Nitrogen[c] (G2,G5) | Renovated[d] (G3,G8) |
|---|---|---|---|---|---|
| No. steers at start | | 4 | 6 | 6 | 6 |
| Initial weight, lb. | | 718 | 719 | 718 | 715 |
| Final weight, lb. | | 864 | 874 | 890 | 862 |
| Gain/steer, lb. | | 138 | 132 | 154 | 128 |
| Daily gain, lb. | | 1.74 | 1.67 | 1.95 | 1.62 |
| Steer days/acre | | 99 | 148 | 148 | 148 |
| Beef produced/acre, lb. | | 172 | 247 | 289 | 240 |
| Value beef produced/acre at $21.00 cwt. | | $36.12 | $51.87 | $60.69 | $50.40 |
| Fertilizer, lime and manure cost/acre[a] | | $ 0.97 | $20.32 | $20.32 | $17.36 |
| Tillage and seed cost/acre | | | | | $ 6.64 |
| Value beef produced/acre less fertilizer and tillage costs | 1960 | $35.15 | $31.55 | $40.37 | $26.40 |
| | 1959 | $38.91 | $38.83 | $45.27 | $54.61 |
| | 1958 | $68.31 | $58.37 | $53.17 | $92.24 |
| | ave. | $47.46 | $42.92 | $46.27 | $57.75 |

a/ Not grazed 7/7/-7/20 (13 days) in 1960

b/ Manure, 8 tons/acre annually, value $9.60. Also 300 lbs. 0-20-20 in 1957 and 200 lbs. annually since 1957, annual cost $9.75.

c/ Nitrogen, 80 lb N/acre annually, cost $9.60. Also same amount 0-20-20 as on manure. (due to erroe only 60 lb. N was applied in 1959).

d/ Renovated, four workings with a deep tiller and once with disk, cost at $3.00 per operation per acre $15.00 or $5.00 per year over 3 years. Seed was alfalfa 5 lb/acre, alsike 1, Lincoln bromegrass 6, orchardgrass 2 lbs. per acre; cost $4.92, or $1.64 per year over a 3 year period.

e/ Lime, all pastures @ 3 tons per acre, cost $0.97 per year over 10 year period.

# THE EFFECTS OF PASTURE FERTILIZATION AND STILBESTROL IMPLANTS ON BEEF PRODUCTION

A. L. Harvey, O. E. Kolari, Animal Husbandry
P. M. Burson, Soils and A. R. Schmid, Agronomy

Comparisons were started in 1953 to determine the effect of fertilization on yield, palatability and utilization of various pasture mixtures as well as carrying capacity and the amount of beef produced per acre. An average of seven years' results (1953-1959) shows that fertilizing alfalfa-brome pastures increased: (1) carrying capacity 55 steer days (114 to 169 days) or 48%; (2) beef produced per acre 85 pounds (206 to 291 pounds) or 41%; (3) value of beef produced per acre less fertilizer costs $10.04 per acre ($47.64 to $57.68) or 21%. When weather conditions were favorable, as in 1958, 461 pounds of beef were produced per acre on the fertilized pastures, which was 159 pounds more than produced on similar unfertilized pastures. The additional beef produced from the fertilized pastures (valued at $28 per hundredweight) increased the margin, after deducting costs of fertilizing ($15 per acre), $29.52 per acre. There was only one year in seven (1959) when the application of fertilizer did not prove profitable. This was probably due to winter killing of alfalfa and orchard grass the preceding winter and extreme drought the following spring.

Implanting steers with 24 mg. stilbestrol at the start of the pasture season has been a very profitable procedure. Average results for three years' (1957-1959) grazing on legume grass mixtures showed an increase of 51 pounds beef per acre (280 to 331 pounds) or 18% more beef produced by implanted steers. Fifty-one pounds of beef at $28 per hundredweight, less cost of implants ($0.10),

[a]Acknowledgment is due Charles Pfizer & Co., Terre Haute, Indiana for stilbestrol implants; College of Veterinary Medicine for veterinary service; E. Swanson and G. Tompkins who fed and cared for the cattle; and to L. Williamson who assisted in the conduct of the experiment.

resulted in a margin of $14.08 per acre in favor of the implanted steers.

When steers were implanted with 24 mg. stilbestrol and grazed on fertilized alfalfa-brome pastures, the amount of beef produced per acre was 139 pounds (241 vs. 380 pounds) or 58% greater than the amount produced by steers not implanted and grazed on unfertilized pastures. The two procedures increased the return per acre $23.82 over costs of implanting and fertilizing.

During 1959, one group of steers was grazed on pastures (B and F) which consisted principally of bromegrass. Even though the fertilized pastures produced 45 pounds more beef per acre than the controls (125 vs. 170 pounds) it was not sufficient to cover the cost of fertilizer. Furthermore, the steers implanted with 24 mg. of stilbestrol at the start of grazing produced less beef per acre regardless of whether the pastures had been fertilized or not. Because of the unfavorable pasture conditions in 1959 it was decided to repeat the experiment in 1960.

## Procedure

"Medium-to-good" grade yearling steers were lotted as uniformly as possible into three groups, each grazed on a three-pasture rotation. Group I consisted of 6 steers (reduced to 4 steers after 17 days) on unfertilized bromegrass pastures (B3, B4, F2) totaling 5.65 acres; group II consisted of 10 steers (reduced to 6 steers after 17 days) on fertilized bromegrass pastures (B1, B2, F1) totaling 5.65 acres; and group III consisted of 12 steers on fertilized alfalfa-brome pastures (A2, A3, C1) totaling 7.5 acres.

Steers in these pasture trials and one other (Report B-29b) had been used in an experiment the preceding winter (Report B-24). One-half had been implanted with 12 mg. stilbestrol November 24, 1959. One-half of those implanted and one-half those not implanted in the fall of 1959 were implanted with 24 mg. when turned onto pasture May 16, 1960, to determine whether previous implanting affected pasture gains (repeat of preceding year).

## Results and Discussion

The amount of beef produced per acre from all pastures in this experiment averaged 41 pounds per acre (167 vs. 208 pounds) or 25% more than 1959, while the fertilized pastures averaged 56 pounds (189 vs. 245 pounds) or 30% more than 1959. This was probably due to ample rainfall during the spring months even though August was drier than normal. Table 1 contains a summary of results.

Table 1. The effect of stilbestrol implants on steers grazed on unfertilized and fertilized pastures. May 16, 1960 - September 6, 1960, (113 days).

| | Implanted[a] | | | Control | | |
|---|---|---|---|---|---|---|
| Pastures | Unfert. grass (B3,4,F2) | Fertilized grass (B1,2,F1) | Fert. leg.x grass (A2,3,C1) | Unfert. grass (B3,4,F2) | Fertilized grass (B1,2,F1) | Fert. leg. x grass (A2,3,C1) |
| No. steers at start | 3[b] | 5[c] | 6 | 3[b] | 5[c] | 6 |
| Initial weight, lb. | 640 | 625 | 623 | 632 | 644 | 633 |
| Final weight, lb. | 833 | 818 | 822 | 750 | 824 | 784 |
| Gain/steer, lb. | 193 | 193 | 199 | 118 | 180 | 151 |
| Daily gain, lb. | 1.89 | 1.69 | 1.76 | 1.23 | 1.49 | 1.34 |
| Steer days/acre | 86 | 132 | 181 | 86 | 132 | 181 |
| Beef produced/acre, lb. | 162 | 223 | 318 | 105 | 196 | 242 |
| Increase due to implants, lb.(%) | 57(54%) | 27(14%) | 76(31%) | - | - | - |
| Value of beef produced /acre at $21.00/cwt. | $34.02 | $46.83 | $66.78 | $22.05 | $41.16 | $50.82 |
| Daily gain, av. all pastures, lb. | | 1.78 | | | 1.35 | |
| Beef produced/acre, av. all pastures, lb. | | 234 | | | 181 | |
| Increase due to implants, lb.,(%) | | 53(29%) | | | - | |
| Value of beef produced/acre, av. all pastures | | $49.14 | | | $38.01 | |

[a]Implanted with 24 mg. stilbestrol May 16, 1960.
[b]1 steer removed 6/2/60
[c]2 steers removed 6/20/60

Implanting steers with 24 mg. stilbestrol when turned on pasture:

1. Increased average daily gain per head 0.43 pounds (1.35 to 1.78 pounds).
2. Increased beef produced per acre 53 pounds (181 to 234 pounds), or 29%.
3. Increased the value of beef produced per acre $11.13 ($38.01 to $49.14).
4. Increased the beef produced per acre from:
   a. Unfertilized grass pastures 57 pounds (105 to 162 pounds) or 54%.
   b. Fertilized grass pastures 27 pounds (196 to 223 pounds) or 14%.
   c. Fertilized legume-grass pastures 76 pounds (242 to 318 pounds) or 31%.

Table 2 shows the effect on subsequent pasture gains of implanting calves with 12 mg. stilbestrol at the beginning of the wintering experiment and/or implanting with 24 mg. stilbestrol at the beginning of the pasture trial.

Table 2. Effect of various stilbestrol implanting regimes on average daily gains on pasture

| Feeding period | Implanted[a] | | Not implanted | |
|---|---|---|---|---|
| Wintering | 1.45(12 steers) | | 1.38(16 steers) | |
| | Implant[b] | No implant | Implant | No implant |
| Pasture | 1.81 (6 steers) | 1.28 (6 steers) | 1.72 (8 steers) | 1.39 (8 steers) |

[a]12 mg. implant, 11/24/59
[b]24 mg. implant, 5/16/60

In these experiments implanting steers with stilbestrol:

1. Increased the average daily gain .07 pound (1.38 to 1.45 pounds), or 5% during the winter but decreased the average daily gain .09 pound (1.39 to 1.28 pounds), or 6%, during the following pasture season.

2. At the start of the pasture season only, increased the average daily gain .33 pounds (1.39 to 1.72 pounds), or 24%.

3. At the beginning of the wintor and at the start of the pasture season increased the average daily gain .42 pounds (1.39 to 1.81 pounds), or 30%.

Results of several years' experiments show that when moisture conditions are favorable implanting steers with stilbestrol at the start of the pasture season, regardless of previous wintering implanting, is a profitable procedure.

## Sherburne County Potato Fertility Demonstration - 1960

Merle Halverson, J. M. MacGregor and O. C. Turnquist

Location: Odin Odegard farm, 2 miles S.W. of Princeton, Minnesota
Soil: Type: Zimmerman loamy sand (irrigated)
pH: 5.9
O.M. content: 1.2% (low)
Extractable P: 100 lbs/A, (very high)
Exchangeable K: 110 lbs./A, (medium)
Texture: loamy sand
1959 crop: Rye (no manure)
Variety: Waseca
Crop Details: Row spacing: 40" between, 10" within
Planting Date: 22 April, 1960
Irrigations: Four (1 1/4" each)
Plot Size: 6'8" (2 rows) x 2640' (0.39 acres)
Harvest area: 6'8" (2 rows) x 2640' (0.39 acres)
Sprayed: DDT, 23 May
Millers 658 9 July
Vines Killed: Aug. 4 2 gal/A Atlas "A" applied.
Harvest date: August 12
Fertilizer: Nitrogen: 75 lbs/A N applied sidedress to all plots (including check) on May 27, 1960
Grades and Rates: 8-16-24 at 0, 300, 600, 900 and 1200 lbs/A
4-12-36 at 0, 400, 800, 1200 and 1650 lbs/A
Both grades and all rates applied in the row at planting time.
Note: The treatments were not replicated; however, each yield sample was of such size (0.39 acres) as to give the data considerable reliability.

Results:

| Fertilizer grade | Rate, lbs/A | Yield of #1 tubers cwt/A | Specific gravity | % of total yield due to #1 tubers |
|---|---|---|---|---|
| check | ---- | 105.1 | 1.070 | 88.0 |
| 8-16-24 | 300 | 118.9 | 1.068 | 84.9 |
| " | 600 | 128.6 | 1.068 | 84.9 |
| " | 900 | 134.3 | 1.066 | 86.1 |
| " | 1200 | 122.2 | 1.067 | 84.1 |
| 4-12-36 | 400 | 116.6 | 1.068 | 87.0 |
| " | 800 | 120.7 | 1.065 | 83.4 |
| " | 1200 | 121.7 | 1.067 | 82.5 |
| " | 1600 | 111.0 | 1.066 | 80.8 |

Marked yield declines occurred at rates of application exceeding 900 lbs/A of 8-16-24 and 1200 lbs/A of 4-12-36 when these materials were placed in the row. Failure of the 4-12-36 to increase yields as effectively as the 8-16-24 at equal rates of $P_2O_5$ cannot be explained because the ratios of nitrogen to potash in the two fertilizer grades are different.

Failure of yields to attain higher maximum values can probably be attributed to the early potato variety planted. It is also possible that considerable of the nitrogen applied May 27 was lost to undrainage in the irrigation water on this coarse-texture soil.

# Clay County Potato Fertility Demonstrations, 1960

O. A. Daellenbach, O. C. Turnquist and Merle Halverson

Location: Gary Smith Farm, 2 miles south of Baker, Minnesota
Soil: Type: Bearden silt loam
pH: 8.2
O.M. content: 4.6% (medium)
Extractable P: 1 lb/A (very low)
Exchangeable K: 190 lbs/A (medium)
1959 crop: soybeans (spring plowed 1960, no manure)
Variety: Irish Cobbler
Crop Details: Row Spacing: 38" between, 12" within
Date of Planting: June 3, 1960
Harvest Date: September 21, 1960
Plot Size: 0.01 acre 12'8" (4 rows) x 34'5"
Harvest Sampling Area: 6'4" (2 rows) x 16'6"
Experimental:
Nitrogen: (as ammonium nitrate) a broadcast preplant and disced in.
3 rates: 0, 42, and 80 lb. nitrogen per acre.
$P_2O_5$: (as concentrated superphosphate) applied in row at planting
1 rate: 100 lb. $P_2O_5$ per acre
$K_2O$: (as muriate of potash) broadcast preplant and disced in.
4 rates: 0, 42, 80 and 120 lb. $K_2O$ per acre
Replicates: 4
Note: Two potash sources (muriate and sulfate) were also compared at 3 application rates - using 100 lbs. $P_2O_5$/A row placed at one rate of nitrogen (40 lbs N/A) only.

(1) Main effects of nitrogen
(Each figure is an average from 16' plots receiving that nitrogen rate)

| N rate lbs/A | Yield of #1 tubers cwt/A | Specific gravity | % of total yield due to #1 tubers |
|---|---|---|---|
| 0 | 137.0 | 1.085 | 93.5 |
| 40 | 154.7* | 1.083 | 93.0 |
| 80 | 159.4* | 1.084 | 92.9 |

(2) Main effect of potash (muriate)
(Each figure is an average of 12 plots receiving that potash rate)

| $K_2O$ rate lbs./A | Yield of #1 tubers cwt/A | Specific gravity | % of total yield due #1 tubers |
|---|---|---|---|
| 0 | 148.1 | 1.086 | 92.3 |
| 40 | 149.6 | 1.085 | 93.5 |
| 80 | 153.9 | 1.083* | 93.3 |
| 120 | 149.8 | 1.083* | 93.6 |

(3) Effect of 3 rates and 2 sources of potash on yield of #1.
Cobblers using 40 lb. nitrogen and 100 lbs. available phosphate per acre throughout.
(Each figure is an average of 4 replicates receiving that combination of potash rate and source)

| $K_2O$ Source | Chloride | | Sulfate | |
|---|---|---|---|---|
| $K_2O$ Rate | Yield, cwt/A | spec. grav. | Yield, cwt/A | spec. grav. |
| 40 lbs/A | 161.2 | 1.086 | 160.5 | 1.087 |
| 80 lbs/A | 172.9 | 1.084 | 173.2 | 1.086 |
| 120 lbs/A | 167.1 | 1.083 | 171.5 | 1.086 |
| Average | 168.4 | 1.084* | 168.4 | 1.086* |

* denotes significant differences when compared with 0 rate; in the case of (1) and (2), and between potash sources in the case of (3).

Specific gravity tests give an indication of relative cooking quality in potatoes. The test is a measure of total dry matter content and will vary with variety, soil type, season, moisture, fertilization, pest control and maturity. Dry matter content is, however, only one measure of cooking quality. It tells largely the texture or mealiness which can be expected upon cooking. Potatoes having a high specific gravity contain more dry matter than those with a low specific gravity. The following classification ranges are commonly used.

| Specific Gravity | Total Dry Matter (approximate) | Texture | Best Use |
|---|---|---|---|
| Below 1.061 | less than 16% | very soggy | Good pan fryers and salads. Fair boilers |
| 1.061-1.070 | 16 to 18% | soggy | Good pan fryers and salads. Fair boilers |
| 1.071-1.080 | 18 to 20% | waxy | Good bakers and mashers |
| 1.081-1.090 | 20 to 22% | mealy | Good bakers, mashers, chippers and french fryers. |
| 1.091-1.110 | 22 to 24% | very mealy | Good Bakers, chippers and fryers. |

In the opinion of extension specialists in Horticulture and Soils, the nitrogen rates and potash rates and sources used in this work had no deleterious effect upon potato cooking quality from the consumer standpoint. While measurable differences in specific gravity were observed, these differences were so small as to make them undetectable and unimportant to the consumer.

It should be noted that the nitrogen and potash materials used in this work were applied broadcast and not row placement.. As such, the effects noted herein are not necessarily the same as might have occurred had the same materials been used in row placement.

# Fertility Studies on Peat at Hollandale - 1960

R. S. Farnham

The object of this study on peat at Hollandale, Minnesota was to compare the effect of several rates and grades of commercial fertilizers on the yield and quality of Irish Cobbler potatoes.

The organic soil used is a decomposed peat with about 20% mineral matter. The pH varied from 7.0 to 7.3 in the plot area and extractable P by soil test was very high (200 + lbs./acre) and K very high (400-500 lbs/acre). The plot area was adequately drained by tile drainage.

The experiment was a split plot randomized block designed including four replicates. Three fertilizer grades 0-20-20, 4-12-36, and 0-12-36 were applied broadcast in late May prior to seeding at 0, 300, 600 and 900 pounds/acre rates. The plots were harvested October 12, 1960, and total yields of potato tubers and specific gravity data are shown in Table 1.

The highest yield of potatoes was obtained with the 0-12-36 grade at the 900 pound/acre rate, however, the 300 pound rate was the most economical showing an increase of over 4500 pounds per acre over the check. Nitrogen additions appear to depress the yield at the lower rates of 4-12-36 although the 900 pound rate gave a 28 bag increase.

The 0-20-20 grade having a 1 to 1 P to K ratio is not as effective as the 0-12-36 grade with a 1 to 3 P to K ratio. This indicates a definite response to potassium despite a very high initial soil test (400-500) for K.

Increased phosphorus rates using 0-20-20 grade did not increase yields as much as when the 0-12-36 grade was used although the 1 to 1 ratio did give some yield increases.

The 300 and 600 pound rates of 4-12-36 decrease the specific gravity more than any other treatment. This is probably due to a nitrogen effect as the 0-12-36 grade without nitrogen did not decrease the specific gravity except at the 900 pound rate. Indications are that the highest potassium rates generally lower the specific gravity of potatoes.

Table 1. Yield and Specific Gravity of Cobbler Potatoes on an Organic Soil at Hollandale, 1960.

| | 0-20-20 | | 4-12-36 | | 0-12-36 | |
|---|---|---|---|---|---|---|
| Rate | Yield | Sp. Gr. | Yield | Sp. Gr. | Yield | Sp. Gr. |
| | cwt/acre | | cwt/acre | | cwt/acre | |
| 0 | 320.2 | 1.0690 | 316.5 | 1.0692 | 328.2 | 1.0718 |
| 300 | 339.0 | 1.0720 | 315.1 | 1.0685 | 373.9 | 1.0705 |
| 600 | 351.4 | 1.0690 | 328.9 | 1.0672 | 365.2 | 1.0708 |
| 900 | 344.1 | 1.0715 | 344.1 | 1.0692 | 392.8 | 1.0695 |

# Fertilization for Grass Seed Production in Northern Minnesota

J. M. MacGregor, P. M. Burson, and H. W. Kramer

An investigation to determine the effect of commercial fertilizer on grass seed production in northern Minnesota was commenced late in 1959. With the development of Park Kentucky bluegrass and its seed production in Roseau county, there was considerable interest in establishing the possible economic effects of applying different kinds of fertilizers at different rates and at different times during the year, to both new and established stands on both organic and inorganic soils. Fertilization of fields for grass seed production in Roseau County is a well established practice, but there has been no detailed study of what ratios and rates per acre are most effective in grass seed production.

## Greenhouse Experiments

While the major portion of the investigation was to be undertaken in the grass seed production areas of Roseau County, greenhouse studies were also initiated on these soils late in 1959, at the time the first field fertilizer treatments were made. Bulk samples of a mineral soil and a peat soil were transported from Roseau County to St. Paul, and an extensive fertilization experiment was initiated. While an excellent vegetative production resulted in the greenhouse with some fertilizer treatments, no seed production has yet been obtained in these trials. It appears that this lack of seed development may be due to unfavorable light conditions, and further research will be done in an attempt to induce flowering of the Park Kentucky bluegrass in the greenhouse in order to determine fertilizer effect.

## Field Experiments

Four fields of Park Kentucky bluegrass (two on peat soils and two on mineral soils) and two fields of Climax timothy were fertilized in the September of 1959, and adjacent comparative plots were fertilized with the same treatments in the following May. In addition, a high nitrogen treatment experiment was established in May on one field of Park Kentucky bluegrass located on a mineral soil.

The treated plots were harvested in 1960 and the samples were passed twice through a hammer mill, and then repeatedly passed through a fanning mill until sufficiently clean. The seed yields obtained with the different fertilizer treatments are shown in the following tables. Four replications of each treatment were employed on the seven field experiments.

Table 1. The effect of different fertilizer treatments on the 1960 yield of Park Kentucky bluegrass seed, growing on peat soils in Roseau County, Minnesota

| Fertilizer Treat. (lb/A) N $P_2O_5$ $K_2O$ | Pounds of harvested grass seed per acre | | | |
|---|---|---|---|---|
| | Charles Habstritt - Roseau (new seeding on peat) | | Stanley Roadfeldt - Badger (seeding 2 years old) | |
| 0-0-0 | 54 | | 205 | |
| | Fall fertilized | Spring fertilized | Fall fertilized | Spring fertilized |
| 0-80-0 | 167 | 237** | 382** | 300 |
| 0-80-80 | 196* | 242** | 349** | 334* |
| 30-80-0 | 164 | 218* | 327* | 387** |
| 30-80-80 | 197* | 146 | 306 | 372** |
| 60-80-80 | 128 | 255** | 377** | 409** |
| 90-80-80 | 250** | 221* | 331* | 365** |
| 40-20-80 | 186* | 179 | | |
| 33-33-33 (winter) | 173 | | 279 | |
| Average | 184 | 213 | 345 | 361 |

* L.S.D. (5%) = 128#/A.
** " (1%) = 170#/A.

The 33-33-33 winter applied was the farm operator application of 12-12-12 at the rate of 275#/A.

Phosphate was the mineral nutrient most effective for increasing grass seed yield. Potash and nitrogen had little beneficial effect and spring fertilization resulted in a greater average seed yield than was obtained with the fall fertilization. This beneficial effect of spring fertilization was probably a result of the greater availability of the spring applied phosphate in comparison to that spread in the preceding autumn, with the cold soil conditions of the spring growing season.

Table 2 shows the fertilizer effect produced on two fields of mineral soil.

Table 2. The effect of different fertilizer treatments on the 1960 yield of Park Kentucky bluegrass seed growing on two mineral Soils of Roseau County, Minnesota

| Fertilizer treat. (lbs/A.) N $P_2O_5$ $K_2O$ | Pounds of harvested grass seed per acre | | | |
|---|---|---|---|---|
| | Oliver Wold - Roseau (new seeding) | | Helmer Halvorson - Roseau (4 year old seeding) | |
| 0-0-0 | 80 | | 21 | |
| | Fall fertilized | Spring fertilized | Fall fertilized | Spring fertilized |
| 0-80-0 | 117 | 108 | 39 | 35 |
| 0-80-80 | 123 | 101 | 26 | 23 |
| 30-80-0 | 202** | 235** | 98** | 77* |
| 30-80-80 | 183* | 228** | 65* | 61 |
| 60-80-80 | 368** | 284** | 146** | 100** |
| 90-80-80 | 379** | 371** | 196** | 89* |
| 48-48-48 | - | - | - | 71 |
| Average | 229 | 221 | 95 | 64 |

* L.S.D. (5%) = 88#/A. 42#/A.
** L.S.D. (1%) = 118#/A. 57#/A.

On these two mineral soils, phosphate and phosphate-potash tended to increase grass seed yields, but the inclusion of nitrogen in the fertilizer treatment was considerable more effective. Fall fertilization was equally effective as the spring application. These results suggest that more fertilizer nitrogen could be profitably used on these mineral soils than is now commonly used by farmers for grass seed production in the Roseau area.

The Helmer Halvorson field was 4 year old grass stand and was approaching a condition commonly termed "sod-bound". An additional experiment which included heavy nitrogen applications therefore was initiated, to try to determine whether such treatment might at least partially relieve this condition. All treatments were applied late in April of 1960, and the seed yields obtained are shown in Table 3.

Table 3. The effect of mineral and heavy nitrogen treatments made in the spring on the 1960 seed yield of a four year stand of Park Kentucky bluegrass on mineral soil of the Helmer Halvorson Farm at Roseau.

| Fertilizer Applied (lbs/A) | Bluegrass seed Yield in lbs/A | Increase in yield above check |
|---|---|---|
| 0-0-0 | 44 | -- |
| 0-0-80 | 37 | -7 |
| 0-80-0 | 39 | -5 |
| 0-80-80 | 44 | 0 |
| 60-0-0 | 93 | 49 |
| 60-0-80 | 124* | 80* |
| 60-80-0 | 100 | 56 |
| 60-80-80 | 82 | 38 |
| 120-0-0 | 79 | 35 |
| 120-0-80 | 96 | 52 |
| 120-80-0 | 108* | 64* |
| 120-80-80 | 123* | 79* |
| 480-0-0 | 59 | 15 |
| 480-0-80 | 107 | 63 |
| 480-80-0 | 92 | 48 |
| 480-80-80 | 127* | 83* |
| *L.S.D. (5%) | | 64 |
| ** " (1%) | | 85 |

It is obvious that some yield increases resulted from the use of nitrogen combined with phosphate or with phosphate-potash, but even the heaviest nitrogen treatments applied failed to substantially increase the seed yield of the Park Kentucky bluegrass on this field.

Field Experiments with Climax Timothy

Since there is considerable timothy seed grown in the area, it was desirable to determine the effect of fertilizing this crop, and one field was selected on mineral soil and fertilized late in September of 1959. A second field was located in early May of 1960, and both fields were fertilized at this time. The effect of these treatments on the two mineral soils in resultant Climax timothy seed production is shown in Table 5.

Table 5. The effect of different fertilizer treatments on the 1960 yield of Climax timothy seed grown on two mineral soils of Roseau County, Minnesota.

| Fertilizer Treat. (lbs/A) N $P_2O_5$ $K_2O$ | Pounds of grass seed per acre: Clifford Foss - Badger, Fall fertilized | Clifford Foss - Badger, Spring fertilized | Andrew Skaar - Thief River Falls, Spring fertilized |
|---|---|---|---|
| 0-0-0 | 159 | | 225 |
| 0-80-0 | 209 | 144 | 235 |
| 0-80-80 | 176 | 170 | 226 |
| 30-80-0 | 378 | 609** | 568** |
| 30-80-80 | 414 | 596* | 634** |
| 60-80-80 | 621** | 808** | 815** |
| 90-80-80 | 785** | 861** | 892** |
| Average | 431 | 531 | ---- |
| * L.S.D. = (5%) | 341 | | 115 |
| ** L.S.D. = (1%) | 455 | | 159 |

Phosphate and phosphate potash applications tended to produce a slightly increases seed yield, but the inclusion of nitrogen produced substantial increased. On the one field where fall and spring fertilization effect was compared, it appeared to be mainly one of nitrogen availability, with spring applications producing an average of 100 pounds more timothy seed per acre than on the plots receiving the fall fertilization.

## Summary

Although the yield results reported are for one year only, they indicate that:

1. The organic (peat) soils response is mainly to phosphate and to phosphate-potash treatments.
2. The mineral soils are responsive to nitrogen treatments where minerals are adequate. The applications of phosphate or of phosphate-potash (minerals) alone, were much less effective for increasing the yields of either Park Kentucky bluegrass seed or of Climax timothy seed.
3. The relative effectiveness of fall or spring fertilization appears to be associated with nitrogen need and availability in the spring under the cool growing conditions. Where nitrogen was very effective as on the mineral soils, it appeared that the spring applied fertilizer nitrogen was considerably more available to the grasses than were the same treatments made in the previous fall.
4. Top rates of N may be 90# beyond which lodging occurred on the bluegrass. Lodging is not a problem on timothy.

# 1960 Soil Erosion Experimental Results at Rosemount

J. M. MacGregor

Continuous corn was grown for the second year on a 9% slope of Port Byron silt loam, following six years of a corn, oats, alfalfa, alfalfa rotation. Four of the eight plots receive the common seedbed preparation of fall plowing, on the contour and spring discing, whereas the matching four plots have a seedbed preparation of deep surface cultivation on the contour in the fall, and again in the spring before planting. Total rainfall and intensities are recorded from April 1st to November 1st. Losses of soil and water of each rain are measured and corn yields are also studied.

The total rainfall for the seven month period was 21.8" of which 5.8" fell in May. Eight rains of one inch or more occurred during the seven months. Three rains produced runoff water, but there was no measurable loss of soil during this period. The largest and highest intensity rainfall occurred on May 26th, with 1.7" total fall of which 1.5" fell within one two hour period.

The total water loss from the four plowed plots during the three heaviest rains was only 0.65" or 3% of the total seven month rainfall. The cultivated seedbed plots lost a total of 0.34 inches during the same time, representing only 1.5% of the total seven month precipitation.

The average yield of ear corn was 87.6 bushels per acre on the four plots where the seedbed was prepared by plowing, and 74.2 where deep cultivation was used; a difference of 13.4 bushels in favor of the plowing.

During the same months of 1959, there was a total rainfall of 32.5 inches, and 18% of this was lost as runoff water. There was a soil loss of approximately 2 tons per acre, and corn yields averaged 121 bushels per acre. The cultivated soil produced a few bushels more corn per acre, and also had lower losses of both soil and water. It would appear that the results obtained with the two methods of soil preparation vary considerably from year to year with this variation being primarily due to weather conditions during the growing season. In years of ample to excessive precipitation, it is probable that the deep cultivation method of seedbed preparation is more desirable than plowing and discing the seedbed in the saving of both soil and water which frequently results in higher corn yields.

Progress Report 1960
Minnesota Agricultural Experiment Station

Project: 2517RH Soil Structure: Its evaluation with reference to plant growth and development.

Principal Personnel: G. R. Blake, W. P. Martin, J. M. MacGregor, E. P. Adams, J. K. Aase

Major Results:

I. Rosemount, Waukegan silt loam
Compaction studies at this site were terminated this year. Observations on residual effects of surface and subsurface packing last imposed in 1958 were as follows:

1. At low fertilizer rate, yields of corn were slightly higher on plots packed in 1957 and 1958. This was not true at a high fertility rate.

2. A residual packed layer remained from 1957 and 1958 packing below 9 inches and extending to 24 inches depth as measured by bulk densities at 3 inch intervals and by the penetrometer. (See following page)

II. East Grand Forks, Bearden silty clay loam (Cooperative with Am. Cry.Sug.)
Compaction study was also terminated at this site in 1960, residual effects of packing in 1955, 1957 and 1958 being observed in 1960. In addition potatoes were planted on all plots so that crop sequences since 1955 were as follows:

a) Beets, potatoes, wheat, clover-fallow, beets, potatoes
b) Potatoes, wheat, clover-fallow, beets, potatoes, potatoes
c) Wheat, clover-fallow, beets, potatoes, wheat, potatoes
d) Clover-fallow, beets, potatoes, wheat, clover-fallow, potatoes

Results were as follows:

1. Residual effect of 1955, 57 and 58 packing was measured in all crop sequences between 6 and 18 inches in 3 inch intervals by bulk density sampling. (See following page)

2. There was no reduction in yield from residual packing. Potato yields were 292 bu/A after fallow, 291 after beets, 284 after wheat and 246 after potatoes.

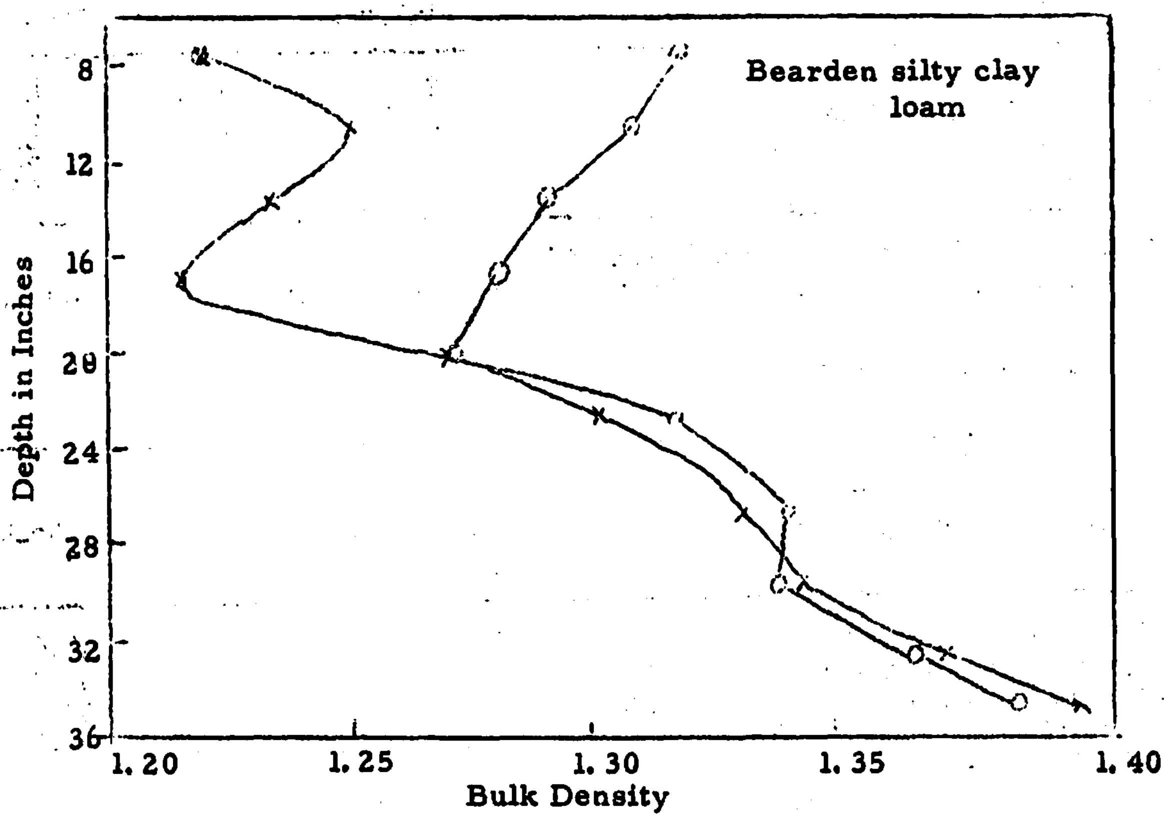
3. Clods over digger, draft on digger, specific gravity of tubers and depth from soil surface to potato tubers were unaffected by residual packing and by preceding crop.

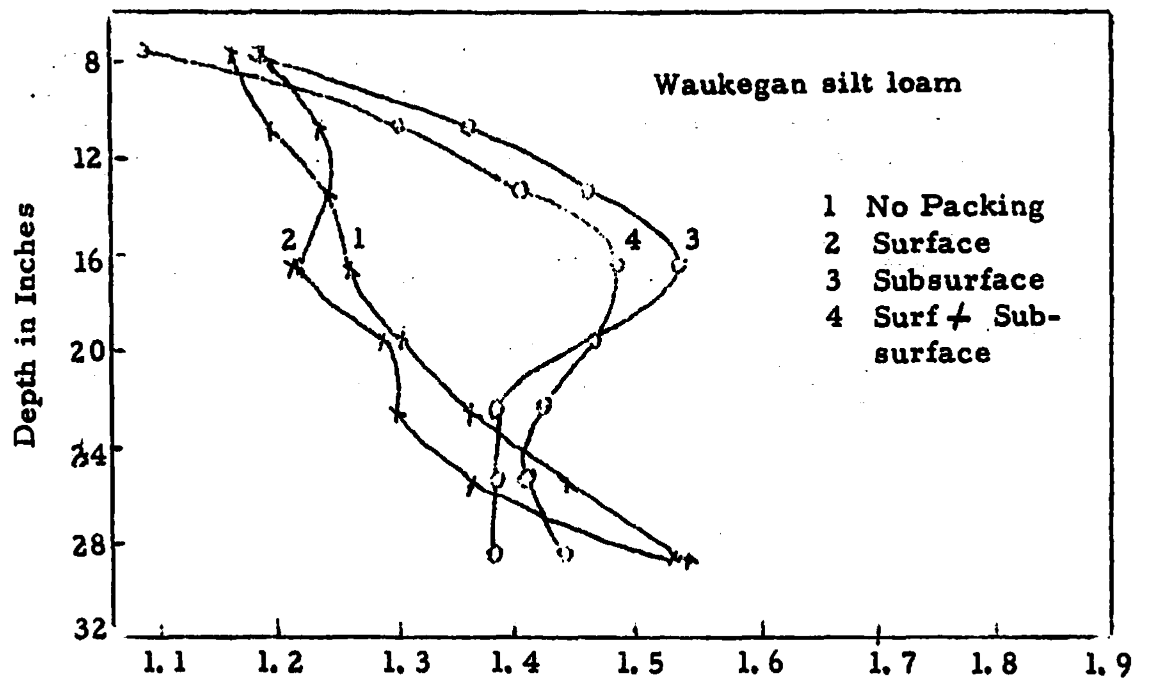
III. Soil structure as related to seedbed preparation and nitrogen level.
Three experiments at branch stations (two on corn, one on potatoes) are being continued comparing seedbed preparation methods of variable intensity. On corn, various nitrogen levels are also imposed to determine their effect on buildup of structure-producing organic constituents.

Extensive soil sampling is planned for the future. Generally, the least tillage has given as good or better crop yields than any greater amount.

-26-

## Residual Effects of Packing in 1960
## Soils Packed in 1958




Bulk Density

Results are as follows:

A. Structure - Nitrogen Study, Crookston. Wheat yields for third crop in each sequence given in table.

| Crop sequence | No Fertilizer | 20-40-20 | 100-40-20 |
|---|---|---|---|
| Wheat - Wheat - Wheat | 28.6 | 42.1 | 48.3 |
| Fallow - Fallow - Wheat | 44.4 | 51.2 | 50.7 |
| Fallow - Fallow - Wheat[1/] | 45.0 | 52.7 | 52.1 |
| Corn - Soybeans - Wheat | 44.0 | 56.1 | 52.2 |

[1/] Straw added at wheat harvest each fallow year.
L.S.D. Crop (.01) 6.2; Fertilizer (.01) 3.5; Fertilize X Crop (.01) 7.0, (.05)6.2

B. Structure - Nitrogen, Morris

| Seedbed Preparation<br>Handling of residues<br>Fall or spring plowed | 0-40-40 | 40-40-40 fall | 40-40-40 | 80-40-40 | 240-40-40 | Average |
|---|---|---|---|---|---|---|
| Minimum - chop - spring | 69.0 | 55.7 | 55.0 | 48.7 | 48.6 | 55.4 |
| Minimum - Not Chop - spring | 53.4 | 43.5 | 61.9 | 52.6 | 55.2 | 53.3 |
| Minimum - Chop - fall | 45.5 | 44.2 | 51.6 | 65.1 | 53.4 | 52.4 |
| Conventional - Chop - fall | 50.5 | 42.6 | 52.0 | 55.7 | 61.2 | 52.0 |
| Chisel plow - Chop - Fall & Spring | 48.1 | 55.2 | 54.8 | 46.3 | 43.9 | 49.6 |
| Averages | 53.3 | 48.2 | 55.0 | 53.7 | 52.5 | |

Differences between treatments not significant. Residual effects of manure, rock and superphosphate from earlier experiment on this land not significant.

C. Structure - Nitrogen Study, Waseca
Experiment was last for 1960. Will be continued on same plots in 1961.

D. Potato Tillage - Cultivation Study, Grand Forks
(Cooperative with Horticulture and A.R.S. at East Grand Forks). Three year summary underway.

IV. New Experiment, Lamberton. Nicollet silty clay loam (initiated May, 1960) Since earlier packing experiments have shown that packed layers persist below the plow layer, an experiment was designed to study persistence of subsoil packed layers. Variables include:

a) Packing 9-24 inches vs. no packing
b) Crop: Corn vs. alfalfa
c) Moisture during winter, i. e., late fall irrigation vs. none

Packing was done with 4 passes of a tractor mounted packing wheel weighing 5600 lbs. giving pressures at 9" of the order of 100 to 200 lbs. inch$^{-2}$. A bulk density profile of packed and non-packed areas is shown in the accompanying graph.

Packing in 1960 reduced corn yields from 110 to 103 bu./A., corn forage 10%, and oat-alfalfa forage 29%.

Irrigation was applied to some plots in November, 1960. Persistence of the packed layer will be observed in subsequent years.

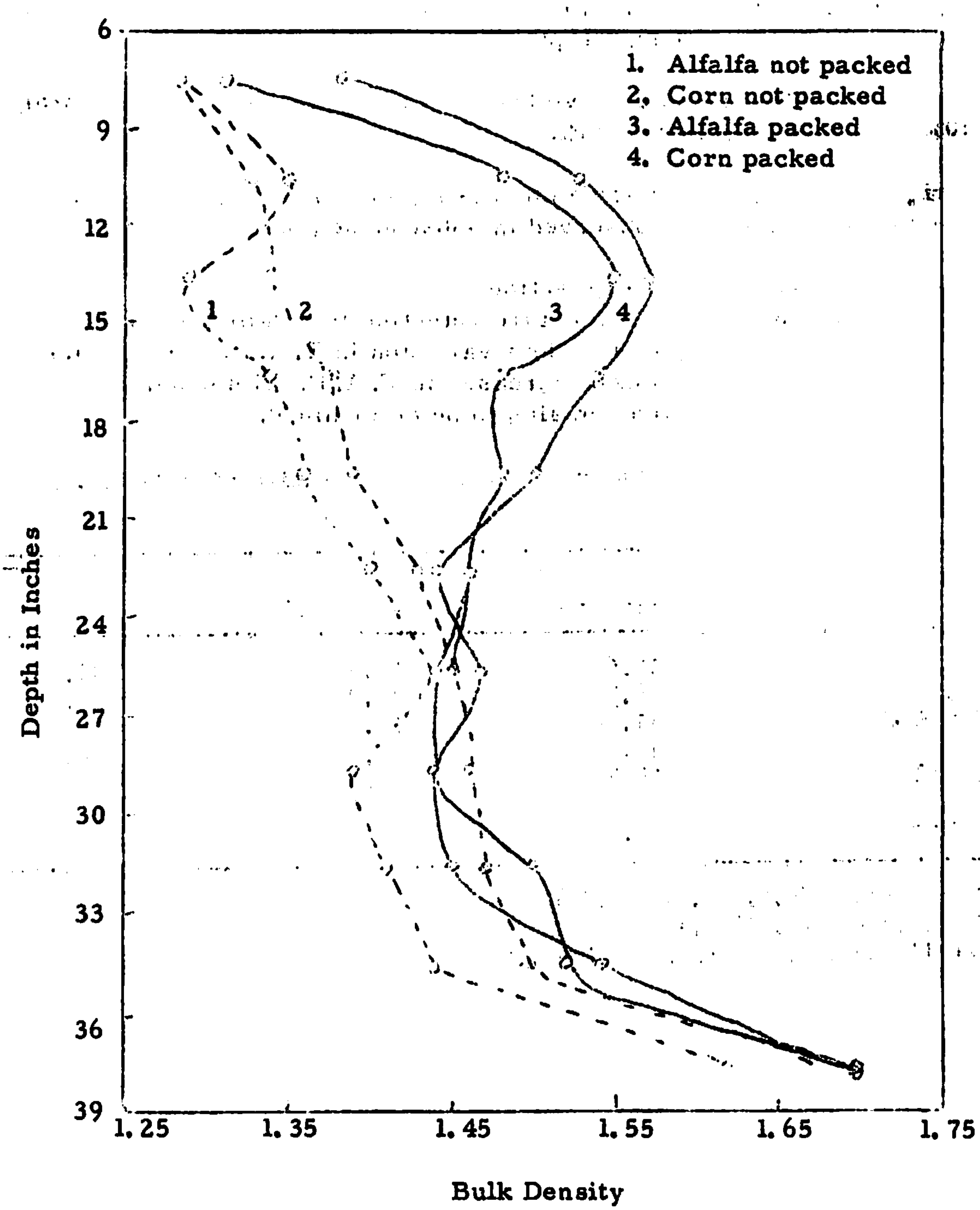
V. Packing and Soil Moisture Retention.
Studies are in progress on moisture retention in relation to compression of soils. As expected, tremendous variation in T. A. P. occurs with bulk density. Whether small increases in F. A. P. with density are real and can be duplicated remains to be determined.

VI. Green Manure Evaluation Study, Crookston (Cooperative with Schmid, Agronomy)

| Green Manure Crop | Wheat Yield (Bu./A.) No fertilizer | Wheat Yield (Bu./A.) 0-40-0 annual | Averages |
|---|---|---|---|
| Check | 10.6 | 14.4 | 12.5 |
| Orchard grass | 8.3 | 10.7 | 9.5 |
| Madrid Sweet Clover | 11.8 | 24.0 | 17.9 |
| Vetch | 12.4 | 19.5 | 16.0 |
| Vernal Alfalfa | 14.4 | 23.0 | 18.7 |
| Averages | 11.5 | 18.3 | |

L.S.D. Green Manure (0.01) 8.9; (0.05) 6.3
Fertilizer (0.01) 6.1
Fertilizer X Green Manure (0.10) 8.2

Subsoil Regeneration Study
Lamberton
Bulk Density
Data book 17:180-200
June 28, 1960



Soil Test Correlation Project on Corn

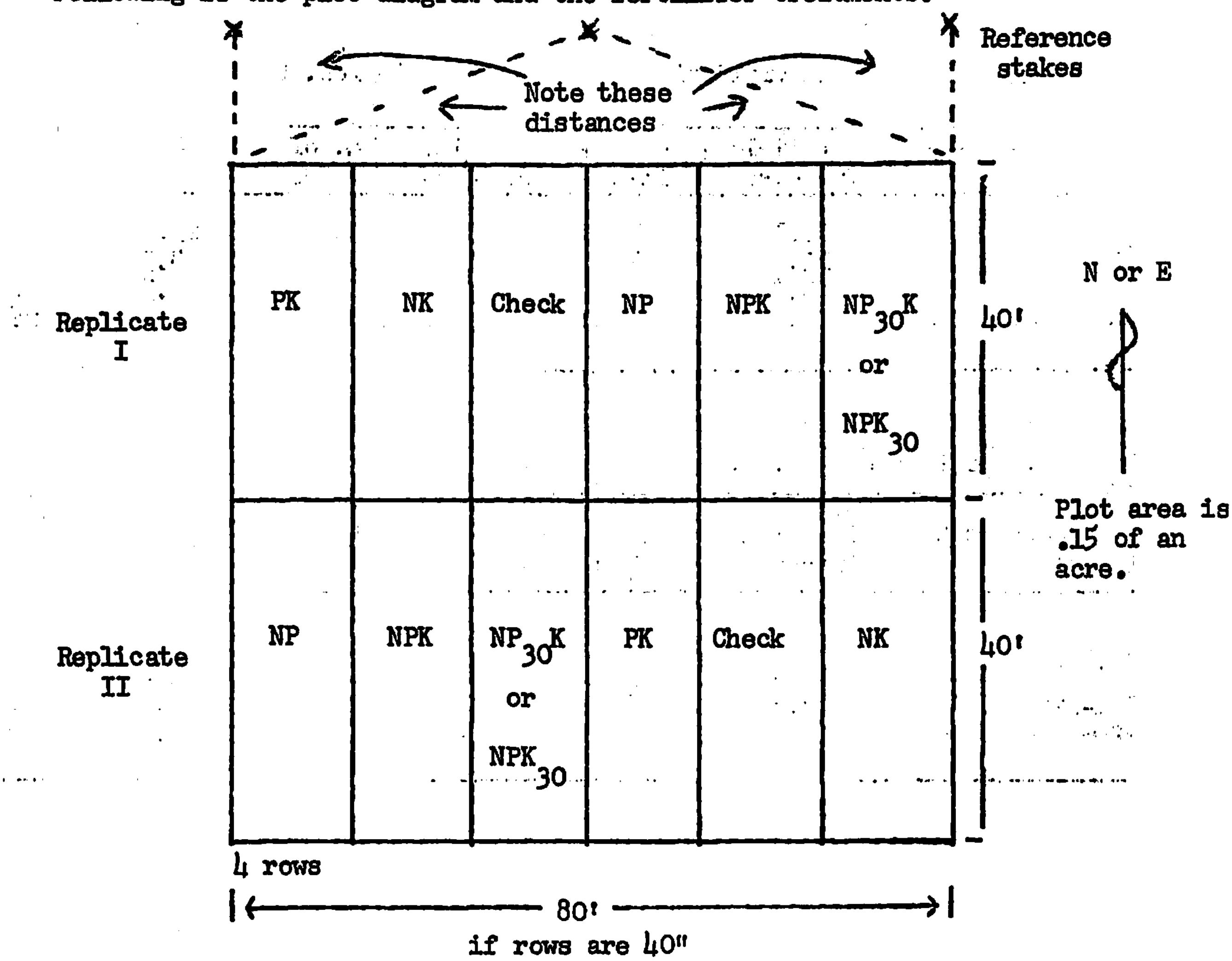
L. D. Hanson, John Grava,
C. J. Overdahl, and Merle Halverson

The 1960 soil test correlation project was carried out, as in 1959, cooperatively between the soil testing laboratory and the extension specialists. Materials for the field plots were assembled at the department and distributed to 50 cooperating counties. A total of 110 field plot kits were distributed of which 83 plots were harvested and reported.

Atrazine sufficient for a 3 pound per acre broadcast rate was applied on the plots for weed control. Heptachlor was also provided for corn root worm control.

All of the fertilizer was broadcast and incorporated in the surface soil except for an 8-32-0 starter applied beside the row on treatments receiving phosphate.

Following is the plot diagram and the fertilizer treatments.



Rates of plant nutrients used, pounds per acre.
(Row fertilizer used only on center two rows of plot).

| | Nitrogen | | Phosphate | | Potash | |
|---|---|---|---|---|---|---|
| | Broadcast | Row | Broadcast | Row | Broadcast | Row |
| Check | 0 | 0 | 0 | 0 | 0 | 0 |
| PK | 0 | 8 | 70 | 32 | 100 | 0 |
| NP | 100 | 8 | 70 | 32 | 0 | 0 |
| NK | 100 | 0 | 0 | 0 | 100 | |
| NPK | 100 | 8 | 70 | 32 | 100 | 0 |
| *$NP_{30}K$ | 100 | 8 | 0 | 32 | 100 | |
| *$NPK_{30}$ | 100 | 8 | 70 | 32 | 0 | 30 |

* One of these two treatments included in each field.

Some preliminary analysis of the data is given below.

<u>Phosphate response with Bray's #1 P test</u>

A summary of 63 fields from which rainfall data was available is given where the fields are divided into the two categories of above or below average rainfall.

Table 1. Difference in yield with 100 lbs. $P_2O_5$, 70 lbs. broadcast and 30 lbs. in row.

| Range of P Test | Ave. Yield Increase | No. of Fields | Ave. Yield Decrease | No. of Fields | Ave. Yield Difference | No. of Fields |
|---|---|---|---|---|---|---|
| 0-5 | 25.1 | 8 | ---- | -- | 25.1 | 8 |
| 6-10 | 11.6 | 17 | 10.3 | 3 | 8.3 | 20 |
| 11-20 | 8.3 | 18 | 6.8 | 11 | 2.5 | 28 |
| 20+ | 7.1 | 18 | 9.3 | 7 | 2.4 | 25 |

Table 2. Difference in yield with broadcast potash at rate of 100 lbs. $K_2O$/A.

| Exchangeable K lbs./A | Ave. Yield Increase | No. of Fields | Ave. Yield Decrease | No. of Fields | Ave. Yield Difference | No. of Fields |
|---|---|---|---|---|---|---|
| 0-90 | 19.2 | 10 | 4.0 | 1 | 17.1 | 11 |
| 91-150 | 6.9 | 13 | 5.0 | 7 | 2.7 | 20 |
| 151-220 | 6.5 | 19 | 5.4 | 10 | 2.4 | 29 |
| 220+ | 5.5 | 11 | 6.2 | 9 | 2.1 | 20 |