Table 4. Residual or carry-over effect of fertilizers applied for legume seed. All the fertilizer applied for the 1st year crop. Percentage increases over the unfertilized land.

Field No.	Year	Crop	0-20-0 500 lbs	0-20-0 1000 lbs	0-20-20 500 lbs	0-20-20 1000 lbs	0-20-40 500 lbs	0-20-40 1000 lbs
1	1st	Red Clover Seed	0.0	0.0	9.0	24.0	10.0	10.0
	2nd	Corn	6.4	14.9	59.5	58.0	63.1	68.4
2	1st	Red Clover Seed	4.6	23.3	---	---	28.7	21.7
	2nd	Silage	15.0	15.0	30.0	30.0	15.0	15.0
3	1st	Red Clover Seed	33.7	---	60.8	---	27.1	---
	2nd	Flax	37.5	---	50.0	---	43.7	---
4	1st	Red Clover Seed*	---	---	---	---	---	---
	2nd	Oats and Wheat	44.0	---	38.0	---	30.0	---
5	1st	Red Clover Seed	73.0	68.0	68.0	64.6	71.0	61.0
	2nd	Red Clover Seed	62.2	90.0	86.1	79.4	100.0	85.4
6	1st	Alsike Clover Seed	236.8	273.0	251.0	348.0	261.1	352.6
	2nd	Barley	60.9	80.6	84.0	94.0	88.7	89.7
	3rd	Barley	38.0	40.1	35.0	35.0	18.7	35.0
	4th	Fallow	---	---	---	---	---	---
	5th	Barley*	---	---	---	---	---	---
	6th	Alsike Seed	84.1	127.6	82.1	162.7	91.7	142.7

*Not Sampled For Yield

In the experiment the equivalent of 167 pounds per acre of 46 per cent super-phosphate was broadcast for corn in a corn, oats, wheat, clover-timothy hay rotation.

The experiment ran for 20 years. This meant that the plots receiving phosphate were fertilized five times at the 167 pound rate and in the 20 year period received a total 835 pounds of super-phosphate per acre.

Following the 20 year period no super-phosohate was applied and the land was cropped to alfalfa, corn, and grain. After a lapse of 10 years, the plots were divided into three parts and a three year rotation of corn, wheat, and clover-timothy hay was re-established, each crop being grown each year. Nine crops were grown. The percentage increases in yields are shown in Table 5.

Using present day prices the annual increase from any one of the crops would, after a lapse of ten years, still have paid for the cost of one of the original 167 pound fertilizer applications.

The data presented in the tables above clearly show that there is a residual or carry-over effect on crops which follow the crop for which the fertilizer was applied.

Furthermore, they show that higher rates of application 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.

These consistent yield return from the use of fertilizer and the residual increases in yields carry through from 2 to 6 years or possibly more, after fertilizer application.

The question now being asked by farmers is what can this practice mean to me on my farm in economic returns?

These residual fertilizer responses indicate that such a fertility program will apply to any type of farming regardless of the crops grown and in the different agricultural areas of Minnesota.

In all the residual yield responses reported above on the 6 fields studied, the dollar ratio return for fertilizer over fertilizer cost ranged from about $3.00 for each $1.00 spent.

For the year of application up to over $9.00 return for a 6 year residual response. To illustrate what these ratios of dollar returns over fertilizer cost would mean as applied to a certain cropping system or field, field No. 6 above is an excellent example.

On the basis of the 0-20-20 fertilizer which gave the greatest consistent increase in crop yields for the 6 years and applied at two ratio of 500 and 1000 pounds per acre and costing $17.00 and $35.00 per acre respectively. The acre return over fertilizer cost would be $164.10 for the 500 pound ratio and $211.50 for the 1000 pound rate. Crop prices were figured on the current farm price.

Table 5. Residual effect of super-phosphate on the nine year average yield of corn, wheat and hay. (No fertilizer applied in the ten years preceding or during the nine years of cropping)*.

Crop	Yield on Unfertilized	Increase From Super-phosphate	Percentage Increase
Corn	47.5 bu.	9.5 bu.	20.0
Wheat	18.3 bu.	4.7 bu.	25.7
Hay	1.38 Tons	0.38 Tons	27.5

*Minnesota Agricultural Experiment Station Bulletin No. 448

If a typical 50 acre Minnesota field was cropped in the same way as field No. 6, 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.

Furthermore, the difference in the return over fertilizer cost between the two rates of application per acre 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 reported in this study 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 different sequences than field 6, 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.

*Paul Burson, Professor of Soils, University of Minnesota. Dr. C. O. Rost, Consulting Chemist, Minnesota Farm Bureau Service Co., formerly Chief of Department of Soils, University of Minnesota.

Know Your Soils for Legume Seed Production

P.M. Burson, H.F. Arneman, F.G. Holdaway, and H.W. Kramer

Successful legume seed production depends on soil type conditions. The soil properties which determine the soil type include soil reaction (pH), texture, structure and surface, and internal drainage.

One soil may produce a good seed crop for one legume but not for another. Soils must therefore be selected for the kind of legume seed to be produced. Soil and climatic conditions determine where legume seed can be most successfully and economically grown.

Every farmer must consider legume seed production on the basis of which legume seed crop best fits the soil-type conditions on his own farm. Because different soil types occur between farms, not all farmers in a community can grow and produce the same legume seeds.

Production of legume seed is specialty farming. Therefore, successful seed production requires a knowledge of soil-type conditions, and good, timely soil management and production practices.

Selecting the Right Soils

All legume seed crops grow best on neutral soils--soils that have a neutral soil reaction or a pH of about 7.0 ("pH is a test of the sourness [acidity] or sweetness [alkalinity] of the soil.) Some legumes; however, are more sensitive to pH changes than others. Alfalfa and sweet clover, for example, are very sensitive to acid soils, especially those having a pH of 6.0 or below.

Legume seed crops may be classified on the basis of their lime requirement. Alfalfa and sweet clover are in the high lime requirement group, medium red clover in the medium group, and alsike clover in the low group. However, if the soils are properly limed the medium and low groups will give a big response to lime treatments. All of these legume seed crops will make vigorous growth on soils of high-lime reaction having a pH range of 7.2 to as high as 8.0. However, alfalfa is very sensitive to pH ranges of 7.5 and higher.

Along with soil reaction, proper fertilization based on soil tests is essential for successful seed production. Important as soil reaction and fertilization are, the careful selection of the proper soil-type conditions--as determined by texture, structure (tilth), and drainage--are the basic factors for the successful production of legume seed crops.

A legume seed production program can be established and set up on either a community or individual farm basis. Use county soil survey reports or the individual Soil Conservation District soil surveys to select the soil type best suited for growing the various legume seed crops. County soil surveys can determine the general soil type groups for different legume crops in certain areas of a county, while individual farm soil surveys can determine what legume seed crop is most adaptable and should be grown on a certain individual farm.

The University of Minnesota--working with committees and cooperating farmers of Roseau, Lake of the Woods, East Polk, West Polk, and Clearwater counties--has carried on extensive research in legume seed production. Researchers studied and grouped all the experimental fields on the basis of their soil type characteristics as related to their adaptability for growing various legume seed crops.

General Classification

The following is a general classification of soil type characteristics according to the adaptability of the various legume seed crop to be produced.

Suitable for all Legume Crops--

Soils of medium texture, moderately well to well drained including: Nebish loam, Rockwood sandy loam, McIntosh silt loam, Aastad loam, Baudette silt loam, Beltrami loam, and Barnes silt loam.

Suitable for Alfalfa--

Sandy, light-textured soils subject to rapid internal drainage. These are two droughty for medium red and alsike clover. Included in this group are Grygla loamy fine sand, Hiwood loamy fine sand, Menahga loamy sand, Gudrid loamy sand, and Ulen loamy sand.

Suitable for Medium Red and Alsike Clovers--

Soils ranging in texture from very fine sandy loam to heavy clays with poor to moderate drainage. These are too wet for alfalfa seed production. These include Shooks clay loam, Bearden silty clay loam, Chilgren loam, Kittson clay loam, and Peat-shallow phase (with special treatments and practices).

Suitable for Alsike clover--

These soils have all textural ranges from wet sands to heavy clays. All are too wet for alfalfa, questionable for medium red clover, but are more suitable for alsike clover. They include: Tanberg fine sandy loam, Fargo clay, Taylor silt loam, Rocksbury clay loam, and Peat-shallow phase--(with special treatments and practices).

Not suitable for legume seed production—

These soils have gravelly layers or gravelly subsoils which retrict growth and developments and include: Marquette sandy loam, Sioux loamy sand, Foxhome sandy loam, and Menahga sand.

The research reported in this story was carried on in Northern Minnesota. There are many other areas of Minnesota that can grow legume seed successfully. Legume seed production, however, has been largely concentrated in the northern part of the state so our research has been conducted in that area.

Plan Your Legume Seed Production Program

1. Plan a community legume seed production program based on the major soil type characteristics of the community.
2. Use the County Soil Survey reports and the Soil Conservation District Soil survey maps to determine the soil type conditions in selecting the suitable legume seed crop for the community.
3. For the individual farm, plant the legume adapted to the major soil conditions on the farm.
4. Fertilize and apply lime according to the soil test.
5. Provide proper pollination on a community and field basis.
6. Control harmful insects.
7. Use adapted and recommended seed varieties.

The Effect of Rate, Time and Kind of Fertilizer on Yield of Alfalfa at Rosemount

March, 1960

J. M. MacGregor

Introduction

There are many acres of productive land in southeastern Minnesota which are too sloping for cultivation without severe losses of soil and water. Much of this land could be utilized for the permanent production of high quality hay, provided a good stand could be maintained for several years. Minnesota farmers now utilize about two million acres for alfalfa production. This acreage of high quality hay could be doubled by better soil fertility management of our more steeply sloping soil areas. In addition, the improved soil fertility practices over our entire potential alfalfa growing area might result in trebling Minnesota alfalfa production--and improve quality as well.

In the autumn of 1949, an experiment was commenced on the Soils Unit of the Rosemount Experiment Station to determine the effect of commercially available fertilizers on yield and maintenance of alfalfa stand.

Experimental

The site selected was a south-southwest facing slope varying from 5 to 12 per cent. The Port Byron silt loam of the experimental area developed from wind laid silty material of varying depth and is underlain by glacial materials at depths of three to five feet. Since the soil was quite acid, (pH 5.2) it was limed at the rate of six tons per acre in the fall of 1949 which resulted in a pH rise to 7.5 when tested late in 1952. Thirty treatments were replicated eight times in plots eighteen feet long and nine feet in width. The initial fertilizer treatments were made in October of 1949, and early June of 1950, with inoculated Ranger alfalfa being seeded on June 16, 1950. Three cuttings per year have been removed annually commencing in 1951.

Within a few years, it was realized that the southeastern replication (8) was producing hay yields considerably above those of the other seven replicates, and the results from this area were then excluded from the reported average.

Results

The following table shows the different fertilizer treatments included in the experiment, the first year alfalfa yields obtained in 1951, those obtained in the eighth year (1958), the total eight year hay yield, as well as the yield increases obtained on the fertilized plots,all arranged or ranked in order of decreasing yields for the eight year period.

TOTAL YIELDS - ROSEMOUNT ALFALFA - 1951 - 1958
AVERAGE OF SEVEN REPLICATIONS - THREE CUTTINGS

8 year yield rank	Treatment	(Tons/Acre @ 15% moisture) 1951	1958	Eight year total Yield	Increase
30	CHECK	3.10	2.46	25.07	------
1	300# 0-20-20 SBS + 200# AS	3.96	4.23	37.54	12.47
2	300# 0-20-20 FBS + 200# AF	3.89	4.26	36.64	11.57
3	300# 5-20-20 SBS + 200# AS	4.03	3.99	36.48	11.41
4	1000# 0-20-20 SBS + 200# AS	4.42	3.84	36.15	11.08
5	1000# 0-20-0 SBS + 200# 5-20-20 AS	4.34	3.42	35.93	10.86
6	1000# 0-20-0 SBS + 200# 0-20-20 AS	4.14	3.87	35.49	10.42
7	200# 0-20-20 AS	3.25	4.18	35.44	10.37
8	1000# 0-20-0 SBS + 100# KCl @ 1st cutting	4.26	4.39	35.27	10.20
9	200# 0-20-20 AF	3.60	3.81	33.89	8.82
10	300# 0-20-20 FBS + 200# BF	3.51	4.28	33.55	8.48
11	1000# 0-20-20 SBS + 200# BS	4.30	2.93	32.93	7.86
12	300# 0-20-20 SBS + 200# BS	3.79	3.24	32.37	7.20
13	1000# 0-20-0 SBS + 200# 0-20-20 BS	3.95	3.10	30.70	5.63
14	300# 0-20-0 SBS + 200# AS	3.77	3.33	30.69	5.62
15	200# 0-20-0 AF	3.84	2.66	29.27	4.20
16	1000# 0-20-20 SBS	4.09	2.88	29.25	4.18
17	200# 0-20-0 AS	3.64	2.76	29.18	4.11
18	300# 0-20-20 SBS	3.90	3.03	29.07	4.00
19	1000# 0-20-0 SBS + 200# AS	4.04	2.40	28.95	3.88
20	300# 0-20-0 FBS + 200# BF	3.68	2.87	28.62	3.55
21	300# 0-20-20 + TRACE ELEMENTS SBS	3.88	2.98	28.18	3.11
22	300# 0-20-0 FBS + 200# AF	3.77	2.24	28.17	3.10
23	300# 0-20-0 SBS + 200# BS	3.64	2.43	27.66	2.59
24	300# 5-20-20 SBS + 20# N AS	3.75	2.89	27.28	2.21
25	300# 0-20-0 FBS	3.61	3.03	26.67	1.60
26	300# 0-20-20 + 20# B SBS	3.84	2.51	26.49	1.42
27	1000# 0-20-0 SBS	4.01	2.16	26.02	0.95
28	300# 0-20-20 FBS	3.78	2.16	25.33	0.26
29	300# 5-20-20 SBS	3.82	2.39	25.29	0.22
31	300# 0-20-0 SBS	3.59	2.60	24.71	-0.36

SBS - Spring before seeding
FBS - Fall before seeding
AS - Annual spring
BS - Biennial spring
AF - Annual fall
BF - Biennial fall
TRACE ELEMENTS - $CuSO_4$ 25#/A; $ZnSO_4$ 25#/A; $MnSO_4$ 25#/A; $FeSO_4$ 25#/A; B 20#/A

Acknowledgement

This experiment was designed and initiated by Dr. C. O. Rost. The original work was carried on by Dr. W. W. Nelson until 1954 and later by J. R. Brownell. The project was originally financed by the Midwest Soil Improvement Committee.

Conclusions

Some of the better fertilizer treatments have maintained alfalfa stands very well over the eight year period, whereas others have been badly invaded by grasses (largely Kentucky bluegrass) and weed growth, and alfalfa stands are now comparatively 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 1959 growing season, the third highest yielding treatment (300 pounds of 5-20-20 spring before seeding and 200 pounds topdressed each spring) produced 12.66 tons alfalfa per acre more than the unfertilized check yields. This nitrogen application over the nine years cost approximately eleven dollars per acre and resulted in somewhat lower alfalfa production than fertilization with the same amounts of phosphorus and potassium with no nitrogen present (13.39 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 (1000 pounds of 0-20-20) would cost a total of $30 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 3.5 tons more hay per acre over the 9 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. 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 much the same increase in alfalfa yields as 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. Good 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.

Studies on Iron Chlorosis

by R. G. Burau and J. M. MacGregor

More attention has recently been focused upon the chlorosis or yellowing of leaves of certain field crops and ornamental plants growing on the high lime soils in western Minnesota. The general symptom of an affected plant is a yellowing of the intra-veinal leaf tissue, while the veins retain a dark green color. Leaves may become paper-white in severely affected plants, and growth is restricted. The reason that affected leaves appear yellow is that chlorophyll, the green pigment of normal leaves, is present only to a limited extent in chlorotic leaves. Thus, the cause of a chlorosis must be related to factors affecting the production and/or preservation of chlorophyll in plant tissues.

Although much of the work on this problem has been confined to investigations with soybeans and flax, similar chloroses have been observed in gladioli, roses, spiraea, flowering crab, strawberries, apple, plum, maple, elm, box elder, larch and birch.

Preliminary work definitely established that the chlorosis in soybeans was a plant nutrient deficiency symptom known as iron chlorosis. It is known that this chlorosis may develop if high pH, excessive amounts of phosphate, bicarbonate, copper, manganese, and zinc reduce the availability of iron in the soil. In any given soil region, only one or a few of these factors may be responsible. Therefore, one line of investigation has been directed toward establishing the causative soil factors with the hope that such information will lead to practical preventive cultural practices.

Results of previous greenhouse experiments with a limited number of soils indicated that high available phosphorus and manganese were possible causative factors. A study of the mineral composition of chlorotic and of green soybean plants in the field was initiated in the spring of 1959. Complete above-ground parts of soybean plants as well as upper, mature soybean leaves were collected, washed to remove dust contamination, and then analyzed for calcium, phosphorus, manganese, and iron. Since the validity of conclusions drawn from greenhouse experiments must be tested in a field situation, the objective of this experiment was to determine if manganese and/or phosphate were possible causative factors. The results of these analyses are shown in Table 1.

Table 1. Mineral concentrations in immature chlorotic (CH) and healthy (HE) soybeans (June, 1959)

Field Number	County	Soybean Variety	% Calcium CH Leaf	% Calcium HE Leaf	% Calcium CH Plant	% Calcium HE Plant	ppm* Iron CH Leaf	ppm* Iron HE Leaf	ppm* Iron CH Plant	ppm* Iron HE Plant	ppm Manganese CH Leaf	ppm Manganese HE Leaf	ppm Manganese CH Plant	ppm Manganese HE Plant	ppt** Phosphorus CH Leaf	ppt** Phosphorus HE Leaf	ppt** Phosphorus CH Plant	ppt** Phosphorus HE Plant
1	Polk	------	1.20	1.65	2.31	2.29	102	102	116	122	118	73	129	76	4.16	2.15	4.46	2.36
2	Norman 1	Comet	1.11	1.64	1.56	1.58	160	195	313	278	185	71	186	69	5.56	3.17	5.98	3.62
3	Norman 2	Flambeau	1.52	1.98	2.43	2.07	79	100	134	122	354	108	332	84	6.50	3.57	8.88	3.78
4	Clay 1	------	1.18	1.16	1.63	1.73	114	130	110	248	128	124	68	117	4.93	1.88	5.37	2.10
5	Clay 2	Flambeau	0.99	1.68	1.36	1.81	371	276	435	392	83	95	96	103	5.88	3.60	5.43	4.07
6	Clay 3	Norchief	1.60	1.66	2.55	2.50	229	183	307	296	187	206	282	153	10.08	7.62	7.69	7.01
7	Wilkin	------	1.13	1.58	1.41	1.36	280	236	280	232	255	215	253	160	7.42	4.68	6.72	4.94
8	Pope 1	Comet	1.91	2.57	2.38	2.46	250	299	441	260	339	244	308	172	5.49	2.71	5.07	3.07
9	Pope 2	Ottawa Mandarin	1.55	1.59	1.63	1.11	97	97	299	81	64	86	158	129	2.64	2.57	5.91	5.75
10	Swift 1	Chippewa	1.46	1.68	1.78	1.89	219	284	370	183	222	198	191	115	5.20	2.42	4.62	2.52
11	Swift 2	------	1.08	1.85	1.77	2.57	75	116	107	100	99	54	92	29	5.21	3.46	5.91	3.75
12	Kani-yohi	Chippewa	0.75	0.88	1.92	1.86	94	165	104	96	59	41	41	38	6.74	4.74	6.34	4.01
13	Renville	-------	1.29	1.61	2.52	2.65	116	102	297	213	102	104	165	88	5.34	3.93	5.56	4.46
14	Sibley	Ottawa Mandarin	1.18	2.30	2.52	2.50	121	134	218	154	67	48	96	50	3.77	3.88	6.56	4.97

* Parts per million
** Parts per thousand

Although the chlorosis is caused by an iron deficiency, iron concentrations in chlorotic leaves are frequently higher than in non-chlorotic leaves. This has been observed by other workers, who suggest that some of the iron measured by a total chemical analysis is present in the plant tissues in an inactive form. Manganese concentrations were generally higher in chlorotic tissues, but the concentrations are probably too low to account for the chlorosis. Some investigators characterize the manganese status of plant tissues by examining the ratio of iron to manganese. On this basis, only in samples from Field 3 is there a clear indication of manganese toxicity since manganese concentrations are high with respect to iron in the chlorotic samples. This data indicates that manganese is probably not a general cause of the chlorosis.

The only element measured which shows a consistent relationship to chlorosis is phosphorus. In general, chlorotic tissues have greater concentrations of phosphorus than the non-chlorotic. On Fields 9 and 14 phosphorus in chlorotic leaves is approximately the same as in non-chlorotic leaves, but the general relationship still holds in the analyses of the whole plant. Very high concentrations of phosphorus in samples from Field 6 may have been related to the severe hail damage which these plants received approximately one week before sampling. It is apparent from these results that phosphorus is the most likely causative agent for the chlorosis. Many of the fields which contained chlorotic soybeans had histories of relatively heavy phosphate fertilization. It is also true that even in these fields only a fraction of the whole field was chlorotic. On the basis of these results and observations, insufficient evidence is present to warrant a general recommendation of decreased phosphate fertilization for soybeans grown on these problem soils.

The experimental soybean plants were harvested in the fall to obtain an estimate of the effect of chlorosis on final yield. The results (Table 2) show that chlorosis significantly decreased yield on seven of the nine fields harvested. Frequently chlorosis which is present early in the season apparently disappears later. Since this situation prevailed in all fields except Field 6, the presence of chlorosis for only part of the growing season still results in decreased soybean yields. Soybeans in Field 6 were damaged by hail and remained chlorotic all summer, which contributed to the drastic yield reduction.

Table 2. Yield of initially chlorotic and of non-chlorotic soybeans (1959)

Field Number	County	Soybean yield (Bu./A) Chlorotic	Non-chlorotic	
1	Polk	15	14	N.S.
2	Norman 1	7	18	***
5	Clay 2	11	11	N.S.
6	Clay 3	2	20	***
7	Wilkin	22	32	***
8	Pope 1	13	20	**
10	Swift 1	18	24	**
11	Swift 2	5	10	*
14	Sibley	22	31	***
	Average	13	20	***

N.S. = Not significant
* = Significantly different at the 10% level
** = Significantly different at the 5% level
*** = Significantly different at the 1% level

Field 1 was located in Polk County where soybeans account for only a small fraction of the total crop acreage, presumably because of the shorter growing season and lower soil temperatures in the spring. Plots in Field 5 were located on a gravelly soil which was probably drouthy with respect to plant growth. Thus, the adverse plant growth conditions present in Fields 1 and 5 probably account for both the low yields and nonsignificant effect of chlorosis on yield.

Another line of investigation was devoted to studying the effectiveness of certain iron compounds in reducing chlorosis. In cooperation with Agricultural Extension Agents in Polk County, field trials with chelated iron compounds were established at three locations. Previous work at locations south of Polk County had shown these compounds to be highly effective in reducing chlorosis and in many cases increased yields of soybeans resulted. The results of trials in Polk County are presented in Table 3.

Table 3. Yield of chlorotic soybeans in Polk County treated with various iron chelates.

Material	Rate of Application (lbs. Fe/A)	George Campbell	George Hagen and Son	Johnson Brothers
Check	----	22.8	21.9	21.1
Sequestrene 330	5	23.8	20.2	24.5
Versenol F	5	22.8	18.5	23.3
Sequestrene 138	5	25.2	23.5	26.1
Sequestrene 138	0.5	25.8	22.8	27.0
Sequestrene 138	0.05	22.6	20.7	22.1

Increased growth and reduction of chlorosis were reported after treatment application; however, yield increases were small. Largest yield increases were obtained with the 5.0 and 0.5 pounds of iron per acre applications of Sequestrene 138 at the Johnson Brothers location. This chelate was found to be superior to the other chelates in previous trials, but the cost of effective application rates of all these materials is excessive for crops such as soybeans and flax. Treatment of chlorotic ornamental plants is more practical because of their greater aesthetic value and because of the smaller areas involved. Currently investigations are being conducted to increase the efficiency of iron chelates for chlorosis-susceptible annual plants by special techniques of application.

In view of the high cost of iron chelates, development of less expensive iron compounds also capable of supplying iron to plants would be desirable. It is known that certain constituents of soil organic matter known as humic acids are capable of solubilizing or chelating iron. It was suspected that iron humates might serve as sources of iron for plants growing on calcareous soils.

In cooperation with the Department of Chemical Engineering at the University of Minnesota, humic acids were extracted from various Minnesota peat deposits, since peat is a relatively rich source of these compounds. Iron humates prepared from these extracts were tested for their ability to supply iron to soybeans growing in an alkaline soil. To identify the iron in the plant which was taken up from the iron humates, a small portion of the total was supplied as a radioactive isotope of iron. Iron chloride and iron chelate treatments were included to estimate the relative efficiency of the iron humates. Iron chloride is known to be a poor source of iron while iron chelates are highly available sources of iron for plants in these soils. It was found experimentally that iron humates were no more efficient than iron chloride. It was therefore concluded that the iron humates were not promising soil amendments, although foliar application of these materials might be more effective.

The Effect of Molybdenum Fertilization of Five Soil Types on Alfalfa

J. M. MacGregor and Roger Hanson

Since the addition of molybdenum to a few soils in the United States has resulted in increased crop production, it is desirable that several important agricultural soils of Minnesota be investigated as to possible fertility effect from the addition of molybdenum. In general, research has shown that molybdenum has been most effective when applied to acid soils and appears to be related to soils where available calcium is generally somewhat limited. Relatively few of the agriculturally important Minnesota soils are strongly acid in reaction, but the value of molybdenum fertilization should be investigated.

Objectives of the Experiment:

1. To determine if molybdenum applications increased alfalfa yields on five well fertilized Minnesota soils.

2. To establish if molybdenum is needed to increase the protein concentrations in the alfalfa grown on these five Minnesota soils.

3. To observe the effect of liming an acid soil prior to applying molybdenum.

Experimental Methods:

Fifty four two gallon glazed crocks were filled with the surface soil of five types in triplicate. The most acid of these soils (Anoka loamy fine sand, having a pH of 5.0) was arranged in two series - one with no lime treatment and the other with lime applied at the rate of 3 tons per acre. Each pot was fertilized with 0-20-20 at the rate of 500 pounds per acre on the basis of surface area of the crocks.

The source of molybdenum used was the commercial preparation with the trade name "Moly-Gro", prepared by American Metal Climax Incorporated, with a minimum molybdenum content of 38%. This was supplied by Midland Cooperatives, Inc.

Three rates of application were used on the five soils:

1. No molybdenum

2. At the recommended rate of approximately 0.1 pound of Mo per acre (4 oz. Moly-Gro per acre).

3. Twice the recommended rate--approximately 0.2 pounds Mo per acre (8 oz. of Moly-Gro per acre).

After the phosphate and potash was thoroughly mixed into the soil, 25 inoculated Ranger Alfalfa seeds were planted in each pot on June 15, 1959. The Moly-Gro was then dissolved in water and the required amount was applied to the surface of the soil in each crock by means of a pipette. The crocks were then dug into the surface soil of a field on the University Farm, leaving approximately two inches of the crock rim projecting above the surface. Due to the limited quantity of soil in the crocks,

rainfall was generally inadequate, so additional water was necessary. Each crock was later thinned to 20 alfalfa plants. In the fall, the pots were moved into the greenhouse and artificial light was used during the hours of darkness to promote normal alfalfa growth as much as possible.

Results

The first cutting of alfalfa was made before the plants were moved into the greenhouse, and growth was so limited that yields were not determined, with only total nitrogen being determined and crude protein levels of the alfalfa being established. The initial soil pH of the five soils and the crude protein (N x 6.25) content of the first cutting is given in Table 1.

Table 1. Soil type, treatment, initial pH and crude protein content of the first cutting of fertilized alfalfa.

Soil Type	Initial soil pH	No. Mo	Recommended* Mo. rate	Double rec. Mo. rate
		average percent protein		
Anoka loamy fine sand	5.0	15.4	14.9	15.5
" " " " + 3 T lime	5.0	14.1	14.2	14.2
Fayette silt loam	6.9	14.6	14.3	15.3
Barnes loam	6.3	14.9	14.3	14.3
Nicollet clay loam	6.7	14.4	14.1	14.6
Hegne clay	7.8	13.4	14.2	14.0
*4 oz. Moly-Gro or 0.1 pound of molybdenum/A	Average	14.5	14.3	14.7

It is apparent that the molybdenum additions to the soil have not appreciably affected protein concentrations in the first cutting.

The second cutting of alfalfa was more substantial and Table 2 presents hay yields, percentage crude protein, and the pounds of crude protein produced on the acre basis.

Table 2. Alfalfa yield and crude protein concentration and production when grown on five soil types with molybdenum treatments (second cutting).

Soils Type	No Mo.			Recommended Mo. rate*			Double Mo. recommended rate		
	+hay T/A	% Pro.	lbs. pro/A.	+hay T/A	% Pro.	lbs. pro./A.	+hay T/A	% pro.	lbs. pro/A.
Anoka l.f.s.	1.78	24.3	773	1.73	24.5	760	1.69	24.2	728
" " " " (+ 3 T lime/A)	1.07	22.3	428	.98	23.1	407	0.96	21.4	359
Fayette si.l.	1.52	22.9	622	1.35	22.2	577	1.16	21.8	453
Barnes l.	1.46	21.9	573	1.27	21.5	491	1.12	21.6	431
Nicollet c.l.	1.52	22.6	615	1.46	22.0	576	1.23	22.1	487
Hegne c.	1.55	21.8	606	1.49	22.3	593	1.27	22.8	520
Average	1.48	22.6	603	1.38	22.6	561	1.23	22.3	498

*4 oz. Moly-Gro or 0.1 pound of molybdenum per acre.
+ calculated yield at 15% moisture level (air-dry)

It is obvious that the two molydbenum treatments have not increased alfalfa yields, protein concentrations or the yield of protein on the acre basis on any of the five soil types investigated.

Since the two rates of molybdenum application used did not appear to have any appreciable effect on alfalfa growth, it was then decided to increase the Mo. application to 10 and 20 times the recommended rates. The results obtained with the third cutting are shown in Table 3.

Table 3. Alfalfa yield and crude protein concentration and production when grown on five soil types with molybdenum treatments (third cutting).

Soil Type	No. Mo.			10 times recommended Mo. rate*			20 times recommended Mo. rate		
	+ hay T/A	% Pro.	lbs. Pro/A	+ hay T/A	% Pro.	lbs. Pro/A	+ hay T/A	% Pro.	lbs. Pro/A
Anoka l.f.s.	1.23	23.6	520	0.94	23.7	397	0.94	21.7	365
" " " " (+ 3 T lime/A)	0.92	26.5	434	0.69	20.9	259	0.80	26.2	377
Fayette si.l.	1.01	25.5	459	0.83	23.3	344	1.10	25.9	455
Barnes l.	1.27	25.6	581	1.10	18.8	460	0.98	19.3	455
Nicollet c.l.	1.16	25.8	536	0.98	23.7	418	0.89	21.7	347
Hegne c.	1.40	25.2	641	1.23	20.1	413	1.16	19.4	402
Average	1.17	25.4	529	0.96	21.8	382	0.98	22.4	400

*40 cc. of Moly-Gro or 1.0 pounds of molybdenum per acre.

+ calculated yield at 15% moisture level (air-dry)

Apparently the heavy molybdenum soil applications have had no beneficial effect on alfalfa yield crude protein concentration or protein production on the five soils investigated.

Conclusions

An experiment with five Minnesota soil types where alfalfa was first grown outside in two gallon crocks and then moved into the greenhouse, molybdenum applications at both recommended rates and doubled rates, then ten and twenty times recommended rates to five Minnesota soils (with adequate previous phosphate-potash treatment) resulted in no increase in alfalfa yield or in protein content of the alfalfa. One of the soils investigated (Anoka loamy fine sand) was quite acid in reaction and would be normally expected to respond to molybdenum applications if these were desirable.

The restricted amount of soil used in the two gallon crocks in growing the alfalfa should induce a nutrient deficiency more readily than where alfalfa is grown in the field. It would be reasonable to assume that molybdenum applications for alfalfa in Minnesota would probably not be a recommended practice.

Grass and Legume-mixture Pasture Trial
L. Hanson and Bill Hueg

One of the seven southeast grass pasture fertilizer demonstration fields conducted in 1958 was followed through in 1959. This was on the Vincent Everman farm in Wabasha County. This was done because of an opportunity to also measure pasture yield from a legume-grass mixture on the same farm. However, the data should not be considered as a completely valid comparison of the pasture type. The fields were not located together and part of the forage yield from the legume was harvested as grass silage.

The data do, however, give an indication of the pasture yields possible from different fertilizer treatments under intensive grazing management. Ration-a-day grazing was used in all plots and barn feeding was adjusted to make maximum use of pasture forage.

All but 50 lbs. N/A of the fertilizer on the grass pasture was applied in 1958. The yield in TDN are calculated on the basis of requirements for maintainence of the animals, milk production and gain in weight, less the amount of TDN fed off the pasture.

The soil type is Fayette and Dubuque silt loam testing high in P and K. Rainfall was below average in 1958 and above average in 1959. The grass pasture is primarily bluegrass and brome. The legume mixture is a combination of alfalfa, red clover and brome.

Grass pasture area - 1958 and 1959 (per acre, per year)

Plot #	Fertilizer Treatment Total for 2 years N	P_2O_5	K_2O	Cow Days	Milk Produced-lbs	Net TDN-lbs	Cost of Fertilizer
1	300 +	40 +	80	260	9160	4352	$44.00
2	250 +	40 +	80	238	8213	4006	38.00
3	200 +	40 +	80	207	7146	3306	32.00
4	150 +	40 +	80	138	4971	1700	26.00
5	100 +	40 +	80	144	5157	2286	20.00
6	Check			110	3818	1717	
7	0 +	40 +	80	75	2534	1174	8.00

Renovated Area. 1959 yield.

Fertilizer Treatment N	P_2O_5	K_2O	Net TDN per acre	Cost of fertilizer per acre
36	66	96	5194	$17.00

2,856 lbs. of the TDN were calculated to come from 8.4 tons of grass silage harvested per acre of the first cutting.

The Effect of Fertilizer on Pasture Composition

Rosemount Agricultural Experiment Station
Soils Experimental Farm
Rosemount, Minnesota

Paul M. Burson and George D. Holcomb
Soils Department

The application of phosphate and potash fertilizers stimulates the growth of legumes. These treatments must be applied if satisfactory stands of legumes are to be established and maintained. The rates per acre and the amount of each should be determined by soil test. Nitrogen fertilizer stimulates the growth of grasses provided sufficient phosphate and potash is available.

Soils that are badly eroded, with no topsoil remaining are low in organic matter and nitrogen. It is on these soils where the available supply of nitrogen is most critical. The response to nitrogen increases as the degree of erosion increases. On soils with little or no topsoil the rates of nitrogen application should be much higher than on soils with six inches or more of topsoil if comparable production of grasses are to be established and maintained.

If pasture grasses are to be successfully established on eroded pasture soils, adequate amounts of nitrogen must be applied at seeding time followed by annual applications to maintain satisfactory growth, yield and a desirable composition of legumes to grasses. However, as regular renovation occurs later and there is some buildup of organic matter and a reserve of nitrogen from the legumes together with some residual carryover from the nitrogen fertilizer, the application of nitrogen at seeding time is not as necessary.

In 1957 annual application of 60 pounds of nitrogen per acre was applied in addition to the annual application of the 200 pounds per acre of phosphate and potash. Not enough nitrogen was obtained from the inoculated legumes to meet the needs for maximum growth of grass and to provide a more balanced composition of grasses to the legumes. These conditions were particularly more noticeable on the more eroded soils where the topsoil was less than 6 inches in depth. Nitrogen fertilizer was applied at different times and at different rates throughout the grazing season, but the total amount for the year was 60 pounds per acre. The time of application and the amounts per acre were as follows: (1) all in early spring during the last of April, (2) all in early June or when the early spring pasture growth was over, (3) one-half (30 pounds of nitrogen) in April and one-half (30 pounds of nitrogen) in early July, (4) one-half applied in early June and one-half applied in early July. The purpose of these comparisons was to determine if it were possible to get more uniformity of grass growth and composition of grasses to legumes throughout the grazing season by reducing letdown in grass production during the midseason. Bloat has been a serious problem when the percentage of legumes was in excess of grasses. It has been observed in these and other studies that if the legume component exceeds 50 per cent of the total pasturage, bloating in cattle may become a very serious problem.

A summary of two years' work (1957 and 1958) in Table I shows that the application of 60 pounds per acre of nitrogen fertilizer, regardless of the time of season applied, increased the percentage of grass composition in the pasturage. This increase in grass composition ranged from 3 percent in May, which is the most vigorous period of grass growth, to 24 per cent in July which is the usual letdown period for grass production. It is during this summer period that legumes continue in good growth and unfertilized grasses are in low production.

Table I. Effect of nitrogen fertilization on pasture composition. 1957-1958.

Month	Grasses - Per cent		
	No nitrogen	60 lb. nitrogen	Increase
1. May	57	60	3
2. June	43	63	20
3. July	38	62	24
4. August	37	52	15
5. September	31	48	17

Pastures fertilized: A, B, C, D, and E.

The split nitrogen applications as compared to applying all of the nitrogen at one time showed little difference in the composition of the pasturage (Table 2). There was very little difference in composition in May regardless of time of application because of the usual early spring growth. In July the single spring application was far superior to the split application. This is probably due to: (1) insufficient amount of nitrogen applied (30 pounds per acre) in the spring to meet the nitrogen need on the eroded soils, (2) shortage of moisture when the summer application of 30 pounds per acre of nitrogen was made. The moisture supply in July quite often may be limited which will make a summer application of nitrogen ineffective.

Table 2 shows the split application resulted in a high of 59 per cent in May to a low of 40 per cent grass in September. When all of the nitrogen was applied in the spring the grass composition was 80 per cent in July and 40 per cent in September. The spring application of 60 pounds of nitrogen all applied at one time was superior because enough nitrogen was supplied to meet the shortage of soil nitrogen and a time when there was sufficient moisture. On the pastures the single application was best.

Table 2. Effect of split versus single application of nitrogen fertilizer on pasture composition. 1957-1958.

	Grasses - Per cent		
		Nitrogen	
Month	No nitrogen	30/30 pounds	60 pounds
1. May	57	59	60
2. June	43	56	61
3. July	38	55	80
4. August	37	57	67
5. September	31	40	40

The Effect of Fertilizer on Pasture Yields Via Clippings

Rosemount Agricultural Experiment Station
Soils Experimental Farm
Grassland-Beef Cattle Project 2512
Rosemount, Minnesota

Paul M. Burson
Soils Department

Yield clippings were taken on pilot plots and all pastures to determine the actual tonnage of pasturage produced per acre. All yields were determined on the basis of tons of pasturage per acre at 15 per cent moisture. The clippings were taken in advance of the movement of the steers to the next pasture.

Yields of pasturage per acre as shown in Table I increased from 1.57 tons per acre on the unfertilized plots to 2.63 tons per acre on fertilized plots. The largest increase was obtained from the first 300 pound per acre increment of 0-20-20.

Table I. Pasturage yields from various amounts of fertilizer applied to a legume-grass mixture in pilot plots. 1953-54.

Soil Treatment	Average tons per acre at 15% moisture
1. Unfertilized	1.57
2. 300 lbs. 0-20-20	2.34
3. 600 lbs. 0-20-20	2.40
4. 900 lbs. 0-20-20	2.55
5. 1200 lbs. 0-20-20	2.63
6. 1500 lbs. 0-20-20	2.63

Seeding mixture: Alfalfa, Ladino clover, bromegrass and meadow fescue.

Beginning in 1957 annual applications of 60 pounds of nitrogen were applied to all pastures in addition to the annual application of 200 pounds of 0-20-20. The nitrogen was applied in two ways: (1) all at one time, in April or June, (2) split applications with one-half in April or June and one-half in the summer. No important difference was found in the yield per acre between the two ways of application. This is shown in Table 2. When all the nitrogen was applied at one time the yield of pasturage increased 0.87 tons per acre (1.28 to 2.15 tons per acre) as compared to the unfertilized pastures. The yield per acre at the different times of application ranged from 2.02 tons where the nitrogen was split in application to 2.15 tons where all the nitrogen was applied as one application. There was an increase of 0.13 ton per acre in favor of the split application. When all of the nitrogen was applied in April as compared to all being applied in early June, the yield increase was only .03 ton in favor of the early June. These data indicate no advantage of using split applications over the single application in yield. By applying all the nitrogen, phosphate, and potash at one time the cost of operation to the farmer can be materially reduced.

Table 2. Clipping yields from fertilized pastures[a] comparing nitrogen fertilization as to time of application and split versus one application. 1958-1959.

Lb. of nitrogen applied per acre	Date of application	Average tons per acre at 15% moisture
1. Unfertilized	-	1.28
2. 60 lb.	April 28	2.12
3. 60 lb.	June 8	2.15
4. 30 lb.	April 28	2.11
30 lb.	July 9	
5. 30 lb.	June 8	2.02
30 lb.	July 9	

[a] Pastures: B, C, D, E, F, and G 2-4-5-6.
Pasture C was renovated in 1959. No yields taken.

Bloat and Pasture Composition

Rosemount Agricultural Experiment Station
Soils Experimental Farm
Grassland-Beef Cattle Project 2512
Rosemount, Minnesota

Paul M. Burson and George D. Holcomb
Soils Department

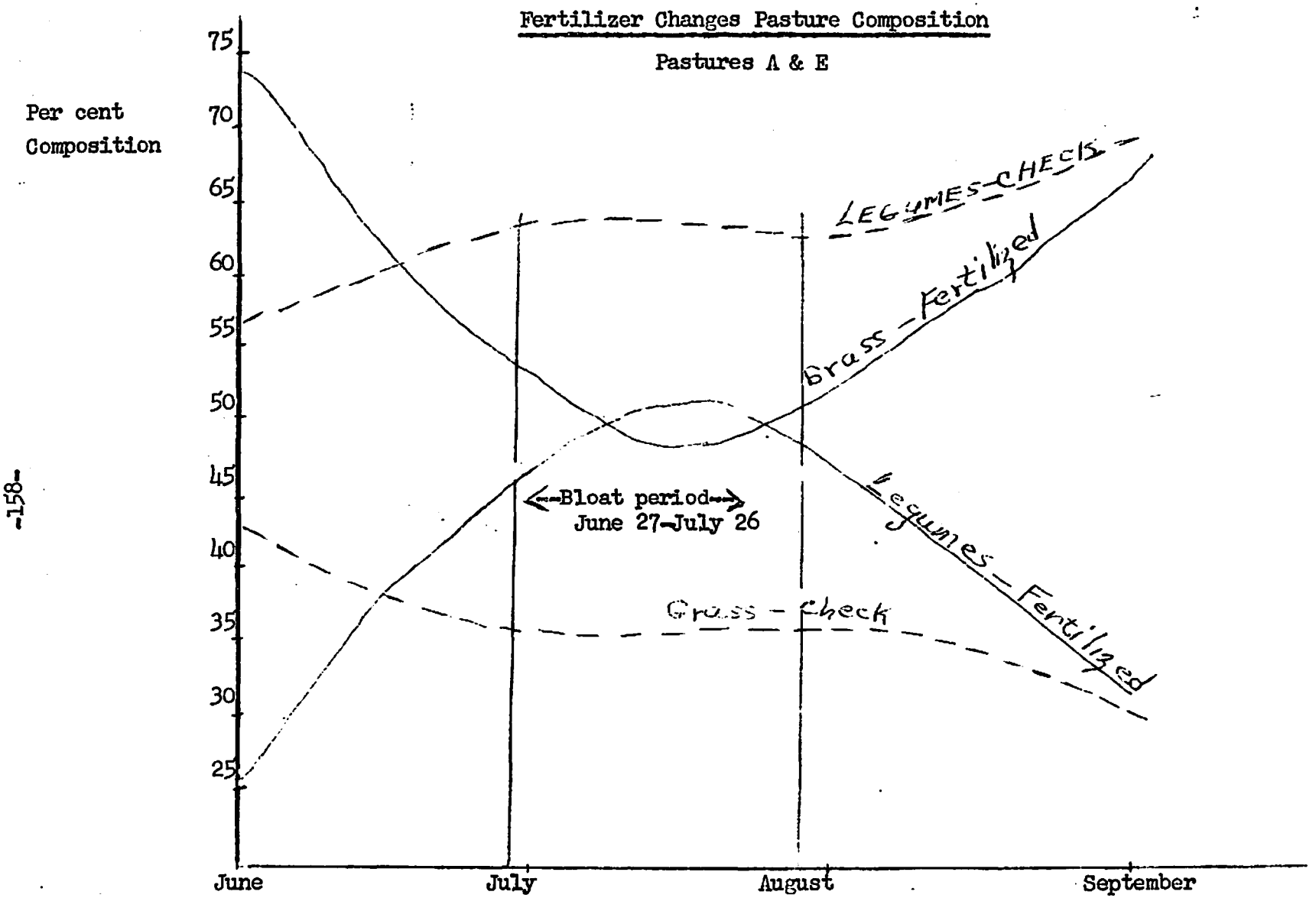
Bloat has been a serious problem in grazing steers on legume-grass pasture. In 1956 and 1957 when comparisons were made between weekly rotational grazing and ration-a-day grazing considerable bloat occurred starting late in June. This trouble may be explained by the fact that the first spring growth of a legume-grass mixture is higher in grass content than midsummer growth. Bloat is less likely to occur with a higher grass content. The two most abundant legumes in the mixture were Ladino clover and alfalfa. Ladino clover normally does not overwinter well in Minnesota. However, the mild winters preceeding the 1956 and 1957 pasture season allowed the Ladino clover to survive and contribute substantially to the pasturage. Since 1957 the pasture mixtures newly seeded contain no Ladino clower but some orchard grass. Orchard grass is not very winter hardy but when it does survive it becomes a good grass contributor.

No fixed pattern of bloating could be observed except that no bloat occurred when the grass percentage was high. On the fertilized pastures on A and E in 1957 less bloat occurred than on the unfertilized because of the higher grass content resulting from the application of 60 pounds of actual nitrogen fertilizer per acre. Some, however, occurred in July when the grass content became near or less than 50 per cent. The grass and legume composition of these pastures is shown in the following graph.

Steers bloated on ration-a-day grazing as well as on weekly rotational grazing. When bloating started, hay was placed in the pastures to help prevent it but was ineffective. One steer bloated on immature alfalfa soilage. The following table shows the bloat record for 1957 with the graph showing the composition of the pasture during the bloat period.

Table 2. Bloat record for 1957

	Number of steers treated for bloat on fertilized and unfertilized pastures			
	A ck.	A fert.	E ck.	E fert.
June 27	1		1 died	
29	1			
July 5	5	6	5	6
17			1 died	
18			2	
19	2			
23	2			
25	1			
26	4			
Total cases of bloat	16	6	9	6



Seeding Mixture - Alfalfa 7#, Ladino 1/2#. Alsike 1/2#, Meadow Fescue 3#, and Lincoln Brome 6# - seeded spring, 1954.

Supplementary Soil Fertility Studies (1959)
A. C. Caldwell and Others

Grand Rapids (North Central Experiment Station)

An old experiment designed to evaluate the effect of fertilizers, time of application, and gypsum on yield of alfalfa was harvested for the last time in 1959. Previous experience has led to the conclusion that time of fertilizer application and gypsum applications were not important influences on hay yields on this location. For this reason, only the fertilizer treatments were studied in 1959. The results shown in Table 1 show no significant fertilizer response of alfalfa-brome hay.

Table I. Effect of Fertilizer Treatment on Yield of Hay at Grand Rapids Experiment Station*

Pounds N, P_2O_5 K_2O Per Acre	Yield Tons Per Acre	Difference From Check
0-0-0	2.37	0.51
60-60-60	2.88	0.40
60-120-120	2.77	0.25
0-60-60	2.62	0.65
0-120-120	3.02	0.36
0-0-120	2.73	0.41
60-0-120	2.78	

*Yields are from a single cutting.

Crookston (Northwest Experiment Station)

Fertilizer Trials on Sugar Beets
O. C. Soine

Fertility work on sugar beets conducted by the Northwest Experiment Station involved a nitrogen study on six different farms in the Crookston area, and a N-P-K combination trial on a three-year rotation at the Experiment Station.

In the nitrogen study, six different rates of ammonium nitrate were used. On three of the farms, a sweet clover or alfalfa fallow was used in 1958, and on three farms, a black fallow was used in 1958. The results are given in Tables 2 and 3.

Table 2. Effect of Nitrogen on Yield and Sugar Content on Legume Fallow versus Black Fallow. (Average of three farms for each type of fallow.)

Treatment	Legume Fallow		Black Fallow	
	Yield Tons/Acre	Per Cent Sugar	Yield Tons/Acre	Per Cent Sugar
Check	17.57	15.35	16.55	14.69
10 lb. N/A	17.45	15.36	16.53	14.82
20 lb. N/A	17.18	15.33	16.36	14.49
30 lb. N/A	18.23	15.02	16.93	14.37
40 lb. N/A	18.08	14.89	16.86	14.23
50 lb. N/A	17.69	14.98	16.79	14.06
General Mean	17.67	15.15	16.67	14.44
Soil Test Report				
pH	7.9		7.8	
Organic Matter	5.7% Medium		6.8% Medium	
Available phosphorus	26.5 lb./A Medium		37.5 lb./A High	
Available potash	320 lb./A High		345 lb./A High	

Summary:

1. The sugar beets on the legume fallow plots averaged one ton more per acre than on the black fallow plots.

2. The sugar content of the beets on the legume fallow averaged 0.71 per cent more sugar thatn the beets from the black fallow.

3. The three highest rates of nitrogen fertilizer increased the yield of sugar beets on the legume fallow plots from .12 to .66 tons per acre; on the black fallow, the same three rates produce increases of .24 to .38 tons per acre.

4. The addition of nitrogen fertilizer lowered the per cent of sugar below the check on all the plots except the 10-lb. rate on the black fallow.

Table 3. The Effect of Nitrogen on the Yield of Sugar and Gross Value per Acre.

	Legume Fallow		Black Fallow	
	Sugar lbs./acre	Gross Value	Sugar lbs./acre	Gross Value
Check	5368	$ 234.70	4844	$ 212.34
10# N/A	5339	232.78	4894	213.73
20# N/A	5249	228.53	4734	207.44
30# N/A	5471	238.63	4864	213.32
40# N/A	5363	234.68	4792	210.46
50# N/A	5282	230.85	4719	207.69
General Mean	5346	233.36	4809	210.83

1. The General Mean shows that the Legume Fallow Plots outyielded the Black Fallow by 537 pounds of sugar.

2. All applications of nitrogen fertilizer, except the 30-lb. rate, produced less sugar per acre than the check plot on the legume fallow.

3. On the black fallow, only the 10-lb. and 30-lb. rates yielded more sugar per acre than the check.

4. The sugar beets on the legume fallow averaged $22.53 more per acre than the black fallow.

5. There was no significant increase in the gross income from the application of nitrogen fertilizer on either legume or black fallow plots.

Red River Valley Potato Research Farm

Yields of Kennebec, Cobbler, Norland, and Pontiac potatoes increased with increasing rate of P_2O_5 application up to 1000 pounds P_2O_5 per acre. Highest yields of potatoes were obtained with the Pontiac variety and a fertilizer treatment of 120-1000-80. While Kennebec potato yields increased with increasing rate of fertilizer, the top yields obtained with this variety were well below those of Pontiacs. (table 9). It should be noted that fertilizer applications up to 1000 pounds P_2O_5 per acre did not reduce potato quality as indicated by specific gravity determinations.

Table 4. Effect of Fertilizers on the Yield and Specific Gravity of Four Potato Varieties (Red River Valley Potato Research Farm, 1959)

Fertilizer per acre			Kennebec	Norland			Kennebec		Norland	
			Cobbler		Pontiac		Cobbler			Pontiac
N	P_2O_5	K_2O	bu/acre, No 1				Sp. gravity			
0	0	0	218.8	184.1	203.8	227.5	1.075	1.085	1.064	1.067
60	100	40	287.6	250.4	294.3	320.8	1.077	1.085	1.063	1.066
60	200	40	324.2	294.6	325.7	336.3	1.079	1.081	1.066	1.065
60	300	40	356.2	320.9	348.1	372.8	1.076	1.078	1.065	1.065
60	400	40	367.5	328.1	345.6	358.0	1.077	1.085	1.064	1.068
60	500	40	374.9	320.3	357.5	416.9	1.077	1.083	1.064	1.065
120	500	80	351.4	390.0	395.5	417.0	1.072	1.083	1.064	1.064
120	1000	80	353.0	425.5	425.2	444.9	1.071	1.083	1.062	1.066

Notes: Soil is a silty clay loam, organic matter content of about 6, available P averaging 10 pounds, exchangeable K 400 pounds per acre, pH 7.8. Plots were on non-fallowed land. Phosphorus was supplied by conc. super, potassium by potassium chloride, nitrogen by ammonium nitrate. All fertilizers were applied with the seed as a band application.

The large and increasing yields with increased fertilizer application indicates substantially more use of fertilizer on potatoes in the Red River Valley.

Note particularly that increased fertilizer use has not affected potato quality (except for Kennebec) as indicated by specific gravity tests.

Chemical and Organic Fertilizer Comparison on Potatoes

C. J. Overdahl

In 1958 on an acid sandy loam soil near St. Cloud 600 pounds per acre of a 1-2-1 organic fertilizer appeared to cut yield 300 to 600 pounds per acre of a chemical fertilizer on corn, soybeans, radishes, and potatoes. The yields, however, were all too low to be considered satisfactory.

A plot of early gem potatoes was established in 1959 on an area where the soil pH was measured at 5.4 in 1958.

Treatments

The total plot area received a basic application of 100 lbs. of N and 40 pounds of P_2O_5. The nitrogen was broadcast at planting time and phosphate was applied with the planter.

Other applications were broadcast as follows:

Potash - 0 and 120 lb/acre.
Organic fertilizer - 0 and 600 lbs/acre.
Gypsum - 0 and 400 lbs/acre to supply calcium as a plant food without raising the pH.
Borated gypsum - 0 and 400 lbs/acre.
Lime - 0, 2, and 8 tons per acre.

Results

Treatment**	No Lime		8 Tons Lime	
	Yield bu/A*	Specific gravity	Yield bu/A*	Specific gravity
NPK	219.5	1.0555	205.0	1.0565
NPKG	190.0	1.0580	186.1	1.0580
NPKGB	210.0	1.0575	196.0	1.0630
NPBG	166.2	1.0580	190.1	1.0560
NPOBG	140.8	1.0570	171.9	1.0605
Average	185.3	1.0572	189.8	1.0588

*Average of 2 reps.
**O = Organic fertilizer, G = gypsum, B = Boron.

Organic fertilizer was applied alone immediately adjacent to the above plots. The yield was 137 bu/acre.

Only the 8 ton lime plots were harvested since there was no visual lime response, and one of the plots harvested having a two-ton rate yielded the same as an equivalent treatment with no lime.

The soil test resulting from a sampling at planting time was as follows: pH -6.1, OM - 2.4 (low), P - 117 (very high), K - 170 (med), texture - sandy loam.

All the plots receiving potash averaged 201.1 bushels and all plots with no potash averaged 167.2 bushels. The average yield increase due to potash was 33.9 bushels. Figuring potatoes conservatively at 1¢ per pound would mean that potash returned $20.34 for a $6 per acre investment.

The plot was not designed to determine the value of nitrogen and phosphate. The small average difference of 4.5 bushels due to the 8 ton per acre lime rate is hardly significant since variation was quite large within treatments. No lime response is not surprising since the pH of the plot area was 6.1. No increases were observed due to calcium supplied by gypsum or to boron applications.

The demonstration did not include a plot with no fertilizer. For this reason it could not be determined whether organic fertilizers gave a response, but this treatment had the lowest yielding plots. They may have given no increase but at least it was apparent that organic fertilizers were not as effective as chemical fertilizers in increasing yield.

Specific Gravity

Specific gravity was low for all the potatoes and no differences are apparent due to treatments.

Insects

Insects damaged the potato vines in July. The plots were sprayed shortly after the insects were discovered but serious damage had already occurred.

Summary

The plot site was established on an area immediately adjacent to where growth differences were observed in 1958 and where the pH was 5.4. The pH 6.1 on the actual plot site, however, prevented establishing whether soil pH was a factor in poor yields. The pH of the organic fertilizer was above 9 and when applied near the seed in 1958 may have had a desirable effect from the improved pH or calcium content. In a preliminary study in small pots Dr. Rose observed very beneficial effects from lime treatments. It was also observed that soybeans on the farm were a pale green color and appeared nitrogen deficient. Soils from the more typical acid fields on the farm should be used in a greenhouse study to more accurately determine the cause of poor yields.

Fertilizer furnished by Howe, Inc., Minneapolis

Cooperators on demonstration: Enock E. Bjuge, Sherburne County Agent
Dr. R. D. Munson, American Potash Institute
Dr. Ray Rose, Howe, Incorporated
Dr. O. C. Turnquist, Extension Horticulturist

Fertilizers in Forestry

H. F. Arneman

A cooperative experiment with the Northwest Paper Co. was started in May of 1958 to test the effect of fertilizers on Red Pine seedlings.

The Northwest Paper Company furnished the seedlings and planted them for the experiment.

Soils used were Menahga loamy sand. The areas planted were "worn-out" agricultural areas that were beginning to revert to timber.

The experiment consisted of a factorial design with 20# and 40# of N, 20# P_2O_5 and 20# and 40# K_2O applied in all combinations. One plot in each replicate had Gypsum applied to it. The treatments were applied in quadruplicate with two replicates located near Huntersville, Wadena County and two replicates near Baxter in Crow Wing County. Each plot contained approximately 100 trees.

Urea (45-0-0) was used as the source of nitrogen, concentrated superphosphate (0-45-0) as the phosphorus source and muriate of potash (0-0-60) the source of potassium. The fertilizer was applied about six inches deep and three inches to the side of each tree.

The only definite results to report at this time is that both the nitrogen and potassium treatments cause considerable mortality of seedlings.

Measurements are being made annually.

A Corn Fertility Trial on a Wright County Peat Soil

by H. P. Hermanson and R. S. Farnham[1]

Purpose

The purpose of this trial was to determine the effect on corn grain yield of ammonium nitrate, treble superphosphate, and muriate of potash applied at different levels to a peat soil in 1958.

Experimental Conditions

The University of Minnesota Soil Testing Service indicated that this partly decomposed fibrous peat was low in "available" phosphorus and exchangeable potassium.

The treatments were applied in a randomized incomplete block design having two reps. The factorial treatments were the combinations required for the dodecohedron response surface points.[2] The plots were 20 by 14.4 feet and consisted of four rows.

The Pioneer 390 corn was seeded during the last of May and fertilized May 30th to June 2nd with the amounts of fertilizer material equivalent to the nutrient levels shown in table 1. The fertilizer was applied in a band 2 to 4 inches to the side of each row at seed level. The blanket treatment, which was broadcast, included magnesium, iron, sulfur and manganese applied as 63.4 lb./A. $MgSO_4 \cdot 7H_2O$, 16.1 lb./A. $Fe_2(SO_4)_3 \cdot 6H_2O$, and 89.9 lb./A. of $MnSO_4$. July 3rd the plots were hoed and the corn thinned to a constant population of 13,730 plants/A.

The summer was cool and the 94 to 98 day corn grew slowly. It was killed by frost before the plants in many plots had reached maturity. The ears from the center two rows were harvested, dried and shelled. The wieght of the grain was obtained and adjusted to 15.5% moisture.

Results

The yield of corn grain is described over the range of fertilizer levels used by the following equation.

$$Y = 57.4 - .2N + 4.4^{*} P + .6K - 2.0N^2 - 2.3P^2 - 1.5K^2 - .5NP + .9NK + 1.3 PK$$

Where:

Y is bu. of 15.5% moisture grain/A.
N is 31.46 lb. N/A units scaled from 82.35 lb. N/A.
P is 19.66 lb. P_2O_5/A. units scaled from 51.47 P_2O_5/A.
K is 39.32 lb. K_2O/A. units scaled from 102.94 lb. K_2O/A.

---

[1] In cooperation with Mr. Richard Vandergon and Mr. Eugene Ellis
[2] As suggested by J. W. Chapman and Dr. C. E. Gates.

The 4.4 is significantly different from zero at the 5% level, -2. at the 10% level, and all others at higher levels. This means that when treble superphosphate was applied over the levels tried, grain yields were increased and that this increase was not straight but convex. Our measurements do not disprove the statement that addition of ammonium nitrate or muriate of potash did not change the amount of grain produced even though consistent trends occurred.

Theoretical treatment of the equation indicates that the highest yield during 1958 would have occurred for the treatment receiving 81 lb. N/A., 73 lb. P_2O_5/A., and 130 lb. K_2O/A. The yield from this treatment would have been 60 bu./A. The change in yield as phosphorus was varied at these levels of nitrogen and potassium is shown in column four of Table 2.

The optimum economic fertilizer treatment for 1958 assuming unlimited capital, a corn price of 90¢/lb., a nitrogen price of 12¢/lb., a P_2O_5 price of 9¢/lb., and a K_2O price of 5¢/lb. would have been the one receiving 34 lb. N/A., 58 lb. P_2O_5/A., and 67 lb. K_2O/A. Column three of Table 2 shows the effect of phosphorus at these levels of nitrogen and potash. This treatment would have given a yield of 54 bu./A. in contrast to the 17 bu./A. for no fertilizer. An increase of 37 bu./A. having a value of 34 dollars. This amount of fertilizer would have cost 13 dollars, so the net return would be 21 dollars/A. This would consist of fertilizer management profit and the additional cost of harvesting the extra 37 bu./A.

The corn maturity seemed to be influenced by fertilizer treatment.

Summary:

Since the corn yield was limited by climatic conditions and plant population and not soil fertility, inferences based on this data about yield on other years must be considered risky. During 1958, treble superphosphate changed the amount of corn produced. On normal years, the temperatures are generally higher and perhaps the increases due to nitrogen lower than observed here.

Table 1. Fertilizer treatments used in the Wright County corn fertility trial and the yields they produced.

Treatment No.	Treatment N (lb./A.)	P_2O_5 (lb./A.)	K_2O (lb./A.)	Yield (bu./A.)
1	114	103	103	53
2	82	32	206	53
3	0	52	64	50
4	133	20	39	40
5	114	0	103	41
6	82	71	0	41
7	0	52	142	47
8	133	83	166	51
9	51	103	103	52
10	82	32	0	45
11	165	52	142	39
12	32	20	166	32
13	51	0	103	39
14	82	71	206	52
15	165	52	64	52
16	32	83	39	51
17	32	83	166	55
18	32	20	39	50
19	133	83	39	55
20	133	20	166	46
21	82	52	103	53
22	82	52	103	52

Table 2. Effect of phosphorus fertilization on yield of corn.

P_2O_5 (lb./A.)	Corn (bu./A., 15.5%H_2O) 0 lb.N/A 0 lb.K_2O/A	35 lb.N/A 70 lb.K_2O/A	80 lb.N/A 130 lb.K_2O/A
0	17	26	27
20	29	40	43
40	37	50	53
60	39	54	59
80	37	54	60
100	31	49	56

The Influence of Fertilization of a Peat Soil in Clearwater County on the Yield of Potatoes

H. P. Hermanson & R. S. Farnham[1]

Purpose

The purpose of the two trials reported here was to observe the effect of nitrogen, phosphorus, and potassium carrying materials on the yield of potatoes grown on an organic soil in 1958.

Experimental Considerations

The two trials were conducted on an organic soil located at SE 1/4 sec. 7 T151N R38W in Clearwater County. The surface eight inches was muck with a pyrophosphate solubility of more than 2%. The underlying fiberous peat had a pyrophosphate solubility of 1/4 to 3/4%. The Soil Testing Laboratory at the University of Minnesota reported that both layers were very low in "available" phosphorus and exchangeable potassium. Mineral soil was encountered at about four feet and is overlaid by six inches of muck. The soil reaction of the upper 20 inches was 6.0 to 6.2. This field had been in meadow and had not been fertilized previously.

The temperature during June and July was 5°F lower than normal. The total precipitation reported by a weather station 15 miles south of the plots showed a dry August.

On June ninth certified Cherekee potatoes were seeded in the loose unpacked seedbed. About two weeks later the fertilizer was banded two to six inches to the side and level with the unsprouted potato pieces.

The nitrogen rate study consisted of a randomized complete block design having five reps. The plots were 30 by 13.7 feet and consisted of four rows. Ammonium nitrate, treble superphosphate, and muriate of potash were applied at rates equivalent to those shown in Table 1.

Table 1. The average plant population and yield for the various treatments in the nitrogen rate trial.

Treatment No.	Treatment (lb/A) N	P_2O_5	K_2O	Population (Plants/A)	Yield[2] (100 lbs/A)
1	39	0	0	6,340	112
2	0	98	292	5,560	75
3	39	98	292	6,160	112
4	78	98	292	6,380	121
5	117	98	292	6,000	99
6	0	0	0	6,500	94
			hsd	1,380	88
			lsd	923	58

[1]In cooperation with Del Darst (grower) and Arnold Heikkila, County Agent, Clearwater Co.

[2]Linearly adjusted to mean population of 6,250 plants/A.

The phosphorus and potassium study utilized the randomized incomplete block design having five reps. The factorial treatments correspond to the points[1] at vertices of a pentagon along with the center point. Ammonium nitrate, treble superphosphate, and potassium sulfate were applied at rates equivalent to those shown in Table 2.

Table 2. The average yields for the various treatments in the phosphorus and potash rate study.

Treatment No.	Treatment (lb/A) N	P_2O_5	K_2O	Yield[1] (100 lb/A)
1	39	195	292	90
2	39	121	585	101
3	39	0	475	91
4	39	0	111	74
5	39	121	0	78
6 to 8	39	121	292	94
			hsd	46
			lsd	25

[1]Linearly adjusted to mean population of 5,750 plants/A.

During the last part of July the two center rows were weeded and the number of plants present was ascertained. The phosphorus-potassium plots were thinned to 30 plants but a large number of plots had less than this. The average population for each treatment of the nitrogen carrier trial is shown in Table 1. This is about a quarter the desired population.

The two center rows from all plots in both experiments were harvested and the tubers were weighed.

Results

The yields were linearly adjusted to mean population. The analysis of variance was conducted on the plant population and potato yields obtained in the nitrogen trial. The hypothesis that these treatments had the same mean population and the same mean yield was accepted even though notes taken the last of July indicated a large vine response to nitrogen. The treatment means are given in Table 1.

Analysis of variance on the phosphorus-potassium data showed no significant treatment difference for potato yield. These means are given in Table 2.

Summary

A poor and variable potato stand resulted in a very high variance and a low yield. The application of nitrogen, phosphorus, and potassium fertilizer materials did not change potato yield to a measurable extent. It is probable that plant population and not soil fertility limited the yield since a quarter of the recommended stand gave half the expected yield. An earlier planting, a firmer seedbed, and a normal season would have produced more favorable and useful results.

A Three Year Fertility Study of Potatoes Grown on an Aitkin County Peat

by H. P. Hermansnn and R. S. Farnham[1]

Purpose

The purpose of this work was to observe the effect of fertilizer materials carrying nitrogen, phosphorus, and potassium on the yield and quality of Red Pontiac potatoes grown on a fibrous peat during the years 1957-1959.

Experimental Details and Discussion

The soil studied was a fibrous peat located in W1/2 SE1/4 section 18 of Fleming Township in Aitkin County. The location used in 1957 had been farmed and fertilized previously and had a reaction of pH 5.7, a very high (51 lb/A) "available" phosphorus content, and a medium (115 lb/A) exchangeable potassium content. This peat is 18% ash and 2.2% N. In 1957 one hundred lbs. K_2O/A as muriate of potash was broadcast before seeding. Certified Red Pontiac potatoes were planted May 16 and the rest of the fertilizer was applied May 22 by spreading on the soil surface on each side of the potato rows. The nutrients were applied as ammonium nitrate, treble superphosphate, and muriate of potash except for treatment six where K_2SO_4 was substituted for KCl. The factorial treatments used are shown in Table 1. They were applied to 5.50×10^{-3} acre plots in a randomized complete block design including three reps.

The 1957 season was about normal for the area.

Duncan's multiple range test indicates that treatment 1 through 5 and 2 through 10 are not significantly different but that treatments 2 through 10 are significantly better than treatment 1. The better yields were produced by the treatments containing no phosphorus. No difference in potato density was observed between the KCl and K_2SO_4 potassium sources.

Table 1. The effect of various fertilizer treatments on potato yield and quality during 1957.

Treatment No.	N-P_2O_5-K_2O (lb/A)[2]	Yield (100 lb/A)	Dry Matter (%)
1	0-100-100	205	------
2	80-200-600	229	------
3	40-150-450	229	------
4	40-100-300	232	17.9
5	0-100-300	243	------
6	40-100-300[1]	249	17.7
7	40-0-100	249	------
8	0-0-100	261	------
9	40-0-300	263	------
10	0-0-300	278	------
	hsd	65	
	lsd	38	

[1]Potassium applied as K_2SO_4

[1]In cooperation with Wm. Ruud and Sons

1958 Season

This season the experiment was located about 300 feet west of the 1957 site. This site had been cultivated eight or ten years before and let go wild again. It probably had not been fertilized. The Minnesota soil testing laboratory indicated that this soil had a soil reaction of pH 5.1, was low (7 lb/A) in "available" phosphorus and very low (60 lb/A) in exchangeable potassium. The season was about 5°F cooler than normal during June and July. Rainfall was three inches below normal for the period March and April.

The factorial treatments shown in Table 2 were applied to 8.22×10^{-3}/A plots in an incomplete block design replicated four times. Red Pontiac potatoes were seeded the last of May and during early June 29 lb/A $MgSO_4$ and 58 lb/A CaO was broadcast over the area. The ammonium nitrate, treble superphosphate, and potassium sulfate were then placed in trenches four to six inches to the side and level with the seed pieces. July 17th the plant population was adjusted to 11.7 thousand plants per acre. The average treatment yields are shown in Table 2 along with the dry matter content. Analysis of variance showed highly significant treatment effect. Since the factorial treatments[1] represent the points at the vertices of a dodecohedron along with the one at the center, the fitting of a quadratic cross product function with the calculation of the reduction in sums of squares is convenient to carry out. It gave the following regression equation in which only the potassium produces a significant effect.

$$Y = 211 - .4N - 8.6P + 19.0^{**}K + 7.1N^2 - 2.8P^2 - 10.7^{*}K^2 - 4.8NP + 1.6NK + 4.3PK$$

Where:

Y is in units of 100 lb/A.
N is 45.2 lb N/A units scaled from 73.2 lb N/A.
P is 60.3 lb P_2O_5/A units scaled from 97.6 lb P_2O_5/A.
K is 180.9 lb K_2O/A units scaled from 292.7 lb K_2O/A.

---

[1] Recommended by Dr. C. E. Gates and J. W. Chapman

Table 2. Yield and dry matter content of Red Pontiac potatoes produced by various N-P_2O_5-K_2O combinations during 1958 and 1959.

Treatment (lb/A)				Yield (100 lb/A)		Dry Matter Content (%)	
				1958	1959	1958[1]	1959[2]
101	195	293		226	226	16.4	15.2
73	60	585		248	257	16.4	13.9
0	98	181		247	253	18.1	16.0
119	37	112		232	194	17.5	16.8
101	0	293		222	162	17.3	14.9
73	135	0		123	104	17.3	16.6
0	98	405		242	272	17.0	14.3
119	158	474		218	223	16.2	13.9
45	195	293		176	170	16.8	14.3
73	60	0		144	123	18.1	16.4
146	98	405		191	155	16.6	13.4
28	37	474		198	206	17.0	13.7
45	0	293		198	140	16.8	14.3
73	135	585		210	194	16.4	13.4
146	98	181		222	172	17.3	15.6
28	158	112		180	230	17.5	16.4
28	158	474		207	194	16.8	13.7
28	37	112		200	183	17.5	15.8
119	158	112		164	151	17.0	16.2
119	37	474		246	185	16.6	13.9
73	98	293		210	180	16.8	14.9
0	0	0		137	104	17.7	17.0
			hsd	70	115	1.6	1.2
			lsd	36	58	.8	.6

[1]Potassium furnished as K_2SO_4
[2]Potassium furnished as KCl

Economic analysis of the surface was performed assuming unlimited capital, a N price of 13¢/lb, a P_2O_5 price of 10¢/lb, a K_2O price of 5¢/lb, and the 1958 potato price of 84¢/100 lb. The optimum economic fertilizer treatment for 1958 was 72 lb N/A, 0 lb P_2O_5/A, and 303 lb K_2O/A which should have produced a yield of 218 bags/A. The net return for this fertilization treatment should have been $43/A which would be attributed to fertilizer management return plus the cost of digging and bringing in the extra 80 bags/A. Table 3 shows the variation in yield upon addition of K_2SO_4 when the nitrogen and phosphorus carrier rates were held at their 1958 economic optimum.

Analysis of variance indicates that the measurable treatment variation in specific gravity was solely attributable to the highly significant linear effect of K_2SO_4 rate and can be adequately expressed by the following regression equation where K_2O is expressed as lb/A. Specific gravity = 1.0676 - .0000102**K_2O.

See Table 3.

Table 3. The effect of rate of potassium carrier on the yield and dry matter content of Red Pontiac potatoes.

K_2O (lb /A)	Yield (100 lb/A)		Dry Matter Content (%)	
	1958[1] 70 lb N/A 0 lb P_2O_5	1959[2] 0 lb N/A 110 lb P_2O_5/A	1958[1]	1959[2]
0	170	186	17.7	16.6
100	192	217	17.5	16.0
200	207	239	17.3	15.6
300	217	251	16.8	14.9
400	221	254	16.8	14.3
500	219	247	16.6	13.7
600	211	230	16.4	13.1
Check	137	104	17.7	17.0

[1]Potassium applied as K_2SO_4
[2]Potassium applied as KCl

1959 Season

The treatments applied in 1959 were applied to the same plots again in 1959. The only variation was that KCl was used instead of K_2SO_4. Red Pontiac potatoes were planted the last of May. Rep four on the north end of the experimental area was fertilized May 30th and rain stopped operations. Five inches of rain fell which evidently leached appreciable nutrients as the rep gave no significant treatment effect. June 2 to 4 the other three reps were fertilized. The spring was somewhat dry while temperatures were about normal. July 2nd the population was adjusted to 11.7 thousand plants per acre. The average potato yields from reps 1 to three and dry matter contents from reps 1 to four are given in Table 2. Analysis of variance of the data from reps 1 to 3 indicated highly significant treatment effect. The following regression equation adequately describes the treatment variation in yield.

$$Y = 220.6 - 16.6^{*} + 6.5\,P + 20.7K^{*} + .0N^2 - 16.3^{*}P^2 - 15.6K^2 - .4NP + 3.4NK - 1.9PK$$

Where:

Y is in units of 100 lb/A
N is 45.2 lb N/A units scaled from 73.2 lb N/A
P is 60.3 lb P_2O_5/A units scaled from 97.6 lb P_2O_5/A
K is 180.9 lb K_2O/A units scaled from 292.7 lb K_2O/A

The nitrogen, phosphorus, and potassium carriers all produced significant effects as shown by the astericks in the regression equation. The significant main effect of N carrier is negative while that for K carrier is positive. The significant second order P carrier effect indicates P response is curvilinear. Similar conditions to those accepted for the 1958 economic analysis were taken with the exception that the potato price was changed to the 1959 figure, $1.39. The optimum ecomomic

treatment for 1959 was calculated to be 0 lb N/A, 109 lb P_2O_5/A, and 378 lb K_2O/A. This treatment should give a yield of 254 bags/A. Table 3 illustrates how KCl changes potato yeild and quality. Fertilization at this optimum economic rate would increase the yield 150 bags/A giving a net return over fertilizer cost of $178/A.

As with the 1958 data, the treatment variation in specific gravity is adequately expressed as a linear function of potassium carrier rate. See Table 3.

Specific gravity = 1.0632 - .0000282**K_2O

The lower specific gravity for this season can be explained partly by the immature stage of the plant when frozen and partly by the use of KCl instead of K_2SO_4.

Summary

During 1957 to 1959, fertility experiments were conducted with Red Pontiac potatoes grown on a fibrous Aitkin County peat soil. The effect of nitrogen, phosphorus, and potassium carriers on yield and specific gravity was observed. Consistantly excellent yields were produced all three years from 300 to 380 lb. K_2O/A, whereas, the specific gravity was decreased by addition of potassium carrier. The yield response to nitrogen and phosphorus carriers was variable.

The Effect of Various Phosphate Fertilizer Materials on the Yield of Celery

H. P. Hermanson and R. S. Farnham[1]

Purpose

The purpose of this experiment was to compare the effect upon celery yield of various phosphate fertilizer materials to that of an ammonium nitrate-treble superphosphate-potassium chloride treatment.

Materials and Methods

The soil was an unfertilized fibrous peat located at Fens in St. Louis County, Minnesota. During the 1957 field season, the addition of nitrogen, phosphorus, and potassium to this soil had each given an increase in celery yield. The University of Minnesota Soil Testing Laboratory reported the following data for this soil: pH 5.2, "available" phosphorus medium (18 lbs/A), and exchangeable potassium very low (35 lbs/A). This peat was 43% C and 2.9% N.

The fertilizer materials applied are shown in table 1. Ammonium nitrate (0-33.5-0) was used to bring the rate of nitrogen application up to 70 lbs/A and potassium chloride (0-0-60) to furnish 526 lbs/A of K_2O. In order to maximize the differential response to phosphorus, nitrogen and potash were applied at the recommended rate for maximum yield and phosphorus at one-half this rate. The phosphate sources were applied at quantities which would furnish 35 lbs/A of available P_2O_5. The NPK fertilizers were applied June 26, 1958, in a trench two inches in depth

[1] In cooperation with Mr. Harold Andrews, A. C. Caldwell, and Richard Curley (T.V.A.)

and four to six inches to the east side of the celery row. Ferro Fritted Trace Elements were broadcast as a blanket treatment at the rate of 300 lbs/A to furnish a minimum of 37 lbs/A Fe, .4 lb/A Mo, 6 lbs/A B, 6 lbs/A Cu, 12 lbs/A Zn, and 15 lbs/A Mn. These figures are based on the total analysis appearing on the fertilizer bag.

June 24, 1958, Utah 52-70 celery slips were planted in rows whose spacing alternated between 28 and 36 inches. Two days later the treatments were applied in a randomized incomplete block design to four row plots 20 feet in length.

Results

September 16, 1958, the celery plants from the two inside rows of each plot were harvested, counted, and weighed. Since plant population was quite variable, the yields were adjusted to that expected for the mean population, 19,100 plants/A, by use of linear regression. The adjusted treatment means are shown in Table 1. Analysis of variance results in rejection at the one percent level of the hypothesis of no treatment difference. Using the test of Roessler[2] the observed yields were compared to that of the treble superphosphate yield. These differences are shown in Table 1. The hypothesis of no difference between the hyperphosphate mean and the control, treble superphosphate mean, was rejected at the one percent level; whereas, the null hypothesis for the calcium metaphosphate and concentrated superphosphate comparison to the control was rejected at the five percent level. The null hypothesis for the other two comparisons was accepted.

Table 1. The effect of fertilizer materials upon celery yields.

Treatment	Fertilizer Analysis	Rate (lb/A)	Replication	Yield (T/A)	Difference from control (T/A)
Hyperphosphate	0-5-0	722	9	6.84	-2.82**
Calcium metaphosphate	0-62-0	58	9	7.50	-2.15*
Potassium metaphosphate	0-55-31	65	3	8.09	-1.56
Treble superphosphate	0-45-0	79	9	9.65	
Diammonium phosphate	21-53-0	67	3	9.92	.27
Concentrated superphosphate	0-53-0	67	3	10.84	1.19*

Summary

The effect of several fertilizer materials on the yield of Utah 52-70 celery grown on peat was observed and compared with an ammonium nitrate-treble superphosphate-potassium chloride control. The hyperphosphate and calcium metaphosphate treatments produced less celery than did the control. This was probably due to the lower availability of the phosphorus. The potassium metaphosphate and diammonium phosphate means could not be distinguished from the control mean, but the concentrated superphosphate treatment produced a higher yield than did the control. It is interesting to note that the phosphorus of the concentrated superphosphate is 100% water soluble; whereas, that of the treble superphosphate is 85% water soluble. If diammonium phosphate were not also 100% water soluble, the increase in yields of the concentrated superphosphate treatment might be attributed to greater phosphorus availability. Phosphorus analysis of the plant material is necessary.

---

[2]Proc. Amer. Soc. Hort. Sci. 47:249. 1946.

Forage Adaptability Study on a Peat Soil at the North Central Agricultural Experiment Station - Grand Rapids, Minnesota

by H. P. Hermanson and R. S. Farnham[1]

Purpose

The purpose of this trial was to determine the adaptability of a commonly recommended seeding mixture and several forage species to produce hay on a fibrous peat soil adequately fertilized with nitrogen, phosphorus, and potassium.

Experimental Considerations

The peat soil is located at SW 1/4 SE 1/4 Sec. 15 T55N R25W on the North Central Agricultural Experiment Station 400 feet west of the new federal Lake States Forestry Building. This soil had not been previously farmed or fertilized. It had been drained earlier (about 1920) and was used as a blue grass pasture until the seedbed was prepared for this trial. The drainage resulted in the water table being below two feet most of the time. The Soil Testing Laboratory of the University of Minnesota reports this soil to be low (6 lb/A) in "available" phosphorus, very low (50 lb/A) in exchangeable potassium, and extremely acid (pH 3.8).

During the last of June, 1958, the forages shown in Table 1 were broadcast on a well prepared seedbed at the rates shown. Six replicates were used for all treatments except Ranger Alfalfa and rough stalked meadow grass which were repeated only three times. The following fertilizer blanket treatment was applied to the (5' x 9') 1.031×10^{-3} acre plots at this time: 10 lb N/A as 33-0-0, 30 lb P_2O_5/A and 90 lb K_2O/A as 0-20-20 and 0-0-60, 25 lb $MgSO_4$/A, 5 lb borax/A, 25 lb $CuSO_4$/A, 2.46T $CaCO_3$ equivalent/A as $Ca(OH)_2$ and $CaCO_3$, 25 lb $MnSO_4$/A, and 1 lb $(NH_4)_2MoO_4$/A. The seedbed was then packed somewhat by running a crawler-type tractor over it.

June and July of 1958 were about 5°F below normal and the period April and May, 1959, received three inches below normal rainfall. Good snow cover existed during the 1958-59 winter.

June 16, 1959, the plots were cut and the yield determined. The dry matter content was estimated to be 25% and the data in Table 1 is expressed on this basis. June 22 to 28, fifty pounds per acre N was applied as 33-0-0 to all treatments consisting solely of grass. All plots received 100 lb P_2O_5/A as 0-46-0 and 300 lb K_2O/A as 0-0-60. August 5, 1959, the second crop was harvested and yield and matter content ascertained. Table 1 shows the dry matter yield for the second harvest and the seasonal total. Duncan's multiple range test shows alsike cover to be superior to all treatments in the first harvest and timothy in the second. Narragansett Alfalfa and alsike clover produced as much forage during the season as timothy.

Summary

The ability of a commonly recommended seeding mixture and several forage species to produce hay on a fibrous peat soil well fertilized with N, P and K has been observed for the first harvest year. Timothy and alsike clover performed very well and exceeded the alfalfa by a very small amount. This work will be continued several years to evaluate the productivity of these stand.

[1] In cooperation with the North Central Agricultural Experiment Station

Table 1. The yield of a seeding mixture and several forage species in 1959

Forage	Treatment: Seeding Rate (lb/A)	Yield (T/A): 1st Cutting	2nd Cutting	Total
Timothy	10	2.1	1.4	3.5
Alsike Clover	8	2.7	.8	3.5
Narragansett Alfalfa	15	2.1	1.1	3.2
Ranger Alfalfa[1]	15	2.1	1.0	3.1
Vernal Alfalfa-smooth bromegrass-timothy	8-6-2	2.0	1.0	3.0
Smooth bromegrass	10	2.0	.9	2.9
Empire birdsfoot trefoil	5	1.9	1.0	2.0
Meadow foxtail	10	1.5	1.2	2.7
Ladino clover	3	1.7	1.0	2.7
Meadow fescue	8	1.7	.7	2.4
Rough stalked meadow grass[1]	10	1.4	.8	2.2
hsd		.6	.4	.7
lsd		.4	.2	.4

[1]Only three replicates used.

A Forage Adaptability Study on an Aitkin County Peat Soil

by H. P. Hermanson and R. S. Farnham[1]

Purpose

The purpose of this trial was to determine the adaptability of several grasses and legumes to production hay on a fibrous peat.

Experimental Considerations

These trials were located at NE 1/4 Sec. 19 T48N R25W on a soil which the Soil Testing Laboratory of the University of Minnesota indicates is low (8 lb/A) in "available" phosphorus and very low (48 lb/A) in exchangeable potassium, and has a pH of 5.6. A sample taken 1/2 mile away has given N, P, and K response for potatoes in greenhouse but only K response in the field. Copper response by Piper Sudan Grass has been observed in the greenhouse. Two sites of differing distance from the drainage ditch were chosen. However, during the experiment little difference in water table level was observed.

During June, 1958, the following blanket treatment was broadcast: 10 lb N/A as 33-0-0, 30 lb P_2O_5/A and 90 lb K_2O/A as 0-20-20 and 0-0-60, 25 lb $MgSO_4$/A, 5 lb boric acid/A, 25 lb $CuSO_4$/A, 2T $CaCO_3$ equivalent/A as hydrated lime, 25 lb $MnSO_4$/A, 1 lb $(NH_4)_2MoO_4$/A and 10 lb $FeSO_4$/A. After broadcasting the grass and legumes shown in Table I at the indicated rates, the soil was rolled. The treatments

[1]In cooperation with Mr. Jacobsen

were repeated four times at each of the two sites,

The rainfall during the rest of 1958 and during the 1959 season was about normal for the area; whereas, the temperatures during June and July, 1958, were about 5°F below normal. Good snow cover existed during the winter and stand counts taken in the fall and the summer of 1959 indicated very good maintenance of stand.

June 27, 1959, the plots were cut and the yield and dry matter content of the forage was ascertained. At this time the alfalfa was just beginning to bloom. Subsequently, the plots were rolled and 50 lb N/A as 33-0-0 was broadcast on the plots having no legume while 100 lb P_2O_5/A as 0-46-0 with 300 lb K_2O/A as 0-0-60 was applied to all plots. August 6, 1959, the plots were again cut and yield and dry matter content determined. The total yield of dry matter of these two cuttings is given in Table 1. Analysis of variance on each site indicated rejection of the hypothesis of no treatment effect at the 1% level. Site had little effect on yield. Duncan's multiple range test indicated that the timothy, Vernal alfalfa-smooth bromegrass-timothy mixture, smooth bromegrass, and Narragansett Alfalfa performed at the same high level. The Kentucky Bluegrass and rough stalked meadow grass contained more weeds than the other treatment so occur higher in the table than their production ability could place them.

Summary

A forage adaptability study showed that with adequate N-P-K fertilization of a fibrous Aitkin County peat soil, timothy, smooth bromegrass and alfalfa produced very good hay yields the first season. Inferences about the overall performance of these legumes and grasses cannot be attempted until several years data is obtained so that maintenance of stand can be observed.

Table 1. Total 1959 forage yields produced by the Aitkin County peat soil

Treatment	Seeding Rate	Yield (T/A)		
Forage	(lb/A)	"Wet" site	"Dry" site	Both sites
Timothy	10	2.72	3.83	3.28
Vernal alfalfa, Smooth bromegrass and Timothy	8-6-2	3.15	3.39	3.27
Smooth bromegrass	10	2.88	3.56	3.22
Narragansett Alfalfa	15	2.80	3.33	3.07
Kentucky Bluegrass	10	2.36	3.21	2.78
Reed canary grass	10	2.16	3.31	2.74
Red top	10	2.00	3.14	2.57
Meadow fescue	7	2.22	2.88	2.55
Meadow foxtail	10	1.99	2.84	2.42
Rough stalked meadow grass	10	1.75	3.04	2.40
Birdsfoot trefoil	5	1.91	2.86	2.38
Red clover	10	1.71	2.67	2.19
hsd		1.00	.64	
lsd		.58	.38	

A Nitrogen, Phosphorus and Potassium Fertility Trial with Celery on a Peat Soil Located in St. Louis County

by R. S. Farnham, W. W. Nelson[1] and H. P. Hermanson

Purpose

The purpose of this trial was to determine the effect of rate of nitrogen, phosphorus, and potassium carriers on the yield of celery grown on a peat soil.

Experimental Considerations

The soil was an unfertilized fibrous peat located one half mile east of the Fens railroad station in St. Louis County, Minnesota. The soil had been recently cleared and had never been farmed or fertilized previously and was adequately drained. The University of Minnesota Soil Testing Laboratory reports this soil to be medium (18 lb/A) in "available" phosphorus, very low (35 lb/A) in exchangeable potassium, and strongly acid (pH 5.2).

In the springs of 1957-59 Utah 52-70 celery was fertilized with nitrogen as ammonium nitrate, P_2O_5 as treble superphosphate, and K_2O as muriate of potash at the rates shown in Table 1. The factorial treatments were laid out in a split plot design[2] having every combination of the nitrogen and phosphorus carrier rates as the 16 whole plots in each replicate. The whole plots were divided into six parts to furnish the subplots for the different potassium carrier rates.

Aster yellows attacked the 1957 crop and produced severe damage. The weather during 1957 and 1959 was near normal for the area but June and July, 1958 was considerably cooler than normal. The yield of celery plants showing no external damage from aster yellows is shown in table 1.

Analysis of variance of the 1957 yield shows that the main effect of nitrogen carrier is significant and those for phosphorus and potash carrier highly significant. No interaction effect was significant. As phosphorus carrier rate increased, portion of marketable celery plants decreased markedly. More aster yellows damaged plants occurred where some phosphorus carrier was applied than where none was put on. This effect is probably related to the physiology of the plant. The percent cull aster yellow plants declined as potassium carrier rate increased. Observation of Table 1 indicates that the highest 1957 yield of celery occurred at the 160-0-640 treatment. The data given is the average yield over all levels of the other two fertilizers. Had aster yellows been controlled, it is likely that a considerable higher response would have been observed especially with respect to phosphorus carrier rate. The top yield of marketable celery in 1957 was 19 T/A produced by the treatment 160-0-640.

---

[1]Dr. Nelson formerly of the NE Experiment Station, Duluth did this work in cooperation with Mr. Harold Andrews of Chunking Co.
[2]Suggested by Dr. C. E. Gates

In 1958 the total weight of celery produced was increased to a highly significant extent by the rates of nitrogen, phosphorus and potassium carriers. The interactions were not significant. Observation of Table 1 indicates that the highest yield would have occurred at a $N-P_2O_5-K_2O$ treatment level of about 160-160-640 during this year. Observations of individual plot yields indicates that 160 lb/A additional nitrogen increased yield from 25.9 to 27.1 T/A.

The analysis of variance has not yet been conducted on the 1959 data but it appears from Table 1 that 80-160-640 would have given the highest yield. The plot receiving this treatment produced 56.6 T/A.

Summary

Three years data indicates that 33-0-0 and 0-0-60 increases the amount of celery grown on a fibrous peat soil located in St. Louis County. The highest yields are produced by 80 to 160 lb N/A and 640 lb K_2O/A. Treble superphosphate increased aster yellow damage to such in 1957 as to cause a decrease in yield of marketable celery. During the following two years 160 lb P_2O_5/A produced the highest total yield of celery.

Table 1. The average yield (T/A) of Utah 52-70 celery produced by several levels of nitrogen, phosphorus and potassium carriers during 1957 to 1959.

N				P_2O_5				K_2O			
Rate (lb/A)	Year 1957[1]	1958[2]	1959[2]	Rate (lb/A)	Year 1957[1]	1958[2]	1959[2]	Rate (lb/A)	Year 1957[1]	1958[2]	1959[2]
0	3.3	14.7	36.6	0	5.1	12.3	13.3	0	1.6	11.1	28.8
80	3.8	15.6	38.2	80	4.4	18.6	38.0	80	2.8	14.4	31.7
160	5.2	18.5	37.6	160	3.8	19.3	39.3	160	3.8	15.8	35.7
320	3.7	17.3	37.0	320	2.7	16.0	38.7	320	4.9	18.2	40.0
								480	5.3	19.0	42.8
								640	5.5	20.3	44.3
hsd	1.8	2.9			1.8	2.9			1.2	1.8	
lsd	1.3	2.5			1.3	2.5			.8	1.2	

[1]Weight of celery showing no external symtoms of aster yellows
[2]Weight of all celery produced.

SOIL SERIES 59

Soil Erosion Experiments at Rosemount in 1959[1]

March, 1960

J. M. MacGregor

Soil erosion studies were initiated in 1952 on a 9% south-facing slope of Port Byron silt loam for the purpose of determining the effect of length and kind of crop rotation on soil and water losses. Resulting yields were also to be obtained on the differentially rotated crops. The twelve plots were 14 feet wide and 80 feet long (approximately 1/39 acre), having corrugated metal strips driven along the sides and the upper ends. A collection trough, sampling wheel, and sample tank were installed at the lower end. The 12" diameter sampling wheel was designed to divert one percent of the total soil and water removed from each plot into the sampling tank, where measurements of such losses could be made. None of the treatments were replicated, since it was initially considered to be more desirable to have a larger number of treatments on the limited areas and equipment available.

In addition to a pair of standard total rainfall gauges, a recording rainfall-intensity gauge was installed near the center of the 12 plot area. Measurements of rainfall characteristics were recorded from April 1st to November 1st of each year. Since the initial recording gauge stopped occasionally, a second recording rainfall-intensity gauge was later installed to insure a continuous record of the rainfall characteristics.

Plots to be planted to corn or to oats were plowed in the late fall of the preceeding year. All residues were returned to the soil. Since the installation of the collection equipment was not completed until late August of 1952, runoff and soil loss data were only obtained during September and October. However, rainfall records and crop yields were obtained.

In 1953, eight additional 14' x 80' plots were established on a west-facing 8% slope of the same soil type, for the purpose of comparing the effect of seedbed preparation by plowing versus that obtained by deep cultivation on the resulting water and soil losses and on crop yields. A four year rotation of corn, oats, and two years of alfalfa was established on each of two four-plot series, the soil of one set to be plowed for corn and for oats, the seedbed of the other set was prepared by deep cultivation for these two crops. Fertilizer was applied in the spring of each year to all 20 plots of the two erosion studies at the rate of 200 pounds of 5-20-20 per acre.

---

[1]The erosion plots are maintained on the Soils Unit of the Agricultural Experiment Station, Rosemount.

Paper No. 1048, Scientific Journal Series, Minnesota Agricultural Experiment Station.

It was soon evident that erosion plots need prompt, experienced, and almost daily care if reasonable results were to be secured. Variations in soil depth and composition within the two experimental areas, the depredations of both pocket and striped gophers, pheasants, badgers, and intra plot competition from crabgrass were real problems. The combined effect of the problems mentioned made the gathering of reliable soil and water loss data from individual plots essentially impossible, and crop yields were generally the most meaningful of the information obtained. Since corn populations were not uniform on all plots, yields were also unreliable in some years. There remained a reasonable possibility that experimental results would have more meaning as the experiment progressed over a period of years, but the results obtained in late years were no more reliable than those originally secured. It also became evident that a rotation with alfalfa occupying the land half of the time was maintaining the soil in very desirable tilth, but this very maintenance allowed little opportunity for measurable losses of soil and water to occur. It was evident that both adequate replication and a more rigorous land use regime were essential in both experiments and should be initiated if reliable results were to be obtained.

Therefore, early in 1959, the entire 12 plot area on the south slope was planted to oats seeded down to alfalfa, with the intention of equalizing the crop rotation effect of the differential cropping systems used during the previous seven year period. This was necessary since the fertility levels of these plots had been considerably modified by the different cropping practices previously employed, and there was little possibility of satisfactory replication until these differences were removed by similar fertility and cropping practices of a few years at least. The collection troughs and sampling equipment were left in place and these plots will be again used with fewer treatments and adequate replication when experimentally practical.

Many Minnesota farmers are growing continuous corn under good fertility management with apparently good results. The success of this innovation on comparatively level fields has made more information of the possibilities and hazards of such practices on sloping fields. For this reason, the cropping system of the eight plots of the western slope, where two methods of seedbed preparation were being compared, was changed in 1959 from the corn-oats-alfalfa-alfalfa rotation to a four-replicate study of soil and water losses under well fertilized continuous corn. The experimental management consisted of contoured 40" rows with a population of approximately 17,000 corn plants per acre, fertilized with 5-20-20 at the rate of 200 pounds per acre in the hill at planting. Ammonium nitrate to supply 80 pounds of fertilizer nitrogen per acre was broadcast on each plot in early July. The plots were cultivated once and later hand-hoed in early July.

Weather

Although the month of April, 1959, was drier than normal, more than 32 inches of rain fell during the seven month (April-October) period, with 12.13 inches falling during August alone. Ten rains caused water runoff from the eight plots, with three of these rains removing measurable amounts of soil.

Water runoff occurred on June 11, 18, 26, and 28; July 8, August 5, 17, 22, and 24; and on September 2. Soil was carried off the plots by the rains of June 26 (averaging 0.30 tons per acre), June 28 (averaging 1.26 tons per acre) and on July 8 (average soil loss of 0.28 tons per acre).

Although rainfall intensity is one important factor contributing to soil and water losses, high intensity rains do not always result in such losses, since they may be of relatively short duration or the soil might be initially dry and relatively absorbent. The dates of the higher intensity rains during the seven month period are shown below:

June 28	-	1 1/4 inches of rain in 45 minutes
July 8	-	2 1/20 inches of rain in 65 minutes
August 5	-	2 1/2 inches of rain in 180 minutes
August 16	-	1 1/2 inches of rain in 60 minutes
August 21	-	1 1/2 inches of rain in 40 minutes

The months of June, July, and August appeared to be the more critical period for possible soil and water losses in 1959.

Results

Runoff and Soil Erosion from Two Types of Seedbed Preparation on an 8% Slope of Port Byron silt loam at Rosemount with Resulting Corn Yields

(April-October inclusive, 1959)

	Av. of 4 plowed plots	Av. of 4 deeply tilled plots	Advantage for deep tillage soil preparation
Water runoff in inches	6.25	5.60	0.65 less
Runoff as % of total pptn.	19.2	17.2	2% less
Soil loss in tons per acre	2.37	1.29	1.08 less
Bushels of ear corn/A @ 15.5% moisture	118.5	122.4	3.9 bushels more
% moisture in ear corn	33.3	31.4	1.9 less

Conclusions from the 1959 experiments

1. Nearly a fifth of the total seven month precipitation was lost by runoff. Approximately six inches of rain which fell was not available for crop production and possible storage in the soil.

2. The six inches of runoff water removed approximately two tons of soil per acre.

3. The plowed corn plots lost more water and more soil than did the corn plots where the seedbed was prepared by deep cultivation only.

4. The eight plots produced ear corn at the average rate of 120 bushels per acre. Although the average yield of the deep tillage plots was approximately four bushels greater than that of the plowed plots, this was of doubtful significance.