Table 16. Sulfur in precipitation.

Location	Park Rapids		St. Paul		Duluth		Lamberton	
	Precip. inches	S lbs/A.	Precip. inches	S lbs/A	Precip. inches	S lbs./A	Precip. inches	S lbs/A
(Oct. '62- Sept. '63)	19.67	3.10	20.74	13.26	19.18	6.91	26.56	6.38
(Oct. '63- Sept. '64)	27.78	4.37	23.75	14.70	36.37	9.49	22.08	6.84
24 Month Total	27.45	7.47	44.49	27.96	55.55	16.40	48.64	13.21
Yearly Average	23.72	3.74	22.24	13.98	27.77	8.20	24.32	6.60

Table 17. Sulfur in the atmosphere.

Location	Park Rapids SO_2 lbs./A	St. Paul SO_2 lbs./A	Duluth SO_2 lbs./A	Lamberton SO_2 lbs./A
(Oct. '62- Sept. '63)	6.50	33.72	9.33	5.58
(Oct. '60- Sept. '64)	3.43	34.11	5.92	3.02
24 Month Total	9.93	67.83	15.25	8.60
Yearly Average	4.96	33.92	7.63	4.30

Sulfur Status of Minnesota Soils

G. W. Rehm

In May of 1964 a study of the sulfur status of Minnesota soils was started. For this study seventy nine samples were collected from widely scattered sites in Minnesota. These soils are being examined in two ways. In one instance the sulfur oxidizing power is being investigated; in the other case the sulfur supplying power to plants is under examination.

Sulfur Oxidation

Of the samples collected, fifty two were selected for this study. These samples were taken from surface horizons and represent a wide range in pH (from 4. 3 to 7. 7), organic matter content, and texture classes.

Procedure:

For this experiment 100 grams of air dried soil was mixed with 100 ppm of elemental sulfur (100 mesh) in a 1/2 pint polyethylene box. The treatments were replicated three times. Water was added to the boxes to maintain a moisture level of 1/2 field capacity. The boxes were aired every three days and water was added once a week to maintain the moisture level. At the end of 30, 60 and 90 days the soils were analyzed for SO_4-S by extraction with 0. 5M ammonium acetate in 0. 25N acetic acid according to the procedure of Bardsley and Lancaster.[1] The pH readings were also taken at the time of extraction.

---

[1]Bardsley, C. E. and Lancaster, J. D. Determination of Reserve Sulfur and Soluble Sulfates in Soils. Proc. Soil Sci. Soc. Am. 24:265-268. 1960.

Results and Discussion:

At the present time analyses are completed for 31 of the 52 soils in this study. The data are presented in Tables 18, 19 and 20. On the basis of studies completed at this time it is generally true that the added sulfur was more completely oxidized in the sands, loams, and silt loams than in the clay loams and silty clays.

In 90% of sandy soils more than 55% of the sulfur was oxidized at the end of 90 days. Except for the Dakota soil, more than 75% of the sulfur was oxidized at the end of 90 days in those soils with a pH greater than 6.0. The Isanti soil with a pH of 4.3 oxidized only 40.4% of the sulfur. Thus in the sandy soils there may be a relationship between soil pH and the amount of sulfur oxidized. However, there seems to be no relationship between the organic matter content of the sandy soils and sulfur oxidation.

With the loams and silt loams more than 55% of the added sulfur was oxidized after 90 days in 75% of the soils studied. In 37% of the soils in these textural classes more than 70% of the sulfur was oxidized. With these textural classes there does not seem to be a relationship between sulfur oxidation and soil pH. In the Adolph soil with a pH of 5.2, 95.7% of the sulfur was oxidized; in the Marna soil of pH 7.2 only 39% of the sulfur was oxidized. As with the sandy soils, there appears to be no correlation between sulfur oxidation and the organic matter content of the soils in this group.

It is interesting to note that more than 100% oxidation occurred in the Winger soil. A possible explanation is that the microbial activity may have been stimulated by the added sulfur thus causing mineralization of the organic matter. Since this soil is extremely high in organic matter, the excess sulfur may have come from this fraction.

In the clay loam and silty clay textural classes more than 55% of the sulfur was oxidized in 43% of the soils studied. There were no instances where more than 70% oxidation occurred. If the Vallers soil is excluded, there again appears to be a relationship to soil pH. Greater oxidation occurred in the soils with a pH greater than 6. 0.

When the analysis is completed on the other soils in this study, we may be able to draw more definite conclusions.

Table 18. The Oxidation of Elemental Sulfur in Loam Sands and Sandy Loams.

Soil Type	pH	% O. M.	Incubation Time (days) 0	30 OS added	30 100 ppm S added	30 S Oxid.	60 OS added	60 100 ppm S added	60 S Oxid.	90 OS added	90 100 ppm S added	90 S Oxid.
			ppm S									
Bock Sandy Loam	5.7	5.1	12.2	25.7	65.8	40.1	26.9	83.6	56.7	33.3	100.4	67.1
Chetek Loamy Sand	5.7	1.8	14.2	11.9	40.0	28.1	13.8	57.4	43.6	11.4	68.5	57.1
Dakota Sandy Loam	6.6	2.9	31.7	32.9	58.3	25.4	38.6	86.7	48.1	37.4	93.1	55.7
Grygla Loamy Sand	7.6	3.5	17.3	22.4	54.6	32.2	22.4	64.4	42.0	31.7	109.6	77.9
Hiwood Loamy Sand	6.2	2.2	20.0	22.3	59.2	36.9	15.8	78.8	63.0	17.8	93.0	75.2
Isanti Loamy Sand	4.3	8.5+	10.7	34.8	63.7	28.9	38.7	85.8	47.1	39.6	80.0	40.4
Lino Loamy Sand	5.0	4.0	6.6	24.3	57.9	39.6	24.4	67.9	43.5	28.2	84.4	56.2
Sverdrup Sandy Loam	6.8	3.0	13.8	20.5	58.0	37.5	25.0	89.0	64.0	27.8	107.2	79.4
Swatora Loamy Sand	5.5	2.8	22.8	24.7	54.4	29.7	27.5	81.6	54.1	29.0	94.3	65.3
Ulen Sandy Loam	7.4	5.2	21.5	18.2	90.8	72.6	17.1	94.3	77.2	22.0	110.6	88.6

Table 19. The Oxidation of Elemental Sulfur in Loams and Silt Loams.

Soil Type	pH	% O. M.	Incubation Time (days) 0	30 OS added	30 100ppm S added	30 S Oxid.	60 OS added	60 100ppm S added	60 S Oxid.	90 OS added	90 100ppm S added	90 S Oxid.
			ppm S									
Adolph Loam	5.2	8.5+	31.5	44.9	87.4	42.5	60.4	125.9	65.5	54.8	150.5	95.7
Bearden Silt Loam	7.6	6.1	45.3	71.4	85.9	14.5	72.9	99.9	27.0	75.3	152.3	77.0
Beltrami Loam	6.8	4.8	9.3	15.9	32.2	16.3	39.0	109.8	70.8	89.0	163.8	74.8
Fayette Silt Loam	6.1	8.5+	12.7	23.2	53.8	30.6	27.0	74.7	47.7	27.4	91.2	63.8
Marna Silt Loam	7.2	7.0	37.1	43.3	71.3	28.0	50.5	92.2	41.7	62.7	101.7	39.0
Moody Silt Loam	7.1	4.9	16.3	19.0	56.8	37.8	20.9	75.1	54.2	28.4	85.4	57.0
Mora Loam	6.6	3.3	12.7	41.8	79.8	38.0	39.0	97.2	58.2	66.0	132.8	66.8
Nebish Silt Loam	6.4	3.8	24.2	30.3	71.4	41.4	34.1	99.7	65.6	38.8	112.0	73.2
Onamia Loam	6.0	2.3	5.6	22.7	63.0	40.3	20.8	80.2	59.4	24.4	96.9	72.5
Parnell Silt Loam	7.3	8.5+	64.3	92.0	110.0	18.0	101.7	143.5	41.8	145.2	214.8	69.6

Table 19 (cont'd)

Soil Type	pH	% O. M.	Incubation Time (days) 0	30 OS added	30 100ppm S added	30 S Oxid.	60 OS added	60 100ppm S added	60 S Oxid.	90 OS added	90 100ppm S added	90 S Oxid.
			ppm S									
Port Byron Silt Loam	5.7	5.2	30.6	29.0	46.0	17.0	26.3	62.6	36.3	28.8	73.5	44.7
Shooks Loam	5.5	2.8	12.4	19.1	42.8	23.7	21.8	63.5	43.7	26.0	85.7	59.7
Tama Silt Loam	6.9	5.0	7.6	25.7	46.0	20.3	32.6	55.3	22.7	29.6	76.4	46.8
Wadena Loam	5.6	5.5	10.2	24.5	46.6	22.1	28.6	57.3	28.7	25.1	60.3	35.2
Winger Silt Loam	7.9	8.5+	86.0	96.0	208.4	112.4	118.0	242.5	124.5	136.3	261.3	125.0
Zim Loam	5.5	6.1	26.8	34.4	57.6	23.2	39.0	89.4	50.4	42.0	102.8	60.8

Table 20. The Oxidation of Elemental Sulfur in Silty Clays and Clay Loams.

Soil Type	pH	%O. M.	Incubation Time (days) 0	30 OS added	30 100ppm S added	30 S Oxid.	60 OS added	60 100 ppm S added	60 S Oxid.	90 OS added	90 100ppm S added	90 S Oxid.
			ppm S									
Brickton Clay loam	5.4	6.4	37.8	30.8	50.7	19.9	37.4	69.8	32.4	45.6	86.6	41.0
Dalbo Clay loam	5.2	4.3	20.2	15.5	39.8	24.3	17.1	55.3	38.2	20.6	69.7	49.1
Kittson Clay loam	7.6	5.7	29.7	31.9	83.3	51.4	34.2	90.5	56.3	44.5	112.3	67.8
Nessel Clay loam	5.7	4.2	28.8	28.8	55.9	27.1	30.2	70.7	40.5	25.4	78.3	52.9
Rothsay Clay loam	7.1	6.7	27.3	26.2	75.9	49.7	28.3	89.6	61.3	37.3	98.6	61.3
Vallers Silty clay	7.5	5.5		256.7	280.0	23.3	244.2	266.7	22.5	301.5	339.7	28.2
Vienna Clay loam	6.5	5.6	13.4	26.0	45.3	19.3	22.2	60.2	38.0	24.9	84.3	59.4

Sulfur Supplying Power

As a result of studies during 1962, 63 and 64, we know that the certain crops grown on the Todd sandy loam will respond to the application of sulfur. (Reports 1, 2, 3 & 4). In 1964 a study was started to determine if other Minnesota soils were more so or just as sulfur deficient as the Todd sandy loam. For this study the seventy nine samples previously described were used.

For this study an airtight chamber 6 ft. x 6 ft. x 4 ft. was used to maintain a sulfur dioxide free atmosphere. Since the atmosphere of St. Paul, Minnesota contains a large amount of sulfur dioxide it is necessary to maintain a sulfur dioxide free atmosphere to accurately measure the sulfur power of soils.

Procedure:

To determine the sulfur supplying power of these soils 350 grams of soil were placed in a waxed cottage cheese carton 4 inches in diameter. Treatments consisted of sulfur as gypsum at 11#/A and no sulfur. These treatments were replicated three times for each soil. Grain sorghum was then planted at a rate sufficient to give 40 plants per cup. The cups were then placed into the chamber, the chamber was completely sealed and the plants were allowed to germinate and grow for 21 days. The cups were watered to field capacity every 3 or 4 days depending upon weather conditions. A nutrient solution was used at alternate watering times. This nutrient solution contained N, P, K, Ca, Mg, Zn, Fe, Mn and B in relatively the same concentrations as described by Hoagland.[2] At the end of 21 days the plants were

---

[2]Hoagland, D. R. and Arnon, D. I. The water culture method for growing plants without soil. Calif. Ag. Exp. Sta. Cir. 347: 1950.

harvested, the dry weight taken and the total sulfur determined by wet digestion.

Results and Discussion:

At the present time analyses are completed for fifteen of the seventy nine soils. The data are presented in Table 21. It is interesting to note that plants grown on the Rockwood soil that received no sulfur were much lower in total sulfur than those grown on the Todd soil. This would indicate that this soil is even more sulfur deficient than the Todd. Plant grown on the control pots of the Lino, Moody, Sverdrup, Swatara, Ulen, and Wadena soils had relatively the same sulfur content as those plants grown on the Todd soil. This indicates that these soils may also be sulfur deficient or show a response to sulfur in the field.

It is also interesting to look at the sulfur content of the plants grown on the sulfur treated soils and then to compare the differences in percent sulfur between plants grown on the control and the sulfur treated soil. Plants grown on the Rockwood soil had a percentage difference of .505 compared to a difference of .328 for plants grown on the Todd soil. Soils which show differences of the same relative magnitude as the Todd are the Lino, Sverdrup and Swatara. Although plants grown on the Ulen soil were low in total sulfur, the plants grown on the sulfur treated soil did not show a great deal of an increase in the total sulfur content. Apparently something is limiting sulfur uptake from this soil.

The studies of sulfur oxidation and the sulfur supplying power of Minnesota soils are being continued. Other work in progress includes the determination of total, available, phosphate extractable and water soluble sulfur in these Minnesota soils.

1964 Boron Experiments on Alfalfa

J. M. MacGregor

For some years the Department of Soil Science has been recommending preventative applications of boron to fertilized alfalfa fields of northeastern Minnesota. The recommendation was originated following the observation of boron deficiency symptoms in alfalfa in several counties of northeastern Minnesota during the relatively dry summer of 1960. A comparatively wet spring followed by a relatively dry mid-summer season favors the development of boron deficiency symptoms, and since the amounts recommended of one to two pounds of boron (10 to 20 pounds of borax) per acre are relatively low in cost, the preventative recommendation has been comparatively routine since 1961.

Several Carlton County farmers with relatively large areas of limed and fertilized legumes (which they leave down from three to five years) have questioned the value of the recommended boron treatment for increasing yields of legume hay, and it was decided early in 1964 to initiate relatively long term studies on several legume fields as to boron effect on both vegetative boron deficiency symptoms and annual hay yields.

Following the removal of the first cutting of hay, three fields were established, and a fourth on a new seeding. Second cutting yields were obtained on the three established fields, although they were relatively light. Ample phosphorus and potassium fertilizer was applied in addition to the boron using six replications in a latin square design.

The following results were obtained:

Treatment No.	Treatment (lbs/A)	Second cut dry hay yield (tons per acre) Benson	Oraskovitch	Waisanen
1	none	0.41	0.22	0.36
2	500 # of 0-12-36/A	0.55	0.22	0.47
3	" " " /" + 1 # of B	0.69	0.19	0.47
4	" " " /" " 2 # " "	0.62	0.24	0.49
5	" " " /" " 1 # " "	0.62	0.23	0.55
6	" " " /" " 2 # " "	0.62	0.24	0.48

On the Benson and Waisanen fields, growth and yellowing seemed improved by the addition of the 0-12-36 and the two rates of boron seemed to decrease the yellowing further, but did not remove it entirely. Although it is still much too early to make any conclusions, the PK treatment improved, but the boron seemed to have little effect on the second cutting of 1956. The Oraskovitch field showed neither visual nor yield effect of either the PK or the B treatments.

Annual applications of boron to treatments 5 and 6 shall be made each spring to determine the effect of annual boron additions to both vegetative color and legume hay yield.

A fifth field shall be established in western Carlton County in the early spring of 1965.

Zinc Deficiency of Corn in Minnesota

Orville Gunderson, David Bezdicek and John MacGregor*

Introduction

All plants require zinc for normal growth and seed production. Since relatively small amounts are essential, zinc is known as one of the 'trace' or 'micronutrient' elements. The average zinc content of corn grown on an acre of Minnesota soil is only about three ounces or less than the amount needed in the manufacture of a ten quart galvanized pail. Since growing plants are unable to extract all of the zinc from the soil, it is essential that a larger total quantity be present in soils.

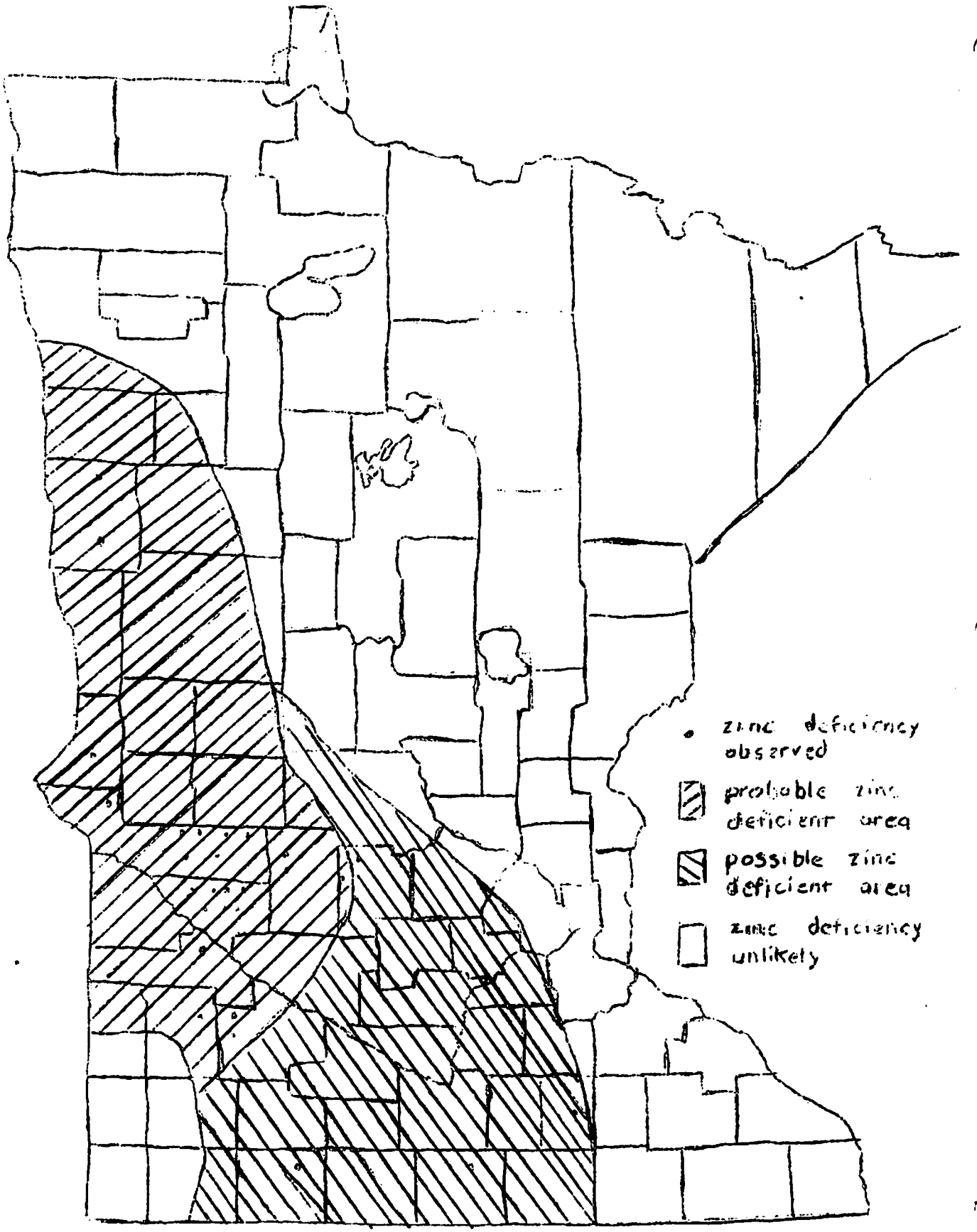
Although zinc deficiencies may occur in plants growing on acid soils, they are usually first observed on alkaline (high pH) organic and mineral soils containing substantial amounts of free lime (calcareous in nature). These soils are found extensively in western and parts of southern Minnesota where the deficiency has been most frequently observed (see map). Such deficiencies are more frequently observed on soils naturally high in phosphorus, or soils that have recently received heavy applications of phosphate fertilizer.

Corn following sugar beets is frequently zinc deficient, and many attribute this to the relatively heavy phosphorus fertilization for the beet crop. Zinc deficiency

---

* A similar presentation of the zinc problem in Minnesota will soon be published in an extension or experiment station bulletin.

Zinc Deficiency of Corn in Minnesota



is more frequently observed following a cool, wet planting season and under poorly drained soil conditions.

Recognizing Zinc Deficiency in Corn

Zinc deficiency symptoms of corn generally occur in a characteristic sequence. More commonly the plants remain green during the first month but have a stunted growth. Then in late June or early July, thin, longitudinal, pale yellow stripes develop between the edge of the leaves and the midrib. These stripes extend from the base to the top of the leaf and often occur in irregular patterns.

The first leaves affected are the older (lower) leaves which are striped and comparatively narrow. The younger (upper) leaves may remain green unless the deficiency is severe. In severe deficiencies, the lower leaves may develop the pale yellow striping shortly after emergence. These pale stripes may then become bleached and appear to dry up. A reddish-bronze coloration is sometimes evident over portions of the seriously deficient leaves. The ears produced by serious deficient plants are poorly filled with chaffy kernels.

In mild deficienceis, only minimal striping of the lower leaves is observed, and bronzing does not occur. A minimum of stunting may be present, and as the growing season progresses, growth appears to be nearly normal with only slightly reduced yields.

The degree of zinc deficiency may vary considerably in a single field depending on local soil conditions. In areas where the deficiency is severe, poor and untimely pollination may occur. Although the entire field may be treated with zinc, such treatment is usually essential only on those portions of the field on which the corn plants are visibly affected.

Results of Field Experiments in Minnesota

In 1962, three field experiments were established in south central Minnesota to determine the most effective methods of zinc application and the rates needed to correct deficiency of corn. At two of the experimental plot locations, severe zinc deficiency sumptoms had been observed on growing corn during the previous year. The third soil site was one that was suspected of being deficient in available zinc.

All three soils were calcareous; one was a peat soil in northwestern Meeker County, and the other two were fine textured mineral soils in southern Kandiyohi County. The experimental plots were fertilized at rates of 100 lbs. nitrogen, 100 lbs. phosphate, and 50 lbs. of potash per acre to insure that adequate amounts of these nutrients would be available for the corn plants. The fertilizer was broadcast and plowed under.

The zinc treatments consisted of various rates of zinc sulfate either broadcast and plowed under, or banded using a corn planter fertilizer attachment. Tw ments of zinc chelate (Na_2Zn) coated to the seed corn were included with tl

tions of each treatment on each field.

The results of the various treatments on one field in Kandiyohi County are shown in the table to illustrate the first year effectiveness of the zinc treatments. A heavy application of atrazine was used late in June 1962 to control a serious quackgrass problem. In 1963, this field was planted to soybeans, and the residual atrazine effect reduced the stand of the soybeans so severely that no crop was harvested. The field was planted to corn in 1964 and the yields were checked in the plot area. The residual effects on zinc applied in 1962 on corn yields in 1964 are also shown in the table.

During the 1962 growing season, severe symptoms of zinc deficiency were observed on the corn plants where no zinc was applied. Broadcasting and plowing the zinc sulfate under at the rate of 30 pounds per acre eliminated essentially all of the vegetative symptoms. The 15 pound-per-acre-rate resulted in about 20% of the corn plants being either stunted or with a noticeable striping of the lower leaves. Analyses of the leaves confirmed the field observation that the zinc sulfate broadcast at the rate of 15 pounds (5 pounds of zinc) per acre and plowed under was barely adequate to correct the zinc deficiency of corn on this field.

The 1962 yield of ear corn was increased by 16 bu. per acre by the application rate of 15 lbs. of zinc sulfate per acre broadcast and plowed under. Rates higher than 30 lbs. of zinc sulfate seldom showed a significant increase in the 1962 corn

yields.

Research has shown that when zinc is applied as a starter fertilizer, it is usually more effective when mixed with some form of ammonium nitrogen. The nitrogen apparently increases the zinc uptake by the growing corn plants. This interaction was evident in the 1962 yields when comparisons were made between the treatment rates of 30 pounds of zinc sulfate per acre, either with or without nitrogen.

Nitrogen without zinc, applied as starter fertilizer, increased the yield of corn over the no zinc corn. This increase probably was due to (1) the placement of the nitrogen stimulating root development in the cool wet spring, and (2) the acidic effect of the nitrogen residue may have increased zinc availability. Zinc alone, applied with a corn planter fertilizer attachment, resulted in a lower yield of corn than where the zinc was mixed with nitrogen fertilizer and applied in the same way.

Zinc banded near the seed was not as effective in correcting the zinc deficiency symptoms of the corn plants as was that broadcast and plowed down. An X-ray fluorescent analysis of the corn leaves showed a greater uptake of zinc by corn plants growing on the broadcast treatments. Yields of ear corn from the banded zinc treatments were slightly lower than those from the broadcast treatments.

Seed treatment (coated) with zinc chelate (Na_2Zn) was apparently not an effective method to correct zinc deficiency of corn in 1962. Yields of corn grain were increased only slightly where the seed was coated with the zinc chelate. No growth response

The Effect of 1962 Zinc Fertilization of a Zinc Deficient Soil in Southern Kandiyohi County on the Yields of 1962 and 1964 Field Corn.

Ear corn yield in bushels per acre at 15.5% moisutre

1962 Treatment (lbs/A)	Direct effect in 1962	Residual effect in 1964
No zinc	43	40
Zinc sulfate broadcast and plowed under		
15 of zinc sulfate	69	58
30 of " "	66	56
60 of " "	76	56
120 of " "	67	60
Zinc sulfate and nitrogen applied as banded starter		
20 of nitrogen (N) alone	61	41
30 of zinc sulfate	59	53
20 of N plus 15 of zinc sulfate	63	58
20 of N plus 30 of " "	63	58
20 of N plus 30 of " "	64	65
20 of N plus 60 of " "	63	62
Zinc chelate coated on seed corn ($7\frac{1}{2}$ oz. Na_2Zn per bushel)		
Seed treatment alone	55	51
Seed treatment plus 30 lbs. of zinc sulfate plowed under	74	67

was noted and there was but little increase in the uptake of zinc by plants from this method of application.

One of the two other fields where the deficiency of zinc was severe showed similar results to those described here. An early fall frost reduced the corn yields, but yield increases from the use of zinc were still significant.

On the third field, only a few corn plants were deficient in zinc. No significant increase in corn yields from any of the rates or methods of application of zinc were obtained on this soil although yields on those plots treated with zinc were 2 to 7 bu. per acre higher than on those where no zinc was applied. Where corn exhibited no symptoms of zinc deficiency, there was little if any increase in yeild from applying zinc.

Residual Effects of Soil Applied Zinc

Carryover or resiudal effect on succeeding crops is of primary interest to corn growers who have zinc deficient soils. Research shows that a soil application of zinc will benefit crops for several years even though some of the applied zinc may be converted to unavailable forms. However, the total amount of zinc taken up by an acre of corn is relatively small and residual effects may be expected for some years. Soil composition will determine how much of the applied zinc remains available in succeeding years, and this will vary from one soil to another.

Residual zinc effect on corn growth was studied in 1964 following the 1962 zinc treatments. No additional zinc was applied. The 1964 corn yields were shown in the previous table.

The 1964 increases in corn yield from the residual 1962 applied zinc were much the same as those obtained two years previously. As little as 15 pounds of zinc sulfate per acre, broadcast in 1962, resulted in an increased corn yield of 26 bu. per acre in the first year and of 18 bu. two years later. There were no significant differences in the yields on those plots receiving higher rates of zinc. There was an increase in the uptake of zinc by the plants with the increased rate of application.

The plots with zinc banded in 1962 also showed a good residual effect. The field had been plowed both in the fall of 1962 and 1963 across the plots and apparently this did a thorough job of mixing the zinc with the soil.

Correction of Zinc Deficiency

If zinc deficiency symptoms are found in a field it is generally difficult to correct it in that year, although Nebraska researchers advise an injection of nitrogen and zinc sulfate water solution. However, zinc should be applied before planting sensitive crops in the following year. In most cases it is not economical to apply zinc fertilizer until a definite deficiency has been observed in the field.

There are several zinc carriers available for farmers which are economically effective in correcting zinc deficiency of corn. The most widely used materials are

zinc sulfate and Na_2Zn (chelate) although any water soluble form of zinc would be beneficial. Most fertilizer dealers can readily obtain a supply of suitable zinc materials. Granular zinc containing compounds which are easy to handle are available and they can be blended with most commercial fertilizers.

Commercial fertilizers with added trace elements usually do not contain enough zinc to correct zinc deficiencies of corn unless specifically manufactured for that purpose. Most research workers agree that the best way to use micronutrients is to identify the deficiency in the crop and then add only those elements needed in quantities sufficient to correct the deficiency.

The recommended rate of zinc application for corn is 10 pounds of zinc per acre when an inorganic carrier such as zinc sulfate is used. Zinc sulfate contains from 26 to 40% zinc. When a chelated form of zinc is used, the rate of application should be 0.5 to 1 pounds of zinc per acre. Chelated zinc compounds usually contain from 6 to 14% zinc. New products of higher analysis will undoubtly be available in the future.

Broadcast and plowed down zinc fertilizer has been shown to be more effective for corn than the starter application. A spot treatment of only the deficient areas in a field may be given a broadcast treatment and it is essential that the zinc be plowed under to get maximum results in the first growing season.

Zinc fertilizer may also be banded slightly below and to the side of the corn seed using a fertilizer attachment on the corn planter. Greater benefits may be obtained when the zinc is mixed with fertilizer containing nitrogen with little, or preferably, no phosphate.

Zinc for Corn Following Sugar Beets

It has been reported in Minnesota and in other states that when corn follows sugar beets in a crop rotation the corn frequently fails to develop normally and often the yields are low. Research has shown that sugar beets are heavy users of zinc but they will seldom respond to applied fertilizer zinc.

When a zinc-sensitive crop such as corn follows sugar beets there is usually a deficiency of zinc for that crop. The deficiency of zinc is most obvious during the early growth of the corn until about mid July. As previously mentioned, heavy phosphorus fertilization of the sugar beet crop may be at least partially responsible for the zinc deficiency of the corn.

When corn is planted after sugar beets on calcareous soils which have had heavy rates of phosphate fertilization, some zinc should be applied to the soil. This can be done when the fertilizer is broadcast for the sugar beets, or with a fertilizer attachment on the corn planter. Rates of application are the same as those suggested above.

Zinc effectiveness may be shown by applying the same rates of fertilizer to the entire field. On part of the field, apply zinc along with the fertilizer and make careful observations should be made both during the corn growing season and at harvest.

The Zinc Concentrations in Corn Leaves of Ten Commercial Hybrids Growing at Waseca, Lamberton and Morris in 1964.

J. M. MacGregor, D. Bezdicek and Robert Peterson

Previous research on the zinc concentrations of corn leaves growing on several soil types in Minnesota had shown a good correlation between the analytical data and the visual evidence of zinc deficiency in corn (striping of the leaves). Other investigators have shown that corn plants whose sixth corn leaf contains less than 15 parts per million (ppm) of zinc will probably respond to zinc fertilization, plants with leaves having 15 to 20 ppm zinc may respond to zinc treatments, while those having leaves with 20 or more ppm. Zinc are not likely to be deficient. Studies conducted on Minnesota soils and corn plants during the past three years have generally been in agreement with this observation.

However, it was desirable to determine the extent of variation in the zinc content of corn leaves of different commercial hybrids growing on the same soil type, since, if significant differences occurred in plants of different hybrids, obviously this would nullify, or at least make much more difficult the analytical separation of zinc deficient corn on the bases of soil type. For this reason five leaves (6th) were sampled on each of four replications from ten different commercial corn hybrids growing on the Corn Performance Trials (Dept. of Agronomy and Plant Genetics) at Waseca, Lamberton, and Morris in mid-July. These leaves were washed, dried, ground, and analyzed for zinc content by the x-ray fluorescence method in the Department of Soil Science, and also by the spectrographic procedure (quantometer) at the Ohio State University. The corn hybrids and the average analyses of leaves from each of four replicate corn plots were as follows:

The Average Zinc Concentrations in Sixth Corn Leaf of Ten Commercial Hybrids Grown at Waseca, Lamberton and Morris in 1964 by X-Ray Fluorescence and by Quantometer Analyses..

(Average of four replicates)

Corn hybrid	X-ray fluorescence data			Quantometer data (Ohio		
	Waseca	Lamberton	Morris	Waseca	Lamberton	Morris
Cargill E 40[2]	27	29	--	33	49	
De Kalb x L 45	34	27	--	44	32	
" " x L 441	--	22	--	--	27	
Kingserost KM571	28	28	--	43	40	
Pioneer 352	31	28	--	52	34	
" 371	25	22	--	25	31	
" 349	29	30	--	30	42	
United Haie UH138	26	22	--	41	22	
Minhybrid 417	33	25	--	45	37	
" 418	33	27	--	51	31	
Cargill 570	--	--	17	--	--	12
De Kalb 61	--	--	20	--	--	16
" " x L 15	--	--	19	--	--	18

(con't)

Kingserost PX487	--	--	22	--	--	19
Pioneer 377A	--	--	18	--	--	20
" 384	--	--	19	--	--	11
" 385	--	--	18	--	--	14
United Hagie UH127	--	--	17	--	--	12
Minhybrid 611	--	--	24	--	--	22
" 612	--	--	18	--	--	14

It is evident that the two methods of analysis from the same samples do not always produce the same values. The quantometer data from Ohio more frequently indicates the leaf zinc concentrations to be much higher than that obtained by x-ray fluorescence equipment in this department. However, both methods of analysis show zinc concentrations of the corn leaves from Waseca and Lamberton to be well above the minimum zinc level previously mentioned as critical for normal corn growth.

At Morris, three plot replicatss were located on the lower lying Aastad soil and one replicate on Barnes loam, about a half-mile distant. The corn leaves from the Aastad soil were markedly lower in zinc than those from plants growing on the Barnes loam.

The corn leaves from Morris contained much lower zinc concentrations than leaves from either Lamberton or from Waseca, but since they were all different hybrids with a shorter maturity, it is not clear whether the lower zinc content is due to the smaller amount of available zinc in the two Morris soils or is caused by the earlier maturing hybrid growth. In general, the hybrids grown at Morris contained questionably low levels of zinc (by both analytical methods) and might respond to zinc fertilization, whereas those from either Lamberton or Waseca apparently contained ample zinc for normal corn growth.

Since the variations in the zinc content of the corn leaves between replications and methods of analysis were quite large, there was no mathematically significant difference between the corn leaves of the different commercial hybrids investigated.

SOIL FERTILITY INVESTIGATIONS OF GRASS SEED PRODUCTION FIELDS IN NORTHWESTERN MINNESOTA - 1964

J. Grava, R. S. Farnham, M. V. Halverson
W. P. Martin and J. M. MacGregor

Grass and legume seed production has become an important agricultural enterprise in Roseau, Lake of the Woods Counties and adjacent areas in Northwestern Minnesota. Kentucky bluegrass and timothy are the two grass species grown for seed production in that area.

Soil fertility investigations were conducted by P. M. Burson, J. M. MacGregor and co-workers from 1959 to 1963[1]. The investigations dealt mainly with the effects of fertilization with primary nutrient elements N, P and K on the yields of grass seed. Fertilizer rates and the time of application were studied on mineral and organic soils in the main seed production areas. The findings of those studies have been helpful to growers in the use of commercial fertilizers on seed production fields.

This report deals with the findings of a survey made in 1964 on the chemical composition of soils and plants obtained from seed production fields. Investigated were eleven fields in Roseau County and one field in Lake of the Woods County. Seven of a total of nine Park Kentucky bluegrass fields were on mineral soils and two on peat. Also studied were two timothy fields on mineral soils.

Plant samples were obtained about the time when grasses were heading out. Soils were classified and samples were collected from the same spots within each field from which the plant material had been obtained.

The mineral soils (Tables 1 to 9) showed the following main characteristics: All of the soils were strongly alkaline, with pH values of 7.4 to 8.1 in surface and 7.8 to 8.6 in subsoil. The exchangeable sodium content in five soils ranged from 0.3 to 0.7 m.e. per 100 grams of soil, in three other soils from 0.3 to 2.1 m.e., and in a Bearden sicl from 1.3 to 4.1 m.e. The electrical conductivity, indicating presence of soluble salts, in saturation extract of the Bearden sicl ranged from 3.1 to 5.2 mmhos./cm. Soils with conductivity readings of more than 4 mmhos. are classified as moderately saline, and the yield of many crops may be restricted. The saturation extract from this Bearden soil also contained sulfates, ranging from 1350 ppm. $SO_4^=$ at 4 - 5 inches to 239 in the 18 - 24 inch layer. The corresponding contents of chlorides were 20.3 ppm. Cl^- at 4 - 5 inches and 56.8 ppm. at 18 - 24 inches. The conductivity values in other mineral soils were not as high and ranged from 0.65 to 3.5 mmhos.

---

1) Preliminary results of the investigations have been reported in the Soil Science Department "Blue Books" of 1961, 1962, 1963 and 1964.

The mineral soils also contained free carbonates, particularly in the subsoil. While the total carbonate content of the topsoils did not exceed 6%, the subsoils, below a depth of 8 or 10 inches showed a carbonate content of 10 to 40%. The cation exchange capacity of soil in the top one inch ranged from 12 - 30 m.e. per 100 grams and 7 - 15 m.e. at the depth of 18 - 24 inches.

The presence of free carbonates in soils may affect the nutrition of grasses. Applied phosphorus may be fixed and thus become unavailable to plants. The uptake of potassium also may be impaired. Sodium and other soluble salts may be detrimental to the seed production of grasses.

Phosphorus availability in the calcareous soils formed from lacustrine sediments is known to be low. Routine soil tests indicated that the P and K top-dressed by growers had remained mainly in the top two to three inches of soil. Present recommendations of limiting the soil depth to the top two or three inches when sampling meadows or grass production fields are substantiated by these findings.

The two peat soils studied were located on the Charles Habstritt farm in Roseau County. The surface horizon of these deep peats were partly decomposed to well decomposed with some fine fiber. Beginning at 10 inches the horizons below the surface were very fibrous to fibrous consisting of plant remains with some finely divided decomposed organic material between fibers.

The data in Tables 10 and 11 show these peats to be high in calcium with pH values at the surface varying from 6.5 to 7.6 extractable phosphorus is concentrated in the surface horizons as is to some extent the extractable potassium. The bluegrass on field No. 9 containing deep peat had the highest content of nitrogen of the two fields sampled, 2.97% N (see Table 12). This might account for the lodging of bluegrass which was observed in July 1964. Excellent stands of bluegrass were observed on both peat soils, however, some late spring frost damage had occurred.

Chemical analysis of plant material involved determinations of 17 elements. The determinations of N, P and K were made at the Soil Science Department. There did not seem to be any obvious differences in N, P and K contents between the two grass species. However, bluegrass from an old and rather unproductive field (No. 6) had the following chemical composition: 1.16% N, 0.13% P and 0.83% K. Much higher nutrient contents were found in bluegrass from a newly seeded field: 1.62% N, 0.24% P and 1.75% K.

Bluegrass with a good seed set from a dense stand on peat had the following composition: 2.97% N, 0.3% P and 2.55% K. Thus a certain relationship seems to exist between the contents of N, P and K in plant material and the growth and productivity of grasses.

Plant samples were also submitted to the Plant Analysis Laboratory, Ohio State University for determinations of secondary and trace elements with an emission spectrograph. Since there is little or no information available on the levels of these elements in grasses, particularly when

used for seed production, these determinations were of an exploratory nature. It was essential, however, to establish a certain level of sufficiency in the trace and secondary element contents of grasses for future reference.

The results of these chemical analyses of soils and plant material are given in the following Tables 1 to 12.

ACKNOWLEDGMENTS

Appreciation is expressed to Mr. William N. Provance, Agricultural Extension Agent of Roseau County, and Mr. Robert C. Munter, Junior Scientist, Soil Science Department, for their assistance in these studies.

Table 1

Field No. 1 (1964)

Soil Type: Bearden silty clay loam

Location: Yvonne Magnuson, Roseau County
SE¼ of SW¼ Sec. 11, Jadis Twp.

Crop: Timothy, new seeding

Depth Inches	pH (1:1)	Organic Matter	Extractable P	Exchangeable K	Total Exchange Capacity	Total Carbonates	Sol. Salts (Sat. Extr.)	Exchangeable Na
		%	pp2m.	pp2m.	m.e. per 100 g.	%	mmhos. per cm.	m.e. per 100 g.
0-1	7.7	4.7	51	320	19.2	4.7	1.2	.4
1-2	7.9	3.9	20	180	37.2	8.7	.9	.4
2-3	8.0	4.1	12	150	21.5	8.7	1.0	.7
3-4	8.0	4.0	11	160	21.3	8.5	1.2	.8
4-5	8.1	3.9	12	190	22.0	8.6	1.4	.8
5-6	8.1	4.4	13	200	19.1	8.7	1.5	.9
6-8	8.1	4.0	10	190	19.9	5.4	1.5	.7
8-10	8.2	2.4	7	130	16.7	11.5	1.6	.5
10-12	8.4	1.1	6	70	17.5	9.3	1.3	.7
12-18	8.2	0.9	6	60	8.2	19.1	3.0	.8
18-24	8.2	0.9	7	80	9.1	21.9	3.0	.7

Table 2

Field No. 2 (1964)

Soil Type: Glyndon fine sandy loam

Location: Albert Efshen, Roseau County
NW¼ of NW¼ Sec. 16, Jadis Twp.

Crop: Bluegrass

Depth Inches	pH (1:1)	Organic Matter	Ex-tract-able P	Ex-change-able K	Total Exchange Capacity	Total Carbo-nates	Sol. Salts (Sat. Extr.)	Ex-change-able Na
		%	pp2m.	pp2m.	m.e. per 100 g.	%	mmhos. per cm.	m.e. per 100 g.
0-1	7.4	3.4	50	270	12.2	2.2	1.7	.4
1-2	7.5	2.8	14	70	12.1	2.0	1.8	.4
2-3	7.6	2.8	8	40	12.9	1.9	1.0	.4
3-4	7.7	2.7	9	50	12.0	2.3	1.2	.4
4-5	7.9	1.9	7	50	11.8	2.0	.9	.4
5-6	7.8	1.0	6	60	12.4	1.9	.8	.4
6-8	7.9	0.8	4	70	9.7	1.4	.8	.3
8-10	7.7	0.7	6	60	11.4	1.4	-	.3
10-12	8.1	0.9	5	60	8.1	1.4	.8	.3
12-18	8.6	0.9	6	30	7.1	16.9	1.2	.4
18-24	8.6	0.8	5	30	-	17.9	1.0	-

Table 3

Field No. 3 (1964)

Soil Type: Glyndon (light) silty clay loam

Location: Kveen, Roseau County
SW¼ of NW¼ Sec. 9, Jadis Twp.

Crop: Bluegrass

Depth Inches	pH (1:1)	Organic Matter	Ex-tract-able P	Ex-change-able K	Total Exchange Capacity	Total Carbo-nates	Sol. Salts (Sat. Extr.)	Ex-change-able Na
		%	pp2m.	pp2m.	m.e. per 100 g.	%	mmhos. per cm.	m.e. per 100 g.
0-1	8.1	3.8	78	260	19.2	5.0	1.3	.3
1-2	8.2	3.7	20	160	19.3	5.8	1.7	.3
2-3	8.1	3.5	10	100	19.7	5.2	1.0	.4
3-4	8.2	3.7	10	90	19.5	5.5	1.0	.4
4-5	8.2	3.5	10	80	20.6	6.3	1.3	.4
5-6	8.3	3.6	9	90	19.7	4.0	1.1	.4
6-8	8.3	3.7	8	80	17.8	8.7	1.0	.4
8-10	8.4	2.6	11	80	10.7	13.1	1.5	.4
10-12	8.5	0.8	4	80	9.0	18.7	-	.5
12-18	8.7	0.6	5	70	7.9	22.5	1.1	.4
18-24	8.8	0.7	5	40	7.2	22.2	1.2	.4

Table 4

Field No. 4 (1964)

Soil Type: Bearden silty clay loam

Location: Roy Kveen, Roseau County
NW¼ of SW¼ Sec. 4, Jadis Twp.

Crop: Timothy, new seeding

Depth Inches	pH (1:1)	Organic Matter	Ex-tract-able P	Ex-change-able K	Total Exchange Capacity	Total Carbo-nates	Sol. Salts (Sat. Extr.)	Ex-change-able Na
		%	pp2m	pp2m.	m.e. per 100 g.	%	mmhos. per cm.	m.e. per 100 g.
0-1	8.1	3.4	27	260	22.1	4.2	1.3	.3
1-2	8.2	3.3	53	100	22.5	4.5	1.0	.5
2-3	8.4	3.3	16	90	21.9	4.7	1.0	.6
3-4	8.4	3.2	14	90	22.4	5.3	1.0	.7
4-5	8.3	3.3	14	100	21.9	5.0	.8	.8
5-6	8.4	3.1	12	90	16.0	4.0	.8	.6
6-8	8.4	1.7	8	100	12.8	11.9	.7	.6
8-10	8.5	1.0	9	70	11.8	24.5	.8	.6
10-12	8.6	1.0	8	70	12.5	32.7	.9	.6
12-18	8.5	1.0	5	80	13.0	24.1	1.0	.6
18-24	8.5	1.0	5	70	10.1	20.1	1.2	.6

Table 5

Field No. 5 (1964)

Soil Type: Bearden silty clay loam

Location: Mary Kveen, Roseau County
NW¼ of NW¼ Sec. 4, Jadis Twp.

Crop: Bluegrass, old stand

Depth Inches	pH (1:1)	Organic Matter	Ex-tract-able P	Ex-change-able K	Total Exchange Capacity	Total Carbo-nates	Sol. Salts (Sat. Extr.)	Ex-change-able Na
		%	pp2m.	pp2m.	m.e. per 100 g.	%	mmhos. per cm.	m.e. per 100 g.
0-1	7.8	4.7	90	180	30.3	0	3.1	1.3
1-2	7.9	4.1	37	110	28.8	0.3	4.0	2.4
2-3	7.7	4.6	44	80	30.2	0.5	4.3	3.0
3-4	7.8	4.4	52	90	30.9	0.7	4.5	3.4
4-5	7.7	4.6	105	110	32.0	1.1	4.5	4.1
5-6	7.7	4.5	34	90	29.2	0.3	4.5	4.1
6-8	7.8	3.0	9	70	24.1	3.9	5.2	3.7
8-10	7.8	1.8	9	60	18.1	7.2	5.0	3.4
10-12	7.9	1.0	7	30	12.7	15.9	4.9	2.3
12-18	8.1	0.9	7	30	9.3	19.2	5.1	2.2
18-24	8.2	0.8	6	40	10.7	20.6	3.7	2.0

Table 6

Field No. 6 (1964)

Soil Type: Viking silty clay to clay

Location: Oliver T. Wold, Roseau County

Crop: Bluegrass, old stand

Depth Inches	p H (1:1)	Organic Matter	Ex-tract-able P	Ex-change-able K	Total Exchange Capacity	Total Carbo-nates	Sol. Salts (Sat. Extr.)	Ex-change-able Na
		%	pp2m.	pp2m.	m.e. per 100 g.	%	mmhos. per cm.	m.e. per 100 g.
0-1	8.0	4.6	15	340	24.2	1.0	1.1	.4
1-2	8.0	3.4	12	280	25.6	1.2	1.1	.4
2-3	8.0	3.9	10	200	21.0	1.1	1.1	.5
3-4	8.0	3.5	9	150	24.8	1.1	.9	.5
4-5	8.0	4.0	7	150	24.8	1.1	1.1	.5
5-6	8.0	4.0	7	130	24.3	1.4	.9	.7
6-8	8.0	2.6	9	120	19.3	1.5	1.0	.7
8-10	8.1	1.2	5	100	11.9	11.4	.8	.5
10-12	8.2	1.1	4	100	13.5	20.2	1.2	.7
12-18	8.2	1.3	4	100	16.8	38.2	1.3	1.0
18-24	8.3	1.0	3	100	14.9	40.3	1.3	1.1

Table 7

Field No. 7 (1964)

Soil Type: Glyndon silt loam

Location: Bjorkman, Roseau County
SE¼ SE¼ Sec. 23, Jadis Twp.

Crop: Bluegrass

Depth Inches	pH (1:1)	Organic Matter	Ex-tract-able P	Ex-change-able K	Total Exchange Capacity	Total Carbo-nates	Sol. Salts (Sat. Extr.)	Ex-change-able Na
		%	pp2m.	pp2m.	m.e. per 100 g.	%	mmhos. per cm.	m.e. per 100 g.
0-1	7.8	5.6	45	140	22.2	1.2	.8	.3
1-2	7.8	5.9	13	90	22.6	1.2	.9	.3
2-3	7.9	5.4	11	90	23.6	1.2	1.0	.6
3-4	7.8	5.3	10	90	23.4	1.5	1.0	.4
4-5	7.9	5.2	9	90	26.0	1.5	1.0	2.1
5-6	7.7	5.0	19	190	25.1	1.8	1.0	.5
6-8	7.8	5.3	19	190	25.8	1.2	1.0	.5
8-10	8.8	2.2	9	110	17.2	3.1	.9	.5
10-12	8.1	1.3	9	80	11.0	17.5	1.3	.3
12-18	8.2	1.0	8	70	8.9	25.2	1.1	.3
18-24	8.4	0.9	6	80	9.9	28.0	.9	.9

Table 8

Field No. 8 (1964)

Soil Type: Glyndon silt loam

Location: Baumgartner, Roseau County
NE¼ SE¼ Sec. 26, Jadis Twp.

Crop: Bluegrass, old, but quite good stand

Depth Inches	pH (1:1)	Organic Matter	Ex-tract-able P	Ex-change-able K	Total Exchange Capacity	Total Carbo-nates	Sol. Salts (Sat. Extr.)	Ex-change-able Na
		%	pp2m.	pp2m.	m.e. per 100 g.	%	mmhos. per cm.	m.e. per 100 g.
0-1	7.8	7.7	80	140	29.4	2.3	1.8	.5
1-2	8.0	8.1	28	70	33.0	2.3	1.6	.7
2-3	7.9	8.1	18	60	32.5	2.2	2.0	1.1
3-4	8.0	8.0	18	50	32.4	2.3	2.1	1.3
4-5	7.9	7.4	23	40	31.7	2.1	2.3	1.2
5-6	7.8	8.1	40	50	34.8	2.2	2.1	1.5
6-8	7.8	7.7	27	50	32.5	2.7	2.2	1.0
8-10	7.9	2.5	15	40	13.5	0.7	2.1	1.0
10-12	8.0	1.0	10	30	10.0	6.3	2.3	.7
12-18	8.3	0.8	5	30	9.9	29.6	1.9	.6
18-24	8.3	0.8	5	30	8.9	36.8	1.7	.5

Table 9

Field No. 11 (1964)

Soil Type: Spooner silt loam

Location: Helmstetter, Lake of the Woods County

Crop: Bluegrass

Depth Inches	pH (1:1)	Organic Matter	Ex-tract-able P	Ex-change-able K	Total Exchange Capacity	Total Carbo-nates	Sol. Salts (Sat. Extr.)	Ex-change-able Na
		%	pp2m.	pp2m.	m.e. per 100 g.	%	mmhos. per cm.	m.e. per 100 g.
0-1	7.9	5.6	80	60	26.4	3.1	1.4	.5
1-2	8.0	5.5	30	40	29.5	3.0	1.7	.4
2-3	8.0	5.5	21	30	28.4	3.1	2.2	.4
3-4	8.0	5.2	18	30	29.3	3.0	2.0	.5
4-5	7.9	5.1	18	40	28.8	3.0	2.4	.6
5-6	8.0	5.2	18	40	26.3	3.0	2.5	.6
6-8	8.0	5.8	21	20	30.0	2.2	2.5	.7
8-10	7.9	5.3	18	30	28.7	2.2	3.5	.6
10-12	8.0	1.7	11	30	17.2	1.4	3.2	.5
12-18	8.1	0.8	6	20	7.1	19.2	2.2	.4
18-24	8.2	0.8	6	10	6.8	21.4	2.8	.3

Table 10

Field No. 9 (1964)

Soil Type: Deep Peat

Location: Charles Habstritt (I), Roseau County
SW¼ SE¼ Sec. 29, T. 163N, R. 39W

Crop: Bluegrass, dense, some lodging

Depth Inches	pH	Extractable P Bray's No. 1	Extractable P Water	Exchangeable K	K	P	Ca	Mg	Na	Si	Mn	Fe	B	Cu	Zn	Al	Sr	Mo	Co	Ba
		pp2m	pp2m	pp2m	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0-1	7.6	63	16	110	.24	.20	3.54	.58	.21	.83	301	>840	38	7	29	709	125	>130	1.6	71
1-2	7.6	35	10	40	.20	.16	3.26	.68	.24	.67	300	"	37	6	26	707	117	"	1.5	46
2-3	7.4	28	8	30	.24	.15	3.38	.76	.22	.78	299	"	37	7	26	707	110	"	1.7	50
3-4	7.5	38	12	40	.22	.18	3.78	.89	.30	.99	301	"	41	7	37	711	127	"	2.0	35
4-5	7.3	30	8	20	.32	.18	4.39	.98	.36	1.24	302	"	47	9	43	708	130	"	2.4	32
5-6	7.2	29	9.2	20	.21	.15	3.40	.91	.41	.80	302	"	39	6	42	709	120	"	1.9	28
6-8	6.2	5	7.2	10	.22	.08	2.61	.77	.39	.79	247	"	34	14	13	704	81	"	1.7	20
8-10	5.5	4	7.2	10	.18	.06	2.11	.50	.33	.30	190	"	23	14	11	704	68	8.3	1.2	16
10-12	5.7	3	6	5	.22	.06	2.07	.43	.29	.42	184	"	22	16	12	707	57	8.7	1.2	16
12-18	5.6	3	6	5	.19	.06	1.90	.44	.31	.29	149	"	22	13	11	699	55	8.0	1.5	12
18-24	5.7	4	7.2	10	.19	.06	2.46	.57	.23	1.67	186	"	27	13	14	709	98	>130	1.0	19

Table 11

Field No. 10 (1964)

Soil Type: Deep Peat

Location: Charles Habstritt (II), Roseau County
SE¼ SW¼ Sec. 32, T. 163N, R. 39W

Crop: Bluegrass, older stand

Depth Inches	pH	Extractable P Bray's No. 1	Extractable P Water	Exchangeable K	K	P	Ca	Mg	Na	Si	Mn	Fe	B	Cu	Zn	Al	Sr	Mo	Co	Ba
		pp2m	pp2m	pp2m	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0-1	6.9	36	14	70	.26	.15	3.34	.57	.18	1.50	292	>840	41	15	29	703	90	>130	1.8	30
1-2	6.7	34	10	60	.26	.14	3.29	.63	.17	1.14	293	"	41	12	29	709	77	"	1.8	23
2-3	6.5	36	13.2	50	.22	.13	3.04	.65	.26	.85	286	"	40	11	26	708	83	"	1.8	17
3-4	6.4	31	14	60	.24	.12	3.00	.77	.31	.68	291	"	39	10	28	703	79	"	1.9	18
4-5	6.2	26	10	100	.25	.12	2.85	.75	.38	.63	285	"	38	10	26	704	75	""	1.9	18
5-6	5.3	6	8	30	.27	.09	2.75	.68	.40	.34	141	"	32	13	19	704	61	"	1.5	16
6-8	5.1	5	10	20	.20	.07	2.28	.64	.34	.22	120	"	28	14	18	699	59	9.6	1.4	13
8-10	5.0	5	7.2	10	.20	.07	2.29	.59	.29	.22	119	"	29	15	18	699	65	8.6	1.5	13
10-12	5.1	4	8	10	.20	.08	2.52	.57	.25	.23	144	"	33	12	19	695	61	8.5	1.1	16
12-18	5.3	4	8	20	.24	.08	2.33	.49	.33	.23	115	"	33	12	21	701	60	9.9	1.8	11
18-24	5.2	5	7	20	.20	.08	2.22	.48	.27	.26	78	"	32	10	19	699	59	7.8	1.3	10

Table 12. Chemical composition of Kentucky bluegrass and timothy from seed production fields - 1964.

Species, Age of Stand Field No., Soil Type	N	P	K	Ca	Mg	Na	Si	Mn	Fe	B	Cu	Zn	Al	Sr	Mo	Co	Ba
	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1. Bluegrass																	
a. New Seedings																	
No. 7 Glyndon sil	1.62	.24	1.75	.29	.17	.15	.27	19	73	5	5	15	45	4	.4	.7	10
No. 9 Deep peat	2.97	.36	2.55	.41	.29	.21	.07	37	80	7	4	22	14	11	.5	.7	16
b. Established Stands																	
No. 2 Glyndon fsl	1.65	.30	1.45	.29	.19	.11	.10	27	50	7	6	15	17	3	.3	.5	20
No. 3 Glyndon sicl	1.19	.19	1.21	.27	.21	.10	.15	42	33	7	4	13	10	6	.2	.4	12
No. 8 Glyndon sil	1.50	.23	1.10	.29	.25	.11	.28	23	131	7	5	20	111	4	.4	.6	14
No. 11 Spooner sil (-N)	1.13	.27	1.45	.26	.14	.13	.14	13	34	8	6	16	18	3	.3	.6	13
No. 11 Spooner sil (+N)	1.36	.21	1.04	.34	.23	.12	.10	16	46	9	7	18	20	3	.5	.9	18
No. 10 Deep peat	1.77	.29	1.78	.27	.22	.12	.05	61	49	7	5	38	14	9	.4	.8	28
c. Old Stands																	
No. 6 Viking sic	1.16	.13	.83	.29	.14	.12	.34	48	60	7	5	16	48	3	.4	.6	11
No. 5 Bearden sicl	1.41	.24	1.33	.16	.16	.15	.12	23	58	6	6	15	33	3	.4	.7	9
2. Timothy																	
No. 1 Bearden sicl	1.39	.17	1.65	.38	.17	.14	.47	34	503	8	6	17	605	6	.8	.5	10
No. 4 Bearden sicl	2.16	.22	2.02	.23	.24	.24	.55	25	522	8	8	17	599	6	1.2	.6	17

Nitrogen Fertilization on Turf - 1964

R. S. Farnham

Nitrogen fertilization studies on bluegrass turf on St. Paul Campus were continued in 1964. Objectives of thse studies were as follows:

1) Continue the study with slow release organic and inorganic nitrogen fertilizers on turf grass.
2) Compare the effectiveness of several new resin-coated nitrogen materials and mixed fertilizers with conventional nitrogen fertilizers.

Results and Discussion

Table 1 shows data of total clipping yields for season for turf plots on St. Paul Campus. The coated mixed fertilizer grades 16-8-8 and 20-10-5 and coated $(NH_4)_2SO_4$ applied at the 8 lb. of N/1000 sq. ft. rate produced the highest total clipping yields of any of the treatments. The eight highest yielding plots were all coated fertilizers provided by the Archer Daniels Midland Company, Minneapolis.

These data compare very favorably with data obtained the past three years in that the highest yielding treatments have consistently been coated fertilizer materials. The release of nitrogen throughout the season is made possible by resin coating nitrogenous fertilizers. Periodic clipping yields during the season show this. Even more important as regards the effectiveness of these coated fertilizers on promoting grass growth is that even in late Sept. and October the grass growth on plots receiving these materials is still good although with uncoated materials nitrogen has been depleted.

Table 1. 1964 Turf Plots

Treat No.	Treatment	Rate lbs N/1000 sq. qt.	Total Clippings gms/peat	Rank
3	16-8-8 (5422-20-E) coated	8	539.8	1
6	20-10-5 (5422-20-C) coated	8	534.9	2
29	16-8-8 (5422-18-M) coated	8	533.2	3
16	$(NH_4)_2SO_4$ (19% leach) (c)	8	507.5	4
30	16-8-8 coated ½, organic (Amer. Humates) ½	8	481.1	5
12	NH_4NO_3 (5422-22 W) c	8	472.1	6
14	$(NH_4)_2SO_4$ 2% leach (c)	8	469.0	7
8	NH_4NO_3 (5422-21-U) (c)	8	462.4	8
20	Milorganite (organic)	8	452.1	9
25	Spencer (30-10-0) (c)	8	448.0	10
27	Uramite	8	436.6	11
4	16-8-8 (uncoated)	8	421.6	12
11	Urea (c) with inhibitor	4	417.1	13
28	NH_4NO_3 ½ + $(NH_4)_2SO_4$ + c	8	413.6	14
18	Urea (med. coat)	4	396.5	15
13	$(NH_4)_2SO_4$ coated	4	392.2	16
17	Urea (med. coat)	8	389.3	17
22	Amer. Humates (organic)	8	378.5	18
5	20-10-5 (coated)	4	374.5	19
15	$(NH_4)_2SO_4$ 19% leach (c)	4	373.0	20
1	16-8-8 (coated)	4	360.0	21
19	Milorganite	4	358.9	22
10	NH_4NO_3 (uncoated)	8	356.5	23
7	NH_4NO_3 (coated) 3% leach	4	353.4	24
2	16-8-8 (uncoated)	4	329.3	25
24	Spencer (S-4383)	8	311.7	26
26	Uramite	4	307.0	27

9	NH_4NO_3 (uncoated)	4	305.2	28
21	Amer. Humates (organic)	4	273.5	29
23	Spencer (S4383)	4	273.3	30
31	Check (No N.)	0	151.8	31
32	Check (No N.)	0	129.5	32

CHEMICAL COMPOSITION OF SIXTH CORN LEAF

JOHN GRAVA

The use of plant analysis as a diagnostic tool seems to be a very popular topic in Minnesota these days. This interest apparently was aroused by the occurrence of certain trace element deficiencies in field crops, and the recent establishment of a plant analysis laboratory by the Ohio State University at Wooster.

Actually determination of N, P, K and certain secondary and trace elements in plant material are made frequently on samples from various departmental research projects. However, because of the expense involved in plant analysis, we have depended mainly on soil tests as a diagnostic tool. Soil testing services are inexpensive and readily available to farmers, florists and homeowners. Unfortunately, soil tests for secondary and trace elements are either complicated and time consuming or somewhat unreliable. Thus the use of an instrument which in a few minutes can determine the contents of some 16 elements in plant ash has brought the mass spectrograph into the limelight.

Certain difficulties may be encountered in the use of plant analysis as a diagnostic tool. The two basic problems are: (1) which part of plant, and at what development stage to sample, (2) what nutrient concentration to consider "adequate" for specific plant growth, and yield goal.

Scientists of the University of California, for example, have provided instructions on sampling petioles of sugarbeets and potatoes (5,7). They also have prepared specific guides to critical nutrient concentrations in these two crops. Dr. A. L. Kenworthy, Department of Horticulture, Michigan State University and others have developed similar procedures and guides for foliar analysis of orchard trees. One finds himself in want for similar instructions and guides when the use of plant analysis is contemplated for field crops such as corn, soybeans, small grains, alfalfa and others. This may be especially true of secondary and trace elements.

Most information in professional publications on chemical composition of corn refers to nutrient content of sixth leaf (first one below and opposite the primary ear shoot) collected at silking time. A number of research papers have dealt with the critical levels of N, P and K in corn leaf. Tyner in 1946 (6) defined "critical level" as that concentration of a nutrient which is just adequate for maximum growth. He suggested following critical levels in sixth corn leaf at silking time (on an oven-dry basis): 3.1% N, 0.315% P, 1.4% K. The concept of "critical level" being a point or a narrow range of values has been questioned by several scientists. Nevertheless, the values of N, P and K contents, suggested by Tyner, still are useful as reference points.

However, information pertaining to the contents of secondary and trace elements in corn is rather scarce. Thus there is a serious need for obtaining and accumulating such information on chemical composition of corn and other field crops. With this in mind, 15 samples of plant material from various past field experiments were submitted for spectrographic analysis. The results are given in table 2. Background information concerning the location, soil type, treatment and corn yields of the experiments from which the samples were obtained is given in table 1. Also reported are references in which the experiments have been described more thoroughly.

REFERENCES

1. Grava, J. and Hanson, L. D. Field fertility studies with corn on Fayette soils - 1961. Report on Field Research in Soils. Feb. 1962. pp. 66-74.

2. Grava, J. and Hanson, L. D. NPK-Rate and placement studies with corn on Fayette soils - 1962. Report on Field Research in Soils. Feb. 1963. pp. 49-53.

3. Grava, J. NPK-Rate study with corn on sandy soils - 1964. Reported elsewhere in this issue of the "Bluebook".

4. Martin, W. P. and Kramer, H. W. Continuous corn-high fertility experiment. Report on Field Research in Soils. Feb. 1963. pp. 47-48.

5. Tyler, K. B. and others. Plant and soil analyses as guides in potato nutrition. Calif. Agr. Exp. Sta. Bul. 781. 1-15. 1961.

6. Tyner, E. H. The relation of corn yields to leaf nitrogen, phosphorus and potassium content. Soil Sci. Soc. Am. Proc. 11:317-323. 1946.

7. Ulrich, Albert, and others. Plant analysis, a guide for sugar beet fertilization. Calif. Agr. Exp. Sta. Bul. 766. 1-23. 1959.

Table 1. Location, treatments, corn yields and other information on experiments from which leaf samples were obtained for plant analysis.

Sample No.	Nutrients Applied Lbs./Acre	Treat. & Rep.	Location	Soil Type	Corn Yield Bu./A.	Year	Reference No.
1	110 + 0 + 120	2-II	E. Freeze, Wabasha Co.	Fayette sil	126	1961	1
2	110 + 40R + 120	4-II	" "	" "	116	"	"
3	110 + 40B + 120	5-II	" "	" "	96	"	"
4	110 + 80(40R + 40B) + 120	12-II	" "	" "	125	"	"
5	110 + 80 + 120	12-III	E. Maus, Winona Co.	Fayette sil	133	1961	1
6	120 + 40R + 120	5-III	Nygren Bros., Goodhue Co.	Fayette/Seaton sil	157	1962	2
7	120 + 40 + 120	5-IV	D. Flueger, Goodhue Co.	Fayette sil	155	"	2
8	120 + 40 + 120	5-IV	E. Freeze, Wabasha Co.	" "	136	"	2
9.	0 + 0 + 0	1-I	Rosemount Exp. Sta.	Port Byron sicl	93	1962	4
10	86 + 40 + 40	4-I	" " "	" " "	114	"	"
11	77 + 88 + 136	6-I	" " "	" " "	117	"	"
12	101 + 136 + 236	9-I	" " "	" " "	119	"	"
13.	110 + 32 + 96	4-III	F. Carlson, Isanti Co.	Anoka lvfs	60[1)]	1964	3
14	110 + 64 + 96	11-III	" "	" "	40[1)]	"	"
15	110 + 32 + 96	4-IV	A. Sorteberg, Anoka Co.	Hubbard s	10[2)]	"	3

[1)] Corn growth and yields affected by moderate drought.
[2)] Corn growth and yields affected by severe drought.

Table 2. Chemical composition of sixth corn leaf at silking time.

Sample No.	N	P	K	Ca	Mg	Na	Si	Mn	Fe	B	Cu	Zn	Al	Sr	Mo	Co	Ba
	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1	3.53	.32	1.41	.68	.52	.01	.27	83	160	11	12	21	74	43	1.5	0.0	11
2	3.39	.33	0.97	.77	.63	.01	.28	83	165	13	11	17	76	38	2.0	.1	8
3	3.48	.32	1.18	.68	.51	.01	.19	64	129	10	11	19	36	41	1.2	<.1	9
4	3.54	.39	1.21	.71	.63	.01	.31	75	159	11	10	15	69	39	1.8	.2	7
5	2.93	.34	1.35	.68	.55	.02	.19	82	112	7	8	17	38	38	1.7	.3	7
6	3.24	.35	3.04	.39	.17	.02	.20	38	92	7	8	11	10	21	.3	0.0	5
7	3.31	.33	1.70	.57	.43	.01	.16	44	108	6	9	12	26	23	.8	.1	4
8	3.15	.28	2.11	.35	.24	.02	.13	40	74	6	4	10	12	21	.5	.3	4
9	3.15	.28	1.22	.85	.67	.01	.34	45	110	6	5	24	38	20	1.7	.2	10
10	3.10	.30	2.01	.77	.35	.02	.26	51	108	6	5	20	34	14	1.1	0.0	5
11	2.74	.29	2.39	.70	.32	.02	.19	37	93	6	4	16	29	16	.7	.1	6
12	3.03	.33	2.75	.79	.24	.02	.25	69	132	5	3	19	38	21	.5	0.0	5
13	2.95	.30	2.28	.81	.34	.01	.19	61	147	7	6	14	74	62	.7	<.1	13
14	2.84	.30	1.83	.73	.40	.02	.16	100	124	8	7	23	61	53	.9	<.1	19
15	2.56	.30	1.91	.72	.50	.02	.23	104	133	14	7	29	111	39	1.6	.2	12

Note: The nitrogen determinations were made by the Kjeldahl method at the Department of Soil Science. Determinations of other elements, reported here, were made with an emission spectrograph by the Plant Analysis Laboratory, Wooster, Ohio.

SOIL TESTING IN MINNESOTA DURING 1964

JOHN GRAVA

Currently the University of Minnesota Soil Testing Laboratory processes more than thirty-five thousand samples annually. The following data show the number of various types of samples analyzed in 1964:

Regular farm, garden and lawn samples	33,074
Florist (greenhouse) samples	1,335
Limestone	109
Departmental research samples	1,594
Total	36,112

The monthly distribution of regular soil samples received by the laboratory is shown in table 1.

Table 1. Monthly Distribution of Soil Samples Received by the University of Minnesota Soil Testing Laboratory During 1964.

Month	Number of Samples
January	2988
February	2980
March	3082
April	3784
May	880
June	393
July	507
August	1213
September	2347
October	4959
November	5554
December	4287