Soil Acidity in Alberta
Part 1. Extent and Importance to Crop Production

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Introduction

Investigations at the Research Station Beaverlodge in the early 1960's showed that soil acidity reduced crop yields on some soils in the Peace River region. Out of this early work has grown a substantial research effort and a general concern for soil acidity in Alberta. Although, soils with a low pH were encountered and recognized by soil survey, their relatively high base saturation and the presence of free lime within the rooting depth of crops were cited as reasons why the acidity of these soils was of little concern to crop production.

A summary by the Alberta Soil & Feed Testing Laboratory (A.S.F.T.L.) of some 80,000 farm soil samples indicates that more than 20% are pH 6.0 or less (Table 1). The general distribution of these acid soils in the province is shown in Figure 1. Assuming a reasonably uniform sampling pattern throughout the province, this indicated approximately 20% of the cultivated acreage (5 to 6 million acres) is pH 6.0 or less. An estimate of the cultivated acreage of acid soils by region is shown in Table 2. This 20% of the cultivated acreage that is pH 6.0 or less is significant from two reasons: (i) Research in other areas has clearly established that alfalfa and sweet clover do not fix nitrogen efficiently when soil pH is below 6.0. Therefore, many soils in Alberta are not suited to the production of these crops. (ii) Acidification of these soils through the use of acid forming fertilizers will result in cereal crops production being affected on a very sizeable acreage. Acidification of soils in the range of pH 6.0 or less to a degree where growth of cereal crops may be effected can occur within the foreseeable future. Application of 40 lbs/acre of ammonium nitrogen annually for 5 to 10 years will lower pH of many soils 0.5

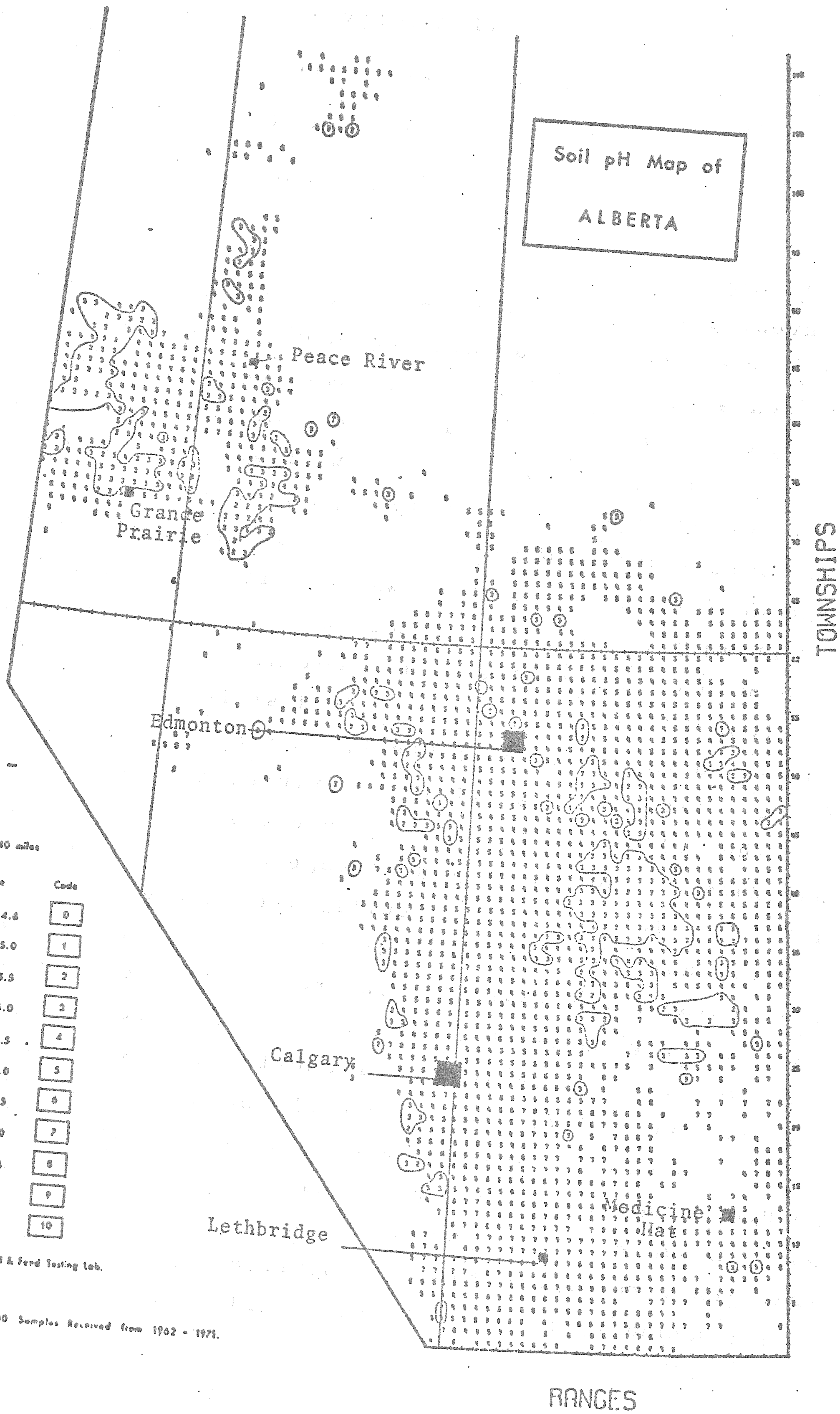


FIGURE I -

LEGEND:

Scale: 1 inch = 40 miles

pH Range	Code
below 4.6	0
4.6 to 5.0	1
5.1 to 5.5	2
5.6 to 6.0	3
6.1 to 6.5	4
6.6 to 7.0	5
7.1 to 7.5	6
7.6 to 8.0	7
8.1 to 8.5	8
8.6 to 9.0	9
above 9.0	10

Compiled by the Soil & Feed Testing Lab.

October 1st, 1971.

Based on 80,000 Samples Received from 1962 - 1971.

units (3).

Table 1

Summary of pH values of farm samples analyzed by the Soil Testing Laboratory (from 1961 to 1971).

pH Range	Percent of Samples
Less than 5.1	0.4
5.1 to 5.5	3.5
5.6 to 6.0	16.7
6.1 to 6.5	27.2
6.6 to 7.0	22.5
Greater than 7.0	29.7

Table 2

Amounts of cultivated farm land with soils falling into different acid pH ranges.

Area	pH Range	% of farmland	Acres of farmland
Alberta, excluding the Peace River Region	Less than 5.0	0.4	70,000
	5.1 to 5.5	3.3	660,000
	5.6 to 6.0	16.0	3,200,000
Peace River region of Alberta and British Columbia	Less than 5.0	0.8	40,000
	5.1 to 5.5	7.2	360,000
	5.6 to 6.0	30.9	1,545,000

About 4 percent of the samples received by the laboratory are pH 5.5 or less. Growth of such crops as barley, wheat and rapeseed can be seriously affected by acidity on these soils. Evidence from some preliminary sampling in late fall of 1972 in East Central Alberta indicates that in townships where the average pH is in the range 5.5 to 5.7, 1/4 to 1/3 of some fields have a pH of only 4.8 to 5.3. The extent and importance of this type of field variation requires further investigation.

Crop Response to Lime

To determine the extent and degree of soil acidity damage to crops in Alberta, a project conducted by C.D.A., Beaverlodge and the U. of A., Soils Department was initiated in 1970. Field experiments at 30 sites from north of Ft. St. John, B.C. to Drumheller in East Central Alberta were conducted growing two varieties of barley, rapeseed, alfalfa and red clover on the soil limed to pH 6.5 and on the unlimed soil. All crops were grown at a high level of fertility to mask any indirect affects of liming, such as increased availability of nitrogen or phosphorus. On the legume crops, a nitrogen and no-nitrogen treatment was included to separate the effect of symbiotic nitrogen fixation from other more direct effects of acidity.

A summary of yield response to lime by crops in various pH ranges is given in tables 3,4,5, and 6. With alfalfa substantial yield increases from liming occurred even in the pH range of 5.6 to 6.0. Significant yield increases on red clover did not occur until soil pH was 5.0 or less. (Table 3) Note, however, that the average yield of limed alfalfa is substantially higher than unlimed red clover. Alfalfa and red clover yields were similar only on a few sites where available moisture was higher.

A comparison of the effects of lime and nitrogen are given in Table 4. In 1971, 100 lbs/acre of N was applied in early spring. In 1972 the nitrogen treatments received two applications of 100 lbs/acre; one in late fall or early spring and again after the first cut. Only 1972 yield results are shown because the 100 lbs/acre rate was found to be inadequate for two cuts. Particularly with alfalfa on soils in the pH range 5.6 to 6.0 one would expect that the main cause

Table 3

Average yield & yield increase from lime on soils of various pH ranges

Soil pH	Year	Number of Sites and Site Years	Crop Yield (cwt per acre) Alfalfa No Lime	Alfalfa Increase	Number of Site Years	Red Clover No Lime	Red Clover Increase
≤ 5.0	1971	5	14.1	40.9	5	33.1	18.2
	1972	6	15.2	44.0	6	35.0	19.3
AVERAGE		11	14.7	42.6	11	34.1	18.8
5.1 - 5.5	1971	11	21.7	22.8	10	35.6	2.3
	1972	13	29.4	17.1	11	32.3	6.8
AVERAGE		24	25.6	20.0	21	33.9	3.8
5.6 - 6.0	1971	7	44.4	15.8	6	42.5	-1.0
	1972	6	33.8	14.1	5	34.3	1.5
AVERAGE		13	37.5	15.0	11	38.8	0.1
6.1	1971	1	77.6	-6.8	1	73.1	19.4
	1972	1	69.5	-3.1	1	62.1	2.1
AVERAGE		2	73.6	-5.0	2	69.2	10.8

Table 4

A comparison of the effect of lime and nitrogen on alfalfa and red clover yields

Soil pH	Year	No. of Sites	Crop Yield (cwt. per acre)			
			Alfalfa		Red Clover	
			Lime (-N)	No Lime (+N)	Lime (-N)	No Lime (+N)
≤ 5.0	1972	6	59.2	31.4	54.3	35.2
5.1 - 5.5	1972	13	46.5	39.7	33.1	27.2
5.6 - 6.0	1972	6 (5)*	48.0	35.8	35.8	30.8

* 5 sites for red clover

of reduced yields would be reduced nitrogen fixation. However, even with the application of 200 lbs/acre of N, yields on the nitrogen treatments were lower than on the lime treatments (35.8 cwt compare to 48.0 cwt). The reason yields on the N treatments were not similar to the lime treatment could be partially due to increased grass and weed competition in the nitrogen treatments.

Substantial yield increases of Galt barley were obtained in the pH ranges $\leq$ 5.0 and 5.1 to 5.5 (Table 5). Only moderate yield increases occurred with Olli barley. This varietal difference is consistent with results obtained in the greenhouse. However, because of the large difference in yield potential of these two varieties, Olli barley produced higher yields on the unlimed soils only in the pH range $\leq$ 5.0.

Rape was generally affected to a greater extent than barley by adverse soil and climatic conditions. As a result, rapeseed yields were more erratic. The relative yields of rapeseed and Olli barley are similar in the pH range $\leq$ 5.0 (Table 6). Above pH 5.0 yield responses of rapeseed to lime were generally not significant. In a greenhouse experiment conducted in 1970-71, Olli barley and Echo rape produced similar relative yields on a grey wooded soil of pH 5.0 containing 6 ppm of 0.02M $CaCl_2$ soluble aluminium.

Prediction of crop damage from soil acidity

The cost of liming materials in Alberta is and will likely remain relatively high for some time. Because of this, the need for an accurate nethod of predicting crop response to lime and the lime requirement of soils is particularly important. It is well established that aluminium and to a lesser extent manganese toxicity are the main causes of poor crop growth on acid soils. A relatively simple and rapid extraction method for Al and Mn using dilute $CaCl_2$ developed by Hoyt and Nyborg provides useful means of predicting crop response to lime by routine laboratory analysis. With the recent improvement in aluminium lamps both Al and Mn can be readily determined by atomic

Table 5

Average yield & yield increase from lime on soils of various pH ranges

Soil pH	Year	Number of Sites and Site Years	Crop Yield (cwt. per acre)			
			Barley			
			Galt		Olli	
			No Lime	Increase	No Lime	Increase
$\leq$ 5.0	1971	4	16.2	15.8	20.1	4.6
	1972	3	17.8	11.3	17.4	4.5
AVERAGE		7	16.9	13.9	18.8	4.6
5.1 - 5.5	1971	11	28.4	4.0	24.6	1.4
	1972	12	25.2	5.4	22.5	2.8
AVERAGE		23	26.7	4.8	23.5	2.1
5.6 - 6.0	1971	5	39.0	1.5	27.5	1.7
	1972	5	33.0	2.6	29.6	2.4
AVERAGE		10	36.0	2.1	28.5	2.1
6.1	1971	1	30.8	-2.0	23.5	-2.3
	1972	1	25.8	4.1		
				1.0		

Table 6

Average yield & yield increase from lime on soils of various pH ranges

		Span Rapeseed Crop Yield (cwt. per acre)		
Soil pH	Year	Number of Sites and Site Years	No Lime	Increase
$\leq$ 5.0	1971	4	12.0	3.3
	1972	3	10.8	2.6
AVERAGE		7	11.5	3.0
5.1 - 5.5	1971	11	13.4	1.0
	1972	12	13.5	0.0
AVERAGE		23	13.5	0.5
5.6 - 6.0	1971	5	16.8	0.4
	1972	5	17.0	2.2
AVERAGE		10	16.9	1.3

absorption spectroscopy.

The scatter diagrams (Figures 2, 3 and 4) show the type of relationships obtained between $CaCl_2$ - soluble Al, pH and the yield of barley, red clover and alfalfa. A comparison of the simple correlation coefficients (r) obtained with soluble aluminium and pH are showing in Table 7. Soluble aluminium was better than pH for predicting crop response to lime on barley, rapeseed and red clover. For alfalfa pH in water was better than soluble Al. This would be expected because alfalfa yields are reduced substantially in the pH range 5.5 to 6.0 where little or no soluble Al is present. The inclusion of Mn with Al in a regression analysis generally did not improve the prediction of crop response to lime. Very few of the sites had soluble Mn levels in

FIGURE 2 - YIELD CURVE FOR GALT BARLEY VS. 0.02M $CaCl_2$ Al

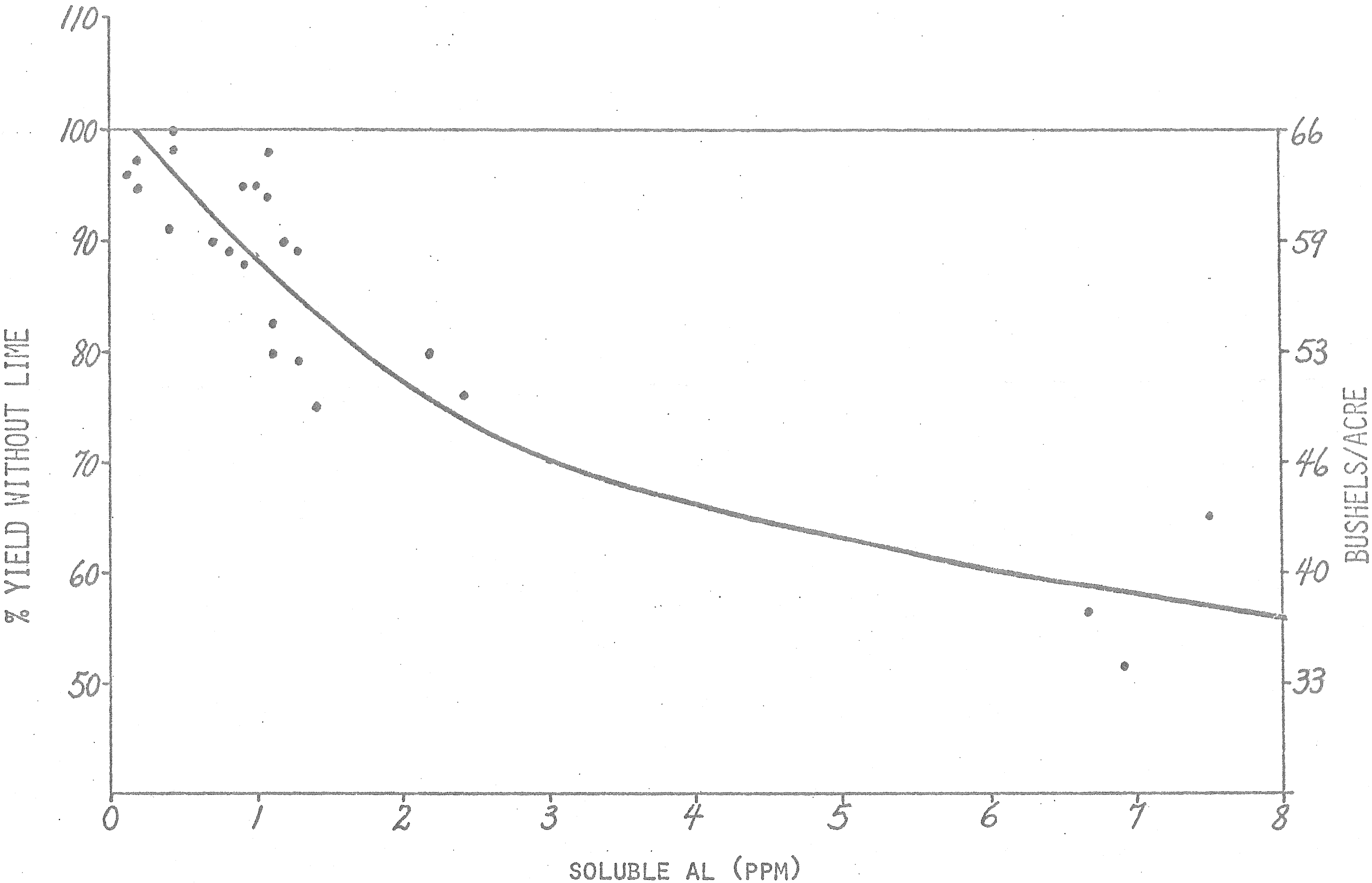


FIGURE 3 - YIELD CURVE FOR RED CLOVER VS. 0.02M $CaCl_2$ Al

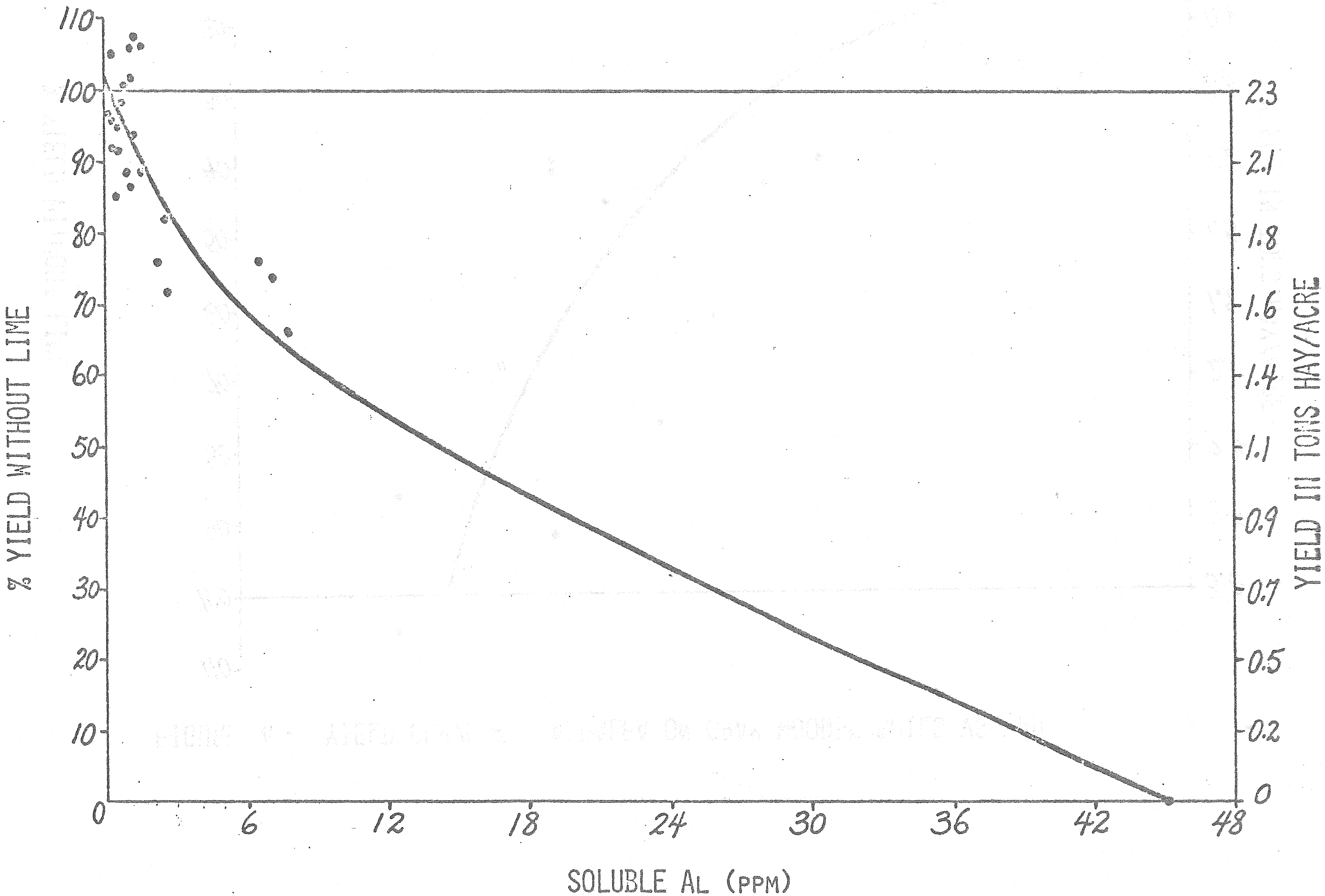
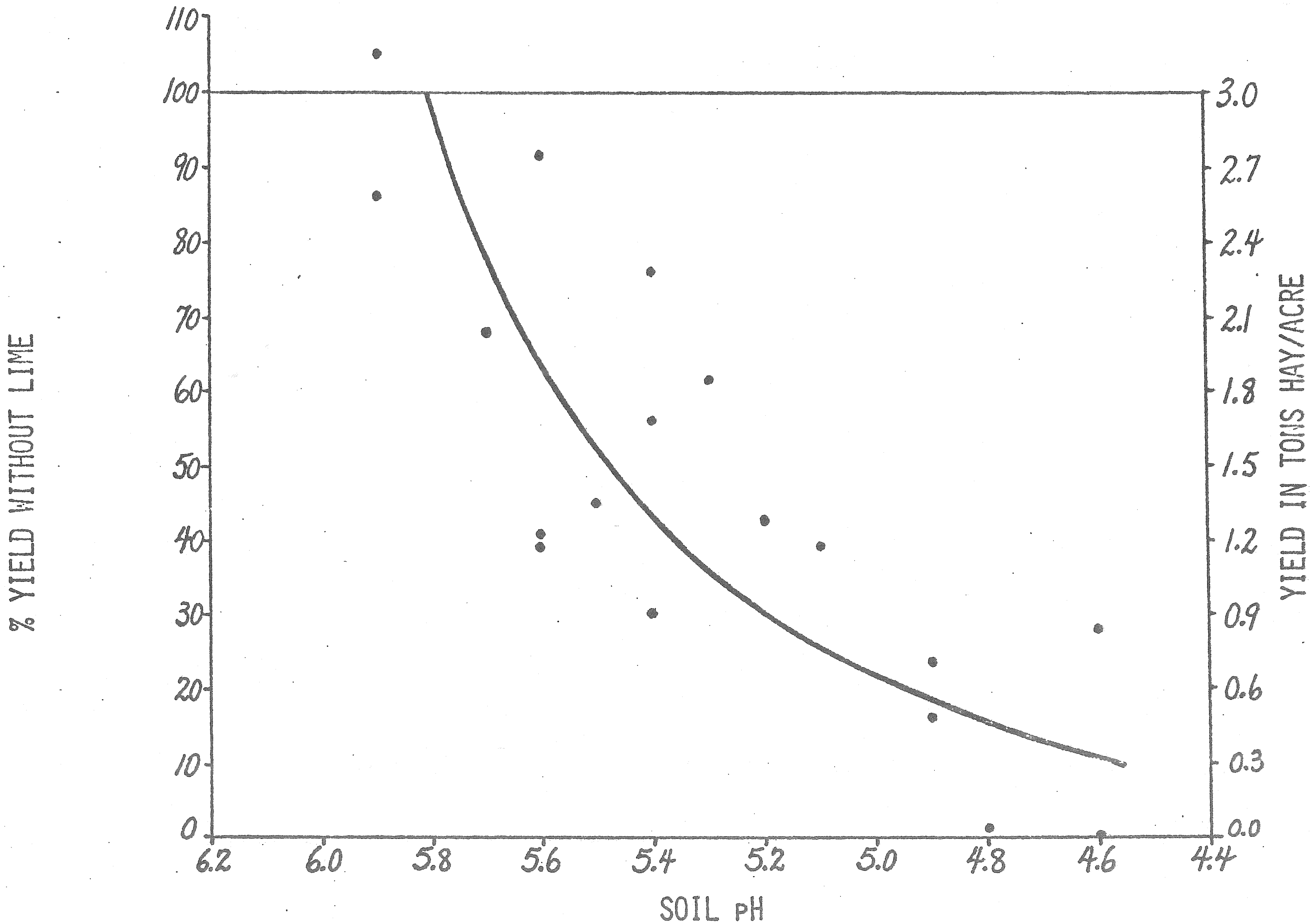


FIGURE 4 - YIELD CURVE FOR ALFALFA ON GRAY WOODED SOILS VS. pH



the range considered to be toxic.

Table 7

Simple correlation coefficient (r) of percent yield without lime vs. pH (water) and 0.02M $CaCl_2$ soluble aluminium (two years data - 1971 and 1972)

Crop	No. of Sites	Correlation Coefficient (r) pH	Correlation Coefficient (r) Al
Red Clover	24	0.67	-0.91
Alfalfa	26	0.79	-0.66 (-0.78)*
Galt barley	25	0.66	-0.85

* Log_{10} transformation

Future Research on Soil Acidity

The bulk of the yield data obtained to date were obtained under conditions of relatively high rates of fertilization and comparing crop growth on the unlimed soil and on the soil limed to near neutrality. Several workers have suggested that maximum crop yields can be obtained with adequate fertilization and liming to reduce Al and Mn below toxic levels (to a pH of about 5.5). Investigations of fertilizer - lime interactions are needed to determine the lowest cost combination. Development of a reliable and relatively rapid lime requirement method is needed. Methods developed to date provide a lime requirement to bring soils to a pH near neutrality. Methods for predicting the lime requirement to reduce Al and Mn below toxic levels require further study.

In some cases, a suitable alternative to liming acid soils is growing acid tolerant crops. This may be particularly important where the cost of lime is high. A complete inventory of the acid tolerance of commonly grown species and varities is needed. Some of this work has been done and is going on.

Summaries of soil test data have provided a good basis for assessing the extent of soil acidity problems. To some extent, further delineation of acid soil problems by sampling surveys of problem areas is needed. In areas where summaries show average pH in the moderately acid range, further sampling is needed to determine the amount of field variation and an estimate of the acreage of strongly acid soils.

Summary

1. Soil acidity is and will become an increasingly important factor in crop production in Alberta. The need for an economical source of lime is evident.
2. The development of methods suitable for routine determination of Al and Mn provide a good basis for predicting crop response to lime. This in conjunction with a reliable lime requirement test will provide a basis for farmers to assess the economics of various management alternatives on acid soils (i.e. - liming and/or growing acid tolerant crops).

References

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