Fertilizer Requirement of Irrigated Alfalfa

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Abstract

An experiment to evaluate the response of irrigated alfalfa to fertilizers and to measure the usefulness of soil and tissue tests to predict these growth responses was conducted in southern Alberta from 1994 to 1996.

Rates of phosphorus (P) were broadcast and banded at nine sites and potassium (K) were applied at six sites. Two rates of nitrogen (N) were applied at each site. Various methods to determine soil P were evaluated. Levels of nutrients in alfalfa tissue test analysis were compared to USA standards. Phosphorus deficiency can be best identified by a combination of soil and tissue tests. Yields did not differ appreciably between high and low rates of P. Yields of alfalfa in response to added P were similar on broadcast and shallow banded treatments. Phosphorus adsorption isotherms indicated large differences in the amount of P absorbed by different soils. Soils which absorb large amounts of P may test deficient with the Miller & Axley method despite having sufficient P. The three Kelowna analysis methods gave a better prediction of available P than the Miller & Axley method on a soil with a large amount of absorbed P.

Potassium deficiencies are frequently incorrectly indicated by tissue tests which use sufficiency standards developed in the USA. Soil tests were more reliable than tissue tests in indicating which soils will respond to K fertilizers. There were no differences in alfalfa response to broadcast and shallow banded K fertilizers.

Nitrogen fertilizer gave small increases in yield of alfalfa for the first harvest after application.

Plant tissue levels of copper (Cu) and Zinc (Zn) on treatments which received applications of P were lower than the control treatments. In some cases the tissue levels of Cu and Zn were below USA sufficiency limits. Foliar Cu fertilizer applied at one site gave no increase in forage yield but it increased tissue Cu levels. The tissue nutrient levels of calcium (Ca) and N were higher and K were lower than USA standards. This means that current USA tissue sufficiency standards and nutrient ratios for alfalfa need to be modified to meet southern Alberta growing conditions.

Nature, Scope and Background

Alfalfa (*Medicago sativa L.*), a major crop in southern Alberta, has increased in acreage and has potential for further increases. In the irrigated areas there are about 130,000 ha (320,000 acres) of forage alfalfa and about 26,000 ha (64,000 acres) of cereal crops underseeded to alfalfa. Eight cubing or pelleting plants in southern Alberta produce about 180,000 tonnes/year ($22 million) of processed alfalfa for dairy cattle, most of which is sold on the export market. The potential for future export sales is limited by the quantity of top quality alfalfa hay available. Lower quality alfalfa hay provides a major source of winter feed for the expanding cow-calf industry.

Alfalfa is an important component in rotations on irrigated soils. On irrigated land alfalfa is a nonchemical method of weed control when in rotation with annual crops. Alfalfa improves the soil by fixing atmospheric N and adding it to the soil by increasing the soil organic matter and extracting moisture to depth; thereby, reducing ground water which may cause saline seeps. It grows well on soils with little nitrogen and is able to extract excess nitrogen from high N soils thus reducing the risk of contaminating ground water.

Alfalfa hay removes larger amounts of P and about 10 times as much K as grains or oilseeds (Table 1). Because of its different nutrient requirements from most annual crops and its deeper rooting depth than annual crops its fertilizer requirements are different. Much research has been done on the fertilizer requirement of cereals on irrigated soils but little conclusive work has been done with alfalfa.

To develop a data base for Diagnostic Recommendation Integrated System (DRIS) tissue analysis standards and to determine the nutrient status of alfalfa , the Alberta Special Crops and Horticulture Centre (ASCHRC) at Brooks conducted a survey from 1989 to

Table 1. Phosphorus and potassium removed by alfalfa, wheat and canola◊

		P lbs/ac	K lbs/ac
Alfalfa	Hay 5 tons/acre	27	249
Wheat	Grain 70 bu/ac Grain and Straw	18 25	25 105
Canola	Seed 50 bu/ac	26	25

◊ Based on 1992 data from Western Canada Fertilizer Association.

1992 on soil and tissue nutrient content and yield of 100 irrigated alfalfa fields in the Brooks, Hays and Bow Island areas (Table 2). DRIS which uses nutrient tissue ratios (McKenzie et al 1993) is less sensitive to the time of sampling than nutrient sufficiency levels (Beverley 1991). DRIS was developed in South Africa and has been evaluated with some crops in the USA but its standards for alfalfa have not been evaluated in Canada.

Table 2. Nutrient status of irrigated alfalfa fields in southern Alberta, 1989-92.

	% deficient	% marginal	% adequate
P Soil Tissue	70 44	18 -	11 56
K Soil Tissue	0 79	12 -	88 21
N Soil Tissue	96 1	2 -	2 99

Results indicated soil P was deficient by Alberta Agriculture soil test standards on 70% of fields and marginal on 18% of fields. However, tissue P was deficient on only 44% of fields. Soil K was, by Alberta Agriculture standards, adequate on 88% of fields sampled and marginal on 12% of fields sampled. Tissue K was low by American Society of Agronomy (Understander, et al 1994) standards on 79% of fields sampled or by Midwest USA DRIS standards (Beverley 1991) on 32% of fields sampled. Tissue N was normal or above normal on 99% of fields. The current soil fertility standards are based on limited soil testing done on neutral or acidic black or grey rain-fed soils from central or northern Alberta and do not appear to be applicable to high pH irrigated soils in southern Alberta.

Because alfalfa is regarded as a soil improvement crop, 28% of farmers surveyed did not fertilize alfalfa and 13% fertilized at less than 50 kg/ha of P_2O_5 (22 kg/ha P) only in the establishment year. Potassium was applied at rates greater than 56 kg/ha of K_2O (46 kg/ha K) on 2% of fields surveyed. Nitrogen is sometimes broadcast on alfalfa because of the commonly held belief that old stands of alfalfa cannot fix N. (18% of farmers surveyed had applied more than 56 kg/ha of N.)

The currently used Alberta Miller & Axley test for soil P was more reliable 20 or more years ago when P was derived chiefly from organic sources or from dissolution of phosphate containing minerals in the soil. Since then large amounts of fertilizer phosphates have been added to many soils. The test is now often not reliable and may result in unnecessary amounts of P being recommended. Alberta Agriculture has ongoing research to evaluate soil P tests for wheat (*Triticum*), barley (*Hordeum*) and canola (*Brassica*). Recent work at Lacombe and at the University of Alberta (Malhi et al 1992) has indicated alfalfa and other forages only use a small proportion of P and K which is broadcast. Leyshon (1982) has shown serious damage to alfalfa by banding fertilizer to depth. Malhi et al (1992) had increased uptake of both P and K and had minimal damage to forages when banded to a depth of 3.5 cm. Alberta Agriculture and Agriculture Canada at Lethbridge have successfully applied fertilizer into forages with a spoke injector.

Tissue testing of alfalfa has been occasionally used in Alberta since about 1990 and more farmers are using it each year. The laboratories which offer this service rely on various sources for standards to interpret deficiencies and excesses. These standards are not uniform and have not been calibrated in Alberta or western Canada. Also, the recommended techniques for collecting samples are not always the same. There is a need to establish standards for tissue analysis which apply to local conditions.

Objectives

1. To improve the yield and profitability of forage alfalfa by improving the effectiveness of applied fertilizers.
2. To determine if fields which test low in soil P and adequate in alfalfa tissue P respond with increased growth to P fertilizer applied with various methods.
3. To determine if soils which test adequate in soil K and deficient in tissue K give increased yields of alfalfa with K fertilizer.
4. To compare the Miller & Axley, Kelowna, University of Saskatchewan-Kelowna, Norwest Kelowna, and membrane strip methods of soil analysis for predicting the response of alfalfa to applied P on high pH irrigated soils.
5. To enlarge the data base for a DRIS tissue analysis model for alfalfa and evaluate the feasibility of DRIS for alfalfa.

Methods

Six alfalfa fields were selected in the spring of 1994 in the irrigated area of southern Alberta and included sites (producers) near Gem (R), Tilley (S), Scandia (C), Rolling Hills (L), Hays (K) and Bow Island (H). The alfalfa fields selected were low in available soil P as measured by the Miller & Axley method. Alfalfa had been seeded in these fields in 1993 and 1994 was the first hay production year. In the fall of 1995 three new fields and producers were selected, Duchess (G), Hays (M) and Rosemary (N). These fields had been seeded in 1995 and 1996 was the first year of hay production.

The nine fields had a range of textures (Table 3) from heavy clay - clay for site N, clay, silty clay and heavy clay at site 5 to loamy sand at site L and sandy loam at site K. The remaining sites were medium textured. Field C was flood irrigated, four fields H, S, K and N were irrigated by centre pivot systems and the remainder were irrigated by wheel roll irrigation systems.

Potassium fertilizer treatments were applied to three of the six sites fertilized in 1994 and to the three new sites commenced in 1996. The three sites fertilized with K in 1994 consisted of one soil with deficient levels of K (0-150 ppm 0-.15 m layer) by Alberta standards one with marginal (75-150 ppm) and one with sufficient K.

In the spring of 1995, the plot on the C field was abandoned because of an uneven stand and in the fall of 1995 the alfalfa crop at S and K were terminated by the producer. In the fall of 1995, three new fields which were low or marginal in P and K were chosen. In 1996, the alfalfa field at site H was terminated by the producer because of winter killing.

The three new sites fertilized in 1996 all had sufficient levels of soil K (above 150 ppm) in the 0.0 - 0.15 m depth. They were chosen because they had marginal levels of K with unreplicated preliminary samples. Two of these sites at G and M had lower amounts of K in the .15-.30 m and the .30-.60 m depths than in the surface layers.

Soil analyses of the alfalfa fields before fertilizer treatments were applied is given in Table 3. Fertilizer treatments applied are listed in Tables 4 and 5. In 1996 the rates of K were increased on all treatments. The G, N and M sites received higher rates of K in their first year (1996) than the other sites which had their first year in 1994 (Table 5).

Nitrogen was applied as ammonium phosphate (12-51-0) or as ammonium nitrate (34-0-0) on treatments 9 and 10. Phosphorus was applied as ammonium phosphate (12-51-0)

Table 3. Soil analysis of irrigated alfalfa plot sites.

3a. Initial plot sites, Spring 1994

C ■ **Scandia**					(ppm)								
Depth (m)	pH	Text	E.C. (dS/m)	% $CaCO_3$	NH_4-N	NO_3-N	PO_4-P‡	K°	Zn	B	Cu	Mn	Fe
0.00-0.15	8.1	L	0.98	8.0	6	3	4	263	0.76	0.48	0.63	3.78	11.6
0.15-0.30	8.2	L	2.38	7.5	7	2	4	140	0.80	0.56	0.53	2.78	13.4
0.30-0.60	8.2	CL	4.20	4.6	7	1	0	134					
0.60-0.90	8.0	CL	6.05		7	2	1	156					

R ○ **Gem**					(ppm)								
Depth (m)	pH	Text	E.C. (dS/m)	% $CaCO_3$	NH_4-N	NO_3-N	PO_4-P‡	K°	Zn	B	Cu	Mn	Fe
0.00-0.15	6.9	SCL	0.43	0.15	6	8	4	120	0.54	0.35	0.77	8.03	21.8
0.15-0.30	7.4	SCL	0.38	0.85	4	3	1	90	0.28	0.24	0.76	3.48	10.0
0.30-0.60	7.8	L	0.45	10.0	4	1	1	76					
0.60-0.90	8.1	L	0.60		4	1	1	71					

H ◇ **Bow Island**					(ppm)								
Depth (m)	pH	Text	E.C. (dS/m)	% $CaCO_3$	NH_4-N	NO_3-N	PO_4-P‡	K°	Zn	B	Cu	Mn	Fe
0.00-0.15	7.4	CL	0.40	0.95	6	2	14	179	0.77	0.52	0.88	5.22	14.0
0.15-0.30	7.7	CL	0.43	0.97	4	2	4	124	0.48	0.39	0.96	3.89	11.0
0.30-0.60	8.0	CL	0.50	3.27	5	1	1	93					
0.60-0.90	8.4	CL	0.53		5	0	1	103					

L ♦ **Rolling Hills**					(ppm)								
Depth (m)	pH	Text	E.C. (dS/m)	% $CaCO_3$	NH_4-N	NO_3-N	PO_4-P‡	K°	Zn	B	Cu	Mn	Fe
0.00-0.15	6.7	LS	0.18	0.25	6	1	9	59	0.40	0.23	0.92	6.89	47.4
0.15-0.30	6.9	LS	0.20	0.60	5	2	7	47	0.38	0.23	0.72	5.36	41.8
0.30-0.60	7.7	LS	0.43	0.52	5	1	6	61					
0.60-0.90	8.0	SCL	0.63		5	1	2	100					

S ★ **Tilley**					(ppm)								
Depth (m)	pH	Text	E.C. (dS/m)	% $CaCO_3$	NH_4-N	NO_3-N	PO_4-P‡	K°	Zn	B	Cu	Mn	Fe
0.00-0.15	7.7	C	0.83	1.25	6	14	4	305	1.08	0.58	1.45	6.89	16.0
0.15-0.30	7.9	SiC	1.08	3.02	5	10	1	249	0.64	0.49	1.62	4.67	13.8
0.30-0.60	8.2	SiC	2.83	0.52	5	9	0	136					
0.60-0.90	8.2	Hv C	5.93		6	13	0	114					

K □ **Hays**					(ppm)								
Depth (m)	pH	Text	E.C. (dS/m)	% $CaCO_3$	NH_4-N	NO_3-N	PO_4-P‡	K°	Zn	B	Cu	Mn	Fe
0.00-0.15	6.5	SL	0.18	0.08	5	3	8	136	0.59	0.24	1.04	9.78	43.5
0.15-0.30	6.8	SL	0.20	0.02	5	3	5	104	0.55	0.28	0.52	6.67	28.4
0.30-0.60	7.4	SL	0.23	0.10	4	1	3	76					
0.60-0.90	8.0	SCL	0.43		4	1	1	73					

‡ Miller & Axley ° Ammonium acetate

3b. New plot sites, Autumn 1995

G ● Duchess			E.C. dS/m	% $CaCO_3$	(ppm)								
Depth (m)	pH	Text			NH_4-N	NO_3-N	PO_4-P‡	K⊗	Zn	B	Cu	Mn	Fe
0.00-0.15	7.6	CL	0.62	5.4	4	4	4	148	0..37	0.36	0.79	5.60	7.7
0.15-0.30	7.8	CL	0.65	6.4	4	3	1	163	0.25	0.34	0.82	3.50	10.4
0.30-0.60	8.0	SiL	2.15	9.2	5	2	0	84					
0.60-0.90		SiL											

M ✱ Hays			E.C. dS/m	% $CaCO_3$	(ppm)								
Depth (m)	pH	Text			NH_4-N	NO_3-N	PO_4-P‡	K ⊗	Zn	B	Cu	Mn	Fe
0.00-0.15	7.7	SiL	0.70	2.80	4	6	5	197	0.43	0.28	0.88	5.4	21.7
0.15-0.30	7.8	SiCL	1.42	5.3	4	3	0	118	0.19	0.25	0.74	3.0	10.0
0.30-0.60	7.9	SiCL	1.70	11.1	5	3	0	106					
0.60-0.90		SiL											

N ■ Rosemary			E.C. dS/m	% $CaCO_3$	(ppm)								
Depth (m)	pH	Text			NH_4-N	NO_3-N	PO_4-P‡	K ⊗	Zn	B	Cu	Mn	Fe
0.00-0.15	7.5	C-HC	0.68	1.60	3	1	19	360	0.74	0.78	2.18	7.5	20.1
0.15-0.30	8.2	HC	0.98	2.35	2	0	9	382	0.20	1.13	2.67	2.9	17.5
0.30-0.60	8.3	HC	1.98	2.50	2	0	18	461					
0.60-0.90		C											

‡ Miller & Axley ⊗ Ammonium acetate

Table 4. Fertilizer in kg/ha applied to P experiment.

	Year 1		Year 2		Year 3	
Treatment	N	P	N	P	N	P
1 check	0	0	0	0	0	0
2 broadcast	11	20	11	20	11	20
3 broadcast	21	40	21	40	21	40
4 broadcast	32	60	0	0	0	0
5 broadcast	63	120	0	0	0	0
6 banded	11	20	11	20	11	20
7 banded	32	60	0	0	0	0
8 banded	0	0	0	0	0	0
9 broadcast	32	0	32	0	32	0
10 broadcast	128	60	96	0	96	0

and K as potassium chloride (0-0-60). Except where otherwise indicated, fertilizer was applied as a broadcast treatment. Banded treatments were applied at a depth of 1.5 to 2 cm with a zero till disc drill. Fertilizers were applied from April 20-27 in 1994, 1995 and 1996 except for the Tilley site which was fertilized on May 6 in 1994. The R site in April 1996, (year 3) received an additional application of fertilizer by the producer to provide in kg/ha 56 N, 20 P and 28 K.

Table 5. Fertilizer in kg/ha applied to K experiment.

Treatment	Year 1 1994			Year 2 1995			Year 3 1996			Year 1 1996		
	N	P	K	N	P	K	N	P	K	N	P	K
11 broadcast	0	0	50	0	0	50	0	0	50	0	0	75
12 broadcast	32	60	50	32	60	50	32	60	50	32	60	75
13 broadcast	0	0	100	0	0	100	0	0	100	0	0	150
14 broadcast	32	60	100	0	0	100	0	0	100	32	60	150
15 broadcast	32	60	200	0	0	0	0	0	200	32	60	300
16 check	0	0	0	0	0	0	0	0	0	0	0	0
17 banded	32	60	100	0	0	100	0	0	100	32	60	150
18 check	0	0	0	0	0	0	0	0	0	0	0	0

Forage harvests of the experimental plots were taken at or near the time of the farmers' harvests (Table 6). Two harvests were taken from most plot sites each year except for H in 1994 and 1995 and S in 1994 where the farmer took three harvests in a year. At the time of harvest, a subsample was taken for dry matter determination and tissue samples were collected consisting of the upper 20 cm of stems and leaves. Soil samples were taken to 90 cm from each plot before fertilizer applications. At the end of each season, soil samples were taken to 30 cm from each broadcast treatment and the results for 0-15 cm are reported.

Table 6. Harvest and tissue sample dates of the alfalfa plots.

Site	1994			1995			1996	
C ▪	30/6	29/8						
R ○	4/7	26/8		10/7	27/9		2/7	10/9
H ◇	17/6	21/7	1/9	21/6	31/7	10/10		
L♦	21/6	23/8		23/6	25/8		4/7	27/8
S ★	29/6	2/8	19/9	15/6	17/8			
K 1 □	22/6	17/8		29/6	21/8			
G ●							8/7	22/8
M 2 ✱							3/7	28/8
N ■							5/7	3/9

Soil P was determined by the Miller & Axley, Kelowna, Norwest-Kelowna, Sask-Kelowna (Quan et al 1994) and on four fields by the Olsen (as used by Sask lab) method in 1994. In 1995 and 1996 soil P was determined by the Miller & Axley and the Kelowna methods. Soil K was determined in 1994 by the Kelowna, Norwest Kelowna, Sask. Kelowna and ammonium acetate methods. In 1995 and 1996 soil K was determined by the ammonium acetate and Kelowna methods. Plant tissue sampled after peroxide digestion were analysed to determine total nutrients. Analysis was provided by the Soil and Crop Diagnostic Centre, Edmonton, and the Plains Innovative Laboratory (now Envirotest), Saskatoon.

Phosphorus adsorption isotherms were determined for the nine soils used in this project. Soils used to determine the amount of P absorbed were taken from the control treatment. Fifty ml of a 0.01 $CaCl_2$ solution containing P at 0, 8, 16, 32, 64, 128, 256, 512 ppm was added to 5 g of soil and shaken for 24 hours and centrifuged for 30 minutes. The P remaining in solution was determined by colorimetric means with an autoanalyzer to find the difference with the original P to determine the amount of P absorbed by the soil.

The L site had low levels of tissue Cu on the treatments which received high rates of P. In 1997 a Cu fertilizer experiment was set out at this site. Plots from treatments 3 and 5 (high rates of P) 1, 8, 11 and 16 (checks and banded checks) and 14 and 15 (high rates of K) were split in half and half of each received foliar sprays of Cu. Foliar applications of Cu were made on June 6, 1997, as a solution of $CuSO_4$ + lime at the rate of 0.45 kg/ha Cu. On July 14 and 29, 1977, for the second harvest, two foliar applications of a solution of CuOCl was made at a rate of 0.5 kg/ha Cu per application. In 1997 Cu was the only fertilizer applied at this site. Forage samples were taken from 4 replicates of these plots and tissue samples were collected at the time of harvest. Harvests were taken June 17, 1997 and August 20, 1997. For the first harvest, one composite tissue sample and for the second harvest, two composite samples from each treatment were analyzed. Forage yields were analysed by a split plot randomized block design using S.A.S.

Deviations

The membrane strip method of soil analysis for P was not evaluated. This method would require considerable replication to measure the equivalent of a composite sample. The Olsen method of analysis was added to the methods listed in the initial objectives. This method is sometimes used for soil P analysis by the Enviro test lab in Saskatoon.

The objective of enlarging the data base for DRIS analysis and evaluating the feasibility for using DRIS analysis was not done. The project was proposed and designed in 1993 and now by 1997 DRIS analysis is no longer being used as much as in 1993. The premise that DRIS was designed on that tissue nutrient ratios remain near constant at all growth stages is frequently not valid. However nutrient levels determined in this project are compared to DRIS standards and to sufficiency level standards to determine if problems may exist.

Results and Discussion

Soil chemical and mechanical analysis of all sites before fertilizer treatments were applied is given for those sites started in 1994 (Table 3a) and for the 1996 sites (Table 3b).

Yield Responses to P Fertilizer

In 1994 (Figure 1, Appendix 1) four of the 6 sites gave positive responses in forage yield to P fertilizer. In 1995 (Figure 2, Appendix 1) with 5 of the original sites still being harvested, four of these gave positive responses to P. In 1996 three new sites were added and two of the original sites were still in production. Two of these three new sites gave positive responses to P. Higher rates of P usually gave larger yields than lower rates. However, 40 kg/ha P for 3 years (Figure 3) gave a higher average yield in the 3rd year than 120 kg/ha P applied only in the first year. The six sites that responded to P - C, L, S, K, M and G (Figure 4) - all had 3-9 ppm soil P (as measured by the Miller & Axley method) in the 0-15 cm layer which was deficient by Alberta Agriculture standards.

Figure 1. Average 1994 yields (%) of alfalfa forage on two fields which were not responsive and four fields which were resoponsive to P fertilizer treatments

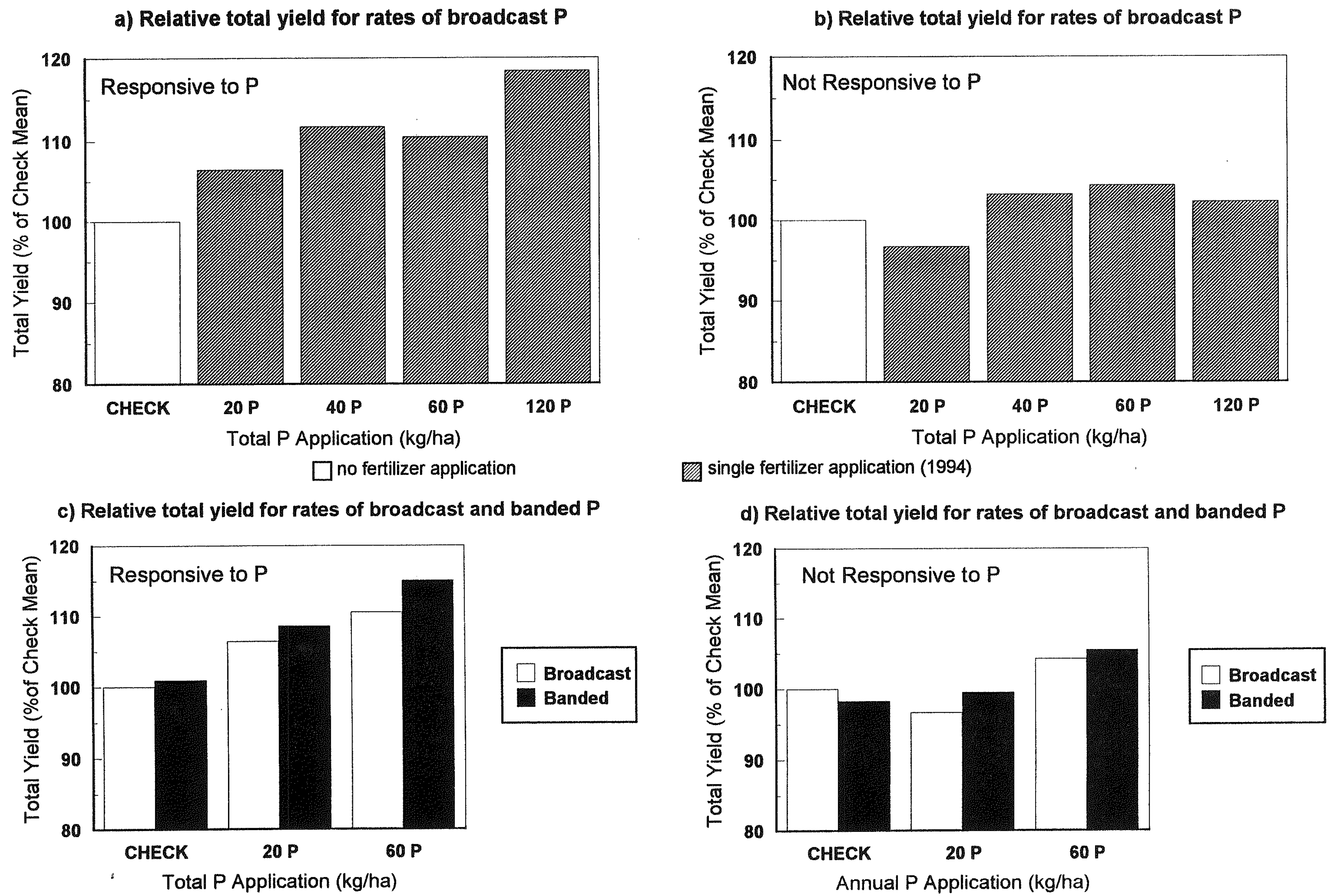


Figure 2. Average 1995 yields (%) of alfalfa forage on one field which was not responsive and four fields which were responsive to P fertilizer treatments in 1994

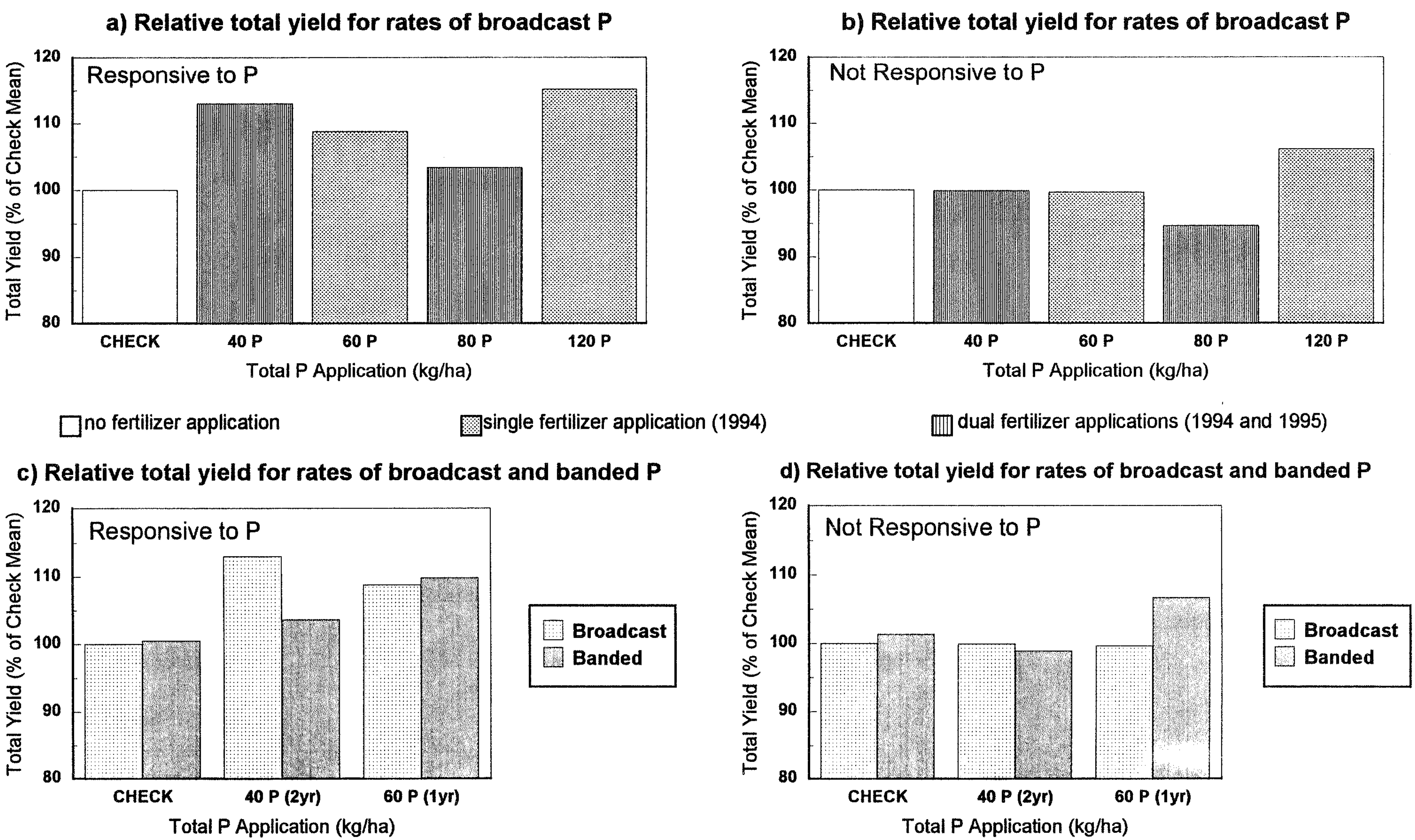
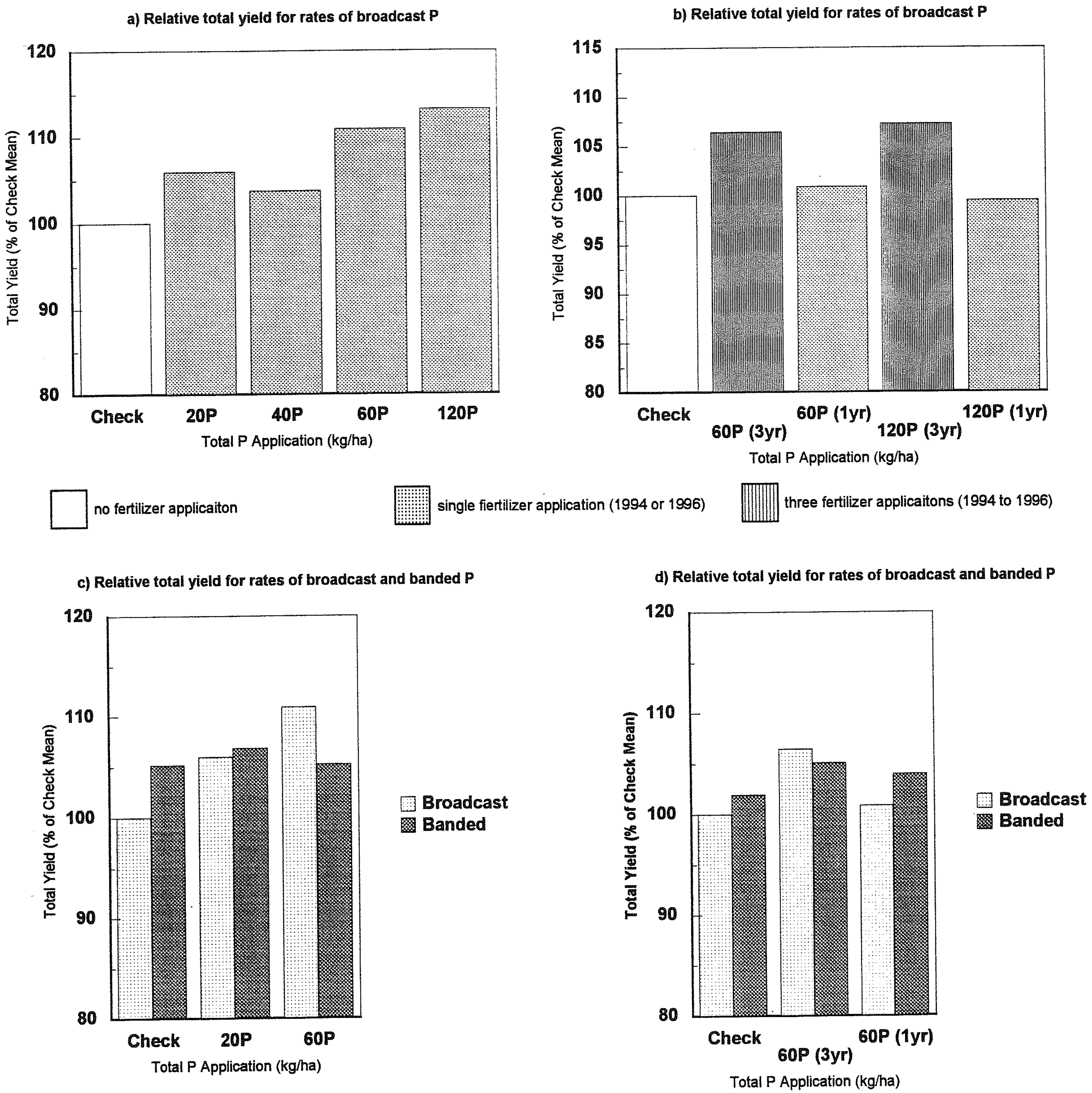


Figure 3. Average 1996 yield (%) response of alfalfa forage to P fertilizer treatments on three fields initiated in 1996 and two fields initiated in 1994



Two of the sites which did not respond to P fertilizer, H and N, had Miller & Axley soil P of 14 and 19 ppm (Figure 4), respectively, which was marginal by Alberta Agriculture standards (Laverty, et al, 1988). However, when the H site was tested in the fall after harvest in 1994 and 1995 the unfertilized treatments were deficient (7-10 ppm of Miller & Axley P) and the fertilized treatments were marginal for soil P. Tissue P (Figure 5) for all treatments were sufficient at this site. It had a clay loam texture, a surface pH of 7.4. The N site had marginal Miller & Axley soil P in the fall of 1995 and on the control treatments in 1996. The fertilized treatments at N had adequate soil P after harvest in 1996. A third site, C, with 4 ppm soil P in the fall of 1993 also did not respond to P fertilizer. This site had a high pH of 8.1 in the 0-15 cm layer and also had a high P adsorption capacity.

Tissue P

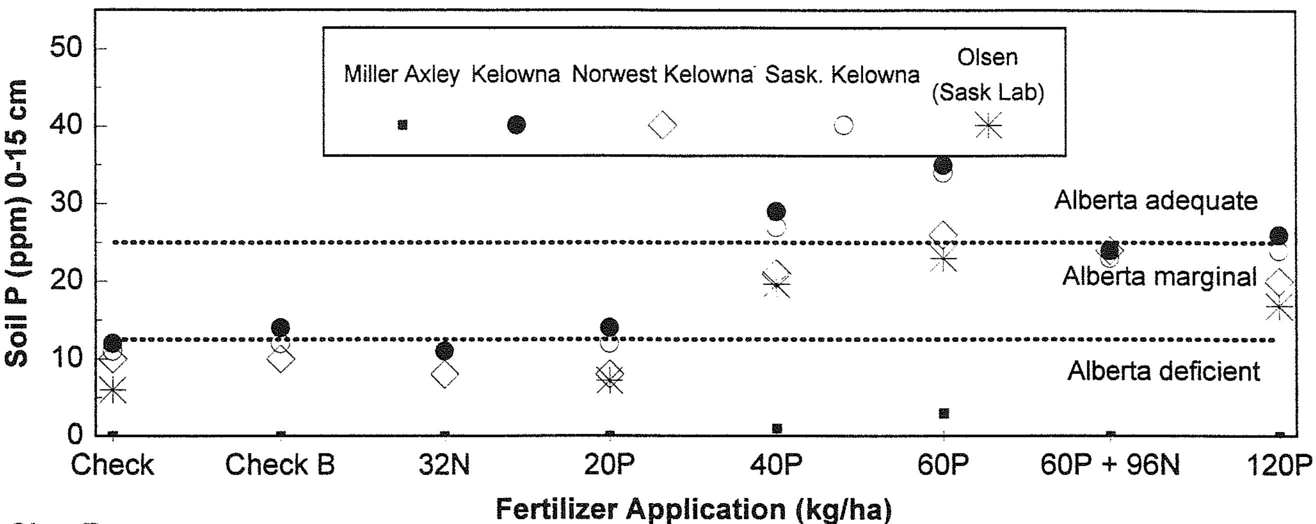
Tissue P (Figure 5) of most fields was sufficient (between 26 and 70 ppm) according to Wisconsin Minnesota standards (Undersander et al 1994). One field, R was deficient on most treatments on the first harvest in 1994 and the second harvest in 1995 and in 1996. Field K was deficient on the check and the first treatment #2 on the first harvest in 1994 and on the second harvest in 1995. Field L was marginal on the check and treatments #2 on most harvest for three years. All three sites which did not respond to fertilizer P had sufficient tissue P on all treatments.

The tissue P levels were increased by about 5 ppm on the highest P fertilizer treatment #5 as compared to the check treatment #1. The tissue P level is influenced by the available soil P and is reduced on the more mature samples. The date of harvest or the time between harvests explains much of the differences as in tissue P contents on fields.

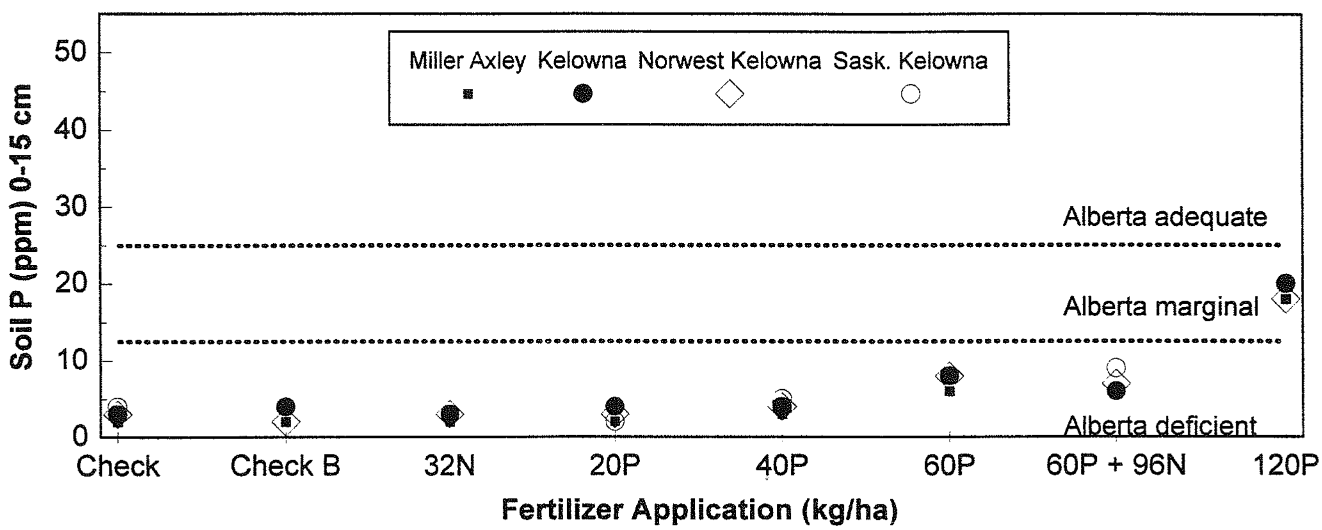
Figure 4. Soil P for three years on P fertilizer treatments as measured by different extraction methods, compared to Alberta Agriculture standards

Figure 4a). 1994 Soil P at six sites as measured by 4 or 5 extraction methods

Site: C



Site: R



Site: H

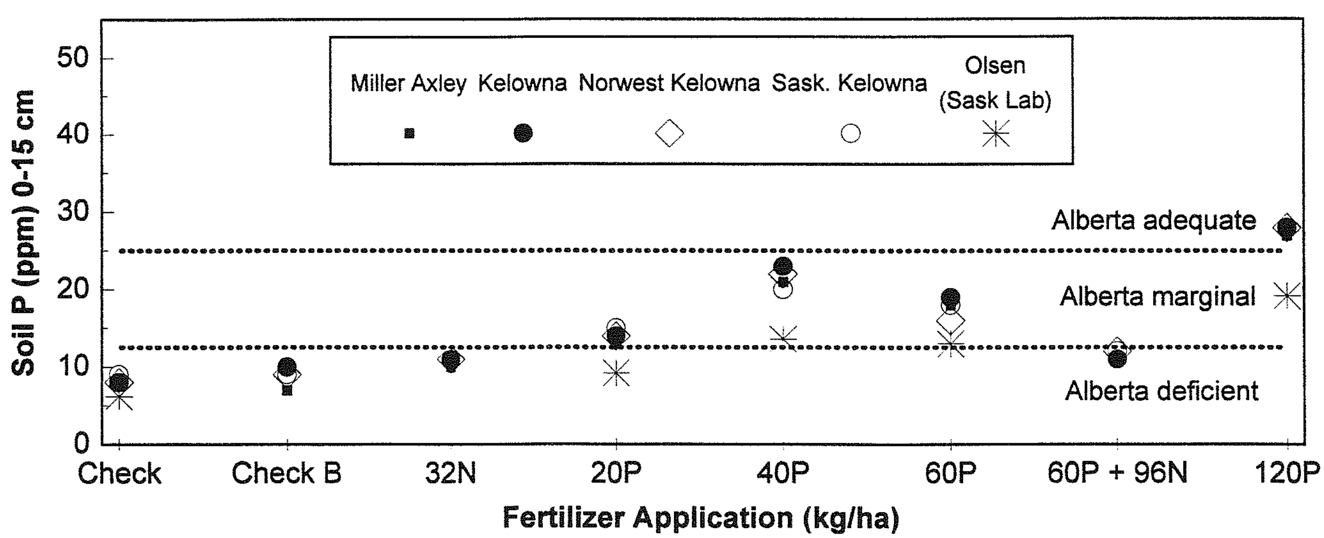
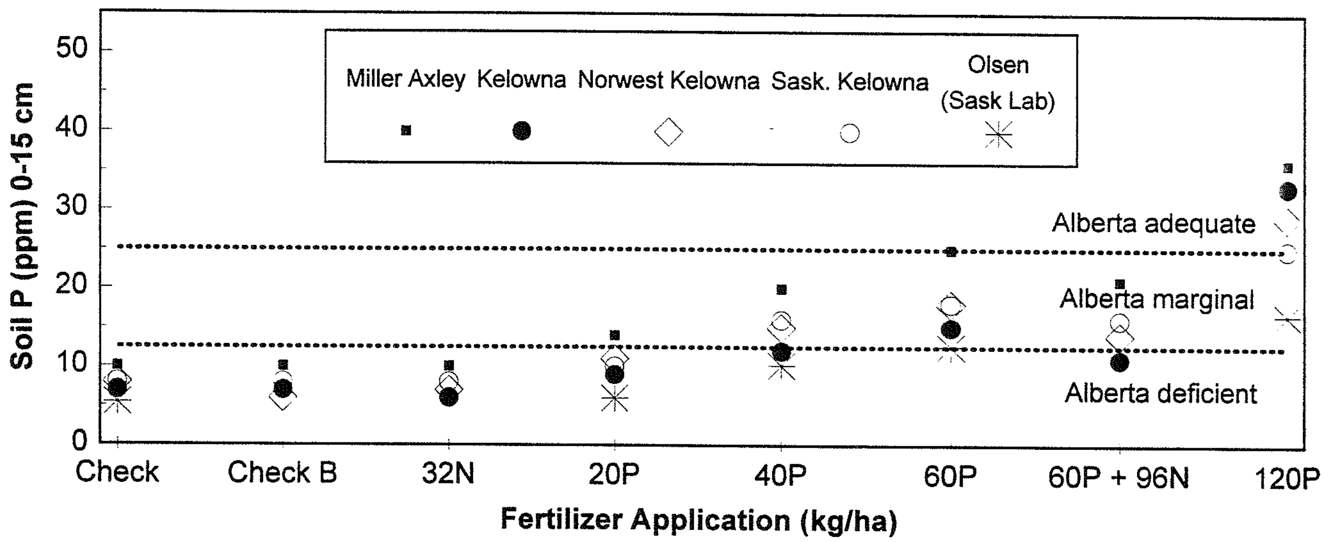
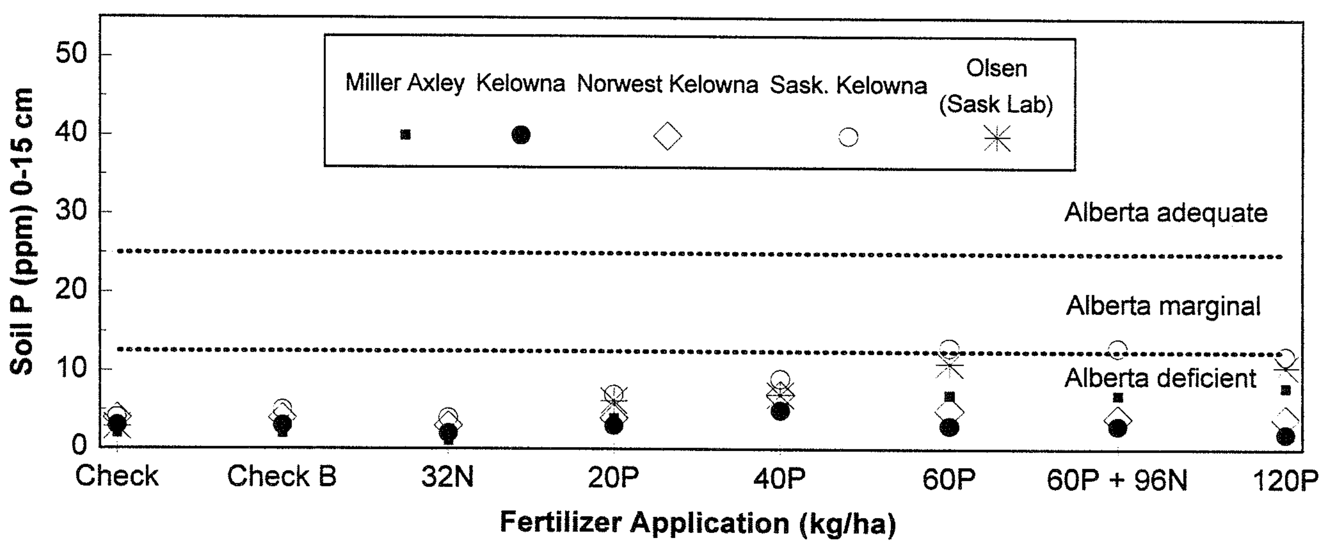


Figure 4a) (cont.).

Site: L



Site: S



Site: K

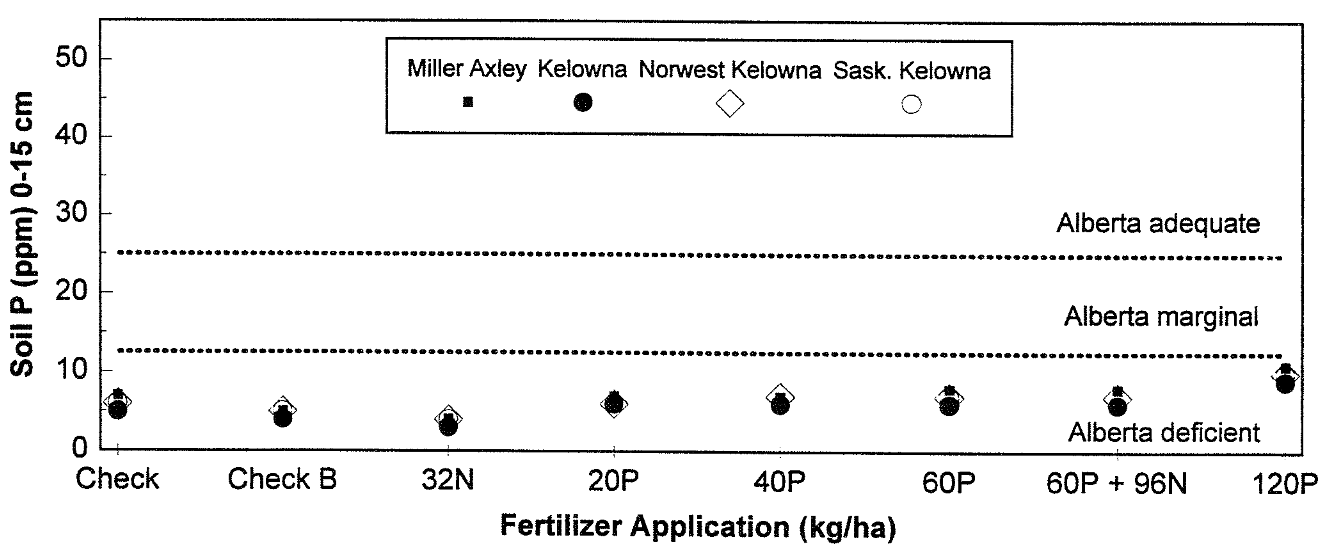


Figure 4b). 1995 Miller Axley soil P at four sites

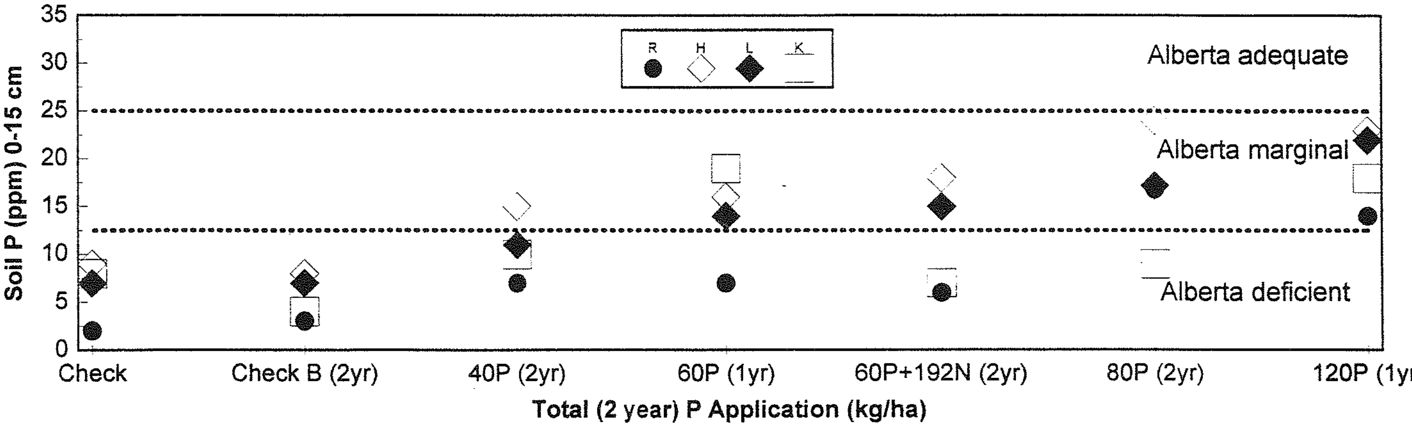


Figure 4c). 1995 Kelowna soil P at four sites

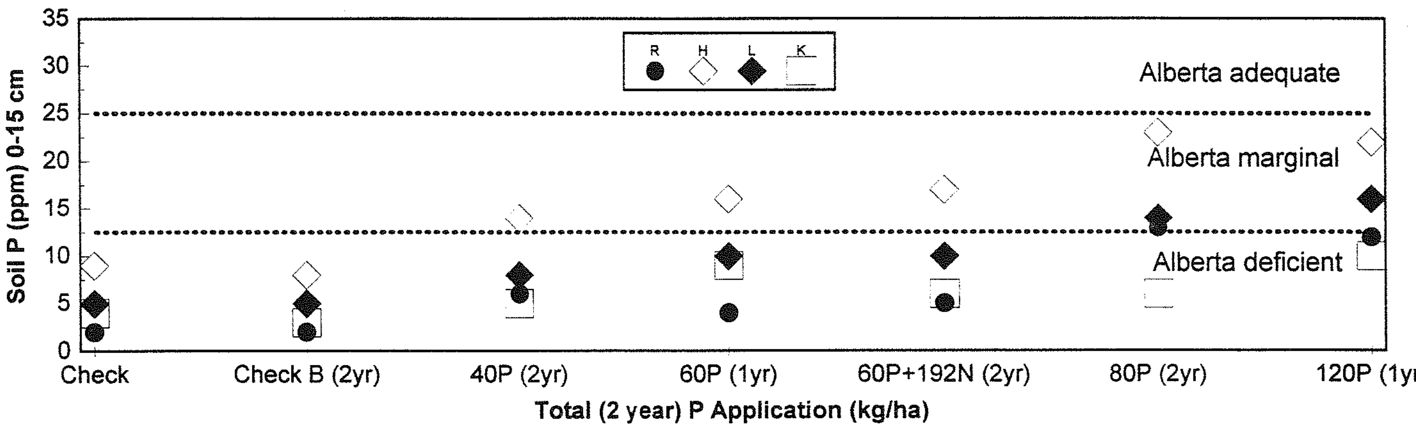


Figure 4d). 1996 Miller Axley soil P at five sites

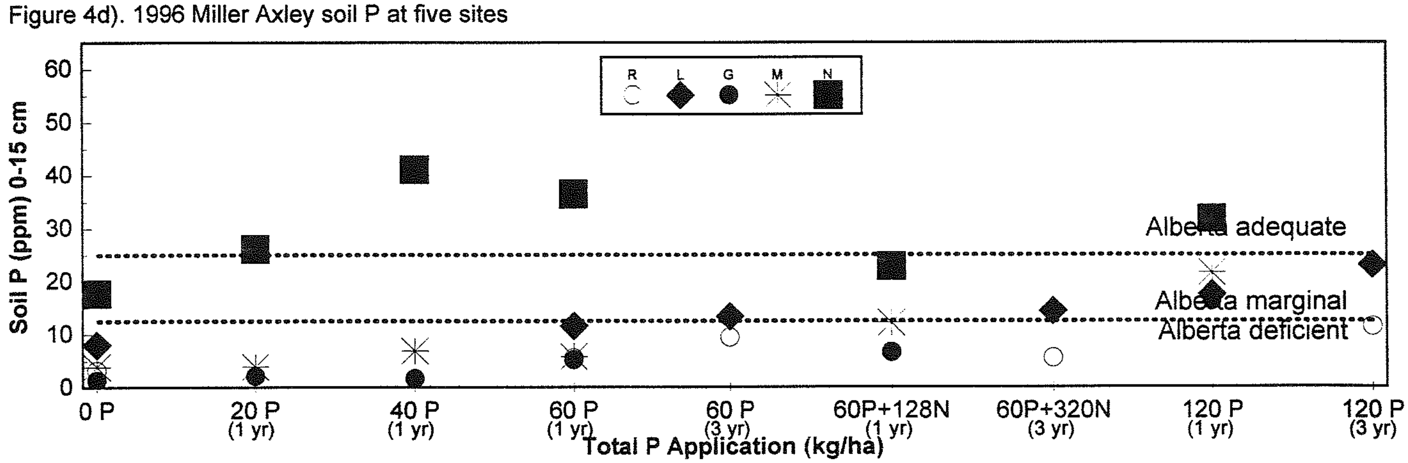


Figure 4e). 1996 Kelowna soil P at five sites

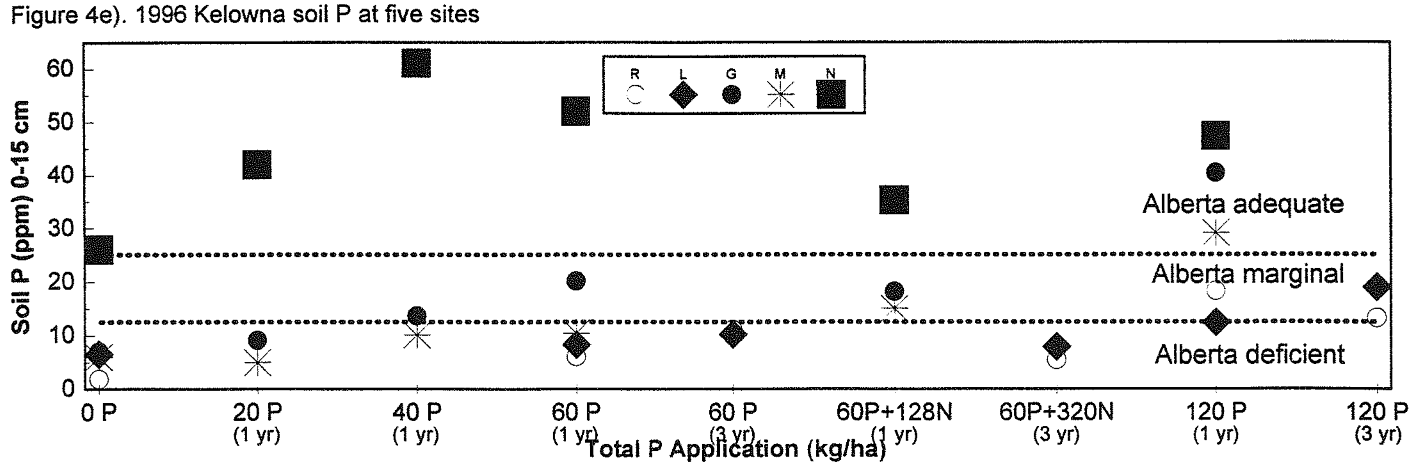
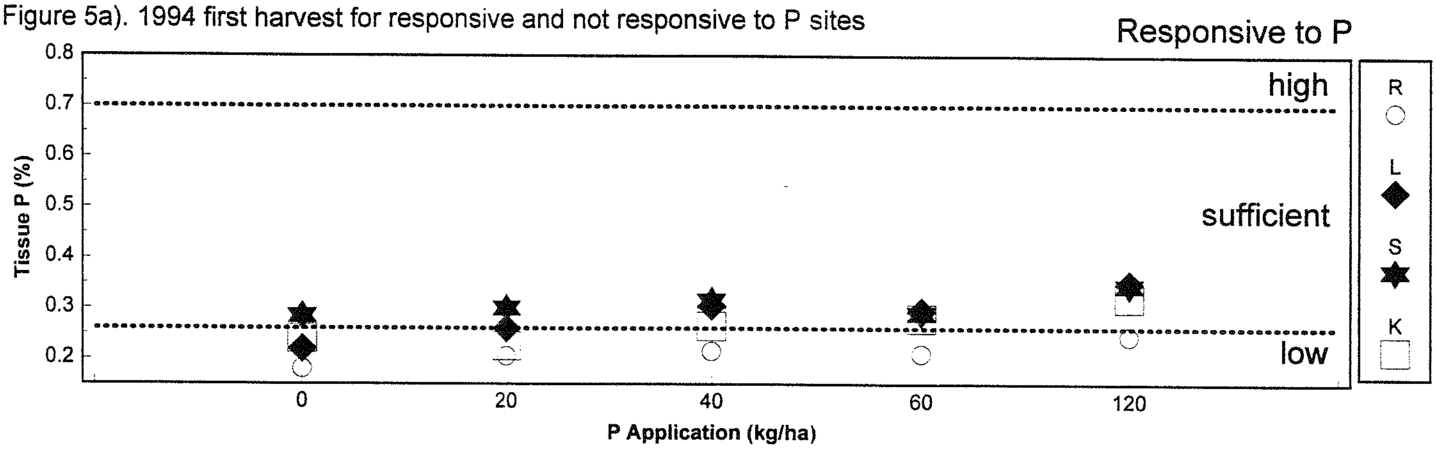


Figure 5. Alfalfa tissue P for two harvests and three years on P fertilizer treatments as compared to Wisconsin, Minnesota standards

Figure 5a). 1994 first harvest for responsive and not responsive to P sites



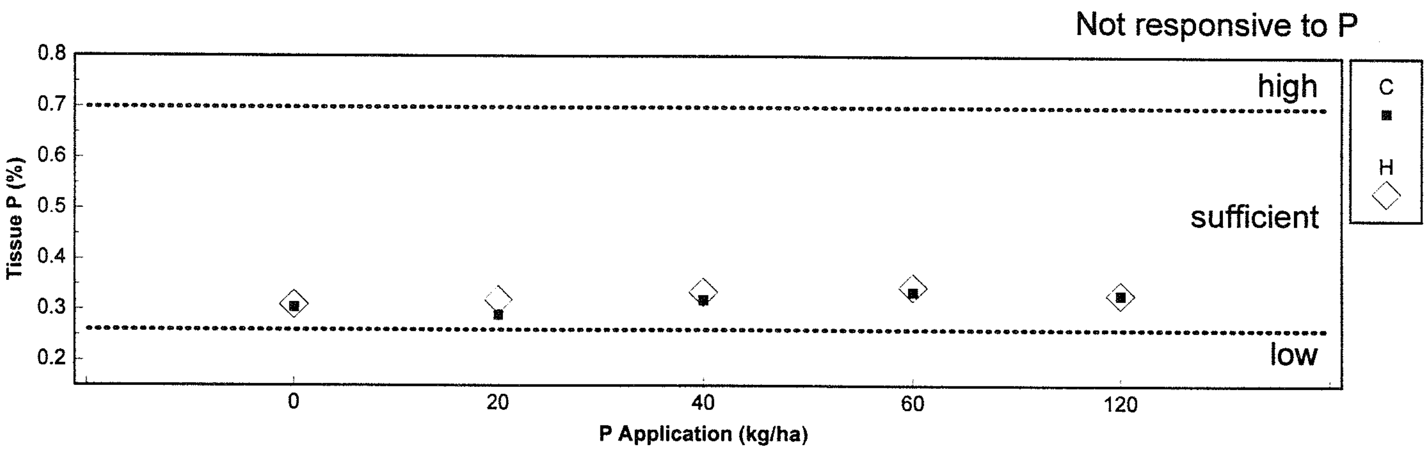
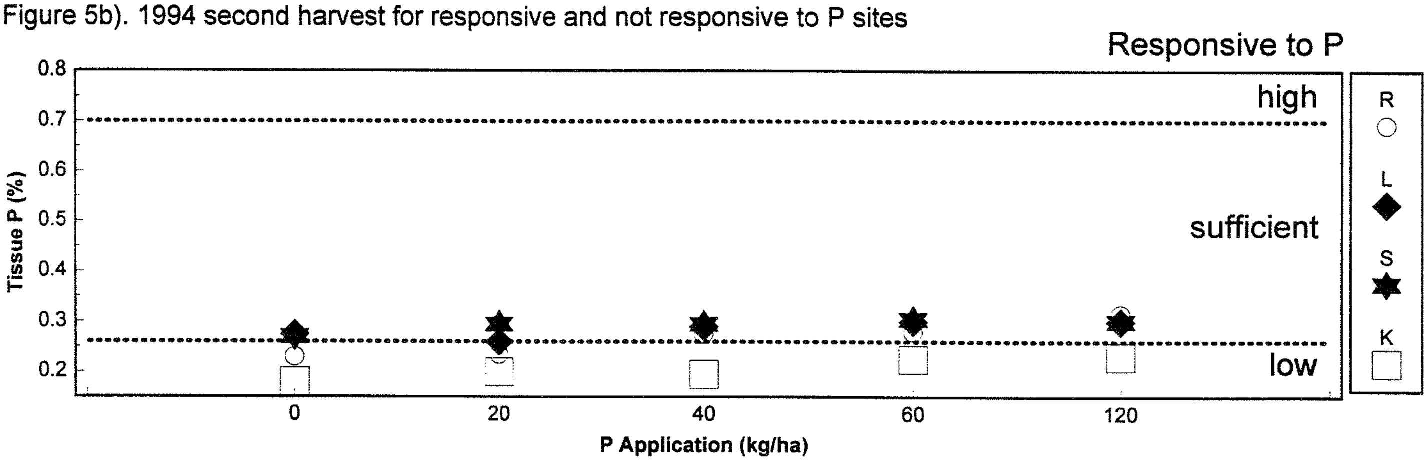


Figure 5b). 1994 second harvest for responsive and not responsive to P sites



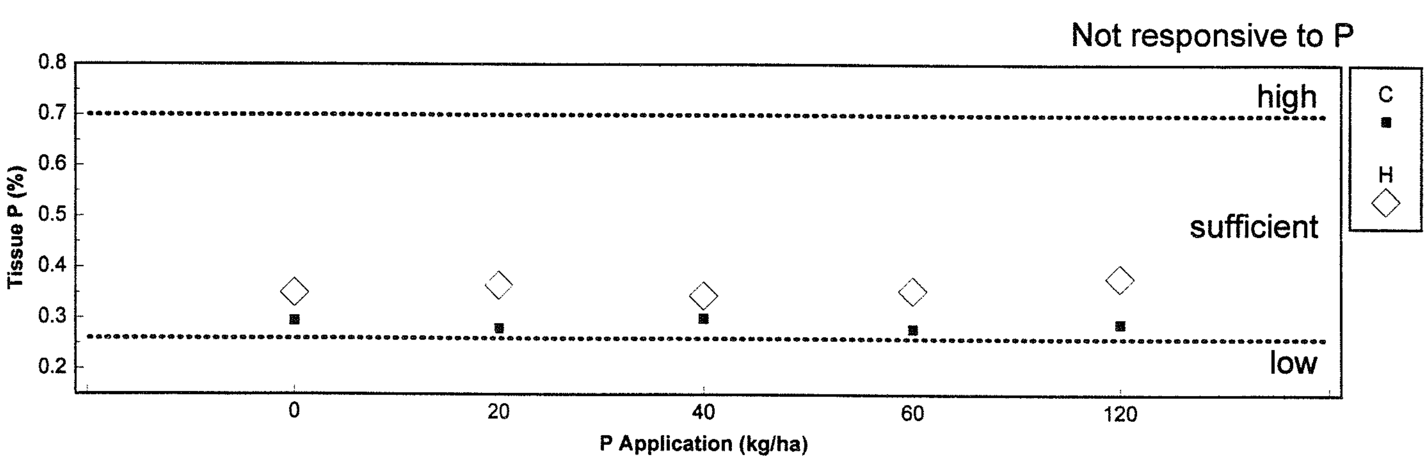


Figure 5c). 1995 first harvest for five sites

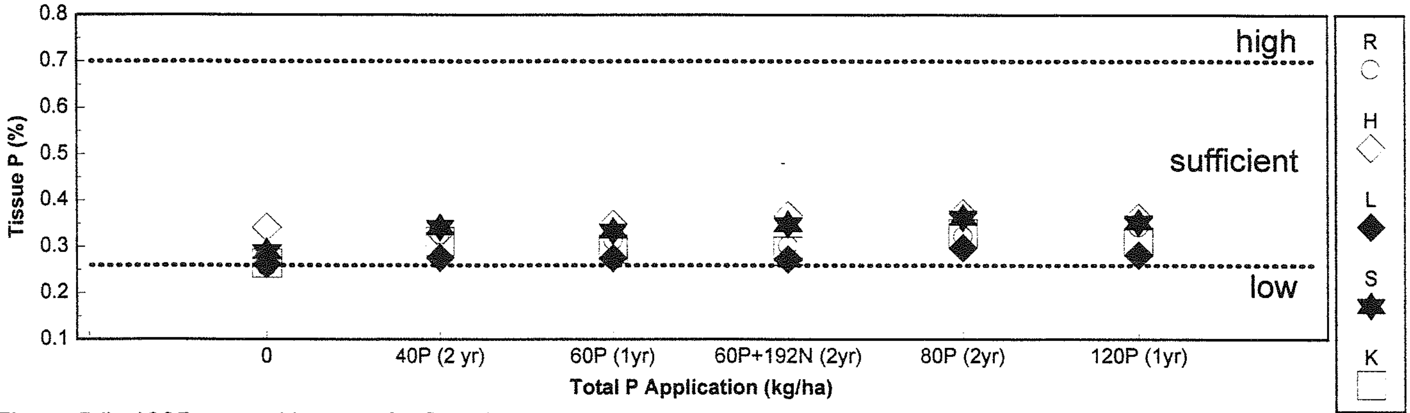


Figure 5d). 1995 second harvest for five sites

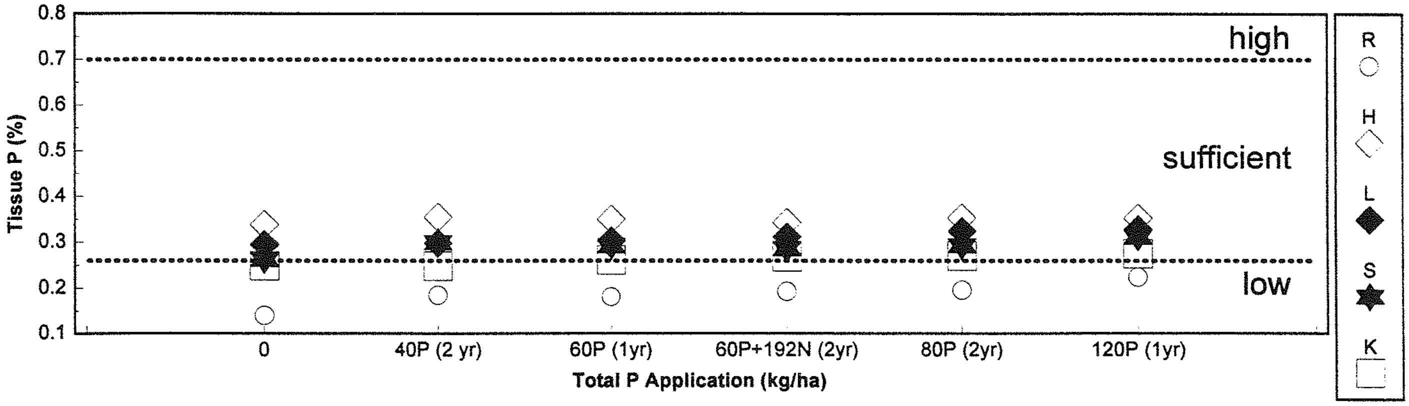


Figure 5e). 1996 first harvest for five sites

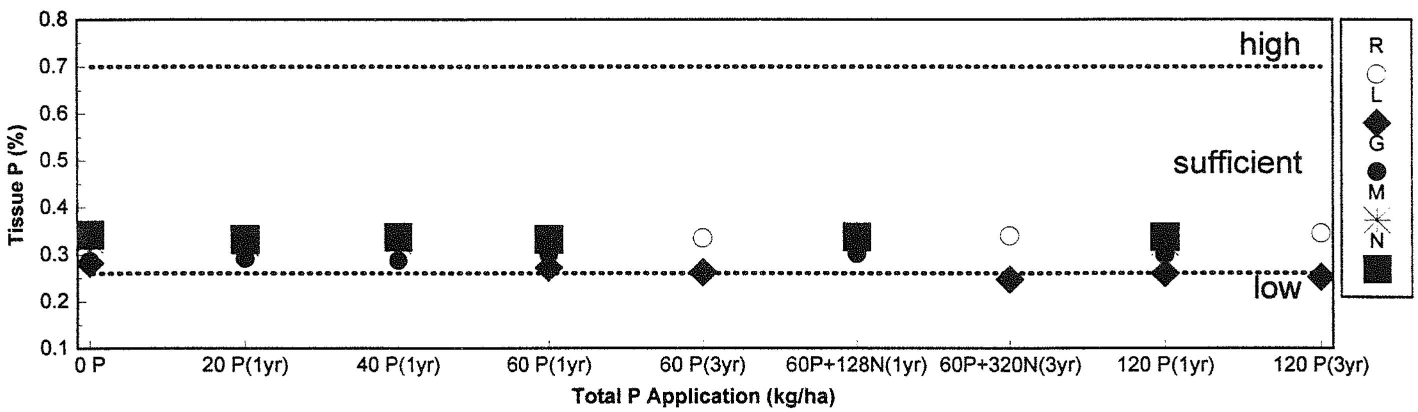
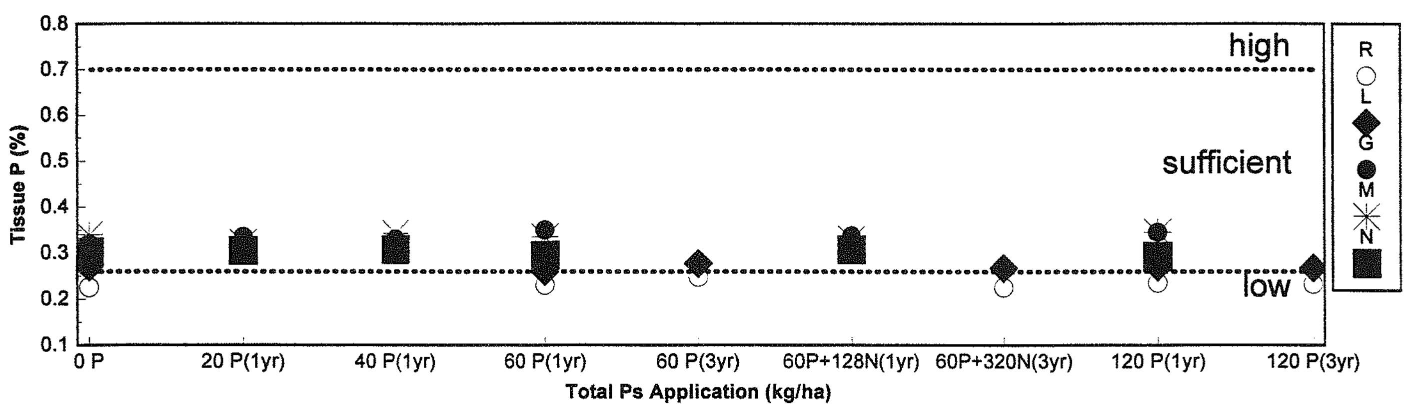


Figure 5f). 1996 second harvest for five sites

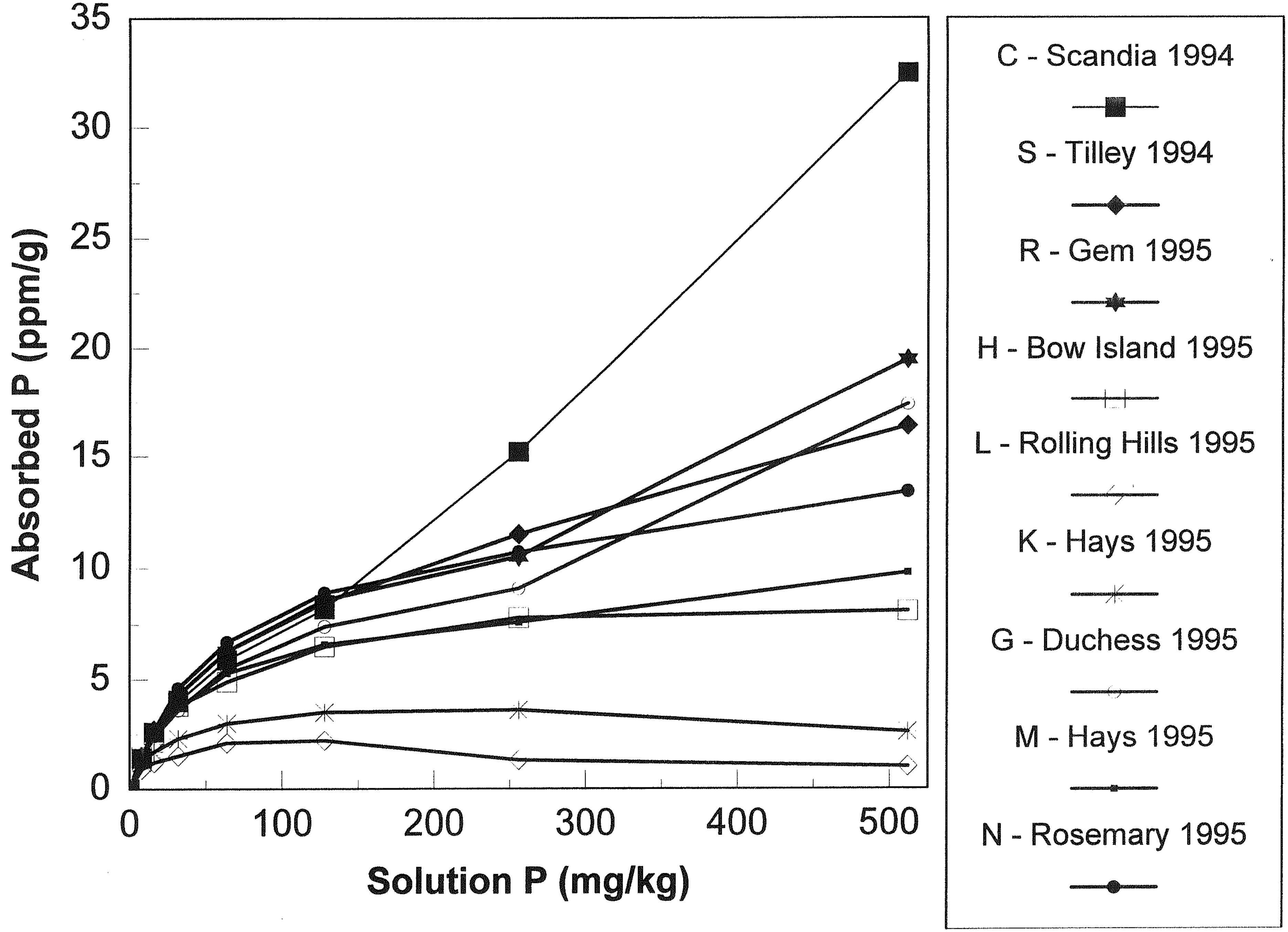


Soil P Methods and P Absorption

Soil P was determined on 0-0.15 m samples each fall from the treatments which had received broadcast P and from the control. In 1994 (Figure 4a) 5 methods to determine soil P were used on samples from 6 sites. Three sites - R, H and K - gave close agreement between all methods. In site L a loamy sand soil with a pH of 6.7 the Miller & Axley method measured about 20% more P than the other methods. In field C the Miller & Axley gave from 0 to 3 ppm of P on all treatments while the other methods gave from 10-12 ppm P on the unfertilized controls and from 20 to 35 ppm P on the treatments receiving from 40 to 120 kg/ha P_2O_5. Since this site did not respond to P fertilizer and tissue levels of P were adequate, the Miller & Axley method was not reliable at this site. This field had a pH of 8.1 which means the solubility of P is low, particularly as measured by the Miller & Axley method. In site S, a clay soil with a pH of 7.7, the Olsen and Sask Kelowna methods had from 10-13 ppm P on the treatments which had received 60 to 120 kg/ha P while the Miller & Axley, Norwest Kelowna and Kelowna had from 4 to 8 ppm of P.

The P adsorption isotherms (Figure 6) indicate large differences in the amount of absorbed or precipitated P. At solution P levels above 100 ppm, some soils will precipitate significant amounts of P. When solution P was 500 ppm, the amount of P removed from solution by the soil by the C site was 32.5 ppm as contrasted to 1.0 ppm, P absorbed by the L site and 3 ppm by the G site. The C site had high pH of 8.1 and a loam texture. The two sites with low P fixing capacity had pH values of 6.7 and 6.5 and loamy sand and sandy loam textures. The C site did not show a yield response to P fertilizer while the two soils with low P adsorption capacities responded. The other 6 sites had intermediate P fixing capacities. This ranged from 8.1 ppm at H, a clay loam soil, which did not show a yield response to P fertilizer to 14.5 ppm at R, a sandy clay loam, which did respond to P.

Figure 6. P Adsorption Isotherms for Nine Soils



Yield Responses to K Fertilizer

The treatments fertilized with K did show an increase in yield over unfertilized control treatments in 1994 at the C site and in 1996 at the G site. The treatments which received both K and P yielded similar to treatments which only received P (Figures 7,8,9). The L site was deficient and the C site was marginal in soil potassium as determined by Alberta Agriculture standards (Laverty, et al, 1988) (Figures 10), yet they did not consistently give positive yield responses to K fertilizer.

Tissue K Levels

Tissue K was low on most of the samples at all the sites (Figure 11). These low levels of tissue K were not a reliable indicator of fields which would give a positive yield response to K fertilizer. At R, K content varied from 1.39% to 2.08% over three years. These are much below the Wisconsin Minnesota standards (Understander, et al, 1994) of 2.41% to 3.80%. Similarly, at L tissue K varied from 1.23% to 2.04%. The three sites commenced in 1996 all had low tissue K according to the Wisconsin Minnesota standards on all treatments. The H site had sufficient tissue K of 2.5% to 3.0% in 1994 but all treatments were deficient in 1995.

Nitrogen

A N fertilizer treatment was used to identify whether yield increases from ammonium phosphate (12-51-0) fertilizers were from the N contained in the fertilizer and to determine if their was any response to higher rates of N. The lowest rate of N treatment #9 (32 kg/ha N) gave an increase (2.3%) in yield over the control treatment #1 (Figure 12). The higher rate (treatment #10 which received 96 kg/ha N annually in the spring more than treatment #4) gave an average increase in yield of 11.1% on the first harvest over treatment #4. On the second harvest there was an average decrease of 0.8% of treatment 9 over treatment #1 and an increase of 2.9% of treatment #10 over treatment #4. It was not measured how much of these increases were due to increased growth of grasses or weeds within the alfalfa plots.

Figure 7. Total 1994 forage yields for K fertilizer treatments

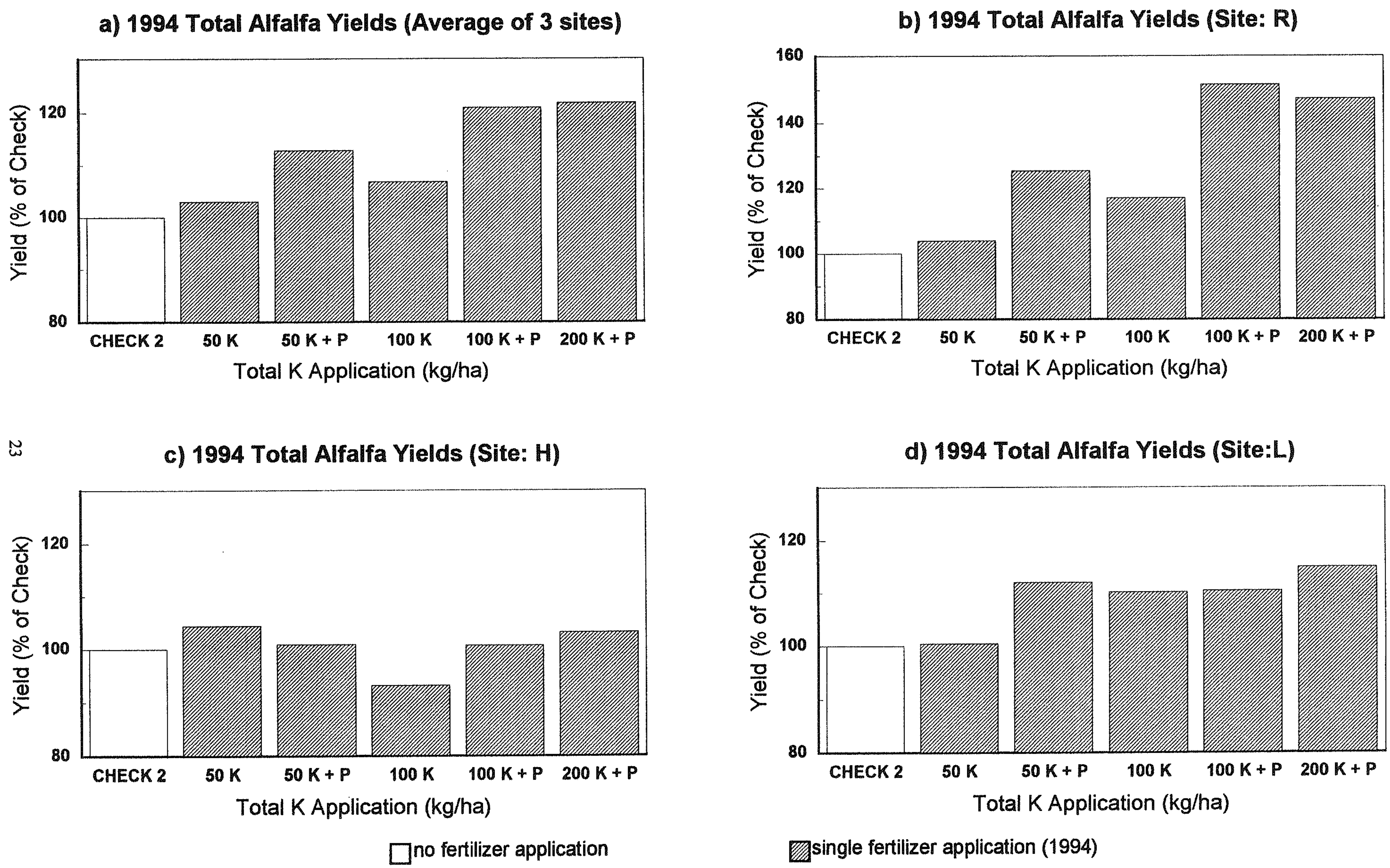


Figure 8. Total 1995 alfalfa forage yields for K fertilizer treatments

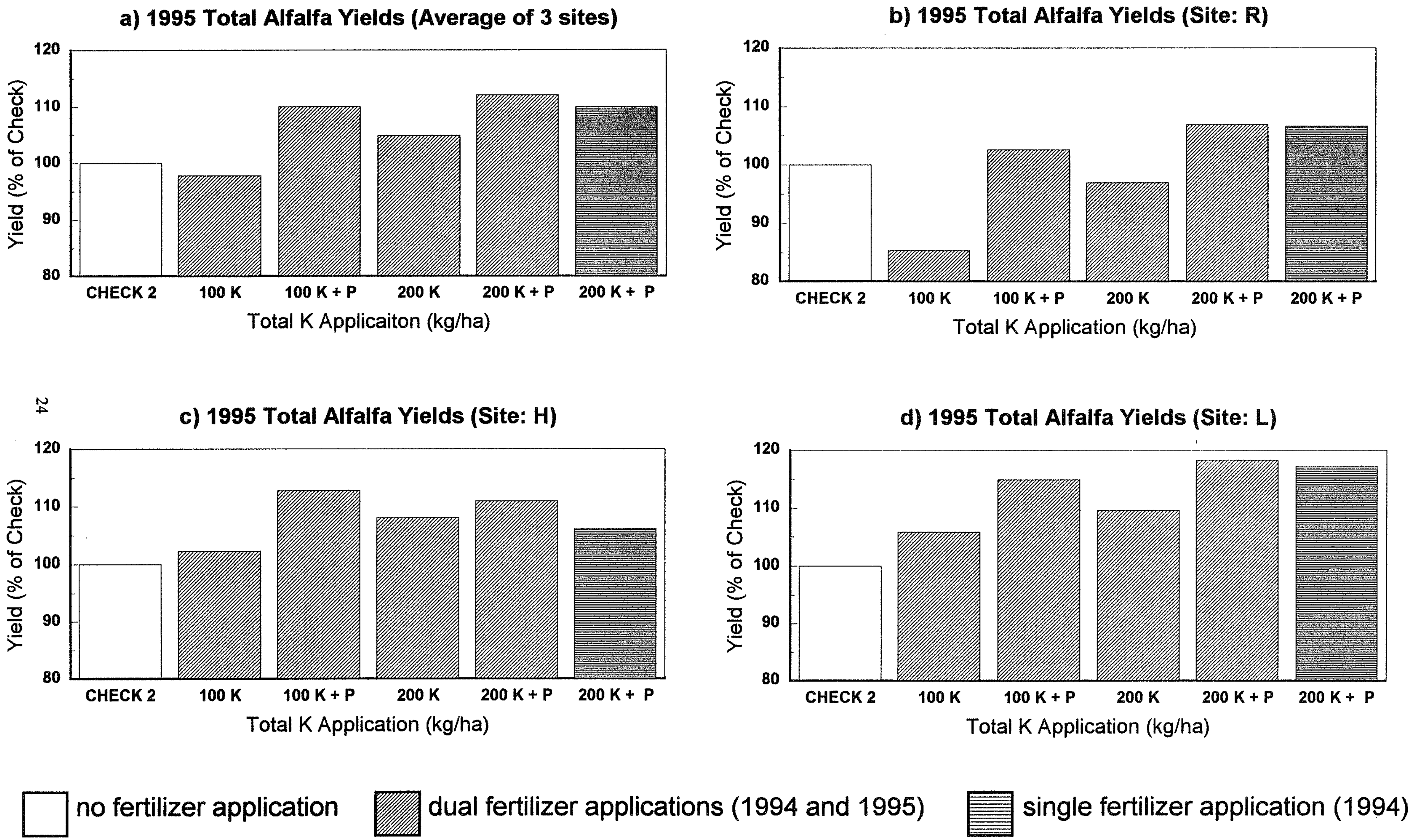


Figure. 9 Average 1996 yield (%) response of alfalfa forage to potassium fertilizer on three fields initiated in 1996 and two fields in 1994.

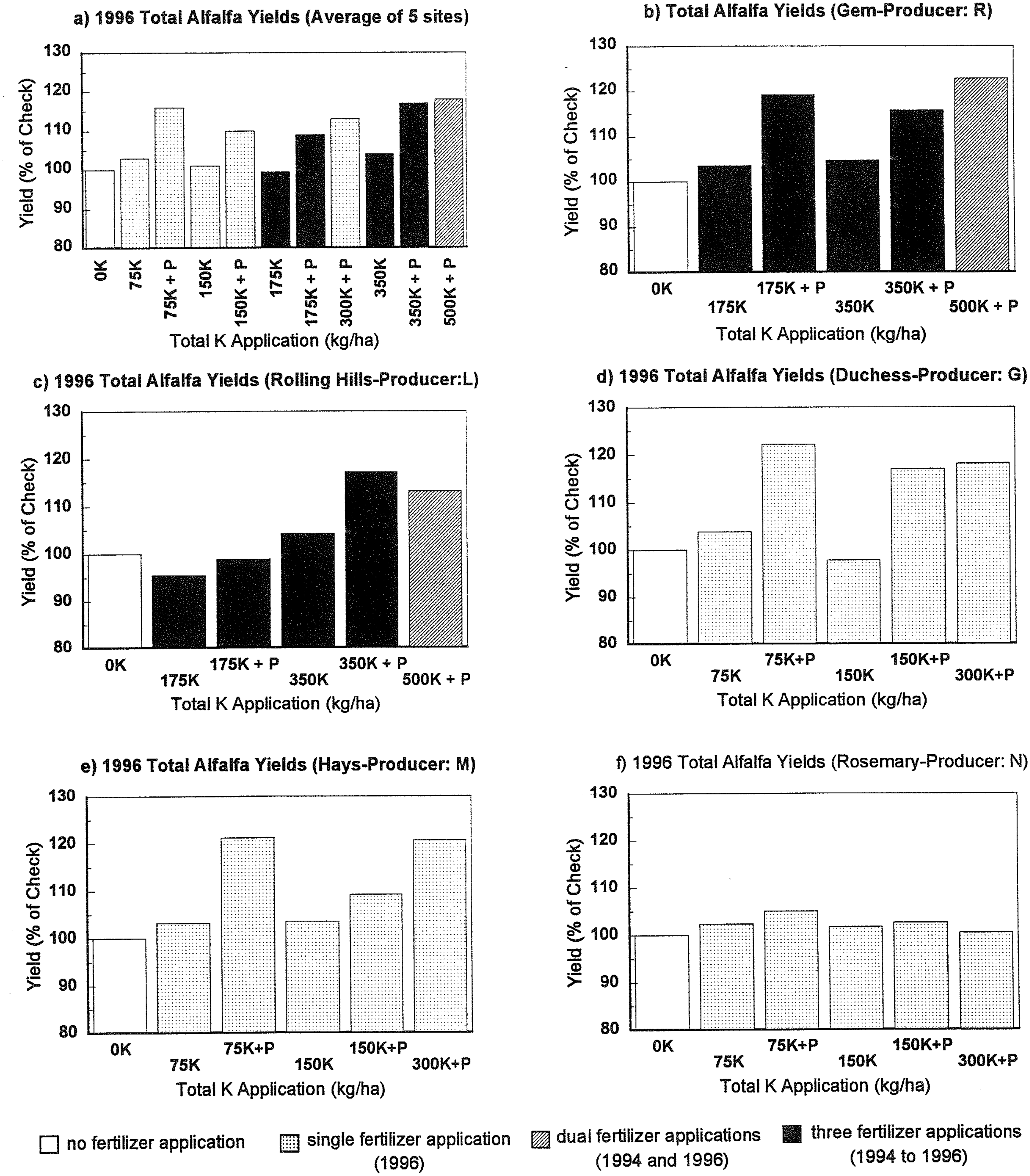
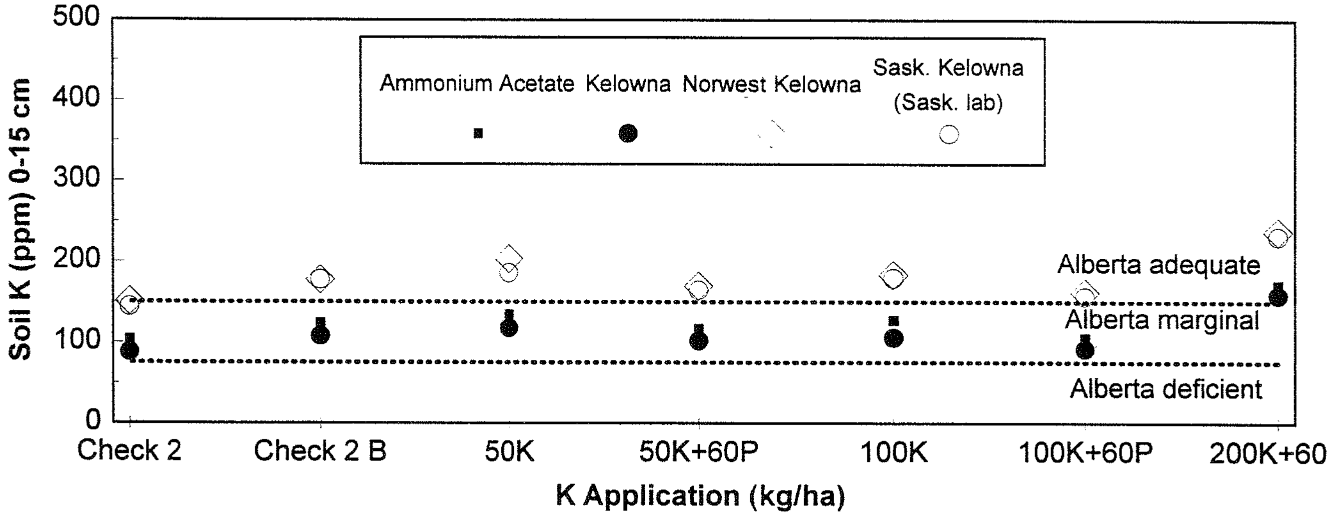


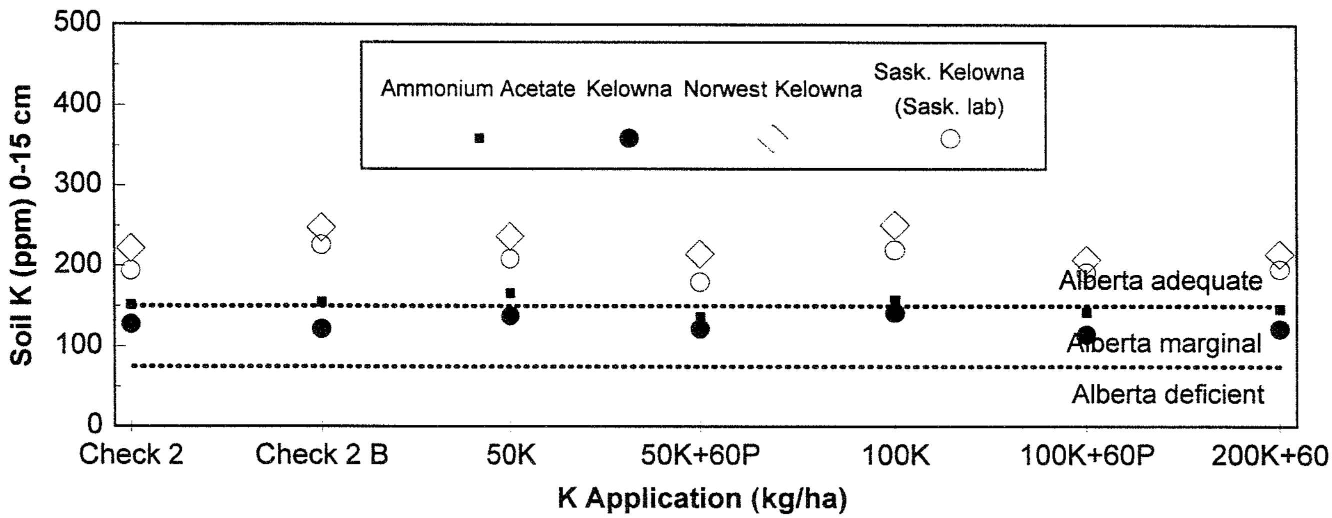
Figure 10. Soil K for three years on K fertilizer treatments as measured by different extraction methods, compared to Alberta Agriculture stadards

Figure 10 a). 1994 Soil K at three sites

Site: R



Site: H



Site: L

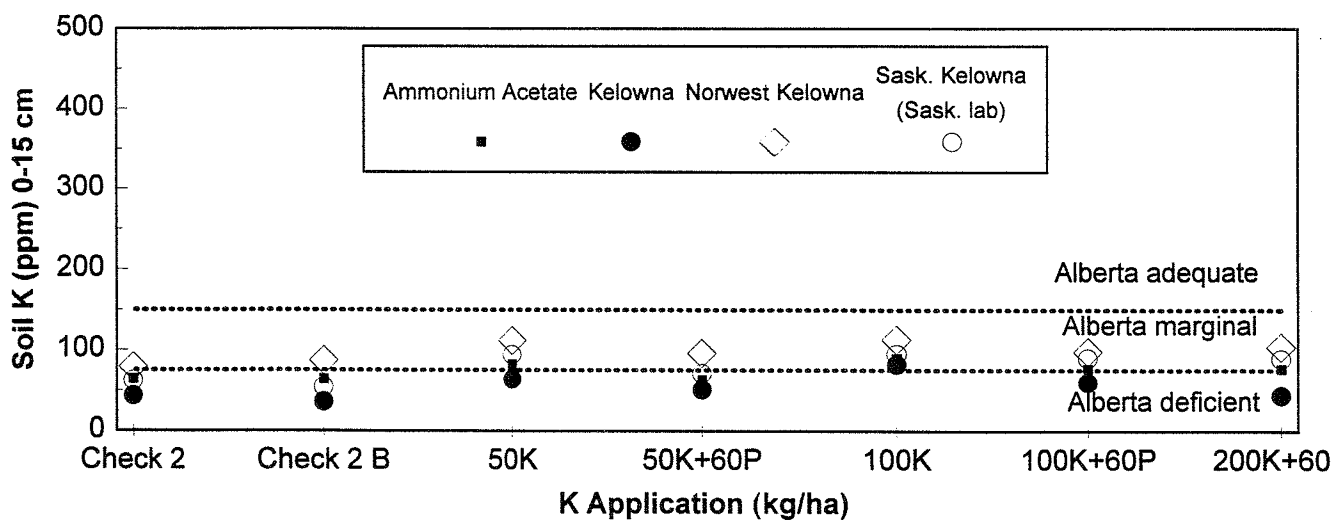


Figure 10 b). 1995 Soil ammonium acetate K at three sites

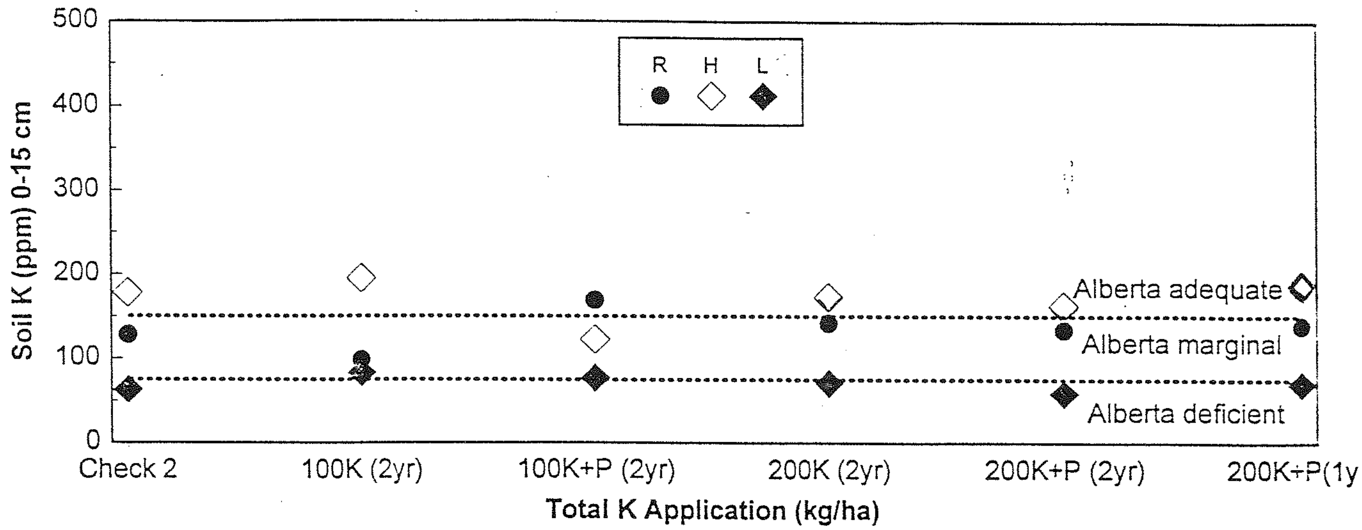
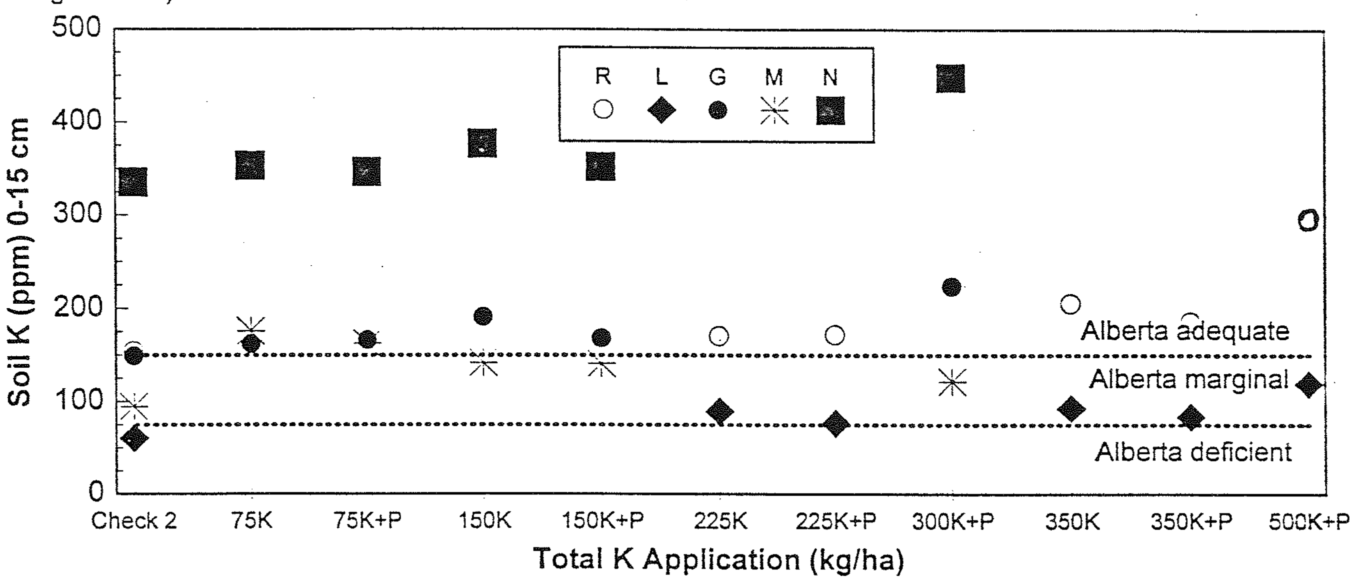


Figure 10 c). 1996 Soil ammonium acetate K at five sites



Tissue Analysis of Nutrients

Total tissue analysis for all sites is reported and compared to Wisconsin Minnesota standards for the control and for the high P and K treatments in Appendix 2. As previously mentioned, P was deficient on the unfertilized treatments on some sites. Potassium was deficient on the tissue samples. Nitrogen was slightly high (above 5.0%) on some treatments from 5 of the 9 sites. Sulfur was also slightly high (above 0.50%) on some treatments from 5 of the 9 sites.

Figure 11. Alfalfa tissue K for two harvests and three years on K fertilizer treatments as compared to Wisconsin, Minnesota standards

Figure 11 a). 1994 Alfalfa tissue K for six K treatments (first harvest)

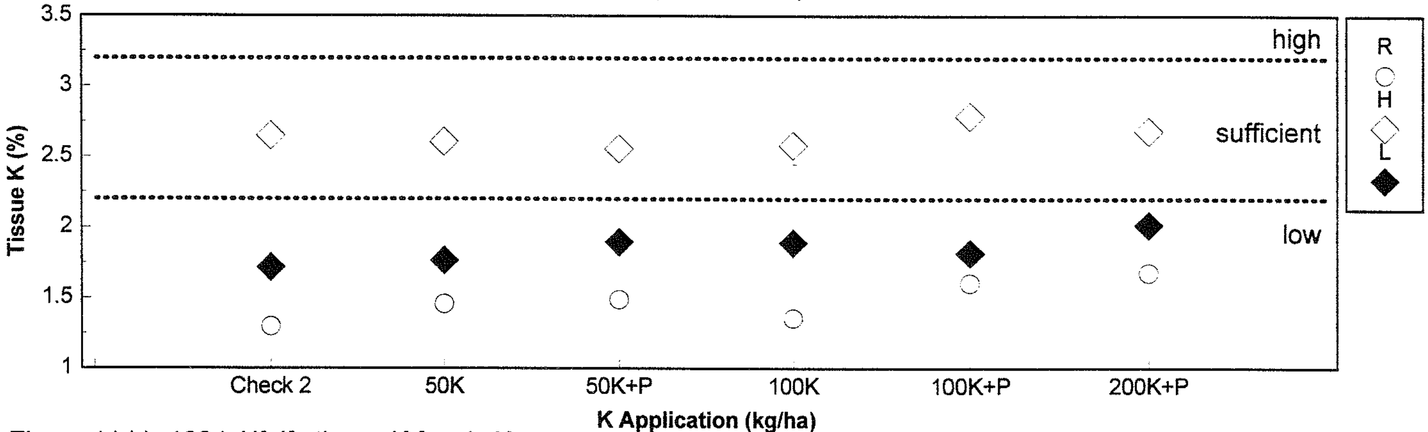


Figure 11 b). 1994 Alfalfa tissue K for six K treatments (second harvest)

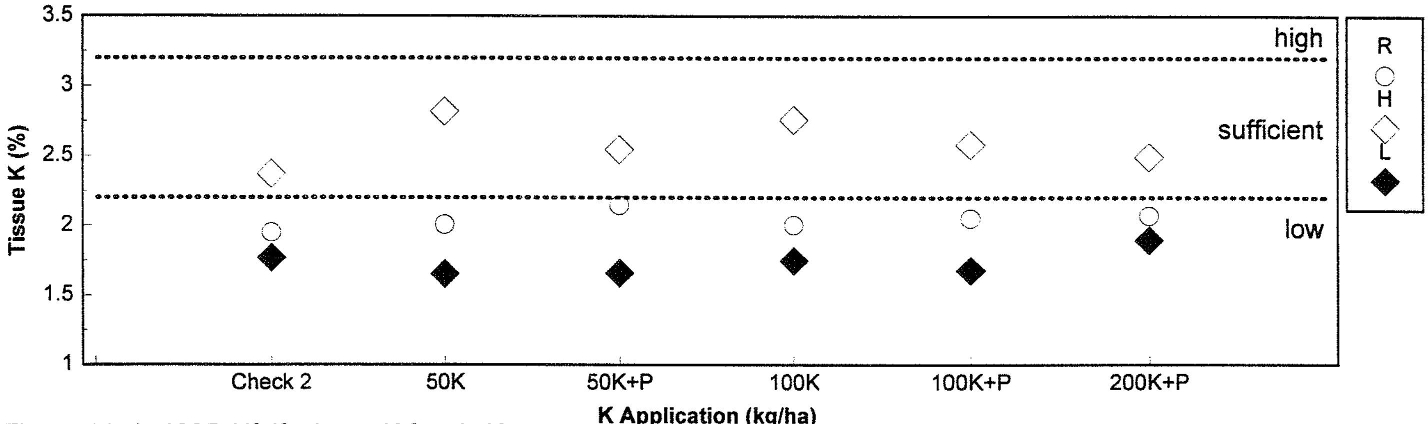


Figure 11 c). 1995 Alfalfa tissue K for six K treatments (first harvest)

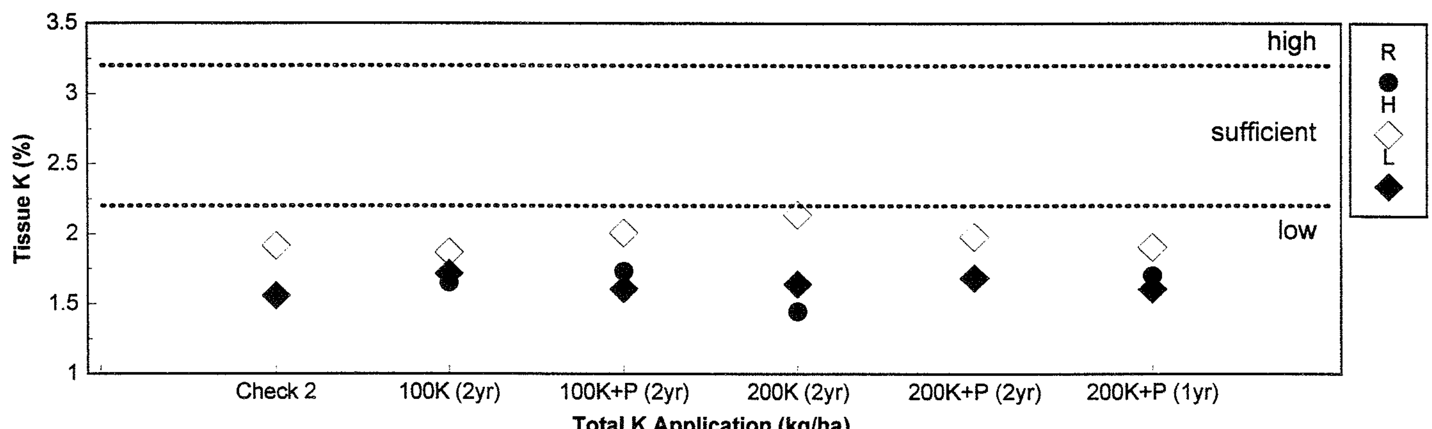


Figure 11 d). 1995 Alfalfa tissue K for six K treatmets (second harvest)

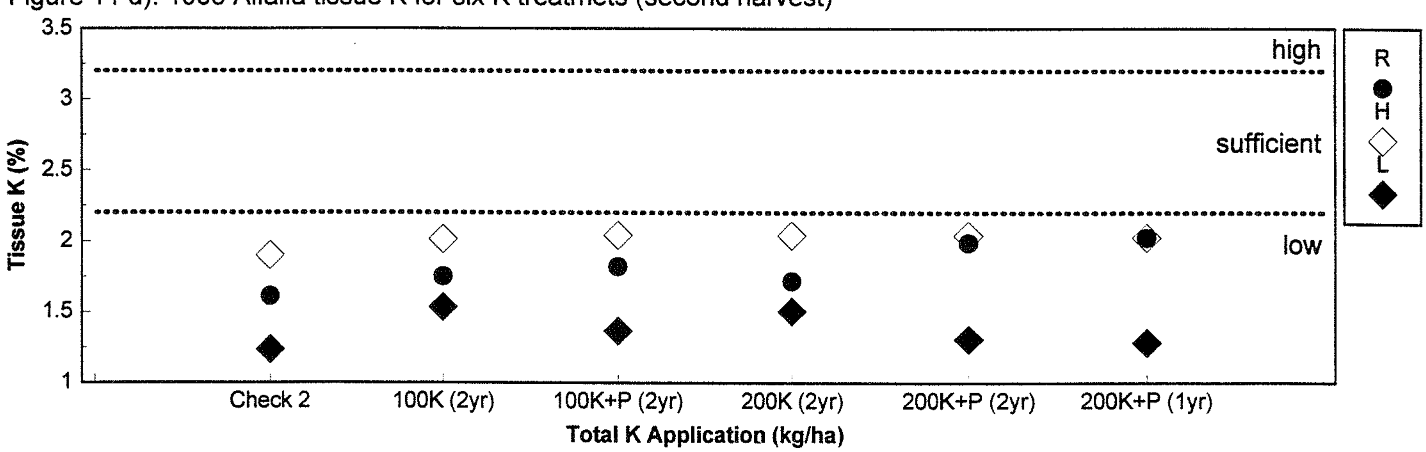


Figure 11 e). 1996 Alfalfa tissue K for eleven K treatments (first harvest)

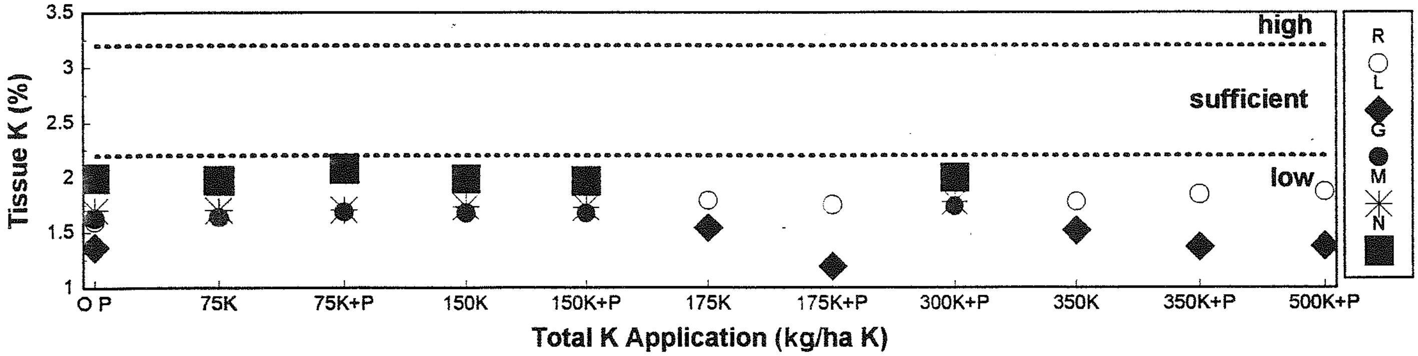
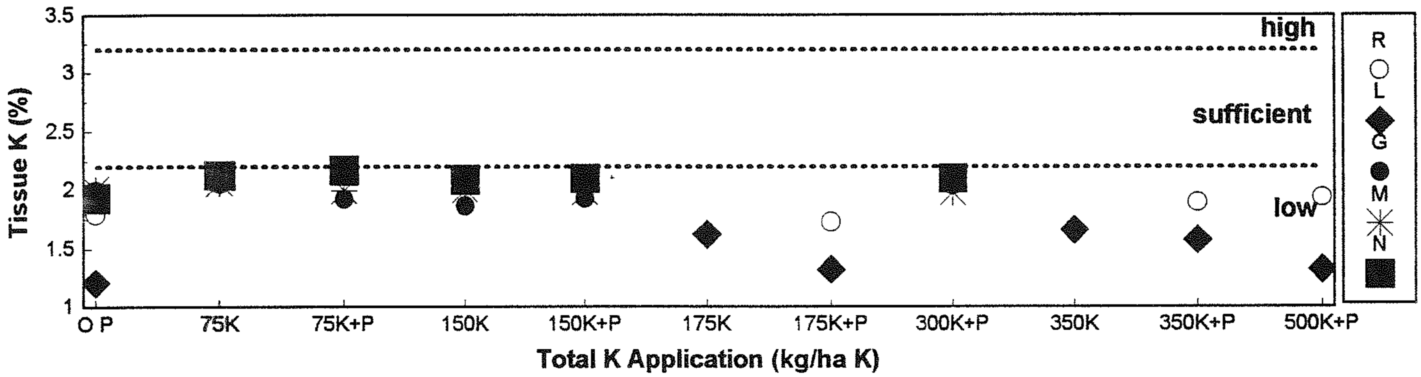


Figure 11 f). 1996 Alfalfa tissue K for eleven K treatments (second harvest)



Micronutrient levels Appendix 2 were usually within adequate levels when compared to Wisconsin Minnesota standards. The C site had deficient levels of Mn at the first harvest in 1994. Zinc was deficient on those treatments receiving P fertilizer at R on the first cut in 1994 and the second cuts in 1994 and 1995 (Figure 13). Zinc was also deficient on P fertilizer treated plots at the second cut at K and the first cut at the S sites in 1994. Copper was deficient at the L site from 1994 to 1996 on those treatments receiving P or appreciable amounts of K fertilizers.

DRIS Standards

There was not a sufficient range of treatments and soil types to determine nutrient rates at maximum yield to determine DRIS standards. The data collected in this project was compared to DRIS standards from Georgia and from Midwest USA (Walworth, 1991) and to conventional tissue sufficiency level standards (Table 7).

Figure 12. Alfalfa yield response to N fertilizer treatments for the first harvest for three years

Figure 12 a). 1994 yields for six sites

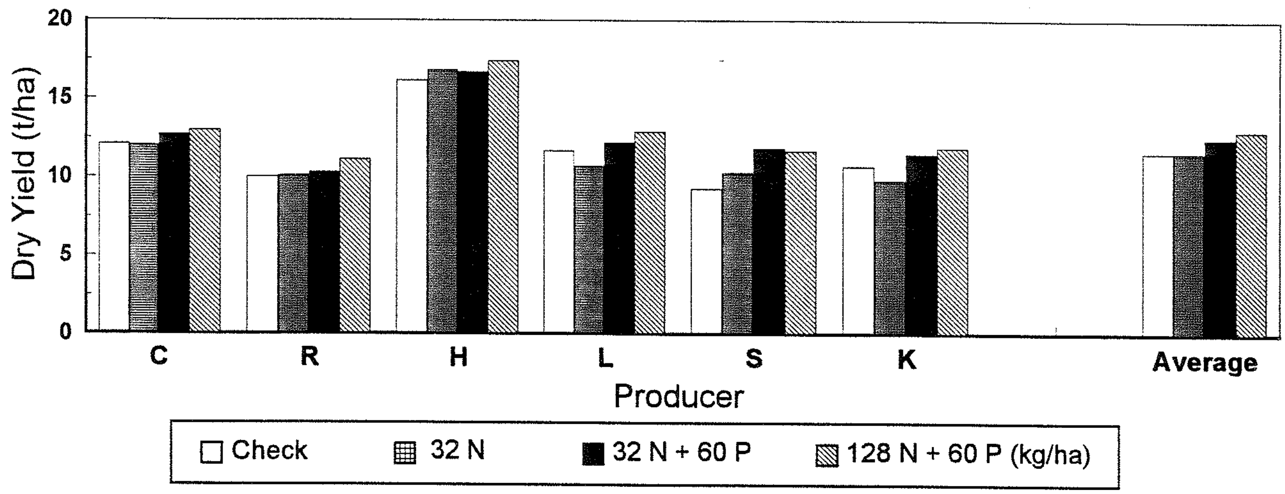


Figure 12 b). 1995 yields for five sites

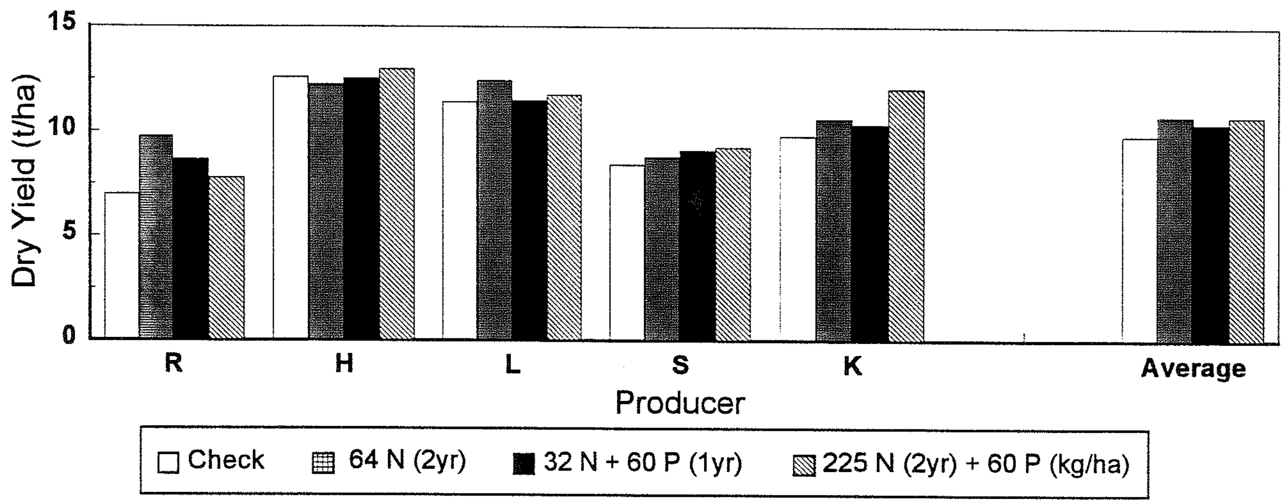


Figure 12 c). 1996 yields for five sites

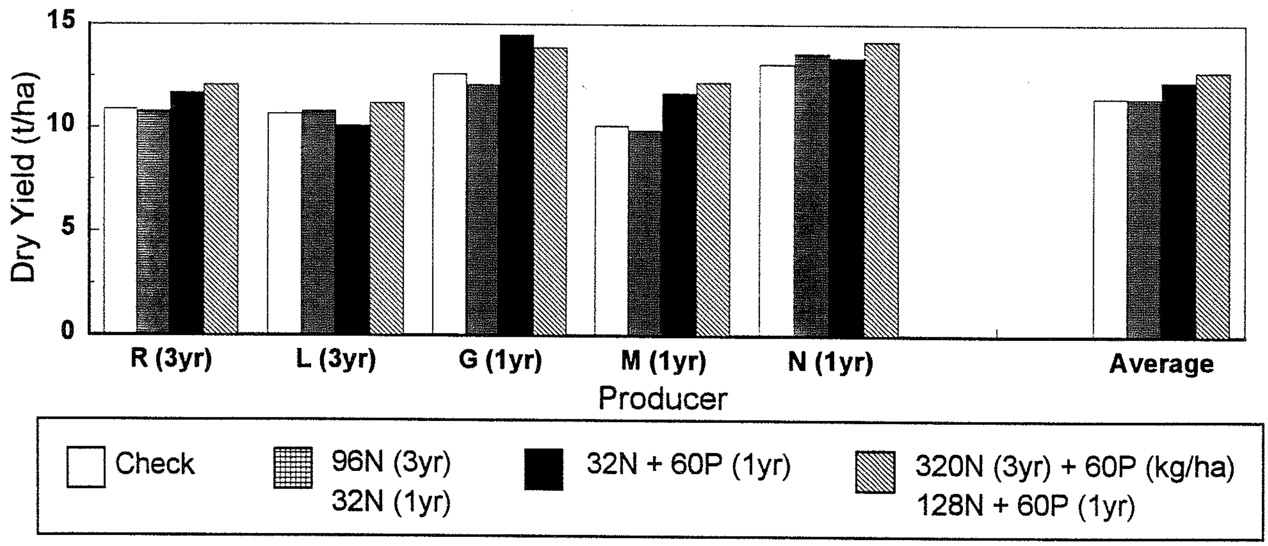


Figure 13. Alfalfa tissue Zn for two harvests and three years on P fertilizer treatments as compared to Wisconsin, Minnesota standards

Figure 13 a). 1994 Alfalfa tissue Zn on five P fertilizer treatments (first harvest)

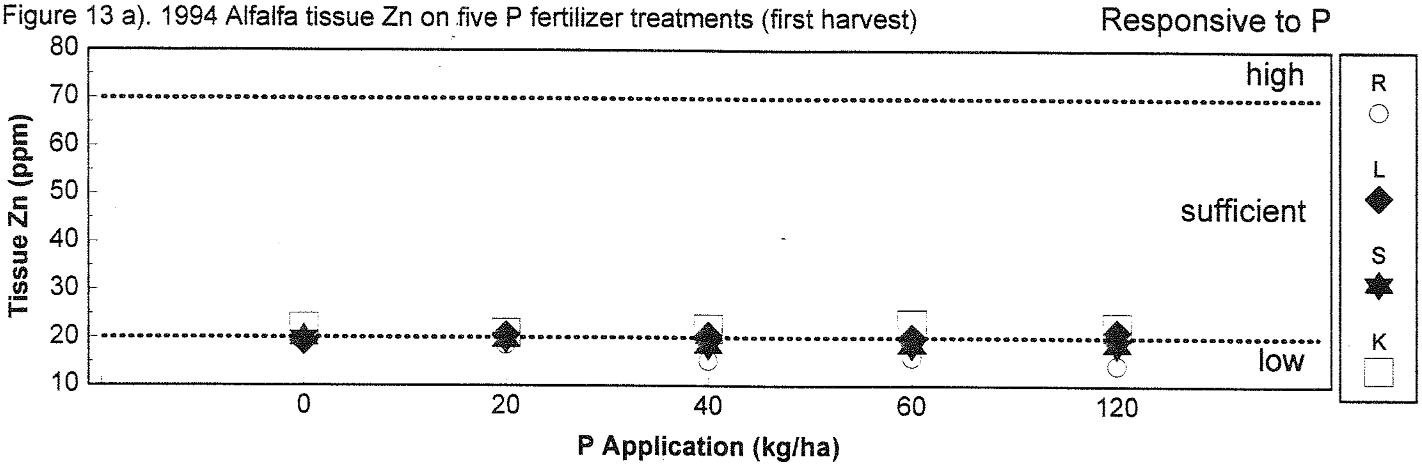


Figure 13 b). 1994 Alfalfa tissue Zn on five P fertilizer treatments (first harvest)

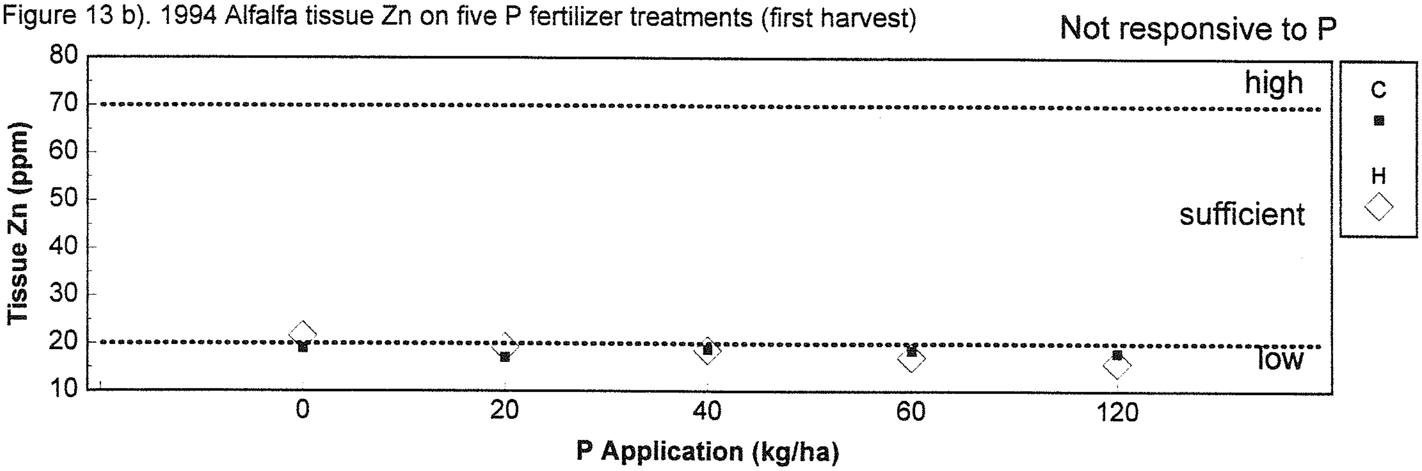


Figure 13 c). 1994 Alfalfa tissue Zn on five P fertilizer treatments (second harvest)

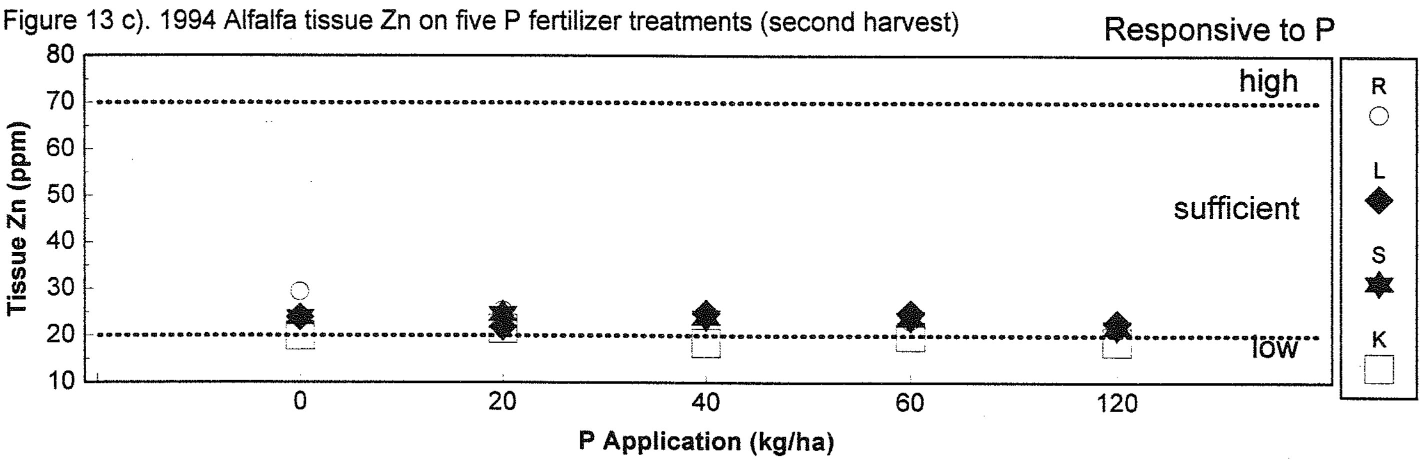


Figure 13 d). 1994 Alfalfa tissue Zn on five P fertilizer treatments (second harvest)

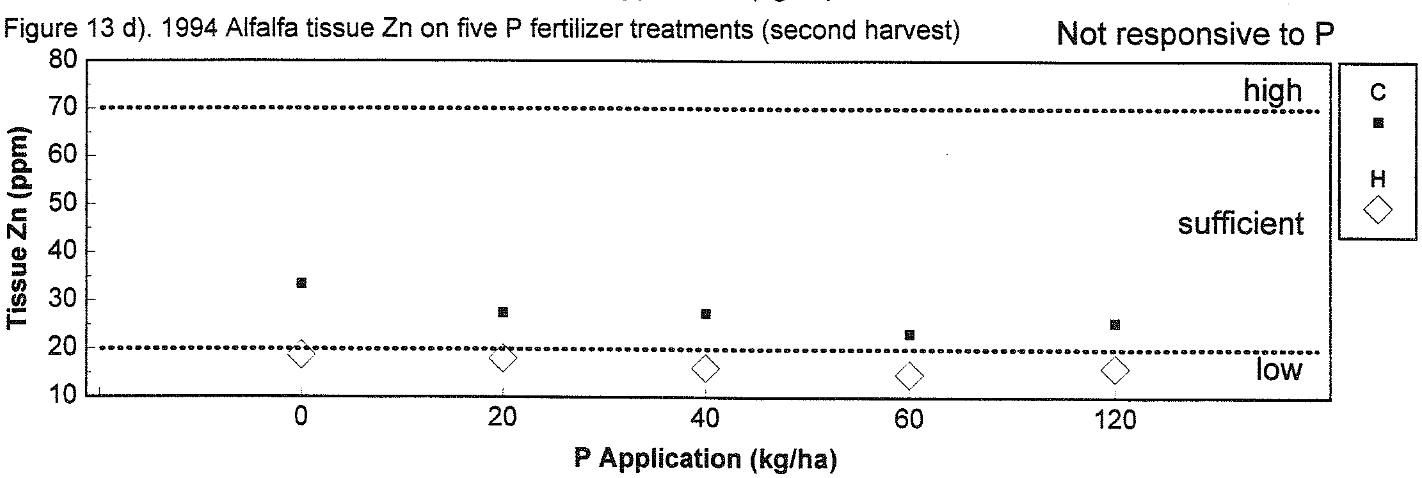


Figure 13 e). 1995 Alfalfa tissue Zn on five P fertilizer treatments (first harvest)

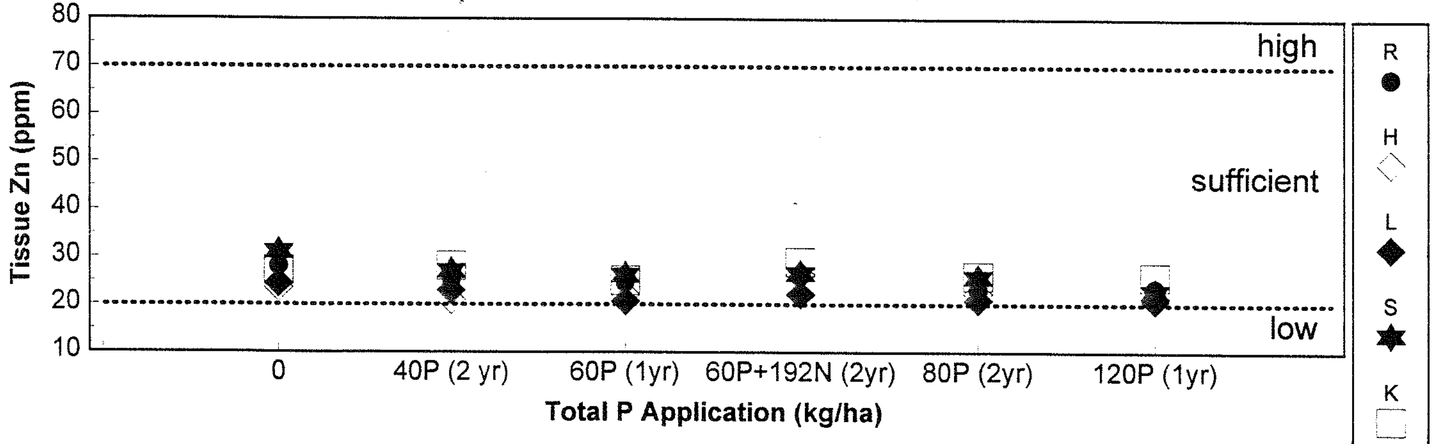


Figure 13 f). 1995 Alfalfa tissue Zn on five P fertilizer treatments (second harvest)

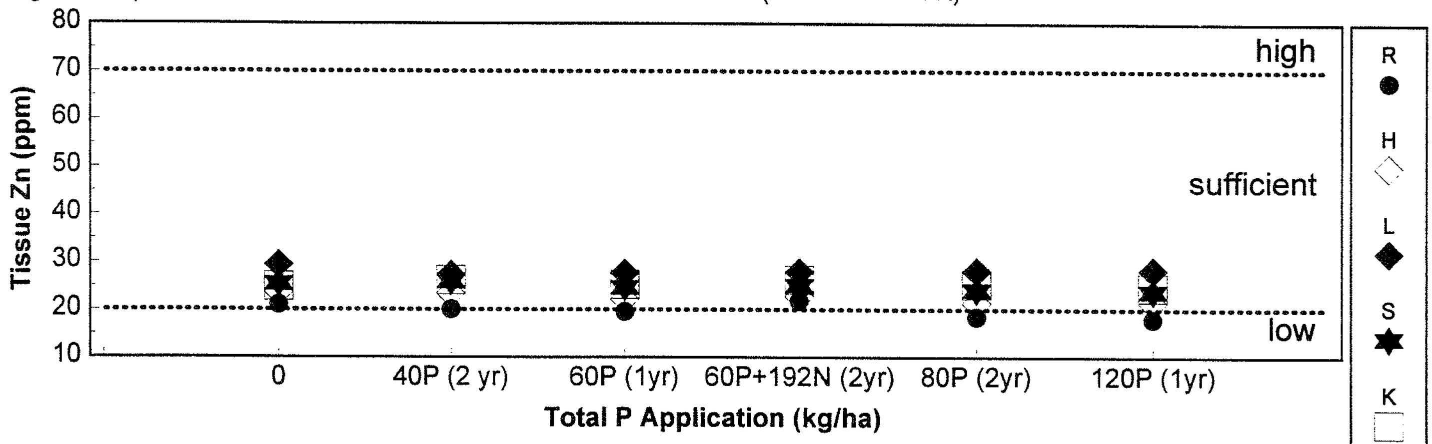


Figure 13 g). 1996 Alfalfa tissue Zn on nine P fertilizer treatments (first harvest)

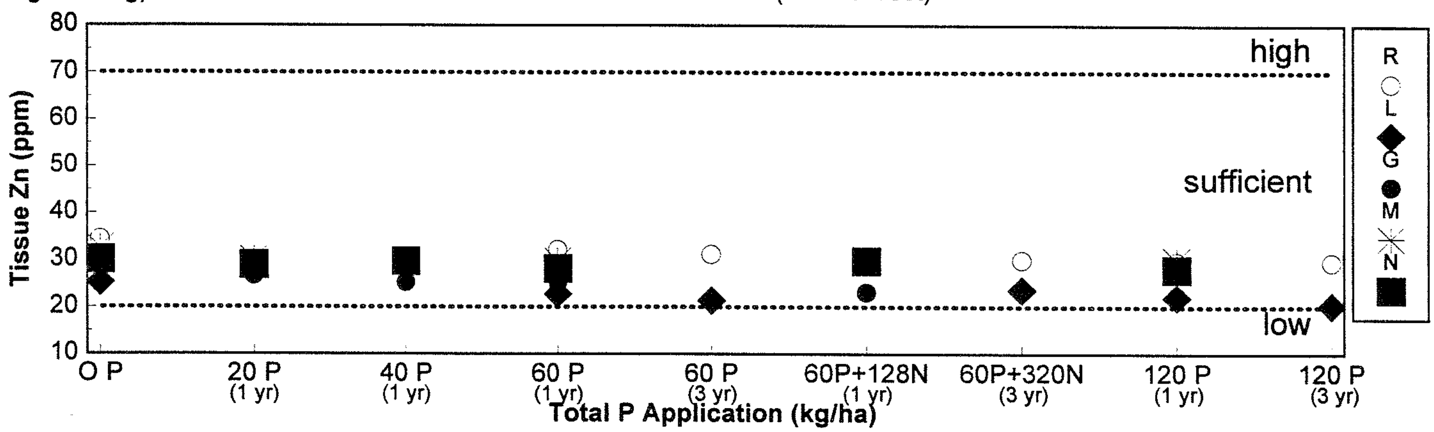
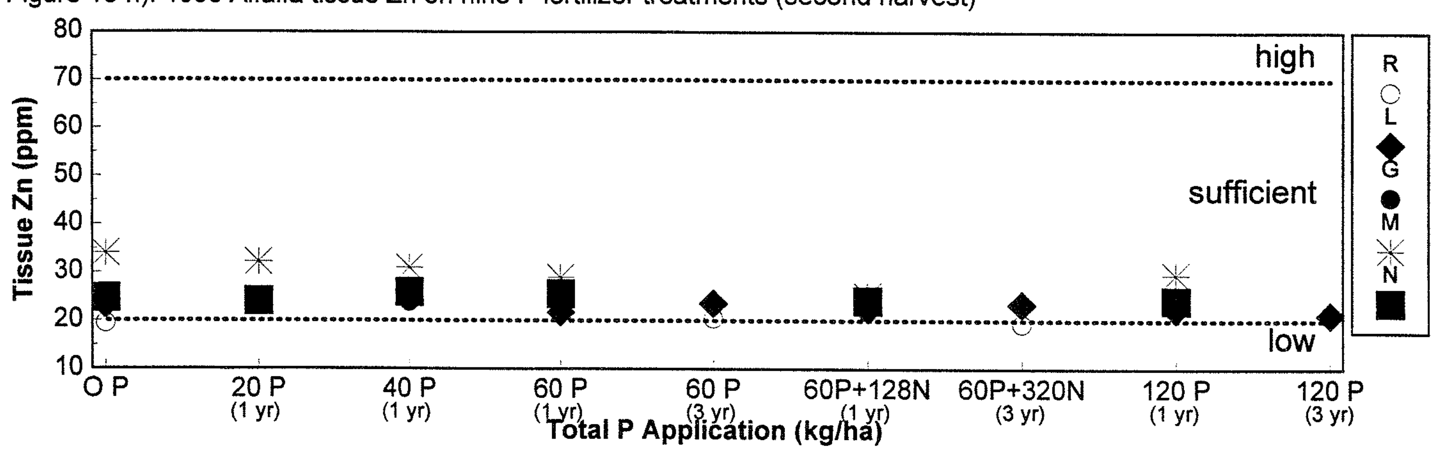


Figure 13 h). 1996 Alfalfa tissue Zn on nine P fertilizer treatments (second harvest)



DRIS emphasizes the importance of nutrient ratios. Because the tissue levels of P, K from the Alberta project are lower and tissue levels for N, Ca and Mg are higher than DRIS standards, some nutrient ratios differ greatly from DRIS standards (Table 8). For example, the Midwest DRIS P/Ca ratio is 0.22 and the Georgia DRIS ratio is 0.23 while the median for the Alberta data is 0.16. The N/K DRIS ratio is 1.50 for Georgia and 1.26 for the Midwest and the median of the Alberta data is 2.21.

Soils in southern Alberta have higher levels of Ca and Na, higher pH and lower temperatures and the days are longer than those in Georgia and the Midwest USA. Jones, et al (1991) discusses these factors which influence nutrient uptake and nutrient ratios in plant tissue. Sodium sulphate and sodium bicarbonate reduce the uptake of K and increase the uptake of P. High levels of soil calcium will reduce the uptake of K. A high soil pH encourages nitrogen fixation and this increases the nitrogen content of plant tissue. At low soil temperatures as compared to higher soil temperatures the uptake of K and P and Zn are reduced.

To obtain optimum nutrient sufficiency levels or nutrient ratios for alfalfa, existing standards from other areas will need to be modified to fit Alberta conditions. The standards that are suitable for the irrigated soils of southern Alberta may not be suitable for the black and grey soils of central and northern Alberta.

Banded Fertilizer

Treatments which were banded (Figures 1c & d, 2c & d and 3c &d) showed no advantage in yield over similar rates which were broadcast. This is in contrast to findings of Malhi et al (1992) at Lacombe who obtained increased yields on banded treatments of P on alfalfa as compared to broadcast treatments. However, Simons et al (1995) at Brandon obtained similar yields on broadcast and on banded alfalfa. Leyson (1982) at Swift

Current found banded treatments of dryland alfalfa had yields reduced by the banding process. He used a hoe drill to apply the banded fertilizers which would do more damage to the alfalfa crowns than the disc drill used in this project and by Malhi et al and by Simons et al.

Table 7. Standards for Interpreting Nutrient Deficiencies from Tissue Analysis of Alfalfa at First Bloom.

	Wisconsin ❀ Minnesota	Benton✲ Jones	Midwest✧ Labs	Georgia✭ DRIS	Midwest✭ DRIS	Alberta✽ Project
N %	3.0 - 5.0	4.5 - 5.0	3.0 - 4.5	2.95	3.29	3.1 - 5.4
P %	.26 - .37	.26 -.70	.25 - .45	.24	.32	.18 - .37
K %	2.41 - 3.80	2.0 - 3.5	2.5 - 3.8	2.0	2.7	1.16 - 2.68
S %	.26 - .50	.26 - .50	.25 - .35			.31-.57
Ca %	.50 - 3.0	1.80 - 3.0	1.0 - 2.5	1.19	1.36	1.1 - 2.5
Mg %	.31 - 1.0	.30 - 1.0	.30 - .80	0.16	0.29	.27 - .46
Zn ppm	20 - 70	21 - 70	25 - 70	21		14 - 34
Cu ppm	5 - 30	7 - 30	8 - 20	6.9		3.5-12.1
B ppm	30 - 80	30 - 80	25 - 80	44	31	36 - 64
Fe ppm			50 - 250			47 - 104
Mn ppm	25 - 200	31 - 100	26 - 100			21 - 72
Mo ppm	1 - 5	1 - 5				2.2 - 4.5

❀ Undersander et al 1994
✲ Benton Jones et al 1991
✧ D. Ankerman and R. Large
✭ Walworth 1986
✽ Range of data on this project (first harvest)

Table 8.DRIS alfalfa tissue ratios and means of tissue analysis from Alberta project.

Ratio	Georgia DRIS✭	Midwest DRIS✭	Alberta Means
N/P	12.4	10.3	14.6
N/K	1.50	1.26	2.09
N/Ca	2.53	2.46	2.24
P/K	0.124	0.124	0.144
P/Ca	0.216	0.230	0.154
Mg/P	0.672	0.924	1.28
K/Ca	1.94	1.87	1.08
Mg/K	0.083	-	1.84

✭ Beverly 1991

Winter Survival of Alfalfa

Potassium fertilizers have been found to increase winter survival of alfalfa (Calder and Macleod, 1966). In May of 1996 stand emergence counts were made on seven treatments and four replicates of the K treatments at the H site (Table 9). The farmer then cultivated the field to remove the alfalfa because of irregular stand due to winterkill. There were no significant differences between plant populations in the check or fertilized treatments. The late harvest the preceeding season (Oct.10, 1995) was likely the cause of the poor winter survival.

In 1997 similar stand counts (Table 9) were made on three alfalfa stands. Like the Bow Island site there also were no significant differences in stand population between the check and fertilizer treatments on these three sites. Four other alfalfa fields had been terminated by the farmer and one site (L) had a dense stand on all treatments where it was not possible to identify individual plants.

Table 9. Emergence as plants m^2 in May of 1996 and 1997.

Treatment	Site and date			
	H Bow Island 2,5,1996	Duchess G 6,5,1997	Hays M 6,5,1997	Rosemary N 7,5,1997
Check	24.5 a◆	36.6 a◆	29.5 a	39.0 a
Banded Check	20.5 a	34.7 a	29.4 a	38.6 a
50 K	26.1 a	31.8 a	29.6 a	38.4 a
50 K + 60 P	20.0 a	34.4 a	28.9 a	38.3 a
100 K	30.0 a	35.7 a	27.2 a	41.5 a
100 K + 60 P	15.5 a	34.6 a	27.6 a	40.2 a
200 K + 60 P	21.4 a	34.1 a	28.6 a	38.0 a

◆ means for each site followed by the same letter are not significantly different at the 5% level according to the Student-Newmans-Keul test

Copper Fertilizer

At the L site in 1997, no significant differences in yield occurred between the treatments which received foliar applications of Cu and the treatments which did not receive Cu. Treatments 3 and 5 which had received a total application of 120 kg/ha P in previous years yielded slightly (+6.0%) more than the nonfertilized treatments (1, 8, 16, 18), but these differences were not significant at the 5% level.

Tissue Cu analysis was done without replication on the first harvest and with 2 replicates on the second harvest. On samples from the second harvest, additions of foliar Cu significantly increased the Cu content. There were also significant differences between treatments on Cu content. Copper levels on the control treatments were 7.8 ppm without foliar Cu and 12.4 ppm with Cu. The P treatments had 5.2 ppm Cu without foliar Cu and 9.6 ppm with Cu and the K treatments were 9.2 ppm Cu without foliar Cu and 17.9 ppm with foliar Cu. P reduced the uptake of copper but did not create a deficiency sufficient to reduce yield. Potassium appears to enhance the uptake of Cu.

Conclusions

Phosphorus deficiency can be best identified by a combination of soil and tissue tests. On some soils, soil tests alone, may indicate low levels of P even when high rates of fertilizer have been applied and no increase in yield occurs. Tissue tests alone do not provide large distinctions between deficient and adequate soils. Care must be taken in interpreting tissue test results as they are greatly influenced by the maturity of the alfalfa.

High rates of P fertilizer on responsive soils do not give appreciable differences in alfalfa yield over three years when compared to low rates. Batch applications were also similar to yearly applications over three years. The batch application yielded more than the yearly application in the first year and less in the third year. Broadcast P applications were similar to shallow banded P.

Phosphorus adsorption isotherms indicated large differences in the amount of P absorbed by different soils. The Miller & Axley method to determine available soil P was compared to the Kelowna, Norwest Kelowna, Sask Kelowna and Olsen methods. On some soils they were similar. On several soils the Miller & Axley method showed more available P than the Kelowna method. On one high pH soil with a high P adsorption capacity the Miller & Axley method was not reliable while the other methods gave an estimate of the amount of available P. The three Kelowna methods were similar on measuring available P.

Potassium deficiencies were better identified by soil tests than by tissue tests. Tissue test limits adapted in the USA indicated more deficiencies than were identified by soil tests and by increases in yield obtained with K fertilizers. There were no differences in yield of alfalfa between broadcast and shallow banded K fertilizer treatments.

Potassium fertilizer treatments were not found to have any influence on winter survival of alfalfa. One of the fields where counts were taken, had considerable winter killing.

Nitrogen fertilizer increased the yield of alfalfa on the first harvest after application. The value of the increases in yield were about equal to the cost of nitrogen. The possibility that N fertilizer reduces the proportion of alfalfa in the stand was not measured.

Copper and Zn levels in alfalfa tissue were lowered by applications of P fertilizers. Deficiencies of Cu and Zn were indicated in some cases by tissue levels which were lower than USA standards. At one site treatments that had received P and K fertilizer during the previous three years had low levels of tissue Cu, particularly on the P treatments. In the fourth year foliar Cu applications gave no improvement in yield but it raised tissue levels of Cu.

Tissue analysis of nutrients indicated N content was often higher than DRIS norms. This should be an advantage when alfalfa is sold to buyers requiring a high protein hay. Calcium was often higher and K was frequently lower than the USA sufficiency levels or DRIS norms. Low K levels in tissue samples can be caused by high levels of Na or Ca and by low soil temperatures. Levels of some nutrients in southern Alberta are appreciably different from the USA sufficiency ranges and DRIS norms. These appreciable differences in nutrient levels mean that nutrient sufficiency ranges or DRIS norms from elsewhere need to be modified in order to obtain optimum growth standards for irrigated conditions in southern Alberta.

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Appendix I. Alfalfa Dry Matter Yields and Fertilizer Applications

C SCANDIA 1994

	1994 Dry Matter Yields (t/ha)				
Trt	Fertilizer	Cut 1	Cut 2	Total-	SNK⁑
Phosphorus Experiment					
1	Check	6.4	5.7	12.1	a
2	20 P	6.4	5.2	11.5	a
3	40 P	6.7	5.8	12.5	a
4	60 P	6.8	5.9	12.7	a
5	120 P	6.6	6.0	12.6	a
6	20 P Band	6.2	5.7	12.0	a
7	60 P Band	6.9	6.0	12.9	a
8	Check Band	6.1	5.5	11.7	a
9	32 N	6.2	5.9	12.0	a
10	128 N + 60 P	6.9	6.1	13.0	a

⁑ Student-Newman-Keuls test for significant difference of total yields: treatments with the same letter are not significantly different at the 5% level.

R GEM 1994-1996

	1994 Dry Matter Yields (t/ha)					1995 Dry Matter Yields (t/ha)					1996 Dry Matter Yields (t/ha)				
Trt	Fertilizer	Cut 1	Cut 2	Total-	SNK⁑	Fertilizer	Cut 1	Cut 2	Total-	SNK⁑	Fertilizer	Cut 1	Cut 2	Total-	SNK⁑
Phosphorus Experiment															
1	Check	4.3	5.6	9.9	a	Check	4.1	2.9	7.0	abc	Check	6.9	4.0	10.9	b
2	20 P	4.6	5.7	10.3	a	20 P	6.0	3.4	9.4	abc	20 P	8.2	4.1	12.2	ab
3	40 P	4.6	6.3	10.9	a	40 P	4.8	3.6	8.4	ab	40 P	8.1	4.5	12.6	a
4	60 P	5.1	5.2	10.3	a	~	5.4	3.3	8.7	abc	~	7.4	4.4	11.7	ab
5	120 P	5.3	6.8	12.1	a	~	6.4	4.1	10.5	a	~	7.3	3.7	11.0	b
6	20 P Band	5.1	7.0	12.1	a	20 P Band	5.0	3.0	8.0	bc	20 P Band	7.6	4.3	11.9	ab
7	60 P Band	4.8	8.0	12.8	a	~	6.3	3.2	9.5	abc	~	7.7	4.0	11.7	ab
8	Check Band	4.2	6.2	10.4	a	Check Band	5.1	2.2	7.3	c	Check Band	7.0	4.1	11.1	b
9	32 N	4.6	5.6	10.2	a	32 N	6.5	3.2	9.7	abc	32 N	6.9	3.9	10.8	b
10	128 N + 60 P	5.7	5.4	11.1	a	96 N	4.1	3.6	7.7	abc	96 N	7.8	4.4	12.1	ab
Potassium Experiment															
11	50 K	4.0	5.8	9.8	c	50 K	5.1	2.5	7.6	a	75 K	6.6	4.2	10.8	a
12	50 K + 60 P	6.3	5.5	11.8	abc	50 K	5.7	3.5	9.2	a	75 K + 60 P	8.0	4.5	12.4	a
13	100 K	5.3	5.7	11	bc	100 K	5.8	2.9	8.7	a	150 K	6.7	4.2	10.9	a
14	100 K + 60 P	6.0	8.2	14.2	a	100 K	6.2	3.4	9.6	a	150 K + 60 P	7.9	4.2	12.1	a
15	200 K + 60 P	5.6	8.2	13.8	b	~	6.0	3.6	9.6	a	300 K + 60 P	8.1	4.7	12.8	a
16	Check #2	4.0	5.4	9.4	c	Check #2	5.8	3.2	9.0	a	Check #2	6.1	4.3	10.4	a
17	100 K + 60 P Band	4.8	8.0	12.8	ab	100 K Band	6.3	3.4	9.7	a	150 K + 60 P Band	7.9	4.0	11.9	a
18	Check Band #2	5.1	7.7	12.8	ab	Check Band #2	5.0	2.6	7.6	a	Check Band #2	6.8	3.9	10.7	a

⁑ Student-Newman-Keuls test for significant difference of total yields: treatments with the same letter are not significantly different at the 5% level.

H BOW ISLAND 1994-1995

	1994 Dry Matter Yields (t/ha)						1995 Dry Matter Yields (t/ha)					
Trt	Fertilizer	Cut 1	Cut 2	Cut 3	Total-	SNK[X]	Fertilizer	Cut 1	Cut 2	Cut 3	Total-	SNK[X]
Phosphorus Experiment												
1	Check	5.8	5.2	5.1	16.1	a	Check	5.5	3.8	3.2	12.5	a
2	20 P	5.7	5.2	4.9	15.8	a	20 P	6.3	3.3	3.0	12.6	a
3	40 P	6.2	4.8	5.5	16.5	a	40 P	5.9	3.3	2.7	11.9	a
4	60 P	6.2	5.4	5.0	16.6	a	~	5.9	3.4	3.2	12.5	a
5	120 P	6.0	5.2	5.0	16.2	a	~	6.2	3.9	3.2	13.3	a
6	20 P Band	5.6	5.2	5.3	16.1	a	20 P Band	5.6	3.5	3.4	12.5	a
7	60 P Band	6.4	5.5	4.8	16.7	a	~	6.6	3.5	3.3	13.4	a
8	Check Band	5.5	5.4	5.2	16.1	a	Check Band	6.0	3.7	3.1	12.8	a
9	32 N	6.3	5.2	5.3	16.8	a	32 N	5.9	3.3	3.1	12.3	a
10	128 N + 60 P	7.0	5.4	5.0	17.4	a	96 N	6.1	3.5	3.3	12.9	a
Potassium Experiment												
11	50 K	5.5	5.3	5.8	16.6	a	50 K	6.6	3.3	2.7	12.6	a
12	50 K + 60 P	5.5	5.2	5.3	16.0	a	50 K	7.0	3.5	3.4	13.9	a
13	100 K	4.9	4.8	5.1	14.8	a	100 K	7.0	3.5	2.9	13.3	a
14	100 K + 60 P	5.8	5.0	5.2	16.0	a	100 K	7.6	3.4	2.7	13.7	a
15	200 K + 60 P	5.7	5.4	5.3	16.4	a	~	6.8	3.3	3.0	13.1	a
16	Check #2	5.4	5.4	5.2	16.0	a	Check #2	6.0	3.4	3.0	12.4	a
17	100 K + 60 P Band	5.6	4.9	5.4	15.9	a	100 K Band	6.6	3.4	2.9	12.9	a
18	Check Band #2	4.6	4.4	5.2	14.2	a	Check Band #2	6.4	3.3	2.6	12.3	a

[X] Student-Newman-Keuls test for significant difference of total yields: treatments with the same letter are not significantly different at the 5% level.

L ROLLING HILLS 1994-1996

	1994 Dry Matter Yields (t/ha)					1995 Dry Matter Yields (t/ha)					1996 Dry Matter Yields (t/ha)				
Trt	Fertilizer	Cut 1	Cut 2	Total-	SNKX	Fertilizer	Cut 1	Cut 2	Total-	SNKX	Fertilizer	Cut 1	Cut 2	Total-	SNKX
Phosphorus Experiment															
1	Check	5.9	5.8	11.7	ab	Check	6.6	4.9	11.5	a	Check	7.3	3.4	10.7	a
2	20 P	6.0	5.8	11.8	ab	20 P	6.4	5.2	11.6	a	20 P	7.5	3.3	10.8	a
3	40 P	6.2	6.1	12.3	ab	40 P	6.5	4.1	10.6	a	40 P	7.5	3.1	10.6	a
4	60 P	6.5	5.7	12.2	ab	~	7.1	4.4	11.5	a	~	7.0	3.1	10.1	a
5	120 P	6.2	6.1	12.3	ab	~	6.7	4.6	11.3	a	~	7.0	3.4	10.4	a
6	20 P Band	5.7	5.5	11.2	b	20 P Band	6.2	4.2	10.4	a	20 P Band	7.4	3.4	10.8	a
7	60 P Band	5.8	6.1	1.9	ab	~	6.6	4.5	11.1	a	~	7.4	3.5	10.9	a
8	Check Band	5.7	5.4	11.1	b	Check Band	5.9	4.6	10.5	a	Check Band	7.7	3.3	11.0	a
9	32 N	5.8	5.0	10.8	b	32 N	7.1	5.3	12.4	a	32 N	7.4	3.4	10.8	a
10	128 N + 60 P	6.5	6.4	12.9	a	96 N	7.2	4.6	11.8	a	96 N	7.6	3.6	11.2	a
Potassium Experiment															
11	50 K	5.3	4.9	10.2	a	50 K	5.0	4.6	9.6	a	75 K	6.1	3.1	9.2	a
12	50 K + 60 P	6.1	5.3	11.4	a	50 K	6.5	4.0	10.5	a	75 K + 60 P	6.6	3.0	9.6	a
13	100 K	5.7	5.4	11.1	a	100 K	5.4	4.6	10.0	a	150 K	6.8	3.3	10.1	a
14	100 K + 60 P	5.8	5.3	11.1	a	100 K	6.6	4.2	10.8	a	150 K + 60 P	8.1	3.2	11.3	a
15	200 K + 60 P	5.9	5.7	11.6	a	~	6.7	4.0	10.7	a	300 K + 60 P	7.4	3.5	11.0	a
16	Check #2	5.2	4.9	10.1	a	Check #2	5.0	4.2	8.2	a	Check #2	6.6	3.1	9.7	a
17	100 K + 60 P Band	5.6	6.0	11.6	a	100 K Band	6.5	4.5	11.0	a	150 K + 60 P Band	7.5	3.6	11.1	a
18	Check Band #2	5.3	5.6	10.9	a	Check Band #2	5.4	4.1	9.5	a	Check Band #2	6.5	3.3	9.8	a

X Student-Newman-Keuls test for significant difference of total yields: treatments with the same letter are not significantly different at the 5% level.

S TILLEY 1994-1995

	1994 Dry Matter Yields (t/ha)						1995 Dry Matter Yields (t/ha)				
Trt	Fertilizer	Cut 1	Cut 2	Cut 3	Total-	SNK‡	Fertilizer	Cut 1	Cut 2	Total-	SNK‡
Phosphorus Experiment											
1	Check	3.2	2.6	3.4	9.2	c	Check	3.2	5.2	8.4	a
2	20 P	4.1	2.6	3.9	10.6	abc	20 P	4.1	5.9	10.0	a
3	40 P	4.7	3.0	4.4	12.1	ab	40 P	4.7	4.6	9.3	a
4	60 P	4.5	3.1	4.2	11.8	abc	~	3.6	5.5	9.1	a
5	120 P	5.2	3.0	4.6	12.8	a	~	4.4	5.4	9.8	a
6	20 P Band	3.9	3.0	4.3	11.1	abc	20 P Band	4.3	5.1	9.4	a
7	60 P Band	4.8	2.8	4.2	11.8	abc	~	4.4	5.4	9.8	a
8	Check Band	3.3	2.9	3.6	9.8	bc	Check Band	3.5	5.1	8.6	a
9	32 N	4.3	2.3	3.7	10.3	abc	32 N	3.3	5.6	8.9	a
10	128 N + 60 P	4.9	2.6	4.2	11.7	abc	96 N	4.2	5.1	9.3	a

‡ Student-Newman-Keuls test for significant difference of total yields: treatments with the same letter are not significantly different at the 5% level.

K HAYS 1994-1995

	1994 Dry Matter Yields (t/ha)					1995 Dry Matter Yields (t/ha)				
Trt	Fertilizer	Cut 1	Cut 2	Total-	SNK ‡	Fertilizer	Cut 1	Cut 2	Total-	SNK‡
Phosphorus Experiment										
1	Check	5.8	4.9	10.7	ab	Check	4.7	5.1	9.8	b
2	20 P	6.3	5.1	11.4	a	20 P	4.8	5.2	10.0	b
3	40 P	6.2	4.7	11.9	ab	40 P	5.8	5.1	10.9	ab
4	60 P	6.4	5.0	11.4	a	~	5.4	5.0	10.4	ab
5	120 P	6.7	5.0	11.7	a	~	5.4	5.2	10.6	ab
6	20 P Band	5.6	4.7	10.3	ab	20 P Band	5.8	5.2	11.0	ab
7	60 P Band	6.4	4.6	11.0	ab	~	5.2	4.9	10.1	b
8	Check Band	5.7	4.9	10.6	ab	Check Band	5.6	4.9	10.5	ab
9	32 N	5.3	4.5	9.8	b	32 N	5.6	5.0	10.6	ab
10	128 N + 60 P	6.8	5.1	11.9	a	96 N	6.8	5.3	12.1	a

‡ Student-Newman-Keuls test for significant difference of total yields: treatments with the same letter are not significantly different at the 5% level.

G DUCHESS 1996

	1996 Dry Matter Yields (t/ha)				
Trt	Fertilizer	Cut 1	Cut 2	Total-	SNKχ
Phosphorus Experiment					
1	Check	7.4	5.2	12.6	ab
2	20 P	7.8	5.5	13.3	ab
3	40 P	7.6	5.5	13.1	ab
4	60 P	8.5	6.0	14.5	a
5	120 P	8.6	5.	14.6	a
6	20 P Band	8.0	5.5	13.5	ab
7	60 P Band	8.1	5.8	13.9	ab
8	Check Band	8.1	5.0	13.2	ab
9	32 N	6.5	5.6	12.1	b
10	128 N + 60 P	8.1	5.8	13.9	ab
Potassium Experiment					
11	75 K	6.5	5.5	12.0	ab
12	75 K + 60 P	7.8	6.2	14.1	a
13	150 K	6.3	5.0	11.3	b
14	150 K + 60 P	7.5	6.0	13.5	ab
15	300 K + 60 P	8.1	5.5	13.6	ab
16	Check #2	6.3	5.2	11.5	b
17	150 K + 60 P Band	8.0	6.1	14.2	a
18	Check Band #2	6.9	4.9	11.8	ab

χ Student-Newman-Keuls test for significant difference of total yields: treatments with the same letter are not significantly different at the 5% level.

M HAYS 1996

	1996 Dry Matter Yields (t/ha)				
Trt	Fertilizer	Cut 1	Cut 2	Total-	SNK$^{\Chi}$
Phosphorus Experiment					
1	Check	4.4	5.7	10.1	b
2	20 P	5.3	5.9	11.2	ab
3	40 P	4.9	5.8	10.7	ab
4	60 P	5.5	6.2	11.7	ab
5	120 P	5.7	6.1	11.8	ab
6	20 P Band	4.6	6.2	10.8	ab
7	60 P Band	5.2	5.5	10.7	ab
8	Check Band	4.7	6.1	10.8	ab
9	32 N	4.3	5.6	9.9	b
10	128 N + 60 P	6.3	5.9	12.2	a
Potassium Experiment					
11	75 K	4.6	5.7	10.3	a
12	75 K + 60 P	6.1	6.0	12.1	a
13	150 K	4.5	5.8	10.3	a
14	150 K + 60 P	5.3	5.6	10.9	a
15	300 K + 60 P	5.7	6.4	12.1	a
16	Check #2	4.5	5.5	10.0	a
17	150 K + 60 P Band	5.1	6.0	11.1	a
18	Check Band #2	4.8	5.8	10.6	a

$^{\Chi}$ Student-Newman-Keuls test for significant difference of total yields: treatments with the same letter are not significantly different at the 5% level.

N ROSEMARY 1996

	1996 Dry Matter Yields (t/ha)				
Trt	Fertilizer	Cut 1	Cut 2	Total-	SNKX
Phosphorus Experiment					
1	Check	8.4	4.8	13.1	a
2	20 P	8.6	4.7	13.4	a
3	40 P	8.6	4.7	13.3	a
4	60 P	8.5	4.9	13.4	a
5	120 P	9.0	5.0	14.0	a
6	20 P Band	9.1	4.8	13.9	a
7	60 P Band	8.5	4.6	13.1	a
8	Check Band	9.0	4.7	13.6	a
9	32 N	8.6	5.0	13.6	a
10	128 N + 60 P	9.4	4.9	14.2	a
Potassium Experiment					
11	75 K	7.5	4.7	12.2	a
12	75 K + 60 P	8.3	4.2	12.5	a
13	150 K	7.5	4.6	12.1	a
14	150 K + 60 P	7.7	4.5	12.2	a
15	300 K + 60 P	7.8	4.2	12.0	a
16	Check #2	7.4	4.5	11.9	a
17	150 K + 60 P Band	7.9	4.4	12.3	a
18	Check Band #2	5.5	4.2	9.7	a

X Student-Newman-Keuls test for significant difference of total yields: treatments with the same letter are not significantly different at the 5% level.

Appendix II. Tissue Analysis of Alfalfa

C SCANDIA 1994

ANNUAL FERTILIZER APPLICATIONS (kg/ha)	
TRTMT	1994 FERTILIZER
1	-
4	60 P
5	120 P

PLANT TISSUE ANALYSIS - TOP 0.15 m OF STEMS														
Cut 1 - June 30, 1994														
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	4.1	0.31	2.54	0.35	1.2	0.37	8.3	**23**	57	**19**	76	30	0.98	3.7
4	4.1	0.34	2.55	0.32	1.1	0.36	7.1	**22**	49	**19**	85	33	0.94	3.7
5	4.0	0.33	2.41	0.34	1.2	0.34	7.2	**21**	48	**18**	76	26	0.91	3.8
Cut 2 - August 29, 1994														
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	4.0	0.30	**1.82**	*0.61*	1.5	0.45	7.5	57	*99*	33	120	51	3.73	*6.1*
4	3.8	0.28	**1.77**	*0.51*	1.5	0.37	6.7	46	79	23	97	42	2.65	*5.6*
5	3.9	0.29	**1.74**	0.49	1.5	0.38	7.0	46	72	26	91	39	2.62	*5.5*

Bold numbering indicates **deficient** by Wisconsin - Minnesota standards
Italic numbering indicates *high* by Wisconsin - Minnesota standards

R GEM 1994-1996

ANNUAL FERTILIZER APPLICATIONS (kg/ha)				
TRTMT	1994 FERT	1995 FERT	1996 FERT	TOTAL TREATMENT
1	-	-	-	Check
3	40 P	40 P	40 P	120 P (3 yr)
5	120 P	-	-	120 P (1 yr)
15	200 K + 60 P	-	300 K + 60 P	500 K + 60 P (2 yr)
16	-	-	-	Check 2

PLANT TISSUE ANALYSIS - TOP 0.15 m OF STEMS														
Cut 1 - July 4, 1994														
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	3.1	**0.18**	**1.66**	0.33	2.0	0.46	8.3	42	61	**19**	51	15	1.12	4.5
3	3.3	**0.22**	**1.43**	0.35	2.2	0.43	6.3	40	45	**15**	47	9	0.75	4.0
5	3.3	**0.25**	**1.39**	0.36	2.0	0.44	5.9	42	46	**14**	49	11	0.77	3.3
15	3.2	**0.23**	**1.68**	0.31	1.8	0.36	5.9	45	36	**15**	49	10	0.84	2.9
16	3.3	**0.18**	**1.30**	0.33	2.4	0.38	7.4	42	37	**17**	52	9	0.86	3.5

Cut 2 - August 26, 1994

Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	4.0	**0.23**	**2.08**	0.57	2.0	0.44	11.4	59	79	29	104	46	2.06	*6.2*
3	4.4	0.28	**2.03**	0.46	2.2	0.44	9.1	54	68	24	106	44	2.11	*6.8*
5	4.5	0.32	**1.99**	0.48	2.2	0.48	8.4	65	72	23	105	47	2.12	*6.4*
15	4.3	0.27	**2.07**	0.48	2.0	0.42	8.3	84	74	24	117	53	2.28	*5.6*
16	4.2	**0.24**	**1.95**	*0.57*	2.1	0.42	10.9	71	83	29	116	51	2.45	*6.5*

Cut 1 - July 10, 1995

Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	4.0	0.26	**1.74**	0.36	2.0	0.33	8.8	40	52	28	71	18	1.05	4.1
3	4.3	0.32	**1.73**	0.36	1.8	0.37	6.4	45	48	23	64	14	1.08	3.9
5	4.4	0.34	**1.79**	0.35	1.9	0.38	6.1	43	46	23	64	15	1.21	3.5
15	4.4	0.31	**1.70**	0.33	1.8	0.30	6.6	47	40	25	68	16	1.00	3.0
16	4.1	0.28	**1.55**	0.36	2.4	0.37	8.5	51	43	33	79	23	1.26	3.2

Cut 2 - September 27, 1995

Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	3.3	**0.14**	**1.54**	0.48	4.2	0.54	10.1	82	*114*	21	99	43	1.95	*7.3*
3	3.7	**0.20**	**1.89**	0.42	3.0	0.42	8.9	44	*91*	**19**	84	33	1.54	*5.6*
5	3.9	**0.22**	**1.88**	0.41	2.9	0.38	7.7	44	*81*	**18**	79	38	1.59	4.8
15	3.7	**0.18**	**2.03**	0.38	3.0	0.31	8.2	58	*77*	**18**	83	21	1.55	4.6
16	3.4	**0.14**	**1.61**	0.40	4.4	0.53	9.2	85	*73*	21	107	32	2.10	4.5

Cut 1 - July 2, 1996✦

Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	*5.1*	0.33	**1.85**	0.44	2.1	0.42	10.4	47	53	34	72	9		
3	*5.2*	0.35	**1.73**	0.43	2.0	0.41	7.4	42	50	30	66	7		
5	5.0	0.34	**1.72**	0.44	2.0	0.40	8.0	46	52	30	79	11		
15	*5.1*	0.34	**1.98**	0.42	2.0	0.34	8.1	65	46	29	71	11		
16	4.9	0.33	**1.69**	0.43	2.2	0.38	9.1	58	49	33	98	11		

Cut 2 - September 10, 1996

Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	3.7	**0.23**	**1.79**	0.44	2.7	0.34	9.0	44	*102*	**19**	83	32		
3	3.8	**0.23**	**1.89**	0.41	2.4	0.34	7.8	41	*86*	**18**	88	31		
5	3.9	**0.24**	**1.75**	0.43	2.5	0.37	7.8	45	*86*	**19**	97	33		
15	4.2	0.28	**2.04**	0.41	2.3	**0.27**	7.5	53	70	**19**	87	35		
16	3.9	**0.24**	**1.88**	0.45	2.6	**0.28**	8.3	52	70	**19**	82	33		

Bold numbering indicates **deficient** by Wisconsin - Minnesota standards
Italic numbering indicates *high* by Wisconsin - Minnesota standards
✦ In April 1996, farmer applied 56 kg/ha N, 20 kg/ha P and 28 kg/ha K to all treatments

H BOW ISLAND 1994-1995

ANNUAL FERTILIZER APPLICATIONS (kg/ha)			
TRT	1994 FERT	1995 FERT	TOTAL TREATMENT
1	-	-	Check
3	40 P	40 P	80 P (2 yr)
5	120 P	-	120 P (1 yr)
15	200 K + 60 P	-	200 K + 60 P (1 yr)
16	-	-	Check 2

PLANT TISSUE ANALYSIS - TOP 0.15 m OF STEMS													
Cut 1 - June 16, 1994													
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	4.3	0.31	2.59	0.39	2.1	0.31	7.2	38	49	22	90	26	1.02	2.4
3	4.2	0.34	2.53	0.34	1.9	**0.28**	6.3	36	43	**19**	104	35	0.74	2.3
5	3.9	0.33	**2.39**	0.34	2.0	**0.27**	6.7	34	42	**16**	83	24	0.63	2.2
15	4.4	0.33	2.68	0.33	2.1	**0.29**	7.7	32	43	**19**	102	54	0.70	2.2
16	4.5	0.31	2.65	0.36	2.2	0.31	8.3	31	45	20	65	19	0.78	2.3
Cut 2 - July 21, 1994														
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	4.9	0.35	2.59	0.40	2.1	**0.29**	7.3	37	71	**19**	60	11	0.15	1.7
3	4.6	0.35	2.43	0.39	1.9	**0.29**	5.9	38	66	**16**	62	12	0.19	2.0
5	4.8	0.38	2.76	0.40	2.0	0.34	5.5	43	68	**16**	66	13	0.25	2.0
15	4.6	0.33	2.49	0.37	1.9	0.32	6.9	39	63	**18**	67	13	0.49	2.5
16	4.4	0.31	**2.37**	0.38	1.8	0.31	7.5	34	63	**19**	61	12	0.40	2.3
Cut 3 - September 1, 1994														
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	4.4	0.28	**2.28**	0.43	2.0	**0.30**	8.3	49	60	23	89	32	1.57	3.2
3	4.3	0.28	2.41	0.45	2.1	0.35	8.0	52	59	22	92	31	1.95	3.6
5	4.0	0.28	2.43	0.42	2.1	0.40	7.2	50	56	20	89	29	1.92	3.7
15	4.3	**0.25**	**2.30**	0.44	2.0	0.35	9.0	54	56	23	92	32	2.09	*5.0*
16	4.2	0.26	**2.24**	0.43	1.9	0.36	9.6	43	57	25	90	33	2.11	*5.1*
Cut 1 - June 21, 1995														
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	*5.2*	0.34	**1.96**	0.44	2.2	**0.29**	8.9	47	56	24	80	19	0.85	2.5
3	*5.4*	0.37	**1.83**	0.44	2.3	0.32	7.8	54	57	22	86	17	0.88	2.9
5	*5.3*	0.36	**1.87**	0.43	2.3	0.32	8.0	53	55	21	82	17	1.00	3.0
15	4.9	0.32	**1.90**	0.42	2.2	**0.29**	7.9	43	52	21	73	17	0.53	2.7
16	5.0	0.30	**1.92**	0.43	2.2	**0.27**	8.8	39	56	23	72	18	0.59	3.1

Cut 2 - July 31, 1995														
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	*5.3*	0.34	**2.22**	0.48	2.2	0.31	8.9	47	*106*	24	114	50	1.19	3.2
3	*5.3*	0.35	**2.03**	0.46	2.3	0.31	7.7	52	55	21	82	16	1.13	3.7
5	*5.2*	0.35	**2.15**	0.45	2.2	0.31	7.4	48	58	21	80	16	1.25	3.5
15	*5.2*	0.34	**2.03**	0.46	2.2	**0.30**	8.5	48	52	22	82	12	1.08	3.6
16	*5.3*	0.31	**1.90**	0.49	2.3	**0.29**	9.4	46	58	24	80	12	1.17	4.2
Cut 3 - October 10, 1995														
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	4.3	**0.22**	**2.21**	0.44	2.4	0.34	8.8	53	73	**18**	112	40	1.77	3.6
3	4.3	**0.24**	**1.91**	0.37	2.5	0.34	7.1	50	60	**17**	95	34	1.46	3.7
5	4.3	0.26	**2.13**	0.40	2.8	0.38	6.8	57	62	**17**	97	37	1.74	3.4
15	4.5	**0.25**	**1.93**	0.42	2.7	0.35	8.4	50	59	**17**	111	35	1.81	4.6
16	4.4	**0.21**	**2.18**	0.41	2.4	0.31	8.9	51	67	20	97	29	1.55	4.4

Bold numbering indicates **deficient** by Wisconsin - Minnesota standards
Italic numbering indicates *high* by Wisconsin - Minnesota standards

L ROLLING HILLS 1994-1996

ANNUAL FERTILIZER APPLICATIONS (kg/ha)				
TRT	1994 FERT	1995 FERT	1996 FERT	TOTAL TREATMENT
1	-	-	-	Check
3	40 P	40 P	40 P	120 P (3 yr)
5	120 P	-	-	120 P (1 yr)
15	200 K + 60 P	-	300 K + 60 P	500 K + 60 P (2 yr)
16	-	-	-	Check 2

PLANT TISSUE ANALYSIS - TOP 0.15 m OF STEMS														
Cut 1 - June 21, 1994														
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	3.5	**0.22**	**1.82**	0.35	1.7	0.31	5.1	42	64	**19**	68	20	0.84	2.9
3	4.1	0.31	**2.01**	0.37	1.7	0.36	**4.5**	37	56	21	65	21	0.88	3.3
5	4.3	0.35	**2.04**	0.36	1.7	0.37	**4.3**	36	53	21	58	24	0.92	3.0
15	3.8	0.30	**2.02**	0.36	1.5	0.38	5.4	44	54	21	61	16	1.07	3.1
16	3.7	**0.22**	**1.72**	0.37	1.8	0.38	6.8	48	62	22	81	17	1.06	3.5
Cut 2 - August 22-23, 1994														
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	4.3	0.28	**1.95**	0.45	1.9	0.37	6.5	45	72	24	101	39	2.54	*6.6*
3	4.2	0.29	**1.87**	0.45	1.9	0.43	5.7	50	91	25	109	44	2.56	*5.6*
5	4.2	0.30	**1.93**	0.50	2.0	0.45	**4.8**	72	92	23	113	43	3.07	5.0
15	3.8	0.27	**1.90**	0.47	1.7	0.42	5.9	56	80	20	100	43	2.62	4.8
16	3.7	**0.24**	**1.77**	*0.55*	2.0	0.42	8.1	82	82	25	102	39	2.57	*5.1*

Cut 1 - June 23, 1995														
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	4.5	0.26	**1.75**	0.47	2.1	0.34	6.0	49	62	24	86	21	0.65	3.6
3	4.5	0.30	**1.60**	0.45	2.1	0.37	**4.5**	48	61	21	81	25	0.72	3.4
5	4.4	0.28	**1.69**	0.46	2.0	0.35	**4.3**	47	61	21	86	22	0.45	3.0
15	4.5	0.26	**1.61**	0.45	1.9	0.37	6.4	51	58	22	102	25	0.56	2.9
16	4.2	**0.23**	**1.56**	0.49	2.2	0.38	8.4	52	61	27	85	25	0.60	3.3
Cut 2 - August 25, 1995														
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	4.6	0.29	**1.47**	0.49	2.3	0.42	7.3	71	*81*	29	104	35	2.24	4.9
3	4.7	0.32	**1.43**	0.47	2.3	0.44	5.7	74	80	28	105	32	2.16	4.7
5	4.6	0.33	**1.49**	*0.51*	2.2	0.50	6.1	84	*82*	28	110	34	2.48	4.1
15	4.2	0.28	**1.28**	0.47	2.0	0.45	7.8	92	73	26	108	36	2.14	4.3
16	4.1	**0.25**	**1.23**	0.50	2.3	0.47	9.0	78	80	27	97	38	2.23	4.6
Cut 1 - July 4, 1996														
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	4.4	0.28	**1.41**	0.43	2.2	0.31	5.8	54	54	25	70	17		
3	4.0	**0.25**	**1.16**	0.36	2.1	0.32	**3.5**	46	49	20	70	23		
5	4.2	0.26	**1.17**	0.41	2.2	0.34	**3.9**	52	51	22	65	16		
15	4.1	0.27	**1.47**	0.39	2.0	0.31	**4.9**	64	44	23	65	19		
16	4.6	0.29	**1.46**	0.46	2.4	0.33	8.7	58	54	28	72	18		
Cut 2 - August 27, 1996														
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	4.2	0.27	**1.68**	0.55	2.6	0.38	8.3	63	78	23	84	26		
3	4.2	0.27	**1.47**	0.50	2.5	0.40	6.1	67	73	21	98	31		
5	4.3	0.27	**1.52**	0.52	2.5	0.39	6.2	61	73	22	86	30		
15	4.0	0.27	**1.42**	0.48	2.4	0.36	6.0	70	55	**17**	73	26		
16	4.2	0.27	**1.29**	0.51	2.7	0.36	7.6	52	63	20	62	16		

Bold numbering indicates **deficient** by Wisconsin - Minnesota standards
Italic numbering indicates *high* by Wisconsin - Minnesota standards

S TILLEY 1994-1995

ANNUAL FERTILIZER APPLICATIONS (kg/ha)			
TRTMT	1994 FERT	1995 FERT	TOTAL TREATMENT
1	-	-	Check
3	40 P	40 P	80 P (2 yr)
5	120 P	-	120 P (1 yr)

PLANT TISSUE ANALYSIS - TOP 0.15 m OF STEMS														
Cut 1 - June 29, 1994														
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	4.2	0.29	**2.32**	0.40	1.7	0.41	10.0	41	56	20	54	13	0.63	3.8
3	4.1	0.32	2.44	0.39	1.7	0.41	8.4	46	53	**18**	55	13	0.78	3.5
5	4.3	0.35	2.43	0.41	1.8	0.41	8.2	49	62	**19**	60	16	0.73	3.7
Cut 2 - August 2, 1994														
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	4.7	0.27	**2.17**	0.44	1.8	0.42	9.3	48	62	24	70	16	0.23	3.0
3	4.6	0.30	**2.01**	0.46	1.9	0.47	9.5	53	61	24	76	16	0.41	3.1
5	4.4	0.30	**2.19**	0.41	1.7	0.50	8.3	49	56	22	69	15	0.51	2.8
Cut 3 - September 19, 1994														
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	*5.2*	0.31	**2.12**	0.45	1.6	0.36	13.6	55	72	29	82	24	1.86	*7.4*
3	4.7	0.32	**2.70**	0.44	1.6	0.39	11.3	58	66	29	77	24	1.39	*5.7*
5	5.0	0.35	**2.71**	0.44	1.7	0.45	11.6	61	62	27	79	26	1.50	*5.4*
Cut 1 - June 15, 1995														
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	**5.2**	0.29	2.46	*0.56*	1.9	0.35	10.7	54	56	31	78	39	0.00	3.8
3	**5.5**	0.36	2.43	*0.57*	2.1	0.44	8.6	63	55	26	83	36	0.00	3.7
5	**5.4**	0.35	**2.34**	*0.52*	2.1	0.44	8.0	63	53	23	89	40	0.00	3.4
Cut 2 - August 17, 1995														
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	4.5	0.26	**1.99**	0.47	1.8	0.36	10.7	57	69	25	70	17	1.09	4.7
3	4.8	0.29	**1.76**	0.43	2.0	0.40	8.9	73	66	24	75	14	1.28	4.8
5	4.5	0.31	**1.90**	0.44	1.9	0.44	8.8	76	58	24	77	17	1.41	4.0

Bold numbering indicates **deficient** by Wisconsin - Minnesota standards
Italic numbering indicates *high* by Wisconsin - Minnesota standards

K HAYS 1994-1995

ANNUAL FERTILIZER APPLICATIONS (kg/ha)			
TRTMT	1994 FERT	1995 FERT	TOTAL TREATMENT
1	-	-	Check
3	40 P	40 P	80 P (2 yr)
5	120 P	-	120 P (1 yr)

PLANT TISSUE ANALYSIS - TOP 0.15 m OF STEMS														
Cut 1 - June 22, 1994														
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	3.9	**0.24**	**2.21**	0.36	1.9	0.34	7.7	48	48	22	64	11	0.85	2.5
3	4.0	0.27	**2.36**	0.34	1.9	0.36	6.4	45	52	22	63	11	0.89	2.3
5	4.3	0.32	**2.17**	0.39	2.1	0.38	6.1	55	59	22	73	16	0.98	2.3
Cut 2 - August 17, 1994														
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	3.3	**0.18**	**2.35**	0.39	1.7	0.34	8.3	41	66	20	74	25	1.16	3.2
3	3.0	**0.20**	**2.20**	0.39	1.7	0.35	7.3	42	61	**18**	72	26	1.19	3.0
5	3.3	**0.23**	**2.13**	0.39	1.8	0.40	6.3	48	53	**19**	75	21	1.36	3.3
Cut 1 - June 29, 1995														
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	4.3	0.26	**1.65**	0.46	2.1	0.40	9.5	47	59	27	78	28	1.52	3.4
3	4.5	0.33	**1.62**	0.45	2.0	0.37	6.7	50	62	26	78	27	1.58	3.2
5	4.5	0.31	**1.54**	0.46	2.1	0.39	7.3	68	64	26	87	26	1.58	3.3
Cut 2 - August 21, 1995														
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)	Co (ppm)	Mo (ppm)
1	4.4	**0.25**	**1.99**	*0.52*	2.3	0.35	9.8	57	71	25	84	25	1.29	3.5
3	4.3	0.27	**2.11**	*0.52*	2.4	0.40	8.1	69	72	25	91	24	1.39	3.0
5	4.5	0.28	**2.06**	0.50	2.3	0.36	8.0	68	68	25	89	23	1.37	3.1

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G DUCHESS 1996

FERTILIZER APPLICATIONS (kg/ha)	
TRT	1996 FERTILIZER
1	Check
4	60 P
5	120 P
15	300 K + 60 P
16	Check 2

PLANT TISSUE ANALYSIS - TOP 0.15 m OF STEMS												
Cut 1 - July 8, 1996												
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)
1	4.4	0.29	**1.89**	0.45	2.4	0.33	9.2	33	53	25	73	21
4	4.6	0.30	**1.89**	0.48	2.4	0.35	9.1	32	53	25	80	24
5	4.6	0.30	**1.86**	0.48	2.5	0.36	8.2	36	54	22	78	22
15	4.6	0.31	**1.84**	0.47	2.3	0.37	7.8	50	47	24	75	20
16	4.5	0.28	**1.72**	0.46	2.3	0.35	9.3	45	54	25	72	21
Cut 2 - August 22, 1996												
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)
1	5.0	0.32	**2.22**	0.44	2.2	**0.29**	10.0	28	62	23	81	31
4	*5.4*	0.35	**2.08**	0.47	2.2	0.32	9.2	30	61	24	94	28
5	*5.4*	0.35	**1.97**	0.48	2.3	0.34	8.5	35	60	23	99	32
15	*5.4*	0.35	**2.15**	0.46	2.2	0.34	8.1	46	53	21	89	28
16	*5.1*	0.33	**2.10**	0.48	2.3	0.32	10.2	38	59	25	84	28

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M HAYS 1996

FERTILIZER APPLICATIONS (kg/ha)	
TRTMT	1996 FERTILIZER
1	Check
4	60 P
5	120 P
15	300 K + 60 P
16	Check 2

PLANT TISSUE ANALYSIS - TOP 0.15 m OF STEMS												
Cut 1 - July 3, 1996												
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)
1	5.2	0.33	**1.77**	0.50	2.2	0.37	12.1	46	50	33	78	13
4	5.2	0.34	**1.81**	*0.51*	2.2	0.40	10.8	48	48	30	81	17
5	5.1	0.33	**1.80**	0.47	2.2	0.45	10.4	47	47	30	77	14
15	5.1	0.35	**1.87**	0.46	2.1	0.37	8.8	72	50	28	95	14

16	4.8	0.32	**1.79**	0.47	2.2	0.36	10.3	55	55	31	76	14
Cut 2 - August 26-27, 1996												
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)
1	5.3	0.34	**1.77**	*0.51*	2.0	0.35	11.6	43	60	34	127	33
4	5.1	0.34	**1.77**	0.49	2.1	0.41	10.0	42	58	29	137	41
5	5.3	0.35	**1.67**	0.49	2.0	0.42	9.6	45	55	30	128	36
15	4.9	0.32	**2.05**	0.47	2.2	0.36	8.5	64	68	26	135	39
16	5.0	0.32	**2.08**	*0.51*	2.3	0.36	10.4	56	72	31	127	38

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N ROSEMARY 1996

FERTILIZER APPLICATIONS (kg/ha)	
TRTMT	1996 FERTILIZER
1	Check
4	60 P
5	120 P
15	300 K + 60 P
16	Check 2

PLANT TISSUE ANALYSIS - TOP 0.15 m OF STEMS												
Cut 1 - July 5, 1996												
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)
1	*5.1*	0.34	**2.18**	0.47	2.3	0.33	11.6	61	59	30	85	20
4	4.9	0.33	**2.16**	0.44	2.2	0.33	9.3	61	57	28	82	20
5	5.0	0.34	**2.20**	0.43	2.2	0.33	9.1	64	61	28	83	21
15	4.9	0.33	**2.13**	0.40	2.2	0.32	9.0	61	53	27	77	18
16	4.9	0.33	**2.13**	0.43	2.2	0.33	10.0	56	56	27	80	20
Cut 2 - September 3, 1996												
Trt	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Al (ppm)
1	4.3	0.30	**2.11**	0.45	2.2	**0.29**	11.3	64	85	25	108	46
4	4.3	0.30	**2.09**	0.48	2.3	0.34	10.8	73	88	26	121	57
5	4.3	0.29	**2.08**	0.47	2.4	0.33	10.3	81	92	24	119	46
15	4.4	0.31	**2.26**	0.48	2.3	0.33	10.3	72	90	26	144	76
16	4.2	0.28	**2.08**	0.49	2.2	0.31	10.9	70	92	25	127	60

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