AB-11

Fertilizer Requirement of Irrigated Alfalfa

Progress Report - December, 1995

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INTRODUCTION

In 1994 an experiment was set out to determine the phosphorus, potassium and nitrogen fertilizer response of irrigated alfalfa on six fields. The initial fields were all established pure alfalfa stands in their first or second year of production. The project is funded by the Alberta Agriculture Research Institute, Potash and Phosphate Institute of Canada, Sherritt Fertilizers, Tirol Alfalfa and Westco Fertilizers. R.H. McKenzie of AAFRD, Lethbridge, and L. Kryzanowski of AAFRD, Edmonton, are collaborators on the project.

A previous survey indicated 70% of 99 irrigated alfalfa fields in southern Alberta were deficient in soil phosphorus while only 43% were deficient in tissue phosphorus. This survey also indicated 12% of fields were marginal and no fields were deficient in soil potassium while 79% of the same fields were deficient in tissue potassium. These discrepancies left a question as to which fields would respond to phosphorus and potassium fertilizers. An experiment was established to answer this question.

The same survey indicated amounts of fertilizer applied to alfalfa fields were much less than the crops' use. Only 29% of farmers added sufficient phosphorus during the life of the stand to supply one year's crop requirement. Another 7% applied manure to the field. Potassium fertilizer was supplied to 15% of fields but only 2% received more than 50 kg/ha of potassium. Nitrogen was used by 34% of farmers at the time of seeding but only 9% used it in subsequent years.

METHODS

The six fields that were chosen tested low in soil phosphorus and three of the fields or adjacent fields were known to be low in tissue potassium (Table 1). All fields received four rates of broadcast phosphorus fertilizer and an unfertilized control. The three fields with low potassium also received three broadcast potassium treatments. Phosphorus (12-51-0) and potassium (0-0-60) were also shallow-banded with a zero-till disc drill at about 1.5 cm depth. All sites received two rates of nitrogen (34-0-0). Fertilizer treatments were applied near the end of April, 1994. The lower rates of phosphorus and potassium and both nitrogen treatments were repeated on the same plots in the spring of 1995. In 1995 one field (C) was abandoned due to a poor stand.

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Table 1. Soil analysis of irrigated alfalfa plot sites, Spring 1994

Producer: C ■ Scandia			E.C.	(ppm)								
Depth (m)	pH	Texture	(dS/m)	NH_4-N	NO_3-N	PO_4-P[‡]	K[⊛]	Zn	B	Cu	Mn	Fe
0.00-0.15	8.1	L	0.98	6	3	4	263	0.76	0.48	0.63	3.78	11.57
0.15-0.30	8.2	L	2.38	7	2	4	140	0.80	0.56	0.53	2.78	13.35
0.30-0.60	8.2	CL	4.20	7	1	0	134					
0.60-0.90	8.0	CL	6.05	7	2	1	156					

Producer: R ○ Gem			E.C.	(ppm)								
Depth (m)	pH	Texture	(dS/m)	NH_4-N	NO_3-N	PO_4-P[‡]	K[⊛]	Zn	B	Cu	Mn	Fe
0.00-0.15	6.9	SCL	0.43	6	8	4	120	0.54	0.35	0.77	8.03	21.75
0.15-0.30	7.4	SCL	0.38	4	3	1	90	0.28	0.24	0.76	3.48	10.00
0.30-0.60	7.8	L	0.45	4	1	1	76					
0.60-0.90	8.1	L	0.60	4	1	1	71					

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

Producer: L ◆ Rolling Hills			E.C.	(ppm)								
Depth (m)	pH	Texture	(dS/m)	NH_4-N	NO_3-N	PO_4-P[‡]	K[⊛]	Zn	B	Cu	Mn	Fe
0.00-0.15	6.7	LS	0.18	6	1	9	59	0.40	0.23	0.92	6.89	47.3
0.15-0.30	6.9	LS	0.20	5	2	7	47	0.38	0.23	0.72	5.36	41.8
0.30-0.60	7.7	LS	0.43	5	1	6	61					
0.60-0.90	8.0	SCL	0.63	5	1	2	100					

Producer: S ★ Tilley			E.C.	(ppm)								
Depth (m)	pH	Texture	(dS/m)	NH_4-N	NO_3-N	PO_4-P[‡]	K[⊛]	Zn	B	Cu	Mn	Fe
0.00-0.15	7.7	C	0.83	6	14	4	305	1.08	0.58	1.45	6.89	16.0
0.15-0.30	7.9	SiC	1.08	5	10	1	249	0.64	0.49	1.62	4.67	13.7
0.30-0.60	8.2	SiC	2.83	5	9	0	136					
0.60-0.90	8.2	Heavy C	5.93	6	13	0	114					

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

‡ Miller Axley

⊛ Ammonium acetate

Fields S and H in 1994 and H in 1995 were harvested three times. All other fields were harvested twice. Harvests were done at about the same time as the farmers' harvests.

Analytical Methods

The five methods used in this project to determine plant available soil phosphorus for 1994 were the Miller Axley, Kelowna, Norwest Kelowna, Saskatchewan Kelowna and Olsen. In 1995 only Miller Axley and Kelowna were used. The Olsen and the Saskatchewan Kelowna methods were done on some of the samples in 1994 by the Plains Innovative Lab in Saskatoon. Other analyses and all analyses in 1995 on soils and plants were done by the AAFRD Soils and Animal Nutrition Lab in Edmonton.

The Miller Axley method has been used by the AAFRD Soils and Animal Nutrition Lab since the late 1950s for making phosphate fertilizer recommendations to Alberta farmers. The extraction solution is a relatively strong acid, which seems to have performed reasonably well for making annual crop phosphate fertilizer recommendations on acidic and neutral pH soils, particularly on summerfallowed fields. The Miller Axley method has not worked well on higher pH, Brown and Dark Brown soils in southern Alberta. Serious limitations have been observed on high pH, calcareous irrigated soils. Because of these problems, other methods of determining soil P have been examined. In the latter 1980s, the Kelowna method, a highly buffered weak acid extractant was developed by the B.C. Ministry of Agriculture, Food and Fisheries, at their Soil Testing Lab. This method has since been modified by both Norwest Labs and the Saskatchewan Soil Testing Lab. These latter two methods are now used to make the majority of phosphate fertilizer recommendations to Canadian prairie farmers. The extraction solutions are also used to determine plant available potassium (K).

RESULTS

Phosphorus Fertilizer

A response to phosphorus fertilizer occurred on 3 out of 6 fields in 1994 (Figure 1) and 3 out of 5 fields in 1995 (Figure 2). Two sites, both of which tested low in available phosphorus, did not respond to phosphate fertilizer in 1994. One of these sites (H) was a clay loam soil with a history of regular applications of phosphorus to preceding crops. The other site (C) was a loam to clay loam with a high pH in the surface layers. A third site (K, a sandy loam soil) showed marginal responses to phosphorus in 1994 and 1995. The response curve in 1994 appeared to level off at an application of about 40 kg/ha of P (160 lbs/acre 11-51-0 or 82 lbs/acre P_2O_5). All yields were high, particularly on the first harvest in 1994. This occurred because the harvester collected old stubble and dry matter from the preceding crops.

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

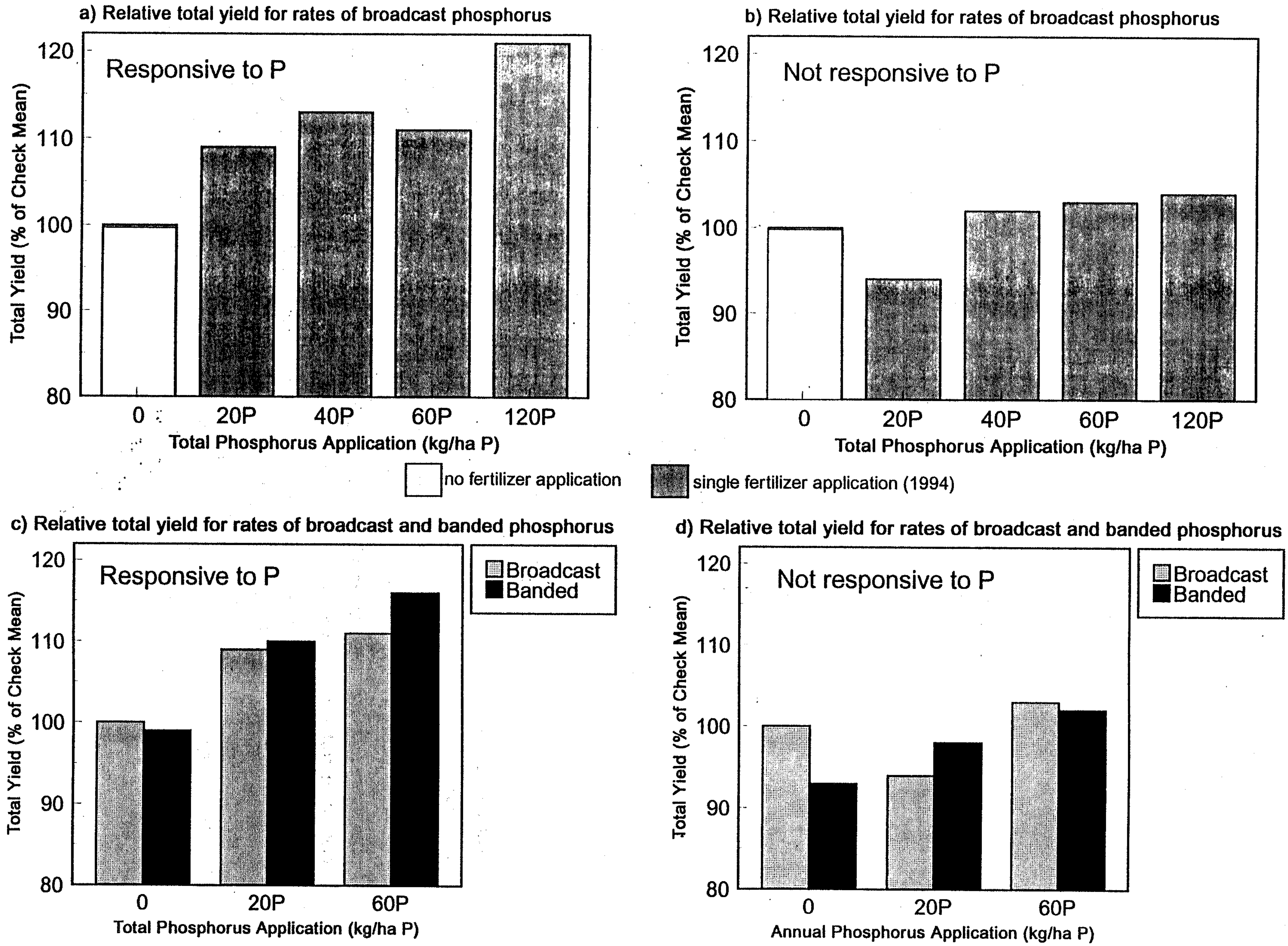
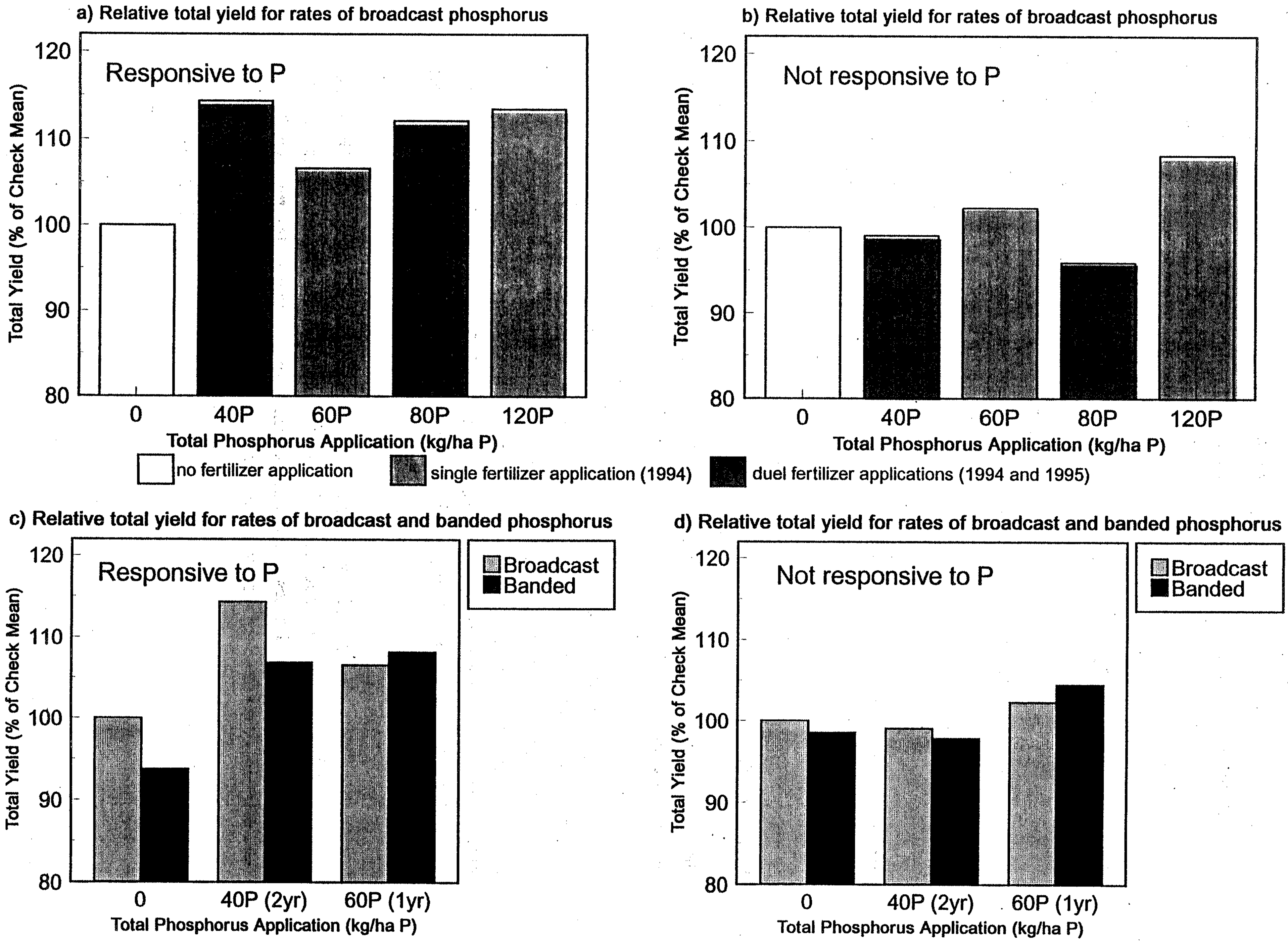


Figure 2. Average 1995 yields (%) of alfalfa forage on one field which was not responsive and four fields which were responsive to phosphorus fertilizer.



There was no increase in yield with banded phosphate as compared to broadcast phosphate. The banding was done to 1 to 2 cm depth with a zero till disc drill. The act of banding was also tested and it did not significantly reduce yields on a banded check as compared to an unbanded check.

Soil tests for all six fields (Figure 3) indicated phosphorus was deficient on the treatments that had not received phosphorus fertilizer. However, fields R, S and K showed little increase in soil test phosphorus with either the Kelowna method or the Miller Axley method, with additions of phosphorus fertilizer. Fields R and K are coarse textured and have pH of 6.9 and 6.5 in the surface layer (Table 1). Field S is a clay with a pH of 7.7 in the surface horizon. In 1994 field C (Figure 3a) showed a difference between methods with the Kelowna methods showing some available phosphorus on the controls and increased amounts of available phosphorus on the fertilizer treatments. Meanwhile, the Miller Axley method showed almost no available phosphorus on all treatments. Site C is a medium to fine textured soil with a pH of 8.1 in the surface layer. This is an example of where the Miller Axley method is not reliable on high pH soils with free lime. Site C did not show an increase in yield with phosphate fertilizers. Field H, a fine textured soil and L, a coarse textured soil, showed similar soil test results with the Kelowna methods and the Miller Axley method. However, the alfalfa in field H did not respond to phosphorus fertilizer and field L, with only slightly less soil test phosphorus than field H, did respond to phosphorus fertilizer.

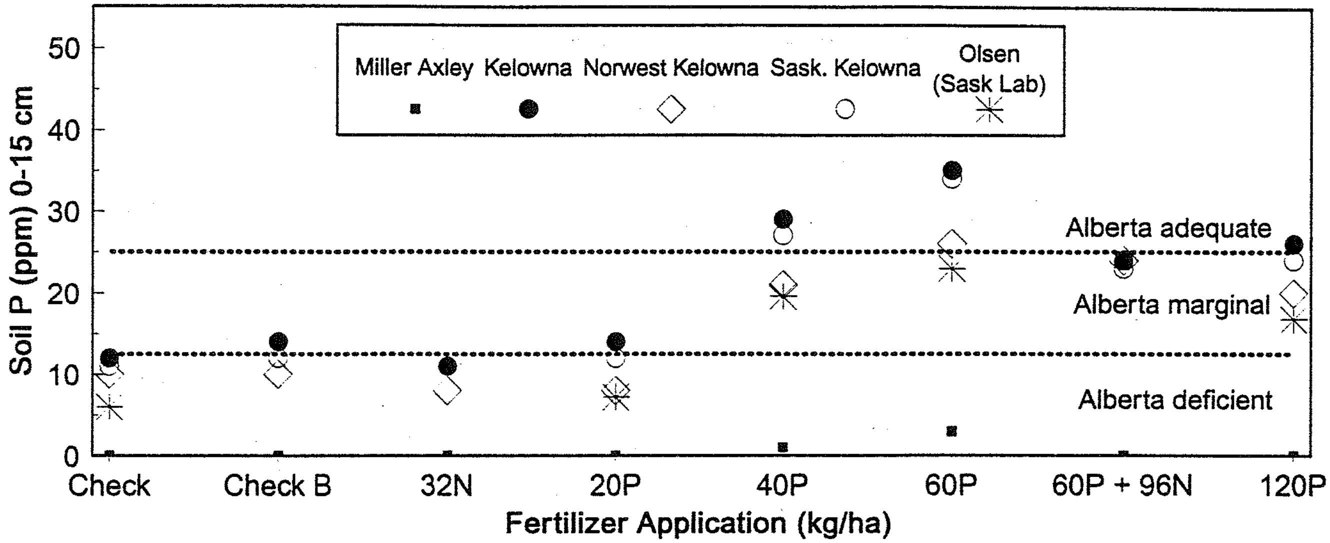
Tissue test phosphorus levels increased slightly with additional amounts of phosphorus fertilizer (Figure 4). These differences were significant at the 5% level in 1994 and in 1995. In 1995 the mean was 0.29% P on the treatments that received phosphorus and 0.26% P on the treatments that did not receive phosphorus. In both years there were also significant differences in phosphorus contents between fields. In 1995 the lowest field varied from an average of 0.26% P on the phosphorus treatments to 0.21% P on the treatments that did not receive phosphorus.

Tissue test levels varied and some fields were appreciably lower at some harvests. An example of this was field R, both at the first harvest in 1994 and the second harvest in 1995 (on September 27). The lateness of the harvest may be the reason for the low P level on field R in 1995 as the crop had some frost prior to this date. These increases in phosphorus content obtained with increasing amounts of fertilizer were not sufficient to indicate by themselves if there is a need for phosphorus fertilizer. However, the fields which did not respond to phosphorus did not show deficient tissue phosphorus content.

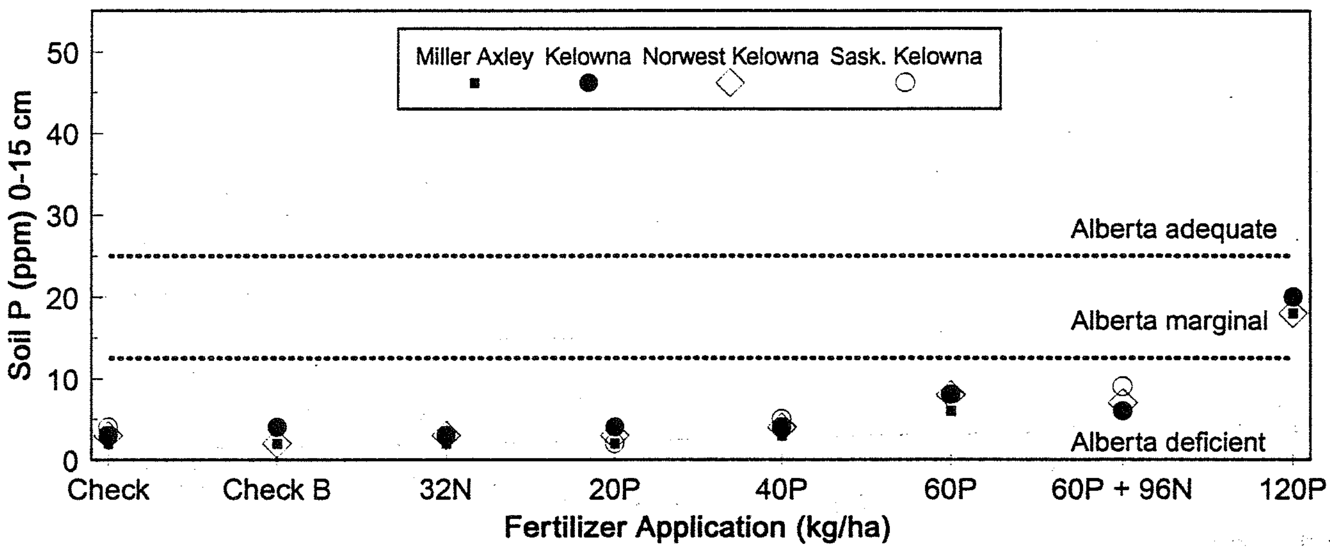
A similar increase in phosphorus content occurred on the forage samples as on the tissue samples. This improves the nutritive value of the forage. Overwintering beef cows require

Figure 3a). 1994 Soil phosphorus levels on 8 fertilizer treatments as measured by 4 or 5 extraction methods

Producer: C



Producer: R



Producer: H

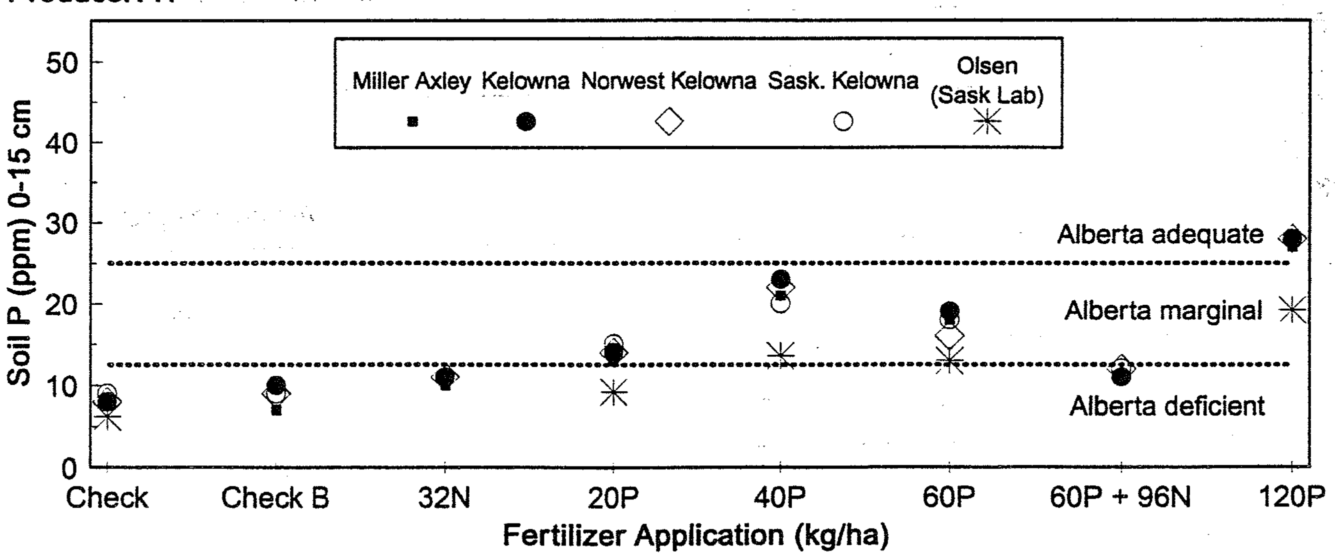
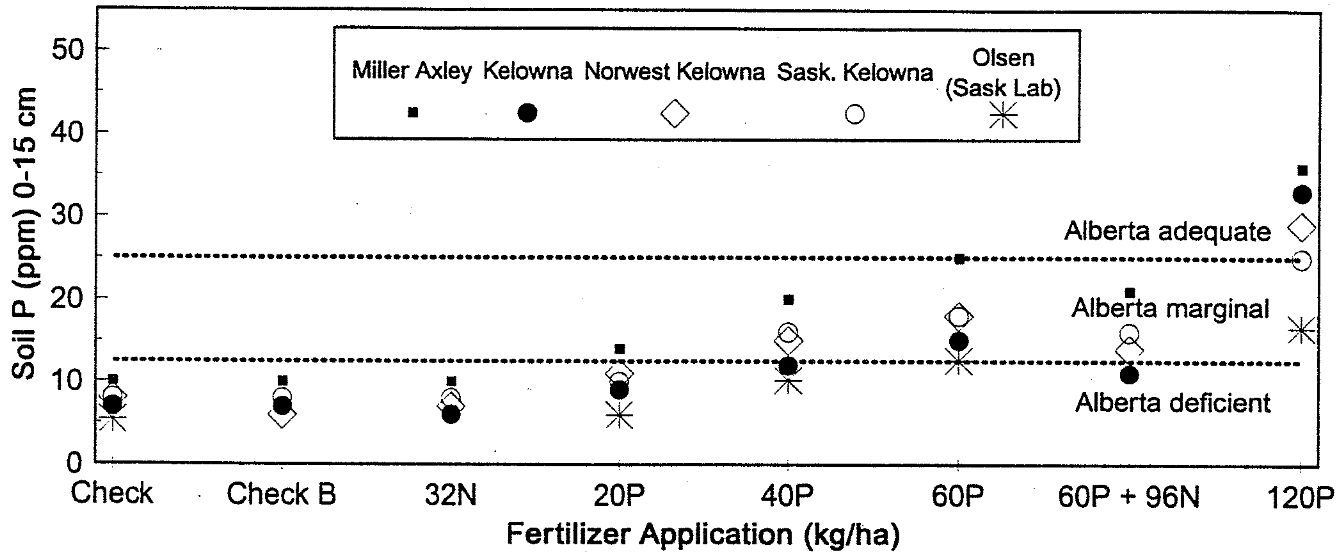
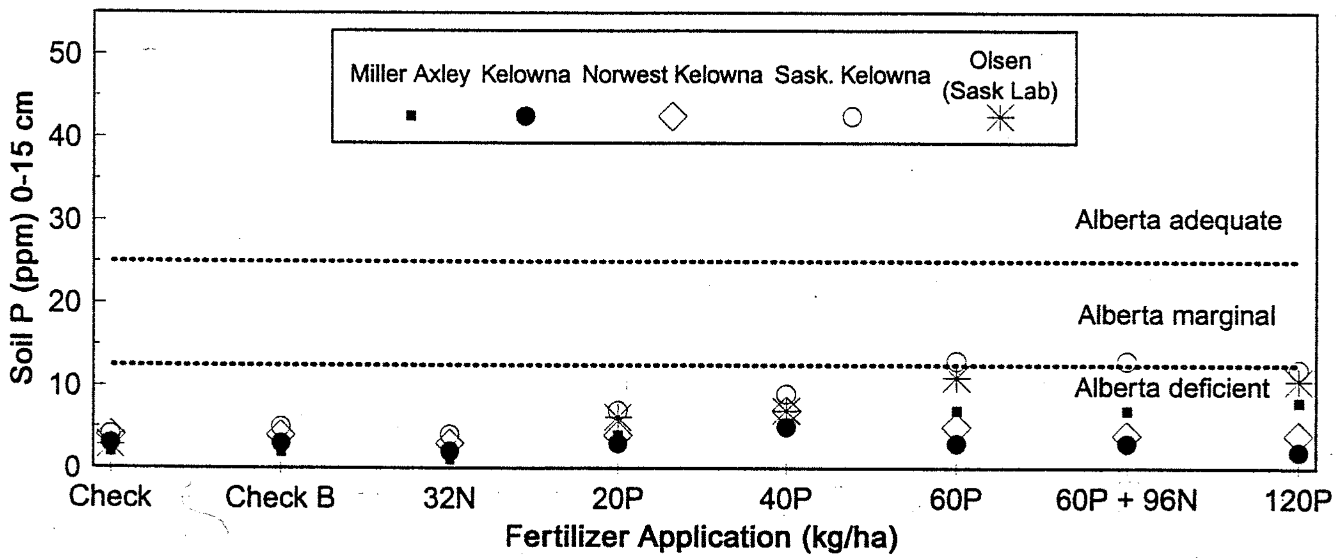


Figure 3a) (cont.). 1994 Soil phosphorus levels on 8 fertilizer treatments as measured by 4 or 5 extraction methods

Producer: L



Producer: S



Producer: K

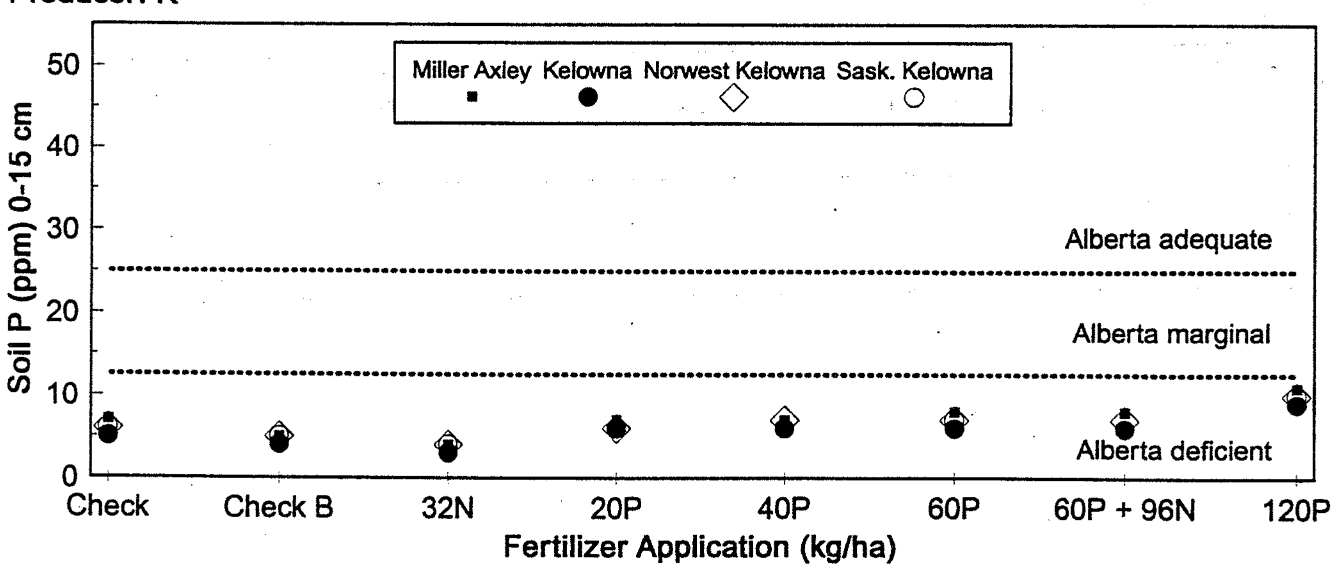


Figure 3b). 1995 Miller Axley soil phosphorus compared to Alberta standards

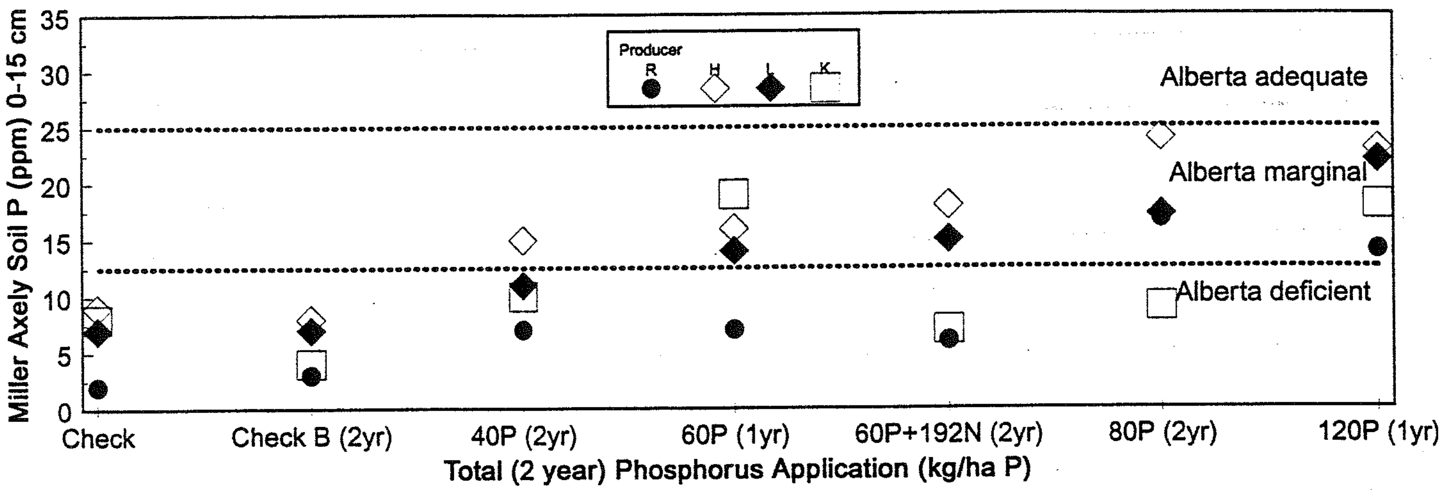
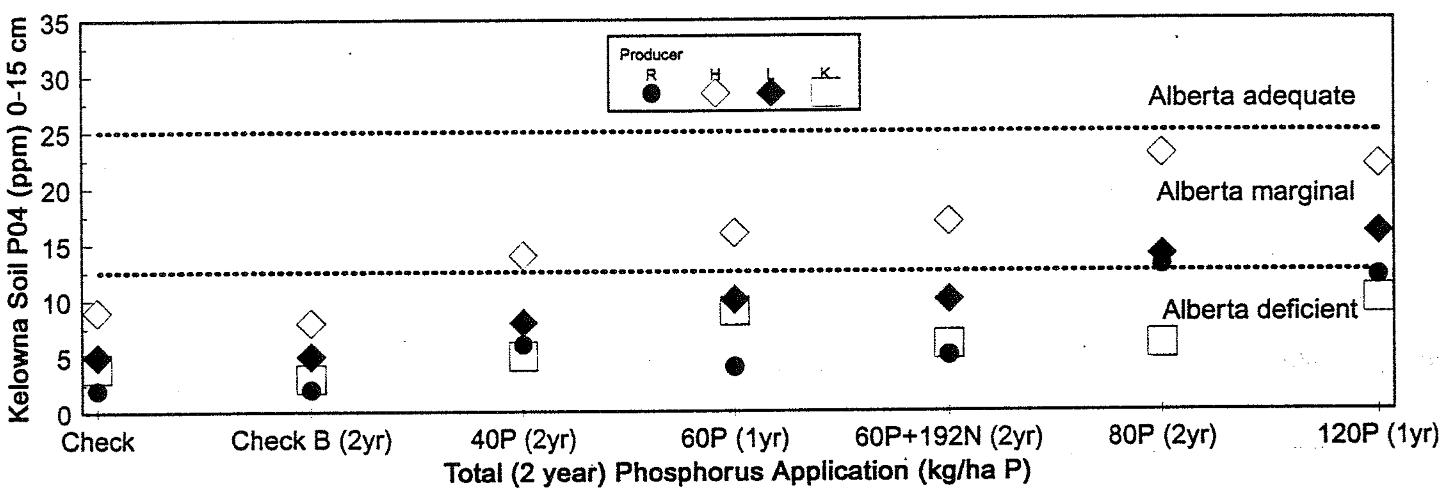


Figure 3b). 1995 Kelowna soil phosphorus compared to Alberta standards



a minimum phosphorus content of 0.17% to 0.19% and lactating beef or dairy cattle require more. One site (R) in 1995 had forage with a mean of 0.15% P on the unfertilized and 0.19% P on the fertilized treatments. Site K had 0.17% P on the unfertilized and 0.22% P on the fertilized treatments. Site S varied from 0.24 on unfertilized to 0.28% on the fertilized. This indicates that on some fields the use of phosphorus fertilizer will improve the nutritive value of the forage or reduce the need for phosphorus supplements. A 0.05% increase in P content of forage has a value of about $1/tonne as a replacement for P supplement.

Potassium Fertilizer

Potassium fertilizer did not give any increase in yield (Figure 5 and 6) in 1994 and 1995. Two of the three sites (R and L) had increases in yield when potassium was combined with phosphorus but not from potassium alone. Potassium fertilizer when banded also did not give an increase in yield.

Figure 4a). 1994 Alfalfa tissue phosphorus levels as compared to USA standards for 5 phosphorus treatments (first harvest)

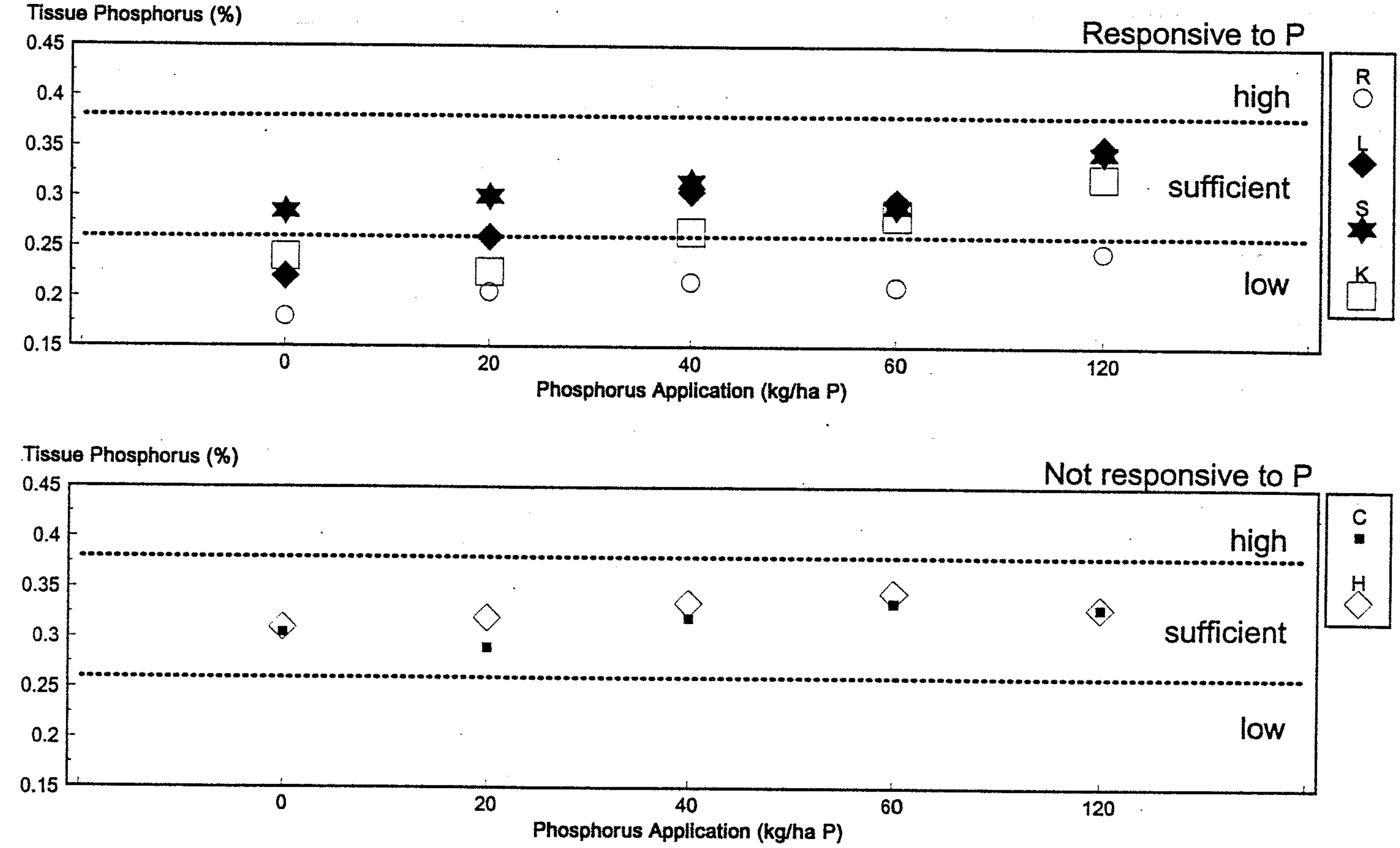


Figure 4b). 1994 Alfalfa tissue phosphorus levels as compared to USA standards for 5 phosphorus treatments (second harvest)

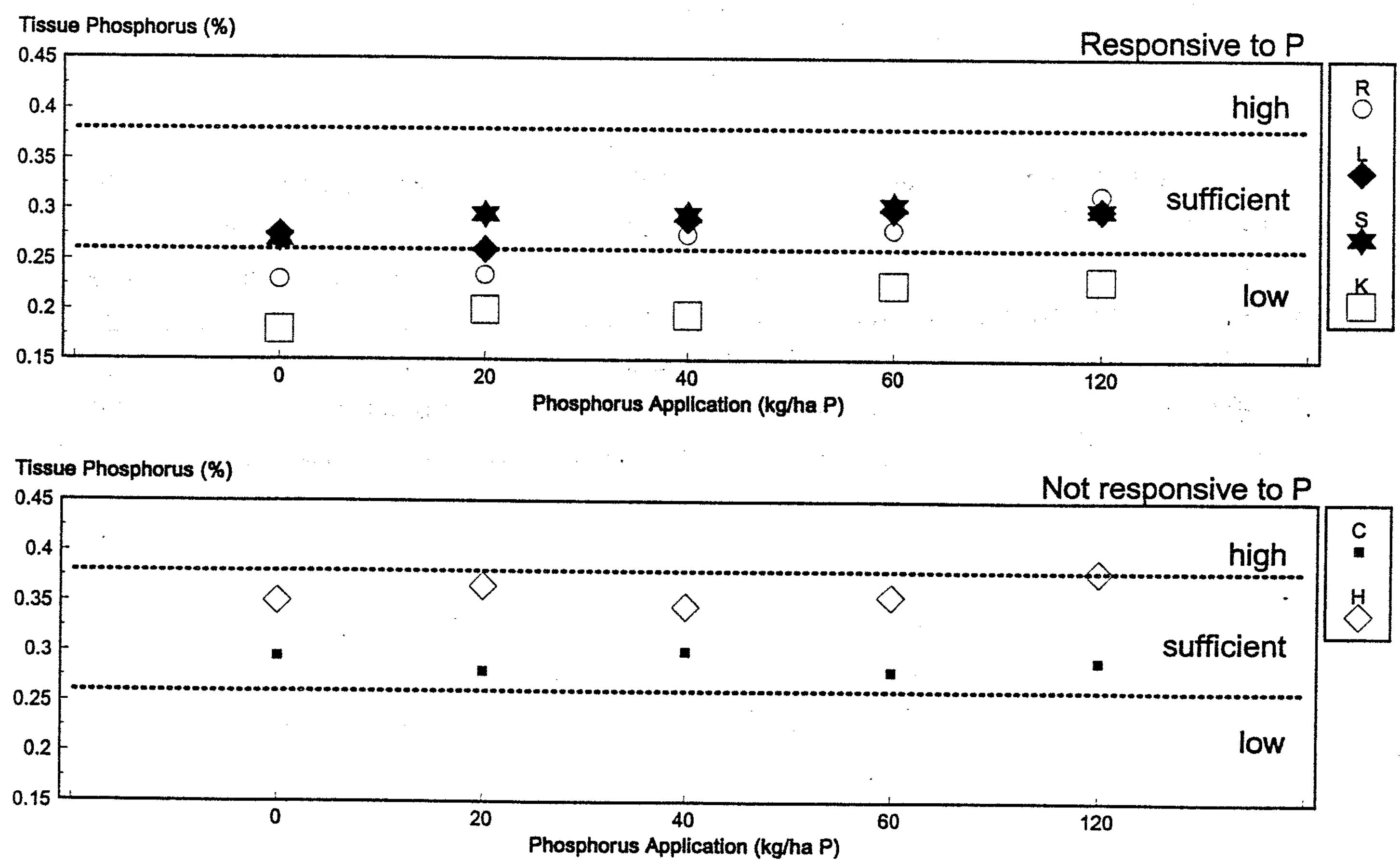


Figure 4c). 1995 Alfalfa tissue phosphorus levels as compared to USA standards for 6 phosphorus treatments (first harvest)

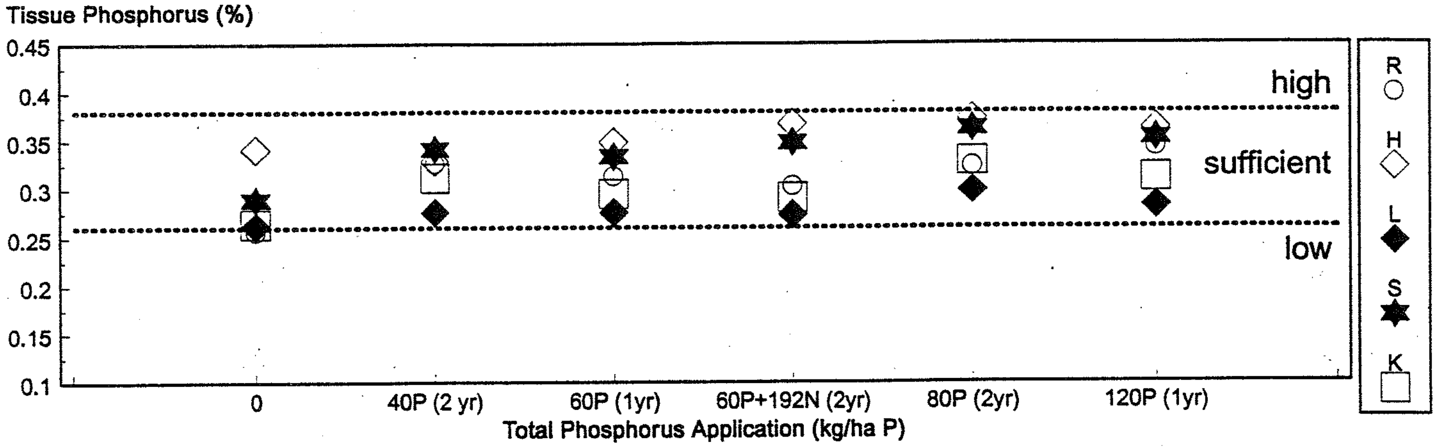
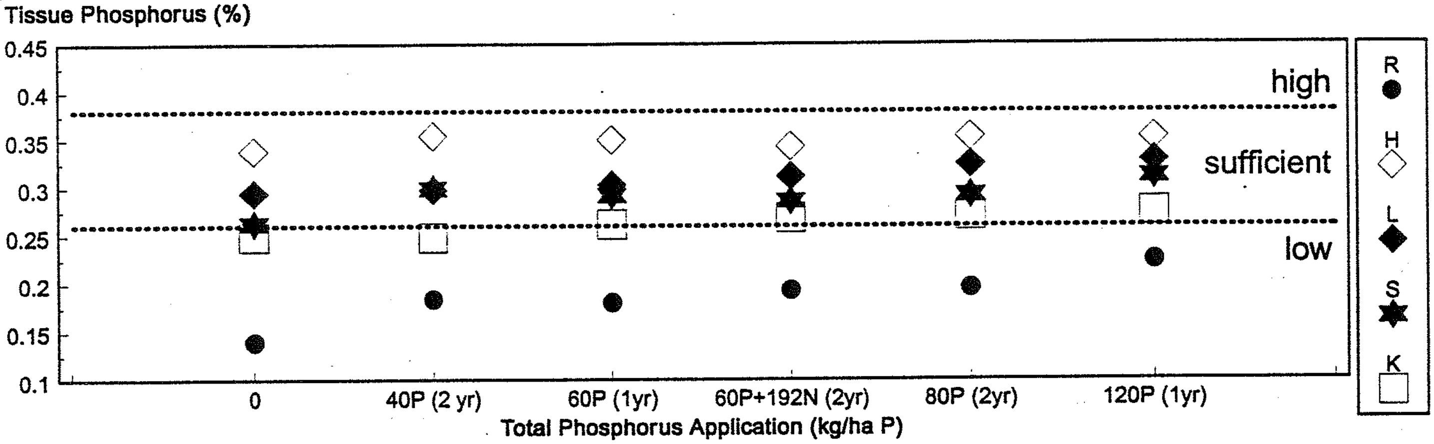


Figure 4d). 1995 Alfalfa tissue phosphorus levels as compared to USA standards for 6 phosphorus treatments (second harvest)



In 1994 soil potassium (Figure 7) measured by the ammonium acetate and Kelowna methods was appreciably lower on R, H and L than when measured by the Norwest Kelowna or Saskatchewan Kelowna methods. By Alberta standards soil test potassium was marginal onfields R and H and deficient on field L when measured by the ammonium acetate and Kelowna methods.

Fertilizer potassium did not appreciably alter the available potassium levels as measured by the soil test. A soil which has a marginal level of 100 ppm of soil potassium has 1344 kg/ha of K in the top 0.9 m or 224 kg/ha K in 0.15 m. An application of 100 kg/ha K is only a small addition to the total available supply but should appear as an appreciable addition to the 0-0.15 m surface layer and yet it did not do so.

Tissue test potassium (Figure 9) was low, according to USA standards, on fields R and L. Field H tested sufficient in 1994 and marginal in 1995. Potassium uptake is restricted by low soil temperatures but there is no apparent difference in tissue potassium content between first harvest in June and second harvest which is usually in August. Tissue potassium levels did not appreciably increase with potassium fertilizer applications as compared to the control.

Figure 5: Total 1994 alfalfa forage yields obtained with potassium treatments

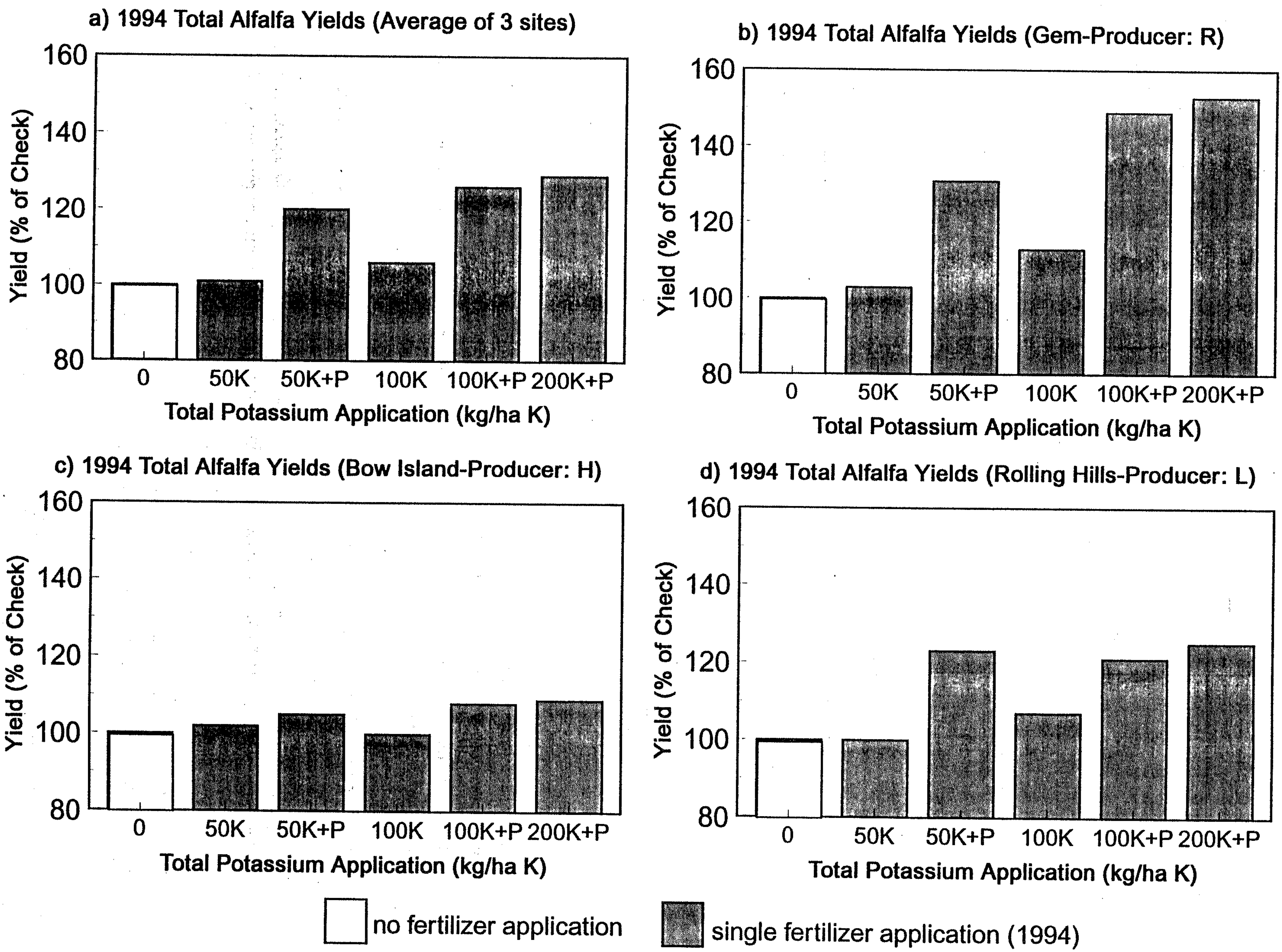


Figure 6: Total 1995 alfalfa forage yields obtained with potassium treatments

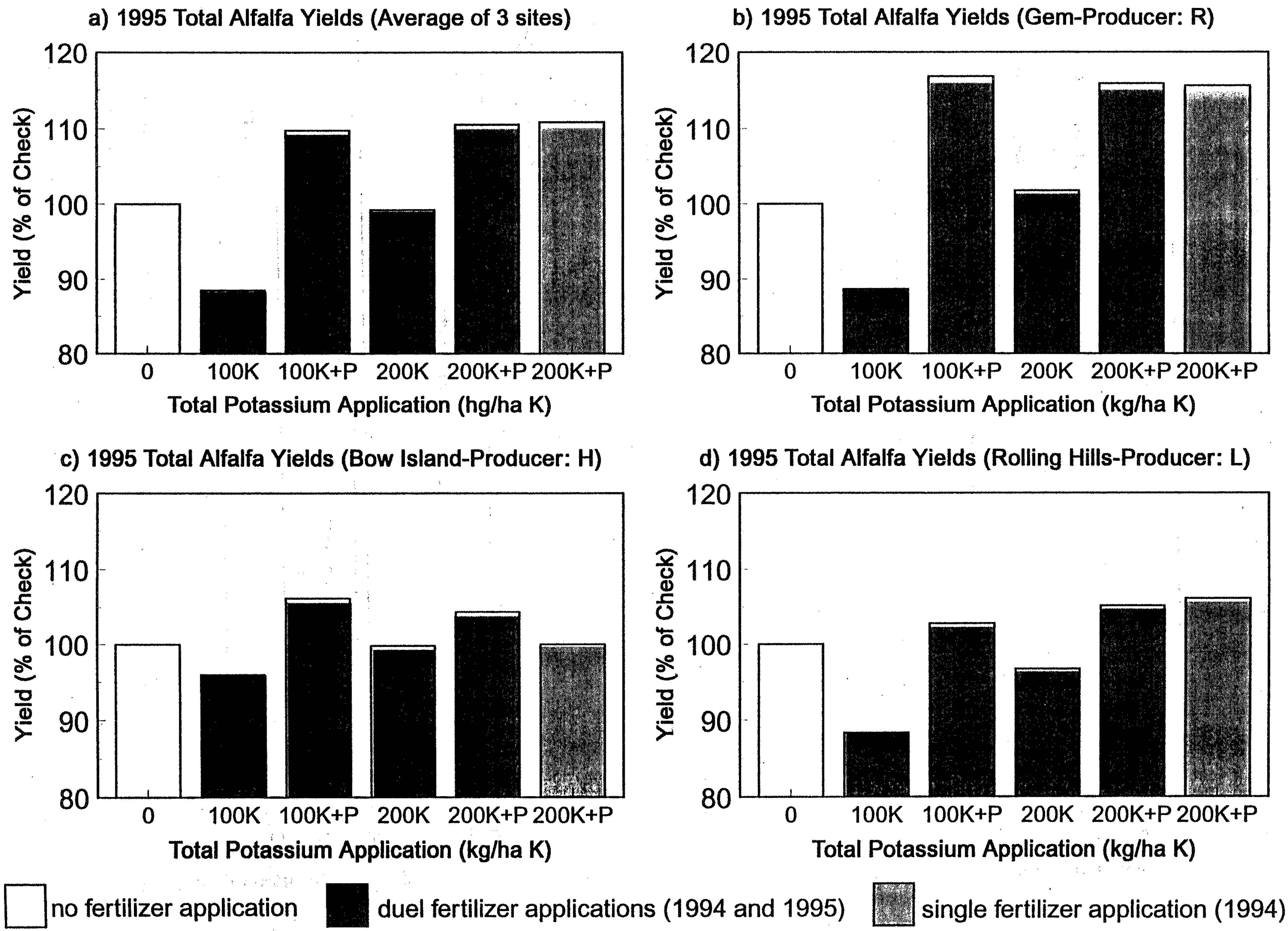


Figure 7. 1994 Soil potassium levels on 7 fertilizer treatments as measured by 4 extraction methods

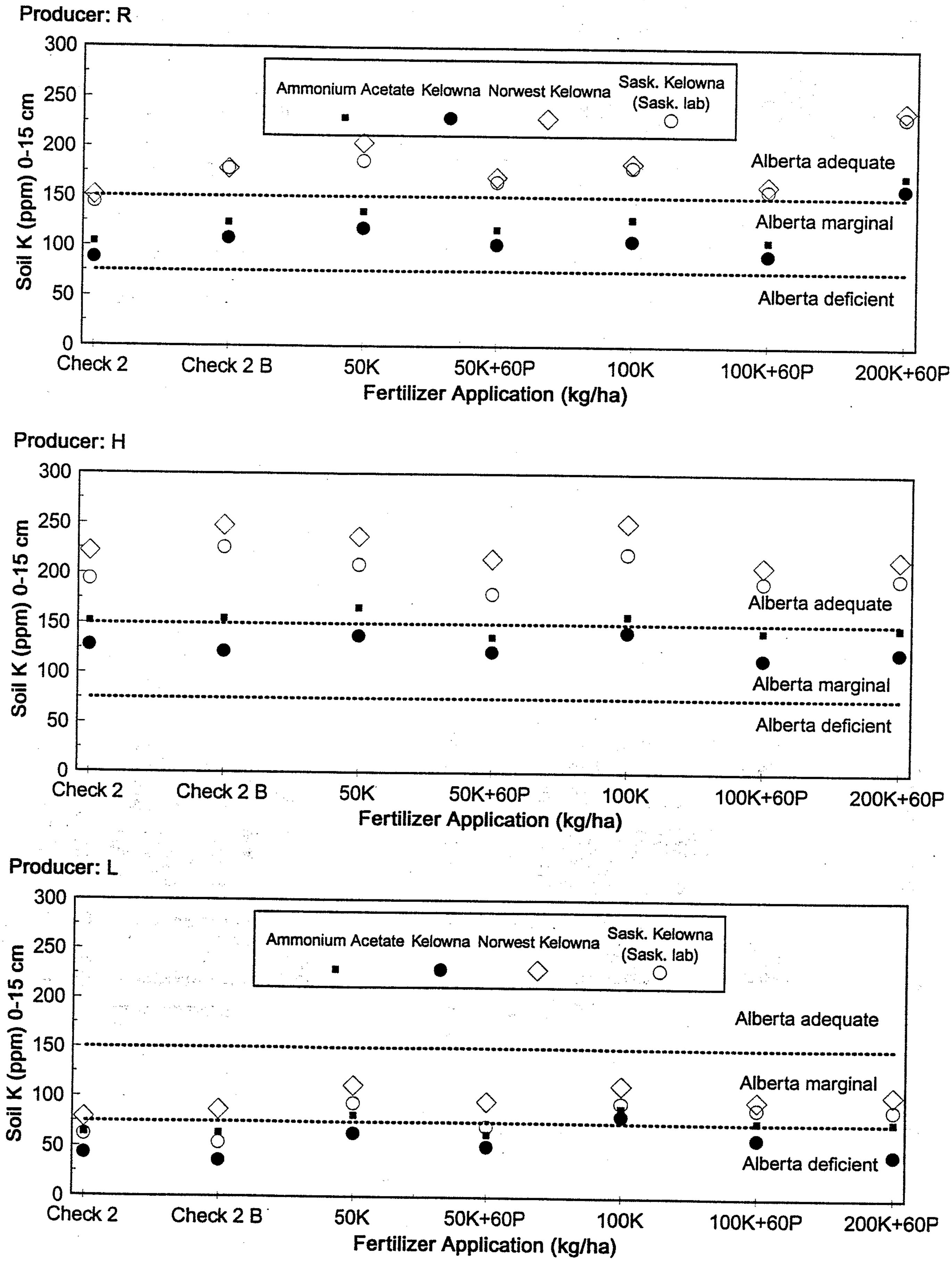
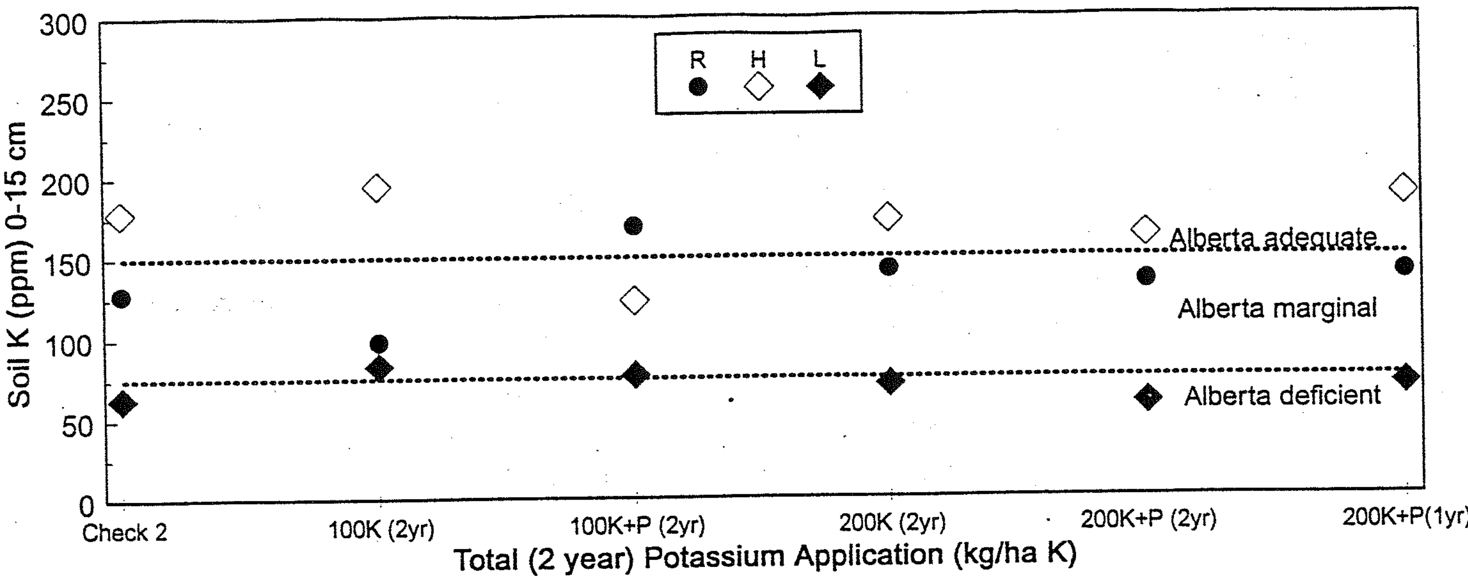


Figure 8. 1995 Soil ammonium acetate potassium levels on 6 fertilizer treatments for 3 producers



Nitrogen Fertilizer

Ammonium phosphate and a high rate (80 kg/ha) of extra nitrogen applied annually, as compared to ammonium phosphate alone, increased the average yield of the first harvest by 10% in 1994 and 12% in 1995 (Figure 10). The average yield of the low rate of nitrogen treatment with 32 kg/ha N (29 lbs/ac) as ammonium nitrate as compared to the check, increased the yield by 0% in 1994 and 8% in 1995. The response to nitrogen fertilizer varied between sites with site H having the largest increase in yield in 1994 and site S in 1995. In 1995 site S had a lot of weeds which were not separated out from the alfalfa. Weeds would be expected to have a greater response to nitrogen than alfalfa.

Micronutrients

In the spring of 1994 analysis was done on the soil (Table 1) for micronutrients. Copper, iron, manganese, zinc, boron, molybdenum and cobalt were determined on tissue samples from all fertilizer treatments for both years. Tissue zinc was on or slightly above the lower limit of sufficient for both first and second harvest for both years (Figure 11). Tissue zinc was significantly reduced on phosphorus fertilizer treatments. Copper was similarly marginally low in tissue samples and also was significantly reduced on phosphorus fertilizer treatments.

CONCLUSION

This study has shown that the soil phosphorus testing methods used did not reliably indicate whether sufficient phosphorus is available for alfalfa on irrigated soils. The best option for the producer is to use a combination of soil test and plant tissue tests for phosphorus. A sufficient tissue test appears to be an indication that soil phosphorus levels are adequate. However, on a late harvest, tissue tests were low on all phosphorus treatments and the control. The use of phosphorus fertilizer significantly increased the protein content of tissue samples in 1995, but not in 1994. The unfertilized treatments at some sites produced forage which was deficient or marginally adequate in phosphorus for cattle. Fertilized treatments had a significantly higher phosphorus content which was nutritionally adequate for cattle.

A soil test indicates a deficiency more frequently than is shown by responses to phosphorus fertilizer. This was shown by two of the original sites not responding to phosphorus. The Kelowna methods indicated more available P (10-35 ppm vs 0-3 ppm) than the Miller Axley method on one high pH soil. On four other fields available P was similar at all rates of phosphorus fertilizer indicating none of the methods were identifying the fertilizer phosphate added to the soil. On one field the Miller Axley Method indicated slightly more phosphorus than the Kelowna methods.

Yield responses of alfalfa to potassium fertilizers were not obtained even when the soil test indicated potassium was deficient. On the previous field survey, no alfalfa fields were deficient in soil potassium while 70% were deficient in tissue potassium. In this study, tissue test values for potassium were low on all treatments in 1995 and on two out of three fields in 1994. The tissue test values for potassium did not increase with applications of potassium fertilizer. This lack of response is surprising because the amount of potassium removed by alfalfa forage is large and many of these soils have been frequently used for production of alfalfa. More research needs to be done to determine the appropriate limits for potassium deficiency with respect to both tissue and soil analysis.

Responses to nitrogen fertilizer were obtained on the first harvest of alfalfa after application of nitrogen. They indicate that on some fields it may be profitable to fertilize with nitrogen. However, these results do not indicate how to predict which fields may respond to nitrogen. In 1996 with a different harvesting system, weeds will be separated and weighed as part of the harvest samples and this may give an indication if an increase in weed growth is associated with a yield response from nitrogen.

Levels of tissue and zinc and copper were slightly above the American Society of Agronomy deficient limits for alfalfa. Both zinc and copper tissue levels were significantly reduced by applications of phosphorus fertilizer.

One more year of testing will be done on 3 new first year forage alfalfa sites and 3 of the original sites will be continued. The 1996 fields will all have treatments of phosphorus, potassium and nitrogen. The phosphorus adsorption capacity of the surface horizon is being determined on the 6 original sites and the 3 new sites.

ACKNOWLEDGEMENTS

Assistance on interpreting animal nutrition requirements was provided by R. Corbett and A. McNeil, AAFRD, Edmonton, and Lacombe, respectively, and by B. Graham, Lakeside, Brooks. Laboratory analysis was provided by the AAFRD Soils and Animal Nutrition Lab, Edmonton and the Plains Innovative Laboratory, Saskatoon.

Figure 9a). 1994 Alfalfa tissue potassium levels as compared to USA standards for 6 potassium treatments (first harvest)

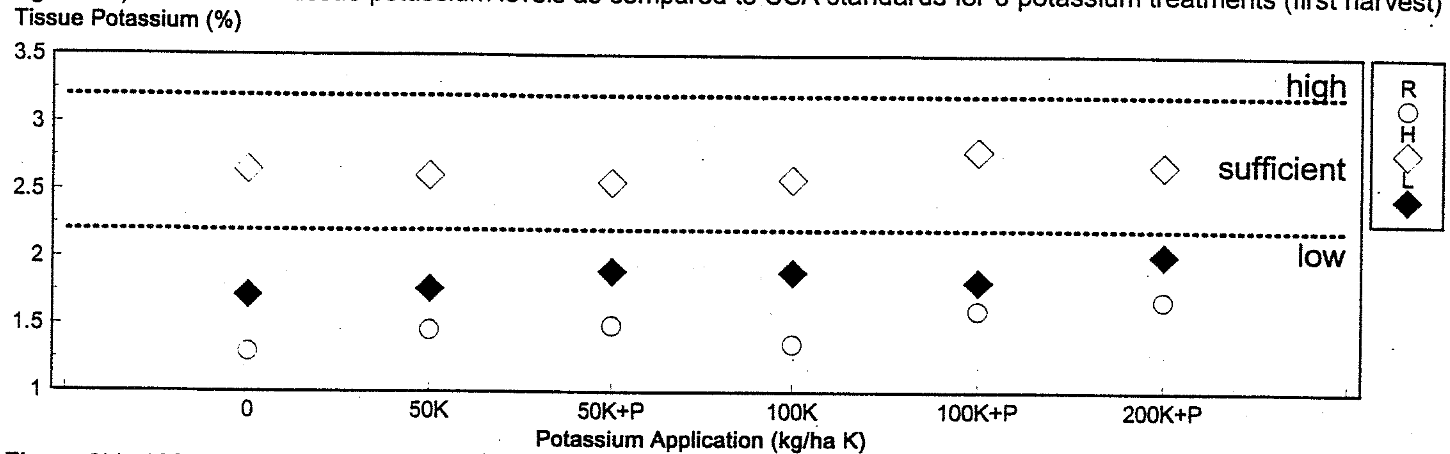


Figure 9b). 1994 Alfalfa tissue potassium levels as compared to USA standards for 6 potassium treatments (second harvest)

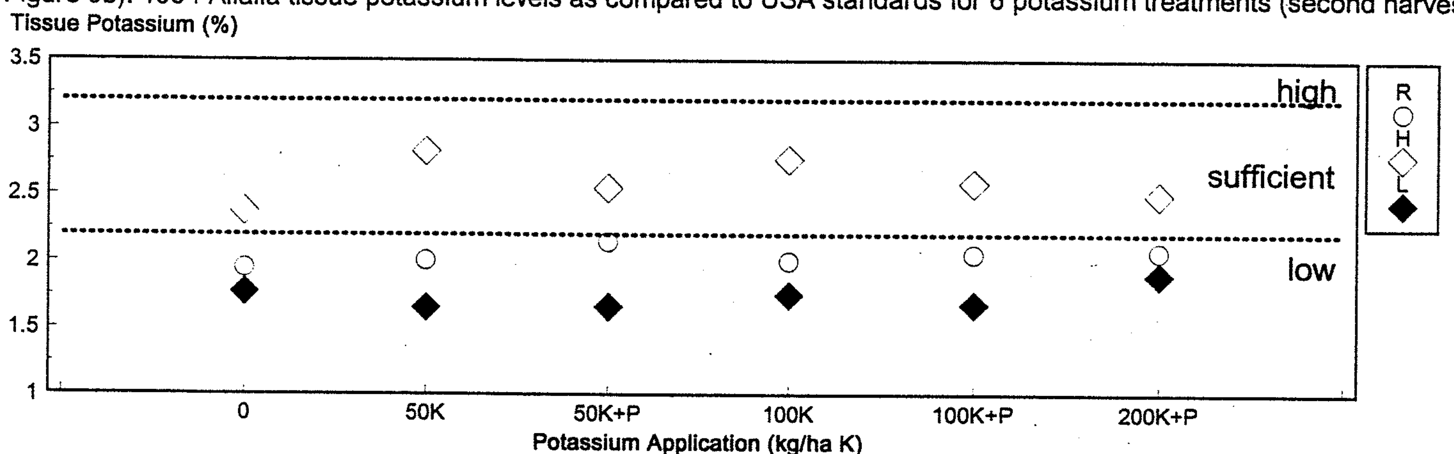


Figure 9c). 1995 Alfalfa tissue potassium levels as compared to USA standards for 6 potassium treatments (first harvest)

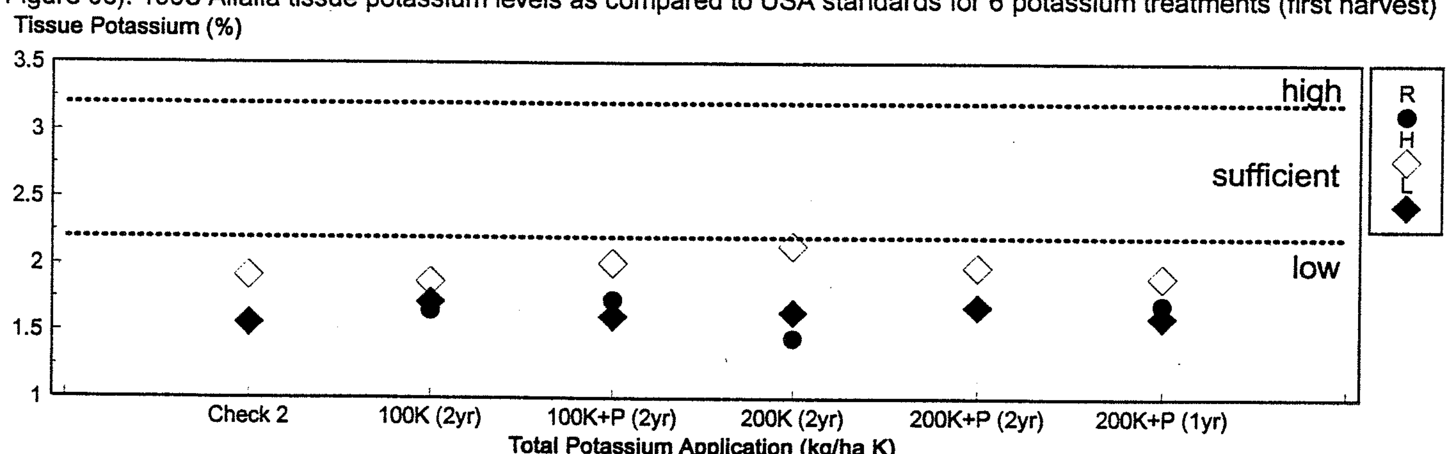


Figure 9d). 1995 Alfalfa tissue potassium levels as compared to USA standards for 6 potassium treatments (second harvest)

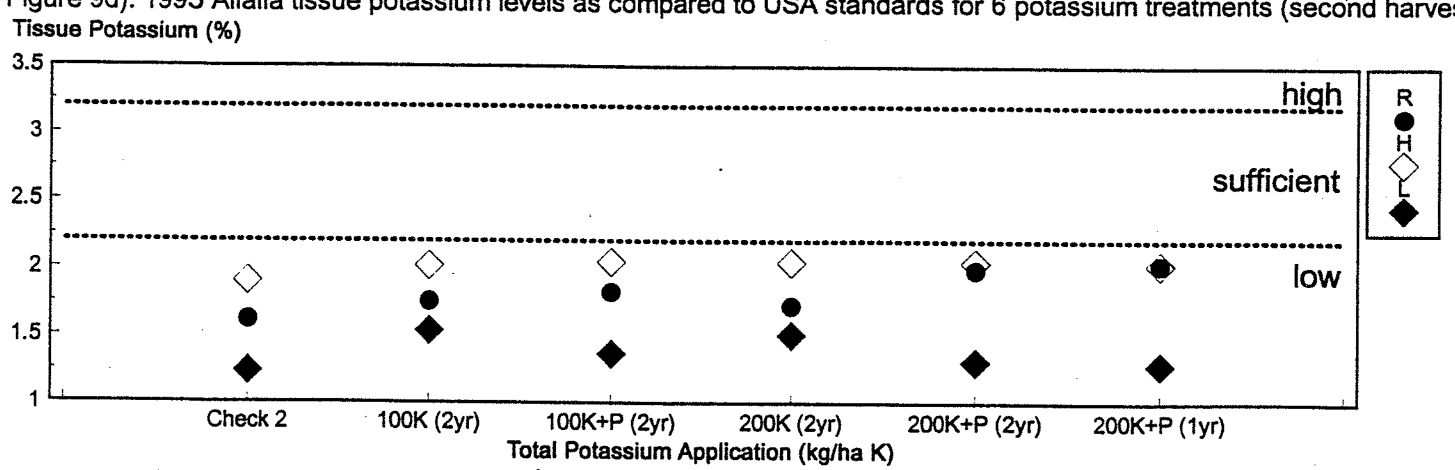


Figure 10a). Nitrogen response of 1994 irrigated alfalfa (first harvest)

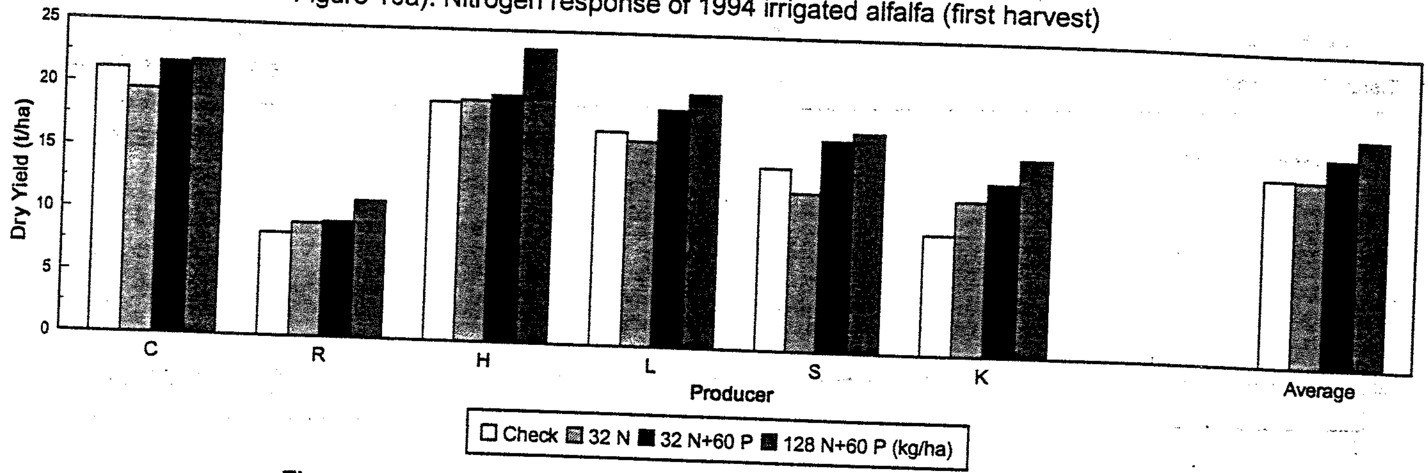


Figure 10b). Nitrogen response of 1995 irrigated alfalfa (first harvest)

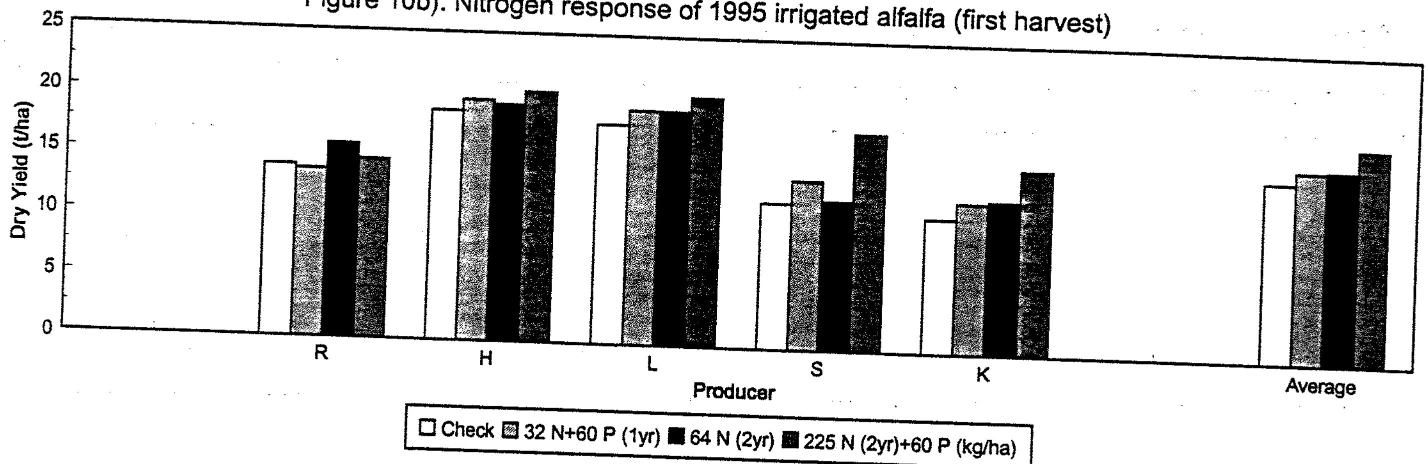


Figure 11a). 1994 Alfalfa tissue zinc levels as compared to USA standards for 5 phosphorus treatments (first harvest)

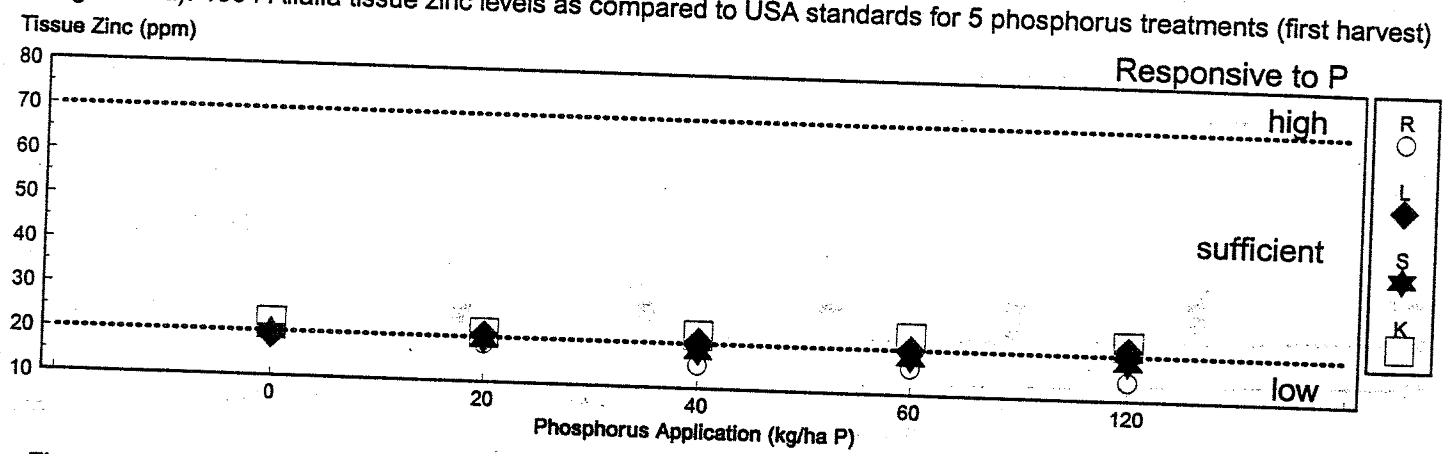


Figure 11b). 1994 Alfalfa tissue zinc levels as compared to USA standards for 5 phosphorus treatments (first harvest)

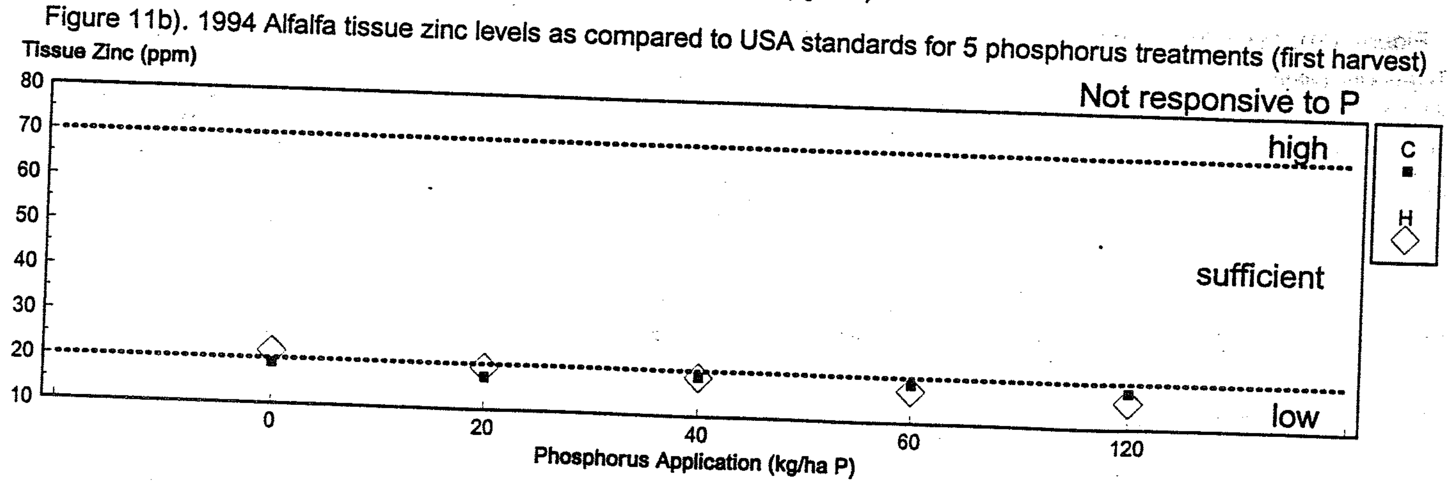


Figure 11c). 1994 Alfalfa tissue zinc levels as compared to USA standards for 5 phosphorus treatments (second harvest)

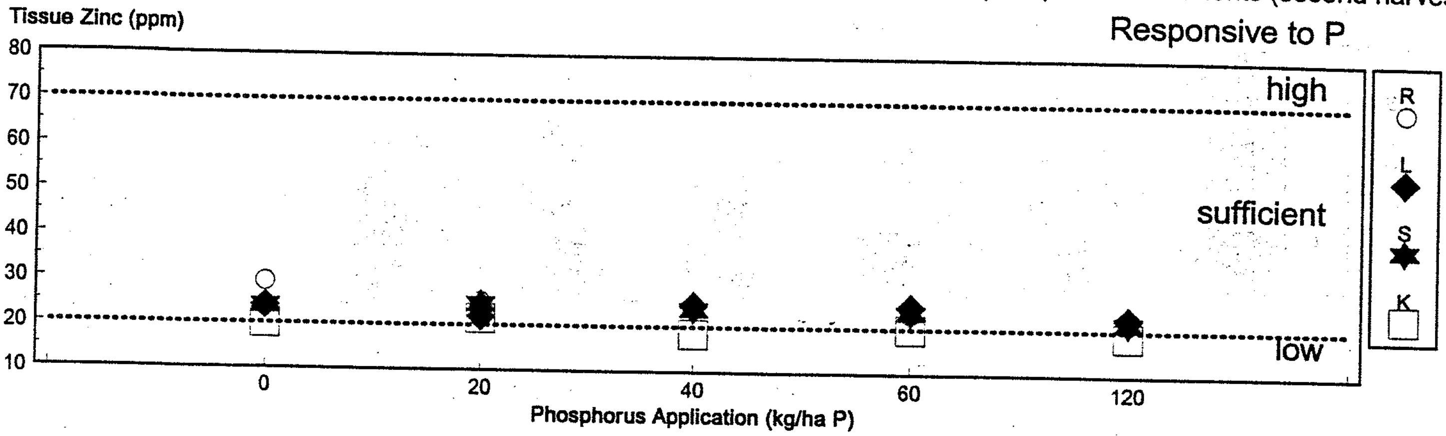


Figure 11d). 1994 Alfalfa tissue zinc levels as compared to USA standards for 5 phosphorus treatments (second harvest)

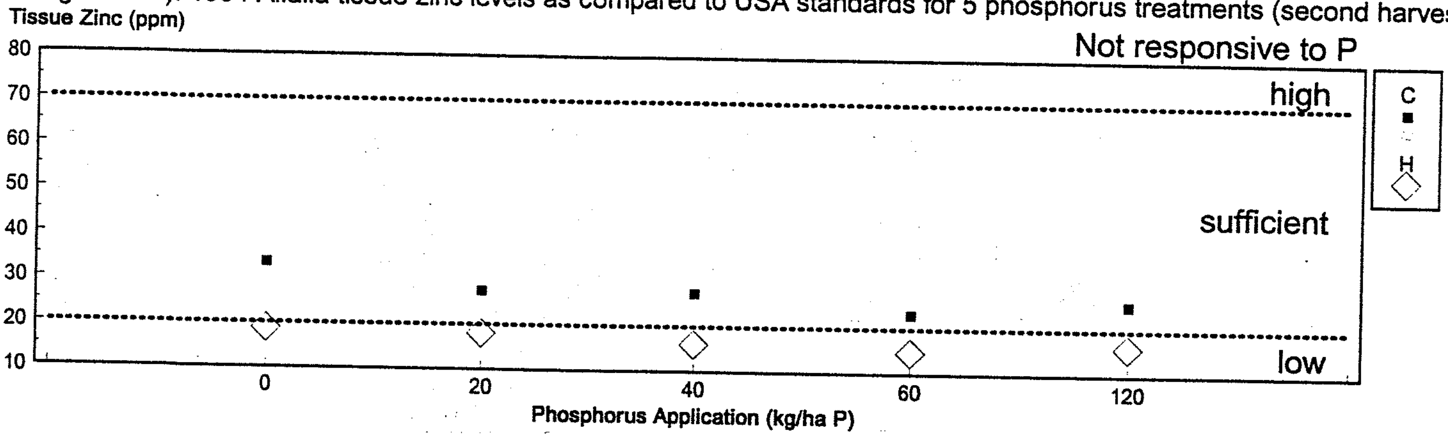


Figure 11e). 1995 Alfalfa tissue zinc levels as compared to USA standards for 6 phosphorus treatments (first harvest)

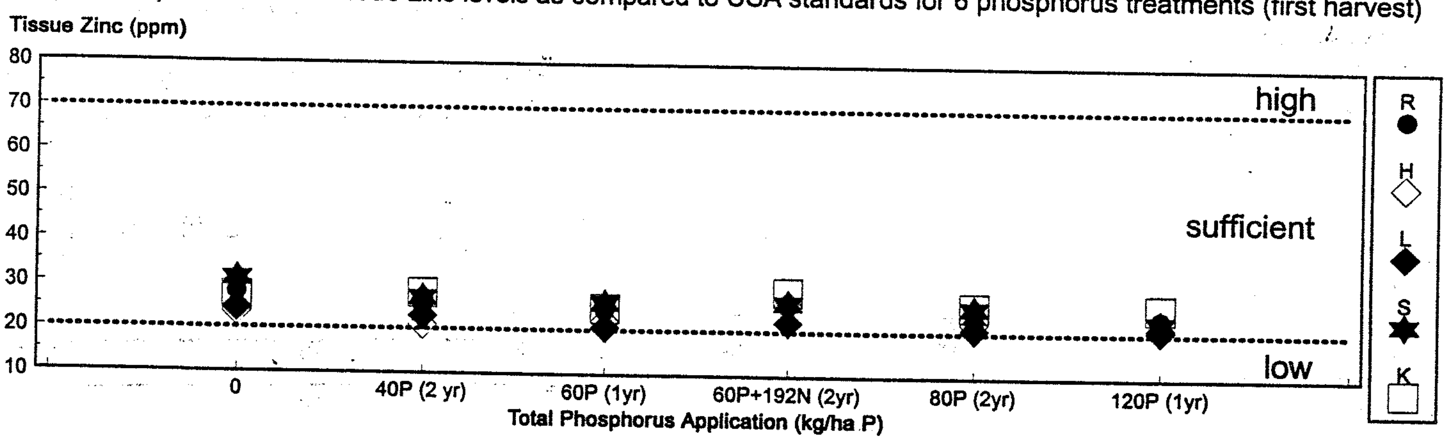


Figure 11f). 1995 Alfalfa tissue zinc levels as compared to USA standards for 6 phosphorus treatments (second harvest)