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Quantitative and Qualitative Response of Established Alfalfa Forage to Methods of Application of Phosphorus and Potassium Fertilizers
Report for 1992

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BACKGROUND

Although alfalfa is the predominant forage grown on the Canadian prairies, management of fertilizer applications to produce the optimum yield and quality is often neglected. Only about 15% of the alfalfa grown on the prairies is fertilized annually, and generally with low rates of P. Therefore, P and K are often inadequate to produce the most economic yield. These two nutrients are relatively immobile in the soil, their availability to the plant may be strongly influenced by their method of placement. The P and K that is applied to alfalfa in the prairies is generally applied as a broadcast application, which may limit availability to the plant under dry conditions. This study was undertaken to evaluate the effect of broadcast and banded applications of P and K on the yield and quality of established alfalfa stands.

OBJECTIVE

To evaluate application techniques that may increase the availability of P and K fertilizer to alfalfa, thus resulting in increased forage yield and improved protein and mineral composition.

METHODOLOGY

Two research sites were selected in 1989. The first was a Marringhurst sandy loam soil near Brandon and the second a Newdale clay loam soil, near Newdale, MB. Each site had been sown to Algonquin alfalfa three years previously and had been cut for two years. Neither had been fertilized in the previous year. Uniform areas were selected for the experimental site. In 1989, fertilizer was applied to the Marringhurst sandy loam on May 30 and harvests were taken on June 21, July 27 and September 27. Fertilizer was applied to the Newdale clay loam soil on May 26 and harvests were taken on June 27, August 1 and September 27. In 1990, fertilizer was applied in the first week of May on both sites. Harvests were taken on the Marringhurst soil on June 21, July 27 to August 2 and September 27. On the Newdale soil, harvests were taken on June 19-20 and July 24-26. No third harvest was taken on the Newdale soil in 1990, due to insufficient regrowth. In 1991, fertilizer was applied on April 18 on the Newdale site and April 19 on the Marringhurst site. Harvests were taken on June 10 and July 19 on the Newdale soil and June 11, July 17 and September 20 on the Marringhurst soil. In 1992, fertilizer was applied on April 30 to May 1 on the Newdale site and April 28 on the Marringhurst site.

Assessments of winter survival (scale of 1=poor to 9=good) and grass infestation (0=none to 5=all grass) were taken on May 13 on the sandy loam soil and May 19 on the clay loam soil. Harvests were taken on June 24 and August 14 on the Newdale site and June 23, August 13 and October 2 on the Marringhurst site. Plant samples were dried, ground and submitted to the laboratory for analysis for N, P and K. Statistical analysis was conducted using the GLM procedure of SAS (SAS Institute 1982). In 1992, grass infestation of the plots was used as a covariate in the analysis.

RESULTS AND DISCUSSION

DRY MATTER YIELD
1989 Crop Year
Marringhurst Sandy Loam

Table 1: Yield of alfalfa on the Marringhurst sandy loam soil as influenced by method and rate of P and K fertilization (1989).

P	K	Placement	Harvest 1	Harvest 2	Harvest 3	Total
-kg	ha^{-1}		---------- t ha^{-1} ----------			
0	0	Broadcast	5.4	4.8	2.3	12.6
0	0	Banded	4.7	4.6	2.4	11.7
0	50	Broadcast	5.1	4.9	2.5	12.5
0	50	Banded	4.9	5.0	2.2	12.2
0	100	Broadcast	6.0	5.4	2.4	13.7
0	100	Banded	4.6	4.9	2.6	12.1
20	0	Broadcast	4.5	4.2	2.2	10.8
20	0	Banded	4.0	4.7	2.6	11.3
20	50	Broadcast	6.2	5.0	2.2	13.4
20	50	Banded	4.6	5.7	2.6	12.9
20	100	Broadcast	5.5	4.8	2.5	12.8
20	100	Banded	4.8	5.0	2.4	12.2
40	0	Broadcast	4.9	4.7	2.1	11.6
40	0	Banded	4.7	4.6	2.6	11.9
40	50	Broadcast	5.5	5.1	2.4	13.0
40	50	Banded	4.2	4.4	2.2	10.8
40	100	Broadcast	5.8	4.7	2.6	13.1
40	100	Banded	4.8	4.9	2.3	11.9
80	0	Broadcast	5.4	4.5	2.5	12.3
80	0	Banded	4.9	5.0	2.5	12.4
80	50	Broadcast	5.6	5.1	2.3	13.0
80	50	Banded	5.0	5.2	2.7	13.0
80	100	Broadcast	5.4	4.9	2.2	12.6
80	100	Banded	4.5	4.8	2.6	12.0

Alfalfa yield on the sandy loam soil was extremely high (Table 1). The site was located in a depressional area and received ample moisture. The site location also permitted early warming of the soil, thus resulting in early regrowth of the alfalfa. The stand was thick, lush and productive. Dry matter yield at the first harvest was reduced by the banding operation (Tables 1 and 2). By

the second harvest, differences due to placement were no longer significant. Total dry weight production over the season was lower with banded rather than broadcast fertilizer application. Dry matter yield at the first and third harvests were not significantly influenced by fertilizer application. However, yield at the second harvest was increased with application of K. Total dry weight production over the season was increased by application of K.

Newdale Clay Loam

Yield on the clay loam soil was low, due to dry conditions throughout the growing season. The banding operation did not depress yield as strongly as it did in the sandy soil, possibly because the dry conditions resulted in the roots growing deeper into the soil profile, away from the soil surface. Dry matter yield at the first harvest was not significantly influenced by fertilization (Tables 2 and 3). By the second and third harvests, yield was increased with application of P at 20 kg ha^{-1} and increased further with the application of 40 or 80 kg P ha^{-1}. Total dry matter yield through the season increased with increasing P. The highest total yields were obtained when both P and K were applied at moderate to high levels.

Table 3: Yield of alfalfa on the Newdale clay loam soil as influenced by method and rate of P and K fertilization (1989).

P	K	Placement	Harvest 1	Harvest 2	Harvest 3	Total
-kg ha^{-1}			----------t ha^{-1}----------			
0	0	Broadcast	1.2	1.4	0.9	3.5
0	0	Banded	1.0	1.3	0.7	3.0
0	25	Broadcast	1.0	1.0	0.5	2.5
0	25	Banded	1.2	1.3	0.9	3.4
0	50	Broadcast	1.3	1.4	0.9	3.6
0	50	Banded	1.1	1.1	0.8	3.1
20	0	Broadcast	1.2	1.2	0.9	3.3
20	0	Banded	1.0	1.4	1.0	3.4
20	25	Broadcast	1.2	0.9	1.1	3.2
20	25	Banded	0.9	1.1	0.8	2.8
20	50	Broadcast	0.9	1.4	0.9	3.1
20	50	Banded	1.3	1.6	1.2	4.1
40	0	Broadcast	1.2	1.4	1.0	3.5
40	0	Banded	1.1	1.3	1.2	3.6
40	25	Broadcast	1.5	1.2	1.3	4.0
40	25	Banded	1.4	1.3	1.2	3.9
40	50	Broadcast	1.1	1.4	1.2	3.7
40	50	Banded	1.0	1.3	1.0	3.3
0	0	Broadcast	0.9	1.2	1.0	3.1
80	0	Banded	1.0	1.3	1.2	3.4
80	25	Broadcast	1.2	1.5	1.4	4.1
80	25	Banded	1.2	1.6	1.3	4.1
80	50	Broadcast	1.4	1.7	1.5	4.6
80	50	Banded	1.0	1.6	1.3	3.9

1990 Crop Year

Marringhurst Sandy Loam

In 1990, alfalfa yield on the sandy loam soil although high, was slightly lower than in 1989. Yield of the first harvest was reduced by band placement of fertilizer (Tables 4 and 5). At the later harvests, and for total yield, there was no effect of fertilizer placement. Potassium application increased the first harvest yield but only when the fertilizer was broadcast ($p<0.052$). On the second harvest, there was no effect of fertilizer application or placement method on alfalfa yield, while at the third harvest, yield increased with application of 50 or 100 kg K ha^{-1}, banded or broadcast.

Table 4: Yield of alfalfa on the Marringhurst sandy loam soil as influenced by method and rate of P and K fertilization (1990).

P	K	Placement	Harvest 1	Harvest 2	Harvest 3	Total
-kg	ha^{-1}		----------kg ha-1----------			
0	0	Broadcast	5.0	3.3	1.6	9.9
0	0	Banded	5.2	3.9	1.2	10.2
0	50	Broadcast	5.3	3.5	1.9	10.7
0	50	Banded	4.6	3.2	1.9	9.7
0	100	Broadcast	5.2	3.1	1.5	9.9
0	100	Banded	4.9	3.5	1.8	10.2
20	0	Broadcast	4.8	2.8	1.4	9.0
20	0	Banded	4.9	3.2	1.7	9.9
20	50	Broadcast	5.6	3.5	2.0	10.6
20	50	Banded	5.1	3.4	1.5	10.0
20	100	Broadcast	5.0	3.6	1.9	10.5
20	100	Banded	4.7	3.3	2.2	10.1
40	0	Broadcast	4.7	3.4	1.5	9.6
40	0	Banded	5.0	3.3	1.5	9.8
40	50	Broadcast	5.2	3.4	2.3	10.9
40	50	Banded	4.5	3.0	1.6	9.1
40	100	Broadcast	4.9	3.5	1.7	10.0
40	100	Banded	4.8	3.4	1.6	9.9
80	0	Broadcast	5.3	3.3	1.7	10.3
80	0	Banded	5.1	3.6	1.5	10.1
80	50	Broadcast	5.3	3.4	1.9	10.7
80	50	Banded	4.9	3.6	1.9	10.3
80	100	Broadcast	5.3	3.3	1.9	10.4
80	100	Banded	4.7	3.5	1.9	10.1

Newdale Clay Loam

In 1990, on the clay loam soil, yield was slightly higher than that in 1989. Adequate early season moisture led to moderate yields at the first and second harvests, but drought during the midsummer reduced regrowth and no third harvest was taken. Yield at the first harvest was increased by P application to 40 kg P ha^{-1} (Tables 5 and 6). At the second harvest, yield was again increased with

P application to 40 kg P ha^{-1}, but the yields were higher with banded rather than broadcast fertilization. Presumably, by the second harvest, drying of the soil surface and reaction of the phosphate with the soil to form less soluble reaction products was restricting uptake of the surface broadcast P and availability of the banded P was superior. Final total yield was increased by application of P to 40 kg ha^{-1}, but was not influenced by fertilizer placement. Response to P application tended to be greater where 25 kg K ha^{-1} was applied.

Table 6: Yield of alfalfa on the Newdale clay loam soil as influenced by method and rate of P and K fertilization (1990).

P	K	Placement	Harvest 1	Harvest 2	Harvest 3	Total
-kg ha^{-1}			----------kg ha-1----------			
0	0	Broadcast	2.4	1.4	.	3.8
0	0	Banded	2.1	1.5	.	3.6
0	25	Broadcast	1.6	1.0	.	2.6
0	25	Banded	2.3	1.5	.	3.7
0	50	Broadcast	2.3	1.3	.	3.6
0	50	Banded	2.3	1.6	.	3.9
20	0	Broadcast	2.4	1.6	.	4.1
20	0	Banded	2.6	2.1	.	4.8
20	25	Broadcast	2.5	2.0	.	4.4
20	25	Banded	2.5	2.0	.	4.5
20	50	Broadcast	2.6	1.8	.	4.4
20	50	Banded	2.9	2.1	.	5.1
40	0	Broadcast	3.2	2.2	.	5.3
40	0	Banded	2.7	2.2	.	4.7
40	25	Broadcast	3.6	2.4	.	6.1
40	25	Banded	3.1	2.3	.	5.4
40	50	Broadcast	3.2	2.2	.	5.4
40	50	Banded	2.5	2.0	.	4.5
80	0	Broadcast	2.8	1.9	.	4.8
80	0	Banded	2.9	2.3	.	5.2
80	25	Broadcast	3.5	2.2	.	5.7
80	25	Banded	3.5	2.7	.	6.2
80	50	Broadcast	3.6	2.4	.	6.0
80	50	Banded	3.1	2.3	.	5.4

1991 Crop Year

Marringhurst Sandy Loam

Although the season started off with poor soil moisture conditions, adequate and timely rainfall throughout the growing season led to high alfalfa yields in 1991, particularly on the Marringhurst soil (Table 7). In spite of the high yields, there was no response of yield to fertilizer application on the Marringhurst soil at the first harvest (Tables 7 and 8). As in the previous years, yield was reduced at the first harvest by the banding operation, so yield at the first harvest was higher when fertilizer was broadcast as compared to banded. At the second harvest, there was a slight

reduction in yield with application of low levels of P, but not when 80 kg P_2O_5 ha^{-1} was applied. The yield advantage of broadcast as compared to banded fertilizer applications was less at the second than the first harvest, indicating a recovery from damage due to banding. There was a K placement interaction, which reflected an increase in yield when K was broadcast but not when K was banded. At the third harvest, there was no response to fertilizer application or fertilizer placement. Total yield was not influenced significantly by fertilizer K application, but showed a quadratic response to P, being lower at 20 or 40 kg P_2O_5 ha^{-1}, than at 0 or 80 kg P_2O_5 ha^{-1}. Total yield was lower when fertilizer was banded than when no fertilizer was applied.

Newdale Clay Loam

On the Newdale clay loam site, soil moisture was low in the spring, but adequate rainfall led to production slightly higher than in 1990 (Table 9). Although insufficient growth occurred to take a third harvest, the stand had considerably more regrowth going into the winter in 1991 than in the previous years of the study. Yield at the first harvest was increased strongly by P application, with yield almost doubling with application of 80 kg P_2O_5 ha^{-1} as compared to treatments which did not receive P (3.21 versus 1.74 t ha^{-1}) (Tables 8 and 9). No response occurred to applications of K. At the second harvest, yield was higher when fertilizer was banded rather than broadcast, and the response to P application was high. Presumably, application of banded P was more available to the plant than the broadcast P later in the season, leading to higher yields where the P deficiency was great. However, the banding procedure itself apparently increased yield somewhat at the second harvest in 1991, since yield was higher with banding even where no fertilizer was applied. Total yield was increased 80% by P application and the highest yield was obtained when the fertilizer was banded.

1992 Crop Year

Marringhurst Sandy Loam

Growing conditions through the 1992 season were extremely cool. Moisture levels were slightly below normal, but evapotranspiration was also low, due to the low temperatures. Dry matter yield on the sandy loam soil was again quite high, but lower than in previous years, presumably due to natural aging of the stand (Table 10). No difference occurred among treatments in stand survival. Grass infestation was low and was reduced by application of K fertilizer (Table 11 and 12). Fertilizer applications and placements did not have a significant effect on dry matter yield (Table 10 and 12), although there was a tendency to increased yields at the first harvest and in total production with K application ($P<0.10$). The lack of damage from band application of fertilizer in 1992 may relate to the cool temperatures at the time of fertilization. Growth initiation from dormance was slow and the plants were less susceptible to damage than in warmer springs. There was a tendency towards slightly lower yield at the first harvest with P application ($P<0.10$), similar to that observed in the second

harvest of 1991. The reason for this is unknown.

Table 10: Yield of alfalfa on the Marringhurst sandy loam soil as influenced by method and rate of P and K fertilization (1992).

P	K	Placement	Harvest 1	Harvest 2	Harvest 3	Total
-kg ha^{-1}			---------- kg ha^{-1} ----------			
0	0	Broadcast	4.07	3.87	1.25	9.20
0	0	Banded	4.83	4.70	1.28	10.82
0	50	Broadcast	4.61	4.10	1.20	9.91
0	50	Banded	3.97	3.73	1.22	8.92
0	100	Broadcast	5.61	4.06	1.21	10.87
0	100	Banded	4.64	4.27	1.25	10.16
20	0	Broadcast	4.27	3.43	1.01	8.71
20	0	Banded	4.51	4.09	1.06	9.65
20	50	Broadcast	5.09	4.29	1.28	10.65
20	50	Banded	4.79	4.47	1.17	10.43
20	100	Broadcast	4.75	4.19	1.23	10.17
20	100	Banded	5.00	4.09	1.24	10.34
40	0	Broadcast	4.80	4.49	1.22	10.51
40	0	Banded	3.91	3.81	0.89	8.61
40	50	Broadcast	4.79	4.32	1.19	10.29
40	50	Banded	4.33	3.86	0.98	9.17
40	100	Broadcast	5.02	4.59	1.43	11.04
40	100	Banded	4.16	4.63	1.13	9.92
80	0	Broadcast	4.28	4.25	1.15	9.69
80	0	Banded	4.25	4.14	1.20	9.59
80	50	Broadcast	3.61	3.95	1.27	8.83
80	50	Banded	5.32	4.55	1.38	11.25
80	100	Broadcast	4.66	4.14	1.14	9.94
80	100	Banded	3.91	3.99	0.94	8.85

Newdale Clay Loam

The cool temperatures and moderate moisture experienced during the 1992 growing season led to the production of moderate yields on the Newdale soil (Table 13). Yields were similar to those attained in 1991. No differences occurred among treatments in stand survival. Grass infestation was low and, as on the Marringhurst soil, was reduced by K application (Table 11 and 12). Dry matter yield at both harvests and the total dry matter yield was strongly influenced by P fertilization (Table 12 and 13). Dry matter yield at the first harvest increased by approximately 50% with application of 20 kg P ha^{-1} with no further increase with additional P application. At the second harvest, dry matter yield increased by nearly 70% with application of 20 kg P ha^{-1}, and then increased by another 14% when level of P was increased to 80 kg ha^{-1}. Total dry matter yield was increased by 60% with 20 kg P ha^{-1} and by an additional 10% when P level was increased from 20 to 80 kg P ha^{-1}. Unlike previous years, dry matter yield was also increased by K application. Dry matter yield at the first harvest increased by 18% with application of 25 kg K ha^{-1} with no further increase with additional K. At the second harvest, yield increased by 10% with

application of 25 kg K ha^{-1}, with no further increase with additional K. There was a tendency towards an interaction between P and K at the first harvest and in total dry matter yield, with response to P or K being greatest when both nutrients were applied together. Total dry matter yield was increased by 13% with application of 25 Kg K ha^{-1}. Previous research with K fertilization on alfalfa carried out at Brandon on the Newdale soils shows similar results. That is, the Newdale soils appear to have an adequate supply of K to produce 2 to 3 years of alfalfa, but the supply is depleted with time and must be replaced with fertilizer K. Placement of fertilizer did not have any effect on dry matter yield at any harvest.

Table 11: Grass infestation in alfalfa stands, rated on a 0 to 5 scale where 0 = no grass and 5 = all grass, on the Marringhurst sandy loam and Newdale clay loam soils as influenced by method and rate of P and K fertilization (1992).

P -kg	K ha^{-1}	Placement	Marringhurst	Newdale
0	0	Broadcast	0.00	1.00
0	0	Banded	0.50	1.00
0	50	Broadcast	0.00	1.00
0	50	Banded	0.00	0.00
0	100	Broadcast	0.00	1.00
0	100	Banded	0.00	0.00
20	0	Broadcast	1.00	1.25
20	0	Banded	0.50	0.00
20	50	Broadcast	0.00	0.75
20	50	Banded	0.25	0.50
20	100	Broadcast	0.00	1.00
20	100	Banded	0.00	0.00
40	0	Broadcast	0.25	1.50
40	0	Banded	0.50	1.00
40	50	Broadcast	0.00	0.00
40	50	Banded	0.50	0.00
40	100	Broadcast	0.25	0.00
40	100	Banded	0.75	1.00
80	0	Broadcast	0.75	1.50
80	0	Banded	0.25	1.25
80	50	Broadcast	0.00	0.00
80	50	Banded	0.00	0.00
80	100	Broadcast	0.00	0.25
80	100	Banded	0.00	0.25

Table 13: Yield of alfalfa on the Newdale clay loam soil as influenced by method and rate of P and K fertilization (1992).

P	K	Placement	Harvest 1	Harvest 2	Harvest 3	Total
-kg ha^{-1}			----------kg ha-1----------			
0	0	Broadcast	1.70	1.56	.	3.26
0	0	Banded	1.27	1.62	.	2.89
0	25	Broadcast	1.28	1.35	.	2.63
0	25	Banded	1.30	1.74	.	3.04
0	50	Broadcast	1.44	1.72	.	3.16
0	50	Banded	1.49	1.64	.	3.13
20	0	Broadcast	1.82	2.60	.	4.42
20	0	Banded	1.96	2.72	.	4.67
20	25	Broadcast	2.15	2.60	.	4.76
20	25	Banded	2.24	2.88	.	5.12
20	50	Broadcast	2.01	2.44	.	4.45
20	50	Banded	2.47	3.01	.	5.48
40	0	Broadcast	1.83	2.79	.	4.62
40	0	Banded	2.19	2.66	.	4.85
40	25	Broadcast	2.53	3.25	.	5.77
40	25	Banded	2.31	3.07	.	5.38
40	50	Broadcast	2.31	2.92	.	5.23
40	50	Banded	1.68	2.65	.	4.32
80	0	Broadcast	1.70	2.65	.	4.25
80	0	Banded	1.78	2.95	.	4.73
80	25	Broadcast	2.27	3.24	.	5.52
80	25	Banded	2.71	3.35	.	6.06
80	50	Broadcast	2.67	3.53	.	6.20
80	50	Banded	2.02	2.83	.	4.85

Combined Yield - 1989-1992
Marringhurst sandy loam

When the data for the four years were combined, P did not significantly influence dry matter yield at any harvest or total dry matter yield on the sandy loam soil (Tables 14 and 15). Dry matter yield was increased by K applications, with the effect being greater at the later harvests than at the first harvest. However, total yield was only increased by approximately 4%, so the effect was not great and application of K fertilizer would be unlikely to produce an economic benefit on this soil.

Band application of fertilizer led to lower yields at harvest 1 than broadcast application in most years, due to damage to the stand. This soil tends to warm relatively quickly in the spring. Early initiation of growth from dormancy may have encouraged damage from the banding equipment, thus reducing yield. By the second harvest, there was no difference between placement techniques. There was a K by placement interaction, with response to K application being greater when the fertilizer was broadcast rather than banded. The stress of banding apparently reduced the ability

of the plants to respond to K application. Banding led to a 3.5% lower total dry matter yield as compared to broadcast application of fertilizer, which although statistically significant, was a small difference. As band applications are more costly than broadcast applications of fertilizer, on this soil where responses to fertilizer applications are small, broadcast application of fertilizer would be preferable to band application.

Newdale Clay Loam

Dry matter production on the Newdale soil showed a consistent and large response to P application (Tables 14 and 15). The response to P was greatest with the first increment of fertilizer, but yield increased with each application to 80 kg P ha^{-1} at each harvest and for the total dry matter yield production. Dry matter yield at the first harvest and total dry matter yield also increased with low levels of K application , but increasing the K level from 25 to 50 kg K^{-1} did not increase yield further. There was a P by K interaction, with highest yield occurring when both nutrients were provided.

Placement of fertilizer influenced yield at the second harvest in some years, with banded fertilizer producing a 6% higher yield than broadcast. Damage from banding to the stand was lower on the clay loam than the sandy loam soil and in some years the banding action seemed to be beneficial, apart from its effect on fertilizer efficiency. On this soil, which had a larger response to P application than did the sandy loam soil, the increased efficiency of fertilizer use with band placement translated into a higher yield by the second harvest, however the total yield over the growing season was not significantly higher with banded as compared to broadcast fertilization, being only 2% greater.

CONCLUSIONS

In the first three years, banding fertilizer disrupted the alfalfa stand in the Marringhurst sandy loam soil, which generally reduced yield in banded compared to broadcast fertilizer treatments at the first harvest. By the third harvest, differences were not significant. However, the total dry matter production over the season was still lower in the banded as compared to the broadcast treatments in 1989 and 1991. In 1990, the difference between placements was not significant, but K fertilizer response was greater where the K was broadcast rather than banded ($p<0.0557$). In 1992, placement did not influence yield, possibly because cool growing conditions early in the season limited plant activity and reduced stand damage. Over the four years of the study, broadcast fertilizer application was superior to band application on this soil.

In the Newdale clay loam soil, differences between banding and broadcast treatments were less than in the sandy loam soil and

banded applications showed a slight advantage at the second harvest, which was significant in both 1990 and 1991. In 1991, banded fertilizer applications promoted higher second harvest and total yields than broadcast applications. This was apparently due both to the effect of the increased fertilizer efficiency and a physical effect of the banding operation, since yields were slightly higher in the unfertilized treatment that had received a banding operation than in the undisturbed unfertilized treatment. Over the four years of the study, band application produced a 6% higher second harvest yield than broadcast application, but total yield was only 2% higher.

Although total yield was increased slightly on the Marringhurst sandy loam soil by the application of K in 1989 and 1990, in 1991 there was no response to fertilizer addition and in 1992, the effect was only significant at the $P<0.10$ level. Over the four years of the study, dry matter yield was increased with K application, particularly in the latter harvests. However, the increase was small and fertilization may not have been economically advisable. The high yield obtained on this site in the absence of applied fertilizers is noteworthy. In contrast, yield on the Newdale clay loam soil was increased substantially by the application of P in all years, although yield was low in comparison to that on the sandy loam.

Table 2. F values as calculated by general linear models analysis of effects for P and K fertilizer placement on dry matter yield of alfalfa at 3 harvests, on a Marringhurst sandy loam and Newdale clay loam (1989).

Source	DF	Marringhurst Sandy Loam				Newdale Clay Loam			
		Harvest 1	Harvest 2	Harvest 3	Total	Harvest 1	Harvest 2	Harvest 3	Total
P	1	0.04	0.02	0.23	0.04	0.0	6.93**	38.83****	11.71**
K	1	3.71	3.00	0.35	4.70*	0.93	1.57	3.54	2.68
P^2	1	0.95	1.16	0.60	1.77	0.56	0.11	2.82	1.15
K^2	1	0.76	4.48*	0.20	2.02	1.25	0.07	0.25	0.28
P x K	1	1.65	0.47	1.00	1.94	0.73	3.14	2.62	2.96
Placement	1	24.99****	0.28	2.41	5.23*	2.56	0.01	0.08	0.36
P x Placement	1	0.18	0.12	0.76	0.46	0.24	0.04	0.44	0.29
K x Placement	1	2.01	0.74	1.08	2.46	0.10	0.35	0.77	0.20
CV		15.19	12.77	15.33	10.37	26.66	23.67	26.18	20.88

1. *, **, **** P values of 0.05, 0.01 and 0.0001, respectively.

NOTE: Preliminary analysis was conducted and indicated highly significant differences due to harvest and site.

Table 5. F values as calculated by general linear models analysis of effects for P and K fertilizer placement on dry matter yield of alfalfa at 3 harvests, on a Marringhurst sandy loam and Newdale clay loam (1990).

		Marringhurst Sandy Loam				Newdale Clay Loam			
Source	DF	Harvest 1	Harvest 2	Harvest 3	Total	Harvest 1	Harvest 2	Harvest 3	Total
P	1	0.26	0.22	0.69	0.69	69.05****	117.78****	---	98.88****
K	1	0.37	0.20	6.20*	1.48	1.69	1.04	---	1.63
P^2	1	3.44	1.29	0.04	1.71	8.46**	36.74****	---	19.41****
K^2	1	0.10	0.04	3.60	1.47	0.54	1.73	---	1.05
P x K	1	0.41	0.02	0.10	0.11	1.51	1.72	---	1.83
Placement	1	7.82**	0.53	0.43	1.50	0.90	8.20**	---	0.30
P x Placement	1	0.33	0.02	0.15	0.24	1.98	0.44	---	1.45
K x Placement	1	3.89	0.66	0.69	0.65	0.13	1.19	---	0.46
CV		8.53	14.40	29.70	9.67	16.62	14.36	---	14.63

1. *, **, **** P values of 0.05, 0.01 and 0.0001, respectively.

NOTE: Preliminary analysis was conducted and indicated highly significant differences due to harvest and site.

le 7. Yield of alfalfa on the Marringhurst sandy loam soil as influenced by method and rate of P and K fertilization (1991).

P	K	Placement	Harvest 1	Harvest 2	Harvest 3	Total
kg ha^{-1}			t ha^{-1}			
0	0	Broadcast	6.00	3.32	2.65	11.97
0	0	Knifed	5.61	3.31	2.80	11.71
0	50	Broadcast	5.83	3.26	3.06	12.15
0	50	Knifed	5.59	3.50	2.65	11.74
0	100	Broadcast	6.14	3.67	2.60	12.41
0	100	Knifed	5.51	3.28	3.31	12.10
20	0	Broadcast	5.74	2.80	2.34	10.89
20	0	Knifed	5.78	3.05	3.10	11.93
20	50	Broadcast	5.99	3.11	2.97	12.08
20	50	Knifed	5.77	2.84	2.90	11.51
20	100	Broadcast	5.96	3.54	2.91	12.41
20	100	Knifed	5.67	3.27	2.79	11.73
40	0	Broadcast	5.86	3.15	2.82	11.84
40	0	Knifed	5.55	3.14	2.49	11.19
40	50	Broadcast	6.10	3.35	2.49	11.93
40	50	Knifed	5.26	2.82	2.72	10.81
40	100	Broadcast	6.24	3.39	2.98	12.61
40	100	Knifed	5.30	3.02	2.75	11.07
80	0	Broadcast	6.15	3.31	2.80	12.25
80	0	Knifed	5.53	3.23	3.10	11.86
80	50	Broadcast	6.04	3.37	2.76	12.17
80	50	Knifed	5.78	3.13	3.03	11.94
80	100	Broadcast	5.94	3.31	3.12	12.36
80	100	Knifed	5.57	3.07	2.89	11.54

Table 8. F values as calculated by general linear models analysis of effects for P and K fertilizer placement on dry matter yield of alfalfa at 3 harvests, on a Marringhurst sandy loam and Newdale clay loam (1991).

Source	DF	Marringhurst Sandy Loam				Newdale Clay Loam			
		Harvest 1	Harvest 2	Harvest 3	Total	Harvest 1	Harvest 2	Harvest 3	Total
P	1	0.08	0.81	0.60	0.04	120.45****	195.21****	---	175.65****
K	1	0.01	3.18	1.94	2.32	2.70	0.09	---	1.62
P^2	1	0.26	7.02**	2.13	4.52*	33.92****	91.25****	---	62.16****
K^2	1	0.01	0.80	0.04	0.17	0.42	0.08	---	0.32
P x K	1	0.14	2.44	0.24	1.20	3.13	1.46	---	2.96
Placement	1	20.88****	4.94*	0.88	8.16**	0.02	26.39****	---	4.64*
P x Placement	1	0.21	0.61	0.09	0.52	0.20	0.05	---	0.16
K x Placement	1	1.10	4.07*	0.72	3.36	2.60	0.23	---	2.59
CV		7.83	10.79	15.76	7.17	16.34	11.44	---	12.87

1. *, **, **** P values of 0.05, 0.01 and 0.0001, respectively.

NOTE: Preliminary analysis was conducted and indicated highly significant differences due to harvest and site.

Table 9. Yield of alfalfa on the Newdale clay loam soil as influenced by method and rate of P and K fertilization (1991).

P	K	Placement	Harvest 1	Harvest 2	Harvest 3	Total
kg ha^{-1}			t ha^{-1}			
0	0	Broadcast	1.77	1.42	--	3.19
0	0	Knifed	1.86	1.61	--	3.47
0	25	Broadcast	1.39	1.10	--	2.49
0	25	Knifed	1.83	1.60	--	3.43
0	50	Broadcast	1.88	1.27	--	3.15
0	50	Knifed	1.70	1.67	--	3.37
20	0	Broadcast	2.71	2.04	--	4.75
20	0	Knifed	2.72	2.41	--	5.13
20	25	Broadcast	2.61	2.10	--	4.71
20	25	Knifed	2.70	2.37	--	5.07
20	50	Broadcast	2.74	2.06	--	4.80
20	50	Knifed	2.92	2.25	--	5.17
40	0	Broadcast	2.78	2.32	--	5.10
40	0	Knifed	2.79	2.48	--	5.27
40	25	Broadcast	3.34	2.45	--	5.79
40	25	Knifed	3.06	2.72	--	5.78
40	50	Broadcast	3.67	2.58	--	5.64
40	50	Knifed	2.74	2.32	--	5.06
80	0	Broadcast	2.62	2.24	--	4.86
80	0	Knifed	3.17	2.65	--	5.82
80	25	Broadcast	3.35	2.30	--	5.65
80	25	Knifed	3.34	2.71	--	6.05
80	50	Broadcast	3.61	2.48	--	6.09
80	50	Knifed	3.19	2.68	--	5.87

Table 12. F values as calculated by general linear models analysis of effects for P and K fertilizer and fertilizer placement on grass infestation and dry matter yield of alfalfa at 3 harvests, on a Marringhurst sandy loam and Newdale clay loam (1992).

		Marringhurst Sandy Loam					Newdale Clay Loam				
Source	DF	Grass	Harvest 1	Harvest 2	Harvest 3	Total	Grass	Harvest 1	Harvest 2	Harvest 3	Total
P	1	0.09	2.40	0.27	0.25	0.73	0.14	31.21****	147.76****	--	94.61****
K	1	5.73*	3.07^{+}	1.24	0.83	3.01^{+}	5.49*	4.82*	2.34	--	4.36*
P^2	1	3.57^{+}	0.19	0.47	1.21	0.10	0.02	19.81****	54.52****	--	42.51****
K^2	1	2.67	0.01	0.01	0.57	0.04	4.12*	5.02*	4.16*	--	5.69*
P x K	1	0.01	1.43	0.10	0.71	1.10	1.23	3.38^{+}	1.31	--	2.80^{+}
Placement	1	0.51	0.97	0.26	1.48	0.44	2.64	0.08	0.23	--	0.01
P x Placement	1	0.52	0.98	0.41	0.20	0.07	1.63	0.05	2.41	--	0.91
K x Placement	1	0.43	2.20	0.40	0.19	1.62	0.22	1.20	1.14	--	1.45
Grass	1	--	10.15**	1.07	3.64^{+}	7.88**	--	19.37****	8.18**	--	16.59****
CV		250.60	17.79	12.79	23.59	13.18	179.72	21.34	15.05	--	15.97

L. $^{+,*,**,***,****}$ P values of 0.10, 0.05, 0.01 and 0.0001, respectively.

NOTE: Preliminary analysis was conducted and indicated highly significant differences due to harvest and site.

Table 14. F values as calculated by general linear models analysis of effects for P and K fertilizer placement on dry matter yield of alfalfa at 3 harvests over 4 years, on a Marringhurst sandy loam and Newdale clay loam.

		Marringhurst Sandy Loam				Newdale Clay Loam			
Source	DF	Harvest 1	Harvest 2	Harvest 3	Total	Harvest 1	Harvest 2	Harvest 3[2]	Total
P	1	0.31	0.01	0.94	0.00	158.61****	275.79****	---	263.51****
K	1	3.79^{+1}	6.12*	8.12**	10.21**	3.92*	2.71	---	6.22*
P^2	1	1.06	3.08^{+}	1.90	3.76^{+}	49.70****	104.09****	---	85.17****
K^2	1	0.47	1.05	1.25	1.49	5.33*	1.62	---	3.53^{+}
P x K	1	3.05^{+}	1.12	1.40	3.41^{+}	7.60**	5.09*	---	8.73**
Placement	1	32.93****	0.03	0.15	10.52**	1.91	7.32**	---	0.35
P x Placement	1	0.25	0.21	0.02	0.01	0.94	2.32	---	2.05
K x Placement	1	6.84**	3.78^{+}	0.31	6.47*	0.43	2.60	---	2.00
Year	3	54.13****	216.42****	298.05****	106.61****	282.16****	216.61****	---	61.95****
P x Year	3	1.08	0.03	0.36	0.51	26.67	22.81***	---	12.64****
K x Year	3	1.72	0.48	1.39	0.43	0.41	0.70	---	0.32
Placement x Year	3	3.86**	1.16	1.36	0.72	0.32	2.92*	---	1.09
CV		13.48	12.96	20.41	10.47	20.13	16.67	---	16.39

[1] $^{+}$, *, **, **** P values of 0.10, 0.05 and 0.01 and 0.0001, respectively.
[2] A third harvest was only taken on the Newdale soil in year 1, so the third harvest was eliminated from the combined analysis.

Table 15. Dry matter of alfalfa on a Marringhurst sandy loam and a Newdale clay loam soil as influenced by P and K level and placement over 3 harvests and 4 years.

			Marringhurst Sandy Loam				Newdale Clay Loam			
P	K	Placement	Harvest 1	Harvest 2	Harvest 3	Total	Harvest 1	Harvest 2	Harvest 3[1]	Total
			t ha^{-1}							
0	0[2]	Broadcast	5.14	3.82	1.95	10.98	1.70	1.44	--	3.39
0	0	Banded	5.06	4.12	1.92	11.10	1.48	1.52	--	3.21
0	50	Broadcast	5.22	3.94	2.15	11.31	1.31	1.13	--	2.57
0	50	Banded	4.77	3.88	1.99	10.64	1.43	1.55	--	3.28
0	100	Broadcast	5.73	4.05	1.93	11.71	1.64	1.42	--	3.30
0	100	Banded	4.92	3.98	2.24	11.14	1.44	1.48	--	3.18
20	0	Broadcast	4.81	3.32	1.71	9.84	2.04	1.91	--	4.21
20	0	Banded	4.80	3.78	2.11	10.69	2.01	2.14	--	4.41
20	50	Broadcast	5.60	3.97	2.11	11.68	2.10	1.99	--	4.38
20	50	Banded	5.07	4.11	2.03	11.21	2.03	2.12	--	4.37
20	100	Broadcast	5.31	4.02	2.14	11.46	1.88	1.95	--	4.12
20	100	Banded	5.03	3.91	2.16	11.10	2.38	2.22	--	4.91
40	0	Broadcast	5.07	3.92	1.90	10.89	2.19	2.18	--	4.62
40	0	Banded	4.81	3.70	1.85	10.36	2.08	2.16	--	4.60
40	50	Broadcast	5.38	4.04	2.09	11.50	2.54	2.46	--	5.39
40	50	Banded	4.57	3.53	1.87	9.97	2.45	2.35	--	5.12
40	100	Broadcast	5.50	4.02	2.17	11.69	2.29	2.29	--	4.95
40	100	Banded	4.76	3.99	1.95	10.70	1.84	2.04	--	4.21
80	0	Broadcast	5.27	3.84	2.04	11.15	2.03	2.06	--	4.36
80	0	Banded	4.94	3.97	2.07	10.98	2.10	2.28	--	4.72
80	50	Broadcast	5.12	3.97	2.06	11.15	2.53	2.33	--	5.22
80	50	Banded	5.24	4.12	2.25	11.61	2.57	2.54	--	5.47
80	100	Broadcast	5.31	3.92	2.08	11.31	2.70	2.51	--	5.64
80	100	Banded	4.67	3.83	2.08	10.58	2.24	2.34	--	4.96

[1] A third harvest was possible on the Newdale soil in only 1 year, so the third harvest was eliminated from the combined analysis.
[2] K levels on the Newdale soil were 0, 25 and 50 kg ha^{-1} rather than 0, 50 and 100 kg ha^{-1}.