2004 Progress Report for Research Project
Missouri Fertilizer and Lime Council

Title: Effect of Potassium Fertilization on Leafhopper Tolerance and Persistence of Alfalfa

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Objectives:

1. Determine effect of K-fertilization on leafhopper tolerance.
2. Measure effect of glandular hairs on leafhopper tolerance.
3. Evaluate interaction of K-fertilization and glandular hairs on alfalfa persistence.

Background for Research:

Potato leafhopper is likely the most serious pest of alfalfa in Missouri, costing alfalfa producers more than $1 million per year due to costs for control treatments and losses of production and quality when not controlled. Alfalfa weevil, another major alfalfa pest, is more predictable, with damage limited largely to the first harvest, and with clearly visible symptoms. In contrast, potato leafhoppers are small (Fig. 1), infestations are less predictable, and scouting with a sweep net is needed to determine threshold levels for treatment. The typical symptoms of leaf yellowing and stunted growth appear after the damage is done and insecticide treatments after visible symptoms appear are ineffective. Thus, preventive measures, such as selection of a glandular-haired variety, using good soil fertility practices (especially K) to maintain stand health, and using IPM methodologies for detection and early control of potato leafhopper can be effective and provide economic alternatives to routine scheduled sprays.

Our goal has been to evaluate effects of glandular hairs on new alfalfa varieties and rates of K fertilization on populations of potato leafhopper and stand persistence. The experiment is being conducted at the Forage Systems Research Center near Linneus in North Central Missouri. Soil is Lagonda silt loam that slopes to an Armstrong silty clay loam. The site was selected in 2000 based on 1998 soil tests. Lime and P were applied according to soil-test recommendations. Our first two seeding attempts (fall, 2000 and spring, 2001) did not give stands that were uniform enough for the project, so the area was tilled and reseeded in fall, 2001. That stand was excellent. We retested the soil in October, 2001, and topdressed the plot area with 400 lbs of 0-46-0 to increase seedling vigor and develop good ground cover to enhance survival over winter.

Eight blocks (four replicates of two alfalfa varieties) of 2 acres each were established. One variety (normal) has smooth stems and leaves (PLH susceptible) whereas the other variety (PLH resistant) has glandular hairs that deter infestation and feeding by potato leafhoppers (Figure 1). Sub-plots were 1) no insecticide (control), 2) insecticide applied when the leafhopper population reached economic threshold (IPM standard), and 3) insecticide applied to the regrowth 7 days and 21 days after harvests 1 and 2 (scheduled spray). Insect treatments were subdivided into K treatments of 0, 125, and 250 lbs/acre annually, half applied after the harvest 1 and half applied after harvest 4 in mid-September. After the experiment began, all plots received annual applications of P (75 lbs/acre) after harvest 4. We initiated the experiment with the insect and K treatments beginning after harvest 1 in 2002. Data were collected in 2002, 2003 and 2004.

Changes in Soil Test for K

Soil K levels were moderate when the experiment began, and the pH of 6.7 was in the optimum range for alfalfa. Soil test K has gradually decreased in the 0-K treatment (Table 1) and to a lesser extent in the 125-K treatment. The 250-K treatment is maintaining the soil test value with yields of about 5.5 tons/acre annually (Table 2), which would be consistent with a removal rate of about 50 lbs K/ton of forage. Thus, the K-tests are decreasing, especially at the low application rates (Table 1). This is desired for our research as our hypothesis is that plants at low-K levels will be less resistant to the potato leafhopper.

We plan to take samples for soil tests again after harvest 1 in 2005. Our expectation is the soil tests for K will continue to decrease, especially at the lower fertilization rates as the productive stand uses more K annually than is applied. In addition, we propose to take some tissue samples for K analysis during times when leafhoppers are in the stand. Our hypothesis is that tissue-K may be more important than soil-test K for conferring resistance to the potato leafhopper. The upper third of the canopy will be sampled midway in growths that constitute harvest 2 and harvest 3 because these growths are commonly attacked.

Leafhopper Populations

Leafhoppers typically arrive in Missouri about May 5 in winds from the southwest and lay eggs that develop into a damaging population of nymphs. The life cycle in Missouri is such that leafhopper populations rarely reach economic levels prior to harvest 1 (Figure 2). Generally, few leafhoppers are found during regrowth after harvest 3, and this has also been the case in our research. We counted both the adults and the nymphs (immature, non-mobile stage), and in all three years the adult component was much greater than the nymph component.

After harvest 1, the population of leafhoppers increased rapidly during early to mid-June each year. In 2002, the PLH-resistant variety in the no-spray treatment (control) had 30% fewer leafhoppers than did the normal variety. However, 2003 both varieties had nearly the same potato leafhopper populations as the infestation built rapidly in early June. The very rapid increase in 2003 was unexpected, especially for the glandular-haired variety, and even the scheduled spray treatment did not keep the population in check (compare treatments for 2003 in Figure 2). After increasing rapidly, leafhopper populations declined in the PLH-resistant variety suggesting some control while they continued to increase in the normal variety. Except for this period, the scheduled spray treatment did an excellent job of control between harvests in all years. Some oscillations occurred in the leafhopper populations, mainly due to weather events.

Leafhopper populations exceeded the IPM thresholds in 2002 and 2003, but not in 2004 (Figure 2). In 2002, the normal variety reached the economic threshold only 7 days after harvest 1. Yield of harvest 2 was 0.67 tons/acre for the normal variety with no spray compared with 0.88 tons/acre for the PLH-resistant variety with no spray, showing the value of the glandular hairs. In harvest 3 of 2002 the leafhopper population in the control treatment developed slower, did not reach the same level, and did not affect alfalfa yield (both treatments yielded 0.87 tons/acre).

In 2002 and 2003, except for the harvest 3 of 2003 when the economic threshold was not reached, a single insecticide application in the IPM treatment controlled the leafhoppers until the next harvest date. In 2004, with the unique weather patterns, the leafhopper populations did not reach economic threshold in any harvest. Even so, the populations in the PLH resistant variety were about 55-75% those in the normal variety, again showing the resistance even at low populations. Therefore, over the 3-year period, the scheduled spray treatment required 12 sprays whereas only three were needed when treatment was based on scouting and IPM thresholds.

The K fertilization treatment did not affect leafhopper populations in 2002. On June 18, 2003, however, there were about 20% more adults in the high K treatment than the control, but the K treatments of 125 and 250 lb/acre had significantly fewer nymphs, the most damaging form (data not shown). On July 17, 2003 there were again significantly fewer nymphs on the 250 lb/acre K treatment than on the 0 and 125 lb/acre K treatments. The trend was not as consistent in 2004 with the lower populations of both adults and nymphs. In 2004, however, we noted that the proportion of nymphs was highest (27-37% of total leafhoppers) one week after harvest 1 or harvest 2, after which the proportion decreased to less than 5% at 2 week before increasing again to 7-11% at 3 weeks and to about 25% at 4 weeks. The change was consistent for each regrowth and was largely due to oscillations in the adult population as the nymph populations were relatively stable. These data are preliminary and we expect more definitive results in the future as differentials in K treatments broaden.

Alfalfa Yields

Insect treatments did not affect yield in 2002, 2003, or 2004 except for the variety difference in the control treatment at harvest 2 of 2002, harvest 3 of 2003, and harvest 4 of 2004 (Table 3). In all years, the yields of the two varieties were similar in harvest 1 as potato leafhopper infestations were very low or absent. Thus, the glandular-haired character is always effective, but advantageous only when insect populations are at or exceed the established thresholds. These resistance responses have caused Extension agents in some other states to increase the economic threshold populations for glandular-haired varieties by three times (or more) compared with that for normal varieties. Our data can not be used to verify those suggestions.

Alfalfa yields were not affected by K fertilization rate in 2002 (Table 3), mainly because the treatments were initially applied after harvest 1, and only half the K was applied. The differential in K did not have a major influence on yield during the lower yielding periods of summer, 2002, even though that is the time when potato leafhopper damage is most likely. The rest of the K was applied after harvest 4.

Effects of K rates on yield became apparent in 2003, mainly in harvest 2 when populations of potato leafhopper increased rapidly regardless of insecticide treatment. Total yields in 2003 for K rates of 125 and 250 lbs/acre were higher than the control ($p<0.06$). In 2004, the trend continued with the 125 and 250 lb K-treatments yielding more than the 0-K control, with total annual yield being about 0.65 tons/acre higher. This suggests that the K treatments are beginning to separate, high K removal will continue to decrease the soil-test K and may affect the tissue-K level and the leafhopper tolerance of the plants.

Changes in Plant Density

Stands of both varieties were good in early June, 2002, when plant density was counted after harvest 1 (Table 2). The K and leafhopper treatments had not begun so there was no effect on plant density due to K or insect control. We did note, however, that plant density of the PLH-resistant variety was about 30% higher than the normal variety. The seed of the normal variety was coated (adding 30% in weight) so the pure live seed planted per unit of “seed” weight was also lower. One advertised advantage of coating is that germination and seedling survival are improved, so the same seeding rate, based on seed weight, should have given a similar stand. That did not occur here, and the perceived value of the seed coating was not realized. This result should be tested further under Missouri conditions.

Plant density was determined again after harvest 4 in 2002 and after harvests 1 and 4 in 2003 and 2004 (Table 2). The plant density for all treatments gradually decreased with time, but the change was not affected by the insect management strategy. As the stands lost plants, the PLH-resistant variety continued to maintain its advantage of higher plant density over the normal variety, and the high-K treatment retained its initial advantage over the control (due to natural effects of field variation despite plot randomization). This is consistent with earlier seeding rate studies. Based on earlier studies we do not expect reductions in forage yield due to low plant density until the stand has fewer than four plants/sq ft. Yield is maintained because the remaining plants with high K have sufficient capacity to produce and elongate additional stems from the crown to offset the loss of nearby plants and to maintain a high number of stems/sq ft.

As the stands thin with time, i.e., plants/sq ft decrease, the number of stems/plant that contributes to yield at a given harvest will increase. This is evident from the first harvest in 2002 when plant density was high for both varieties, and number of stems/plant was inversely related to plant density, averaging 2.4 stems/plant for the PLH-resistant variety and 2.9 stems/plant for the normal variety. As the stands thinned the stems/plant gradually increased. We expect the stems/plant to show a K effect as stands thin, especially as it approaches four plants/sq ft. The effect of the leafhopper treatments may be accentuated at that time as the plants will be less vigorous and more stressed. A goal is to continue to follow the stand reduction for a longer time.

Similar to the May count in 2002, despite the continued thinning of the stand plant densities after harvests 1 and 4 in 2003 and again in 2004 did not differ due to the K or leafhopper treatments. But the PLH-resistant variety, which began with about 30% more plants/sq ft than the normal variety, thinned at a faster rate such that densities were similar for the varieties in 2004. This was expected as plant competition is stronger with more plants. We counted stems/plant allowing us to calculate stems/sq ft (data not shown). Despite the 30% lower plant density, by mid-September the crowns of the normal variety had expanded to have only 8% fewer stems/sq ft, mainly because the lower plant density was offset by having 23% more stems/plant (Table 2). In other studies we found that alfalfa plants in stands with low densities tend to develop larger crowns and support more stems. We calculated the weight (yield) per stem using yield data for the harvest just prior to the plant and stem counts. The yield enhancement that was showing up in 2004 due to maintaining a high K soil test was due almost exclusively to greater weight per stem. This response may be due to more rapid regrowth allowing the canopy to capture more of the radiation early in the regrowth period.

We expected little effect on plant density due to K fertilization or leafhopper control this early in the experiment because the young plants are vigorous and are thinning mainly due to plant competition for light. This is also indicated by the rapid loss of plants during the summer period, when plant to plant competition for light, minerals and water is strong. We expect stems/sq ft to remain stable for both varieties until plant density is reduced to about four plants per sq ft. Thereafter, the reduced ability of the crown to spread with low K will not completely offset the continued plant loss, resulting in a gradual yield decrease. Thus, as stands thin, the ability of the crown to spread or compensate for plant loss will be compromised by low K and the detrimental effects from leafhoppers will be more evident.

Objectives for Year 4 (2005):

The 3-years of funding for this project expired at the end of 2004, but we have requested an extension. The objectives are to continue the experiment, but add some more to the data collection as the stands thin. It is anticipated the K effect will be expressed even more dramatically if leafhopper populations are high, so we will continue to monitor alfalfa weevil and especially potato leafhopper throughout the growing season to get more years of data for evaluating year-to-year effects. The control, IPM and scheduled spray treatments will be maintained. Forage yield will be measured. We will use the sod cutter to lift alfalfa plants from the soil for accurate counting after harvests 1 and 4. As before, stems/plant will also be counted.

We will take soil samples each year after harvest 1 to continue to monitor the soil-test K levels and any other nutrients that may be changing. We will also take tissue samples from the upper third of the canopy about midway through the regrowth periods that contribute to harvests 2 and 3. Our expectation is that tissue-K at low-K application rates may decrease faster with time than will the soil test and yield response. The tissue-K is likely more closely associated with leafhopper resistance than is soil-K. The University Soil Test lab has a new instrument for accurately measuring minerals in plant tissues.

Other funds were used in 2001 to establish the stand. We knew we it would take 3 years (2002, 2003, and 2004) to get good base data on responses, but that the stands would likely last longer. So far the stands have begun to thin, but are still above threshold population of 3-4 plants/sq ft for yield responses. The K will help sustain the stand by enhancing crown development. We hope to continue this integrated experiment beyond 2004 as it is contributing to our knowledge of the insect and how interactions of crop management strategies affect an important pest in an environmentally friendly way.

Summary of Findings to Date

1. Potato leafhoppers apparently migrate to Missouri too late to build populations that cause a yield loss prior to harvest 1 that occurs in mid-to late May. Similarly, the populations are low or non-existent after harvest 3 (about August 5) in a 4-cut system. Thus, major concerns are with the growths following harvests 1 and 2.

2. The leafhopper populations on the alfalfa variety with glandular hairs were consistently 25 to 45% lower than for the control cultivar. The effects were similar for the adult and the nymph forms of the leafhopper.

3. In our Missouri studies, the leafhopper population consisted mainly of adults, which contrasts other states where the main stage is nymphs. We have no explanation for this observation, but adults are generally regarded as being less damaging than nymphs to alfalfa plants.

4. During the first 3 years of the experiment, the rate of K fertilization has not altered the leafhopper populations in either variety.

5. Alfalfa yields did not respond to K fertilizer until the soil-test K had decreased to 133 lbs/acre. The

primary component affected by K was weight or yield per stem. This is similar to our earlier research, in which a transition occurred when the stand thinned to fewer than 4 plants/sq.ft. With the thinner stand, high K rates stimulated crown activity so when a plant died the adjacent plants developed more stems/plant to maintain the threshold number of stems/sq ft. Maintaining the high number of stems/sq ft helps minimize weed invasion and associated competition that further weakens thin stands when K is low.

6. In this study the PLH resistant variety began with more plants/sq ft because, without coating, the effective seeding rate was higher. But the plant density decreased for both varieties, especially the PLH resistant one due to more plant-to-plant competition. Plant density of the varieties decreased at different rates (due to competition) and after 3 production years both varieties had similar densities. We expect the two will remain similar as they continue to thin until they reach a density of about 4 plants/sq ft, after which the variety in which crown development responds best to K may thin slower, very likely the PLH-resistant one as leafhoppers will cause less stress to those plants allowing them to spread the crown.

7. It is important to dig roots of alfalfa for counting as often 2, 3, and sometimes 4 plants will coexist as one (see 2003 report). The way the “clump” thins is important to understand, i.e., do all plants in a clump die at the same time? Or, do stronger plants persist until only one is left? Unfortunately, the current experiment is not designed to give that answer.

8. In this study, like others, the plant density gradually declines as the stand ages. In our case, a similar number of plants disappeared during summer as during winter, i.e., between May and September and between September and May, respectively. Summer death is likely due to stresses of diseases, insects and severe competition among plants. Winter death is likely due to diseases, winter kill, and some plant heaving, but the latter two were minimized by taking harvest 4 before September 15, allowing a tall stubble to be maintained over winter to help moderate soil temperature changes. Effects of leafhopper control and K fertilization will become more evident as the stand thins.

Figure 1. Electron micrographs of a potato leafhopper (left) and of glandular hairs on an alfalfa leaf (right). The hairs are multi-cellular extensions of epidermal cells, and can be upright or flat. The upright hairs are the more effective than flat hairs in conferring resistance. The sticky exudates from the hair ends and the physical structure of the upright hairs are deterrents to egg laying and feeding by the leafhoppers. Some nymphs can actually be entrapped by the sticky hairs.

Table 1. Soil test results from samples taken at different times prior to and during the experimental period. Plots were established in fall, 2001. Samples were taken to 6 inches.

Sampling Date	Sampled Area	Remarks	K	pH	P
			lb/a		lb/a
July 14, 1998	Field	Prepare for establishment	192	6.0	22
April 26, 2002	Field	Before insect and K started	184	6.7	63
May 28, 2003	0 – K plots	K treatments in 2003 and and 2004 were applied after harvest 1	142	6.4	45
	125 – K plots		145	6.5	54
	250 – K plots		147	6.5	55
June 7, 2004	0 – K plots		108	6.4	65
	125 – K plots		133	6.5	74
	250 – K plots		154	6.3	67

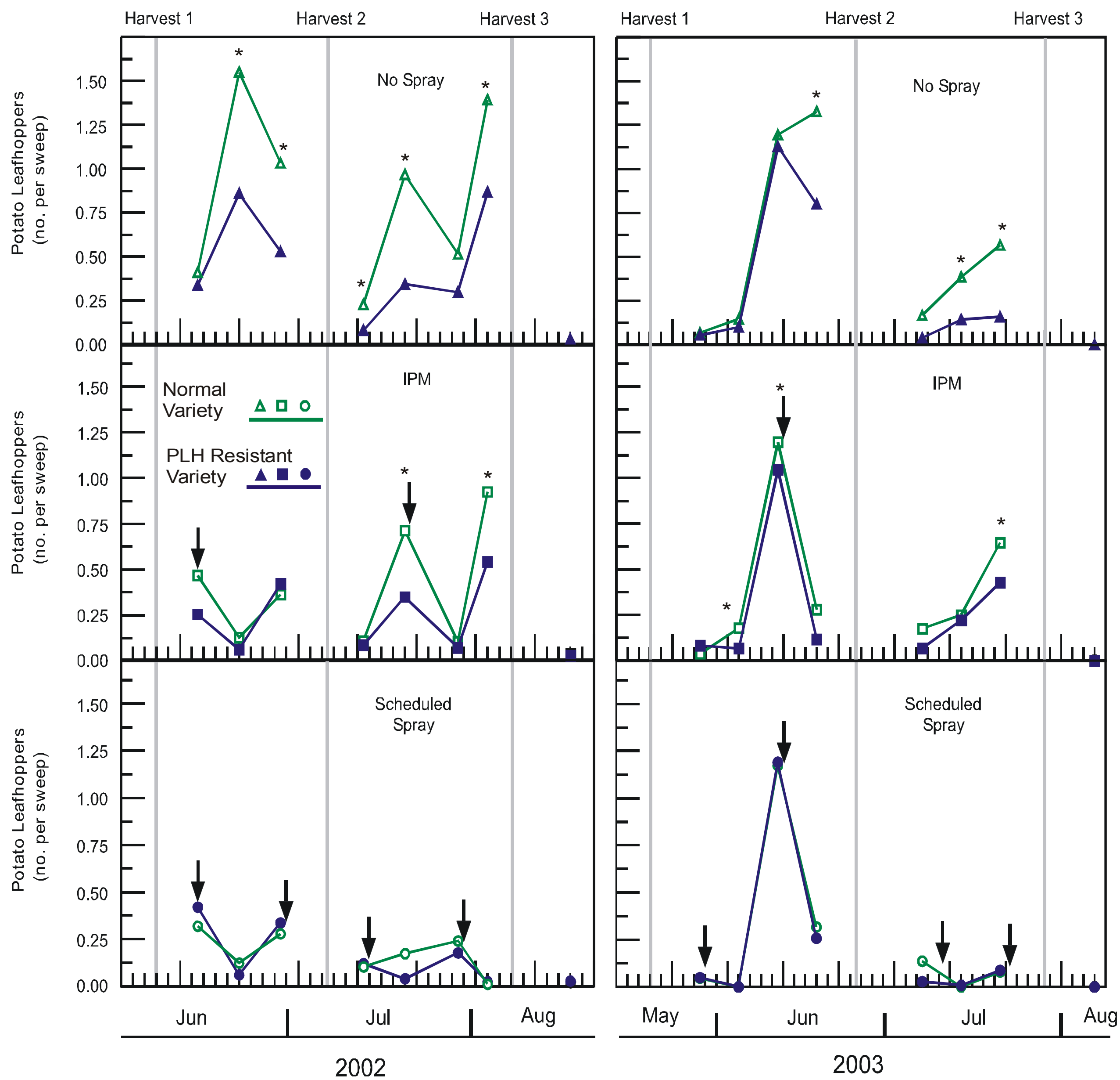

Figure 2. Top panel shows populations of potato leafhopper between harvest dates in the no-spray treatment (control). Note the relative control provided by the PLH-resistant variety compared with the normal variety. Middle panel shows the populations in the spray treatment based on IPM, with dates of needed sprays indicated by arrows. Note the excellent control after the spray. The lower panel shows the populations in the scheduled spray treatment with the arrows showing spray dates scheduled 7 and 21 days after harvests 1 and 2. Leafhoppers were not found previous to harvest 1 and only a few were detected after harvest 3. Asterisks (*) indicate dates when populations are significantly different ($p<0.05$) between varieties.

Leafhopper populations are not shown for 2004 because they did not reach threshold levels during any growth period. Similar to other years very few leafhoppers were detected in 2004 prior to harvest 1 and after harvest 3.

Table 2. Effects of potato leafhopper control treatments, potassium fertilization rates, and varieties (PLH-resistant vs. normal) on plant density and stems/plant on several dates in 2002, 2003 and 2004.

Summary of	Plant Density						Stems/plant				
treatments	6-02	9-02	5-03	9-03	5-04	9-04	9-02	5-03	9-03	5-04	9-04
	----------------------no./sq. ft. -------------------------------						-------------------------------no. ----------------------				
Insect control											
No spray	20.3	18.9	18.9	11.3	10.2	9.8	2.7	3.4	6.7	4.1	3.8
IPM spray	18.3	18.6	16.3	11.7	11.8	10.6	2.6	3.1	6.7	3.7	3.7
Scheduled	18.7	17.9	15.0	11.0	11.7	10.2	2.7	3.1	6.6	3.7	3.8
Pr > F*	0.56	0.66	0.64	0.59	0.22	0.35	0.28	0.55	0.88	0.27	0.60
LSD (0.05)**	NS***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
K treatment											
0 lbs/acre	18.2	17.8	15.1	10.9	11.0	10.0	2.8	3.2	6.8	4.0	3.8
125 lbs/acre	18.5	18.4	14.5	10.8	11.0	10.1	2.7	3.3	6.8	3.8	3.8
250 lbs/acre	20.7	19.1	16.7	12.3	11.7	10.5	2.5	3.1	6.4	3.7	3.7
Pr > F	0.18	0.58	0.10	0.02	0.81	0.60	0.12	0.49	0.46	0.66	0.73
LSD (0.05)	NS	NS	NS	1.1	NS	NS	NS	NS	NS	NS	NS
Variety											
PLH resistant	22.3	21.0	17.7	12.6	11.8	10.2	2.4	3.0	6.0	3.7	3.6
Normal	15.9	15.9	13.1	10.0	10.7	10.2	2.9	3.4	7.4	4.0	3.9
Pr > F	0.01	0.01	0.01	0.01	0.09	0.93	0.01	0.01	0.01	0.16	0.05
LSD (0.05)	2.3	1.8	1.4	0.9	NS	NS	0.2	0.3	0.6	NS	0.3

* Probability values of 0.05 or lower indicate the treatment means are significantly different
** LSD indicates the difference among means that is needed to be statistically different
*** NS = not significant

Table 3. Effects of potato leafhopper control treatments, potassium fertilization rates, and varieties (PLH-resistant vs. normal) on yield of alfalfa at each of four harvests in 2002, 2003 and 2004. Harvest dates and total annual yields are also shown.

	2002					2003					2004				
Summary of treatments	H-1 6-10	H-2 7-08	H-3 8-09	H-4 9-10	Total Yield	H-1 5-19	H-2 6-25	H-3 7-29	H-4 9-11	Total Yield	H-1 5-17	H-2 6-22	H-3 7-26	H-4 9-16	Total Yield
								------tons / acre--							
Insect treatment															
No spray	2.52	0.77	0.87	0.96	5.12	1.92	1.81	0.42	0.36	4.51	2.53	1.63	1.49	1.02	6.67
IPM spray	2.46	0.84	0.84	0.93	5.07	1.89	1.74	0.41	0.36	4.40	2.48	1.55	1.45	0.98	6.46
Scheduled spray	2.67	0.79	0.87	0.92	5.24	1.95	1.81	0.45	0.34	4.55	2.50	1.52	1.45	1.08	6.56
Pr>F*	0.65	0.29	0.22	0.45	0.81	0.35	0.23	0.47	0.51	0.36	0.84	0.06	0.59	0.09	0.40
LSD (0.05)**	NS***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
K treatment															
0 lbs/acre	2.55	0.80	0.91	0.91	5.17	1.89	1.69	0.44	0.33	4.35	2.39	1.58	1.26	0.90	6.13
125 lbs/acre	2.61	0.80	0.85	0.95	5.21	1.92	1.82	0.45	0.38	4.57	2.56	1.57	1.57	1.09	6.79
250 lbs/acre	2.49	0.80	0.82	0.95	5.05	1.94	1.86	0.40	0.35	4.55	2.57	1.55	1.56	1.09	6.77
Pr>F	0.56	0.99	0.19	0.64	0.72	0.28	0.01	0.47	0.19	0.06	0.01	0.68	0.01	0.01	0.01
LSD (0.05)	NS	NS	NS	NS	NS	NS	0.08	NS	NS	NS	0.08	NS	0.09	0.05	0.24
Variety															
PLH resistant	2.61	0.83	0.86	0.95	5.25	1.91	1.77	0.45	0.37	4.50	2.53	1.57	1.45	1.06	6.61
Normal	2.49	0.77	0.86	0.93	5.04	1.93	1.81	0.41	0.33	4.48	2.48	1.56	1.48	0.99	6.51
Pr>F	0.07	0.01	0.77	0.55	0.07	0.57	0.12	0.04	0.01	0.70	0.09	0.73	0.32	0.01	0.12
LSD (0.05)	NS	0.05	NS	NS	NS	NS	NS	0.04	0.02	NS	NS	NS	NS	0.04	NS

* Probability values of 0.05 or lower indicate the means are significantly different

** LSD indicates the difference among treatment means that is needed to be statistically different

** NS = not significant