2003 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 for control treatments and losses of production and quality when not controlled. Alfalfa weevil, another major alfalfa pest, is more predictable, damage is limited largely to the first harvest, and the symptoms are clearly visible for determining if and how to manage the pest. In contrast, potato leafhoppers are small, infestations are less predictable, and scouting with a sweep net is needed to determine threshold levels for treatment. The typical visible symptoms of leaf yellowing and stunted growth appear after the damage is done and any treatment then will be late and 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 was to evaluate how glandular hairs on some new varieties and rates of K fertilization affect populations of potato leafhopper in alfalfa. The experiment is being conducted at the Forage Systems Research Center near Linneus in North Central Missouri. At the site the Lagonda silt loam soil slopes to an Armstrong silty clay loam. The site was selected in 2000 and the entire field was limed and P was applied according to soil test recommendations. Our first two attempts (fall, 2000 and spring, 2001) did not yield uniform stands that were acceptable for the project so they were tilled up. We established an excellent stand in fall, 2001. We also retested the soil fertility level 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 planted. One variety (normal) has smooth stems and leaves (PLH susceptible) whereas the other variety (PLH resistant) has glandular hairs that deter infestation and feeding of 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 being applied after the first harvest and half being applied after the fourth harvest in mid-September. All plots receive P (75 lbs/acre) annually after the fourth harvest.

We had good alfalfa emergence, and the unusually warm weather during October and November of 2001 was favorable for development of the alfalfa seedlings and their ability to over winter. The seedlings entered winter with more than six leaves, a stage that allows plants to develop good winter hardiness and a root system that tolerates normal freezing and thawing. We had a good stand in spring 2002, and were able to initiate the experiment with the insect and K treatments beginning immediately after the first harvest. Year 1 of the project was 2002, Year 2 was 2003. We are now ready to go to Year 3 (2004).

Changes in Soil Test for K

Soil samples had been taken to 6 inches over the entire field by sub-sampling within four replicate sections in July, 1998 (Table 1). This was prior to lime and fertilizer application in anticipation of using the area for experimental use. The soil was fertilized with P and limed to soil test in 2000. After seeding in fall of 2001 we re-sampled the area and topdressed 400 lbs of P to further raise the level of 39 lbs/acre. It is apparent that the P fixation capacity of this soil is higher than for many soils as it took more P than expected to raise the soil-test P. The P test was adequate on samples collected in April of 2002 before the experimental treatments began (Table 1). The K levels were moderate and the pH of 6.7 was in the optimum range for alfalfa.

The K treatments were first applied (half the annual rate) after the first harvest in May of 2002; the remaining half rate of the K and the total annual P was applied after the fourth harvest in September. Soil in the plots was sampled to 6 inches again after the first harvest of 2003. At that time the P level averaged about 50 lb/acre and the K level of the control treatment (0 K) was significantly lower ($p<0.05$) than that at the 250 lb rate. Yields in 2002 and the first harvest of 2003 totaled about 6.0 tons/acre (Table 3), so a typical removal rate of 50 lbs K/ton of forage would exceed even the highest application rate of 250 lbs/acre. Thus, the K-test was decreasing, especially at the low fertilization 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 soil samples and test again after the first harvest in 2004. Our expectation is the soil tests for K will continue to decrease, especially at the lower rates as the productive stand uses more K annually than is applied. In addition, we propose to take some tissue samples for K analysis as we expect 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 the second and third harvests as these are attacked most commonly.

Leafhopper Populations

Leafhoppers typically arrive in Missouri about May 5 in winds from the southwest and must lay eggs that hatch to develop a damaging population. The life cycle is such that leafhopper populations rarely reach economic levels prior to the first harvest (Figure 2). Generally, few leafhoppers are found during regrowth after the third harvest in Missouri, and this has also been the case in our research. We counted

both the adults and the nymphs (immature, non-mobile stage), and in both years the adult component made up more than 80% of the total count.
After the first harvest, the population of leafhoppers increased rapidly during early to mid-June in both years, but in 2002 the PLH-resistant variety in the no-spray treatment (control) had fewer than 30% as many leafhoppers as did the normal variety. In 2003 both varieties had nearly the same level as the infestation built rapidly in early June. The rapid increase was unexpected as the glandular-haired varieties usually show resistance in field studies, but the populations in the IPM and scheduled spray treatments also increased very rapidly, such that not even the scheduled spray treatment kept the population in check (compare treatments for 2003 in Figure 2). But, after climbing 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 leafhopper control between harvests in both years. Some oscillations occurred in the leafhopper populations, mainly due to weather events.

Leafhopper populations exceeded the IPM thresholds in both years (Figure 2). The leafhopper populations developed rapidly shortly after the first harvest of 2002 and reached the highest levels of the summer. In fact, the normal variety reached the economic threshold only 7 days after the first harvest in 2002. Yield of the second harvest 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 the third harvest 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 both years, except for the third growth of 2003 as the threshold was not reached, a single insecticide application in the IPM treatment controlled the leafhoppers until the next harvest date. Therefore, over the two years, the number of sprays was reduced from eight with the scheduled spray treatment to only three when 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. 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 or 2003 except, as mentioned above, for the variety difference in the control treatment at the second harvest (Table 3). In 2003, the PLH-resistant variety had a higher yield in the third harvest than the control. In all cases, the yields of the two varieties were similar in the first and fourth harvests when potato leafhopper infestations were very low or absent. Thus, the glandular-haired character is effective, yet advantageous only when the insect pest is present, and when the 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 the economic threshold for normal varieties.

Alfalfa yields were not affected by K fertilization rate in 2002 (Table 3), mainly because the treatments were initially applied after the first harvest 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 even though that is the time when potato leafhopper damage is most likely. This is consistent with our earlier research that shows that K stimulates crown development in a gradual manner, especially over winter. The rest of the K was applied after the last (fourth) harvest.

In 2003 some effects of the K rates became apparent, mainly in the second harvest when populations of potato leafhopper increased very rapidly regardless of insecticide treatment. The cumulative total yield in 2003 for the K rates of 125 and 250 lbs/acre was nearly ($p<0.06$) significantly higher than the control. This suggests that treatments are beginning to separate, and will be of great interest next year (2004) as removal will continue to decrease the soil-test K.

Changes in Plant Density

The alfalfa stands looked good for both varieties in spring, 2002, when plant density was counted after the first harvest (Table 2). The K and leafhopper treatments did not begin until after the first harvest so there was no effect on plant density due to K or insect control. We did note, however, that the plant density of the PLH-resistant variety was about 30% lower 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 should give 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 the fourth harvest in 2002 and after the first and fourth harvests in 2003 (Table 2). The plant density for all treatments gradually decreased with time through 2002 and 2003. As the stands lost plants, the PLH-resistant variety continued to maintain its advantage of higher plant density, a factor we have noted before in many earlier studies that compare seeding rates. Similarly, the high-K treatment retained its initial advantage over the control (due to natural effects of field variation despite plot randomization) as the stand decreased through both years, again being consistent with previous studies. We do not expect reductions in yield due to low plant density until the stand has fewer than four plants/sq ft. This occurs because the plants still have sufficient capacity to produce and elongate additional stems from the crown to offset the loss of nearby plants and 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. Number of stems/plant was inversely related to plant density and averaged

2.4 stems/plant for the PLH-resistant variety and 2.9 stems/plant for the normal variety. As the stand thinned the stems/plant gradually increased. We expect the stems/plant to begin to show a K effect as the stand thins, especially as it approaches four plants/sq ft. The effect of the leafhopper treatments may also 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, plant densities after the first and fourth harvests in 2003 did not differ due to the K or leafhopper treatments, but the PLH-resistant variety continued to have about 30% more plants/sq ft than the normal variety. We counted stems per plant allowing us to calculate stems/sq ft (data not shown). We calculated the weight (yield) per stem using yield data for the fourth harvest. 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 expected little effect on plant density due to K fertilization or leafhopper control this early in the experiment as the young plants are vigorous and are thinning mainly due to plant competition for light. 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 offset the continued plant loss, resulting in a gradual yield decrease. Thus, as the stands thin, the ability of the crown to spread or compensate for plant loss will be compromised and detrimental effects from leafhoppers will be more evident.

Objectives for Year 3 (2004):

Our objectives are to continue the experiment as proposed. It is anticipated the K effect will be expressed even more dramatically if leafhopper populations are high, so we will monitor alfalfa weevil and especially potato leafhopper throughout the growing season. The control, IPM and scheduled spray treatment 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 the first and fourth harvests. As before, stems/plant will be counted after the first and fourth cuttings to monitor development and spread of the crowns.

We will take soil samples again after the first harvest to continue to monitor the soil-test K levels and any other nutrient 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 level may decrease faster with time than will the soil test and yield response. The tissue-K is likely associated with leafhopper resistance. The University Soil Test lab has a new instrument for accurately measuring minerals in plant tissues. We will thus sample topgrowth from four replications, two sample dates, three K rates, two varieties, and three insect treatments. The total is 4X2X3X2X3= 144 total samples. Samples will be dried, ground and analyzed. With a processing and analytical cost of $15/sample, these analyses add $2160 to the Year 3 budget.

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 last longer. So far the stands have begun to thin, but are still above threshold population for yield responses. The K will help sustain the stand by enhancing crown development. We hope to continue this integrated experiment beyond 2004 as is contributing to our understanding of how interactions of crop management strategies affect an important pest in an environmentally friendly way.

Proposed budget for year 3 (2004):

	2002	2003	**2004**	Total
Salaries[1]	2000	2000	**2000**	$6000
Operating[2]	3000	3000	**4000**	10000
Plant analyses[3]			**2160**	2160
Equipment[4]				0
Other (travel)[5]	1700	2250	**2250**	6750
Total	$6700	$7250	**$10410**	$24910

[1]Part-time labor ($2,000) for sampling and counting insects at the FSRC. Originally, we were going to count the insects in Columbia, but staff members at FSRC have been trained to do both the sampling and counting of the insects. Staff at FSRC will also help with the harvests and plant counts.

[2]Fertilizer, pesticides, maintenance of spreader, sprayer, and harvester, soil tests and general supplies. Rental of sod cutter ($300/year). Standard soil tests will be done on all plots in the spring of 2004 to calculate removal and residual P and K. Includes regular trips by PIs to FSRC to do regular duties of the project.

[3]Plant analyses include collecting, processing and analyzing tissue samples for K and other elements in summer growths that are affected by potato leafhopper

[4]No special equipment needed.

[5]Travel is to professional meetings ($750 each PI/year). In addition, PIs on the project are associated with two multi-state projects (NC-225, Forage-Beef systems; and NC-226, Alfalfa Persistence) which both have an annual meeting to discuss research findings.

Figure 1. Electron micrographs of a leafhopper and of glandular hairs on an alfalfa leaf. The hairs are multi-cellular extensions of epidermal cells, and can be upright or flat. The upright hairs are the most effective 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 actually are entrapped by the sticky hairs.

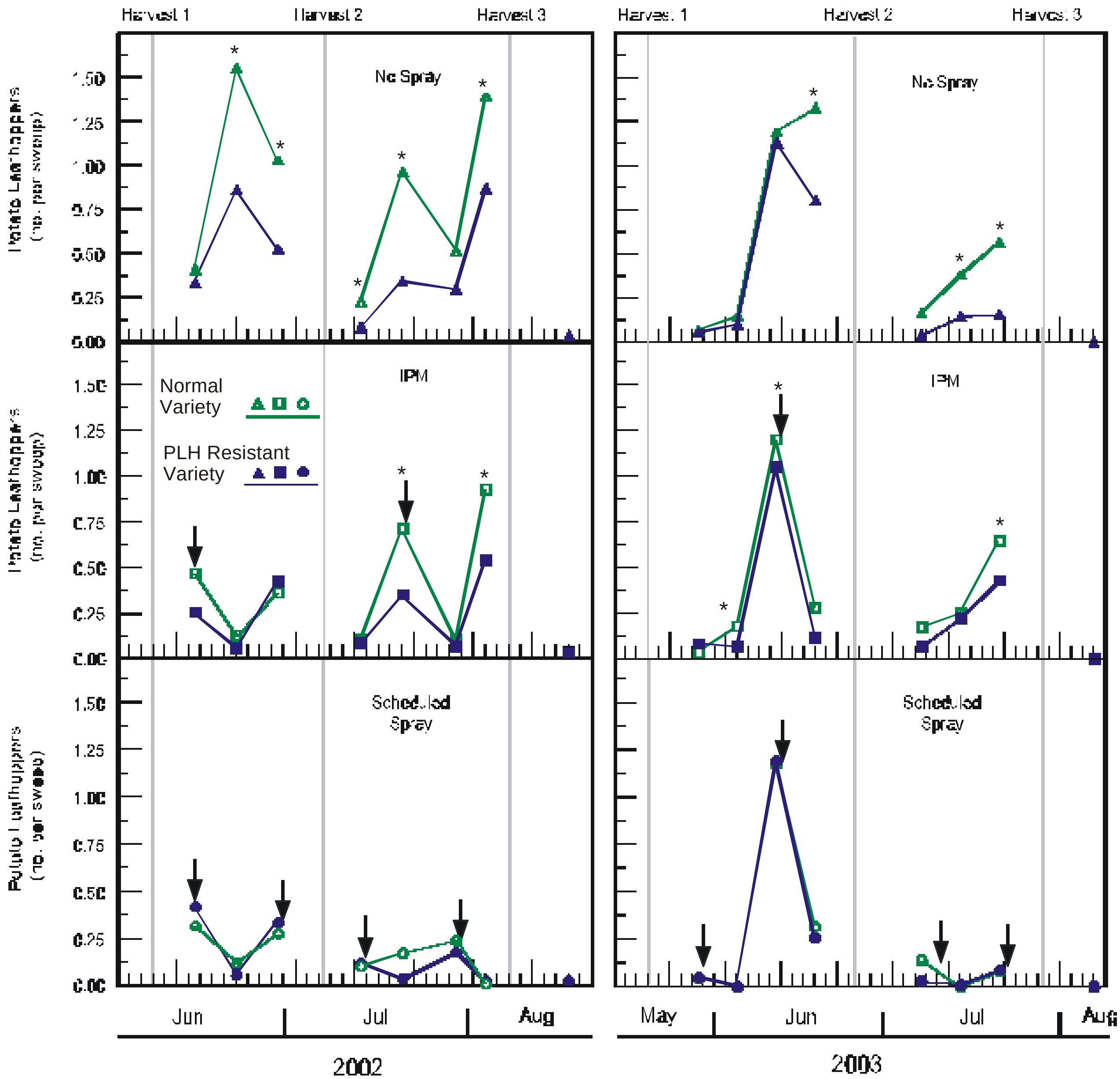

Figure 2. Top panel shows populations of potato leafhopper between harvest dates in the no-spray treatment (control). Each panel also indicates the relative control provided by the PLH-resistant variety compared with the normal variety. Middle panel shows the populations in the spray treatment based on IPM and population sampling with dates of 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 the dates of spray that were scheduled 7 and 21 days after the first and second harvests. Leafhoppers were not found previous to the first harvest and only a few were captured in the sweep net in the early regrowth of the fourth harvest. Asterisks (*) indicate the leafhopper populations are significantly different ($p<0.05$) between the two varieties on those sampling dates.

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

Sample 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 experiment started	184	6.7	63
May 28, 2003	0 – K plots	After first cutting, but	142	6.4	45
	125 – K plots	before K treatments	145	6.5	54
	250 – K plots	were applied in 2003	147	6.5	55

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 and 2003.

Summary of treatments	Plants on 6-02	Plants on 9-02	Plants on 5-03	Plants on 9-03	Stems/plt on 9-02	Stems/plt on 5-03	Stems/plt on 9-03
	----------------------no./sq. ft. ----------------				--------------------no. ---------------		
Insect control							
No spray	20.3	18.9	18.9	11.3	2.7	3.4	6.7
IPM spray	18.3	18.6	16.3	11.7	2.6	3.1	6.7
Scheduled	18.7	17.9	15.0	11.0	2.7	3.1	6.6
Pr > F*	0.56	0.66	0.64	0.59	0.28	0.55	0.88
LSD (0.05)**	NS***	NS	NS	NS	NS	NS	NS
K treatment							
0 lbs/acre	18.2	17.8	15.1	10.9	2.8	3.2	6.8
125 lbs/acre	18.5	18.4	14.5	10.8	2.7	3.3	6.8
250 lbs/acre	20.7	19.1	16.7	12.3	2.5	3.1	6.4
Pr > F	0.18	0.58	0.10	0.02	0.12	0.49	0.46
LSD (0.05)	NS	NS	NS	1.1	NS	NS	NS
Variety							
PLH resistant	22.3	21.0	17.7	12.6	2.4	3.0	6.0
Normal	15.9	15.9	13.1	10.0	2.9	3.4	7.4
Pr > F	0.01	0.01	0.01	0.01	0.01	0.01	0.01

LSD (0.05)	2.3	1.8	1.4	0.9	0.2	0.3	0.6

* 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 and 2003. Harvest dates and total annual yields are also shown.

	2002					2003				
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
	--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
IPM spray	2.46	0.84	0.84	0.93	5.07	1.89	1.74	0.41	0.36	4.40
Scheduled spray	2.67	0.79	0.87	0.92	5.24	1.95	1.81	0.45	0.34	4.55
Pr>F*	0.65	0.29	0.22	0.45	0.81	0.35	0.23	0.47	0.51	0.36
LSD (0.05)**	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
125 lbs/acre	2.61	0.80	0.85	0.95	5.21	1.92	1.82	0.45	0.38	4.57
250 lbs/acre	2.49	0.80	0.82	0.95	5.05	1.94	1.86	0.40	0.35	4.55
Pr>F	0.56	0.99	0.19	0.64	0.72	0.28	0.01	0.47	0.19	0.06
LSD (0.05)	NS	NS	NS	NS	NS	NS	0.08	NS	NS	NS
Variety										
PLH resistant	2.61	0.83	0.86	0.95	5.25	1.91	1.77	0.45	0.37	4.50
Normal	2.49	0.77	0.86	0.93	5.04	1.93	1.81	0.41	0.33	4.48
Pr>F	0.07	0.01	0.77	0.55	0.07	0.57	0.12	0.04	0.01	0.70
LSD (0.05)	NS	0.05	NS	NS	NS	NS	NS	0.04	0.02	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