Crop Rotation, Prosaro Fungicide, Seed Treatment and Cultivar as Management Tools to Control Disease on 6-Row Barley, Langdon, 2009

Halley, S.*, Crop Protection Scientist, McMullen, M., Extension Plant Pathologist, and Misek, K., Research Specialist. Corresponding author* North Dakota State University-Langdon Research Extension Center Langdon, ND 58249. PH: (701) 256-2582, E-mail: Scott.Halley@ndsu.edu.

Efforts have been initiated and funded by the U.S. Wheat and Barley Scab Initiative to communicate some of the research progress made in developing and identifying strategies that will reduce or minimize the effect on small grains from the disease Fusarium head blight (FHB) or scab. Seed treatment was added to this study with support from the North Dakota Barley Council. One of these efforts is reported here that compares using crop rotation, a foliar fungicide treatment, a seed treatment and cultivars with different levels of resistance or tolerance to FHB. The study utilized a common regional crop rotation, 6-row barley after canola, as a comparison to a small grain rotation, 6-row barley after hard red spring wheat. The theory behind this is that the quantity of inoculum would be reduced when the previous crop was not susceptible to FHB. The second strategy researched was an application of Prosaro fungicide to minimize the effects of FHB. The third strategy researched would be the selection of a cultivar with less susceptibility to FHB. The final strategy tested compared a broad spectrum seed treatment with untreated seed.

MATERIALS AND METHODS

These studies were initiated in 2008 by planting six randomized replicated strips of hard red spring wheat and canola on the North Dakota State University Langdon Research Extension Center. The study plan was a randomized complete block design with a split split plot arrangement. Whole plot factor was previous crop, split plot factor was Prosaro fungicide and split split plot factor was cultivar. An additional factor was added by reducing the 6 replicates to three and adding the broad spectrum seed treatment to three of the six replicates and leaving the other three replicates untreated. In 2009 six 6-row barley cultivars, Excel, Legacy, Quest, ND20448, Robust and Tradition were treated with seed treatment. The cultivar Quest followed by ND20448 would be expected to have slightly greater resistance to deoxynivalenol accumulation in the seed than the other cultivars. The cultivars were selected because they have been planted on significant acreages of growers in North Dakota or fit a range of susceptibility to FHB. The seed treatments included BASF fungicides Charter F2 (triticonazole/metalaxyl) applied at rate of 5.4 fl oz/cwt, Stamina (pyraclostrobin) applied at rate of 0.4 fl oz/cwt and the BASF insecticide Axcess (imidicloprid) applied at a rate of 0.2 fl oz/cwt. The seed treatments were individually applied with a syringe to 2 lb lots of barley with a Hege Model 11 liquid seed treater (Wintersteiger Inc, Salt Lake City, Utah). Seed was planted at 1.25 million pure live seed per acre, determined by blotter paper germination in vitro.

The plots were seven rows wide six-inch row spacing and measured 20 feet long. An Almaco double disk drill was used to seed the plots on 18 May. Nitrogen liquid fertilizer was spring applied by broadcast method to achieve a target yield goal of 100 bushel /acre. A solution of Prosaro fungicide and Induce adjuvant (Helena Chemical Co.) was applied at 6.5 fl oz /acre and 0.125%v/v, respectively, at head extended growth stage on barley. Prosaro fungicide (421 SC 3.57 lb/gal. formulation of prothioconazole/tebuconazole, 19% +19% w/w, manufactured by Bayer CropScience), applied at Feekes growth stage 10.5, is recommended to reduce the effects of FHB in small grains. Fungicide treatments were applied with a CO_2-pressurzed backpack sprayer. The boom was equipped with two Spraying Systems Co. XR8001 nozzles mounted on a double swivel. The swivels were spaced on 20-inch centers and oriented to spray 30 degrees downward from horizontal and forward and backward. The spray volume was 18.4 GPA obtained by pressurizing the boom at 40 psi. Twenty days after the fungicide application (soft dough growth stage, Feekes 11.2) 20 heads were removed and evaluated to determine FHB incidence (number of spikes infected) and severity of the infected heads (number of FHB infected kernels per head divided by total kernels). FHB index is the summation of the incidence times the severity. The plots were harvested with a Hege plot combine and the sample processed to determine yield, test weight and plump on the barley. Immediately after harvest the remaining plant including roots was removed with a spade from approximately six feet of row, bagged, dried and stored. The sub crown internode was removed from each of the roots. Fifteen roots were scored using a scale of 1-4, one (0-25%), two (26-50%), three (51-75%) and four (76-100%) severity. Some samples did not have an intact sub crown internode. An assumption was made that the sub crown internode was severely infected and assessed a score of 4. An index was calculated by summing the number of samples times the score for each category and dividing by the total root sample number of 15. A sub sample of the grain was sent to North Dakota State University NDSU Barley Quality Lab to determine the presence of the toxin deoxynivalenol (DON). North Dakota State University Extension recommended production practices for barley for Northeast North Dakota were followed. Data was analyzed with the general linear model (GLM) in SAS. Fischer's protected least significant differences (LSD) were used to compare means at the 5% probability level (Table 1).

RESULTS

Data was initially analyzed as a four factor experiment. The significant effects that included the seed treatment factor are reported in Tables 1, 2 and 3. The seed treatment factor was removed and the trial was re-analyzed as a three factor experiment with split split plot arrangement and six replicates. The data is divided into three data pools to partition the degrees of freedom and increase the likelihood of measuring differences among the three remaining treatments. These results are reported in Tables 1, 2, 4 and 5. The data for the roots are presented in Tables 4, 6, 7 and 8.

Seed Treatment. Applying seed treatment decreased 1000 seed weight, Table 2. Interactions were measured for FHB incidence and index, test weight and plump for previous crop residue*foliar fungicide treatment*seed treatment, Table 3. The application of seed treatment to the seed when Prosaro was applied to barley grown on previous crop canola compared to all other treatments decreased both FHB incidence and index. No differences were measured among the other treatments for incidence where previous crop was canola. Where previous crop was HRSW results from the addition of treatment to the seed were very different with decreased incidence for the treatment with Prosaro and no seed treatment. Disease index followed similar trend except for increased index when previous crop was HRSW, no foliar fungicide was applied and seed was treated. Test weight was increased when previous crop residue was canola and Prosaro fungicide and seed treatment were applied. When the previous crop was HRSW the greatest test weight occurred when Prosaro fungicide was applied and the seed was not treated. This treatment had greater test weight than the Prosaro fungicide with seed treatment and the no Prosaro fungicide and no seed treatment. Plump was greater on previous crop canola when both Prosaro fungicide and seed treatment were applied. Plump was lowest when no seed treatment was applied with Prosaro fungicide and no Prosaro fungicide and no seed treatment were used. When previous crop was HRSW a reduction was measured in plump: Prosaro + no seed treatment > Prosaro + seed treatment > Untreated + no seed treatment > Untreated + seed treatment. No differences were determined for seed treatment averaged over previous crop residue, foliar fungicide treatment, and cultivar for any of the root scoring categories, Table 6. An interaction was determined for fungicide by seed treatment averaged over all previous crop residues and cultivars, Table 8. The assessment category one is not presented due to very low sample numbers. Category three had a greater number of roots scoring in category three than four for Prosaro fungicide treatment and seed treatment which was different from the Prosaro fungicide treatment and no seed treatment which had much more roots scoring fours. When no foliar fungicide treatment was applied no differences were determined. A similar pattern was determined root severity and index.

Previous Crop Residue. Averaged over all seed treatments, fungicide treatments and cultivars, previous crop residue only affected two measured parameters, Table 2. Yield was increased by 26.5 bushel/ acre by planting barley into previous crop residue canola. Test weight was also increased by 0.8 pound/ bushel. When previous crop residue was canola both disease severity and index were lower and the sub crown internodes were categorized accordingly, Table 7. Previous crop residue canola lower in numbers in category score three and four and greater in previous crop residue HRSW in category score three and four. An interaction was measured for the previous crop residue by cultivar for the sub crown internode score category three, Table 4. Lower numbers of roots were found where previous crop residue was HRSW compared to canola. Magnitude of the differences were less for the cultivar Quest and greater for the cultivar ND20448.

Prosaro Fungicide. The application of Prosaro fungicide, averaged over all seed treatments, previous crop residues and cultivars reduced disease for all measured parameters including deoxynivalenol accumulation in the seed, Table 2. The application of Prosaro also increased test weight. Prosaro fungicide treatment did not affect the sub crown internodes except as reported in the seed treatment, Table 8.

Cultivar. Differences for all parameters were measured for cultivar averaged over seed treatments, previous crop residues and foliar treatments, Table 2. Visual disease levels were lowest on Legacy and greatest on Tradition, Table 3. Deoxynivalenol accumulation was lowest on Quest and greatest on Legacy and Excel. Yield was greatest on Excel followed by Quest and lowest on ND20448. Greatest test weight occurred on Robust followed by Tradition. All plumps were excellent. Excel and Quest had slightly lower plumps than the other cultivars. Stands of ND20448 and especially Legacy were lowest in this environment. Thousand seed weight was greatest on ND20448 and Robust. Quest had a much lower seed weight than all other cultivars. An interaction was measured for previous crop residue*cultivar for plump, Table 4. Plump decreased when previous crop was HRSW on Robust and ND20448. An interaction was also measured for fungicide treatment*cultivar for yield. Yield was increase by foliar fungicide treatment on ND20448 and Robust. Differences in sub crown internode disease assessment were measured for categories three and four and severity and index, Table 7. For the number of roots with sub crown internode scoring four, ND20448 was greater than Legacy, Tradition, Excel and Robust. Quest had the lowest number of sub crown internodes scoring four at 5.3 but was not different from Robust, Excel and Tradition at 6.0, 6.3 and 6.6, respectively. The most susceptible cultivar was ND20448 which was greater than Legacy and Tradition = Excel, Robust and Quest for severity.

Discussion. The season was cool and the planting date later than previous years at Langdon. Increases in 1000 seed weight on untreated compared to treated are common. Often the increased levels of disease on the roots decrease the longevity of tillers which allows for increased nutrition to the main stems seeds and increased seed weight, Table 2. More difficult to explain is the interaction of previous crop residue*Prosaro fungicide*seed treatment. Reduced FHB symptoms and increased test weight and plump on canola residue can be attributed to greatest effect from the application of the Prosaro fungicide and lower level of root disease. More difficult to explain is the increase of FHB index by seed treatment when Prosaro fungicide was not applied. Differences in index measured on previous crop HRSW were similar to incidence but different in some aspects. The density of the canopy of small grains including barley when planted in canola residue can be increased substantially compared to planting canola in HRSW residue. In one previous experiment deoxynivalenol accumulation increased slightly when planted in canola residue. This increase in plant tissue density and mass may be related to both differences in root development and an array of other differences such as nutritional parameters like micronutrient availability to the plant. Nevertheless, the improvements are real and show the large benefit of crop rotation, foliar fungicide and seed treatment to minimize the effects of disease when the environment is conducive to their spread. This warrants further research. This study was a great example of the substantial increase in yield and test weight that can be attributed to crop rotation. While the effects of rotation are not always as substantial, in some environments like 2009 the rotation affects are large. The benefits of applying foliar fungicide are shown by reduced FHB disease levels. Some of the visual parameter reductions are not always seen in barley studies but the reduction in deoxynivalenol accumulation is fairly consistent. A test weight increase is an additive benefit to foliar fungicide. Differences among cultivars should be expected. Quest was released by University of Minnesota barley program recently, Kevin Smith breeder, and is touted as having 0.5 ppm lower deoxynivalenol accumulation. ND20448 from North Dakota State University barley program, Richard Horsley breeder, is reported to have similar but less reduction in deoxynivalenol accumulation, 0.3 ppm. Notice that the visual disease parameters do not necessarily follow similar trend as deoxynivalenol accumulation. One has to use caution in interpreting results for cultivar comparisons in un-inoculated and un-misted FHB studies as some of the differences are related to disease escape. Of note was the reduced stand establishment of ND20448 and Legacy. Both stand reductions likely affected yield. ND20448 has been reported to be affected severely by the common root rot pathogen in some environments, Stephen Neate, personal communication. More research is warranted if this line is released. The interaction between Prosaro fungicide treatment and cultivars ND 20448 and Robust is also very interesting. A similar interaction was measured in a study conducted in Langdon in 2008 on barley. Further study is warranted. If similar interaction trends continue between fungicide and cultivars recommended management strategies could be tailored to specific cultivars.

The effect of seed treatment on the disease of the sub crown internode was only statistically significant when included with the foliar fungicide treatment. This combination of treatments needs to be assessed again in another environment so the study should be repeated. It is plausible to not expect the seed treatment to still be affecting the disease levels in roots for this long of time period. Usually fungicides start to lose efficacy within a ten day time period. The possibility exists that the sequential fungicide application via foliar treatment may have given the plant improved overall health. The effects of crop rotation are quite impressive in this environment. Crop rotation is a relatively low cost input to producers and the effects are substantial. The differences in resistance to root disease provided by cultivars with differing genetics shows the importance of knowing the potential strengths and weakness of your selection. More studies assessing the differences in susceptibility of disease infection in the root region would benefit growers.

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Table 1. Source of variation and confidence intervals for seed treatment, previous crop residue, fungicide and cultivar and confidence intervals for Fusarium head blight disease severity, incidence and index, deoxynivalenol concentration (DON), yield, test weight, plump, stand and 1000 seed weight on 6-row barley, Langdon 2009.

Source of Variation	Severity	Incidence	Index	DON	Yield	Test Weight	Plump	Stand	1000 Seed weight
Replicate (3) [z]	0.0004	0.0315	0.0003	<0.0001	<0.0001	0.1574	<0.0001	0.0004	0.6984
Seed treatment	0.9644	0.4980	0.7002	0.9006	0.5818	0.0513	0.9542	0.7317	0.0287
Res.*Seedtrt	0.3538	0.1121	0.6403	0.2939	0.6135	0.1417	0.1102	0.2004	0.2781
Fung*Seedtrt	0.3003	0.3958	0.1208	0.5848	0.0707	0.5265	0.2045	0.2666	0.1518
Cultivar*Seedtrt	0.7175	0.9301	0.7038	0.9600	0.7338	0.6577	0.4228	0.5438	0.2176
Res*Fung*Seedtrt	0.1212	0.0006	0.0204	0.1874	0.8678	0.0002	<0.0001	0.3139	0.8845
Replicate (6) [z]	0.0003	0.0012	<0.0001	<0.0001	<0.0001	0.0010	<0.0001	<0.0001	<0.0001
Residue	0.2706	0.7295	0.2317	0.3276	<0.0001	0.0092	0.0956	0.4850	0.1350
Rep*Res	0.3285	0.9842	0.5090	0.4872	0.0360	0.0016	0.0410	0.4872	0.2742
Fungicide	0.0020	0.0036	0.0003	0.0007	0.1482	0.0461	0.0699	0.7821	0.1806
Res*Fung	0.2090	0.5997	0.2308	0.8991	0.3988	0.6650	0.6441	0.3100	0.4585
Rep*Fung(Res)	0.8124	0.6159	0.8327	0.0056	<0.0001	0.0003	0.0465	0.0056	0.0366
Cultivar	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Res*Cult	0.8934	0.6636	0.9204	0.8532	0.4772	0.0793	0.0112	0.8532	0.0517
Fung*Cult	0.2512	0.3397	0.1443	0.5887	0.0362	0.5872	0.5394	0.5887	0.5915
Res* Fung*Cult	0.2060	0.8137	0.2178	0.9471	0.7069	0.8729	0.6684	0.9471	0.8103
% C.V.	37.8	9.7	42.4	38.1	8.3	1.1	1.0	25.0	2.5

[z] Seed treatment was analyzed with ANOVA in a factorial arrangement with three replicates. Seed treatment was dropped for second ANOVA analysis in split split plot arrangement with six replicates to increase the degrees of freedom for the parameter pools for the analysis.

Table 2. Fusarium head blight severity, incidence and index, deoxynivalenol accumulation (DON), yield, test weight, plump, stand and 1000 seed weight for seed treatment averaged across previous crop residues, fungicide treatments and cultivars; residue average across fungicide treatments and cultivars; fungicide averaged across previous crop residues and cultivars; and cultivar averaged across residues and fungicide treatments on 6-row barley, Langdon 2009.

Main Effects	Fusarium Head Blight Severity	Fusarium Head Blight Incidence	Fusarium Head Blight Index	DON	Yield	Test Weight	Plump	Stand	1000 Seed weight
Seed Treatment	(%)	(%)		(ppm)	(bu/a)	(lb/bu)	(%)	(plt/a)	(g)
Untreated	8.0	90.2	6.9	1.3	100.9	48.3	95.1	795,575	43.4
Treated	8.0	91.1	7.1	1.2	102.2	48.5	95.1	781,055	42.9
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	0.4
Residue									
Canola	7.7	90.6	6.7	1.2	114.8	48.8	95.3	800,012	43.3
HRSW	8.3	90.8	7.3	1.3	88.3	48.0	94.8	776,618	42.9
LSD (P=0.05)	NS	NS	NS	NS	5.7	0.5	NS	NS	NS
Fungicide									
Untreated	8.8	93.2	8.0	1.9	99.2	48.2	94.9	780,652	42.9
Prosaro	7.2	88.2	6.0	0.7	103.9	48.6	95.3	795,978	43.3
LSD (P=0.05)	0.9	2.9	0.8	0.6	NS	0.4	NS	NS	NS
Cultivar									
Excel	7.6	87.5	6.3	1.6	111.5	47.8	93.7	811,305	43.3
Legacy	5.3	77.5	3.4	2.0	98.9	47.5	95.1	502,755	43.1
Quest	6.7	91.0	5.7	0.7	104.2	47.8	92.6	905,685	41.9
ND20448	9.7	95.8	9.1	1.0	91.2	48.0	96.7	785,895	43.8
Robust	7.9	95.0	7.3	1.1	103.6	49.9	95.8	914,155	43.5
Tradition	10.7	97.1	10.2	1.1	100.0	49.3	96.6	810,095	43.1
LSD (P=0.05)	1.7	5.0	1.7	0.3	4.8	0.3	0.6	111,701	0.6

Table 3. Fusarium head blight (FHB) incidence and index, test weight and plump by residue, fungicide treatment and seed treatment averaged across cultivars in 6-row barley, Langdon 2009.

Fungicide	Seed treatment	FHB Incidence (%)	FHB Index (%)	Test Weight (lb/bu)	Plump (%)
Canola					
Prosaro	None	92.2	6.2	48.7	94.8
	Treated	84.7	4.7	49.4	96.3
Untreated	None	90.3	6.7	48.5	95.6
	Treated	95.1	9.1	48.6	94.7
HRSW					
Prosaro	None	84.4	6.4	48.4	95.6
	Treated	91.4	6.7	48.0	94.6
Untreated	None	93.9	8.3	47.6	94.3
	Treated	93.3	7.8	48.1	93.8
LSD $_{(P=0.05)}$		5.6	2.0	0.4	0.3

Table 4. Seed plump and disease from assessment of the sub crown internode (1-4) for roots scoring three by previous crop residue and cultivar averaged across fungicide treatments in 6-row barley, Langdon 2009.

	Canola Residue	HRSW Residue	Canola Residue	HRSW Residue
Cultivar	Plump (%)	Plump (%)	Root Scores (3)	Root Scores (3)
Excel	93.9	93.6	8.3	4.6
Legacy	95.3	94.7	7.9	4.2
Quest	92.4	92.8	8.0	6.5
ND20448	97.3	96.0	7.8	2.6
Robust	96.5	95.0	8.0	5.2
Tradition	96.7	96.6	7.8	5.2

Yield LSD=0.7 for a_1c_0 vs. a_0c_0 and LSD= 0.8 for a_0c_0 vs. a_0c_1. Root Severity LSD=2.7 for a_1c_0 vs. a_0c_0 and LSD=1.6 for a_0c_0 vs. a_0c_1.

Table 5. Yield by fungicide treatment and cultivar averaged across previous crop residues in 6-row barley, Langdon 2009

Cultivar	Fungicide Treatment	
	Prosaro	Untreated
	Yield (bu/acre)	Yield (bu/acre)
Excel	113.8	109.2
Legacy	98.2	99.6
Quest	104.4	104.0
ND20448	97.7	84.7
Robust	108.0	99.3
Tradition	101.3	98.7

DON LSD= 6.8 for a_0c_0 vs. a_0c_1 and LSD=5.73 for a_0c_0 vs. a_1c_0 and a_0c_0 vs. a_1c_1.

Table 6. Source of variation and confidence intervals for disease from assessment of the sub crown internode (1-4) for roots scoring one, two, three, four, severity and index on 6-row barley, Langdon 2009.

Source of Variation	One	Two	Three	Four	Severity	Index
Replicate (3) [z]	0.5746	0.0323	0.9384	0.2934	0.0648	0.0648
Seed treatment	0.4572	0.2085	0.2512	0.0651	0.0519	0.0519
Res.*Seedtrt	0.4572	0.3829	0.8615	0.4358	0.2976	0.2976
Fung*Seedtrt	0.0275	0.0673	0.0212	0.0009	0.0006	0.0006
Cultivar*Seedtrt	0.5148	0.0941	0.6989	0.1612	0.0625	0.0625
Res*Fung*Seedtrt	0.5148	0.1840	0.9166	0.8643	0.0625	0.0625
Replicate (6) [z]	0.1856	0.0248	0.0005	<0.0001	<0.0001	<0.0001
Residue	0.1219	0.0001	0.0131	0.0012	0.0004	0.0004
Rep*Res	0.1856	0.6453	<0.0001	0.0002	0.0115	0.0115
Fungicide	0.5490	0.9335	0.7008	0.8272	0.9491	0.8481
Res*Fung	05490	0.8025	0.7008	0.7438	0.8484	0.8484
Rep*Fung(Res)	0.1379	0.2837	0.5615	0.1218	0.0503	0.0503
Cultivar	0.4807	0.3719	0.0260	0.0006	0.0033	0.0033
Res*Cult	0.4807	0.5321	0.0464	0.5323	0.7914	0.7914
Fung*Cult	0.4807	0.9690	0.6622	0.7798	0.8497	0.8497
Res* Fung*Cult	0.4807	0.7824	0.2048	0.5504	0.7607	0.7607
% C.V.	520.5	87.3	32.0	35.9	8.8	7.4

[z] Seed treatment was analyzed with ANOVA in a factorial arrangement with three replicates. Seed treatment was dropped for second ANOVA analysis in split split plot arrangement with six replicates to increase the degrees of freedom for the parameter pools for the analysis.

Table 7. Disease from assessment of the sub crown internode (1-4) for roots scoring one, two, three, four, severity and index for seed treatment averaged across previous crop residues, fungicide treatments and cultivars; residue averaged across fungicide treatments and cultivars; fungicide averaged across previous crop residues and cultivars; and cultivar averaged across residues and fungicide treatments on 6-row barley, Langdon 2009.

	Sub Crown Internode Scores					
Main Effects	One	Two	Three	Four	Severity	Index
Seed Treatment	(Count)	(Count)	(Count)	(Count)	(%)	
Untreated	0.8	1.8	6.1	7.0	71	3.34
Treated	0.4	2.2	6.6	6.2	69	3.25
LSD $_{(P=0.05)}$	NS	NS	NS	NS	NS	NS
Residue						
Canola	0.00	3.3	8.0	3.6	62	3.00
HRSW	0.13	0.7	4.7	9.6	77	3.59
LSD $_{(P=0.05)}$	NS	0.6	2.2	2.4	4	0.2
Fungicide						
Untreated	0.04	2.0	6.4	6.5	70	3.29
Prosaro	0.08	2.0	6.3	6.6	70	3.30
LSD $_{(P=0.05)}$	NS	NS	NS	NS	NS	NS
Cultivar						
Excel	0.04	2.3	6.5	6.3	69	3.26
Legacy	0.17	1.9	6.0	6.9	70	3.31
Quest	0.08	2.4	7.3	5.3	67	3.18
ND20448	0.00	1.4	5.2	8.4	74	3.47
Robust	0.08	2.3	6.6	6.0	68	3.24
Tradition	0.00	1.9	6.5	6.6	70	3.31
LSD $_{(P=0.05)}$	NS	NS	1.2	1.4	4	0.14

Table 8. Disease from assessment of the sub crown internode (1-4) for roots scoring three, four, severity and index, by fungicide treatment and seed treatment averaged across previous crop residues and cultivars in 6-row barley, Langdon 2009.

Fungicide	Seed treatment	Three (count)	Four (count)	Severity (%)	Index
Prosaro	None	5.6	7.9	73	3.42
	Treated	7.0	5.4	67	3.18
Untreated	None	6.6	6.2	69	3.26
	Treated	6.2	6.9	71	3.33
LSD $_{(P=0.05)}$		1.1	1.3	3	0.12