REPORT TO NY IPM PROGRAM, 2000

Title**: Development of Integrated Pest Management Strategies for Apple Fruit Russet.**

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Status of research objectives

1. Complete the NY apple russet survey, record and organize data and make it available to the NY IPM program and to the NY fruit industry.

The NY apple russet survey was completed and reported in Volume 8 of the New York Fruit Quarterly. We learned that russet occurs on a wide range of apple cultivars in NY. Although Golden Delicious was selected as the most russet-prone, others were also frequently listed as having russet. These included Fuji, Jonagold, Ida Red, Crispin and Gala; all reported as having russet by more than 65 percent of the respondents. We also learned that monetary loss from russet can be great and in some years may reduce the value of a bin by as much as $100. Regional consultants listed six practices that in their opinions help to reduce the severity of russet.

2. Determine population densities of *A. pullulans* on apple fruit that are required to induce fruit russet and the period of time that induction requires.

Our previous work has shown that to induce severe russet on fruit we need to apply a relatively high concentration of *A. pullulans* (about 10^7 spores/ml). In attempts to determine how long the high level of fungus needs to be in contact with the fruit before russet is induced we inoculated fruit with the fungus and then applied captan (as a means of killing the fungus) at various intervals. Treatments on McIntosh fruit included:1) non-treated 2) inoculated 3) inoculated and then captan applied after 1hr 4) inoculated then captan after 6hr 5) inoculated then captan after 24hr 6) inoculated then captan after 48 hr. *A. pullulans* populations were measured at 0, 24, 96, and 168 hours after captan application. At harvest, fruits from all treatments were rated for russet (see rating procedure below). The experiment was conducted one week after full bloom and then repeated three weeks after full bloom.

Results are given in Appendix I.

Summary: After inoculating fruit with *A. pullulans* the population of the fungus declined over a 48 h period at which point it was comparable to populations on non-inoculated fruit (about 10^5 spores/gram of fruit). When captan was applied to the fruit, the population declined (usually be a factor of 10). However, significant numbers of *A. pullulans* remained on the fruit surfaces even after a thorough application of captan. This may indicate that the fungicide was not contacting the fungus or that part of the fungus population is resistant to captan.

In the first replication of the experiment (done one week after full bloom) fruit carried a level of about 3 X 10^6 spores of *A. pullulans* one hour after inoculation and the severity rating of russet at harvest was 19.68. When captan was applied 1, 6 or 24 hour after fungal inoculation the severity at harvest was significantly reduced. If applied 48 h after the fungus, russet was not reduced. This may indicate that russet is induced on fruit within a short period (less than 48 h) after fungal populations reach a certain threshold. In the second replication (done 3 week after full bloom) about 10-fold fewer *A. pullulans* spores were applied. However, russet severity was greater (23.40) than in replication one. This could mean that fruit are more susceptible to russet 3 weeks after full bloom. In replication two, none of the captan applications resulted in decreased russet severity.

We have speculated that inconsistencies in the effectiveness of fungicides for reducing russet may because of fungicide resistance. We selected 50 isolates of *A. pullulans* from fruit in the above experiments and are testing them for sensitivity to captan. Results from the first group of isolates is given below and clearly shows that some isolates appear resistant to captan. Interestingly, an isolated that was obtained from Norway Spruce (probably never had contact with captan) was highly sensitive to the fungicide. We plan to complete this screening process and to also screen other fungicides that have shown activity against russet.

3. Identify effective control strategies for russet and determine factors that affect their performance.

None of the fungicides tested thus far control russet all of the time, however those that have shown activity against russet include captan, polyram, thiram, mancozeb and the strobilurin fungicides Sovran and Flint. We hypothesized that factors affecting fungicide effectiveness may be spray coverage, rainfall following application and variation in the sensitivity of isolates of *A. pullulans* to the fungicides. Spray coverage should not be a problem in our experiments since fruits are sprayed to runoff with a handgun sprayer. In addition, captan and polyram were also applied in combination with the adjuvant LI700 (a surfactant, penetrant, acidifier). We feel that it is necessary to identify alternatives to the traditional fungicides since some of them may be deregistered through FQPA, and because the fungus may develop resistance to them.

Results from the 2000 chemical control experiments are given in Appendix II.

Summary: Golden Delicious and Jonagold had the highest incidences of russet over all experiments (about 56 and 50 % of fruit, respectively). Severity of GD controls was 29.63 meaning that severity ratings per fruit averaged greater than one (4 to 20% of the fruit surface with russet). For Jonagold (severity of 16.97) ratings averaged much less than one. All treatments reduced the incidence of russet on both cultivars. Severity on Goldens was significantly reduced by Captan/Sovran, Sovran and by Polyram/Sovran. All treatments reduced the severity on Jonagold. Other cultivars had low incidences and low severity ratings making it difficult to separate out differences between treatments. On Empire and Jonagold, LI700 alone reduced the severity of russet. Since LI 700 is an acidifier, under certain conditions it may create an environment that is not favorable for the fungus. This finding warrants further investigation since LI700 may provide an alternative to fungicides for russet control.

<u>Non-technical summary of the relevance of research results and how they impact IPM</u>

We have discovered that two common fungi, *A. pullulans* and *R. glutinis* are able to cause russet on apple and pear and we believe that they are important causes of russet in NY orchards. *A. pullulans* causes the most severe russet and therefore most of our research has been focused on it. It has been determined that several varieties are affected by russet and that *A. pullulans* is commonly found sporulating in russeted tissues. Isolates of *A. pullulans* from several different sources were all able to cause russet. A grower/processor/consultant survey provided additional information on apple varieties that are most affected by russet, factors that growers and consultants have observed that contribute to russet and information on the monetary significance of russet on apple in NY state.

Research this year suggests that *A. pullulans* may induce russet after a short contact period with fruit. However additional experiments will be needed to prove this point. Such information suggests that once *A. pullulans* reaches a certain population level on fruit, it can induce russet within 48 hours. Therefore, we are attempting to determine which factors affect population buildup and then it will be possible to circumvent the russet process.

Related research with Dr. Martin Goffinet this year also provides evidence suggesting that the fungus induces russet rapidly after reaching a certain population threshold. This was done by making observations of fungus-fruit interactions using electron and light microscopy. Previously it was observed that the fungus causes erosion of the fruit wax and cuticle layers. This year it was first observed that the fungus induces cell divisions in outer apple tissues that are associated with the classical wound response. Additional research is needed to explain why often only certain segments of the fruit become russeted following inoculation of the entire fruit.

Although some fungicides, such as captan, are inhibitory to russet fungi, control is erratic. We discovered that this may result because a certain component of the fungal population is resistant of the fungicide. It may be that isolates from apple (having been exposed to captan) are more likely to be resistant than are isolates from other plants that are not sprayed. Further research is needed to determine whether the fungus is resistant to other fungicides that could be used to reduce russet severity (Polyram, Sovran). The adjuvant, penetrant, acidifier, LI700, also significantly reduced russet on some varieties. It may be that the material is altering the fruit surface in a way that the fungus does not survive well. This could provide an alternative to fungicides for russet control and therefore warrants further investigation.

Appendix I. Effect of captan on populations of *A. pullulans* on fruit and subsequent russet development

	Average population of *A. pullulans*/gm fruit		
Treatment, rep 1	**0 hr**	**24 hr**	**1 week**
Captan, 1 hr	3×10^6	7×10^5	5×10^5
Captan, 6 hr	3×10^6	4×10^4	2×10^5
Captan, 24 hr	8×10^5	3×10^4	4×10^4
Captan, 48 hr	5×10^5	4×10^4	1×10^4
Non-inoc. No captan	3×10^5		
Replication 2			
Captan, 1 hr	4×10^5	5×10^4	4×10^4
Captan, 6 hr	2×10^5	9×10^4	2×10^4
Captan, 24 hr	3×10^5	5×10^4	5×10^4
Captan, 48 hr	1×10^5	6×10^4	2×10^3
Non-inoc. No captan	1×10^5		

	Results for Replication 1		**Results for Replication 2**	
Treatment	**Russet Incidence**	**Russet Severity**	**Russet Incidence**	**Russet Severity**
Nontreated	5.33 c	16.52 ab	7.67	16.70 c
Inoc. No captan	29.00 a	19.68 a	50.00 ab	23.40 bc
Inoc. Captan 1hr	28.33 a	14.80 bc	65.33 a	33.39 a
Inoc. Captan 6 hr	24.00 ab	11.88 c	51.00 ab	25.64 ab
Inoc. Captan 24 hr	11.67 bc	11.96 c	46.67 b	21.92 bc
Inoc. Captan 48 hr	36.00 a	17.00 ab	50.67 ab	23.40 bc

Appendix II, Effect of Chemical Applications on the Development of Russet

Fruit were sprayed beginning at 1/4-in green with labelled rates of all chemicals used.
Data was collected at harvest from 50 fruit per each of three or four replications per cultivar.

<u>**Fruit russet rating**</u>: Fruit were rated on a scale of 0 to 4 based on an approximation of the area of fruit surface with russet. A rating of 0 (0 to 3% of the fruit surface having russet); 1 (4 to 20% russet); 2 (21 to 45% russet); 3 (46 to 74% russet) or 4 (greater than 75% russet) were given to each fruit.

Severity values for russet was calculated for each replication as: [Σ (rating X the number of fruit with the rating) / 4 X total number of fruit] X 100**.** Ratings given in the tables for each treatment equal the average russet severity rating. Values in same column followed by different letters differ significantly at *P*= 0.05 according to the SAS General linear Models *t* test.

Golden Delicious Russet

Treatment	**Incidence**	**Severity**
Control	28.33 a	29.63 a
LI700	17.67 b	29.76 a
Polyram	8.00 bcd	21.97 ab
Polyram LI700	9.67 bcd	22.62 ab
Captan	12.00 bcd	21.71 ab
Captan/Sovran	8.67 bcd	20.64 b
Captan/LI700	16.33 bc	21.45 ab
Sovran	7.00 cd	20.37 b
Polyram/Sovran	6.00 d	15.66 b
LSD	10.29	8.89

	Jonagold Russet		**Empire Russet**	
Treatment	**Incidence**	**Severity**	**Incidence**	**Severity**
Control	24.50 a	16.97 a	5.00 a	11.98 a
LI700	9.00 b	10.94 b	0.50 d	2.66 f
Polyram	7.25 bc	9.99 b	2.50 abcd	5.99 cde
Polyram LI700	4.50 cd	9.45 b	2.25 bcd	7.61 cde
Captan	6.50 bcd	9.95 b	4.00 ab	10.58 ab
Captan/Sovran	7.75 bc	11.66 b	2.50 abcd	8.06 bcd
Captan/LI700	6.25 bcd	9.55 b	4.25 ab	8.51 bc
Sovran	5.25 bcd	9.64 b	0.50 d	4.00 ef
Polyram/Sovran	2.75 d	9.69 b	3.50 abc	6.38 cde
Ziram	6.75 bcd	11.93 b	1.25 cd	5.31 def
LSD	4.18	3.39	2.73	2.79

	McIntosh Russet		Crispin Russet	
Treatment	**Incidence**	**Severity**	**Incidence**	**Severity**
Control	5.00 a	17.46 ab	9.67 a	21.81 a
LI700	3.75 a	15.98 abc	1.00 b	10.34 a
Polyram	3.50 a	13.73 abc	7.00 ab	18.02 a
Polyram/LI700	3.25 a	17.96 ab	3.33 ab	14.78 a
Captan	4.00 a	12.96 bc	1.00 b	11.12 a
Captan/Sovran	2.25 a	16.02 abc	3.33 ab	15.80 a
Captan/LI700	3.25 a	16.92 abc	7.67 ab	22.28 a
Sovran	3.25 a	18.50 a	6.33 ab	19.82 a
Polyram/Sovran	2.00 a	12.02 c	8.33 ab	18.32 a
Ziram	3.00 a	13.46 bc	4.00 ab	18.08 a
LSD	3.40	4.99	8.27	12.86

Inhibition of *A. pullulans* growth by captan

		Concentration of Captan				
***A. pullulans* isolate**	**Source**	**.3 mg/ml**	**.6 mg/ml**	**1.2 mg/ml**	**1.6 mg/ml**	**2.4* mg/ml**
YT 16	Apple	0.67	2.33	2.67	4.00	5.00
YT 142	Pear	2.00	2.67	5.00	6.00	6.33
YT 170	Norway Spruce	0.00	2.33	3.33	3.33	4.67
YT 175	Grape	0.00	0.00	0.50	0.17	0.00
ATCC 11942		0.50	1.00	2.00	3.00	4.00
YT 301	Apple, 2000	0.00	0.33	0.67	1.67	2.67
YT 302	“	5.33	6.33	7.33	8.00	6.00
YT 303	“	5.33	8.33	9.00	10.00	10.00
YT 304	“	0.00	1.00	2.33	2.67	0.17
YT 305	“	0.67	0.33	0.50	0.50	1.00
YT 306	“	0.17	0.67	0.83	1.33	1.33
YT 307	“	0.00	0.50	1.33	1.67	1.67
YT 308	“	0.00	0.17	0.50	0.67	1.33
YT 309	“	0.00	0.17	0.17	0.00	0.50
YT 310	“	0.00	0.50	1.00	1.33	2.00

*** concentration equal to 2 lb/100 gal**