Chapter 6
Summary and Future Research

Through RAPD-PCR and *Wolbachia* strain analysis, plum curculios of unknown strains (univoltine vs. multivoltine) can quickly be categorized in the laboratory. This will allow testing of the plum curculio taken in transects across Virginia. If no multivoltine populations are found, then the export barriers currently being sanctioned against Virginia fruit are unfounded and could be lifted. Periodic testing of the populations to determine the arrival or natural and human-mediated spread of multivoltine populations should be done.

Testing plum curculio in Virginia using the RAPD assay and a *Wolbachia* assay will allow a better understanding of the genetics of plum curculio in this state. Other states can adapt these assays to test their populations of plum curculio. Multivoltine population ranges can then be mapped and a 'big picture' approach to dealing with this strain can be developed.

Because there is no genetic information in GenBank on plum curculio, future work arising from the RAPDs should include the characterization of some of the amplimers that characterize one population from the other. Building a body of genetic information will allow researchers to look for more differences between the two strains of plum curculio on a molecular level. This could eventually payoff in greater understanding of the differences of behaviour between the two strains. A better understanding of the behaviours will allow for better management of this pest.

The discovery of *Wolbachia* infections in plum curculio indicates that *Wolbachia* infection may impact strain variation and voltinism. The fitness costs of *Wolbachia* infections are unknown. The histological changes seen by Padula and Smith (1971) may be caused by the *Wolbachia* infection, or may be a separate prezygotic barrier to interbreeding strains of plum curculio. Based on Shoemaker et al. (1999) and Bordenstein et al. (2001) this may be the beginning of speciation between the univoltine strains and the multivoltine strains of plum curculio. Or it may only establish a *status quo* between the two populations in areas where both strains of plum curculio are present.

The effect of the host on the *Wolbachia* is also unknown. Specific strains of *Wolbachia* are closely linked to certain mitochondrial haplotypes in *Drosophila* spp. (O'Neill 1997). Perhaps the mitochondria of the univoltine and multivoltine strains have evolved so that the infections of *Wolbachia* in plum curculio are linked also. Then the mitrochondria within a population of plum curculio would control the infection of *Wolbachia* present in that population, thus creating even more definitive strains of plum curculio. This along with the seasonal differences in behaviour and reduced fecundity may be evidence enough to separate the strains by giving them a tri-nomial.

The trapping studies suggest that no effective trapping systems are available for plum curculio in Virginia orchards. These results; however, contradict the literature. Perhaps some geographical influence is responsible for these differences.

There is much more research to be done with plum curculio. For the growers of fruit in Virginia and elsewhere, effective trapping systems must be found. This is a basic requirement for IPM programs. Efforts are ongoing in Virginia and West Virginia to unravel the visual and olfactory cues that are attractive to plum curculio. Another area of research is the cues that are repellent to the plum curculio adults. This work has been started by Dr. T. Leskey at USDA-ARS in West Virginia.

References

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Appendix A

Nucleotide and Predicted Protein Sequence Similarities for 29 *Wolbachia wsp* gene sequences from different hosts.

Above the line is nucleotide similarity, below the line of asterisks is predicted protein similarity.

	*w*Dro	Atab-1	*W*whi	*w*Nov	*w*Naw	*w*Des	FLA	Aus	*w*AscD	GA
Trichopria drosophilae	*	99.6	94.85	91.68	88.71	90.29	89.9	89.7	89.5	89.1
Asobara tabida	99.33	*	94.85	91.68	88.71	90.29	89.9	89.7	89.5	89.1
Lutzomyia shannoni	90	90	*	91.29	87.52	89.5	89.11	88.91	88.71	88.71
Aedes novoniveus	85.33	85.33	87.33	*	88.32	89.7	89.5	89.11	89.31	88.92
Telenomus nawai	78.67	78.67	78	78	*	86.93	86.53	86.34	86.14	86.14
Dacus destillatoria	85.33	85.33	86	85.33	81.33	*	99.6	99.01	98.81	98.81
Florida Curculios	85.33	85.33	86	85.33	81.33	100	*	98.61	98.41	98.41
Callosobruchus chinensis	83.33	83.33	84	83.33	79.33	98	98	*	97.82	97.82
Bactrocera sp.	84.67	84.67	86.67	87.33	78.67	94.67	94.67	92.67	*	97.62
Georgia Curculios	72.67	72.67	72.67	72	67.33	80.67	80.67	79.33	78.67	*
Muscidifurax uniraptor	74.67	74.67	76	78	71.33	87.33	87.33	86.67	82.67	68
Pachycrepoideus dubius	76	76	77.33	78	71.33	87.33	87.33	86.67	82.67	68
Armigeres subalbatus	74	74	75.33	74.67	67.33	83.33	83.33	83.33	80	66
Phlebotomus papatasi	80	80	81.33	81.33	75.33	91.33	91.33	90	86.67	72
Phlebotomus perniciosus	72	72	72	71.33	74	72	72	70.67	72	62
Bemisia tabaci 5	72.67	72.67	72.67	72	75.33	73.33	73.33	72	73.33	61.33
Bemisia tabaci 2	72.67	72.67	72.67	72	75.33	73.33	73.33	72	73.33	61.33
Bemisia tabaci 1	72.67	72.67	72.67	72	75.33	73.33	73.33	72	73.33	61.33
Dryinid wasp	72.67	72.67	72.67	72	75.33	73.33	73.33	72	73.33	61.33
Coquillettidia crassipes	72	72	72	71.33	74.67	72.67	72.67	71.33	72.67	60.67
Aleurotrachelus sp.	72.67	72.67	72.67	72	75.33	73.33	73.33	72	73.33	61.33
Culex sitiens	72	72	72	72	75.33	73.33	40	72	73.33	61.33
Torymus bedeguaris	72.67	72.67	72.67	72	75.33	73.33	73.33	72	73.33	61.33
Tribolium confusum	72.67	72.67	72.67	72	75.33	73.33	73.33	72	73.33	62
Bactrocera pyrifoliae	72.67	72.67	72.67	71.33	75.33	74	74	72.67	72.67	61.33
Bactrocera cucurbitae	72.67	72.67	72.67	71.33	75.33	74	74	72.67	72	61.33
Acraea encedon	74	74	74	72.67	77.33	74.67	74.67	73.33	74	62.67
Massachusetts Curculios	73.33	73.33	73.33	70.67	73.33	74	74	72.67	72	64
Perithemis tenera	72.67	72.67	72.67	71.33	74	72.67	72.67	71.33	72.67	62.67

Trichopria drosophilae = *w*Dro
Lutzomyia shannoni = *w*Whi
Telenomus nawai = *w*Naw
Florida Curculios = FLA
Bactrocera sp.= *w*AscD
Muscidifurax uniraptor =*w*Uni
Armigeres subalbatus = *w*Sub
Phlebotomus perniciosus = *w*Prn
Dryinid wasp = *w*Dry
Aleurotrachelus sp. = *w*Alesp
Torymus bedeguaris = *w*Bed
Bactrocera pyrifoliae = *w*Pyr
Acraea encedon = *w*Enc
Perithemis tenera = *w*Ten

Asobara tabida = Atab-1
Aedes novoniveus = *w*Nov
Dacus destillatoria = *w*Des
Callosobruchus chinensis = Aus
Georgia Curculios= GA
Pachycrepoideus dubius = Pdub
Phlebotomus papatasi = *w*Pap
Bemisia tabaci (5, 2, 1) =Btab 5, 2, 1
Coquillettidia crassipes = *w*Cra
Culex sitiens = *w*Sit
Tribolium confusum = *w*Con
Bactrocera cucurbitae = *w*Cur
Massachusetts Curculios = MA

	*w*Uni	Pdub1	*w*Sub	*w*Pap	*w*Prn	*w*Btab5	*w*Btab2	*w*Btab1	*w*Dry	*w*Cra
Trichopria drosophilae	83.36	83.96	82.38	80.99	84.15	84.36	84.36	84.36	84.36	84.16
Asobara tabida	83.76	84.36	82.38	80.99	84.15	84.36	84.36	84.36	84.39	84.16
Lutzomyia shannoni	82.77	83.37	82.38	81.58	81.98	81.98	81.98	81.98	81.98	81.78
Aedes novoniveus	82.97	83.17	80.99	80.59	80.79	81.39	81.39	81.39	81.39	81.19
Telenomus nawai	79.6	79.8	77.03	77.03	80.99	80.79	80.79	80.79	80.79	80.59
Dacus destillatoria	89.11	89.31	85.35	84.95	80.99	81.39	81.39	81.39	81.39	81.19
Florida Curculios	88.71	88.91	84.95	84.55	80.59	80.99	80.99	80.99	80.99	80.79
Callosobruchus chinensis	88.51	88.71	85.15	84.55	80.59	80.99	80.99	80.99	80.99	80.79
Bactrocera sp.	87.92	88.12	84.16	83.76	80.99	80.79	80.79	80.79	80.79	80.59
Georgia Curculios	87.92	88.12	84.16	83.96	79.8	80.2	80.2	80.2	80.2	80
Muscidifurax uniraptor	*	99.4	92.47	84.36	77.03	77.42	77.42	77.42	77.42	77.23
Pachycrepoideus dubius	98.67	*	93.07	84.95	77.23	77.62	77.62	77.62	77.62	77.42
Armigeres subalbatus	90.67	92	*	82.57	77.62	77.62	77.62	77.62	77.62	77.42
Phlebotomus papatasi	90	91.33	85.33	*	76.43	77.23	77.23	77.23	77.23	77.03
Phlebotomus perniciosus	68.67	68.67	66.67	71.33	*	96.24	96.24	96.24	96.24	96.04
Bemisia tabaci 5	70	70	67.33	72.67	94	*	100	100	100	99.8
Bemisia tabaci 2	70	70	67.33	72.67	94	100	*	100	100	99.8
Bemisia tabaci 1	70	70	67.33	72.67	94	100	100	*	100	99.8
Dryinid wasp	70	70	67.33	72.67	94	100	100	100	*	99.8
Coquillettidia crassipes	69.33	69.33	66.67	72	93.33	99.33	99.33	99.33	99.33	*
Aleurotrachelus sp.	70	70	67.33	72.67	94	100	100	100	100	100
Culex sitiens	70	70	66.67	72.67	93.33	99.33	99.33	99.33	99.33	98.67
Torymus bedeguaris	70	70	67.33	72.67	93.33	98.67	98.67	98.67	98.67	98
Tribolium confusum	70	70	67.33	72.67	92.67	99.33	99.33	99.33	99.33	98.67
Bactrocera pyrifoliae	70.67	70.67	67.33	73.33	92.67	98	98	98	98	97.33
Bactrocera cucurbitae	70.67	70.67	67.33	73.33	92.67	97.33	97.33	97.33	97.33	96.67
Acraea encedon	70.67	70.67	68	73.33	91.33	96	96	96	96	95.33
Massachusetts Curculios	68.67	70	68	74	90	85.33	85.33	85.33	85.33	84.67
Perithemis tenera	68	68	66	72	92.67	86.67	86.67	86.67	86.67	86

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	*w*Alesp	*w*Sit	*W*Bed	*w*Con	*w*Pyr	*w*Cuc	*w*Enc	MA	*w*Ten
Trichopria drosophilae	84.36	83.96	84.55	84.55	83.76	83.56	85.54	81.58	82.77
Asobara tabida	84.36	83.96	84.55	84.55	83.76	83.56	85.54	81.58	82.77
Lutzomyia shannoni	81.98	81.58	82.18	82.18	81.58	81.39	82.38	79.41	81.39
Aedes novoniveus	81.39	80.99	81.19	81.19	80.2	80.2	81.39	77.23	79.6
Telenomus nawai	80.79	80.39	80.59	80.59	79.6	79.6	81.19	78.22	79.8
Dacus destillatoria	81.39	80.99	81.39	81.58	80.39	80.39	81.39	77.42	81.39
Florida Curculios	80.99	80.59	80.79	81.19	80	80	80.99	77.03	80.99
Callosobruchus chinensis	80.99	80.59	80.79	81.19	80	80	80.99	77.03	80.99
Bactrocera sp.	80.79	80.39	80.59	80.99	79.8	79.8	80.79	77.23	81.19
Georgia Curculios	80.2	79.8	80	80.39	79.21	79.21	80.2	76.24	80.2
Muscidifurax uniraptor	77.42	77.03	77.23	77.62	76.24	76.24	77.42	71.48	75.64
Pachycrepoideus dubius	77.62	77.23	77.42	77.82	76.43	76.43	77.62	72.08	75.84
Armigeres subalbatus	77.62	77.23	77.82	78.22	76.83	76.83	77.62	72.47	76.04
Phlebotomus papatasi	77.23	76.83	77.03	77.23	76.04	76.04	76.83	71.68	74.85
Phlebotomus perniciosus	96.24	95.84	96.04	96.63	95.44	95.44	94.85	89.5	91.09
Bemisia tabaci 5	100	99.6	99.4	98.41	98.41	98.22	98.22	88.71	90.1
Bemisia tabaci 2	100	99.6	99.4	98.41	98.41	98.22	98.22	88.71	90.1
Bemisia tabaci 1	100	99.6	99.4	98.41	98.41	98.22	98.22	88.71	90.1
Dryinid wasp	100	99.6	99.4	98.41	98.41	98.22	98.22	88.71	90.1
Coquillettidia crassipes	99.8	100	99.4	99.6	98.22	98.22	98.02	88.51	89.9
Aleurotrachelus sp.	*	99.6	99.4	98.41	98.41	98.22	98.22	88.71	90.1
Culex sitiens	99.33	*	99.01	98.02	98.02	97.82	97.82	88.31	89.7
Torymus bedeguaris	98.67	98	*	98.22	98.22	98.02	98.02	88.12	89.5
Tribolium confusum	99.33	98.67	98	*	98.02	97.82	97.42	88.12	89.9
Bactrocera pyrifoliae	98	97.33	96.67	97.33	*	99.8	97.82	87.52	88.71
Bactrocera cucurbitae	97.33	96.67	96	96.67	99.33	*	97.62	87.52	88.71
Acraea encedon	96	95.33	94.67	95.33	95.33	94.67	*	87.33	88.51
Massachusetts Curculios	85.33	85.67	84	84.67	84.67	84.67	84	*	91.48
Perithemis tenera	86.67	86	86	86	86	86	85.33	97.33	*

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