Chapter Six
Summary and Recommendations

The need to understand the impact of re-emerging viruses in Virginia soybean must be given the attention it deserves if the level of soybean production is to be sustained or improved. This is because some viruses, which were considered less important in soybean, are fast gaining prominence and some of these virus isolates are highly virulent. *Bean pod mottle virus* (BPMV, Genus *Comovirus*, Family: *Comoviridae*) is a virus that has been known to occur in Virginia (Skotland, 1958).

Field surveys have demonstrated that BPMV is in soybeans grown in Virginia, and while there is low incidence, there is no adequate information on what is exactly going on in terms of the actual spread of BPMV in the state. This is because there have been erratic and sporadic surveys. BPMV is on the increase in all soybean growing areas in the USA (Giesler et al., 2002). The spread of BPMV to other countries like Canada, Brazil and Peru soybean (Fribourg and Pérez 1994; Anjos et al., 1999; Michelutti et al., 2002) is also an indication that the virus will soon be an international problem. According to Tolin and Lacy (2004) there may be high diversity of Comoviruses in South America. Whether this spread to other areas will mean more virulent isolates, is not known at this time. Because no high resistance to BPMV is currently available, this raises a number of challenges. These challenges include proper documentation of BPMV isolates existing in a locale, proper documentation of the different characteristics of the existing isolates, and the need to accurately assess and provide a database of the actual impact of these isolates on different cultivars in terms of quality and yield losses.

There are a number of gaps in the proper understanding of the epidemiology of BPMV and even though a few breakthroughs in molecular approaches have been made, such as sequencing of RNA1 and RNA2, more research will be needed to complete our understanding on how the virus spreads especially in reservoir hosts. In studies where the source of inoculum has been investigated, only a few plants believed to act as reservoir hosts have tested positive for BPMV (Krell et al., 2003). Seed transmission of the virus in soybeans is less than 1%. It has also been shown that overwintering beetles

are not very efficient transmitters of the virus. These observations have left a number of researchers concerned with how BPMV spreads in nature.

It is therefore imperative that more surveys should be conducted in all soybean growing areas to collect and characterize existing isolates and observe any new or re-assortment among existing isolates.

The results from enhanced synergistic interactions of new isolates of BPMV and SMV on Hutcheson soybean and its Roundup Ready® isolines have been demonstrated in only one year's field research. Due to lack of financial resources and time, it was not possible to repeat the same experiment in the greenhouse or field. The findings from the field experiments have shown that Hutcheson and its isolines are vulnerable to BPMV and SMV isolates. It is imperative that the same experiment should be repeated in the greenhouse. There should be a second years field data to confirm the result, which may be an important step in formulating management strategies for these viruses.

This study has also demonstrated super-sensitivity of Hutcheson to the new Virginia isolates, alone and in combination, raising a question of whether there is a need to incorporate another SMV *R* gene in Hutcheson. This will present another challenge to breeders. The time of inoculum introduction into the host plant may also be playing a vital role in determining the overall disease outcome. And whether growers adequately incorporate effective vector control coupled with proper cultural practices may be another dimension that needs to be explored if adequate disease management strategies have to be used to control quality and yield losses from BPMV and SMV.

Finally, a phenomenon was observed at the Glade Road soybean Nursery, at Virginia Polytechnic Institute and State University in Blacksburg, whereby although cultivars tested for seed transmission were grown from seeds harvested from plants previously inoculated with BPMV isolates and known to have shown symptoms of BPMV infection, most of the leaf blot immunoassay results of plants emerging from seeds harvested from these plants were positive for SMV. In most tests there were less than 30% of positive cases of BPMV compared to 70% of highly positive SMV results. This phenomenon generated curiosity about what exactly is happening when seeds harvested from BPMV inoculated plants are replanted in the field. More research is needed to clarify this observation.

REFERENCES

Anjos, J. R. N., P. S. T. Brioso, and M. J. A. Charchar. 1999. Caracterização parcial de um isolado do "bean pod mottle virus" no Brasil. Fitopatologia Brasil. 24: 85-87.

Fribourg, C. E., and W. Pérez. 1994. Bean pod mottle virus (BPMV) affecting *Glycine max* (L.) Merr. in the Peruvian jungle. Fitopatologia 29: 207-210.

Giesler, L. J., S. A. Ghabrial, T. E. Hunt, and J. H. Hill. 2002. Bean pod mottle virus: A threat to U. S. soybean production. Plant Dis. 86: 1280-1289.

Krell, R. K., L. P. Pedigo, J. H. Hill, and M. E. Rice. 2003. Potential primary inoculum sources of *Bean pod mottle virus* in Iowa. Plant Dis. 87: 1416-1422.

Michelutti, R., J. C. Tu, D. W. A. Hunt, D. Gagnier, T. R. Anderson, and T. W. Welacky. 2002. First report of *Bean pod mottle virus* in soybean in Canada. Plant Dis. 86: 330.

Tolin, S. A., and G. H. Lacy. 2004. Viral, bacterial, and phytoplasmal diseases. p. 765-819. *In*: Boerma, H. R., and J. E. Specht (eds.) Soybeans: Improvement, production, and uses. 3rd edition, American Society of Agronomy, Inc., Madison, Wisconsin.

Appendices

Appendix A: References from web pages

Holshouser, D. 2004. Soybean production in Virginia. http://www.vaes.vt.edu/tidewater/soybean/, (retrieved 4. 5. 2004).

States planting soybean (USA). 2004. Joint Agricultural Weather Facility of NOAA/ USDA, retrieved 3. 20. 2004).

Sullivan, P. 2003. Edible soybean production and marketing. Curren. Topic, www.attra.ncat.org (retrieved 6.12.04).

USDA. 2003. Global crop production review. http://www.Soyatech.com; (retrieved 6.12.04).

Virginia Statistics. 2004. USDA, National Agricultural Statistics Services. http://www.nass.usda.gov:81/ipedb/ (retrieved 03. 20. 04).

Appendix B: Soybean Cultivars and Lines

Row #	Name	Pedigree	MG	Foliar1	Foliar2	Seed WT	ELISA
SMV Inoculated							
1001	Lee 68		6	1.0	1.0	8.4	0.913
1002	York		5	1.0	1.0	11.0	0.107
1003	Essex		5	2.0	1.0	9.1	0.134
1004	V73-178		5	1.0	2.0	11.5	0.106
1005	MANOKIN	L70-L3048 × D74-7824	Uni4	1.5	2.0	9.5	0.581
1006	KS4602N	Delsoy4710 × K1191	Uni4	1.0	2.0	14.3	0.097
1007	DK4868 (RR)	Commercial Check RR	Uni4	1.5	1.0	14.2	0.855
1008	5002T	N85-578 × Manokin	Uni4	1.5	1.0	9.9	0.048
1009	DT97-4290	A5979 × DP3478	Uni4	2.0	2.0	14.8	0.070
1010	DT98-7278	Hutcheson × (D91-4657 × P9592)	Uni4	1.5	1.0	10.4	0.050
1011	DT98-9102	N90-516 × P9592	Uni4	2.0	1.0	8.2	1.349
1012	DT99-17018	DT96-6840 × Bolivar	Uni4	1.0	1.0	9.3	0.023
1013	DT99-17400	UARK5798 × Bolivar	Uni4	2.0	1.0	9.5	0.047
1014	K1539RR	KS4895///KS4895//Resnik2/40-3-2	Uni4	2.5	3.5	13.3	0.916
1015	K1574	BP KY90-120,NK S42-60,P9521	Uni4	1.0	1.0	11.1	0.043
1016	K1575	BP, K1218,S92-1403,N93-54	Uni4	3.0	5.0	9.8	0.634
1017	LS99-3619	LS79-238 × KY88-4080	Uni4	3.5	4.0	9.9	0.956
1018	LS99-3630	LS79-238 × KY88-4080	Uni4	3.5	5.0	10.1	1.224
1019	Md 97-6491	Holladay × Stressland	Uni4	1.0	1.0	16.2	0.063
1020	Md 99-1098-2RR	MD92-5769 × (MD92-5769 × Monsanto RR)	Uni4	1.0	1.0	9.3	0.688
1021	R96-1689F	A4715 × HS89-3261	Uni4	3.0	4.0	10.1	0.813
1022	R98-1817	HARTZ 5545 × KS 4895	Uni4	2.5	3.0	6.7	1.048
1023	R99-2088	N90-516 × Hartz 4994	Uni4	1.0	1.0	8.4	0.070
1024	R99-2172	N90-516 × Hartz 4994	Uni4	1.5	1.0	8.3	0.038
1025	R00-1158F	A4715 × DP 3478	Uni4	2.0	1.0	14.6	0.039
1026	S99-2281	N90-516 × S92-1069	Uni4	3.0	4.0	7.4	1.351
1027	S00-9925-10	K1393 × Anand	Uni4	3.0	3.0	8.9	0.900
1028	TN96-115	K1192 × Manokin	Uni4	3.0	4.0	8.1	1.290

1029	TN00-60	MD92-5769 × Fillmore	Uni4	1.0	2.0	10.7	0.039
1030	V99-0023	KS4895 × TN90-03	Uni4	2.5	4.0	12.7	0.930
1131	RT-3799N		3	4.0	3.0	12.5	0.808
1132	RT-3975		3	3.5	5.0	4.9	1.108
1133	4512RR/N		4E	4.0	5.0	10.0	1.238
1134	DKB44-51		4E	2.5	5.0	9.2	1.232
1135	DP4344RR		4E	2.5	4.0	13.9	0.854
1136	DP4690RR		4E	2.5	4.0	11.8	1.065
1137	RT-4098		4E	2.0	3.0	13.0	1.008
1138	S46-W8		4E	2.0	3.0	12.7	0.105
1139	Stressland		4E	1.0	2.5	12.8	0.112
1140	V442NRR		4E	1.0	2.0	12.4	0.124
1141	V462NRS		4E	1.0	2.0	12.1	1.213
1142	94B73		4L	1.5	4.0	12.0	1.197
1143	DK4868RR		4L	1.5	3.0	13.2	0.139
1144	DP4748S		4L	1.0	2.0	10.0	0.171
1145	RT-4980		4L	2.5	3.0	13.7	0.967
1146	540nRR		4L	1.0	2.0	9.7	1.349
1147	7522nRR		4L	3.0	4.0	9.9	0.078
1148	Aoba		5E	1.0	2.0	7.3	0.093
1149	Delsoy 5500		5E	1.0	1.0	11.4	0.085
1150	DP5110S		5E	1.0	1.0	12.8	0.041
1155	DP5414RR		5E	1.0	2.0	9.0	1.267
1156	DP5644RR		5E	3.0	4.0	8.1	1.673
1157	MFS-553		5E	4.0	5.0	1.4	1.038
1158	RT-5001N		5E	2.5	4.0	8.7	1.332
1159	RT-557N		5E	2.5	3.0	7.9	0.853
1160	S52-U3		5E	2.0	2.5	7.2	0.714
1161	95B96		5L	1.0	2.0	8.7	0.002
1162	Anand		5L	1.5	3.0	8.4	0.423
1163	DP5915RR		5L	1.0	1.0	8.5	0.415
1164	MFS-591		5L	3.0	4.0	4.2	1.235

Non-inoculated

2001	Lee 68		6	1.0	1.0	8.2	ND
2002	York		5	1.0	1.0	10.7	ND
2003	Essex		5	1.0	1.0	12.4	ND
2004	V73-178		5	1.0	1.0	9.0	ND
2005	MANOKIN	L70-L3048 × D74-7824	Uni4	1.0	1.0	9.7	ND
2006	KS4602N	Delsoy4710 × K1191	Uni4	1.0	1.0	15.2	ND
2007	DK4868 (RR)	Commercial Check RR	Uni4	1.0	1.0	13.1	ND
2008	5002T	N85-578 × Manokin	Uni4	1.0	1.0	10.7	ND
2009	DT97-4290	A5979 × DP3478	Uni4	2.0	2.0	14.1	ND
2010	DT98-7278	Hutcheson × (D91-4657 × P9592)	Uni4	1.0	2.0	9.8	ND
2011	DT98-9102	N90-516 × P9592	Uni4	1.0	2.0	9.3	ND
2012	DT99-17018	DT96-6840 × Bolivar	Uni4	1.0	3.0	10.2	ND
2013	DT99-17400	UARK5798 × Bolivar	Uni4	1.0	3.0	10.2	ND
2014	K1539RR	KS4895///KS4895//Resnik2/40-3-2	Uni4	1.0	2.0	14.3	ND
2015	K1574	BP KY90-120,NK S42-60,P9521	Uni4	1.0	2.0	11.0	ND
2016	K1575	BP, K1218,S92-1403,N93-54	Uni4	1.0	2.0	10.9	ND
2017	LS99-3619	LS79-238 × KY88-4080	Uni4	1.0	2.0	10.2	ND
2018	LS99-3630	LS79-238 × KY88-4080	Uni4	1.0	2.0	10.8	ND
2019	Md 97-6491	Holladay × Stressland	Uni4	1.0	2.0	15.8	ND
2020	Md 99-1098-2RR	MD92-5769 × (MD92-5769 × Monsanto RR)	Uni4	1.0	2.0	10.3	ND
2021	R96-1689F	A4715 × HS89-3261	Uni4	1.0	2.0	11.7	ND
2022	R98-1817	HARTZ 5545 × KS 4895	Uni4	1.5	2.0	8.8	ND
2023	R99-2088	N90-516 × Hartz 4994	Uni4	1.0	2.0	10.1	ND
2024	R99-2172	N90-516 × Hartz 4994	Uni4	2.0	2.0	9.6	ND
2025	R00-1158F	A4715 × DP 3478	Uni4	1.0	2.0	14.3	ND
2026	S99-2281	N90-516 × S92-1069	Uni4	1.0	2.0	8.8	ND
2027	S00-9925-10	K1393 × Anand	Uni4	1.0	2.0	9.4	ND
2028	TN96-115	K1192 × Manokin	Uni4	1.0	2.0	9.4	ND
2029	TN00-60	MD92-5769 × Fillmore	Uni4	1.0	2.0	11.5	ND
2030	V99-0023	KS4895 × TN90-03	Uni4	1.0	2.0	10.2	ND
2131	RT-3799N		3	1.0	1.0	13.4	ND

2132	RT-3975	3	1.5	1.0	13.8	ND
2133	4512RR/N	4E	1.0	1.0	11.2	ND
2134	DKB44-51	4E	1.0	1.0	10.4	ND
2135	DP4344RR	4E	1.0	1.0	11.9	ND
2136	DP4690RR	4E	1.0	2.5	10.8	ND
2137	RT-4098	4E	1.0	2.0	12.8	ND
2138	S46-W8	4E	1.0	1.0	11.7	ND
2139	Stressland	4E	1.0	1.0	11.8	ND
2140	V442NRR	4E	1.0	1.0	10.7	ND
2141	V462NRS	4E	1.0	1.0	13.6	ND
2142	94B73	4L	1.0	1.0	12.1	ND
2143	DK4868RR	4L	1.0	1.0	11.7	ND
2144	DP4748S	4L	1.0	1.0	12.0	ND
2145	RT-4980	4L	1.0	1.0	13.2	ND
2146	540nRR	4L	1.0	1.0	9.2	ND
2147	7522nRR	4L	1.5	1.0	7.8	ND
2148	Aoba	5E	1.0	1.0	6.1	ND
2149	Delsoy 5500	5E	1.0	1.0	10.6	ND
2150	DP5110S	5E	1.0	1.0	10.9	ND
2155	DP5414RR	5E	1.0	1.0	10.1	ND
2156	DP5644RR	5E	2.0	3.0	7.7	ND
2157	MFS-553	5E	1.0	1.0	5.3	ND
2158	RT-5001N	5E	1.0	1.0	8.2	ND
2159	RT-557N	5E	1.0	1.0	10.2	ND
2160	S52-U3	5E	1.0	1.0	7.9	ND
2161	95B96	5L	2.0	1.0	8.8	ND
2162	Anand	5L	1.0	1.0	9.7	ND
2163	DP5915RR	5L	1.0	1.0	8.4	ND
2164	MFS-591	5L	2.0	1.0	5.1	ND
BPMV Inoculated						
3001	Lee 68	6	2.0	3.0	7.5	ND
3002	York	5	2.0	3.0	9.5	ND

3003	Essex		5	2.0	3.0	8.7	ND
3004	V73-178		5	2.0	3.0	8.4	ND
3005	MANOKIN	L70-L3048 × D74-7824	Uni4	2.0	3.0	8.9	ND
3006	KS4602N	Delsoy4710 × K1191	Uni4	1.0	3.0	13.6	ND
3007	DK4868 (RR)	Commercial Check RR	Uni4	1.0	3.0	11.5	ND
3008	5002T	N85-578 × Manokin	Uni4	2.0	3.0	9.6	ND
3009	DT97-4290	A5979 × DP3478	Uni4	2.0	3.0	14.4	ND
3010	DT98-7278	Hutcheson × (D91-4657 × P9592)	Uni4	2.0	3.0	10.5	ND
3011	DT98-9102	N90-516 × P9592	Uni4	2.0	3.0	8.9	ND
3012	DT99-17018	DT96-6840 × Bolivar	Uni4	3.0	3.0	9.2	ND
3013	DT99-17400	UARK5798 × Bolivar	Uni4	3.0	3.0	9.3	ND
3014	K1539RR	KS4895///KS4895//Resnik2/40-3-2	Uni4	2.0	3.0	14.2	ND
3015	K1574	BP KY90-120,NK S42-60,P9521	Uni4	2.5	3.0	11.4	ND
3016	K1575	BP, K1218,S92-1403,N93-54	Uni4	1.0	2.0	10.5	ND
3017	LS99-3619	LS79-238 × KY88-4080	Uni4	1.5	2.0	10.2	ND
3018	LS99-3630	LS79-238 × KY88-4080	Uni4	2.0	3.0	9.7	ND
3019	Md 97-6491	Holladay × Stressland	Uni4	2.0	3.0	16.6	ND
3020	Md 99-1098-2RR	MD92-5769 × (MD92-5769 × Monsanto RR)	Uni4	2.0	3.0	9.6	ND
3021	R96-1689F	A4715 × HS89-3261	Uni4	1.0	3.0	10.6	ND
3022	R98-1817	HARTZ 5545 × KS 4895	Uni4	1.5	3.0	9.1	ND
3023	R99-2088	N90-516 × Hartz 4994	Uni4	2.0	3.0	9.9	ND
3024	R99-2172	N90-516 × Hartz 4994	Uni4	1.0	2.0	9.2	ND
3025	R00-1158F	A4715 × DP 3478	Uni4	1.5	3.0	13.5	ND
3026	S99-2281	N90-516 × S92-1069	Uni4	1.0	2.0	8.2	ND
3027	S00-9925-10	K1393 × Anand	Uni4	1.0	1.0	9.4	ND
3028	TN96-115	K1192 × Manokin	Uni4	1.5	2.5	9.1	ND
3029	TN00-60	MD92-5769 × Fillmore	Uni4	1.0	2.0	10.9	ND
3030	V99-0023	KS4895 × TN90-03	Uni4	1.0	2.0	10.4	ND
3131	RT-3799N		3	1.0	4.0	14.6	ND
3132	RT-3975		3	2.0	3.0	13.8	ND
3133	4512RR/N		4E	1.0	3.0	12.1	ND
3134	DKB44-51		4E	1.0	3.0	10.9	ND

3135	DP4344RR	4E	1.0	2.5	12.7	ND
3136	DP4690RR	4E	1.0	3.0	10.2	ND
3137	RT-4098	4E	1.0	3.0	12.6	ND
3138	S46-W8	4E	1.0	3.0	12.2	ND
3139	Stressland	4E	1.0	3.0	11.6	ND
3140	V442NRR	4E	1.0	3.0	11.4	ND
3141	V462NRS	4E	1.0	3.0	12.3	ND
3142	94B73	4L	1.0	2.5	12.3	ND
3143	DK4868RR	4L	1.0	3.0	12.0	ND
3144	DP4748S	4L	1.5	3.0	12.5	ND
3145	RT-4980	4L	1.0	3.0	12.6	ND
3146	540nRR	4L	1.0	3.0	9.7	ND
3147	7522nRR	4L	2.0	3.0	8.8	ND
3148	Aoba	5E	1.5	3.0	6.4	ND
3149	Delsoy 5500	5E	2.0	3.0	10.7	ND
3150	DP5110S	5E	2.0	3.0	12.0	ND
3155	DP5414RR	5E	1.5	3.0	9.7	ND
3156	DP5644RR	5E	1.5	3.0	8.8	ND
3157	MFS-553	5E	1.0	3.0	5.7	ND
3158	RT-5001N	5E	1.5	3.0	9.9	ND
3159	RT-557N	5E	1.5	3.0	9.1	ND
3160	S52-U3	5E	1.5	2.5	8.4	ND
3161	95B96	5L	1.5	3.0	8.0	ND
3162	Anand	5L	1.0	2.5	9.0	ND
3163	DP5915RR	5L	1.0	2.5	7.5	ND
3164	MFS-591	5L	1.0	3.0	4.7	ND

[a]ND = not determined