CHARPTER 4

Results

1. Incidence and distribution of viral diseases of cucurbits in the Royal Project's areas

1.1 Viral symptoms found in the cucurbits fields

A survey was carried out in the Royal Project's cucurbit plantations in the highland of northern Thailand. A total 8,060 samples were collected from different sites in cucurbit growing areas at ten Royal Project Development Centers (RPDCs) including 3,559 zucchini, 1,043 pumpkin, and 3,456 cucumber samples (Table 4.1). Samples with characteristic virus or virus-like symptoms were found at a higher incidence in the dry season than in rainy season. General virus symptom in the cucurbit samples included mottling, mosaic, vein banding, and leaf deformation. Severe symptoms in cucurbits included distortion and deformation of leaves and fruits. Mild mottling and mosaic symptoms were observed at the seedling stage. Mixed foliar symptoms, including mottling, mosaic, crinkling, curling, puckering, vein banding, chlorosis, and dark green knobby patches on leaf were observed from flowering to the end of cucurbit growing season (Table 4.3).

1.1.1 Viral symptoms observed on zucchini

The zucchini samples were collected from two RPDCs; Mae Hae, and Mae Tha Nuea where the crop was grown in northern Thailand. The symptoms observed in zucchini were mottling, mosaic, crinkling, curling, dark green blisters, vein banding and severe deformation of shoots (Figure 4.1). Severe symptoms on zucchini leaves were fan leaf and shoestring (Figure 4.1H-M) with reduction of fruit size and deformed fruits. The general symptoms on fruits were mottling, knobby areas, color deviation and deformed fruits (Figure 4.2). The samples collected from Mae Hae revealed several virus symptoms more than collected samples from Mae Tha Nuea. While, collected

samples from Mae Tha Nuea revealed leaf mottling, mosaic and curling and stunting (Table 4.2).

Figure 4.1 General viral foliar symptom in zucchini: mottling (A), mosaic (B), dark green blisters (C), crinkling (D), curling (E), vein banding (F), dark green patches at veins (G), fan leaf (H), various deformations (I-J) and shoe string (M).

Figure 4.2 General viral symptoms in zucchini fruits: mottling (A), mosaic (B), various types of knobs and deformation (C-H) and color deviation (I).

1.1.2 Viral symptoms observed on pumpkin

The pumpkin samples were collected from five RPDCs; Mon Ngo, Mok Cham, Wat Chan, and Kae Noi in Chiang Mai province and Mae La Noi in Mae Hong Son province where pumpkins are grown in northern Thailand. The foliar symptoms observed in pumpkin were mottling, mosaic, chlorotic spots, blistering, curling, vein banding and several other types of leaf deformations (Figure 4.3). The symptoms consisted of varying degrees of mosaic with leaf blistering and leaf deformation. Severe symptoms in pumpkin leaves were fan leaf and various leaf deformations (Figure 4.3 G-K) with deformation and reduction in size of fruits. The common symptoms on fruits were knobby areas and other types of deformation (Figure 4.4). The most severe symptoms on pumpkin samples were observed at Mon Ngo (Table 4.2).

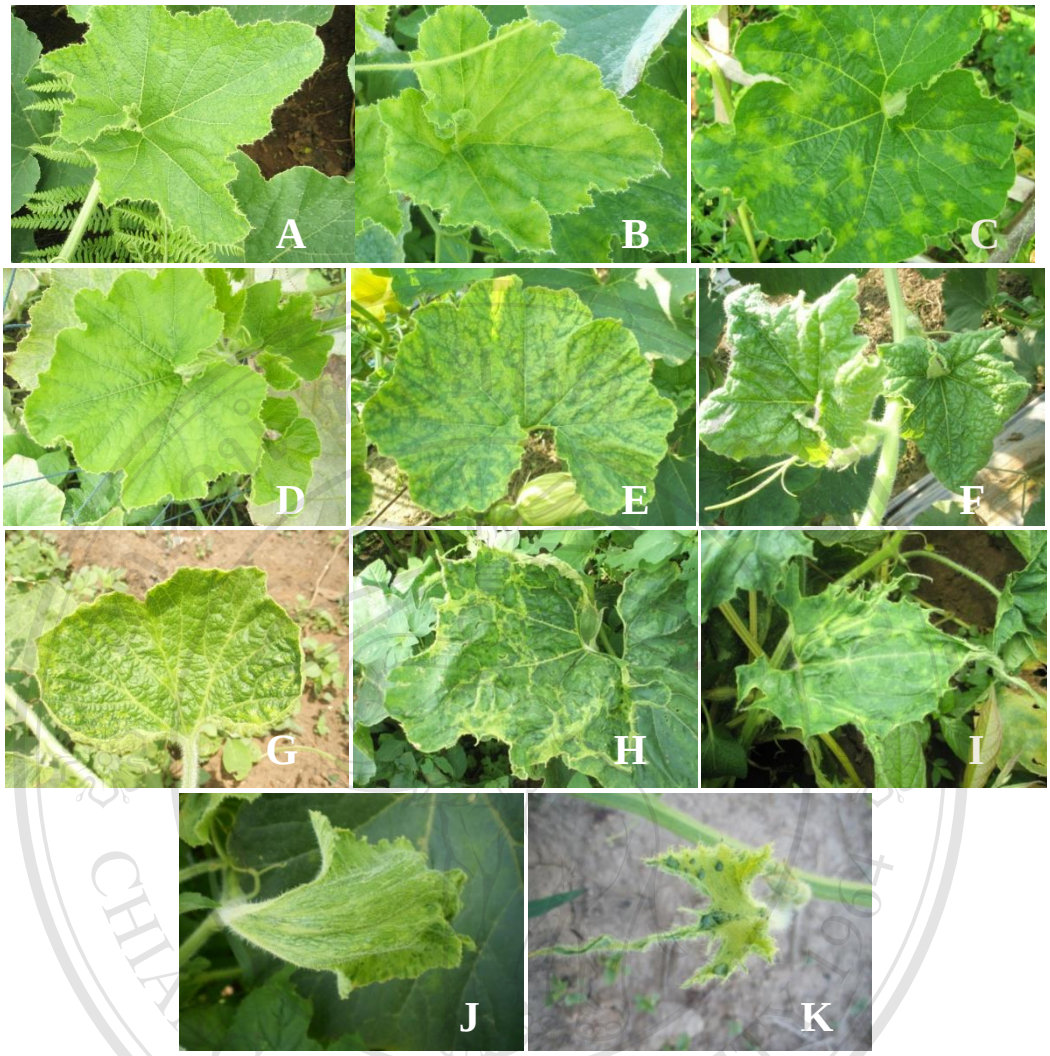

Figure 4.3 General viral foliar symptoms in the pumpkin samples: mottling (A), mosaic (B), yellow patches (C), vein banding (D), internal chlorosis (E), curling (F) and various deformations (G-K).

Figure 4.4 General viral symptoms in pumpkin fruits: mottling (A), knobs (B) and deformation (C).

1.1.3 Viral symptoms observed on cucumber

The cucumber samples were collected from four RPDCs; Mae Tha Nuea (field-grown), Huai Luk (open greenhouse-grown without insect exclusion), Mae Sa Mai (greenhouse-grown), and Mae Phae (air-circulated greenhouse-grown) where cucumbers were grown in northern Thailand. The virus symptoms in samples from Mae Tha Nuea and Huai Luk were more severe than Mae Sa Mai and Mae Phae. The common foliar symptoms observed in cucumber were mottle, mosaic, chlorosis, yellowing, crinkle, blister, curling, vein banding and deformation (Figure 4.5). The symptoms consisted of varying degrees of mosaic with leaf blistering and leaf deformation. Severe symptoms on cucumber were crinkling and deformation of leaves with size reduction and deformation of fruit. The common symptoms on fruits were mottling and deformed fruits (Figure 4.6). Mottling of leaves was observed at the seedling stage. Mixed symptoms, mosaic, crinkling, vein banding, curling, puckering, chlorosis and blistering were observed at flowering to the end of cucumber growing season. Silver patches and silver chlorosis were foliar symptoms only observed in Mae Tha Nuea.

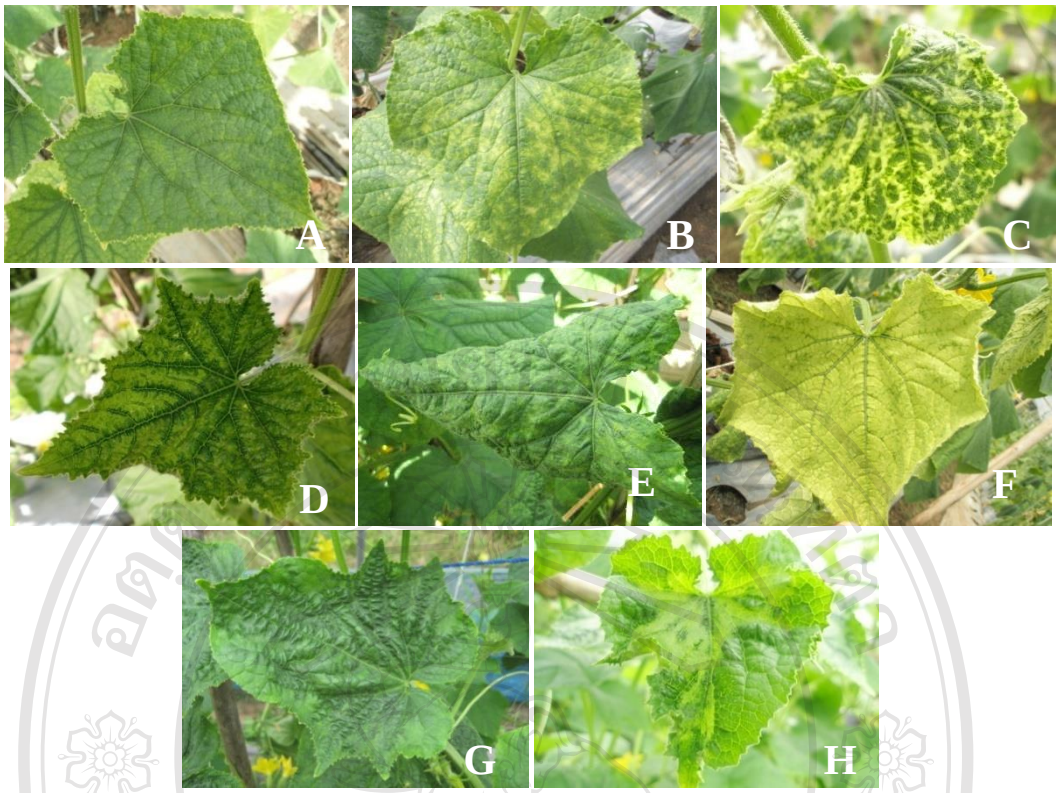

Figure 4.5 General viral symptom in the cucumber samples: (A), mosaic (B), yellow chlorosis (C), vein banding (D), curling (E), yellowing (F), puckering and deformation (G), and mosaic, blistering and deformation (H).

Figure 4.6 General viral symptom in the cucumber fruits included mottling (A) and deformation (B).

Table 4.1 The total number of disease samples collected and tested from different location at RPDC' areas.

Crop	Locality (RPDCs)	Sample collection periods (year)				Total of samples	
		2008		2009			
		No. of field samples collected	No. of samples tested[1]	No. of fields samples collected	No. of samples tested[1]	No. of fields samples collected	No. of samples tested[1]
Zucchini[2]	Mae Hae	1,400	140	1038	104	2,438	244
	Mae Tha Nuea	654	65	469	47	1,123	112
	Total	2,054	205	1,507	156	3,559	356
Pumpkin[3]	Mon Ngo	155	16	117	12	272	27
	Wat Chan	93	9	94	9	187	19
	Mok Cham	116	12	113	11	229	23
	Kae Noi	114	11	101	10	115	11
	Mae La Noi	73	7	67	7	140	14
	Total	551	55	492	49	1,043	104
Cucumber[4]	Mae Tha Nuea	496	50	323	32	819	82
	Huai Luk	558	56	524	52	1,082	108
	Mae Sa Mai	426	43	327	33	753	76
	Mae Phae	462	46	345	34	807	80
	Total	1,947	195	1,509	151	3,456	346
Total		4,552	455	3,508	351	8,060	806

[1]The number of disease samples tested from each field was about 10% of disease samples collected.

[2]zucchini was cultivated at a density of 1,200 plants per field

[3]pumpkin was cultivated at a density of 250 plants per field

[4] cucumber were cultivated at a density of 1,500 plants per field

Table 4.2 The viral symptoms appearing on growth stages of cucurbits indifferent location at RPDC' areas during 2008-2009.

Crop	Locality (RPDCs)	No. samples	Symptoms
Zucchini	Mae Hae	2,438	M, Mo, VB, DL, IC, Cu, Cr, D, P, Bl, Kb, St, S, DF,
	Mae Tha Nuea	1,123	M, Mo, VB, DL, Cr, Cu, D, P, Bl, Kb, St, DF
	Total	3,559	
Pumpkin	Mon Ngo	272	M, Mo, VB, DL, C, Cu, D, Y, Bl, P, St, DF, Kb
	Wat Chan	187	M, Mo, VB, DL, Bl, Cu, P, DF, Kb
	Mok Cham	229	M, Mo, VB, DL, C, Cu, D, Y, Bl, P, St, DF, Kb
	Kae Noi	115	M, Mo, VB, DL, C, Cu, D, Y, Bl, P, St, DF, Bb
	Mae La Noi	140	M, Mo, VB, DL, Cu, Bl, P, DF, Bb
	Total	1,043	
Cucumber	Mae Tha Nuea	819	M, Mo, VB, DL, D, IC C, Cu, Y, Cr, P, Bl, SP, DF
	Huai Luk	1,082	M, Mo, VB, DL, D, IC C, Cu, Y, Cr, P, Bl, DF
	Mae Sa Mai	753	M, Mo, VB, DL, D, IC C, Cu, Y, Cr, P, Bl, DF
	Mae Phae	807	M, Mo, VB, DL, D, C, Cu, Y, Cr, P, Bl, DF
	Total	3,456	

M=mottling, Mo=mosaic, VB=vein banding, DL=deformed leaf, DF=deformed fruit, St=shoes string, D=distortion, IC=interveinal chlorosis, C=chlorosis, Cu= curling, Y=yellowing, Cr=crinkling, P=puckering, Bl=blistering, Kb=knobby, SP=silver patch, S=stunting.

Table 4.3 The viral symptoms appearing on growth stages of cucurbits indifferent location at RPDC' areas during 2008-2009.

Crop	Locality (RPDCs)	Symptoms			
		Seedling[1]	Flowering[2]	Fruiting[3]	Harvesting[4]
Zucchini	Mae Hae	M, Mo, Cr	M, Mo, Cr, VB, C, Cu, P, Bl	M, Mo, VB, DL, IC, C, Cu, Cr, P, Bl, Bb, D, DF	M, Mo, VB, DL, IC, C, Cu, Cr, P, D, Bl, Kb, St, S, DF,
	Mae Tha Nuea	M, Mo	M, Mo, Cr, VB, Cu, P, Bl	M, Mo, VB, DL, Cr, Cu, P, DF	M, Mo, VB, DL, Cr, Cu, P, D, Bl, Kb, St, DF
Pumpkin	Mon Ngo	M, Mo	M, Mo, Cr, VB, Cu, P, C Bl	M, Mo, VB, Cr, DF, D Y, P, C, Bb	M, Mo, VB, DL, C, Cu, D, Y, Bl, P, St, DF, Kb
	Wat Chan	M	M, Mo, Cr, Cu, P, C, Bl	M, Mo, VB, Cr, Cu, P, C, DF, D, Y,	M, Mo, VB, DL, Bl, Cu, P, DF, Kb
	Mok Cham	M, Mo	M, Mo, Cr, VB, Cu, P, C Bl	M, Mo, Cr, VB, Cu, P, C, Y, Bl, DF	M, Mo, VB, DL, C, Cu, D, Y, Bl, P, St, DF, Kb
	Kae Noi	M, Mo	M, Mo, Cr, Cu, P, C Bl	M, Mo, Cr, VB, Cu, P, C, Y, Bl, DF	M, Mo, VB, DL, C, Cu, D, Y, Bl, P, St, DF, Kb
	Mae La Noi	M, Mo	M, Mo, Cr, Cu, P, C Bl	M, Mo, Cr, VB, Cu, P, C, Y, Bl, DF	M, Mo, VB, DL, Cu, Bl, P, DF, Kb
Cucumber	Mae Tha Nuea	M	M, Mo, Cr, VB, Cu, P, C, Y	M, Mo, Cr, VB, Cu, P, C, D, Y, Bl, SP, DF	M, Mo, VB, DL, D, IC C, Cu, Y, Cr, P, Bl, SP, S, DF
	Huai Luk	M	M, Mo, Cr, VB, Cu, P, C,Y	M, Mo, Cr, VB, Cu, P, C, D, Y, Bl, DF	M, Mo, VB, DL, D, IC C, Cu, Y, Cr, P, Bl, S, DF
	Mae Sa Mai	M	M, Mo, Cr, VB, Cu, P, C	M, Mo, Cr, VB, Cu, P, C, D, Y, Bl, DF	M, Mo, VB,DL, D, IC C, Cu, Y, Cr, P, Bl, DF
	Mae Phae	M	M, Mo, Cr, Cu, P, C	M, Mo, Cr, VB, Cu, P, C, D, Y, Bl, DF	M, Mo, VB, DL, D, C, Cu, Y, Cr, P, Bl, DF

[1]7-10 days after transplanting (dat) [2]25-30 dat of zucchini, 35-45 dap of pumpkin, 30-35 dat of cucumber [3]30-37 dat [4] 1 month after fruit setting set

M=mottling, Mo=mosaic, VB=vein banding, DL=deformed leaf, DF=deformed fruit, St=shoes string, D=distortion, IC=interveinal chlorosis, C=chlorosis, Cu= curling, Y=yellowing, Cr=crinkling, P=puckering, Bl=blistering, Kb=knobby, SP=silver patch, S=stunting.

1.2 Virus detection and incidence in cucurbits.

A total of 8,060 cucurbit samples were collected from the RPDCs surveyed. About 10% of the samples collected from each location were tested due to reagent and time limitations. A total of 806 samples were tested by DAS-ELISA. The polyclonal antibody ELISA kits from Bioreba (Switzerland) were used for detecting ZYMV, CMV, SqMV, PRSV-W, WMV-2 and Tospovirus. The results are summarized in Table 4.4. A total of 629 diseased samples (78.04%) were positive for one or more viruses. Samples exhibiting virus-like symptoms but testing negative for viruses (ZYMV, CMV, SqMV, PRSV-W, WMV-2 and Tospovirus) antisera used in serological tests totaled 177 (21.96%).The results of serological tests showed that cucurbit plants were infected with either single or multipleviruses. Viral infections were detected in zucchini, pumpkin, and cucumber at incidences of 80.62, 88.46, and 72.25%, respectively. Unidentified viruses were shown as 19.38, 11.54, and 27.74%, respectively. Tospovirus was only detected in cucumber, at an incidence of 1.49%. Single infections of ZYMV, CMV, PRSV-W, WMV-2 and SqMV were detected at incidences of 12.03, 5.33, 3.72, 3.6 and 1.98%, respectively. ZYMV was the most commonly detected virus in zucchini, pumpkin, and cucumber samples at incidence of 19.39, 8.65, and 5.49% respectively. CMV was commonly detected at incidences of 2.25, 3.85, and 8.96% in zucchini, pumpkin, and cucumber samples respectively. PRSV-W was detected at incidences of 3.93, 2.53, and 2.02%, in zucchini, pumpkin, and cucumber samples respectively.

Mixed viruses were detected at incidences of 51.68, 61.54, and 44.51% in zucchini, pumpkin, and cucumber samples, respectively. Double virus infections were detected in zucchini, pumpkin, and cucumber samples at incidences of 35.11, 38.49, and 36.42% respectively. Dual infections of ZYMV+PRSV-W, ZYMV+CMV and PRSV-W+CMV were detected in zucchini, pumpkin, and cucumber samples at incidences of 10.92, 7.57 and 5.96%, respectively. Infections of ZYMV+PRSV-W were the most commonly detected dual infections in zucchini, pumpkin, and cucumber at incidences of 16.85, 11.54 and 4.62%, respectively. ZYMV+CMV were common detected in the same hosts at incidences of 3.93, 10.58, and 10.69%, respectively. PRSV-W+CMV were detected at 1.68, 7.69 and 9.83% respectively. Triple infections were detected in

zucchini, pumpkin, and cucumber samples at 16.57, 20.19, 8.09%, respectively. Triple infections of ZYMV+PRSV-W+CMV, ZYMV+WMV-2+SqMV and ZYMV+PRSV-W+SqMV were detected at 3.72, 3.35, and 2.98%, respectively. Triple infections of ZYMV+PRSV-W+CMV were detected in zucchini, pumpkin, and cucumber samples at incidences of 2.25, 3.85, and 5.20%, respectively. ZYMV+WMV-2+SqMV and ZYMV+PRSV-W+SqMV were detected in zucchini and pumpkin. ZYMV+WMV-2+SqMV were detected at 4.78 and 9.61% and 5.34 and 4.81%, respectively. ZYMV+PRSV-W+WMV-2 were detected at 1.40, 0.96, and 2.02% in zucchini, pumpkin, and cucumber samples, respectively (Table 4.4).

Viral combinations involving ZYMV, PRSV-W, CMV, WMV-2, and SqMV were detected as 52.23, 29.15, 26.55, 19.72, and 13.61%, respectively. ZYMV was detected in combination with other viruses at 68.25, 55.77, and 34.68% in zucchini, pumpkin, and cucumber, respectively. Cucurbits infected with ZYMV showed leaf mottling, mosaic, and deformation (Figure 4.7). Severe symptoms included dark green blisters, fan leaf and shoe string in leaves and knobby fruits. CMV was detected with other viruses in zucchini, pumpkin, and cucumber with other viruses at incidences of 12.92, 28.85 and 39.88%, respectively. Cucurbits infected with CMV exhibited mottling and mild mosaic (Figure 4.8). Severe symptoms of CMV infection included mosaic and deformed leaves. PRSV-W was found with other viruses at 32.30, 43.27, and 24.57% respectively. Cucurbits were infected with PRSV-W exhibited mottling, mosaic, and distortion in leaves (Figure 4.9). Severe symptoms were included curling and deformed leaves. Mixed infection of WMV-2 with other viruses was found at 12.64, 40.38 20.81%, respectively. Cucurbits were infected with WMV-2 exhibited mottling and mosaic (Figure 4.10). Severe symptoms of WMV-2 infection included blistering and deformation of leaves. Mixed infections of SqMV with other viruses were found in the same hosts at 22.47, 25.96 and 0.88%, respectively. Cucurbits infected with SqMV exhibited mottling (Figure 4.11). Severe symptoms of SqMV included deformed leaves and knobby fruits.

The results of serological tests showed that zucchini samples had either single or mixed virus infections. Zucchini samples were infected at an incidence of 80.62% (287 samples) (Table 4.5). Sixty nine samples that showed virus-like symptoms tested

negative by all antisera used. Field-cultivated zucchini had incidences of 28.93 and 51.68% involving single and mixed virus infections respectively. Incidences of viral infection at seedling, flowering, fruiting, and harvesting stages were 5.62, 10.11, 7.54 and 5.62% respectively. The samples were infected with single viral infection e.g. ZYMV, CMV, SqMV, PRSV-W and WMV-2 at seedling. Single viral infection including ZYMV, PRSV-W, SqMV, CMV and WMV-2 at seedling stage was detected as 19.38, 3.93, 2.53, 2.25 and 0.84%, respectively. Tospovirus was not detected by ELISA in any of the cucurbit samples. Mixed virus infections were not detected at the seedling stage. Double virus infections were detected at the flowering, fruiting, and harvesting stages, and were identified as 11.26, 10.11, and 13.76%, respectively. ZYMV+PRSV-W, ZYMV+SqMV and ZYMV+WMV-2 were detected at incidences of 16.85, 7.02, and 4.49%, respectively. Triple virus infections were detected as 12.92, 13.76, 25.0% at flowering, fruiting, and harvesting stages, respectively. ZYMV+PRSV-W+SqMV, ZYMV+WMV-2+SqMV and ZYMV+CMV+SqMV were detected at 5.34, 4.78, and 2.81%, respectively. Viral combinations between involving ZYMV, PRSV-W, SqMV, CMV, and WMV-2 were detected at 68.25, 32.30, 22.47, 12.92, and 12.64% respectively. ZYMV was the predominant virus detected at incidences of 1.92, 14.42, 19.23, and 29.19% at the seedling, flowering, fruiting and harvesting stages, respectively. PRSV-W was commonly detected at all four crop stages at incidences of 0.96, 9.61, 16.35, and 17.31%, respectively, as was SqMV at 0.96, 6.73, 8.65, and 9.61%, respectively.

The results of serological tests showed that pumpkin samples were infected with single or multiple viruses. The great majority of pumpkin samples (93 samples/89.42%) tested positive for virus (Table 4.7). Eleven samples that showed virus-like symptoms did not give any positive reaction with any of the antisera used. Incidences of single and multiple virus infection in field-cultivated pumpkin cultivation fields were 38.46 and 61.54%, respectively. Samples showing single viral infection at seedling, flowering, fruiting, and harvesting stages were identified as 4.81, 8.65, 7.69 and 6.73% respectively. Single viral infection of pumpkin at the seedling stage included ZYMV, PRSV-W, SqMV, CMV and WMV-2 at 8.65, 3.85, 5.77, 2.53 and 0.96%, respectively. Tospovirus was not detecting in pumpkin by ELISA. Mixed virus

infections were not detected in pumpkin at the seedling stage. Double virus infections were detected at flowering, fruiting, and harvesting stages at 10.58, 14.42, and 13.46, respectively. ZYMV+PRSV-W, ZYMV+CMV and PRSV-W+CMV were detected at11.54, 10.58, and 7.69%, respectively. Triple virus infections were detected at 14.42, 23.08, 23.08% at flowering, fruiting, and harvesting stages, respectively. ZYMV+WMV-2+SqMV ZYMV+PRSV-W+SqMV and ZYMV+PRSV-W+CMV were detected at the flowering, fruiting, and harvesting stagesat9.61, 4.81 and 3.85%, respectively.

Cucumber plants surveyed were infected with one or multiple viruses. The 250 samples (72.25%) tested positive (Table 4.9). Ninety six samples that showed virus-like symptoms did not give any positive reaction with the antisera used. Incidence of single and mixed viral infection detected in cucumber was 27.74 and 44.51%, respectively. Samples showing single viral infection at seedling, flowering, fruiting, and harvesting stages were identified as 2.60, 6.65, 8.09, and 10.15% respectively. Single viral infection including CMV, ZYMV, WMV-2, Tospovirus, PRSV-W and SqMV at seedling stage was detected at 8.96, 5.49, 7.51, 3.47, 2.02, and 0.29%, respectively. Mixed virus infections were not detected at the seedling stage. Double virus infections were detected at flowering, fruiting, and harvesting stages at 10.98, 11.52 and 13.58, respectively. ZYMV+CMV, PRSV-W+CMV and ZYMV+WMV-2 were detected at 10.69, 9.83 and 6.07%, respectively. Triple virus infections were detected as 0.87, 4.05, 3.18% at flowering, fruiting, and harvesting stages, respectively. ZYMV+PRSV-W+CMV, ZYMV+PRSV-W+WMV-2 and CMV+PRSV-W+WMV-2 were detected at 5.20, 2.02, and 0.58%, respectively.

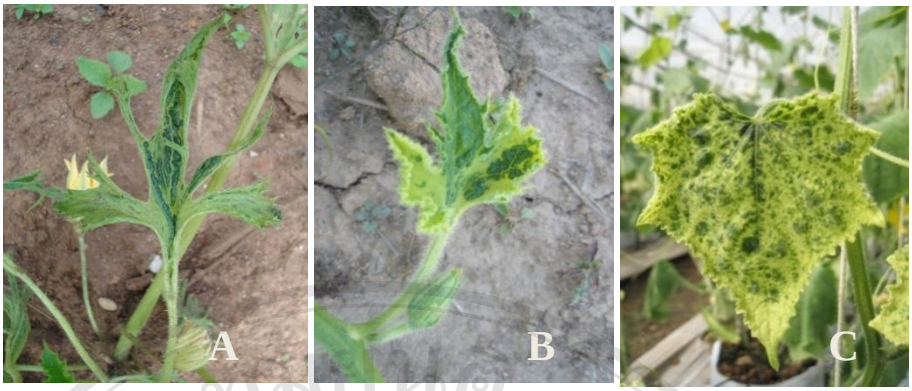

Figure 4.7 Commonly observed foliar symptoms of ZYMV in cucurbits: shoe string on zucchini (A), deformation on pumpkin (B), and yellow chlorosis on cucumber (C).

Figure 4.8 Common foliar symptoms of CMV in cucurbits: vein banding, and mottling on zucchini (A), mottling on pumpkin (B) and cucumber (C).

Figure 4.9 Common foliar symptoms of PRSV-W in cucurbits: blistering and distortion on zucchini (A), pumpkin (B) leaf and vein banding and blistering on cucumber (C).

Figure 4.10 Common foliar symptoms of WMV-2 in cucurbits: mosaic and roll up on zucchini (A), mottling on pumpkin (B) and blistering on cucumber (C).

Figure 4.11 Common foliar symptoms of SqMV in cucurbits: vein banding on zucchini (A), yellow chlorosis and green bubble on pumpkin (B) and blistering crinkle leaf on cucumber (C).

Figure 4.12 Common foliar symptoms of Tospovirus in cucumber: mottling (A) and blistering (B).

Figure 4.13 Foliar symptoms of ZYMV+PRSV-W: mosaic, dark green bubble, distortion on zucchini (A), dark green patch on pumpkin (B) and yellow chlorosis and blistering on cucumber (C).

Figure 4.14 Foliar symptoms of ZYMV+CMV: mottling and deformed leaves and fruit on zucchini (A), vein banding on pumpkin (B) and yellow mosaic and blistering on cucumber (C).

Figure 4.15 Foliar symptoms of PRSV-W+CMV: malformation of zucchini (A) leaf, yellow mosaic on pumpkin (B) and mosaic and blistering on cucumber (C).

Figure 4.16 Foliar symptoms of ZYMV+PRSV-W+CMV: dark green bubble patch and malformation on zucchini (A), blistering and malformation on pumpkin (B), and mosaic and blistering on cucumber (C).

Figure 4.17 Foliar symptoms of ZYMV+WMV-2+SqMV: dark green bubble patch and curling on zucchini (A), dark green bubble patch and mosaic on cucumber (C).

Figure 4.18 Foliar symptoms of ZYMV+PRSV-W+SqMV: dark green bubble patch and malformation on zucchini (A), yellow mosaic on pumpkin (B) and vein banding and yellow mosaic on cucumber (C).

Figure 4.19 Foliar symptoms of ZYMV+PRSV-W+WMV-2: dark green bubble patch and yellow mosaic on zucchini (A), malformation on pumpkin (B), and yellow mosaic and vein banding on cucumber (C).

Figure 4.20 Symptoms of ZYMV+PRSV-W in zucchini fruit: knobs and deformation

Figure 4.21 Symptoms of ZYMV+PRSV-W+CMV in pumpkin fruits: knobs and deformation.

Figure 4.22 Characterization of PRSV-W and CMV infected cucumber fruits was yellow mosaic and deformed fruits.

Figure 4.23 Mottling in chlorotic patches on cucumber leaves infected with un-identified virus

Figure 4.24 Silver patches on cucumber leaves (A), internal chlorosis (B), and silver chlorosis (C) infected with un-identified virus.

Table 4.4 Virus incidence in cucurbits grown at Royal Project Development Centers (RPDCs) in northern Thailand in 2008-2009 by DAS-ELISA.

Virus	Zucchini		Pumpkin		Cucumber		Total	
	No. of samples tested	Plant infection (%)	No. of samples tested	Plant infection (%)	No. of samples tested	Plant infection (%)	No. of samples tested	Plant infection (%)
Single virus infection								
ZYMV	69	19.38	9	8.65	19	5.49	97	12.03
CMV	8	2.25	4	3.85	31	8.96	43	5.33
SqMV	9	2.53	6	5.77	1	0.29	16	1.98
PRSV-W	14	3.93	9	2.53	7	2.02	30	3.72
WMV-2	3	0.84	1	0.96	26	7.51	29	3.6
Tospovirus	0	0	0	0	12	3.47	12	1.49
Total	103	28.93	28	26.92	96	27.74	227	28.09
Double virus infection								
ZYMV+CMV	14	3.93	10	10.58	37	10.69	61	7.57
ZYMV+SqMV	25	7.02	5	4.81	1	0.29	31	3.85
ZYMV+PRSV-W	60	16.85	12	11.54	16	4.62	88	10.92
ZYMV+WMV-2	16	4.49	1	0.96	21	6.07	38	4.71
PRSV-W+WMV-2	4	1.12	4	3.85	2	0.58	10	1.24
PRSV-W+CMV	6	1.68	8	7.69	34	9.83	48	5.96
CMV+WMV-2	0	0	0	0	15	4.33	15	1.89
Total	125	35.11	40	38.46	126	36.42	291	36.10
Triple virus infection								
ZYMV+PRSV-W+WMV-2	5	1.40	1	0.96	7	2.02	13	1.61
ZYMV+PRSV-W+SqMV	19	5.34	5	4.81	0	0	24	2.98
ZYMV+CMV+SqMV	10	2.81	1	0.96	1	0.29	12	1.49
ZYMV+WMV-2+SqMV	17	4.78	10	9.61	0	0	27	3.35
ZYMV+PRSV-W+CMV	8	2.25	4	3.85	18	5.20	30	3.72
CMV+PRSV-W+WMV-2	0	0	3	2.88	2	0.58	5	0.62
Total	59	16.57	21	20.19	28	8.09	111	13.77
Total mixed infection	184	51.68	64	61.54	154	44.51	402	49.87
Total infection	287	80.62	92	88.46	250	72.25	629	78.04
Un-identified viruses	69	19.38	12	11.54	96	27.74	177	21.96
Total	356	100	104	100	346	100	806	100
ZYMV with others	243	68.25	58	55.77	120	34.68	421	52.23
CMV with others	46	12.92	30	28.85	138	39.88	214	26.55
SqMV with others	80	22.47	27	25.96	3	0.88	110	13.65
PRSV-W with others	115	32.30	45	43.27	85	24.57	245	29.15
WMV-2 with others	45	12.64	42	40.38	72	20.81	159	19.72

Table 4.5 Effect of growth stage on detection of virus in zucchini grown at RPDCs in northern Thailand during 2008-2009 by DAS-ELISA.

No. of virus(es) detected	Growth stages									
	Seedling		Flowering		Fruit setting		Harvesting		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Single virus infection										
ZYMV	16	4.49	28	7.86	15	4.21	10	2.81	69	19.38
CMV	1	0.28	2	0.56	2	0.56	3	0.84	8	2.25
SqMV	0	0	2	0.56	4	1.12	3	0.84	9	2.53
PRSV-W	3	0.84	3	0.84	5	1.4	3	0.84	14	3.93
WMV-2	0	0	1	0.28	1	0.28	1	0.28	3	0.84
Tospovirus	0	0	0	0	0	0	0	0	0	0
Total	20	5.62	36	10.11	27	7.54	20	5.62	103	28.93
Double virus infection										
ZYMV+CMV	0	0	2	0.56	4	1.12	8	2.25	14	3.93
ZYMV+SqMV	0	0	6	1.68	6	1.68	13	3.65	25	7.02
ZYMV+ PRSV-W	0	0	26	7.3	18	5.05	16	4.49	60	16.85
ZYMV+WMV -2	0	0	5	1.4	6	1.68	5	1.4	16	4.49
PRSV- W+WMV-2	0	0	1	0.28	1	0.28	2	0.56	4	1.12
PRSV+CMV	0	0	0	0	1	0.28	5	1.4	6	1.68
CMV+WMV- 2	0	0	0	0	0	0	0	0	0	0
Total	0	0	40	11.26	36	10.11	49	13.76	125	35.11
Triple virus infection										
ZYMV+PRSV -W+WMV-2	0	0	0	0	0	0	5	1.4	5	1.4
ZYMV+PRSV -W+SqMV	0	0	2	0.56	4	1.12	13	3.61	19	5.34
ZYMV+CMV + SqMV	0	0	1	0.28	1	0.28	8	2.25	10	2.81
ZYMV+ WMV- 2+SqMV	0	0	1	0.28	5	1.4	11	3.09	17	4.78
ZYMV+ PRSV- W+CMV	0	0	2	0.56	3	0.84	3	0.84	8	2.25
CMV+PRSV- W+WMV-2	0	0	0	0	0	0	0	0	0	0
Total	0	0	6	1.68	13	3.61	40	11.23	59	16.57
Total mixed infection	0	0	46	12.92	49	13.76	89	25.0	184	51.68
Total infection	20	5.62	82	23.03	76	21.35	60	16.85	287	80.62
Un-identified viruses	25	7.02	29	8.15	9	2.53	6	1.68	69	19.38
Total	45	12.64	111	31.18	85	23.88	66	18.54	356	100
ZYMV with others	16	4.49	73	20.50	62	17.41	92	25.84	243	68.25
CMV with others	1	0.28	7	1.97	11	3.09	27	7.58	46	12.92
SqMV with others	0	0	12	3.37	20	5.62	48	13.48	80	22.47
PRSV-W with others	3	0.84	34	9.55	31	8.71	47	13.20	115	32.30
WMV-2 with others	3	0.84	7	1.97	13	3.65	22	6.18	45	12.64

Table 4.6 Effect of growth stage on detection of virus in zucchini grown at RPDCs in Mae Hae and Mae Tha Nuea in northern Thailand during 2008-2009 by DAS-ELISA.

Virus (es)	No of virus (es) detected in diseased samples at growth stages													
	Seedling			Flowering			Fruiting			Harvesting			Total	%
	MaeHae	MaeThaNuea	total	MaeHae	MaeThaNeua	total	MaeHae	MaeThaNuea	total	MaeHae	MaeThaNue	total		
Single infections														
ZYMV	8	8	16	18	10	28	9	6	15	6	4	10	69	19.38
CMV	1	0	1	1	1	2	1	1	2	1	2	3	8	2.25
SqMV	0	0	0	1	1	2	2	2	4	1	2	3	9	2.53
PRSV-W	2	1	3	2	1	3	3	2	5	1	2	3	14	3.93
WMV-2	0	0	0	1	0	1	1	0	1	0	1	1	3	0.84
Tospovirus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	11	9	20	23	13	36	16	11	27	9	11	20	103	28.93
%	3.09	2.53	5.62	6.46	3.65	10.11	4.49	3.09	7.53	2.53	3.09	5.62	28.93	
Double infection														
ZYMV+CMV	0	0	0	2	0	2	2	2	4	5	3	8	14	3.39
ZYMV+SqMV	0	0	0	4	2	6	3	3	6	8	6	13	25	7.02
ZYMV+PRSV-W	0	0	0	18	8	26	14	4	18	10	6	16	60	16.85
ZYMV+WMV-2	0	0	0	3	2	5	5	1	6	3	2	5	16	4.49
PRSV-W+WMV-2	0	0	0	1	0	1	1	0	1	1	1	2	4	1.12
PRSV-W+CMV	0	0	0	0	0	0	1	0	1	3	2	5	6	1.68
CMV+WMV-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	28	12	40	26	10	36	36	19	49	125	35.11
%	0	0	0	7.65	3.29	11.26	7.3	2.81	10.11	10.11	5.34	13.76	35.11	
Triple infection														
ZYMV+PRSV-W+WMV-2	0	0	0	0	0	0	0	0	0	0	2	5	5	1.4
ZYMV+PRSV-W+SqMV	0	0	0	2	0	2	2	2	4	4	5	13	19	5.34
ZYMV+CMV+SqMV	0	0	0	1	0	1	1	0	1	1	3	8	10	2.81
ZYMV+WMV-2+SqMV	0	0	0	1	0	1	2	3	5	5	4	11	17	4.78
ZYMV+PRSV-W+CMV	0	0	0	1	1	2	2	1	3	3	1	3	8	2.25
CMV+PRSV-W+WMV-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	5	1	6	7	6	13	13	15	40	59	16.57
%	0	0	0	1.4	0.28	1.63	1.97	1.68	3.61	3.61	4.21	11.23	16.57	
Total mixed infection	0	0	0	33	13	46	33	16	49	49	34	89	184	51.68
%	0	0	0	9.27	3.65	12.93	9.27	4.49	13.76	13.72	9.55	25	51.68	
Total infection	11	9	20	55	26	82	49	27	76	76	45	109	287	80.62
%	3.09	2.53	5.62	17	7.3	23.03	13.76	7.58	21.35	21.35	12.64	30.62	80.62	
Un-identified virus	15	10	25	4.78	12	29	6	3	9	9	4	6	69	19.38
%	4.21	2.81	7.02	72	3.37	8.15	1.68	0.84	2.53	2.53	1.12	1.68	19.38	
Total	26	19	45	20.22	38	111	55	30	85	85	49	115	356	100
%	7.3	5.34	12.64	10.67	31.18	15.47	8.43	23.88	23.88	13.76	32.3	100		

Table 4.7 Effect of growth stage on detection of virus in pumpkin grown at RPDCs in northern Thailand during 2008-2009 by DAS-ELISA.

No. of virus(es) detected	Growth stages									
	Seedling		Flowering		Fruit setting		Harvesting		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Single virus infection										
ZYMV	2	1.92	3	2.88	3	2.88	1	0.96	9	8.65
CMV	1	0.96	1	0.96	0	0	2	1.92	4	3.85
SqMV	1	0.96	3	2.88	1	0.96	1	0.96	6	5.77
PRSV-W	1	0.96	2	1.92	3	2.88	3	2.88	9	2.53
WMV-2	0	0	0	0	1	0.96	0	0	1	0.96
Tospovirus	0	0	0	0	0	0	0	0	0	0
Total	5	4.81	9	8.65	8	7.69	7	6.73	29	27.88
Double virus infection										
ZYMV+CMV	0	0	3	2.88	3	2.88	4	3.85	10	10.58
ZYMV+SqMV	0	0	1	0.96	2	1.92	2	1.92	5	4.81
ZYMV+PRSV-W	0	0	4	3.85	4	3.85	4	3.85	12	11.54
ZYMV+WMV-2	0	0	0	0	1	0.96	0	0	1	0.96
PRSV-W+WMV-2	0	0	2	1.92	1	0.96	1	0.96	4	3.85
PRSV+CMV	0	0	1	0.96	4	3.85	3	2.88	8	7.69
CMV+WMV-2	0	0	0	0	0	0	0	0	0	0
Total	0	0	11	10.58	15	14.42	14	13.46	40	38.46
Triple virus infection										
ZYMV+PRSV-W+WMV-2	0	0	0	0	0	0	1	0.96	1	0.96
ZYMV+PRSV-W+SqMV	0	0	0	0	2	1.92	3	2.88	5	4.81
ZYMV+CMV+SqMV	0	0	0	0	1	0.96	0	0	1	0.96
ZYMV+WMV-2+SqMV	0	0	3	2.88	3	2.88	4	3.85	10	9.61
ZYMV+PRSV-W+CMV	0	0	1	0.96	2	1.92	1	0.96	4	3.85
CMV+PRSV-W+WMV-2	0	0	0	0	1	0.96	2	1.92	3	2.88
Total	0	0	4	3.85	9	8.85	10	9.61	21	20.19
Total mixed infection	0	0	15	14.42	24	23.08	24	23.08	64	61.54
Total infection	5	4.81	26	25.0	32	30.77	33	31.73	93	89.42
Un-identified viruses	2	1.92	3	2.88	4	3.84	3	2.88	11	10.58
Total	7	6.73	29	27.88	36	34.61	36	34.61	104	100
ZYMV with others	2	1.92	15	14,42	20	19.23	21	29.19	58	55.77
CMV with others	1	0.96	8	7.69	11	10.58	12	11.54	30	28.85
SqMV with others	1	0.96	7	6.73	9	8.65	10	9.61	27	25.96
PRSV-W with others	1	0.96	10	9.61	17	16.35	18	17.31	46	44.23
WMV-2 with others	0	0	5	4.81	7	6.73	8	7.69	42	40.38

Table 4.8 Effect of growth stage on detection of virus in pumpkin grown at five RPDCs in northern Thailand during 2008-2009 by DAS-ELISA.

	No. of virus (es) detected in diseased sample at growth stages																									
	Seedling						Flowering						Fruiting						Harvesting							
Virus (es)	Mon Ngo	Mok Cham	Kae Noi	Wat Chan	Mae La Noi	total	Mon Ngo	Mok Cham	Kae Noi	Wat Chan	Mae La Noi	total	Mon Ngo	Mok Cham	Kae Noi	Wat Chan	Mae La Noi	total	Mon Ngo	Mok Cham	Kae Noi	Wat Chan	Mae La Noi	total	Total	%
Single infection																										
ZYMV	1	1	0	0	0	2	0	0	1	1	1	**3**	0	0	1	1	1	**3**	0	0	0	0	1	**1**	9	8.65
CMV	1	0	0	0	0	1	1	0	0	0	0	**1**	0	0	0	0	0	**0**	1	1	0	0	0	**2**	4	3.85
SqMV	1	0	0	0	0	1	1	1	1	0	0	**3**	1	1	0	1	0	**3**	1	0	0	0	0	**1**	6	5.77
PRSV-W	1	0	0	0	0	1	1	1	0	0	0	**2**	1	1	0	0	0	**2**	1	1	0	1	0	**3**	9	2.53
WMV-2	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0	1	1	**0**	0	0	0	0	0	**0**	1	0.96
Tospovirus	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	0	**0**	0	0
total	4	1	0	0	0	5	3	2	2	1	1	**9**	2	2	1	3	2	**8**	3	2	0	1	1	**7**	29	27.88
%	3.85	0.96	0	0	0	4.81	2.88	1.92	1.92	0.96	0.96	8.65	1.96	1.96	0.96	2.88	1.92	7.69	2.88	1.92	0	0.96	0.96	6.73	27.88	
Double infection																										
ZYMV+CMV	0	0	0	0	0	0	1	1	1	0	0	**3**	1	0	0	1	1	**3**	1	1	1	1	0	4	10	10.58
ZYMV+SqMV	0	0	0	0	0	0	1	0	0	0	0	**1**	1	1	0	0	0	**1**	1	1	0	0	0	2	5	4.81
ZYMV+PRSV-W	0	0	0	0	0	0	1	1	0	1	1	**4**	1	1	1	0	1	**4**	1	0	1	1	1	4	12	11.54
ZYMV+WMV-2	0	0	0	0	0	0	0	0	0	0	0	**0**	0	1	0	0	0	**1**	0	0	0	0	0	0	1	0.96
PRSV-W+WMV	0	0	0	0	0	0	1	1	0	0	0	**2**	0	1	0	0	0	**1**	1	0	0	0	0	1	4	3.85
PRSV-W+CMV	0	0	0	0	0	0	1	0	0	0	0	**1**	1	1	1	1	0	**4**	1	1	1	0	0	3	8	7.69
CMV+WMV	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0
total	0	0	0	0	0	0	5	3	1	1	1	**11**	4	5	2	2	2	**14**	5	3	3	2	1	14	40	38.46
%	0	0	0	0	0	0	4.81	2.88	0.96	0.96	0.96	10.58	3.85	4.81	1.96	1.96	1.96	13.46	4.81	2.88	2.88	1.92	0.96	13.46	38.46	
Triple infection																										
ZYMV+PRSV-W+WMV-2	0	0	0	0	0	0	0	0	0	0	0	**0**	0	1	0	0	0	**1**	0	1	0	0	0	1	1	0.96
ZYMV+PRSV-W+SqMV	0	0	0	0	0	0	0	0	0	0	0	**0**	1	1	0	0	0	**2**	1	1	0	1	0	3	5	4.81
ZYMV+CMV+SqMV	0	0	0	0	0	0	0	0	0	0	0	**0**	1	0	0	0	0	**1**	0	0	0	0	0	0	1	0.96
ZYMV+WMV-2+SqMV	0	0	0	0	0	0	1	1	1	0	0	**3**	1	1	0	1	0	**2**	0	1	1	1	1	4	10	9.61
ZYMV+PRSV+CMV	0	0	0	0	0	0	1	0	0	0	0	**1**	1	1	0	0	0	**2**	0	0	1	0	0	1	4	3.85
CMV+PRSV-W+WMV-2	0	0	0	0	0	0	0	0	0	0	0	**0**	0	1	0	0	0	**1**	1	1	0	0	0	2	3	2.88
total	0	0	0	0	0	0	2	1	1	0	0	**4**	4	5	0	1	0	**10**	2	4	2	2	1	11	24	23.08
%	0	0	0	0	0	0	1.92	0.96	0.96	0	0	3.85	3.85	4.81	0	0.96	0	9.61	1.92	3.85	1.92	1.92	96	10.58	23.08	
Total mixed infection	0	0	0	0	0	0	7	4	2	1	1	15	8	5	2	3	2	24	7	6	5	4	2	21	64	61.54
%	0	0	0	0	0	0	6.73	3.85	1.92	0.96	0.96	14.42	7.69	4.81	1.92	2.88	1.92	23.08	6.73	5.77	4.81	3.85	1.92	20.19	61.54	
Total infection	4	1	0	0	0	5	10	6	4	2	2	26	10	7	3	6	4	32	10	8	5	5	3	28	93	89.42
%	3.85	0.96	0	0	0	4.81	9.61	5.77	3.85	1.92	1.92	25	9.61	6.73	2.88	5.77	3.85	30.77	9.61	7.69	4.81	4.81	2.88	26.92	89.42	
Un-identified virus	1	1	0	0	0	2	1	1	0	1	0	3	0	1	1	1	1	4	1	1	0	1	0	3	11	10.58
%	0.96	0.96	0	0	0	1.92	0.96	0.96	0	0.96	0	2.88	0	0.96	0.96	0.96	0.96	3.85	0.96	0.96	0	0.96	0	2.88	10.58	
Total	5	2	0	0	0	7	11	7	4	3	2	29	10	8	4	7	5	36	11	9	5	6	3	31	104	100
%	4.81	1.92	0	0	0	6.73	10.58	6.73	3.85	2.88	1.92	27.88	9.61	7.69	3.85	6.73	4.81	34.61	10.58	8.65	4.81	5.77	2.88	29.81	100	

Table 4.9 Effect of growth stage on detection of virus in cucumber grown at RPDCs in in northern Thailand during 2008-2009 by DAS-ELISA.

No. of virus(es) detected	Growth stages									
	Seedling		Flowering		Fruit setting		Harvesting		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Single virus infection										
ZYMV	3	0.87	5	1.44	6	1.73	5	1.44	19	5.49
CMV	3	0.87	11	3.18	7	2.02	10	2.89	31	8.96
SqMV	0	0	0	0	0	0	1	0.29	1	0.29
PRSV-W	1	0.29	1	0.29	3	0.87	2	0.58	7	2.02
WMV-2	1	0.29	4	1.16	8	2.31	12	3.47	26	7.51
Tospovirus	1	0.29	2	0.58	4	1.16	5	1.44	12	3.47
Total	9	2.60	23	6.65	28	8.09	35	10.15	96	27.74
Double virus infection										
ZYMV+CMV	0	0	13	3.76	13	3.76	11	3.18	37	10.69
ZYMV+SqMV	0	0	0	0	1	0.29	0	0	1	0.29
ZYMV+PRSV-W	0	0	3	0.87	5	1.44	8	2.31	16	4.62
ZYMV+WMV-2	0	0	7	2.02	4	1.16	10	2.89	21	6.07
PRSV-W+WMV-2	0	0	1	0.29	1	0.29	0	0	2	0.58
PRSV+CMV	0	0	9	2.60	11	3.18	14	4.05	34	9.83
CMV+WMV-2	0	0	5	1.44	6	1.73	4	1.16	15	4.33
Total	0	0	38	10.98	41	11.52	47	13.58	126	36.42
Triple virus infection										
ZYMV+PRSV-W+WMV-2	0	0	1	0.29	4	1.16	2	0.58	7	2.02
ZYMV+PRSV-W+SqMV	0	0	0	0	0	0	0	0	0	0
ZYMV+CMV+SqMV	0	0	0	0	0	0	1	0.29	1	0.29
ZYMV+WMV-2+SqMV	0	0	0	0	0	0	0	0	0	0
ZYMV+PRSV-W+CMV	0	0	2	0.58	9	2.60	7	2.02	18	5.20
CMV+PRSV-W+WMV-2	0	0	0	0	1	0.29	1	0.29	2	0.58
Total	0	0	3	0.87	14	4.05	11	3.18	28	8.09
Total mixed infection	0	0	41	11.52	55	15.89	58	16.76	154	44.51
Total infection	9	2.60	64	18.50	83	23.99	93	26.88	250	72.25
Un-identified viruses	25	7.22	27	7.80	27	7.80	33	9.54	96	27.74
Total	43	12.43	91	26.30	110	31.79	131	37.86	346	100
ZYMV with others	3	0.87	31	8.96	42	12.14	44	12.71	120	34.68
CMV with others	3	0.87	40	11.56	47	13.58	48	13.87	138	39.88
SqMV with others	0	0	0	0	1	0.29	2	0.58	3	0.88
PRSV-W with others	1	0.29	17	4.91	34	9.83	34	9.83	85	24.57
WMV-2 with others	1	0.29	18	5.20	24	6.94	29	8.38	72	20.81

Table 4.10 Effect of growth stage on detection of virus in cucumber grown at four RPDCs in northern Thailand during 2008-2009 by DAS-ELISA.

	No. of virus (es) detected in diseased sample at growth stage																					
	Seedling					Flowering					Fruiting					Harvesting						
Virus (es)	Mae Tha Ni	Mae Sa Ma	Mae Phae	Huai Luek	total	Mae Tha Ni	Mae Sa Ma	Mae Phae	Huai Luek	total	Mae Tha Ni	Mae Sa Ma	Mae Phae	Huai Luek	total	Mae Tha Ni	Mae Sa Ma	Mae Phae	Huai Luek	total	Total	%
Single infection																						
ZYMV	1	0	1	1	3	1	1	1	2	5	2	1	1	2	6	2	1	1	1	5	19	5.49
CMV	1	0	1	1	3	5	1	1	4	11	3	2	2	2	7	4	1	2	3	10	31	8.69
SqMV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0.29
PRSV-W	1	0	0	0	1	0	0	0	1	1	1	0	1	1	3	1	1	0	0	2	7	2.02
WMV-2	1	0	0	0	1	1	1	1	1	4	3	1	1	3	8	4	1	2	5	12	26	7.51
Tospovirus	0	0	0	1	1	1	0	0	1	2	1	1	1	1	4	1	1	2	1	5	12	3.47
total	4	0	2	3	9	8	3	3	9	23	10	5	6	9	28	13	5	7	10	35	96	27.74
%	1.16	0	0.58	0.87	2.6	2.6	0.87	0.87	2.6	6.65	2.89	1.44	1.73	2.6	8.09	3.76	1.44	2.02	2.89	10.15	27.74	
Double infection																						
ZYMV+CMV	0	0	0	0	0	5	1	3	4	13	6	1	1	5	13	3	2	2	4	11	37	10.69
ZYMV+SqMV	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0.29
ZYMV+PRSV-W	0	0	0	0	0	1	0	1	1	3	1	1	1	2	5	2	2	2	2	8	16	4.62
ZYMV+WMV-2	0	0	0	0	0	2	1	1	3	7	1	1	1	1	4	2	1	2	3	8	21	6.07
PRSV-W+WMV	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1		0	1	2	2	0.58
PRSV-W+CMV	0	0	0	0	0	3	2	1	3	9	4	2	2	3	11	5	1	3	5	14	34	9.83
CMV+WMV	0	0	0	0	0	1	1	1	2	5	2	1	1	2	6	1	1	1	1	4	15	4.33
total	0	0	0	0	0	12	5	7	14	38	16	6	6	13	41	14	7	10	16	47	126	36.42
%	0	0	0	0	0	3.47	1.44	2.02	4.05	10.98	4.62	1.73	1.73	3.76	11.52	4.05	2.02	2.89	4.62	13.58	36.42	
Triple infection																						
ZYMV+PRSV-W+WMV-2	0	0	0	0	0	0	0	0	1	1	1	1	1	1	4	1	0	0	1	2	7	2.02
ZYMV+PRSV-W+SqMV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZYMV+CMV+SqMV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0.29
ZYMV+WMV-2+SqMV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZYMV+PRSV+CMV	0	0	0	0	0	1	0	0	1	2	3	1	2	3	9	3	1	1	2	7	18	5.2
CMV+PRSV-W+WMV-2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	2	0.58	
total	0	0	0	0	0	1	0	0	2	3	4	2	3	4	14	6	1	1	3	11	28	8.09
%	0	0	0	0	0	0.29	0	0	0.59	0.87	1.16	0.59	0.87	1.16	4.05	1.73	0.29	0.29	0.87	3.18	8.09	
Tota mixed infection	0	0	0	0	0	13	5	7	41	41	20	8	9	17	55	20	8	11	19	58	154	44.51
%	0	0	0	0	0	3.76	1.44	2.02	11.85	11.85	5.78	2.31	2.6	4.91	15.89	5.78	2.31	3.18	5.49	16.76	44.51	
Total infection	4	0	2	3	9	22	8	11	64	66	30	13	15	26	83	33	13	18	29	93	250	72.25
%	1.16	0	0.58	0.87	2.6	6.36	2.31	3.18	18.5	19.08	8.67	3.76	4.34	7.51	23.99	9.54	3.76	5.2	8.38	26.88	7.22	
Un-identified virus	9	3	4	9	25	9	3	4	10	27	5	5	9	8	27	10	4	6	13	33	96	27.74
%	2.6	0.87	1.16	2.6	7.22	2.6	0.87	1.16	2.89	7.8	1.44	1.44	2.6	2.31	2.8	2.89	1.16	1.73	3.76	9.54	27.74	
Total	13	3	6	12	34	31	11	15	74	93	35	18	24	34	110	43	17	24	42	126	346	100
%	3.76	0.87	1.73	3.47	9.83	8.96	3.18	4.34	21.39	26.88	10.12	5.2	6.94	9.83	31.79	12.43	4.91	6.94	12.14	36.42	100	

2. Distribution of plant virus insect vectors and alternate hosts in the Royal Project areas

2.1 Survey of insect vectors in the main areas of cultivation.

The number of insect vectors of plant viruses was monitored on a selected leaf per plant (leaf number three from the top) from cucurbit growing areas in northern Thailand during 2008-2009. The average numbers of all insect vectors, aphids, thrips, adult whiteflies, and beetles detected during the survey were 2.02, 0.32, 0.14, and 0.6 per leaf, respectively. Aphids were detected at the highest levels, and 3.0, 2.14, and 0.92were found per leaf in zucchini, cucumber, and pumpkin respectively. Beetle numbers were also commonly found at incidences of 0.8, 0.6, and 0.4 per leaf in cucumber, zucchini, and pumpkin, respectively. Thrips were found in the same hosts at levels of0.5, 0.29, and 0.17 per leaf, respectively (Table 4.11).

Table 4.11 Number of plant virus insect vectors detected per plant[1] from cucurbits growing areas in northern Thailand during 2008-2009.

Plant fields	Mean number. of insect vectors			
	Aphids	Thrips	Whiteflies	Beetles
Zucchini	3.0±1.96	0.5±0.22	0.2±0.6	0.6±0.88
Pumpkin	0.92±0.55	0.17±0.34	0.12±0.65	0.4±0.64
Cucumber	2.14±1.22	0.29±0.56	0.1±0.31	0.8±0.52

[1]Insect vectors were counted on one leaf per plant (leaf number three from the top)

2.1.1 Plant virus insect vectors in zucchini growing areas.

A survey of insect vectors was conducted in three seasons (rainy, summer, cool) at Mae Hae and Mae Tha Nuea where zucchini were grown. Beetles were not found at the end of crop season. While, whitefly were not found in the rainy or cool seasons at the seedling stage. Aphids were found in all the growing seasons at both sites during both survey years (Tables 4.12 and 4.13). The number of aphids increased during the summer season at Mae Hae. Aphid populations at this site during summer 2008 at the seedling, flowering, fruit setting, and harvesting stages were 1.55, 2.05, 2.5, 1.85, and

1.55 aphids/leaf, respectively, and 0.95, 2.5, 1.55, and 1.9 aphid/leaf, respectively at the same growth stages in summer 2009. Thrips were not found at the seedling stage in the rainy or summer seasons. At Mae Tha Neua the number of aphids found at the seedling, flowering, fruit setting, and harvesting stages during summer in 2008 were 0.7, 1.55, 1.4, and 1.15 aphid/leaf, respectively and 0.8, 1.35, 1.5and 1.6 aphid/leaf, respectively at the same growth stages in summer 2009. Thrips were not found at the early growing stage in any of the crop seasons.

Table 4.12 Kind and number of plant virus insect vectors collected from zucchini at Mae Hae in three seasons at four growth stages in 2008 and 2009.

		No. of insect vectors counted in zucchini growing stage							
		Seedling		Flowering		Fruiting		Harvesting	
Insect vectors	Seasons	2008	2009	2008	2009	2008	2009	2008	2009
Aphids	Rainy	0.1±0.31	0.15±0.37	0.6±1.05	0.6±0.88	0.55±0.89	0.85±1.18	0.9±1.37	0.55±0.40
	Summer	1.55±2.01	0.95±1.90	2.05±3.28	2.5±3.42	1.85±2.06	1.55±2.09	1.55±2.37	1.9±2.59
	Cool	1±0.65	1±1.08	1.55±1.96	1.75±2.07	1.25±1.62	1.4±2.06	1.05±1.60	1.15±1.56
Thrips	Rainy	0	0	0.05±0.22	0.05±0.22	0.1±0.31	0	0.15±0.37	0.15±0.37
	Summer	0	0	0.6±0.88	0.4±0.60	0.75±1.07	0.55±0.89	0.15±0.49	0.2±0.52
	Cool	0.35±0.67	0.25±0.55	0.35±0.59	0.25±0.55	0.65±1.18	0.6±1.05	0.15±0.49	0.1±0.31
Whitefly	Rainy	0	0	0.1±0.31	0.05±0.22	0.05±0.22	0.05±0.22	0.05±0.22	0.1±0.31
	Summer	0.05±0.22	0.05±0.22	0.1±0.31	0.15±0.37	0.3±0.66	0.25±0.55	0.15±0.37	0.25±0.72
	Cool	0	0	0.1±0.31	0.1±0.31	0.15±0.37	0.1±0.31	0.05±0.22	0.1±0.31
Beetle	Rainy	0.1±0.45	0.1±0.31	0.5±0.83	0.4±0.82	0.05±0.22	0.2±0.41	0	0
	Summer	0.1±0.31	0	0.95±0.76	0.8±0.52	0.85±0.99	0.5±0.83	0	0
	Cool	0.05±0.22	0.05±0.22	1.45±1.05	0.65±0.93	0.85±1.09	0.5±0.76	0	0

Table 4.13 Kind and number of plant virus insect vectors collected from zucchini at Mae Tha Neua in three seasons at four growth stages in 2008 and 2009.

		No. of insect vectors counted in zucchini growing stage							
		Seedling		Flowering		Fruiting		Harvesting	
Insect vectors	Seasons	2008	2009	2008	2009	2008	2009	2008	2009
Aphids	Rainy	0.05±0.22	1±1.08	1.55±1.96	1.75±2.07	1.4±1.64	1.4±2.06	1.05±1.60	1.15±1.56
	Summer	0.7±0.92	0.8±0.89	1.25±1.80	1.35±1.95	1.1±1.97	1.5±2.09	1.15±1.81	1.6±1.90
	Cool	0.6±0.94	0.9±1.16	1±1.52	1.7±2.30	1.65±2.28	1.5±2.16	2.2±3.17	3.2±3.14
Thrips	Rainy	0	0	0.05±0.22	0.05±0.22	0.05±0.22	0.05±0.22	0.1±0.31	0.2±0.52
	Summer	0	0	0.5±0.89	0.65±0.93	0.5±0.89	0.55±0.90	0.2±0.52	0.25±0.44
	Cool	0	0	0.45±0.76	0.55±1.05	0.5±0.89	0.3±0.66	0.1±0.31	0.25±0.55
Whitefly	Rainny	0	0	0	0.05±0.22	0	0.1±0.45	0	0.05±0.22
	Summer	0.05±0.22	0.05±0.22	0.4±0.99	0.05±0.22	0.2±0.62	0.2±0.41	0.05±0.22	0.2±0.70
	Cool	0	0	0.05±0.22	0.15±0.49	0.05±0.22	0.1±0.45	0.1±0.31	0.05±0.22
Beetle	Rainny	0.1±0.31	0.1±0.45	0.45±0.89	0.25±0.64	0.05±0.22	0.2±0.52	0	0
	Summer	0.05±0.22	0.15±0.49	0.5±0.69	0.55±0.82	0.2±0.41	0.4±0.82	0	0
	Cool	0.05±0.22	0.05±0.22	0.4±0.82	0.7±0.92	0.45±0.60	0.45±0.51	0	0

2.1.2 Plant virus insect vectors in pumpkin growing areas.

A survey of insect vectors in pumpkin was conducted in three seasons at Mongo, Mok Cham, Kae Noi, Wat Chan and Mae La Noi. Aphids and thrips were generally found in all three growing seasons at each of the five survey locations, and aphid populations generally increased during the summer season. Whiteflies were not detected at the seedling stage in any of the growing seasons at any of the five locations. Beetles were almost never detected at these locations at the end of growing season.

At Mon Ngo thrips numbers increased during the cool season and decreased during the rainy season (Table 4.14). The number of thrips found at this location during the seedling, flowering, fruiting, and harvesting stage in summer 2008 was 0.15, 0.1, 0.2, and 0.2 thrips/leaf, respectively, and 0.1, 0.05, 0.15, and 0.25 thrips/leaf, respectively, in summer 2009. Aphids were not found at this location at harvest during 2009.

At Mok Cham the number of aphids found at the seedling, flowering, fruiting, and harvesting stages in summer 2008 was 1.75, 2.0, 1.8, and 1.45 aphid/leaf, respectively, and in summer 2009, 1.15, 2.5, 1.6, and 2.15 aphid/leaf respectively (Table 4.15). Thrips were not found in the rainy season at the seedling stage at this site. The number of thrips increased during the summer season. In summer 2008, 0.15, 0.1, 0.15

and 0.4 thrips/leaf were found during the seedling, flowering, fruiting, and harvesting stages, and 0.05, 0.1, 0.15 and 0.25 aphids/leaf, respectively, in summer 2009.

At Kae Noi the number of aphids detected during the seedling, flowering, fruiting, and harvesting stage in summer 2008 was1.55, 2.0, 1.95and 1.95 aphid/leaf, respectively, and 0.85, 2.25, 1.6 and 1.95 aphid/leaf, respectively, in summerat2009 (Table 4.16). Thrips were found at all crop stages in summer 2008-2009.

At Wat Chan aphids were often found at all growth stages in all growing seasons except the seedling stage in 2008 (Table 4.17). Number of aphids was found at the seedling, flowering, fruiting, and harvesting stage in summer 2008 was1.05, 2.0, 1.9, and 1.3 aphid/leaf, respectively, while found as 0.8, 2.5, 1.35, and 1.3 aphid/leaf respectively. Thrips were not found at either the seedling or flowering stage in both 2008 and 2009. The number of thrips found at the seedling, flowering, fruiting, and harvesting stages in summer 2008 was0.1, 0.1, 0.15, and 0.15 thrips/leaf, respectively, and 0.1, 0.05, 0.15, and 0.2 aphid/leaf, respectively, in summer 2009.

At Mae La Noi The number of aphids found at the seedling, flowering, fruiting, and harvesting stages in summer 2008 was0.55, 0.1, 0.15, and 0.25 aphid/leaf, respectively, and 0.1, 0.1, 0.15, and 0.15 aphid/leaf, respectively, in summer 2009 (Table 4.18). Thrips were not found in the rainy season at the seedling stage in 2008. The number of thrips generally increased during the seedling, flowering, fruiting, and harvesting stage in the cool season in 2008 and 2009. Thrips numbers during the cool season 2008 were 0.05, 0.15, 0.35, and 0.25 thrips/leaf, respectively, and 0.05, 0.25, 0.25, and 0.2thrips/leaf, respectively, in the cool season of 2009.

Table 4.14 Kind and number of plant virus insect vectors collected from pumpkin at Mon Ngo in three seasons at four growth stages in 2008 and 2009.

Insect vectors	Seasons	No. of insect vectors counted in pumpkin growing stage							
		Seedling		Flowering		Fruiting		Harvesting	
		2008	2009	2008	2009	2008	2009	2008	2009
Aphids	Rainy	0.15±0.37	0.2±0.41	1.15±1.56	1.05±1.50	0.5±1.15	0.95±2.30	0.4±0.88	0.55±1.05
	Summer	1.9±2.07	1±1.92	2.2±2.40	2.65±2.91	1.75±1.68	1.65±2.70	1.7±2.05	0
	Cool	1±0.86	0.8±1.24	1.8±2.14	1.95±2.89	1.45±2.28	1.45±2.37	1.3±2.03	1.15±1.46
Thrips	Rainy	0.05±0.22	0	0.1±0.31	0.1±0.45	0.4±0.75	0.1±0.31	0.25±0.72	0.25±0.79
	Summer	0.15±0.50	0.1±0.31	0.1±0.31	0.05±0.22	0.2±0.54	0.15±0.37	0.2±0.71	0.25±0.80
	Cool	0.2±0.62	0.2±0.70	0.1±0.31	0.05±0.22	0.25±0.72	0.25±0.64	0.3±0.80	0.2±0.62
Whitefly	Rainy	0	0	0.05±0.22	0.1±0.45	0.15±0.37	0.1±0.31	0.1±0.31	0.2±0.52
	Summer	0	0	0.2±0.41	0.25±0.64	0.2±0.52	0.15±0.37	0.4±0.99	0.25±0.79
	Cool	0	0	0.1±0.31	0.1±0.31	0.25±0.72	0.25±0.64	0.6±1.14	0.25±0.64
Beetle	Rainy	0.25±0.44	0.2±0.41	0.6±0.82	0.65±0.93	0.45±0.60	0.4±0.60	0	0
	Summer	0.2±0.41	0.3±0.57	0.7±1.08	0.65±0.93	0.35±0.81	0.2±0.52	0	0
	Cool	0.2±0.62	0.2±0.70	0.1±0.31	0.05±0.22	0.25±0.72	0.25±0.64	0.3±0.80	0.2±0.62

Table 4.15 Kind and number of plant virus insect vectors collected from pumpkin at Mok Cham in three seasons at four growth stages in 2008 and 2009.

Insect vectors	Seasons	No. of insect vectors counted in pumpkin growing stage							
		Seedling		Flowering		Fruiting		Harvesting	
		2008	2009	2008	2009	2008	2009	2008	2009
Aphids	Rainy	0.15±0.49	0.2±0.52	1.15±2.03	1.5±1.96	1.1±2.15	0.65±1.42	1±1.52	0.55±1.32
	Summer	1.75±1.71	1.15±1.98	2±3.09	2.5±2.72	1.8±3.38	1.6±2.74	1.45±2.33	2.15±3.86
	Cool	0.9±1.65	1.35±2.06	1.75±2.83	2±2.49	1.35±2.37	1.5±2.52	1.05±1.57	1.25±1.55
Thrips	Rainy	0	0	0.05±0.22	0	0.05±0.22	0.05±0.22	0.35±0.88	0.25±0.64
	Summer	0.15±0.37	0.05±0.22	0.1±0.45	0.1±0.31	0.15±0.37	0.15±0.49	0.4±1.05	0.25±0.64
	Cool	0.05±0.22	0.05±0.22	0.1±0.45	0.05±0.22	0.1±0.31	0.15±0.67	0.3±0.92	0.25±1.12
Whitefly	Rainy	0	0	0.05±0.22	0.15±0.49	0.15±0.37	0.2±0.52	0.1±0.31	0.15±0.49
	Summer	0	0	0.25±0.55	0.25±0.64	0.2±0.52	0.1±0.31	0.25±0.79	0.25±0.79
	Cool	0	0	0.25±0.55	0.25±0.72	0.25±0.72	0.2±0.62	0.5±1.32	0.45±1.14
Beetle	Rainy	0.15±0.37	0.1±0.31	0.7±0.80	0.7±0.86	0.4±0.60	0.35±0.59	0	0
	Summer	0.15±0.37	0.15±0.37	0.55±0.94	0.6±0.94	2±0.82	0.45±0.69	0	0
	Cool	0.25±0.64	0.2±0.70	0.8±1.00	0.85±0.93	0.5±0.83	0.4±0.68	0	0

Table 4.16 Kind and number of plant virus insect vectors collected from pumpkin at Kae Noi in three seasons at four growth stages in 2008 and 2009.

Insect vectors	Seasons	No. of insect vectors counted in pumpkin growing stage							
		Seedling		Flowering		Fruiting		Harvesting	
		2008	2009	2008	2009	2008	2009	2008	2009
Aphids	Rainy	0.1±0.45	0.1±0.31	0.9±2.02	0.95±2.37	0.5±1.10	0.9±2.02	0.85±1.53	0.45±1.28
	Summer	1.55±1.88	0.85±1.93	2±3.13	2.25±2.94	1.95±2.84	1.6±2.26	1.7±2.72	1.95±3.52
	Cool	0.95±1.54	0.9±1.94	1.35±2.28	1.55±2.35	1.2±2.33	1.35±2.28	0.95±2.11	1.15±2.13
Thrips	Rainy	0	0	0.05±0.22	0.1±0.31	0.15±0.49	0.1±0.31	0.2±0.62	0.2±0.70
	Summer	0.05±0.22	0.1±0.31	0.05±0.22	0.1±0.31	0.1±0.45	0.05±0.22	0.25±0.55	0.15±0.49
	Cool	0.05±0.22	0.05±0.22	0.05±0.22	0	0.1±0.31	0.15±0.37	0.4±0.75	0.25±1.12
Whitefly	Rainy	0	0	0.05±0.22	0	0.15±0.37	0.2±0.52	0.15±0.37	0.15±0.49
	Summer	0	0	0.15±0.49	0.2±0.52	0.2±0.52	0.1±0.31	0.2±0.52	0.15±0.49
	Cool	0	0	0.15±0.37	0.1±0.31	0.2±0.52	0.2±0.62	0.35±0.93	0.4±1.05
Beetle	Rainy	0.15±0.37	0.05±0.22	0.65±0.67	0.75±0.79	0.25±0.44	0.25±0.55	0	0
	Summer	0.05±0.23	0.05±0.22	0.65±0.93	0.75±0.91	0.35±0.74	0.5±0.61	0	0
	Cool	0.15±0.49	0.15±0.67	0.7±0.92	0.7±0.80	0.45±0.69	0.45±0.60	0	0

Table 4.17 Kind and number of insect vectors collected from pumpkin at Wat Chan in three seasons at four growth stages in 2008 and 2009.

Insect vectors	Seasons	No. of insect vectors counted in pumpkin growing stage							
		Seedling		Flowering		Fruiting		Harvesting	
		2008	2009	2008	2009	2008	2009	2008	2009
Aphids	Rainy	0	0.1±0.31	0.75±1.62	1±2.05	0.55±1.43	0.75±1.52	0.8±1.64	0.6±1.35
	Summer	1.05±1.32	0.8±1.51	2±2.94	2.6±3.52	1.9±2.57	1.35±2.46	1.3±2.81	1.3±1.98
	Cool	0.8±1.28	0.95±1.57	1.3±2.36	1.5±2.70	1±1.72	1.3±2.30	0.9±1.71	1.05±1.79
Thrips	Rainy	0	0	0	0	0.05±0.22	0.1±0.31	0.15±0.49	0.2±0.52
	Summer	0.1±0.31	0.1±0.31	0.1±0.31	0.05±0.22	0.15±0.49	0.15±0.37	0.15±0.49	0.2±0.89
	Cool	0.05±0.22	0.05±0.22	0.05±0.22	0.15±0.67	0.05±0.22	0.15±0.37	0.25±0.64	0.2±0.62
Whitefly	Rainy	0	0	0.2±0.70	0.15±0.67	0.1±0.31	0.1±0.45	0.1±0.31	0.15±0.49
	Summer	0	0	0.1±0.31	0.05±0.22	0.2±0.52	0.15±0.37	0.2±0.52	0.15±0.49
	Cool	0	0	0.15±0.37	0.1±0.31	0.1±0.31	0.05±0.22	0.3±0.80	0.25±0.79
Beetle	Rainy	0.1±0.31	0.05±0.22	0.75±0.72	0.6±0.82	0.25±0.44	0.15±0.37	0	0
	Summer	0.1±0.31	0.15±0.37	0.6±0.94	0.65±0.93	0.35±0.74	0.45±0.51	0	0
	Cool	0.15±0.49	0.2±0.70	0.55±0.76	0.65±0.81	0.4±0.60	0.2±0.41	0	0

Table 4.18 Kind and number of plant virus insect vectors collected from pumpkin at Mae La Noi in three seasons at four growth stages in 2008 and 2009.

Insect vectors	Seasons	No. of insect vectors counted in pumpkin growing stage							
		Seedling		Flowering		Fruiting		Harvesting	
		2008	2009	2008	2009	2008	2009	2008	2009
Aphids	Rainy	0.05±0.22	0.2±0.41	0.55±1.19	0.9±2.07	0.7±1.38	0.85±1.66	0.65±1.56	0.6±1.35
	Summer	0.85±1.08	0.8±1.70	1.65±2.71	2±2.25	1.55±1.91	1.35±2.76	0.95±1.90	1.15±2.21
	Cool	0.8±1.28	0.85±1.35	0.95±1.96	1.35±2.46	0.9±1.71	1.35±1.68	0.9±1.71	1±1.65
Thrips	Rainy	0	0.05±0.22	0.05±0.22	0.1±0.31	0.15±0.49	0.15±0.37	0.2±0.62	0.2±0.70
	Summer	0.05±0.22	0.1±0.31	0.1±0.45	0.1±0.31	0.15±0.49	0.15±0.37	0.25±0.55	0.15±0.49
	Cool	0.05±0.22	0.05±0.22	0.15±0.49	0.25±0.79	0.35±0.99	0.25±0.55	0.25±0.64	0.2±0.62
Whitefly	Rainy	0	0	0.1±0.31	0.1±0.45	0.05±0.22	0.1±0.45	0.1±0.31	0.05±0.22
	Summer	0	0	0.2±0.52	0.05±0.22	0.2±0.52	0.15±0.37	0.25±0.64	0.15±0.49
	Cool	0	0	0.15±0.37	0.1±0.31	0.1±0.31	0.15±0.49	0.25±0.64	0.3±0.80
Beetle	Rainy	0.2±0.41	0.1±0.31	0.6±0.75	0.55±0.82	0.1±0.31	0.15±0.37	0	0
	Summer	0.1±0.31	0.15±0.37	0.6±0.88	0.6±0.82	0.45±0.82	0.4±0.50	0	0
	Cool	0.15±0.49	0.15±0.37	0.6±0.75	0.7±0.80	0.45±0.60	0.4±0.50	0	0

2.1.3 Plant virus insect vectors in cucumber growing areas.

A survey of insect vectors in cucumber was conducted in three seasons at Mae Tha Nuea (field grown), Ma Sa Mai (insect proof greenhouse), Mae Phae (natural air circulated greenhouse), and Huai Luk (greenhouse without insect proofing). Insect vectors populations increased from the early through the late growth stage. Small insect populations, i.e. aphids and thrips, increased during the dry season and decreased during the rainy season. Whiteflies were not found at early growth stage in all of the growing seasons and beetles not found at the end of cropping season.

At Mae Tha Nuea where cucumber was field grown, the number of aphids increased in the summer and decreased in the rainy season (Table 4.19). The number of aphids found at the seedling, flowering, fruiting, and harvesting stage in summer 2008 was 0.3, 0.4, 0.55, and 0.75 aphid/leaf, respectively, and 0.45, 0.55, 0.45, and 0.65 aphid/leaf, respectively, in 2009. Thrips were not found at seedling stage in either 2008 or 2009.

At Ma Sa Mai where cucumber was grown in insect proof greenhouses, small insect vectors, i.e. aphids and thrips, were found all the growing stages, while whiteflies and beetles were not (Table 4.20). Aphids were often found all the growing seasons except at the seedling stage in 2008 and 2009. Aphids' populations increased

during the cropping season. The number of aphids found at the seedling, flowering, fruiting and harvesting stages in summer 2008 was 0.1, 0.1, 0.25 and 0.35aphids/leaf, respectively, and 0.05, 0.15, 0.15 and 0.3 aphid/leaf, respectively, in summer 2009 at this site. Whiteflies were commonly found in the summer and cool seasons.

Beetles were not found at Mae Phae, where the cucumbers were grown in air-circulated greenhouses (Table 4.21). Whiteflies were only found in the early stage in the rainy season, and increased in number in the flowering stage of both summer and the cool season. Aphids and thrips were often found in cucumber. Aphids were increased of quantity at flowering stage and decreased at rainy season. Thrips were not found at seedling stage at rainy season in 2009.

Aphids were found in every growing season at Huai Luk where the greenhouse was not insect-proof (Table 4.22). The number of aphids increased y in the summer season during both 2008 and 2009. Thrips were found in all seasons and growing stages except at the seedling stage in rainy season of 2008. The number of thrips increased during the summer season. The number of thrips found at the seedling, flowering, fruiting, and harvesting stage in summer 2008 was 0.15, 0.3, 0.35, and 0.75 thrips/leaf, respectively, and 0.1, 0.35, 0.4, and 1.1thrips/leaf, respectively, in 2009. Whiteflies were not found at the seedling and not found only at flowering stage at rainy season during 2008-2009. Beetles were found at the seedling through the fruiting stage but not at the harvesting stage.

Table 4.19 Kind and number of insect vectors collected from cucumber planting plots at Mae Tha Neua in three seasons at four growth stages in 2008 and 2009.

Insect vectors	Seasons	No. of insect vectors counted in cucumber growing stage							
		Seedling		Flowering		Fruiting		Harvesting	
		2008	2009	2008	2009	2008	2009	2008	2009
Aphids	Rainy	0.05±0.22	0.1±0.31	0.35±0.88	0.45±0.94	0.4±1.10	0.4±0.99	0.45±1.28	0.4±1.27
	Summer	0.3±0.92	0.45±1.19	0.4±1.10	0.55±1.32	0.55±1.05	0.65±1.18	0.75±1.52	0.65±1.35
	Cool	0.35±0.88	0.4±1.10	0.4±0.99	0.5±1.23	0.6±1.19	0.55±1.05	0.7±1.38	0.65±1.09
Thrips	Rainy	0	0	0.1±0.45	0.25±0.79	0.15±0.67	0.15±0.49	0.35±0.88	0.55±1.14
	Summer	0.1±0.31	0.1±0.45	0.2±0.62	0.45±0.94	0.25±0.79	0.4±1.19	0.7±1.17	0.45±1.14
	Cool	0.05±0.22	0.05±0.22	0.2±0.62	0.3±0.92	0.25±0.79	0.25±0.79	0.6±1.35	0.9±1.52
Whitefly	Rainny	0	0	0	0	0.1±0.45	0.05±0.22	0.05±0.22	0.05±0.22
	Summer	0	0	0.05±0.22	0.1±0.45	0.1±0.45	0.1±0.45	0.15±0.67	0.2±0.89
	Cool	0	0	0.05±0.22	0.05±0.22	0.15±0.67	0.05±0.22	0.15±0.37	0.25±1.12
Beetle	Rainny	0.15±0.37	0.2±0.41	0.6±0.94	0.75±0.85	0.2±0.41	0.4±0.50	0	0
	Summer	0.2±0.41	0.25±0.55	0.6±0.88	0.75±0.72	0.4±0.60	0.55±0.60	0	0
	Cool	0.25±0.44	0.25±0.44	0.8±0.95	0.85±0.74	0.3±0.57	0.6±0.60	0	0

Table 4.20 Kind and number of insect vectors collected from cucumber planting plots at Mae Sa Mai in three seasons at four growth stages in 2008 and 2009.

Insect vectors	Seasons	No. of insect vectors counted in cucumber growing stage							
		Seedling		Flowering		Fruiting		Harvesting	
		2008	2009	2008	2009	2008	2009	2008	2009
Aphids	Rainy	0	0	0.05±0.22	0.1±0.45	0.15±0.67	0.1±0.45	0.25±0.79	0.3±0.73
	Summer	0.1±0.31	0.05±0.22	0.1±0.45	0.15±0.67	0.25±0.64	0.15±0.67	0.35±1.09	0.3±0.80
	Cool	0.05±0.22	0.05±0.22	0.15±0.49	0.15±0.49	0.15±0.49	0.2±0.52	0.3±0.80	0.3±0.80
Thrips	Rainy	0.1±0.31	0.15±0.37	0	0.1±0.45	0.15±0.67	0.15±0.49	0.35±0.88	0.55±1.14
	Summer	0.15±0.37	0.25±0.64	0.25±0.79	0.35±0.88	0.1±0.45	0.15±0.49	0.2±0.70	0.15±0.67
	Cool	0.15±0.49	0.2±0.62	0.2±0.62	0.25±0.72	0.15±0.67	0.2±0.52	0.15±0.67	0.15±0.37
Whitefly	Rainny	0	0	0	0	0	0	0	0
	Summer	0	0	0	0	0	0	0	0
	Cool	0	0	0	0	0	0	0	0
Beetle	Rainny	0	0	0	0	0	0	0	0
	Summer	0	0	0	0	0	0	0	0
	Cool	0	0	0	0	0	0	0	0

Table 4.21 Kind and number of insect vectors collected from cucumber planting plots at Mae Phae in three seasons at four growth stages in 2008 and 2009.

		No. of insect vectors counted in cucumber growing stage							
		Seedling		Flowering		Fruiting		Harvesting	
Insect vectors	Seasons	2008	2009	2008	2009	2008	2009	2008	2009
Aphids	Rainy	0	0.05±0.22	0.25±0.79	0	0.1±0.45	0.15±0.49	0.2±0.52	0.3±0.92
	Summer	0.15±0.67	0.15±0.37	0.35±0.81	0.5±1.32	0.15±0.67	0.1±0.45	0.45±1.00	0.55±1.10
	Cool	0.1±0.45	0.15±0.67	0.4±1.19	0.35±0.88	0.15±0.49	0.15±0.67	0.6±1.19	0.5±0.94
Thrips	Rainy	0.05±0.22	0	0.1±0.45	0.2±0.62	0.15±0.67	0.3±0.80	0.15±0.67	0.2±0.62
	Summer	0.15±0.37	0.25±0.64	0.25±0.79	0.35±0.88	0.1±0.45	0.15±0.49	0.2±0.70	0.15±0.67
	Cool	0.1±0.31	0.2±0.62	0.15±0.49	0.25±0.72	0.3±0.80	0.2±0.62	0.2±0.70	0.15±0.37
Whitefly	Rainny	0	0	0.15±0.37	0.2±0.41	0.3±0.80	0.3±0.98	0.5±1.05	0.1±0.45
	Summer	0	0	0.45±1.28	0.8±1.44	0.1±0.45	0.15±0.49	0.5±1.32	0.75±1.45
	Cool	0	0	0.4±0.88	0.75±1.37	0.45±1.39	0.6±1.39	0.5±1.24	0.4±0.99
Beetle	Rainny	0	0	0	0	0	0	0	0
	Summer	0	0	0	0	0	0	0	0
	Cool	0	0	0	0	0	0	0	0

Table 4.22 Kind and number of insect vectors collected from cucumber planting plots at Huai Luk in three seasons at four growth stages in 2008 and 2009.

		No. of insect vectors counted in cucumber growing stage							
		Seedling		Flowering		Fruiting		Harvesting	
Insect vectors	Seasons	2008	2009	2008	2009	2008	2009	2008	2009
Aphids	Rainy	0.1±0.45	0.15±0.37	0.35±0.88	0.45±1.14	0.45±1.00	0.5±1.05	0.45±0.89	0.35±0.81
	Summer	0.25±0.79	0.35±0.81	0.45±1.00	0.65±1.50	0.6±1.35	0.55±1.32	0.6±1.43	0.6±1.23
	Cool	0.2±0.90	0.35±0.81	0.4±0.99	0.6±1.50	0.55±1.19	0.55±1.14	0.6±1.10	0.5±1.24
Thrips	Rainy	0	0.1±0.31	0.1±0.45	0.1±0.45	0.2±0.52	0.3±0.80	0.3±0.66	0.6±1.23
	Summer	0.15±0.67	0.1±0.45	0.3±0.92	0.35±0.93	0.35±0.88	0.4±0.88	0.75±0.62	1.1±1.68
	Cool	0.15±0.49	0.2±0.52	0.2±0.52	0.25±0.72	0.35±1.18	0.3±0.80	1±2.13	0.9±1.65
Whitefly	Rainny	0	0	0	0	0.1±0.45	0.05±0.22	0.5±1.05	0.6±1.19
	Summer	0	0	0.15±0.67	0.1±0.45	0.1±0.45	0.15±0.67	0.55±1.23	0.6±1.27
	Cool	0	0	0.2±0.89	0.2±0.70	0.15±0.67	0.25±1.12.	0.55±1.36	0.6±1.39
Beetle	Rainny	0.15±0.37	0.1±0..31	0.4±0.60	0.3±0.66	0.1±0.31	0.15±0.37	0	0
	Summer	0.2±0.41	0.15±0.37	0.8±0.89	0.75±0.85	0.2±0.52	0.25±0.44	0	0
	Cool	0.15±0.37	0.2±0.41	0.8±0.83	0.75±0.91	0.3±0.47	0.25±0.44	0	0

2.2 Insect vector and virus detection.

2.2.1 Insect vectors and virus detection at different growth stages of zucchini.

At Mae Hae, aphids were found at the seedling stage during all growing seasons in both 2008 and 2009, and thrips were detected during the cool season (Table 4.23). ELISA detected ZYMV with other viruses in the rainy season at an incidence of 0.28%. ZYMV and PRSV-W and other viruses were found during the cool season. All insect vectors were found at the flowering stage (Table 4.24). Virus detection was found ZYMV with other viruses in the rainy season at an incidence of 1.56 and 1.4% in 2008 and 2009 respectively. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage. The fruit setting state was found all insect vectors (Table 4.25). Virus detection was found ZYMV with other viruses in the rainy season at an incidence of 0.84 in both 2008 and 2009; PRSV-W with other viruses as 0.28 and 0.56% respectively. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage. The harvesting state was found all insect vectors (Table 4.26). Virus detection was found ZYMV and PRSV-W with other viruses in the rainy season at the same an incidence in fruiting stage. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage.

At Mae Tha Neua (Table 4.27), the survey result of seedling stage during 2008 and 2009 was found aphid all the growing seasons and thrips at the dry seasons. The ELISA result was detected ZYMV with other viruses at rainy season as 0.28%. The dry seasons were found ZYMV and PRSV-W with other viruses. The flowering state was found all insect vectors (Table 4.28). Virus detection was found ZYMV with other viruses at cool season as 0.28% in during 2008 and 2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage. The fruiting state was found all insect vectors (Table 4.29). Virus detection was found PRSV-W with other viruses as 0.28% in 2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage. The harvesting state was found all insect vectors (Table 4.30). Virus detection was found ZYMV with other viruses as 0.84% in 2008 and 2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage.

Table 4.23 Kind of insect vectors and virus detected at seedling stage of zucchini at Mae Hae in 2008 and 2009.

Insects	Years	Seedling			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphids	2008	0.1±0.31	1±0.65	1.55±2.01	ZYMV0.28%	ZYMV1.12% PRSV-W0.28%	ZYMV0.84%
Thrips	2008	0	0.35±0.67	0			
Whitefly	2008	0	0	0.05±0.22			
Beetle	2008	0.1±0.45	0.05±0.22	0.1±0.31			
Aphids	2009	0.15±0.37	1±1.08	0.95±1.90	ZYMV0.28%	ZYMV0.28%	ZYMV0.28% PRSV-W 0.28%
Thrips	2009	0	0.25±0.55	0			
Whitefly	2009	0	0	0.05±0.22			
Beetle	2009	0.1±0..31	0.05±0.22	0			

Table 4.24 Viruses detected in insects on zucchini at the flowering stage at Mae Hae in 2008 and 2009.

Insects	Years	Flowering			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphids	2008	0.6±1.05	1.55±1.96	2.05±3.28	ZYMV1.56%	ZYMV4.49% CMV0.56% SqMV0.84% PRSV-W2.25% WMV-2 0.56%	ZYMV3.09% CMV0.28% SqMV0.84% PRSV-W1.4% WMV-2 0.84%
Thrips	2008	0.05±0.22	0.35±0.59	0.6±0.88			
Whitefly	2008	0.1±0.31	0.1±0.31	0.1±0.31			
Beetle	2008	0.5±0.83	1.45±1.05	095±0.76			
Aphids	2009	0.6±0.88	1.75±2.07	2.5±3.42	ZYMV1.4% SqMV0.28% PRSV-W 0.56% WMV-2 0.28%	ZYMV3.37% CMV0.56% SqMV0.56% PRSV-W 2.25% WMV-2 0.28%	ZYMV4.78% CMV0.28% SqMV0.56% PRSV-W 3.95% WMV-2 0.28%
Thrips	2009	0.05±0.22	0.25±0.55	0.4±0.60			
Whitefly	2009	0.05±0.22	0.1±0.31	0.15±0.37			
Beetle	2009	0.4±0.82	0.65±0.93	0.8±0.52			

Table 4.25 Viruses detected in insects on zucchini at the fruit setting stage at Mae Hae in 2008 and 2009.

Insects	Years	Fruiting			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphids	2008	0.55±0.89	1.25±1.62	1.85±2.06	ZYMV0.84% PRSV-W0.28%	ZYMV2.53% CMV1.56% SqMV0.84% PRSV-W1.4% WMV-2 0.28%	ZYMV2.53% CMV0.28% SqMV1.97% PRSV-W2.25% WMV-2 0.28%
Thrips	2008	0.1±0.31	0.65±1.18	0.75±1.07			
Whitefly	2008	0.05±0.22	0.05±0.22	0.15±0.37			
Beetle	2008	0.05±0.22	0.85±1.09	0.85±0.99			
Aphids	2009	0.85±1.18	1.4±2.06	1.55±2.09	ZYMV0.84% PRSV-W 0.56%	ZYMV2.53% CMV0.28% SqMV1.56% PRSV-W 1.12% WMV-2 0.56%	ZYMV2.81% CMV1.12% SqMV1.12% PRSV-W 1.4% WMV-2 0.56%
Thrips	2009	0	0.6±1.05	0.55±0.89			
Whitefly	2009	0.05±0.22	0.1±0.31	0.25±0.55			
Beetle	2009	0.2±0.41	0.5±0.76	0.5±0.83			

Table 4.26 Viruses detected in insects on zucchini at the harvesting stage at Mae Hae in 2008 and 2009.

Insects	Years	Harvesting			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphids	2008	0.55±0.89	1.25±1.62	1.85±2.06	ZYMV40.84% PRSV-W0.28%	ZYMV2.53% CMV1.56% SqMV0.84% PRSV-W1.4% WMV-2 0.28%	ZYMV2.53% CMV0.28% SqMV1.97% PRSV-W2.25% WMV-2 0.28%
Thrips	2008	0.1±0.31	0.65±1.18	0.75±1.07			
Whitefly	2008	0.05±0.22	0.05±0.22	0.15±0.37			
Beetle	2008	0.05±0.22	0.85±1.09	0.85±0.99			
Aphids	2009	0.85±1.18	1.4±2.06	1.55±2.09	ZYMV0.84% PRSV-W 0.56%	ZYMV2.53% CMV0.28% SqMV1.56% PRSV-W 1.12% WMV-2 0.56%	ZYMV2.81% CMV1.12% SqMV1.12% PRSV-W 1.4% WMV-2 0.56%
Thrips	2009	0	0.6±1.05	0.55±0.89			
Whitefly	2009	0.05±0.22	0.1±0.31	0.25±0.55			
Beetle	2009	0.2±0.41	0.5±0.76	0.5±0.83			

Table 4.27 Viruses detected in insects on zucchini at the seedling stage at Mae Tha Neua in 2008 and 2009.

Insects	Years	Seedling			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphids	2008	0.05±0.31	0.6±0.94	0.7±0.92	ZYMV0.28%	ZYMV0.56% CMV0.28% PRSV-W 0.28%	ZYMV0.84% SqMV0.28%
Thrips	2008	0	0	0			
Whitefly	2008	0	0	0.05±0.22			
Beetle	2008	0.1±0.31	0.05±0.22	0.05±0.22			
Aphids	2009	1±1.08	0.9±1.16	0.8±0.89	ZYMV0.28%	ZYMV0.28% SqMV0.28% PRSV-W 0.28%	ZYMV0.56%
Thrips	2009	0	0	0			
Whitefly	2009	0	0	0.05±0.22			
Beetle	2009	0.1±0.45	0.05±0.22	0.15±0.49			

Table 4.28 Viruses detected in insects on zucchini at the flowering stage at Mae Tha Neua in 2008 and 2009.

Insects	Years	Flowering			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphids	2008	1.55±1.96	1±1.52	2.05±3.28	SqMV0.28%	ZYMV0.28% CMV0.28% SqMV0.56% PRSV-W 0.28% WMV-2 0.28%	SqMV0.84% PRSV-W 0.28% WMV-2 0.28%
Thrips	2008	0.05±0.22	0.35±0.59	0.6±0.88			
Whitefly	2008	0	0	0.05±0.22			
Beetle	2008	0.1±0.31	0.4±0.82	0.5±0.69			
Aphids	2009	1.75±2.07	1.75±2.07	2.5±3.42	SqMV0.56% PRSV-W 0.56% WMV-2 0.28%	ZYMV0.28% CMV0.28% SqMV0.84% PRSV-W 0.28%	CMV0.28% SqMV0.84% PRSV-W 0.28%
Thrips	2009	0.05±0.22	1.7±1.52	0.4±0.60			
Whitefly	2009	0	0	0.05±0.22			
Beetle	2009	0.1±0.45	0.7±0.92	0.55±0.82			

Table 4.29 Viruses detected in insects on zucchini at the fruit setting stage at Mae Tha Neua in 2008 and 2009.

Insects	Years	Fruiting			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphids	2008	1.4±1.64	1.65±2.28	1.1±1.97	0	PRSV-W 0.28% WMV-2 0.28%	CMV0.28% SqMV1.97% PRSV-W 2.25%
Thrips	2008	0.05±0.22	0.5±0.89	0.5±0.89			
Whitefly	2008	0	0.05±0.22	0.2±0.62			
Beetle	2008	0.05±0.22	0.45±0.60	0.2±0.41			
Aphids	2009	0.05±0.22	1.5±2.16	1.5±2.09	PRSV-W 0.28%	CMV0.28% PRSV-W 0.28%	CMV0.28% SqMV0.28% PRSV-W 0.28% WMV-2 0.28%
Thrips	2009	0.05±0.22	0.55±0.89	0.55±0.9			
Whitefly	2009	0.1±0.45	0.1±0.45	0.2±0.41			
Beetle	2009	0.2±0.52	0.45±0.60	0.4±0.82			

Table 4.30 Viruses detected in insects on zucchini at the harvesting stage at Mae Tha Neua in 2008 and 2009.

Insects	Years	Harvesting			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphids	2008	1.95±1.6	2.2±3.17	1.15±1.81	ZYMV40.84% PRSV-W0.28%	ZYMV2.53% CMV1.56% SqMV0.84% PRSV-W1.4% WMV-2 0.28%	ZYMV2.53% CMV0.28% SqMV1.97% PRSV-W2.25% WMV-2 0.28%
Thrips	2008	0.1±0.31	0.1±0.31	0.2±0.52			
Whitefly	2008	0	0.1±0.31	0.05±0.22			
Beetle	2008	0	0	0			
Aphids	2009	1.15±1.56	3.2±3.14	1.6±1.9	ZYMV0.84% PRSV-W 0.28%	ZYMV2.53% CMV1.56% SqMV0.84% PRSV-W 1.4% WMV-2 0.28%	ZYMV2.53% CMV0.28% SqMV1.97% PRSV-W 2.25% WMV-2 0.28%
Thrips	2009	0.2±0.52	0.25±0.55	0.25±0.52			
Whitefly	2009	0.05±0.22	0.05±0.22	0.2±0.70			
Beetle	2009	0	0	0			

2.2.2 Insect vectors and virus detection at different growth stages of pumpkin.

At Mon Ngo (Table 4.31), the survey result of seedling stage during 2008 and 2009 was often found aphid all the growing seasons and thrips at the dry seasons. The ELISA result was detected ZYMV with other viruses at rainy season as 0.28%. The dry seasons were found ZYMV and PRSV-W with other viruses. The flowering state was found all insect vectors (Table 4.32). Virus detection was found ZYMV with

other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage. The fruiting state was found all insect vectors (Table 4.33). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage. The harvesting state was found all insect vectors (Table 4.34). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage.

At Mok Cham (Table 4.35), the survey result of seedling stage during 2008 and 2009 was found aphid all the growing seasons and thrips at the dry seasons. The ELISA result was detected ZYMV with other viruses at rainy season as 0.28%. The dry seasons were found ZYMV and PRSV-W with other viruses. The flowering state was found all insect vectors (Table 4.36). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage. The fruiting state was found all insect vectors (Table 4.37). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage. The flowering state was found all insect vectors (Table 4.38). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage.

At Kae Noi (Table 4.39), the survey result of seedling stage during 2008 and 2009 was found aphid all the growing seasons and thrips at the dry seasons. The ELISA result was detected ZYMV with other viruses at rainy season as 0.28%. The dry seasons were found ZYMV and PRSV-W with other viruses. The flowering state was found all insect vectors (Table 4.40). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage. The fruiting state was found all insect vectors (Table 4.41). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage. The flowering state was found all insect vectors (Table 4.42). Virus detection was found ZYMV with other viruses as 0.28% during

2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage.

At Wat Chan (Table 4.43), the survey result of seedling stage during 2008 and 2009 was found aphid all the growing seasons and thrips at the dry seasons. The ELISA result was detected ZYMV with other viruses at rainy season as 0.28%. The dry seasons were found ZYMV and PRSV-W with other viruses. The flowering state was found all insect vectors (Table 4.44). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage. The fruiting state was found all insect vectors (Table 4.45). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage. The flowering state was found all insect vectors (Table 4.46). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage.

At Mae La Noi (Table 4.47), the survey result of seedling stage during 2008 and 2009 was found aphid all the growing seasons and thrips at the dry seasons. The ELISA result was detected ZYMV with other viruses at rainy season as 0.28%. The dry seasons were found ZYMV and PRSV-W with other viruses. The flowering state was found all insect vectors (Table 4.48). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage. The fruiting state was found all insect vectors (Table 4.49). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage. The flowering state was found all insect vectors (Table 4.50). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage.

Table 4.31 Viruses detected in insects on pumpkin at the seedling stage at Mon Ngo in 2008 and 2009.

Insects	Years	Seedling			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.15±0.37	1.0±0.86	1.9±2.07	0	ZYMV0.28%	ZYMV0.28%
Thrips	2008	0.05±0.22	0.2±0.62	0.15±0.50		CMV0.28%	CMV0.28%
Whitefly	2008	0	0	0		PRSV-W	PRSV-W
Beetle	2008	0.25±0.44	0.2±0.62	0.2±0.41		0.28%	0.28%
Aphids	2009	0.2±0.41	0.8±1.24	1.0±1.92	0	SqMV0.28%	CMV0.28%
Thrips	2009	0	0.2±0.70	0.4±0.31			SqMV0.84%
Whitefly	2009	0	0	0			PRSV-W
Beetle	2009	0.1±0.41	0.2±0.70	0.3±0.57			0.28%

Table 4.32 Viruses detected in insects on pumpkin at the flowering stage at Mon Ngo in 2008 and 2009.

Insects	Years	Flowering			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	1.15±1.56	1.8±2.14	2.25±2.4	CMV0.28%	SqMV0.28%	PRSV-W
Thrips	2008	0.1±0.31	0.1±0.31	0.1±0.22	SqMV0.28%	PRSV-W	0.28%
Whitefly	2008	0.05±0.22	0.1±0.31	02±0.41		0.28%	
Beetle	2008	0.6±0.82	0.05±0.22	0.7±1.08			
Aphids	2009	1.05±1.50	1.95±2.89	2.65±2.91	PRSV-W	SqMV0.28%	CMV0.28%
Thrips	2009	0.1±0.45	0.05±0.22	0.05±0.54	0.28%		PRSV-W
Whitefly	2009	0.1±0.45	0.25±0.64	0.25±0.64			0.28%
Beetle	2009	0.65±0.93	0.25±0.72	0.65±0.93			

Table 4.33 Viruses detected in insects on pumpkin at the fruit setting stage at Mon Ngo in 2008 and 2009.

Insects	Years	fruiting			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.5±1.15	1.45±2.28	1.75±1.68	CMV0.28%	ZYMV0.28%	SqMV0.28%
Thrips	2008	0.4±0.75	0.25±0.72	0.2±0.54		CMV0.28	WMV-2
Whitefly	2008	0.15±0.37	0.25±0.64	02±0.52		PRSV-W	0.28%
Beetle	2008	0.45±0.60	0.05±0.22	0.35±0.52		0.28%	
Aphids	2009	0.95±2.30	1.45±2.37	1.75±2.70	PRSV-W	CMV0.28%	ZYMV0.28%
Thrips	2009	0.1±0.31	0.25±0.64	0.15±0.37	0.28%	PRSV-W	CMV0.28%
Whitefly	2009	0.1±0.31	0.25±0.64	0.15±0.37		0.28%	WMV-2
Beetle	2009	0.4±0.60	0.25±0.72	0.2±0.52			0.28%

Table 4.34 Viruses detected in insects on pumpkin at the harvesting stage at Mon Ngo in 2008 and 2009.

Insects	Years	Harvesting			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.4±0.88	1.3±2.03	1.7±2.05	ZYMV40.84%	ZYMV2.53%	ZYMV2.53%
Thrips	2008	0.25±0.72	0.3±0801	0.2±0.71	PRSV-W	CMV1.56%	CMV0.28%
Whitefly	2008	0.1±0.31	0.6±1.14	0.4±0.99	0.28%	SqMV0.84%	SqMV1.97%
Beetle	2008	0	0	0.3±0.80		PRSV-W	PRSV-W
						1.4%	2.25%
						WMV-2	WMV-2
						0.28%	0.28%
Aphids	2009	0.55±1.05	1.15±1.46	0	ZYMV0.84%	ZYMV2.53%	ZYMV2.53%
Thrips	2009	0.25±0.79	0.2±0.62	0.25±0.80	PRSV-W	CMV1.56%	CMV0.28%
Whitefly	2009	0.2±0.52	0.25±0.64	0.25±0.79	0.28%	SqMV0.84%	SqMV1.97%
Beetle	2009	0	0	0.2±0.62		PRSV-W	PRSV-W
						1.4%	2.25%
						WMV-2	WMV-2
						0.28%	0.28%

Table 4.35 Viruses detected in insects on pumpkin at the seedling stage at Mok Cham in 2008 and 2009.

Insects	Years	Seedling			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.15±0.37	0.9±1.65	1.75±1.71	0	SqMV0.28%	PRSV-W
Thrips	2008	0.05±0.22	0.05±0.22	0.15±0.37		PRSV-W	0.28%
Whitefly	2008	0	0	0		0.28%	
Beetle	2008	0.15±0.37	0.25±0.70	0.15±0.37			
Aphids	2009	0.1±0.31	1.35±2.06	1.15±1.98	0	PRSV-W	CMV0.28%
Thrips	2009	0	0.05±0.22	0.05±0.22		0.28%	SqMV0.84%
Whitefly	2009	0	0	0			
Beetle	2009	0.1±0.31	0.8±1.00	0.15±0.37			

Table 4.36 Viruses detected in insects on pumpkin at the flowering stage at Mon Ngo in 2008 and 2009.

Insects	Years	Flowering			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	1.15±2.03	1.75±2.83	2.00±3.09	CMV0.28%	SqMV0.28%	ZYMV0.28%
Thrips	2008	0.05±0.22	0.1±0.45	0.1±0.45	SqMV0.28%	PRSV-W	CMV0.28%
Whitefly	2008	0.05±0.22	0.25±0.55	025±0.55		0.28%	PRSV-W
Beetle	2008	0.7±0.80	0.8±1.0	0.55±0.94			0.28%
Aphids	2009	1.5±1.96	2.00±2.49	2.65±2.91	PRSV-W	SqMV0.28%	CMV0.28%
Thrips	2009	0	0.05±0.22	0.1±0.31	0.28%		PRSV-W
Whitefly	2009	0.15±0.49	0.25±0.72	0.25±0.64			0.28%
Beetle	2009	0.7±0.86	0.8±0.93	0.6±0.94			

Table 4.37 Viruses detected in insects on pumpkin at the fruit setting stage at Mok Cham in 2008 and 2009.

Insects	Years	fruiting			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	1.1±2.15	1.35±2.37	1.8±3.38	CMV0.28%	ZYMV0.28%	SqMV0.28%
Thrips	2008	0.05±0.22	0.1±0.31	0.15±0.37		CMV0.28	WMV-2
Whitefly	2008	0.15±0.37	0.25±0.72	02±0.52		PRSV-W	0.28%
Beetle	2008	0.4±0.60	0.5±0.83	2.00±0.82		0.28%	
Aphids	2009	0.65±1.42	1.5±2.52	1.6±2.74	PRSV-W	CMV0.28%	ZYMV0.28%
Thrips	2009	0.05±0.22	0.15±0.67	0.15±0.49	0.28%	PRSV-W	CMV0.28%
Whitefly	2009	0.2±0.52	0.2±0.62	0.1±0.31		0.28%	WMV-2
Beetle	2009	0.35±0.59	0.4±0.68	0.45±069			0.28%

Table 4.38 Viruses detected in insects on pumpkin at the harvesting stage at Mok Cham in 2008 and 2009.

Insects	Years	Harvesting			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	1.4±1.52	1.05±1.57	1.45±2.33	ZYMV40.84%	ZYMV2.53%	ZYMV2.53%
Thrips	2008	0.05±0.22	0.1±0.31	0.15±0.37	PRSV-W	CMV1.56%	SqMV1.97%
Whitefly	2008	0.15±0.37	0.25±0.72	0.2±0.52	0.28%	PRSV-W	PRSV-W
Beetle	2008	0	0	0		1.4%	2.25%
						WMV-2	WMV-2
						0.28%	0.28%
Aphids	2009	0.55±0.22	1.25±1.55	2.15±3.86	ZYMV0.84%	ZYMV2.53%	ZYMV2.53%
Thrips	2009	0.25±0.79	0.15±0.67	0.15±0.49	PRSV-W	CMV1.56%	CMV0.28%
Whitefly	2009	0.2±0.52	0.2±0.62	0.1±0.31	0.28%	SqMV0.84%	PRSV-W
Beetle	2009	0	0	0		PRSV-W	2.25%
						1.4%	WMV-2
							0.28%

Table 4.39 Viruses detected in insects on pumpkin at the seedling stage at Kae Noi in 2008 and 2009.

Insects	Years	Seedling			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.1±0.45	0.95±1.54	1.55±1.88	0	0	ZYMV0.28%
Thrips	2008	0	0.05±0.22	0.05±0.22			
Whitefly	2008	0	0	0			
Beetle	2008	0.15±0.37	0.15±0.49	0.05±0.23			
Aphids	2009	0.1±0.31	0.9±1.94	0.85±1.93	0	PRSV-W	CMV0.28%
Thrips	2009	0	0.05±0.22	0.1±0.31		0.28%	SqMV0.28%
Whitefly	2009	0	0	0			
Beetle	2009	0.05±0.22	0.15±0.67	0.05±0.22			

Table 4.40 Viruses detected in insects on pumpkin at the flowering stage at Kae Noi in 2008 and 2009.

Insects	Years	Flowering			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.9±2.02	1.35±2.28	2.00±3.13	CMV0.28%	PRSV-W 0.28%	ZYMV0.28% PRSV-W 0.28%
Thrips	2008	0.05±0.22	0.05±0.22	0.05±0.22			
Whitefly	2008	0.05±0.22	0.15±0.37	025±0.55			
Beetle	2008	0.65±0.67	0.7±0.92	0.65±0.93			
Aphids	2009	0.95±2.37	1.55±2.35	2.25±2.94	PRSV-W 0.28%	SqMV0.28%	CMV0.28% PRSV-W 0.28%
Thrips	2009	0.1±0.31	0	0.1±0.31			
Whitefly	2009	0.05±0.22	0.1±0.31	0.15±0.49			
Beetle	2009	0.75±0.79	0.7±0.80	0.75±0.91			

Table 4.41 Viruses detected in insects on pumpkin at the fruit setting stage at Kae Noi in 2008 and 2009.

Insects	Years	fruiting			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.5±1.10	1.2±2.33	1.95±3.38	CMV0.28%	CMV0.28 PRSV-W 0.28%	PRSV-W 0.28% WMV-2 0.28%
Thrips	2008	0.15±0.49	0.1±0.31	0.15±0.45			
Whitefly	2008	0.15±0.37	0.2±0.52	02±0.52			
Beetle	2008	0.25±0.44	0.45±0.69	0.35±0.74			
Aphids	2009	0.9±2.02	1.35±2.28	2.6±2.26	PRSV-W 0.28%	CMV0.28%	ZYMV0.28% CMV0.28% WMV-2 0.28%
Thrips	2009	0.1±0.31	0.15±0.37	0.05±0.22			
Whitefly	2009	0.2±0.52	0.2±0.62	0.1±0.31			
Beetle	2009	0.25±0.55	0.45±0.60	0.5±061			

Table 4.42 Viruses detected in insects on pumpkin at the harvesting stage at Kae Noi in 2008 and 2009.

Insects	Years	Harvesting			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.85±1.53	0.95±2.11	1.7±2.72	ZYMV40.84% PRSV-W 0.28%	ZYMV2.53% CMV1.56%	SqMV1.97% PRSV-W2.25% WMV-2 0.28%
Thrips	2008	0.2±0.62	0.4±0.75	0.25±0.55			
Whitefly	2008	0.15±0.37	0.35±0.93	0.2±0.52			
Beetle	2008	0	0	0			
Aphids	2009	0.45±1.28	1.15±2.13	1.95±3.52	ZYMV0.84% PRSV-W 0.28%	CMV1.56% SqMV0.84% PRSV-W 1.4%	ZYMV2.53% CMV0.28% WMV-2 0.28%
Thrips	2009	0.2±0.70	0.25±1.12	0.15±0.49			
Whitefly	2009	0.15±0.49	0.4±1.05	0.2±0.49			
Beetle	2009	0	0	0			

Table 4.43 Viruses detected in insects on pumpkin at the seedling stage at Wat Chan in 2008 and 2009.

Insects	Years	Seedling			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0	0.8±1.28	1.05±1.32	0	0	ZYMV0.28%
Thrips	2008	0	0.05±0.22	0.1±0.31			
Whitefly	2008	0	0	0			
Beetle	2008	0.1±0.31	0.15±0.49	0.1±0.31			
Aphids	2009	0.1±0.31	0.95±1.57	0.85±1.93	0	PRSV-W 0.28%	CMV0.28% SqMV0.28%
Thrips	2009	0	0.05±0.22	0.1±0.31			
Whitefly	2009	0	0	0			
Beetle	2009	0.05±0.22	0.2±0.70	0.15±0.37			

Table 4.44 Viruses detected in insects on pumpkin at the flowering stage at Wat Chan in 2008 and 2009.

Insects	Years	Flowering			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.75±1.62	1.3±2.36	2.00±2.94	ZYMV0.28%	PRSV-W 0.28%	ZYMV0.28% PRSV-W 0.28%
Thrips	2008	0	0.05±0.22	0.1±0.31			
Whitefly	2008	0.2±0.70	0.15±0.37	0.1±0.31			
Beetle	2008	0.75±0.72	0.7±0.92	0.6±0.94			
Aphids	2009	1.0±2.05	1.5±2.70	2.25±2.94	PRSV-W 0.28%	SqMV0.28%	ZYMV0.28% CMV0.28%
Thrips	2009	0	0.15±0.67	0.05±0.22			
Whitefly	2009	0.15±0.67	0.1±0.31	0.05±0.22			
Beetle	2009	0.6±0.82	0.7±0.80	0.65±0.93			

Table 4.45 Viruses detected in insects on pumpkin at the fruit setting stage at Wat Chan in 2008 and 2009.

Insects	Years	fruiting			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.55±1.43	1.0±1.72	1.9±2.57	CMV0.28%	CMV0.28 PRSV-W 0.28%	ZYMV0.28% PRSV-W 0.28% WMV-2 0.28%
Thrips	2008	0.05±0.22	0.05±0.22	0.15±0.49			
Whitefly	2008	0.1±0.31	0.1±0.31	02±0.52			
Beetle	2008	0.25±0.44	0.4±0.60	0.35±0.74			
Aphids	2009	0.75±1.52	1.3±2.30	1.35±2.46	PRSV-W 0.28%	CMV0.28%	ZYMV0.28% CMV0.28% WMV-2 0.28%
Thrips	2009	0.1±0.31	0.15±0.37	0.15±0.37			
Whitefly	2009	0.1±0.45	0.05±0.22	0.15±0.37			
Beetle	2009	0.15±0.37	0.2±0.41	0.45±0.51			

Table 4.46 Viruses detected in insects on pumpkin at the harvesting stage at Wat Chan in 2008 and 2009.

Insects	Years	Harvesting			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.80±1.64	0.9±1.71	1.3±1.98	ZYMV40.84%	ZYMV0.2853%	SqMV0.28%
Thrips	2008	0.2±0.62	0.4±0.75	0.25±0.55	PRSV-W	CMV0.28%	PRSV-W
Whitefly	2008	0.1±0.31	0.3±0.80	0.2±0.52	0.28%		0.28%
Beetle	2008	0	0	0			WMV-2
							0.28%
Aphids	2009	0.6±1.35	1.15±2.13	0.6±1.35	ZYMV0.28%	CMV0.56%	ZYMV0.56%
Thrips	2009	0.2±0.70	1.05±1.79	0.15±0.49	PRSV-W	PRSV-W	CMV0.28%
Whitefly	2009	0.1±0.49	0.25±0.79	0.15±0.49	0.28%	0.28%	
Beetle	2009	0	0	0			

Table 4.47 Viruses detected in insects on pumpkin at the seedling stage at Mae La Noi in 2008 and 2009.

Insects	Years	Seedling			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.05±0.22	0.8±1.28	0.85±1.70	0	0	ZYMV0.28%
Thrips	2008	0	0.05±0.22	0.05±0.22			
Whitefly	2008	0	0	0			
Beetle	2008	0.2±0.41	0.15±0.49	0.1±0.31			
Aphids	2009	0.2±0.41	0.85±1.35	0.85±1.93	0	ZYMV	CMV0.28%
Thrips	2009	0.05±0.22	0.05±0.22	0.1±0.31		0.28%	SqMV0.28%
Whitefly	2009	0	0	0			
Beetle	2009	0.1±0.41	0.15±0.37	0.15±0.37			

Table 4.48 Viruses detected in insects on pumpkin at the flowering stage at Mae La Noi in 2008 and 2009.

Insects	Years	Flowering			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.55±1.19	0.95±1.96	1.65±2.71	ZYMV0.28%	PRSV-W	CMV0.28%
Thrips	2008	0.05±0.22	0.15±0.49	0.1±0.45		0.28%	PRSV-W
Whitefly	2008	0.1±0.45	0.15±0.37	0.05±0.22			0.28%
Beetle	2008	0.75±0.75	0.6±0.75	0.6±0.88			
Aphids	2009	0.9±2.05	1.35±2.46	2.0±2.25	PRSV-W	CMV0.28%	ZYMV0.28%
Thrips	2009	0.1±0.31	0.25±0.79	0.1±0.31	0.28%		CMV0.28%
Whitefly	2009	0.05±0.22	0.1±0.31	0.05±0.22			
Beetle	2009	0.55±0.82	0.7±0.80	0.60±0.82			

Table 4.49 Viruses detected in insects on pumpkin at the fruit setting stage at Mae La Noi in 2008 and 2009.

Insects	Years	fruiting			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.7±1.38	0.9±1.71	1.55±1.91	CMV0.28%	CMV0.28	ZYMV0.28%
Thrips	2008	0.15±0.49	0.35±0.99	0.15±0.49		PRSV-W	PRSV-W
Whitefly	2008	0.05±0.22	0.1±0.31	02±0.52		0.28%	0.28%
Beetle	2008	0.1±0.31	0.45±0.60	0.45±0.82			
Aphids	2009	0.85±1.66	1.35±1.68	1.35±2.76	PRSV-W	CMV0.28%	ZYMV0.28%
Thrips	2009	0.1±0.31	0.25±0.55	0.15±0.37	0.28%		CMV0.28%
Whitefly	2009	0.1±0.45	0.15±0.49	0.15±0.37			
Beetle	2009	0.15±0.37	0.4±0.60	0.40±0.50			

Table 4.50 Viruses detected in insects on pumpkin at the harvesting stage at Mae La Noi in 2008 and 2009.

Insects	Years	Harvesting			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.65±1.56	0.9±1.71	0.95±1.90	ZYMV40.84%	ZYMV0.2853%	SqMV0.28%
Thrips	2008	0.2±0.62	0.4±0.75	0.25±0.55	PRSV-W	CMV0.28%	PRSV-W
Whitefly	2008	0.1±0.31	0.25±0.64	0.2±0.52	0.28%		0.28%
Beetle	2008	0.1±0.31	0.25±0.64	0.25±0.64			WMV-2
							0.28%
Aphids	2009	0.2±0.70	1.0±1.65	0.15±2.21	ZYMV0.28%	CMV0.56%	ZYMV0.56%
Thrips	2009	0.2±0.70	1.05±1.79	0.15±0.49	PRSV-W	PRSV-W	CMV0.28%
Whitefly	2009	0.1±0.49	0.20±0.62	0.15±0.49	0.28%	0.28%	SqMV0.28%
Beetle	2009	0.05±0.22	0.3±0.80	0.15±0.49			

2.2.3 Insect vectors and virus detection at different growth stages of cucumber.

At Mae Tha Nuea (Table 4.51), the survey result of seedling stage during 2008 and 2009 was found aphid all the growing seasons and thrips at the dry seasons. The ELISA result was detected ZYMV with other viruses at rainy season as 0.28%. The dry seasons were found ZYMV and PRSV-W with other viruses. The flowering state was found all insect vectors (Table 4.52). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage. The fruiting state was found all

insect vectors (Table 4.53). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage. The harvesting state was found all insect vectors (Table 4.54). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage.

At Mae Sa Mai (Table 4.55), the survey result of seedling stage during 2008 and 2009 was found aphid all the growing seasons and thrips at the dry seasons. The ELISA result was detected ZYMV with other viruses at rainy season as 0.28%. The dry seasons were found ZYMV and PRSV-W with other viruses. The flowering state was found all insect vectors (Table 4.56). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage. The fruiting state was found all insect vectors (Table 4.57). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage. The flowering state was found all insect vectors (Table 4.58). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage.

At Mae Phae (Table 4.59), the survey result of seedling stage during 2008 and 2009 was found aphid all the growing seasons and thrips at the dry seasons. The ELISA result was detected ZYMV with other viruses at rainy season as 0.28%. The dry seasons were found ZYMV and PRSV-W with other viruses. The flowering state was found all insect vectors (Table 4.60). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage. The fruiting state was found all insect vectors (Table 4.61). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage. The flowering state was found all insect vectors (Table 4.62). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, SqMV, PRSV-W, and WMV-2 all the growth stage.

At Huai Luk (Table4.63), the survey result of seedling stage during 2008 and 2009 was found aphid all the growing seasons and thrips at the dry seasons. The ELISA result was detected ZYMV with other viruses at rainy season as 0.28%. The dry seasons were found ZYMV, CMV and PRSV-W with other viruses. The flowering state was found all insect vectors (Table 4.64). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, Tospovirus and, PRSV-W all the growth stage. The fruiting state was found all insect vectors (Table 4.65). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, PRSV-W, and Tospovirus all the growth stage. The flowering state was found all insect vectors (Table 4.66). Virus detection was found ZYMV with other viruses as 0.28% during 2008-2009. The dry seasons were found ZYMV, CMV, PRSV-W, WMV-2, and Tospovirus all the growth stage.

Table 4.51 Viruses detected in insects on cucumber at the seedling stage at Mae Tha Nuea in 2008 and 2009.

Insects	Years	Seedling			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.05±0.22	0.35±0.88	0.3±0.92	0	ZYMV0.28%	ZYMV0.28%
Thrips	2008	0	0.05±0.22	0.10±0.31		PRSV-W 0.28%	CMV0.28%
Whitefly	2008	0	0	0		Tospovirus0.28%	PRSV-W
Beetle	2008	0.15±0.37	0.25±0.44	0.2±0.41			0.28%
Aphids	2009	0.1±0.31	0.4±1.10	0.45±1.19	0	ZMV0.28%	SqMV0.84%
Thrips	2009	0	0.05±0.22	0.1±0.45			PRSV-W
Whitefly	2009	0	0	0			0.28%
Beetle	2009	0.2±0.41	0.25±0.44	0.25±0.55			Tospovirus
							0.28%

Table 4.52 Viruses detected in insects on cucumber at the flowering stage at Mae Tha Nuea in 2008 and 2009.

Insects	Years	Flowering			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.35±0.88	0.5±1.23	0.4±1.10	CMV0.28%	SqMV0.28%	ZYMV0.28%
Thrips	2008	0.1±0.45	0.2±0.62	0.2±0.62	SqMV0.28%	PRSV-W 0.28%	Tospovirus0.28%
Whitefly	2008	0	0.05±0.22	0.05±0.22		Tospovirus0.28%	
Beetle	2008	0.6±0.94	0.8±0.95	0.6±0.88			
Aphids	2009	0.4±1.10	0.60±1.19	0.55±1.32	PRSV-W	SqMV0.28%	ZYMV0.28%
Thrips	2009	0.25±0.79	0.3±0.92	0.45±0.94	0.28%	Tospovirus0.28%	CMV0.28%
Whitefly	2009	0	0.05±0.22	0.10±0.45			
Beetle	2009	0.75±0.85	0.85±0.74	0.75±0.72			

Table 4.53 Viruses detected in insects on cucumber at the fruit setting stage at Mae Tha Nuea in 2008 and 2009.

Insects	Years	fruiting			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.4±1.10	0.6±1.19	0.55±1.05	CMV0.28%	ZYMV0.28%	SqMV0.28%
Thrips	2008	0.15±0.67	0.25±0.79	0.29±0.79		CMV0.28	WMV-2 0.28%
Whitefly	2008	0.10±0.45	0.05±0.22	0.1±0.45		PRSV-W 0.28%	Tospovirus0.28%
Beetle	2008	0.2±0.41	0.3±0.57	0.4±0.60			
Aphids	2009	0.4±0.99	0.55±1.05	1.75±2.70	PRSV-W	CMV0.28%	ZYMV0.28%
Thrips	2009	0.15±0.49	0.25±0.79	0.4±1.19	0.28%	PRSV-W 0.28%	CMV0.28%
Whitefly	2009	0.05±0.22	0.25±0.64	0.10±0.45		Tospovirus0.28%	PRSV-W 0.28%
Beetle	2009	0.4±0.50	0.60±0.60	0.55±0.60			

Table 4.54 Viruses detected in insects on cucumber at the harvesting stage at Mae Tha Nuea in 2008 and 2009.

Insects	Years	Harvesting			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.45±1.28	0.7±1.38	0.75±1.52	ZYMV0.28%	ZYMV0.28%	ZYMV0.283%
Thrips	2008	0.35±0.88	0.6±1.35	0.7±1.17	PRSV-W0.28%	CMV0.56%	CMV0.28%
Whitefly	2008	0.05±0.22	0.15±0.37	0.15±0.67		PRSV-W 0.28%	SqMV0.28%
Beetle	2008	0	0	0		WMV-2 0.28%	PRSV-W 0.28%
							WMV-2 0.28%
							Tospovirus0.28%
Aphids	2009	0.4±1.27	0.65±1.09	0.65±1.35	ZYMV0.84%	ZYMV2.53%	ZYMV2.53%
Thrips	2009	0.55±1.14	0.9±1.52	0.45±1.14	PRSV-W 0.28%	CMV1.56%	CMV0.28%
Whitefly	2009	0.05±0.22	0.25±1.12	0.20±0.89		SqMV0.28%	PRSV-W 0.28%
Beetle	2009	0	0	0		PRSV-W 1.4%	WMV-2 0.28%
						WMV-2 0.28%	Tospovirus0.28%

Table 4.55 Viruses detected in insects on cucumber at the seedling stage at Mae Sa Mai in 2008 and 2009.

Insects	Years	Seedling			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0	0.35±0.88	0.1±0.31	0	PRSV-W 0.28%	ZYMV0.28%
Thrips	2008	0.10±0.31	0.15±0.49	0.15±0.37		Tospovirus0.28%	CMV0.28%
Whitefly	2008	0	0	0			Tospovirus0.28%
Beetle	2008	0	0	0			
Aphids	2009	0	0.4±1.10	0.05±0.22	0	ZMV0.28%	ZYMV0.28%
Thrips	2009	0.15±0.37	0.2±0.62	0.25±0.64		Tospovirus0.28%	CMV0.28%
Whitefly	2009	0	0	0			
Beetle	2009	0	0	0			

Table 4.56 Viruses detected in insects on cucumber at the flowering stage at Mae Sa Mai in 2008 and 2009.

Insects	Years	Flowering			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.05±0.22	0.15±0.49	0.1±0.45	CMV0.28%	PRSV-W 0.28%	ZYMV0.28%
Thrips	2008	0	0.2±0.62	0.25±0.79			Tospovirus0.28%
Whitefly	2008	0	0	0			
Beetle	2008	0.6±0.94	0.8±0.95	0.6±0.88			
Aphids	2009	0.10±0.45	0.15±0.49	0.55±1.32	PRSV-W 0.28%	CMV0.28%	ZYMV0.28%
Thrips	2009	0.10±0.45	0.25±0.72	0.35±0.88		Tospovirus0.28%	CMV0.28%
Whitefly	2009	0	0	0			
Beetle	2009	0	0	0			

Table 4.57 Viruses detected in insects on cucumber at the fruit setting stage at Mae Sa Mai in 2008 and 2009.

Insects	Years	fruiting			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.15±0.67	0.15±0.49	0.25±0.64	CMV0.28%	ZYMV0.28%	CMV0.28
Thrips	2008	0.15±0.67	0.15±0.67	0.10±0.45		Tospovirus0.28%	PRSV-W 0.28%
Whitefly	2008	0	0	0			WMV-2 0.28%
Beetle	2008	0	0	0			
Aphids	2009	0.10±0.45	0.20±0.52	0.15±0.67	PRSV-W 0.28%	CMV0.28%	ZYMV0.28%
Thrips	2009	0.15±0.49	0.20±0.52	0.15±0.49		PRSV-W 0.28%	CMV0.28%
Whitefly	2009	0	0	0			PRSV-W 0.28%
Beetle	2009	0	0	0			Tospovirus0.28%

Table 4.58 Viruses detected in insects on cucumber at the harvesting stage at Mae Sa Mai in 2008 and 2009.

Insects	Years	harvesting			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.25±0.79	0.3±0.8	0.35±1.09	CMV0.28%	ZYMV0.28%	CMV0.28
Thrips	2008	0.35±0.88	0.15±0.67	0.20±0.70	Tospovirus0.28%	Tospovirus0.28%	PRSV-W 0.28%
Whitefly	2008	0	0	0			WMV-2 0.28%
Beetle	2008	0	0	0			
Aphids	2009	0.3±0.73	0.30±0.8	0.3±0.8	PRSV-W 0.28%	CMV0.28%	ZYMV0.28%
Thrips	2009	0.55±1.14	0.15±0.37	0.15±0.67		PRSV-W 0.28%	CMV0.28%
Whitefly	2009	0	0	0		Tospovirus0.28%	PRSV-W 0.28%
Beetle	2009	0	0	0			Tospovirus 0.28%

Table 4.59 Viruses detected in insects on cucumber at the seedling stage at Mae Phae in 2008 and 2009.

Insects	Years	Seedling			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0	0.10±0.45	0.15±0.67	0	CMV 0.28%	ZYMV0.28%
Thrips	2008	0.05±0.22	0.10±0.31	0.15±0.37			CMV0.28%
Whitefly	2008	0	0	0			
Beetle	2008	0	0	0			
Aphids	2009	0.05±0.22	0.15±0.67	0.15±0.37	0	ZMV0.28%	ZYMV0.28%
Thrips	2009	0	0.2±0.62	0.25±0.64			CMV0.28%
Whitefly	2009	0	0	0			Tospovirus0.28%
Beetle	2009	0	0	0			

Table 4.60 Viruses detected in insects on cucumber at the flowering stage at Mae Phae in 2008 and 2009.

Insects	Years	Flowering			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.25±0.79	0.4±1.19	0.35±0.81	CMV0.28%	PRSV-W	ZYMV0.28%
Thrips	2008	0.10±0.45	0.15±0.49	0.25±0.79		0.28%	CMV0.28%
Whitefly	2008	0	0	0			Tospovirus0.28%
Beetle	2008	0.6±0.94	0.8±0.95	0.6±0.88			
Aphids	2009	0	0.35±0.88	0.50±1.32	PRSV-W	CMV0.28%	ZYMV0.28%
Thrips	2009	0.20±0.62	0.25±0.72	0.35±0.88	0.28%		CMV0.28%
Whitefly	2009	0	0	0			PRSV-W 0.28%
Beetle	2009	0	0	0			

Table 4.61 Viruses detected in insects on cucumber at the fruit setting stage at Mae Phae in 2008 and 2009.

Insects	Years	fruiting			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.10±0.45	0.15±0.49	0.15±0.45	CMV0.28%	ZYMV0.28%	CMV0.28
Thrips	2008	0.15±0.67	0.30±0.62	0.10±0.45			PRSV-W 0.28%
Whitefly	2008	0.3±0.80	0.45±1.39	0.10±0.45			WMV-2 0.28%
Beetle	2008	0	0	0			
Aphids	2009	0.15±0.49	0.15±0.67	0.10±0.45	PRSV-W	CMV0.28%	ZYMV0.28%
Thrips	2009	0.3±0.80	0.20±0.80	0.15±0.49	0.28%	PRSV-W	CMV0.28%
Whitefly	2009	0.3±0.98	0.60±1.39	0.15±0.49		0.28%	PRSV-W 0.28%
Beetle	2009	0	0	0			Tospovirus0.28%

Table 4.62 Viruses detected in insects on cucumber at the harvesting stage at Mae Phae in 2008 and 2009.

Insects	Years	Harvesting			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.25±0.79	0.30±0.80	0.35±1.09	ZYMV0.28%	ZYMV0.28%	CMV0.28%
Thrips	2008	0.35±0.88	0.15±0.67	0.2±0.70	PRSV-W0.28%	CMV0.56%	PRSV-W0.28%
Whitefly	2008	0	0	0		WMV-2 0.28%	WMV-2 0.28%
Beetle	2008	0	0	0			Tospovirus0.28%
Aphids	2009	0.30±0.73	0.30±0.80	0.30±0.80	ZYMV0.84%	ZYMV2.53%	CMV0.28%
Thrips	2009	0.55±1.14	0.15±0.67	0.15±0.67	PRSV-W 0.28%	CMV1.56%	PRSV-W 0.28%
Whitefly	2009	0	0	0		SqMV0.28%	WMV-2 0.28%
Beetle	2009	0	0	0		WMV-2 0.28%	Tospovirus0.28%

Table 4.63 Viruses detected in insects on cucumber at the seedling stage at Huai Luk in 2008 and 2009.

Insects	Years	Seedling			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.1±0.45	0.35±0.81	0.40±0.99	ZMV0.28%	CMV 0.28%	ZYMV0.28%
Thrips	2008	0.05±0.22	0.10±0.31	0.15±0.37			CMV0.28%
Whitefly	2008	0	0	0			
Beetle	2008	0	0	0			
Aphids	2009	0.15±0.37	0.45±0.99	0.60±1.50	0	ZMV0.28%	ZYMV0.28%
Thrips	2009	0	0.2±0.62	0.25±0.64			CMV0.28%
Whitefly	2009	0	0	0			Tospovirus0.28%
Beetle	2009	0	0	0			

Table 4.64 Viruses detected in insects on cucumber at the flowering stage at Huai Luk in 2008 and 2009.

Insects	Years	Flowering			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.25±0.79	0.4±0.99	0.45±0.99	CMV0.28%	PRSV-W	ZYMV0.28%
Thrips	2008	0.10±0.45	0.15±0.49	0.25±0.79	ZMV0.28%	0.28%	CMV0.28%
Whitefly	2008	0	0	0			Tospovirus0.28%
Beetle	2008	0.6±0.94	0.8±0.95	0.6±0.88			
Aphids	2009	0	0.6±1.50	0.65±1.49	PRSV-W	CMV0.28%	ZYMV0.28%
Thrips	2009	0.20±0.62	0.25±0.72	0.35±0.88	0.28%		CMV0.28%
Whitefly	2009	0	0	0	ZMV0.28%		PRSV-W 0.28%
Beetle	2009	0	0	0			Tospovirus 0.28%

Table 4.65 Viruses detected in insects on cucumber at the fruit setting stage at Huai Luk in 2008 and 2009.

Insects	Years	fruiting			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.45±0.99	0.55±1.19	0.60±1.35	CMV0.28% ZMV0.28%	ZYMV0.28%	CMV0.28 PRSV-W 0.28% WMV-2 0.28%
Thrips	2008	0.15±0.67	0.30±0.62	0.10±0.45			
Whitefly	2008	0.3±0.80	0.45±1.39	0.10±0.45			
Beetle	2008	0	0	0			
Aphids	2009	0.50±1.05	0.55±1.14	0.55±1.31	PRSV-W 0.28% ZMV0.28%	CMV0.28% PRSV-W 0.28%	ZYMV0.28% CMV0.28% PRSV-W 0.28% Tospovirus0.28%
Thrips	2009	0.3±0.80	0.20±0.80	0.15±0.49			
Whitefly	2009	0.3±0.98	0.60±1.39	0.15±0.49			
Beetle	2009	0	0	0			

Table 4.66 Viruses detected in insects on cucumber at the harvesting stage at Huai Luk in 2008 and 2009.

Insect	Years	Harvesting			%Virus detected		
		Rainy	Cool	Summer	Rainy	Cool	Summer
Aphid	2008	0.25±0.79	0.60±1.10	0.35±1.09	ZYMV0.28% PRSV-W0.28%	ZYMV0.28% CMV0.56% WMV-2 0.28%	CMV0.28% PRSV-W0.28% WMV-2 0.28% Tospovirus0.28%
Thrips	2008	0.35±0.88	0.15±0.67	0.2±0.70			
Whitefly	2008	0	0	0			
Beetle	2008	0	0	0			
Aphids	2009	0.30±0.73	0.50±1.23	0.30±0.80	ZYMV0.84% PRSV-W 0.28%	ZYMV2.53% CMV1.56% SqMV0.28% WMV-2 0.28%	CMV0.28% PRSV-W 0.28% WMV-2 0.28% Tospovirus0.28%
Thrips	2009	0.55±1.14	0.15±0.67	0.15±0.67			
Whitefly	2009	0	0	0			
Beetle	2009	0	0	0			

Table 4.67 Plant virus insect vectors found in the cucurbit growing areas in northern Thailand during 2008-2009 and reported virus ransmission.

Insect vectors	Common name	Scientific name	Viruses transmitted	Reference
	Cotton aphid	*Aphis gossipii*	CMV, ZYMV, PRSV-W, WMV-2	Garzo *et al*., 2004; Gildow *et al*., 2008; Pinto *et al.*, 2008 Mantri *et al*., 2004 Lima *et al*., 2012
	Western flower thrips	*Frankliniella occidentalis*	Tospovirus	Integ, 2011

Table 4.67 (Continued)

Insect vectors	Common name	Scientific name	Transmitted virus	Reference
	Squash Beetle	*Aulacophora simillis*	SqMV	Barbara and Diver, 2002
	black cucurbit beetle	*A. frontalis*	SqMV	Barbara and Diver, 2002
	leaf-feeding ladybird beetle;	*Epilachna borealis*	SqMV	Barbara and Diver, 2002

2.3 Natural enemies of insects and entomopathogenic fungi.

During the surveys, a number of natural enemies were observed in the cucurbit growing areas. Lady beetles were found in fields which had aphid outbreaks (Figure 4.25). Mummy aphids caused by the parasitoid *Lysiphlebus testaceipes*) found on the undersurface of leaves (Figure 4.26). A maggot of a syrphid fly was found preying on an aphid on the under leaf surface (Figure4.27). Moreover, a number of insect species including aphids, beetles, fruit flies and moths appeared to have been killed by entomopathogenic fungi (Figure 4.28-4.31) which covered Lepidoptera and larvae (Figure 4.32).

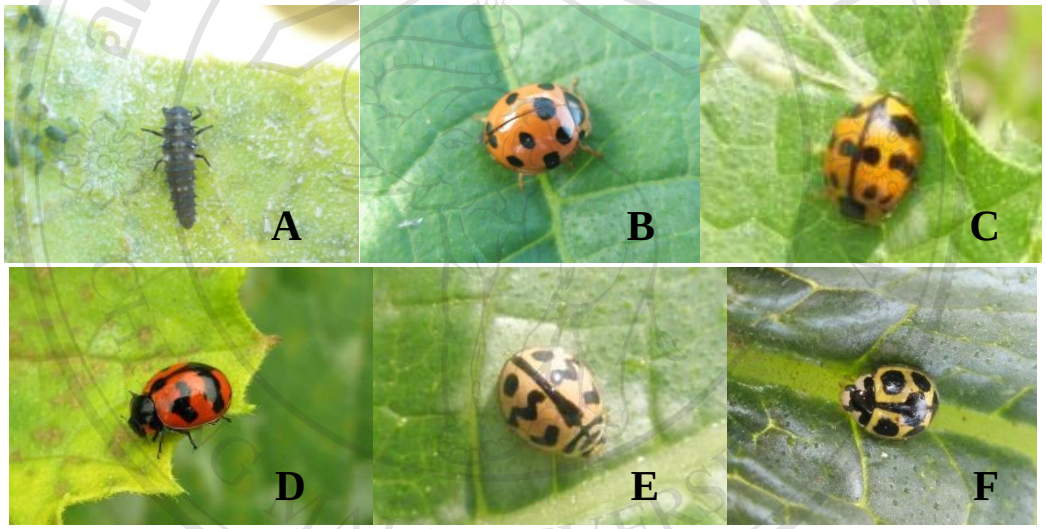

Figure 4.25 Lady beetles: *Coccinella transversalis*(A-B), *Harmonia octomaculata* (C), *Menochilus sexmaculatus* (D-E), and *Rodolia cardinalis* (F) were observed in the cucurbit growing areas.

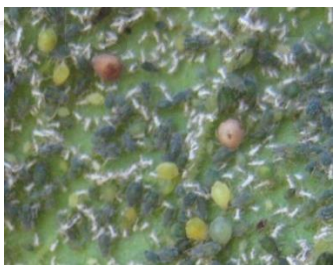

Figure 4.26 Mummy aphids caused by parasitoids of aphids (*Lysiphlebus testaceipes*).

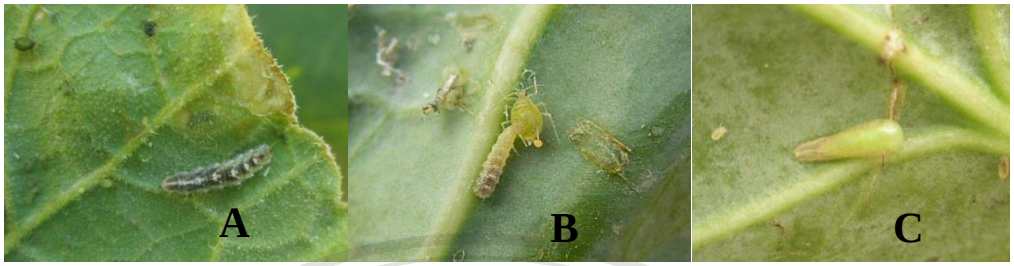

Figure 4.27 Syrphid fly maggot preying on aphid (A-B) and pupa on leaf under surface (C).

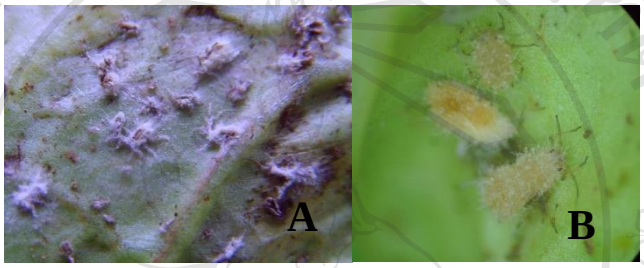

Figure 4.28 Aphids killed by entomopathogenic fungi; *Beauveria* sp. (A-B).

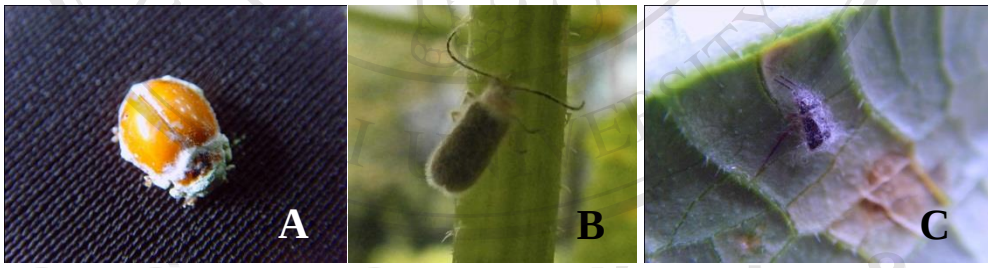

Figure 4.29 Lady beetle (A), cucumber beetle (B) and unidentified beetle (C) were killed by entomopathogenic fungi; *Beauveria* sp.

Figure 4.30 Melon fruit fly (*Bactrocera cucurbitae*) killed by entomopathogenic fungi; *Beauveria* sp.

Figure 4.31 Moth killed by entomopathogenic fungi; *Beauveria* sp.

Figure 4.32 Entomopathogenic fungi; *Beauveria* sp. (A and B) and *Metarhizium* sp. were covering lepidoptera larvae.

2.4 Collection of alternate hosts of the viral diseases of cucurbits.

2.4.1 Symptoms in alternate hosts.

Twenty eight alternate hosts were collected from cucurbit growing areas including *Acmella oleracea, Ageratum conyzoides, Amaranthus lividus, Benincasa hispida, Bidens pilosa, Capsicum annum, Carica papaya, Chenopodium quinoa, Cucurbita moschata* (two types), *C. pepo, Crassocephaium crepidioides, Emilia sonchifolia, Euphorbia heterophylla, Gomphrena globosa, Luffa acutangula, Solanum*

lycopersicum, Nicotinia tabacum, Passiflora laurifolia, Phaseolus vulgaris, Physalis angulate, P. peruviana, Sechium edule, Solanum torvum, Synedrewla nodiflora, Luffa cyliindrical, and *S. Melongena* (Table 4.68). The common symptoms observed in alternate hosts were mottling and mosaic. The symptoms consisted of varying degrees of mottling and mosaic with leaf blistering and leaf deformation.

2.4.2 Virus detection in alternate hosts.

The ELISA results were summarized in Table 4.68. *Acmella oleracea, Amaranthus lividus, Bidens pilosa, Emilia sonchifolia, Euphorbia heterophylla,* and *Synedrewla nodiflora* tested negative for virus. Geminivirus was detected in *Ageratum conyzoides, Solanum torvum* and *S. melongena*, Cucurbitaceae, e.g. *Benincasa hispida, C. moschata, C. pepo, Luffa acutangula, L. cylindrica and Sechium edule,* were found to be infected by CMV, PRSV-W, WMV-2, ZYMV, CGMMV, PVY, MNSV, WSMoV, TMV, TSWV, and unidentified tospovirus and potyvirus. Solanaceae, e.g. *Capsicum annum, Solanum lycopersicum, Physalis angulata, P. peruviana*, and *S. torvum*, were infected by CMV, TMV, ToMV, PMMoV, PeMV, PVY, and unidentified tospovirus. CMV was almost detected in alternate hosts, followed by ZYMV and PRSV-W as 16, 8 and 6 kinds of alternate hosts.

Table 4.68 Alternate hosts, symptoms and viruses found in cucurbit growing areas.

Plants	Common name	Local name	Scientific name	Symptoms	Virus (es) found
	Para cress, Tooth-ach	ผักคราดหัวแหวน	*Acmella oleracea*	M	NS
	Chick weed, Goat weed	สาบแร้งสาบกา	*Ageratum conyzoides*	Y, IC	Geminivirus
	Amaranth	ผักโขม	*Amaranthus lividus*	M	NS
	Hairy beggar picks	ปืนนกไส้, ก้นจ้ำขาว	*Bidens pilosa*	M, Mo	NS

Table 4.68 (Continued).

Plants	Common name	Local name	Scientific name	Symptoms	Virus (es) found
	Bird's eye chili	พริกขี้หนู	*Capsicum annum*	M, Mo, Y	CMV, Tospovirus
	Bell pepper, Sweet pepper	พริกหวาน	*Capsicum annum*	M, Mo, R, Bl, D,	CMV, TMV, ToMV, PMMoV, PeMV, PVY, Tospovirus
	Papaya	มะละกอ	*Carica papaya*	M, Mo, VC, R, DL, D, Y	PRSV-W, TSWV
	Pumpkins, (wild type)	ฟักทอง	*Cucurbita moschata*	M, Mo, Bl, D, DF	CMV, PRSV-W

Table 4.68 (Continued).

Plants	Common name	Local name	Scientific name	Symptoms	Virus (es) found
	Butternut	บัตเตอร์นัท	*C. moschata*	M, Mo, D, DL, C, Y, Cu, Cr, P, Bl,	ZYMV, SqMV, CMV
	Ornamental pumpkin	ฟักประดับ	*C. moschata*	Kb	ZYMV, CMV, PRSV-W, SqMV,
	Crookneck squash	ฟักคอหงส์	*C. pepo*	M, Mo, D, DL, Cr, DF	ZYMV, SqMV
	-	เหงือกปลาช่อน, หญ้าดอกขาว	*Crassocephaium crepidioides*	M, Mo	CMV

Table 4.68 (Continued)

Plants	Common name	Local name	Scientific name	Symptoms	Virus (es) found
	-	หูปลาช่อน	*Emilia sonchifolia*	M, Mo	NS
	Mexican fire plant, Painted spurge	หญ้ายาง	*Euhorbia heterophylla*	M, Mo, Dl	NS
	Globe amaranth,	บานไม่รู้โรย	*Gomphrena globosa*	Ls	CMV
	Angled gourd, Angled loofah	บวมเหลี่ยม	*Luffa acutangula*	M, Mo, DF	CMV, ZYMV, PRSV-W
	Smooth luffa	บวมงู, บวมหอม	*L. cylindrica*	M, Mo, Dl	CMV,PRSV-W, WMV-2, ZYMV,

Table 4.68 (Continued).

Plants	Common name	Local name	Scientific name	Symptoms	Virus (es) found
	Passion fruit	เสาวรส	*Pass* *ifolia*	M, Mo, Cr, Bl, DL, DF	CMV, PWV, EAPV, potyvirus
	Snap bean, Kidney bean, Green bean	ถั่ว	*Phaseolus vulgaris*	M, Mo	CMV, WMV-2
	Hogweed, Ground cherry	โทงเทง	*Physalis angulata*	M	CMV
	Cape gooseberry	เคพกูสเบอรี่	*P. peruviana*	M, Mo, Cr, C, DF	CMV, potyvirus

Table 4.68 (Continued).

Plants	Common name	Local name	Scientific name	Symptoms	Virus (es) found
	Chayote	ซาโยเต้. ฟักแม้ว	*Sechium edule*	M, Mo, Y, Cr, C, DF	CMV, PRSV-W, WMV-2, ZYMV, CGMMV, PVY, MNSV, WSMoV, TMV, TSWV, Tospovirus, Potyvirus
	Tomato	มะเขือเทศ	*Solanum lycopersicum*	Mo, R, Y	CMV, ZYMV, TSWV, TMV, ToMV, TYLCV, Potyvirus, Tospovirus,
	Pea eggplant	มะเขือพวง	*S. torvum*	M, Mo, Y	CMV, ZYMV, Geminivirus
	American weed	ผักแครด	*Synedrewla nodiflora*	M, Mo	NS

Table 4.68 (Continued).

Plants	Common name	Local name	Scientific name	Symptoms	Virus (es) found
	Egg plant	มะเขือ	*S. melongena*	Mo, Y	Geminivirus

M=mottling, Mo=mosaic, VB=vein banding, DL=deformed leaf, D=distortion, IC=Interveinal Chlorosis, C=chlorosis, Cu= curling, Y=yellowing, Cr=crinkling, P=puckering, Bl=blistering, Kb=Knobby, SP=silver patch, S=stunting, Ls=Local lesion, NS=no symptom.

3. Studying the correlation between the aphid vector and the viral pathogen ZYMV

The correlation between the aphid vector and the ZYMV was studied. The viruliferous aphids were obtained by feeding on the ZYMV infected zucchini plants, and tested for the existed virus using the ELISA kit. The minimum of 5 viruliferous aphids were needed for the positive ELISA testing. Latent period of the infected plant was directly varied with the number of aphids used in the transmission, plants showing mottling symptom, the first occurred symptom of ZYMV, within 7 days if 10 viruliferous aphids were used, while single viruliferous aphid produced the same symptom after 15 days of feeding, subsequently the mosaic symptom was detected.

Table 4.69 Effect of aphid number on transmission of ZYMV to zucchini.

No. of inoculate Aphid no.	ZYMV detection by ELISA	Symptom appearance (days after inoculation)												
		1	3	5	7	9	11	13	15	17	19	21	28	35
1	N	-	-	-	-	-	-	-	+	+	++	+++	++++	+++++
2	N	-	-	-	-	-	-	+	+	++	++	+++	++++	+++++
3	N	-	-	-	-	-	+	+	++	++	++	+++	++++	+++++
4	N	-	-	-	-	+	+	+	++	+++	+++	+++	++++	+++++
5	P	-	-	-	-	+	+	++	++	+++	+++	+++	++++	+++++
10	P	-	-	-	+	+	++	++	+++	+++	+++	++++	++++	+++++
15	P	-	-	-	+	+	++	++	+++	+++	++++	++++	++++	+++++
20	P	-	-	-	+	+	++	+++	+++	+++	++++	++++	++++	+++++
25	P	-	-	-	+	+	++	+++	+++	+++	++++	++++	++++	+++++
30	P	-	-	-	+	+	++	+++	+++	++++	++++	++++	++++	+++++

N = negative reaction, P = positive reaction

- = no symptom, + = mild mottling, ++ = mottling, +++ = mosaic, ++++ = mosaic and blistering, +++++ = malformation

4. Detection of seed transmission virus in cucurbitaceous crops (zucchini, Japanese pumpkin and Japanese cucumber).

DAS-ELISA result, CMV, ZYMV, SqMV and CGMMV were not detected in the commercial seeds of zucchini (*C. pepo*) cultivar SENATOR (hybrid squash, lot No.978883); Japanese pumpkin (*C. moschata*) cultivar DELICA (hybrid squash, lot No.08021); and Japanese cucumber (*C. sativas*) cultivar PRETTY SWALLOW 279 (cucumber F1 hybrid, lot No. EA25061). The virus was not found in the ground cucumber seeds, endosperm, seed coated, cotyledons and true leaves (10 dap.) saps.

5. The relationship between the CGMMV transmitted seed and proper detection stages of the infected cucumber plants.

5.1 Detection of CGMMV in Japanese cucumber seed.

Based on the DAS-ELISA result, the CGMMV was not detected in the commercial seeds of Japanese cucumber cultivar Pretty Swallow 279 (cucumber F1 hybrid, lot No. EA25061). The virus was not detected in the sap of whole ground cucumber seeds, endosperm, seed coats, cotyledons or true leaves (10 dap.).

5.2 Detection of CGMMV in cucumber plants.

A total of 398 disease samples were collected showing various symptoms that could have been induced by virus infection. Common symptom found in the disease samples were mottle, mosaic, and deformed leaves (Figures 4.33 and 4.34). Based on DAS-ELISA (Table4.70), CGMMV was not detected in the cucumber samples collected at Thung Roeng where the crop had never been grown before. However, CGMMV was detected in samples collected from the two main cucumber growing areas. CGMMV was detected at an incidence of 30%in cucumber at the seedling stage in Huai Luk where greenhouse culture was used, but was not detected in seedlings from Mae Tha Nuea where the crop was field-grown. CGMMV was detected at flowering stage at incidences of 20.83 and 7.32 percent at Huai Luk and Mae Tha Nuea, respectively. CGMMV incidence at Huai Luk and Mae Tha Nuea at 1 month after fruit set was 12.66 and 8.95 percent, respectively.

Figure 4.33 Symptoms of cucumber seedlings stage showing leaf blister and deformation at Mae Tha Nuea (A), mottle and blistered leaves at Huai Luk (B), and blistered and deformed leaves at Thung Roeng areas (new to cucumber production) (C).

Figure 4.34 Symptoms in cucumber at the flowering stage showing blistering and vein banding of leaves at Mae Tha Nuea (A), curling and blistering of leaves at Huai Luk (B), and interveinal chlorosis in leaves at Thung Roeng (C).

5.3 Effects of CGMMV on cucumber yield.

Analysis of variance followed by mean separation using Duncan's Multiple Range Test (DMRT) indicated a number of significant yield differences between the three cucumber-growing areas studied (Table 4.71). The standard grade 1 fruit weight was significantly higher at Thung Roeng and Huai Luk, 8.75 and 7.75 kg, respectively, than at Mae Tha Nuea, 5.25 kg. The yield of standard grade 2 cucumbers was significantly higher at Thung Roeng (9.62 kg) than Huai Luk (6.25 kg), with Mae Tha Nuea's yield (7.75 kg) being intermediate between the two. Total marketable yield was

significantly higher at Thung Roeng (21.25 kg) than at Huai Luk (16.75 kg) and Mae Tha Nuea (15.87 kg). No significant difference in the yield of unmarketable fruit and total fruit yield (marketable fruit + unmarketable fruit) was observed between the three areas studied.

Table 4.70 Incidence of Cucumber Green Mottle Mosaic (CGMMV) in Japanese cucumber at three growth stages in the highland of Northern Thailand in samples collected in May to July 2011.

Cultivated areas	CGMMV incidence (%) at three growth stage[1\]			Total CGMMV incidence (%)
	seedling	flowering	1 month after fruit set	
1. Mae Tha Nuea (field-grown)	0 ([a]/12[b])	7.32 (3/41)	8.95 (6/67)	7.50 (9/120)
2. Huai Luk, (greenhouse-grown)	30 (6/20)	20.83 (10/48)	12.66 (10/79)	17.69 (26/147)
3. Thung Roeng (field-grown, new to cucumber)	0 (0/21)	0 (0/40)	0 (0/70)	0 (0/131)
Total	11.32 (6/53)	10.08 (13/129)	7.41 (16/216)	8.79 (35/398)

[1\] CGMMV detection by DAS-ELISA (Agdia Inc., Elkhart, In, USA)

[a]=Number of infected plant

[b]=Number of collected plant

Table 4.71 Cucumber yield in the highland of Northern Thailand between May to July, 2011.

Cultivated areas	Graded cucumber yield/100 plants (kg.) [1/]					Total cucumber yield (kg.)
	1	2	Under grade	Total marketable	Rejected/unmarketable	
Mae Tha Nuea[2/] (field-grown)	5.25[b2/]	7.75[ab]	2.875[a]	15.875[b]	19.875[a]	35.750[a]
Huai Luk[2/] (greenhouse-grown)	7.75[a]	6.25[b]	2.75[a]	16.125[b]	21.800[a]	37.925[a]
Thung Roeng (field-grown, new to cucumber)	8.75[a]	9.625[a]	2.875[a]	21.25[a]	20.675[a]	41.925[a]
LSD 0.05[4/]	2.0186	2.7921	1.0693	2.2197	5.8310	7.0946
CV (%)[3/]	16.09	20.49	21.81	7.23	16.22	10.64

[1/]Mean of standard grade of cucumber product /100 plants (kilograms)

[2/]Mae Tha Nuea and Huai Luk are the main cucumber-producing areas in Northern Thailand.

[3/]Means followed by the same letter are not significantly different by DMRT at P = 0.05

[4/]CV (%) = coefficient of variation 95%

6. A study of correlation between viral combination and symptom on zucchini

6.1 Symptom appearance by single and mixed infection.

6.1.1 Symptoms caused by single viruses.

Infection by single and multiple viruses was confirmed by ELISA. Inoculation of zucchini with single virus resulted in a symptom rating of 1 and induced systemic mottle or mosaic symptoms in plants at 7 dai; zucchini infected with ZYMV showed mottling and blistering on leaves (Figure 38A). Mottling was caused by CMV and CGMMV (Figures 4.35B and 4.35E, respectively). PRSV-W and WMV-2 produced systemic mottle and vein clearing on leaves (Figure 4.35C and 4.35D, respectively). At 14 dai, symptom ratings increased to between 2 and 4; typical and severe mosaic, vein clearing, blistering, vein banding and deformation appeared on zucchini leaves. Severe symptoms occurred on the apical leaves, which included crinkling and other types of leaf deformation at 14 dai (Figure 4.36). During the subsequent development of plants, severe stunting and leaf symptoms were observed including deformation and yellow mosaic. CGMMV-inoculated zucchini showed an abrupt cessation of growth, interveinal yellowing and deformed leaves (Figure 4.36E). PRSV-W caused severe stunting over time, mosaic, distorted and wrinkled leaves (Figure 4.36C). WMV-2 caused mosaic, vein clearing and blistering (Figure 4.36D). Infection with ZYMV caused severe mosaic, vein banding, curled and deformed leaves (Figure 4.36A). CMV elicited severe mosaic (Figure 4.36B). At 21 and 28 dai, stunting and growth retardation were observed with all single virus infections. After 28 dai, CGMMV alone caused plant death whereas the same phenomenon was caused by ZYMV and PRSV-W at 35 dai (Table 4.68).

6.1.2 Symptoms caused by multiple virus infections.

Inoculation of zucchini with multiple viruses caused a symptom rating of 1 and produced systemic mottle and mosaic symptoms in plants at 7 dai. The systemic symptoms caused by multiple viruses were initially similar to the single virus infection. At 14 dai, a symptom rating of 4 was commonly found with triple or quadruple virus combinations; severe mosaic, vein clearing, blistering, vein banding and deformation of

leaves were observed. Inoculation of zucchini with PRSV-W+WMV-2 and PRSV-W+CGMMV caused severe mosaic and green bubbles on leaves (Figure 4.37F and 4.37G); whereas mosaic and vein clearing were produced by ZYMV+PRSV-W (Figure 4.37A); vein banding was caused by ZYMV+CGMMV (Figure 4.37D); interveinal yellowing by PRSV-W+CMV (Figure 4.37E); mottling by ZYMV+CMV (Figure 4.37B); yellow mosaic by CMV+CGMMV (Figure 4.37I); yellow patch by ZYMV+WMV-2 (Figure 4.37C) and WMV-2+CGMMV (Figure 4.37J). Triple and quadruple virus infections produced blistering and deformed leaves. Inoculation of zucchini with CMV+PRSV-W+WMV-2 produced mosaic (Figure 4.38G); severe mosaic and green bubble was caused by ZYMV+CMV+CGMMV and CMV+PRSV-W+WMV-2 (Figure 4.38C and 4.39D); mosaic, interveinal chlorosis and deformed leaves by ZYMV+CMV+PRSV-W, ZYMV+CMV+WMV-2, CMV+PRSV-W+CGMMV, PRSV-W+WMV-2+CGMMV, CMV+PRSV-W+CGMMV and PRSV-W+WMV-2+ CGMMV (Figure 4.38A, 4.38B, 4.38E, 4.38F, 4.38H and 4.38I, respectively). Systemic blistering and deformed leaves occurred at 14 dai after multiple virus infection (Figure 4.39). Symptoms that appeared at 21-28 dai were severe mosaic, blistering, vein banding, deformation, stunting and death in zucchini. At 28 dai, CGMMV alone and in combination with other viruses (ZYMV+CGMMV, ZYMV+CMV+CGMMV, ZYMV+PRSV-W+CGMMV, CMV+PRSV-W+WMV-2, ZYMV+CMV+PRSV-W+WMV-2 and ZYMV+CMV+PRSV-W+CGMMV) caused plant death. At 35 days, ZYMV and PRSV-W alone and in combination certain viruses (ZYMV+WMV-2+CGMMV, ZYMV+CMV+WMV-2+CGMMV, and ZYMV+PRSV-W+WMV-2+CGMMV) produced plant death (Table 4.68).

6.1.3 Comparison of symptoms produced in zucchini by infection with single and multiple viruses.

The results of the single and multiple virus infections are summarized in Table 72. Remarkably, the combination of CMV and WMV-2 with ZYMV, PRSV-W and CGMMV led to a reduction of symptoms (indicated by *). The symptom ratings strongly agree with visual symptoms presented in Figures 1-5. Synergistic interactions were rarely observed; at 28 dai CMV+PRSV-W+WMV-2 and ZYMV+CMV+PRSV-

W+WMV-2 produced plant death. CMV and WMV-2 appeared to suppress symptoms produced by ZYMV, PRSV-W and CGMMV at 14, 21, 28 and 35 dai. Antagonistic effects were found at 14 dai that showed diminishing symptom intensity in the case of double infections while single infection by the three more virulent produced severe symptoms. ZYMV alone (Figure 39A) and in combination with PRSV-W (Figure 40A) produced typical yellow mosaic and deformed leaves, while ZYMV+CMV produced mild mottle symptom (Figure 40B).

In the case of plant death, CGMMV alone caused plant death at 28 dai, whereas ZYMV and PRSV-W alone produced plant death at 35 dai. Multiple virus infections including CGMMV alone and in combination with other viruses: ZYMV+CGMMV, ZYMV+CMV+CGMMV, ZYMV+PRSV-W+CGMMV, CMV+PRSV-W+WMV-2, ZYMV+CMV+PRSV-W+WMV-2 and ZYMV+CMV+ PRSV-W+CGMMV) caused plant death at 28 dai. Reduction of symptoms was remarkably observed when CMV and/or WMV-2 were combined with other virus, and no plant death was found at either 28 or 35 dai (Table 72).

Table 4.72 Symptom severity ratings of single and mixed virus infection on zucchini leaves at 7, 14, 21, 28 and 35 days after inoculation (dai).

Viruses	Symptoms rating on leaves at (dai)				
	7	14	21	28	35
ZYMV	1	4	5	5	6
CMV	1	2	4	5	5
PRSV-W	1	4	5	5	6
WMV-2	1	2	4	5	5
CGMMV	1	4	5	6	6
ZYMV+CMV	1	1*	4*	5	5*
ZYMV+PRSV-W	1	3*	5	5	5*
ZYMV+WMV-2	1	2	4	5	5*
ZYMV+CGMMV	1	4	5	6	6
CMV+PRSV-W	1	3*	5	5	5*
CMV+WMV-2	1	2	4	5	5
CMV+CGMMV	1	2*	4*	5	5*
PRSV-W+WMV-2	1	3*	4*	5	5*
PRSV-W+CGMMV	1	3*	5	5	5*
WMV-2+CGMMV	1	2	5	5	5*
ZYMV+CMV+PRSV-W	1	4	5	5	5*
ZYMV+CMV+WMV-2	1	4	5	5	5*
ZYMV+CMV+CGMMV	1	4	5	6	6
ZYMV+PRSV-W+WMV-2	1	4	5	5	5*
ZYMV+PRSV-W+CGMMV	1	4	5	6	6
ZYMV+WMV-2+CGMMV	1	4	5	5*	6
CMV+PRSV-W+WMV-2	1	3*	5	6**	6
CMV+PRSV-W+CGMMV	1	4	5	5*	5*
CMV+WMV-2+CGMMV	1	4	5	5*	5*
PRSV+WMV-2+CGMMV	1	4	5	5*	5*
ZYMV+CMV+PRSV-W+WMV-2	1	4	5	6**	6
ZYMV+CMV+PRSV-W+CGMMV	1	4	5	6	6
ZYMV+CMV+WMV-2+CGMMV	1	4	5	5*	6
ZYMV+PRSV-W+WMV-2+CGMMV	1	4	5	5*	6
CMV+PRSV-W+WMV-2+CGMMV	1	4	5	5*	5*

0=no disease symptoms; 1=mottle or mild mosaic on leaves; 2=typical mosaic, vein clearing and blistering on leaves; 3=leaves near apical meristem deformed slightly, yellow and reduced size; 4=apical meristem with mosaic and deformation; 5=severe mosaic and serious deformation of leaves or plant, and stunting 6=plant death. An asterisk (*) indicates that a reduction of symptoms was observed; a double asterisk (**) indicates that an increase in symptoms was observed.

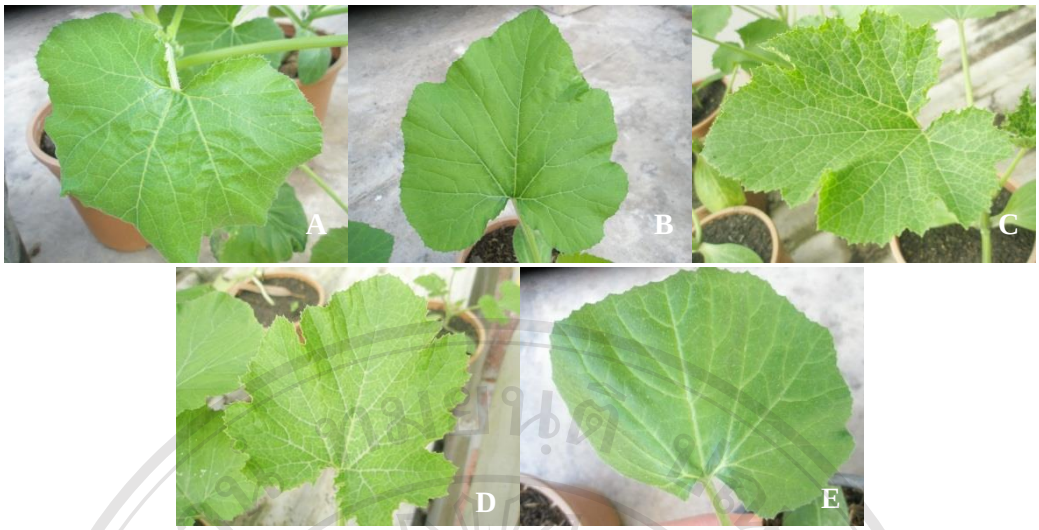

Figure 4.35 Foliar symptoms on zucchini at 7 dai with single infection: mottling and blistering by ZYMV (A), mottling by CMV and CGMMV (B and E), mottling and vein clearing by PRSV-W and WMV-2 (C and D).

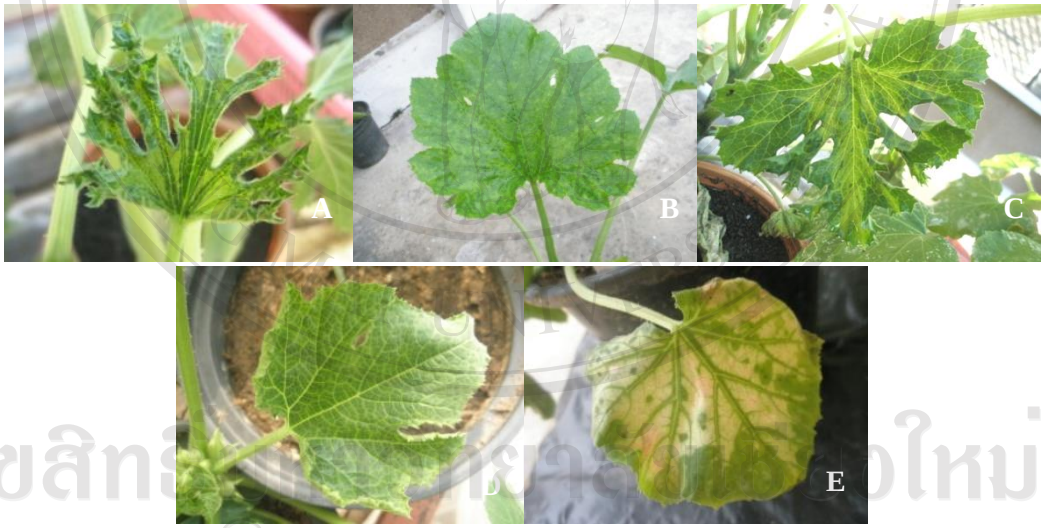

Figure 4.36 Foliar symptoms on zucchini at 14 dai with single infection: mosaic and vein banding by ZYMV (A), mottling by CMV (B), blistering by PRSV-W (C), vein clearing and mottling by WMV-2 (D), and internal vein yellowing by CGMMV (E).

Figure 4.37 Foliar symptoms on zucchini at 14 dai with double virus infection: mosaic and vein clearing by ZYMV+PRSV-W (A), mottling by ZYMV+CMV (B); yellow patch by ZYMV+WMV-2 and WMV-2+CGMMV (C and J, respectively); vein banding by ZYMV+CGMMV (D); interveinal yellowing by PRSV-W+CMV (E); severe mosaic and green bubble on leaves (F and G); mosaic by CMV+WMV-2 (H); yellow mosaic by CMV+CGMMV (I).

Figure 4.38 Foliar symptoms on zucchini at 14 dai with triple virus infection: mosaic, interveinal chlorosis and deformed leaves by ZYMV+CMV+PRSV-W, ZYMV+CMV+WMV-2,CMV+PRSV-W+CGMMV,PRSV-W+WMV-2+ CGMMV,CMV+PRSV-W+CGMMV and PRSV-W+WMV-2+ CGMMV (A, B, E, F, H and I); mosaic by CMV+PRSV-W+WMV-2 (G); severe mosaic and green bubble by ZYMV+CMV+CGMMV and CMV+PRSV-W+WMV-2 (C and D).

Figure 4.39 Foliar symptoms on zucchini at 14 dai with quadruple virus infection: mosaic, interveinal chlorosis and deformed leaves by ZYMV+CMV+PRSV-W+WMV-2,ZYMV+PRSV-W+WMV-2+CGMMV and CMV+PRSV-W+WMV-2+CGMMV (A, D and E); interveinal chlorosis and green bubbles by ZYMV+CMV+PRSV-W+CGMMV (B), and yellow mosaic by ZYMV+CMV+WMV-2+CGMMV (C).