2013-2014 National Honey Bee Pests and Diseases Survey Report

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Executive summary

The 2013 USDA Animal Plant and Health Inspection (APHIS) sponsored National Survey of Honey Bee Pests and Diseases was conducted in collaboration with the University of Maryland (UMD) and the USDA Agricultural Research Service (ARS) and with the cooperation of 32 states and territories from June 2013 through September of 2014. This survey is in its fifth year of implementation. The National Survey expanded from a 3 state Pilot Survey in 2009 to a Limited National Survey of 13 states in 2010, and then progressed to a more extensive survey in 2011 that included 34 states, and in 2012 with 32 states. This expansion has allowed us to augment and extend the baseline pest and pathogen data collected from the previous surveys. The primary focus of repeating the extended survey in 2013 was to verify the absence of exotic threats such as the parasitic mite, *Tropilaelaps* spp., the Asian honey bee, *Apis cerana*, and slow bee paralysis virus. Under current international trade agreements, the U.S. cannot deny import permits from other nations unless the exporting nation has a disease, parasite, or pest of honey bees that is not found in the U.S. Confirming the absence of exotic threats to honey bee populations not thought to be present in the U.S. was the primary objective of this effort. There is real concern that the introduction and establishment of the *Tropilaelaps* mite will increase already high loss rates, jeopardizing pollinator dependent food production. A need exists for a continued national honey bee health survey to quickly detect exotic pest introduction in order to prevent spread. In cooperation with APHIS we have now developed a draft *Tropilaelaps* response plan which is in review.

The secondary objective was to make use of the sampling by determining existing levels of other honey bee diseases and parasites known to be present in the U.S. This was also performed in the previous four surveys. The survey results are used to gauge the overall health of colonies, to create a baseline disease level, and to facilitate interpretation of ongoing and future epidemiological studies. This baseline data, including historic data from research institutions such as the ARS Bee Research Laboratory (BRL) and other ongoing field sampling and management surveys, have been incorporated into a single database as part of the Bee Informed Partnership (www.beeinformed.org), a 5 year grant funded by USDA NIFA (National Institute of Food and Agriculture). The 2013-2014 National Survey effort included collection of samples from 32 states and territories: Alabama, Arkansas, California, Florida, Georgia, Guam,

Hawaii, Illinois, Indiana, Iowa, Maryland, Michigan, Minnesota, Mississippi, Montana, North Carolina, North Dakota, New Jersey, New York, Nevada, Ohio, Oregon, Pennsylvania, Puerto Rico, South Carolina, South Dakota, Tennessee, Texas, Utah, Virginia, West Virginia and Wisconsin. All states were asked to sample 24 operations with the exception of California which targeted sampling 48 operations, with the goal of sampling 24 beekeepers who stay in California year round and 24 beekeepers who migrate to California during almond pollination.

We have redesigned the molecular lab to achieve high throughput analysis in order to avoid large backlogs that have occurred in the past and are now able to send out comprehensive reports including all *Nosema*, *Varroa* and viral data within 1 month of receipt of all the samples. To facilitate a high throughput process, the use of a Qiacube™ Automatic RNA extractor using the RNEasy™ Mini Qiacube kit was implemented.

A total of 792 (32 states and territories x24 samples/state, plus the extra 24 samples for California) samples representing 6,336 colonies are expected at the completion of this survey. To date, 88.3% of the live bee samples (for virus analysis) have been received; however, only 87.4% were analyzed as a result of the live bees dying in transit, loss of sample in long term storage or bad quality RNA due to insufficient nucleic acid extraction. We initiated a standard operating protocol (SOP) from the arrival of the live bee sample to analysis to minimize loss/damage of live bee samples in storage.

Regarding the alcohol samples (for *Varroa* mite, *Nosema* and *Tropilaelaps* determination), of the 792 samples kits sent 93.3% were received and processed. In addition, 100% of the reports on received samples to apiary inspectors and beekeepers have been distributed. A third full National Survey for 2014 was initiated early this summer with 32 participating states. Samples for this survey have already begun to arrive.

The survey samples were analyzed for 11 known honey bee viruses, pests and pathogens. Slow bee paralysis virus (SBPV), a virus not currently found in the U.S., was tested for in all samples and no detection was made. The accuracy of the SBPV detection method was further verified using an additional set of primers. No honey bee diseases or parasites not already known to exist in the country were discovered. One common honey bee viruses, deformed wing virus (DWV) was found in all 31 states. Black queen cell virus (BQCV) was no longer tested as it is considered widespread, and instead we added testing for a relatively newly identified virus, Lake Sinai virus-2 (LSV-2) in order to capture more information about its prevalence. In this 2013 survey, we did not test for *Nosema spp.* as it was determined that the vast majority of *Nosema* in the honey bee population is *Nosema ceranae.* Limiting molecular targets to 7 allowed us to maximize the efficiency to the tests based on the number of wells in the assay plates. In the 2012-2013 survey, 5 samples out of 727 tested positive for *N. apis* (0.7% of the samples), and 503 samples out of 727 tested positive for *N. ceranae,* (69% of the samples). *N. apis* was not detected in the first two survey years (2009 and 2010), but was detected in 1.3% of samples analyzed in 2011. This year we saw no evidence of *Tropilaelaps* mites or the Asiatic honey bee, *Apis cerana*. Since honey bee tracheal mites (*Acarapis woodi*) were not detected in samples in 2009 nor in 2010, the samples were not analyzed for the mite in subsequent years.

Honey bee tracheal mites are known to exist in the country. Our failure to find them may be the result of our sampling, as samples are generally collected during the productive seasons and tracheal mites are more prevalent in the winter months. *Varroa* mites continued to be observed in all states with the exception of the Hawaiian Islands of Maui, Kauai and Molokai. Subsamples have been and continue to be saved for potential examination of other newly discovered pests and pathogens in the future.

For a third time, this survey collected and analyzed bee bread (pollen stored in the colony by bees) for pesticides. Approximately 3 grams of pollen were collected from brood frames and tested for 174 known pesticides. The pollen was collected from the same composite 8 colonies undergoing the standard survey sampling, and sent to the USDA Agricultural Marketing Service (AMS) in Gastonia, NC for analysis. All states were funded to participate in the pollen study, and each state was asked to send in composite samples of pollen from 10 of the 24 apiaries this year. We received 274 samples from these states (out of a possible 330), and of the 174 possible pesticides, 86 were detected. The increase in detections of 34 pesticides from last year's survey to this year's 86 pesticides is concerning. Additionally, 82% of samples were positive for at least one product and pollen samples on average had 2.6 products. The largest number of pesticides found in any one sample was 16.

This survey was designed to be representative of the managed honey bees across the broad geography of the U.S. The survey was open to any state wishing to participate. Beekeeper participation was completely voluntary, and the beekeeper did not have to be present for nor assist with the sampling. The results can be considered as representative of the distribution of pests and pathogens present in the U.S.

Introduction

This 32 state survey of honey bee pests and pathogens began in 2013 and was completed in the late summer of 2014. Funding was provided by the USDA Animal and Plant Health Inspection Service (APHIS), and the survey was conducted in collaboration with the USDA Agricultural Research Service (ARS) and the University of Maryland (UMD). Participating states and territories included the following: Alabama, Arkansas, California, Florida, Georgia, Guam Hawaii, Illinois, Indiana, Iowa, Maryland, Michigan, Minnesota, Mississippi, Montana, North Carolina, North Dakota, New Jersey, New York, Nevada, Ohio, Oregon, Pennsylvania, Puerto Rico, South Carolina, South Dakota, Tennessee, Texas, Utah, Virginia, West Virginia and Wisconsin. The equipment and kits required to sample 24 apiaries were provided to each participating state, with the exception of California, where enough kits to sample 48 apiaries were provided. Of the 792 kits sent, 739 wet samples were returned (93.3%) for *Varroa* and *Nosema* analysis and 699 live bee boxes (88.3%)were returned for viral analysis. Since these are composite samples from 8 colonies, in total, samples were collected from 6,336 colonies nationwide.

Survey Description

Survey kits were distributed to the participating states' Apiary Specialist in May and June of 2013. In some cases, sampling continued well into late summer of 2014 due to various weather events and other isolated circumstances.

Apiary specialists conducted an aggregate sampling from previously identified commercial, migratory, and sideliner beekeepers with at least 8 colonies per apiary. In most cases, apiaries consisted of at least 10 colonies. A single aggregate sample was collected from 8 randomly selected colonies per apiary per operation (APHIS US Honey Bee Survey Sampling Protocol). In each state, apiaries were chosen on a case by case basis with an attempt to give as close to an equal representation of the entire state as possible. Ideally, a state was sectioned into 4 quadrants with apiaries randomly chosen within a quadrant. When possible, ten queen producers were sampled. Of the remaining sampled apiaries, 1/2 were from migratory operations (move out of the state and return prior to sampling) and 1/2 were from stationary operations (only move within the state or do not move at all). Additional apiaries occurring near ports or other areas that could be considered high risk were also considered for sampling (APHIS US Honey Bee Survey Project Plan). The pollen samples were collected concurrently and from the same colonies in the apiary being sampled for the disease and pest survey (APHIS US Honey Bee Survey Pollen Sampling Protocol).

Four distinct collection methods were used to sample each apiary. The first sample was a collection of live adult bees composed of ¼ cup of bees (~ 150 bees) that were shaken off brood frames from each of the 8 sampled colonies. The 2 cups of (~1200 bees) live bees were deposited in a ventilated shipping box containing a water source and hard sugar candy (fondant). This box was shipped the same day to the USDA/ARS in Beltsville, MD where it was immediately frozen at -80°C until molecular testing could be performed. The molecular tests were performed with quantitative-PCR techniques, outlined by Dr. Jay Evans at the USDA/ARS Bee Research Laboratory, to look for molecular evidence of known viruses and other pests (2006 and Honey Bee PCR Diagnostics). We have initiated new, high-performance assays and a more effective and stream-lined sample processing in our molecular analysis. The goal is to achieve greater sensitivity and a faster, more accurate, and more cost effective diagnostic analysis. As a result we can actually quantify viral loads in copies per bee in addition to determining if that sample is positive or negative. Moreover, using new PCR chemistry and automated nucleic acid extractions required that the molecular viral assays be re-evaluated and validated. For example, there are indications that the IAPV primers presently used may actually underestimate the number of samples positive for the virus. Ongoing work will produce new reports on IAPV prevalence for this year and previous years. New viral primers were implemented in the 2013 -2014 survey for all viral targets not including Kashmir bee virus (KBV). This year's molecular assays were designed to detect the presence of the following:

1. Acute bee paralysis virus (ABPV)
2. Deformed wing virus (DWV)
3. Israeli acute paralysis virus (IAPV)
4. Kashmir bee virus (KBV)
5. Chronic bee paralysis virus (CBPV)

6. Lake Sinai virus-2 (LSV-2)
7. Slow bee paralysis virus (SBPV)

The second sample of bees, consisting of ¼ cup of bees from each of the 8 sampled colonies for a total of 2 cups of bees per apiary, originated from the same brood frames as the live bee sample. These bees were put into a bottle of alcohol for preservation. This alcohol-preserved sample analyzed by University of Maryland technicians to visually quantify the following:

1. *Nosema* spp. spores
2. *Varroa* mite loads
3. *A. cerana*

The third sample was taken from debris dislodged by 'bumping' sampled brood frames over a collection pan. This technique was developed by Dr. Jeff Pettis and Dr. Dennis vanEngelsdorp and funded by APHIS as a quick and cost effective way to detect for the Tropilaelaps mite (Pettis et al. 2013). The sample, also preserved in alcohol, included any mites, beetles and other hive debris filtered from bumping the brood frames. This sample was shipped to USDA/ARS Beltsville, MD and analyzed microscopically at the University of Maryland for the presence of the *Tropilaelaps* mite.

Finally, the fourth sample included a minimum of 3 grams of fresh pollen from within the hive from the same colonies, preferably in the same brood area, from the other three samples described above. These samples were placed in a tube, labeled and sent to USDA/ARS Bee Research Laboratory where they were catalogued by UMD personnel and sent to the USDA/AMS lab in Gastonia, NC for pesticide analysis.

All participating beekeepers, as well as State Apiarists/Inspectors, received a single report for each sample taken. The reports detail the analysis results for *Varroa* mite load, *Nosema* load, the presence of viruses (of the 7 mentioned above). They also noted the presence or absence of *A. cerana* and *Tropilaelaps* spp. This report was usually sent within 6 months of receipt of samples, although some reports took up to 12 months to complete from date of sampling due to the redesign of our molecular laboratory. In these instances a partial report with just *Varroa* and *Nosema* data was issued as soon as possible. Reports complete with molecular information also included the national prevalence for viruses as well as specific beekeeper percentile rankings of *Varroa* mite load, *Nosema* spore load. There was a break in production at the USDA/ARS molecular lab and the government shutdown in the fall of 2013 also affected the viral analysis. Due to this, approximately 67% of beekeepers received a partial report with just *Varroa* and *Nosema* data and another later report with molecular data when it became available. Reporting is now complete for all samples to date. We do not anticipate having to issue partial reports in the future, and the turnaround time of the full report is greatly reduced.

Using the U.S. Postal Service, live bee shipments were made to USDA/ARS and percent survivability was tracked for all live bee shipments. The results of this analysis, previously proven to be a robust and suitable alternative for shipping bees on dry ice by the Pilot and Limited Survey, continued to work well. In some states, a small number of live bee samples were degraded, such that no molecular data could be obtained from these samples.

Results

Pest Survey:

***Nosema* spore prevalence and load**

Of the 648 alcohol samples collected for the 2013-2014 at the time data was analyzed for this report 348 (47.0%) had detectable *Nosema* spore loads (Figure 1). Of the samples in 2013 that tested positive for *Nosema*, 93 samples (24%) exceeded the threshold thought to cause damage (> 1 million spores per bee). Samples testing positive for *Nosema* infection had a mean *Nosema* spore load of 790,000 spores per bee (Figure 2). Figures 3 and 4 illustrate *Nosema* prevalence and *Nosema* spore load from all 5 years of the survey on a monthly basis. Any month having less than 3 data points was not included in the monthly calculations. Figure 3 shows the classic seasonal decline in *Nosema* detection in the late summer and early fall in conjunction with a decrease in detectable spore load in those same months (Figure 4). Data on treatment use across the country is being compiled from a management survey that was included with the beekeeper reports this year.

***Varroa* mite prevalence and load**

Varroa mite prevalence for 2013 is higher than that observed in 2012 (93.5%), (2011 (91.8%), 2010 (92.4%) and 2009 (87.1%) with 98.2% of all 648 alcohol samples collected containing at least one *Varroa* mite (Figure 5). Figure 6 illustrates the average *Varroa* mite load for all positive samples from surveys taken in 2009 through the current survey. While the economic threshold for *Varroa* mites is seasonally and regionally specific, an average load of over 3 mites per 100 bees is concerning in 2013, and 299 out of 596 positive samples, or 50.2% were above the economic threshold.

Figures 7 and 8 illustrate the dynamic nature of *Varroa* mite populations over the course of the year. *Varroa* mite levels were highest in the late summer and fall months.

Viral prevalence

Figures 9, 10, 11, 12, and 13 illustrate the viral prevalence profiles for the survey years 2009, 2010, 2011, 2012, and 2013 respectively. Four viruses were consistently tested for all 4 years and include Israeli acute paralysis virus, deformed wing virus, acute bee paralysis virus, and slow bee paralysis virus (SBPV). The survey in 2009 reported the highest incidence of IAPV but 2010 saw the highest incidence of ABPV. DWV remained consistently high (above 80%) for

all 5 survey years. In this survey year, we no longer tested for BQCV because it is considered widespread, and we began testing for LSV-2, a virus that we know less about.

The monthly prevalence of five commonly found viruses (IAPV, DWV, ABPV, KBPV, and LSV-2) is provided in Figures 13, 14, 15, 16, 17 and 18. IAPV (Figure 13) and ABPV (Figure 14), and LSV-2 (Figure 18) illustrate seasonality in these viruses. In contrast, DWV (Figure 15), and KBPV (Figure 16). No monthly prevalence graphs are provided for SBPV as this virus was not detected.

Finally, this study found no evidence of *Tropilaelaps* or *Apis cerana*. Visual analysis of samples collected in alcohol did not detect a presence of this exotic *Apis* species and *A. mellifera* sub-races.

Pesticide Survey:

This year each participating state submitted ten composite pollen samples from 10 of their 24 apiaries. To date, the most prevalent pesticides are miticides applied directly to hives to control *Varroa* mites. These miticides include Coumaphos and its metabolites (detected in 37.7% of the samples), Fluvalinate (detected in 50% of the samples), Thymol (detected in 21.1% of the samples), and the Amitraz metabolite Dimethylphenyl (detected in 21.3% of samples). Chlorpyrifos (detected in 20.4% of the samples) was the most prevalent pesticide found not used for *Varroa* control.

On average each sample had 3 different products and/or metabolites with as many as 15 products and/or metabolites found in a single sample. The full set of results, grouped by their classification as an insecticide, herbicide, or fungicide is given in Figure 19. The level of detection (LOD), or the minimum amount that can be reliably detected, the national prevalence (%) seen by this limited survey, the average level detected (parts per billion or ppb), and the range of detection (ppb) are provided for those samples that tested positive for that specific pesticide. If a pesticide was detected once, a single value is given for the range and it is marked with an asterisk. With the additional information of pollen collected concurrently with the live bee and *Nosema* and *Varroa* mite samples, it may be possible to correlate colony health to in-hive pesticide residue.

Conclusions

The increased sample size this year allows for the expansion of our database of pests and pathogens and places the collected data into a temporal context. This National Survey, which took place from summer 2013 through fall 2014, was expanded to capture some states not previously sampled and the sampling season was lengthened with the inclusion of more southern states. This allowed us to greatly increase viral and pest data for the winter months as shown by the prevalence graphs for the more common viruses. *Varroa* mite loads were seen

to increase over the first three years of the survey and remained high for this fifth year, but did not show further increase.

Results that will be monitored this year include *Varroa* mite loads to determine if the increasing trend continues and what treatments are being applied to the sampled colonies. By gathering yearly, sequential samples from a growing number of states, we may be able to see trends and patterns that relate to colony health. The survey does provide strong evidence that *Tropilaelaps*, slow paralysis virus, and *A. cerana* are not present in the U.S.

Appendix

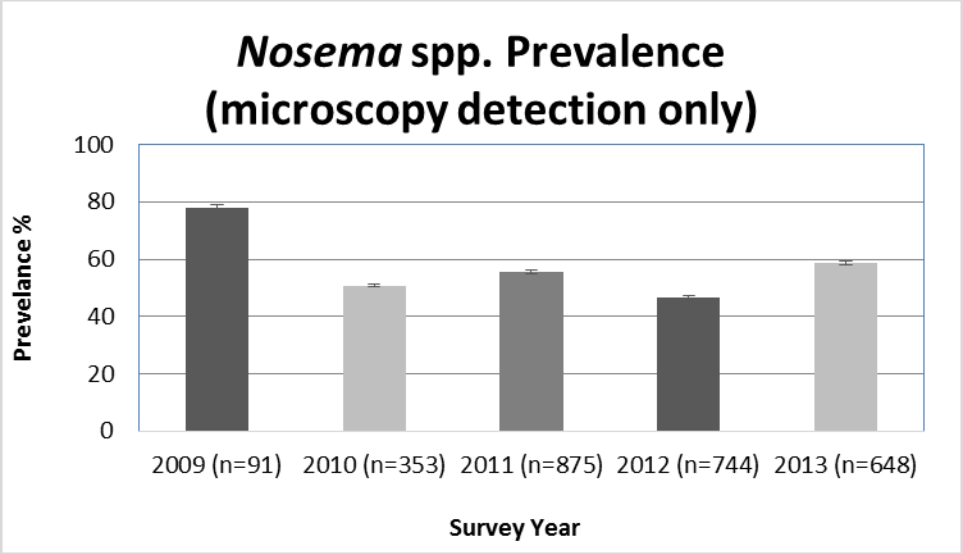

Figure 1: *Nosema* spp. prevalence over 5 years of survey
(95% Confidence Intervals shown)

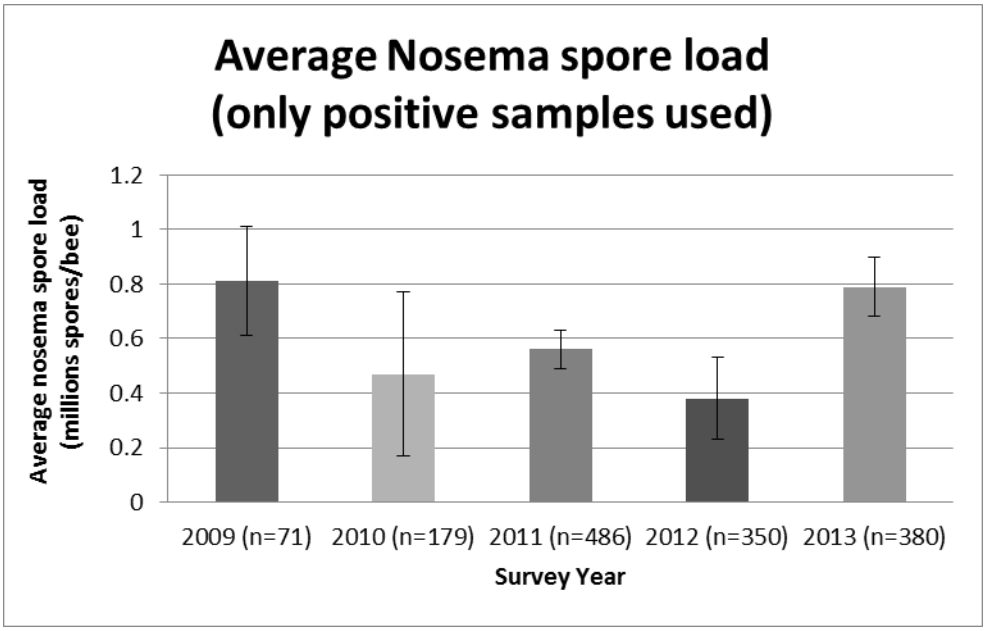

Figure 2: *Nosema* spp. spore load over 5 years of survey

(95% Confidence Intervals shown)

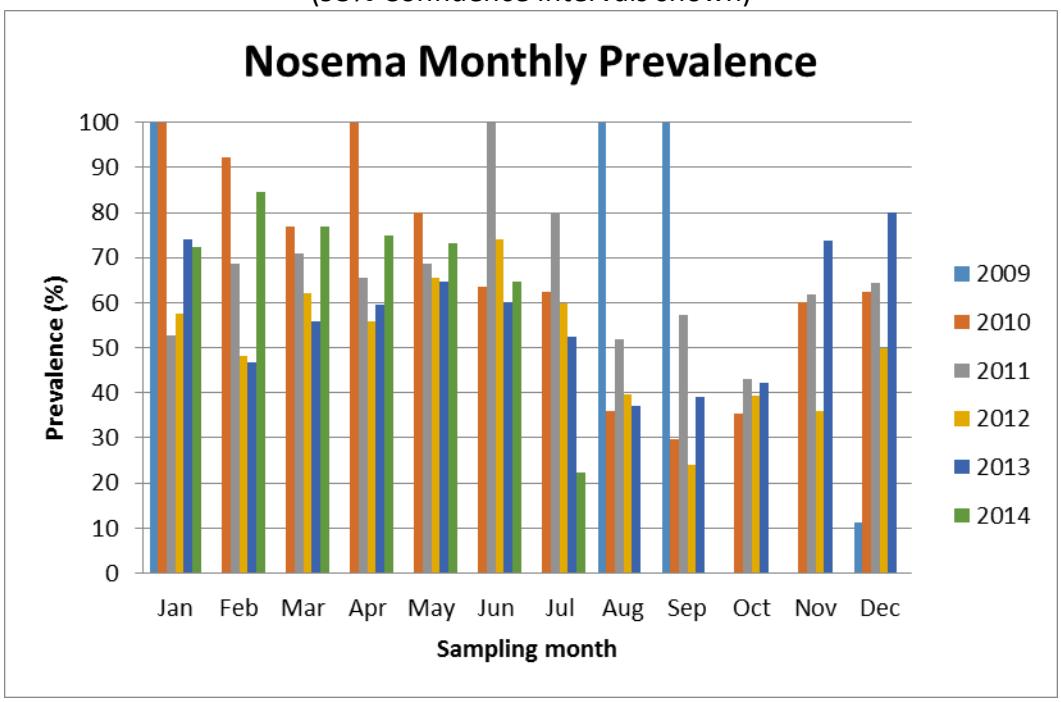

Figure 3: Monthly prevalence for *Nosma* spp.

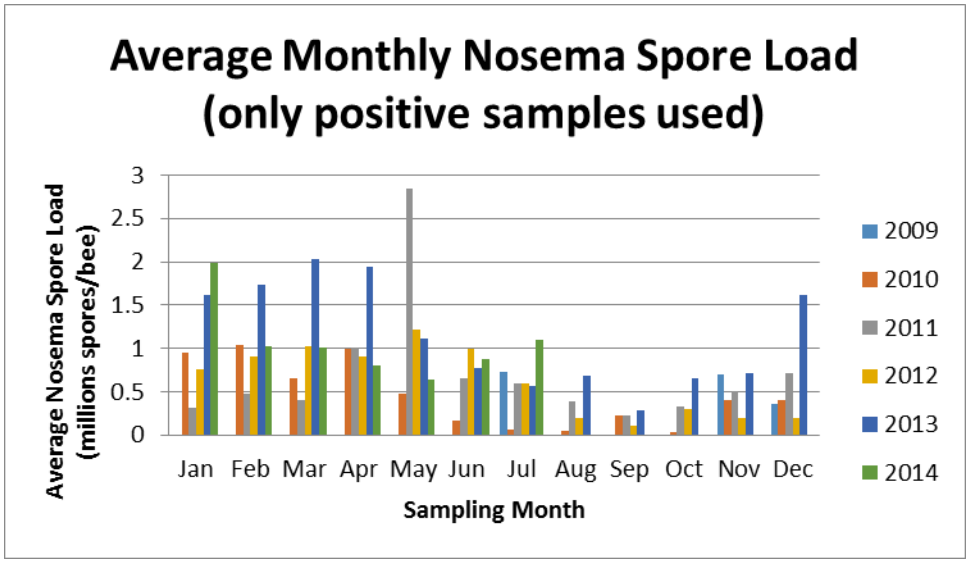

Figure 4: Average Monthly *Nosema* spore load
(for samples testing positive by microscopic spore count)

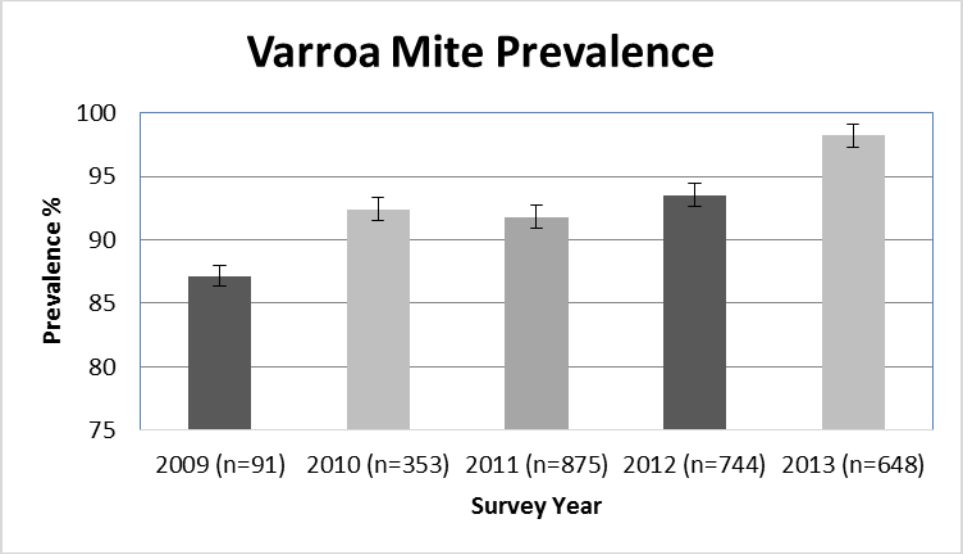

Figure 5: *Varroa* mite prevalence over 5 years of survey
(95% Confidence Intervals shown)

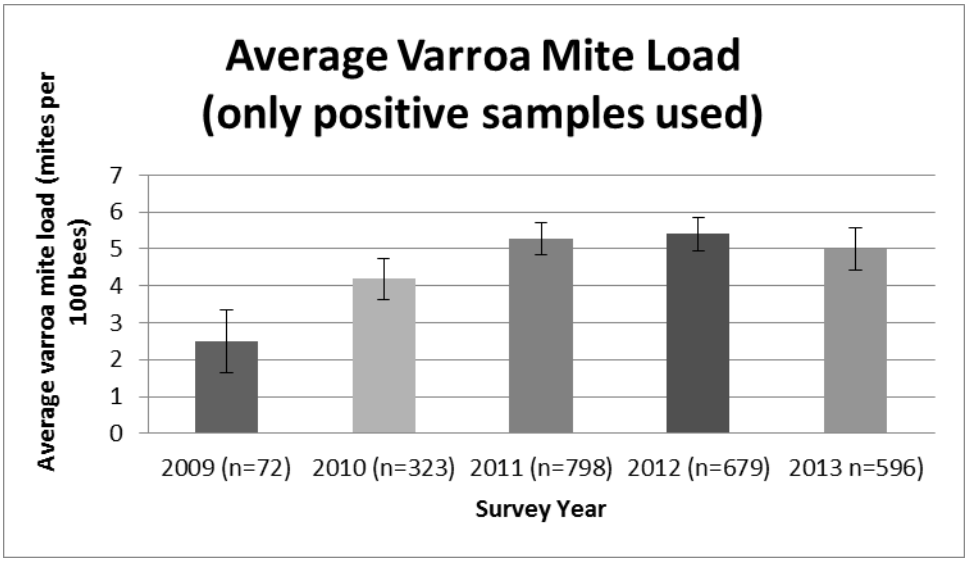

Figure 6: Average *Varroa* mite load over 5 years of survey
(for samples testing positive)
(95% Confidence Intervals shown)

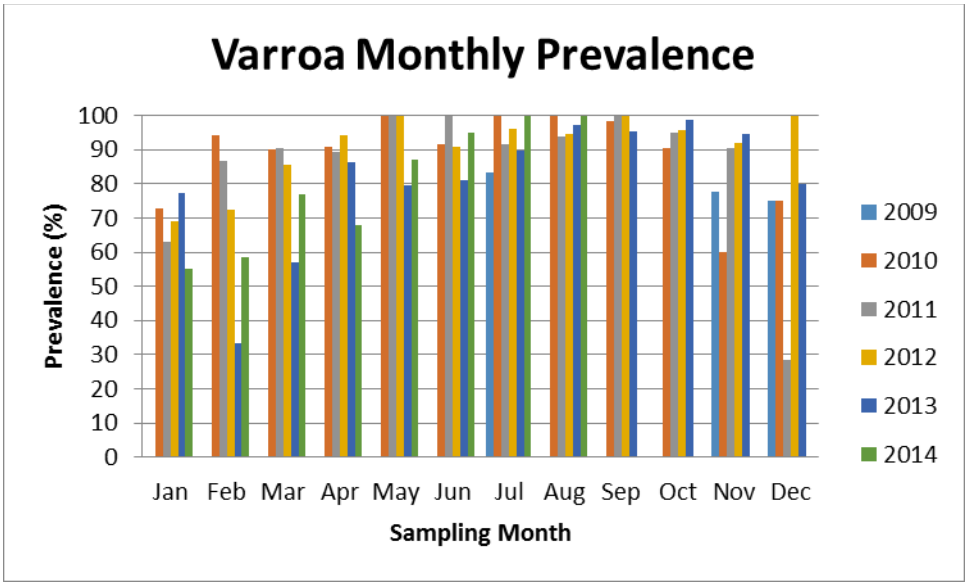

Figure 7: Monthly prevalence for *Varroa* mites

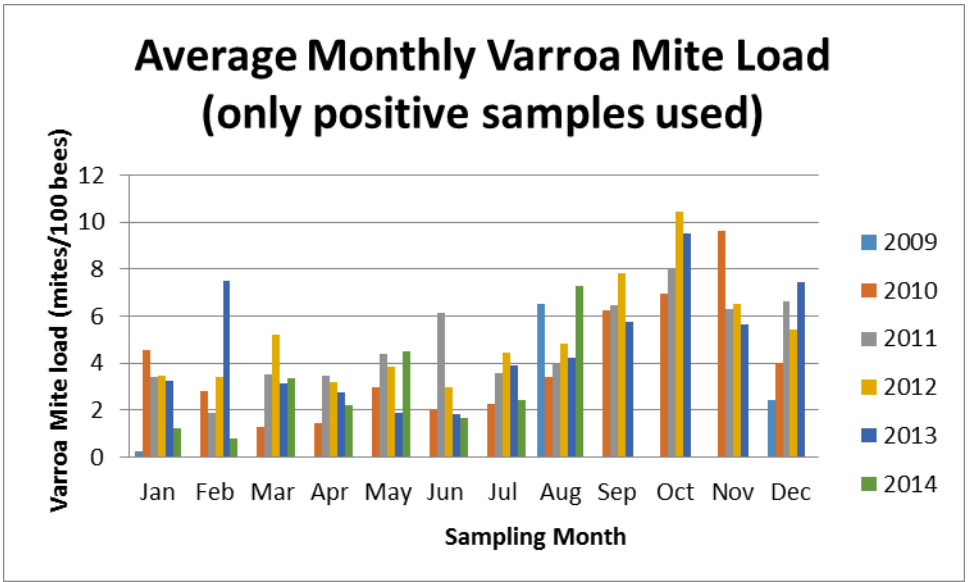

Figure 8: Average monthly *Varroa* mite load
(for samples testing positive)

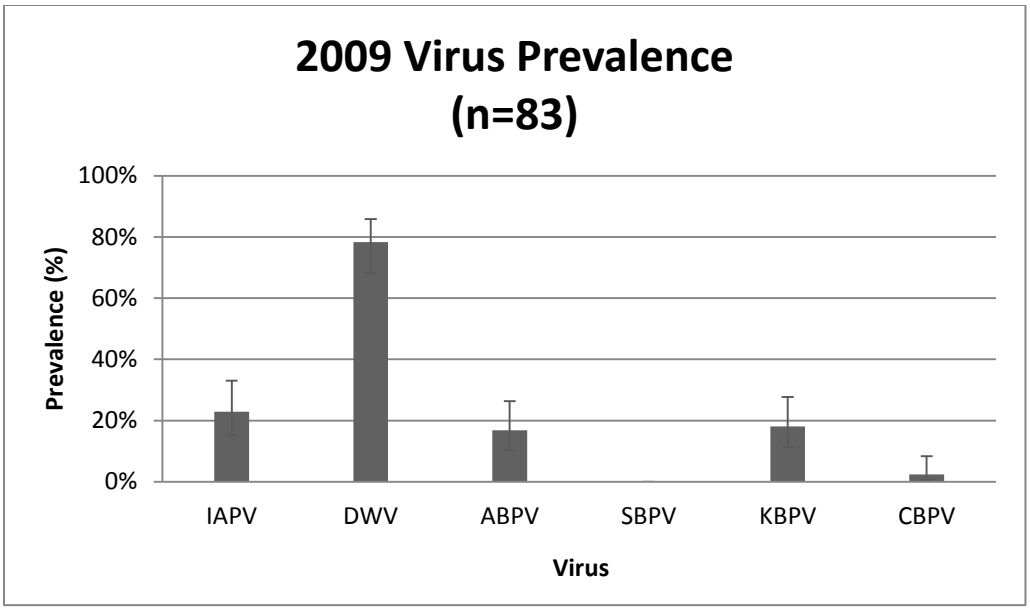

Figure 9: Virus prevalence for 2009 Pilot Survey
(95% Confidence Intervals shown)

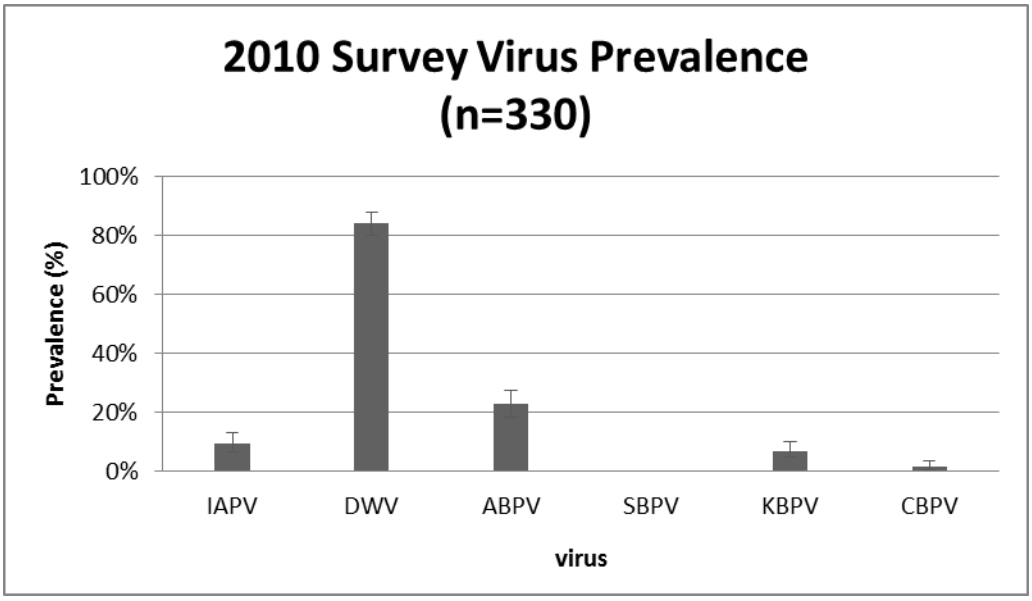

Figure 10: Virus prevalence for 2010 Limited National Survey
(95% Confidence Intervals shown)

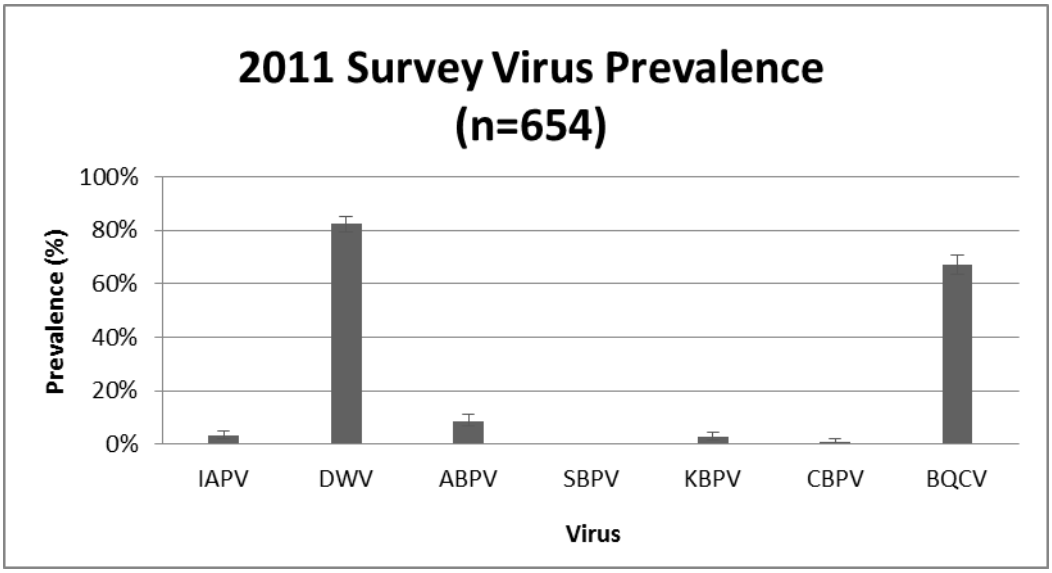

Figure 11: Virus prevalence for 2011 National Survey
(95% Confidence Intervals shown)

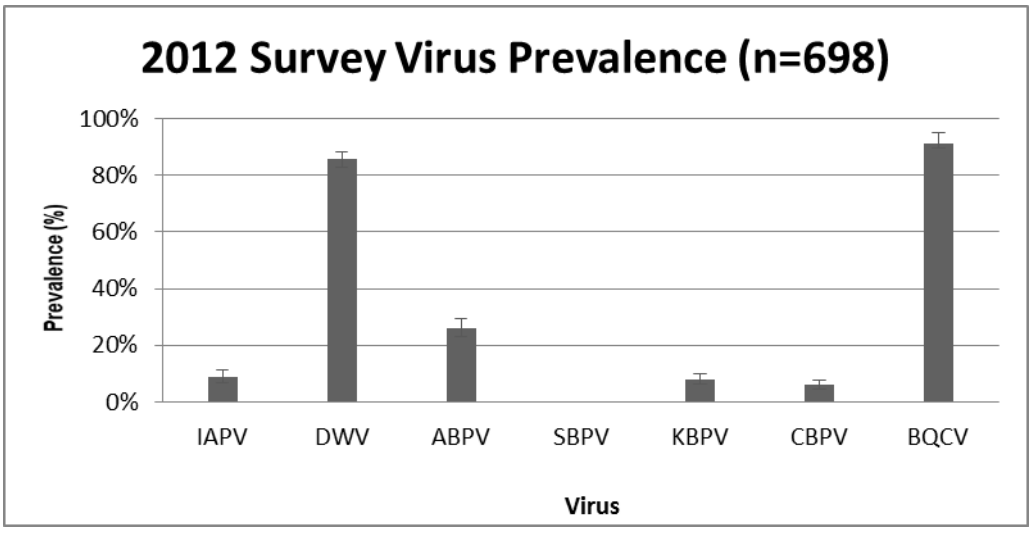

Figure 12: Virus prevalence for 2012 National Survey
(95% Confidence Intervals shown)

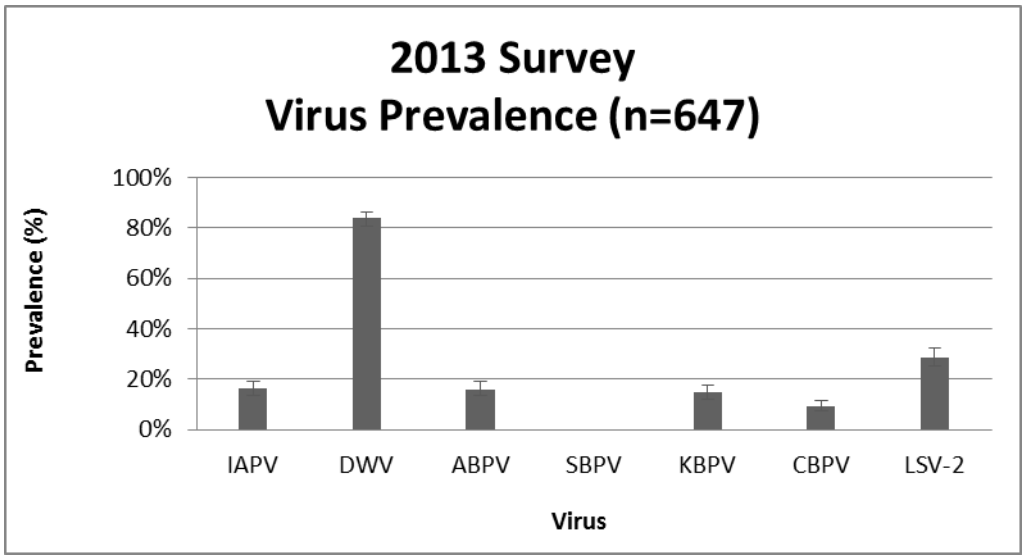

Figure 13: Virus prevalence for 2013 National Survey

(95% Confidence Intervals shown)

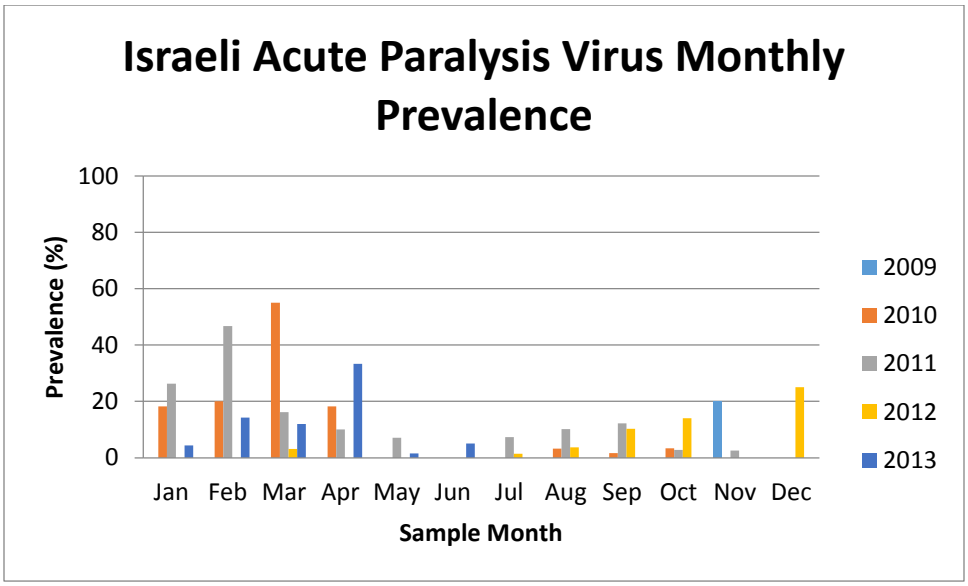

Figure 13: Israeli Acute Paralysis Virus prevalence over 4 years of survey

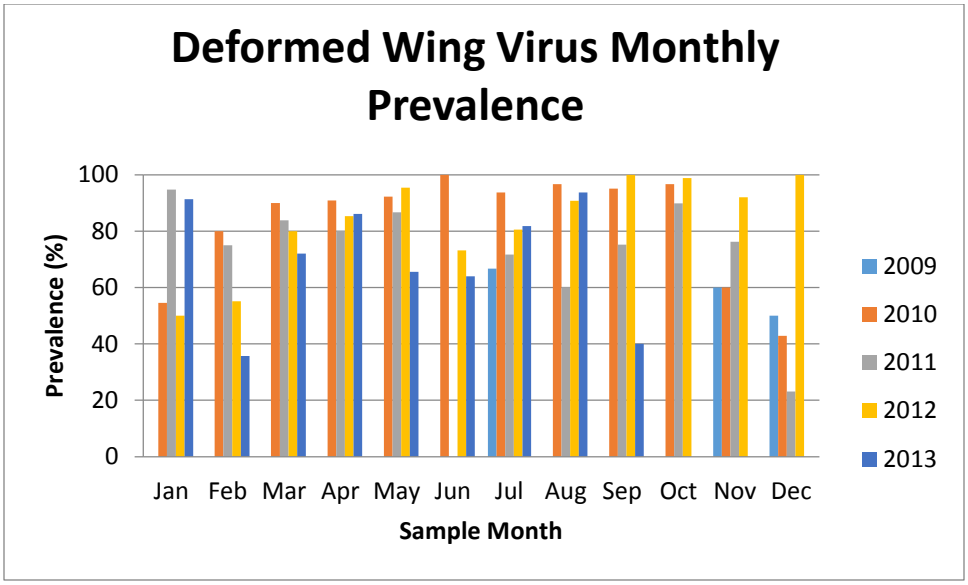

Figure 14: Deformed Wing Virus prevalence over 4 years of survey

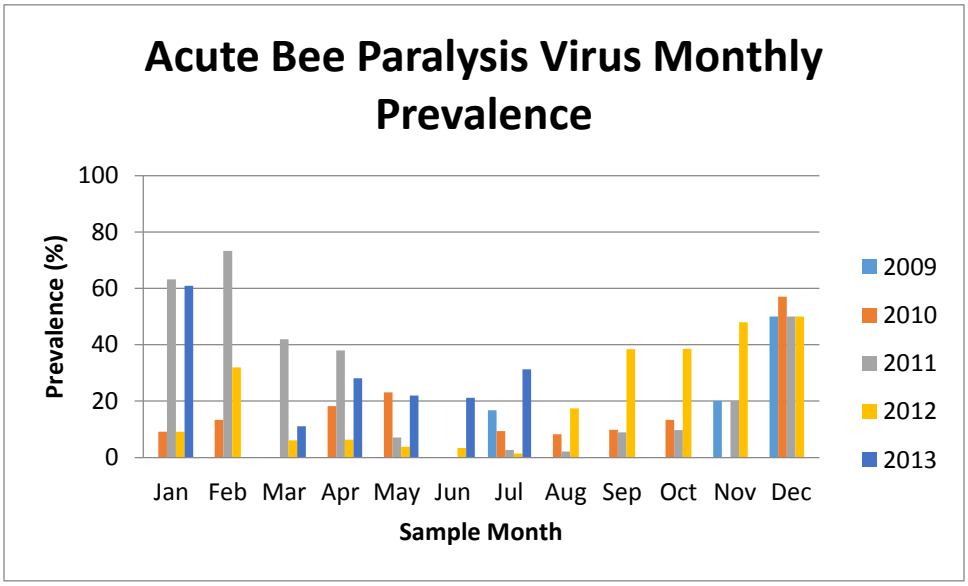

Figure 15: Acute Bee Paralysis Virus prevalence over 4 years of survey

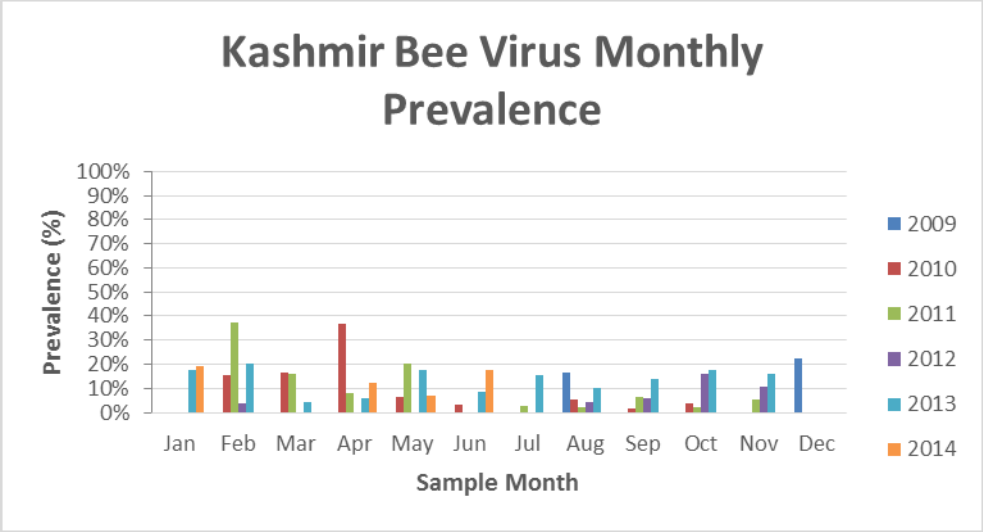

Figure 16: Kashmi Bee Paralysis Virus prevalence

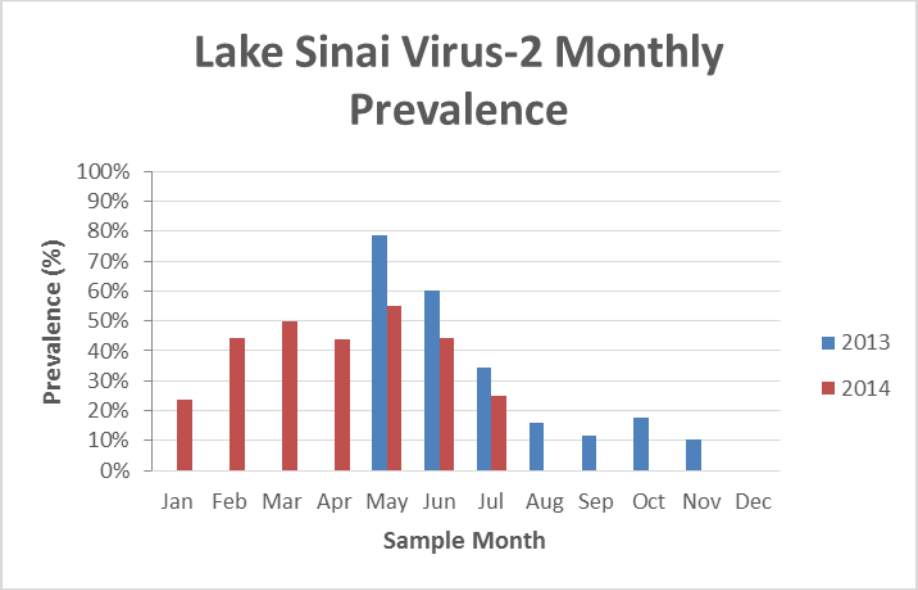

Fig 17: Lake Sinai Virus-2 prevalence, only 2013/2014

Pesticide	LOD	Prevalence	Average Detection if positive for target	Range if positive for target
	(ppb)	%	(ppb)	(ppb)
1-Naphthol	10	0.5	169.8	0 - 0
2,4 Dimethylaniline	50	n/a	n/a	n/a
2,4 Dimethylphenyl formamide (DMPF)	4	18.5	171.4	35.9 - 35.9
3-Hydroxycarbofuran	4	n/a	n/a	n/a
4,4 dibromobenzophenone	4	n/a	n/a	n/a
Acephate	50	0.8	216.3	0 - 0
Acetamiprid	8	0.3	32.8	0 - 0
Acetachlor	10	0.2	52.7	52.7*
Alachlor	10	0.5	52.0	0 - 0
Aldicarb	4	n/a	n/a	n/a
Aldicarb sulfone	3	0.2	14.0	14*
Aldicarb sulfoxide	20	0.2	35.9	35.9*
Aldrin	10	n/a	n/a	n/a
Allethrin	10	n/a	n/a	n/a
Amicarbazone	30	n/a	n/a	n/a
Amitraz	4	n/a	n/a	n/a
Atrazine	6	6.5	65.4	0 - 0
Azinphos methyl	6	n/a	n/a	n/a
Azoxystrobin	2	9.7	57.3	18.3 - 1580
Bendiocarb	2	n/a	n/a	n/a
Benoxacor	4	0.2	Trace	Trace
BHC alpha	4	n/a	n/a	n/a
Bifenazate	20	n/a	n/a	n/a
Bifenthrin	1	6.2	24.7	0 - 0
Boscalid	4	5.4	623.9	0 - 0
Bromuconazole	20	n/a	n/a	n/a
Buprofezin	20	n/a	n/a	n/a
Captan	10	2.5	411.0	72.6 - 4900
Carbaryl	30	0.9	167.3	0 - 0
Carbendazim (MBC)	5	3.9	58.7	1.1 - 303
Carbofuran	5	n/a	n/a	n/a
Carboxin	4	n/a	n/a	n/a
Carfentrazone ethyl	1	n/a	n/a	n/a
Chlorfenopyr	1	n/a	n/a	n/a

Chlorfenvinphos	6	0.9	53.0	5.5 - 180
Chlorferone	50	0.2	192.0	192*
Chlorothalonil	1	5.6	839.9	1.9 - 54.2
Chlorpropham (CIPC)	40	n/a	n/a	n/a
Chlorpyrifos	1	18.5	20.5	0 - 0
Chlorpyrifos methyl	1	n/a	n/a	n/a
Clofentezine	100	n/a	n/a	n/a
Chlothianidin	1	1.5	27.7	0 - 0
Coumaphos	1	33.6	65.3	0 - 0
Coumaphos oxon	1	4.3	28.1	0 - 0
Cyfluthrin	4	0.8	30.9	6.6 - 21.1
Cyhalothrin total	1	7.4	10.3	205 - 205
Cypermethrin	4	1.2	30.8	25 - 25
Cyphenothrin	20	n/a	n/a	n/a
Cyprodinil	4	5.4	147.5	12.4 - 12.4
DDD p,p'	4	n/a	n/a	n/a
DDE p,p’	2	n/a	n/a	n/a
DDT p,p'	4	n/a	n/a	n/a
Deltamethrin	20	n/a	n/a	n/a
Diazinon	1	0.5	15.2	0 - 0
Dichlorvos (DDVP)	10	0.2	205.0	205*
Dicloran	1	0.2	25.0	25.0*
Dicofol	1	0.5	13.4	2.2 - 124
Dieldrin	10	0.2	12.4	12.4*
Difenoconazole	10	n/a	n/a	n/a
Diflubenzuron	20	0.6	159.0	0 - 0
Dimethenamid	10	n/a	n/a	n/a
Dimethoate	20	n/a	n/a	n/a
Dimethomorph	20	n/a	n/a	n/a
Dinotefuran	2	n/a	n/a	n/a
Diphenamid	1	n/a	n/a	n/a
Endosulfan I	2	1.9	34.9	0 - 0
Endosulfan II	2	1.7	21.0	0 - 0
Endosulfan sulfate	2	2.0	10.7	0 - 0
Endrin	10	n/a	n/a	n/a
Epoxiconazole	1	n/a	n/a	n/a
Esfenvalerate	2	3.2	14.4	0 - 0
Ethion	10	0.3	327.0	Trace-327
Ethofumesate	5	0.2	14.2	14.2*
Etoxazole	1	n/a	n/a	n/a
Etridiazole	10	n/a	n/a	n/a

Famoxadone	20	n/a	n/a	n/a
Fenamidone	10	n/a	n/a	n/a
Fenbuconazole	2	1.9	462.4	30.5 - 73.3
Fenhexamid	6	0.5	330.9	0 - 0
Fenpropathrin	1	0.9	43.2	0 - 0
Fenpropathrin N.D. 1.0	1	n/a	n/a	n/a
Fenpyroximate	5	6.3	31.0	2.2 - 1930
Fenthion N.D. 10	10	n/a	n/a	n/a
Fipronil N.D. 10	10	n/a	n/a	n/a
Flonicamid	8	0.3	42.2	0 - 0
Flubendiamide N.D. 25.0	25	n/a	n/a	n/a
Fludioxonil	20	0.3	51.9	0 - 0
Fluoxastrobin N.D. 4.0	4	n/a	n/a	n/a
Fluridone	10	0.3	1279.0	0 - 0
Flutolanil N.D. 4.0	4	n/a	n/a	n/a
Fluvalinate	1	49.4	70.6	0 - 0
Heptachlor N.D. 4.0	4	n/a	n/a	n/a
Heptachlor epoxide N.D. 10	10	n/a	n/a	n/a
Hexachlorobenzene (HCB) N.D. 1.0	1	n/a	n/a	n/a
Hexythiazox N.D. 30	30	n/a	n/a	n/a
Hydroprene N.D. 10	10	n/a	n/a	n/a
Hydroxychlorothalonil	50	0.2	59.4	59.4*
Imazalil N.D. 5.0	5	n/a	n/a	n/a
Imidacloprid	1	2.2	22.2	10.2 - 37.9
Imidacloprid 5-hydroxy N.D. 25	25	n/a	n/a	n/a
Imidacloprid olefin N.D. 10	10	n/a	n/a	n/a
Indoxacarb	3	0.2	Trace	Trace
Iprodione N.D. 20	20	n/a	n/a	n/a
Lindane N.D. 4.0	4	n/a	n/a	n/a
Linuron N.D. 20	20	n/a	n/a	n/a
Malathion	4	0.2	63.9	63.9*
Metalaxyl	2	0.6	20.5	30.1 - 1330
Methamidophos	4	1.1	15.8	0 - 0
Methidathion N.D. 10	10	n/a	n/a	n/a
Methomyl	10	0.3	19.2	1.7 - 13.7
Methoxyfenozide	2	2.2	200.1	80.9 - 1820
Metolachlor	6	0.8	921.4	6.6 - 6.6
Metribuzin	1	0.2	3.5	3.5*
MGK-326	10	0.3	142.9	0 - 0
MGK-326 N.A. 10	10	n/a	n/a	n/a
Myclobutanil	15	1.2	448.0	0 - 0
Norflurazon N.D. 6.0	6	n/a	n/a	n/a
Oxamyl N.D. 5.0	5	n/a	n/a	n/a

Oxyfluorfen	1	2.9	7.7	0 - 0
Paradichlorobenzene	10	4.9	420.3	0 - 0
Parathion methyl	2	0.2	6.6	6.6*
Pendimethalin	6	9.7	38.4	10.7 - 800
Permethrin total	10	0.6	175.6	0 - 0
Phenothrin N.D. 10	10	n/a	n/a	n/a
Phorate N.D. 10	10	n/a	n/a	n/a
Phosalone N.D. 10	10	n/a	n/a	n/a
Phosmet	10	1.1	149.9	0 - 0
Piperonyl butoxide N.D. 6.0	6	n/a	n/a	n/a
Pirimiphos methyl N.D. 4.0	4	n/a	n/a	n/a
Prallethrin	4	2.0	195.7	0 - 0
Profenofos N.D. 10	10	n/a	n/a	n/a
Pronamide N.D. 1.0	1	n/a	n/a	n/a
Propachlor	10	0.2	Trace	Trace
Propanil N.D. 10	10	n/a	n/a	n/a
Propargite N.D. 10	10	n/a	n/a	n/a
Propazine	4	0.2	34.3	34.3*
Propetamphos N.D. 4.0	4	n/a	n/a	n/a
Propham	20	0.2	Trace	Trace
Propiconazole N.D. 10	10	n/a	n/a	n/a
Pymetrozine N.D. 20	20	n/a	n/a	n/a
Pyraclostrobin	15	5.1	217.7	0 - 0
Pyrethrins N.D. 50	50	n/a	n/a	n/a
Pyridaben	1	0.5	1.5	0 - 0
Pyrimethanil	3	1.9	12.7	0 - 0
Pyriproxyfen	2	0.9	7.7	9.9 - 277
Quinoxyfen N.D. 10	10	n/a	n/a	n/a
Quintozene (PCNB) N.D. 1.0	1	n/a	n/a	n/a
Resmethrin total N.D. 10	10	n/a	n/a	n/a
Sethoxydim N.D. 2.0	2	n/a	n/a	n/a
Simazine N.D. 10	10	n/a	n/a	n/a
Spinosad N.D. 28	28	n/a	n/a	n/a
Spirodiclofen N.D. 1.0	1	n/a	n/a	n/a
Spiromesifen N.D. 10	10	n/a	n/a	n/a
Tebuconazole	8	2.2	70.0	49.1 - 326
Tebufenozide	5	0.2	22.7	22.7*
Tebuthiuron	2	0.6	4.8	37.6 - 7060
Tefluthrin	1	0.2	Trace	Trace
Tetrachlorvinphos N.D. 4.0	4	n/a	n/a	n/a
Tetraconazole N.D. 6.0	6	n/a	n/a	n/a
Tetradifon N.D. 1.0	1	n/a	n/a	n/a
Tetramethrin N.D. 10	10	n/a	n/a	n/a

Thiabendazole	1	1.2	2.6	0 - 0
Thiacloprid	1	0.5	151.2	1 - 510
Thiamethoxam	1	1.7	13.5	135 - 483
THPI	50	1.5	2147.8	3.3 - 3.3
Thymol	50	20.7	2581.5	0 - 16
Triadimefon N.D. 2.0	2	n/a	n/a	n/a
Triadimenol N.D. 45	45	n/a	n/a	n/a
Tribufos (DEF) N.D. 2.0	2	n/a	n/a	n/a
Trifloxystrobin	1	1.1	173.2	34.1-638
Triflumizole N.D. 10	10	n/a	n/a	n/a
Trifluralin	1	5.2	87.6	1-510
Triticonazole	10	0.6	310.8	135-483
Vinclozolin	1	0.5	3.3	Trace-3.3

Figure 18: Pesticide analysis up through 2013 survey (451 samples)
(*denotes single detection only)

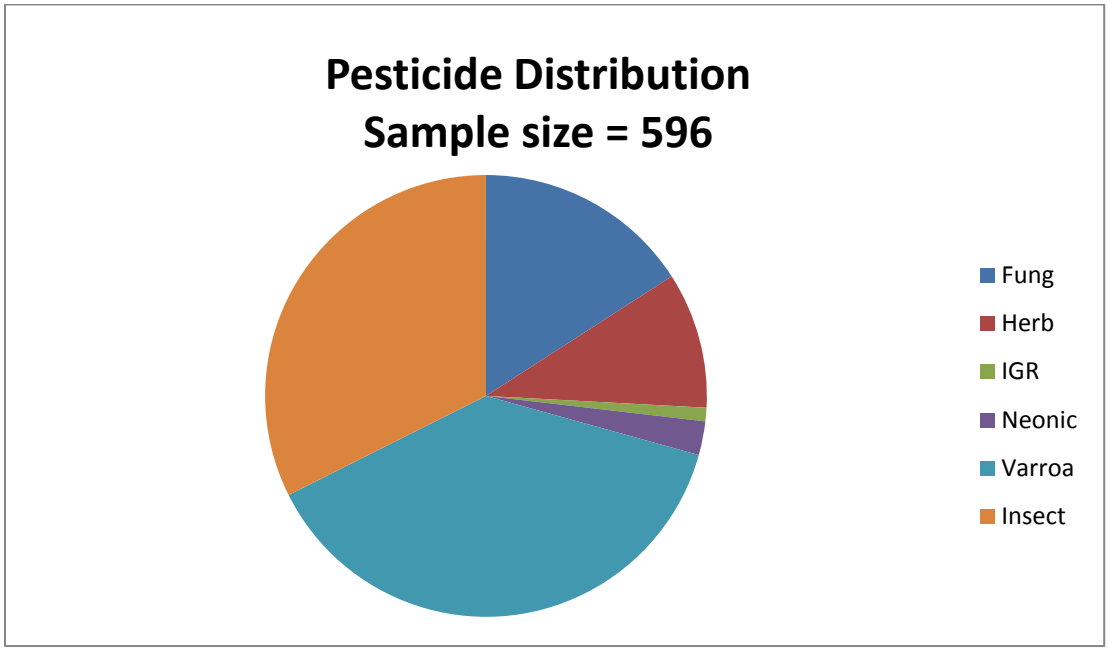

Figure 19: Classification of types of pesticide detected in pollen samples through 2014 .

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