DNA Barcodes for Bio-surveillance: Regulated and Economically Important Arthropod Plant Pests

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DNA Barcodes for Bio-surveillance: Regulated and Economically Important Arthropod Plant
Pests

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Abstract

Many of the arthropod species that are important pests of agriculture and forestry are impossible to discriminate morphologically throughout all of their life stages. Some cannot be differentiated at any life stage. Over the past decade, DNA barcoding has gained increasing adoption as a tool to both identify known species and to reveal cryptic taxa. Although there has not been a focused effort to develop a barcode library for them, reference sequences are now available for 77% of the 409 species of arthropods documented on major pest databases. Aside from developing the reference library needed to guide specimen identifications, past barcode studies have revealed that a significant fraction of arthropod pests are a complex of allied taxa. Because of their importance as pests and disease vectors impacting global agriculture and forestry, DNA barcode results on these arthropods have significant implications for quarantine detection, regulation, and management. The current review discusses these implications in light of the presence of cryptic species in plant pests exposed by DNA barcoding.

Key words: Species identification, cryptic taxa, invasive species, quarantine, pest management

Introduction

Thousands of arthropod species either directly attack economically important plants or transmit viral and bacterial diseases, imposing massive costs on agriculture and forestry. For example, the widely distributed diamondback moth, *Plutella xylostella*, causes \$US4B-5B in damage to crops each year (Zalucki et al. 2012). The economic losses due to arthropods are increasing as new species gain pest status, often following human-mediated range expansions which, in the absence of natural enemies (Liebhold et al. 2013), can lead to population explosions that move a species from non-pest in its native range to pest in newly colonized areas (Aukema et al. 2011). The number of alien species continues to rise with arthropods representing the dominant component of this cross-border traffic, for example in Europe, as documented by the European Environment Agency (<http://www.eea.europa.eu/>). Five major databases track the most important arthropod pests and disease vectors of agriculture and forestry; they are maintained by the Canadian Food Inspection Agency (CFIA) (www.inspection.gc.ca), the European and Mediterranean Plant Protection Organization (EPPO) (www.eppo.int), the Global Invasive Species Database (GISD) (<http://www.iucngisd.org>), the National Agricultural Pest Information System (NAPIS) (<https://napis.ceris.purdue.edu>) and the United States Department of Agriculture - Animal and Plant Health Inspection Service (USDA-APHIS) (www.aphis.usda.gov) (accessed 3-5 January 2016). These databases, which include regulated, invasive and economically important plant pests with a focus on species important in Europe and North America, have been used to compile unified pest lists (Frewin et al. 2013). Since significant progress on DNA barcoding of plant pests has also been made in these regions, the current article draws the core information from these five sources as a basis for a discussion of cryptic species and their implications for DNA barcode applications. All but 21 of the 409 arthropod pest species on these lists belong to five

insect orders (Coleoptera, Diptera, Hemiptera, Lepidoptera, Thysanoptera) (Table S1). An additional 36 cryptic pest species reported in literature but not included in the five databases are considered in this article (Table S1). Taxonomic difficulties continue to constrain the regulation of pest arthropods as indicated by the fact that 18 of the entries on these lists are only identified to a genus (Table S1) while some with a species designation are known to be a species complex (Mally et al. 2015). These taxonomic complexities have provoked growing interest in the adoption of DNA-based approaches for species recognition, creating interesting challenges for traditional approaches to regulatory compliance (Jörger and Schrödl 2013).

The balance of this article begins by considering the effectiveness of DNA barcoding in identifying arthropods and in revealing cryptic species. It then proceeds to consider past studies of cryptic diversity in pest arthropods, before concluding with a discussion of the implications of DNA barcoding for pest regulation, management and quarantine.

Effectiveness of DNA barcodes for arthropod identification

The efficacy of DNA barcoding (Hebert et al. 2003a) for specimen identification and species discovery has stimulated an international research program which has generated a barcode reference library for more than 250,000 described species of animals, fungi and plants, data which resides in BOLD, the Barcode of Life Data System (Ratnasingham and Hebert 2007). Each of the 4.5 million animal records on BOLD has been assigned to a BIN, a Barcode Index Number (Ratnasingham and Hebert 2013), generating 452K BINs, predominantly insects (315K)

(accessed 21 April 2016). Because BINs show strong congruence with species designated through past morphological study (Pentinsaari et al. 2014; Zahiri et al. 2014, Mutanen et al. 2015), they can be viewed as species proxies (Telfer et al. 2015) to facilitate the assessment of large-scale biodiversity patterns (Blagoev et al. 2015) and the detection of cryptic species complexes (Ashfaq et al. 2015; Kekkonen and Hebert 2014). The use of barcode data to identify species (Rakauskas and Basilova 2013) as opposed to BINs requires the species in question be represented in the barcode reference library (Ekrem et al. 2007). Because the barcode reference library now includes records for many agricultural and forestry pests (Ashfaq et al. 2014; Footitt et al. 2014; Raupach et al. 2014), newly encountered specimens of these species can be identified through barcode analysis. As well, the extension of DNA barcoding protocols onto next-generation sequencing (NGS) platforms (Shokralla et al. 2014) is enabling metabarcoding studies which permit large-scale assessments of species composition (Taberlet et al. 2012), an approach of high importance in monitoring plant pests.

DNA barcoding has a strong track record in delivering species-level identifications for the five insect orders with the most pest species - Coleoptera (Rougerie et al. 2015; Woodcock et al. 2013), Diptera (Nagy et al. 2013; Smit et al. 2013), Hemiptera (Park et al. 2011*b*; Raupach et al. 2014), Lepidoptera (Ashfaq et al. 2013; Janzen et al. 2005) and Thysanoptera (Rebijith et al. 2014; Iftikhar et al. 2016). For example, 92.2% of 3514 species of European beetles were assigned to a distinct BIN that coincided with a known morphological species, while most of the other species were assigned to two or three BINs, suggesting they represent cryptic species complexes (Hendrich et al. 2015). Work on Diptera has similarly validated the effectiveness of

DNA barcoding for the identification of species in this order, including some of the most important agricultural pests, such as fruit flies (Virgilio et al. 2012) and leafminers (Amin et al. 2014). Another study that examined 1849 species of Canadian Hemiptera assigned these species to 1867 BINs with high correspondence between species and BINs, but also revealed 27 species with high divergences suggestive of cryptic species complexes (Gwiazdowski et al. 2015). Lepidoptera, the most intensively studied order, is represented by more than 100,000 BINs on BOLD. Work on this group has demonstrated the efficacy of DNA barcoding in identifying known species (Dinca et al. 2015; Wilson et al. 2013) and in revealing cryptic species complexes (Burns et al. 2008; Huemer et al. 2014a). It has also shown that there is very limited geographic variation in barcode sequences in populations of most species so increased geographic scale does not reduce the success of species identification (Lukhtanov et al. 2009; Huemer et al. 2014b, Candek and Kuntner 2015). However, in certain groups, such as diving beetles of the tribe Agabini (Bergsten et al. 2012), the correlation between genetic and geographic distances is strong enough to impact the success of species identification unless sampling of each species is fairly comprehensive. Studies on Lepidoptera have further shown the way in which DNA barcoding can challenge current taxonomic boundaries, can shift understanding of distributions (Rougerie et al. 2014) and can expose inconsistent usage of species names (Mutanen et al. 2012). Finally, work on Lepidoptera has confirmed that BINs are a strong proxy for species. For example, 93% of 215 species of European geometrid moths showed a perfect correspondence between BINs and known species (Hausmann et al. 2013).

The effectiveness of DNA barcoding in species recognition has also been established for Acari, the other major group of arthropods with important plant pests (Young et al. 2012). For example, it allowed resolution of the species composition of spider mites in agricultural settings in Vietnam (Hinomoto et al. 2007) and Europe (Ros and Breeuwer 2007). These studies have stimulated the development of barcode reference libraries, and have also revealed overlooked species in this group of pests (Matsuda et al. 2013).

A search on BOLD (December 22, 2015) revealed sequence coverage for 314 (269 public) of the 409 species (77%) of plant arthropod pests (Table 1). Although sequences and BIN assignments for 45 species on BOLD were private, they were included as taxa with coverage. Coverage for species of Diptera (90%) and Lepidoptera (87%) was higher than that for Coleoptera (71%) and Hemiptera (64%). Table 2 details the number of barcode records, BINs, and intraspecific divergence values for the pest species with five or more sequences on BOLD. All but 18 of these 314 species possessed at least one barcode-compliant (>500 bp, <1% ambiguous bases, no stop-codon or contamination) record and 1/3 of the species (61/178) represented by five or more records showed a BIN split, suggesting that they represent a species complex (Table 2, Table S1). However, the possibility that some of these cases may reflect misidentifications or introgression (Harrison and Larson 2014) cannot be ruled out without detailed study on a case-by-case basis.

Incomplete resolution or flawed taxonomy?

DNA barcoding has failed to separate some congeneric species of important pests such as the tephritid fruit flies *Bactrocera occipitalis* and *B. philippinensis* (Sumalde et al. 2013). Another study which examined 193 tephritid species failed to discriminate six species in the *B. dorsalis* complex (*B. dorsalis*, *B. occipitalis*, *B. carambolae*, *B. papaya*, *B. invadens*, *B. philippinensis*) (Frey et al. 2013; Jiang et al. 2014). This discrepancy between taxonomic assignments and barcode results (Hendrichs et al. 2015) provoked a reevaluation of their taxonomy, work which suggested that at least some of the taxa involved are conspecific (Khamis et al. 2012; Schutze et al. 2012). In fact, a subsequent taxonomic revision synonymized *B. invadens* and *B. papaya* with *B. dorsalis* (Schutze et al. 2015). There are many other cases where pest species on different plants have been assigned to separate species when they likely represent just one taxon. For example, populations of the “mango mealybug” on mango trees in Pakistan were identified to *Drosicha mangiferae* (Latif 1949) while those on forest trees were assigned to *D. stebbingi* (Gul et al. 1997). A barcode study (Ashfaq et al. 2011), supported by results from three other gene regions, did not reveal any genetic divergence between mealybugs on mango and six other fruit and forest trees, supporting an earlier suggestion of their synonymy (Latif 1949).

Cryptic Species

Although the definition of cryptic species is fluid (Jörger and Schrödl 2013), it is generally accepted that lineages with deep mitochondrial divergence without obvious morphological differences are strong candidates (Rivera and Currie 2009). Although divergence patterns in mitochondrial and nuclear genes are sometimes discordant (Humphries et al. 2011), surveys of mitochondrial diversity provide quick insight into species boundaries (Mutanen et al. 2015).

Lineages showing sequence divergence, often termed molecular operational taxonomic units (MOTUs) (Blaxter et al. 2005), have been discriminated by analyzing sequence variation using distance analysis (Schloss and Handelsman 2005), neighbor-joining clustering (Saitou and Nei 1987), phylogenetic trees (Zhang et al. 2013), Bayesian inference (Yang and Rannala 1997), coalescence-based approach (Pons et al. 2006; Fujisawa and Barraclough 2013), barcode-gap analysis (Puillandre et al. 2012) and BINs (Ratnasingham and Hebert 2013). However, there is a growing trend to integrate multiple methods (Ashfaq et al. 2015; Blagoev et al. 2015; Kekkonen et al. 2015) and multiple markers (Jörger et al. 2012; Mrinalini et al. 2015) to assess MOTU diversity. The results from such analyses have frequently been helpful in resolving taxonomic problems and in estimating species richness and abundance (Mutanen et al. 2013; Stahlhut et al. 2013; Unterseher et al. 2011). However, the use of a single, standardized, marker has the advantage of simplifying molecular identification (Savolainen et al. 2005), a valuable feature for pest managers and regulators in field applications (Armstrong and Ball 2005). Reflecting the ease of recovering sequence information, and access to refined analytical tools, the discovery of new cryptic species is now commonplace in many animal groups.

Cryptic species have important implications for taxonomic, evolutionary, and biodiversity studies, but their presence in pest taxa also has economic and regulatory implications (Piffaretti et al. 2013; Rebijith et al. 2014). Several studies have considered the impact of cryptic species on pest management (Frewin et al. 2014; Ovalle et al. 2014), biological control strategies (Derocles et al. 2015), the detection of invasive species (Blacket et al. 2015; Li et al. 2015) and quarantine inspections (Kang et al. 2015). The most obvious implications of DNA barcoding relate to its

capacity to discriminate the members of cryptic species complexes (Robe et al. 2013). Systems which employ sequence matches to identify specimens are already a reality (MacLeod et al. 2010), allowing the automated detection of regulated species (Lammers et al. 2014). However, in large-scale metabarcoding, standardization of metadata and taxonomic identifications still require consensus (Tedersoo et al. 2015), factors which currently limit the application of this approach in a regulatory context. This gap could be addressed through community action, perhaps via the International Barcode of Life (iBOL) (<http://ibol.org>) or the Genomics Standards Consortium (<http://gensc.org/>) model (Yilmaz et al. 2011).

Revealing cryptic species in pest arthropods

The effectiveness of DNA barcoding in revealing overlooked species in global pests like bark beetles, leafminers, gall midges, mealybugs, wireworms, seed borers, gypsy moths, armyworms and thrips is well documented (Table 3). For example, *Liriomyza langei* (Diptera: Agromyzidae), a leafminer pest native to California, is morphologically indistinguishable from the invasive *L. huidobrensis*. However, the two species are easily discriminated by barcoding, a factor which enabled the analysis of their distributions (Scheffer et al. 2014). Similarly, the larvae of *Camptomyia corticalis* and *C. heterobia* which inflict severe damage on the production of shiitake mushrooms are easily separated by their 10.3% barcode divergence (Shin et al. 2013). Aphids are globally important pests and major vectors of many plant diseases, but they are challenging to identify because most of the 3000 species in this family possess striking phenotypic plasticity and life stage diversity. DNA barcoding has proven an effective tool for species discrimination because intraspecific distance is low in most species, averaging just 0.2%,

while congeneric distances are high (Footitt et al. 2008). However, some species, such as *Neomyzus circumflexus*, have higher divergences (>3%), suggesting they represent a complex (Table 3). Tussock moths (Lepidoptera: Lymantriidae) are worldwide pests which have been well-studied taxonomically. Nonetheless, DNA barcode studies revealed deep intraspecific divergences in *Lymantria dispar* (3.1%), *L. mathura* (4.7%) and *L. sinica* (2.9%) suggesting possible overlooked species (Table 3). Similarly, DNA barcode results have generally indicated congruence with morphologically recognized species of thrips (Qiao et al. 2012), but cryptic diversity is common with cases of high intraspecific divergence and deep genetic splits in several pest species (Tables 2, 3).

Practical Implications of DNA Barcoding

Pest regulation and management:

DNA barcoding is gaining broad application in integrated pest management (IPM) (Etzler et al. 2014) and bio-surveillance (Jones et al. 2013) programs as the standard method for species identification by 'matching unknown against the known' (Armstrong 2010). This is evidenced by the development of barcode-based kits for the identification of quarantine pests (Jiang-Ling et al. 2015). IPM requires the correct identification of target species and monitoring of its effectiveness often involves diverse stakeholders including farmers, crop pest regulators and quarantine agents. As long as "query" specimens show close sequence similarity to species in the reference library, match-based identifications are effective (Hebert et al. 2003b). Although most morphological species show congruence with BINs (Pentinsaari et al. 2014; Zahiri et al. 2014;

Table 1), inconsistencies between morphologically recognized species and the genetic clusters discriminated by BINs are not infrequent. Such discrepancies complicate the identification of their component taxa with implications for pest regulation and management. For example, the whitefly, *Bemisia tabaci*, is now known to be a complex of at least 34 species (Lee et al. 2013) which differ in their invasiveness (De Barro and Ahmed 2011), their capacity to transmit plant pathogens (Chowda-Reddy et al. 2012) and their regional pest status (Ashfaq et al. 2014). Likewise, two pest thrips, *Scirtothrips dorsalis* and *Thrips tabaci*, are species complexes whose members vary in their invasiveness and viral-transmission ability (Dickey et al. 2015; Jacobson et al. 2013). Similarly, root weevil, *Diaprepes abbreviatus*, is a species complex (Ascunce et al. 2008) with 13 BINs that show differing geographic distributions. Any effort to regulate such species complexes as a single entity is inappropriate because it can complicate regulatory compliance and compromise management and control efforts by raising concerns when non-invasive or non-vector species are treated as pests. Although many regulated pest species with barcode records are assigned to a single BIN, about one third on BOLD show a BIN split (Table 1). For example, *Leucinodes orbonalis*, a quarantine pest, is represented by six BINs, with diverse geographic origins. The cross-border movements of species with BIN diversity raise complexities that will often create ambiguity in species matches requiring revisions to quarantine regulations. Conversely, there are cases where different species lack barcode divergence, preventing their discrimination. The most dramatic case involves 20 species in the fruit fly genus *Bactrocera* which share the same BIN. While some of these taxa have recently been synonymized (Schutze et al. 2015) and other cases may reflect misidentifications, it is likely that other cases reflect closely allied species which hybridize. Such cases require more detailed

investigation to ascertain if other genetic markers allow their discrimination or reveal that they are actually synonyms.

Since DNA barcoding reliably identifies both immatures and adults (Shin et al. 2013), and can differentiate introduced and native pests (Chown et al. 2008), it has been used to help manage species complexes in agricultural systems (Frewin et al. 2014; Li et al. 2011). Such applications are important because insecticide resistance can vary between closely related species, and even between genotypes of the same species (van Toor et al. 2008). For example, two cryptic whiteflies in the *B. tabaci* complex, *Mediterranean* and *Middle East-Asia Minor 1 (MEAM1)*, differ in their susceptibility to insecticides. A study on the response of mixed populations of these species showed that the *Mediterranean* species prevails under insecticide-based management, but is displaced by *MEAM1* under biological control (Frewin et al. 2014).

Biological control is widely viewed as the optimal pest management strategy, but incorrect identification of either the pest species or its control agent due to cryptic diversity can lead to unpredictable outcomes (Van Lenteren et al. 2003). Because of its capacity to determine host-parasitoid associations (Erlandson et al. 2003), DNA barcoding has been employed to gain a deeper understanding of biological control using natural enemies. For example, Davis et al. (2011) differentiated immatures of *Laricobius rubidus*, a native biological control agent of hemlock woolly adelgid, *Adelges tsugae* (complex of four BINs) from the closely related *L. nigrinus* introduced from Japan while Derocles et al. (2015) examined interactions between a

leafminer and its parasitoids to advance biological control. Several studies have revealed unexpected diversity and interactions linked to cryptic diversity. The outcomes of biological control rapidly gain unpredictability (Roderick et al. 2012) when both the control agent and the target are cryptic species complexes, as for example, in the case of the hymenopteran wasp, *Trichogramma japonicum* (3 BINs) which is employed as a control agent for the brinjal borer, *L. orbonalis* (6 BINs).

Quarantine of invasive alien species:

Expansions in the geographic range of insect pests often require a rapid response (Adrion et al. 2014), and DNA barcoding can provide insights beyond those obtained through morphological analysis. For example, aside from enabling the early detection of invasive species (Onah et al. 2015), DNA barcoding can reveal source regions (Bellis et al. 2015) and introduction patterns (Blacket et al. 2015). Nagoshi et al. (2011) used it to monitor introductions of the invasive armyworm species, *Spodoptera litura* and *S. littoralis*, into Florida, while Tyagi et al. (2015) and Wei et al. (2010) detected the first invasions of *Thrips parvispinus* and *Echinothrips americanus*, in India and China. In a similar fashion, DNA barcoding differentiated *Heliothis armigera* from the native *H. zea*, revealing the spread of the former species after its introduction into Brazil (Mastrangelo et al. 2014). More recently, DNA barcoding led to the recognition of a buprestid beetle, *Agrilus ribesi*, whose introduction to North America had been overlooked for a century (Jendek et al. 2015). Barcoding has also been used to detect invasive tephritid fruit flies in Nigeria (Onah et al. 2015), leafminers in Papua New Guinea (Blacket et al. 2015) and Italy (Bernardo et al. 2015), a stink bug (*Halyomorpha halys*) in Europe (Cesari et al. 2015) and a

cotton bug, *Oxycarenus hyalinipennis* in Florida (Nagoshi et al. 2012). Based on its effectiveness in species identification, the Quarantine Barcode of Life project (www.qbol.org) worked towards establishing DNA barcoding as the core technology for identifying quarantine organisms in support of plant health, and to gain its acceptance by the pest regulators as the standard method for the identification of plant pests (van de Vossenberg et al. 2013). Since DNA barcoding meets the minimum standards (Floyd et al. 2010) set under the International Standards for Phytosanitary Measures (ISPM) No. 27, “Diagnostic Protocols for Regulated Pests” and has been validated for use in regulatory sciences (Jones et al. 2013), it is positioned for adoption as the preferred diagnostic tool for species for quarantine and regulation. For example, USDA-Agriculture Research Service is using DNA barcodes to monitor pest and invasive arthropods (<http://agresearchmag.ars.usda.gov/AR/archive/2012/Apr/insects0412.pdf>). However, the incorporation of this technology into the routine workflows of regulatory agencies is still under development. There is a particular need to develop well-parameterized reference datasets on important pest species for the countries of origin. Because nearly 75% of all BINs on BOLD, in general, derive from North America and Europe, with relatively low coverage for regions that host many potentially important global pests, there is a need for aggressive efforts for further parameterization of the barcode reference library. However, even before this task is complete, DNA barcode analysis makes it possible to signal the detection of any newly encountered species, providing a stimulus for its further investigation.

Conclusions

The increased global trade in plants and plant products has dramatically increased the risk of introducing novel pest species, creating the potential for massive economic losses to agriculture and forestry. For example, loss linked to the introduction of the emerald ash borer into North America has been estimated at tens of billions of dollars (Kovacs et al 2010, Herms and McCullough 2014). Because of its capability to support large-scale bio-surveillance programs, DNA barcoding can be an effective tool for intercepting invasive species at their points of introduction, and can also enable their early detection in natural environments. While species-specific primer sets can be a valuable tool for the quarantine detection of a particular species (Yeh et al. 2014), there is a critical need to gain a deeper understanding of diversity in many pest species as nearly one third of these taxa on BOLD (Table 1) appear to represent a species complex. High throughput sequencing platforms represent a powerful technology which will enable the use of DNA barcoding in large-scale bio-surveillance programs which can target both known pest species and new arrivals (Pochon et al. 2013). Given the complexities in morphological discrimination of many cryptic taxa, there is an obvious need to adopt DNA-based systems of nomenclature for pest regulation and quarantine (Cook et al. 2010).

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Table 1. Progress in the development of a DNA barcode reference library for regulated arthropod plant pests based on records in the Barcode of Life Data Systems (www.boldsystems.org) on December 22, 2015.

Order	Number of pest species ^a	Number of species with barcodes on BOLD (with single record)	Number of species in a single BIN ^b	Number of species with more than one BIN ^b	Number of species without a BIN ^c
Acari	8	4	1	1	2
Coleoptera	162	116 (17)	61	29	9
Diptera	42	38 (2)	24	11	1
Hemiptera	59	38 (4)	20	8	6
Hymenoptera	10	7 (1)	3	3	0
Lepidoptera	115	101 (10)	68	23	0
Orthoptera	3	2	0	2	0
Thysanoptera	10	8	1	7	0
Total	409	314 (34)	178	84	18

^a Sources: CFIA, EPPO (A1 & A2 lists), NAPIS, USDA-APHIS and Global Invasive Species Database (100 of the world's worst invasive alien species).

^b Only species with multiple records are included. Additional information is available in Table S1.

^c Sequences with <500 bp, >1% ambiguous bases or with stop codons are not assigned a BIN.

Table 2. The number of Barcode Index Numbers (BINs) and maximum intraspecific sequence divergences (K2P) at COI for arthropod plant pests based on data in BOLD, the Barcode of Life Data Systems (www.boldsystems.org).

Order	Common name	Species	Barcode records	BINs	Maximum intraspecific divergence (%)
Acari	Red spider mite	<i>Tetranychus evansi</i>	6	2	3.0
Coleoptera	Oak splendour beetle	<i>Agrilus biguttatus</i>	7	2	22.0
	Citrus longhorned beetle	<i>Anoplophora chinensis</i>	33	3	4.6
	Boll weevil	<i>Anthonomus grandis</i>	119	3	7.8
	Strawberry bud weevil	<i>Anthonomus signatus</i>	12	3	4.3
	Spruce beetle	<i>Dendroctonus rufipennis</i>	10	4	5.5
	Northern corn rootworm	<i>Diabrotica barberi</i>	32	3	4.4
	Diaprepes root weevil	<i>Diaprepes abbreviatus</i>	79	13	10.9
	Lesser spruce shoot beetle	<i>Hylurgops palliatus</i>	21	4	5.5
	Alfalfa weevil	<i>Hypera postica</i>	16	2	5.6
	Six-toothed bark beetle	<i>Ips sexdentatus</i>	6	2	12.1
	European spruce bark beetle	<i>Ips typographus</i>	15	2	3.0
	White clover weevil	<i>Ischnopterapion virens</i>	10	2	4.6
	Sugarbeet wireworm	<i>Limonius californicus</i>	81	4	5.7
	Small white-marmorated longhorned beetle	<i>Monochamus sutor</i>	15	2	5.1
	Alfalfa snout beetle	<i>Otiorhynchus ligustici</i>	6	2	4.9
	Cereal leaf beetle	<i>Oulema melanopus</i>	16	3	8.7
	Six-toothed spruce bark beetle	<i>Pityogenes chalcographus</i>	14	4	8.7
	European oak bark beetle	<i>Scolytus intricatus</i>	17	6	11.5
	European spruce longhorn beetle	<i>Tetropium castaneum</i>	12	5	27.0
	Asian ambrosia beetle	<i>Xylosandrus crassiusculus</i>	5	3	11.0
Diptera	Guava fruit fly	<i>Anastrepha striata</i>	18	2	4.2
	Carambola fruit fly	<i>Bactrocera carambolae</i>	109	2	15.8
	Oriental fruit fly	<i>Bactrocera dorsalis</i>	645	5	10.4
	Asian fruit fly	<i>Bactrocera invadens</i>	230	2	8.4
	Olive fruit fly	<i>Bactrocera oleae</i>	107	3	8.6
	Peach fruit fly	<i>Bactrocera zonata</i>	42	4	10.6
	Vegetable leafminer	<i>Liriomyza sativae</i>	38	2	11.8
	American serpentine leafminer	<i>Liriomyza trifolii</i>	12	2	14.1
	Apple maggot	<i>Rhagoletis pomonella</i>	23	2	6.0
	European crane fly	<i>Tipula paludosa</i>	129	2	12.2
Hemiptera	Hemlock woolly adelgid	<i>Adelges tsugae</i>	150	4	8.3
	Silverleaf whitefly	<i>Bemisia tabaci</i>	918	16	20.0
	Green scale	<i>Coccus viridis</i>	5	2	16.8
	Brown marmorated stink bug	<i>Halyomorpha halys</i>	37	3	17.5
Hymenoptera	Vine mealybug	<i>Planococcus ficus</i>	6	2	4.0
	Oriental chestnut gall wasp	<i>Dryocosmus kuriphilus</i>	7	2	2.3
	Green alder sawfly	<i>Monsoma pulveratum</i>	18	2	3.8
Lepidoptera	Summer fruit tortrix moth	<i>Adoxophyes orana</i>	23	3	6.7
	Asiatic rice borer	<i>Chilo suppressalis</i>	57	3	18.9
	Yellow peach moth	<i>Conogethes punctiferalis</i>	202	3	8.9
	Mexican rice borer	<i>Eoreuma loftini</i>	8	2	3.1

	Oriental fruit moth	<i>Grapholita molesta</i>	56	2	6.2
	Old World bollworm	<i>Helicoverpa armigera</i>	433	2	3.2
	Hemlock looper	<i>Lambdina fiscellaria</i>	570	3	3.7
	Pea blue	<i>Lampides boeticus</i>	126	2	8.8
	Soybean pod borer	<i>Leguminivora glycinivorella</i>	17	2	3.7
	Brinjal borer	<i>Leucinodes orbonalis</i>	159	6	8.0
	Pear leaf blister moth	<i>Leucoptera malifoliella</i>	5	2	3.6
	Rosy moth	<i>Lymantria mathura</i>	41	2	9.2
	Soybean pod borer	<i>Maruca vitrata</i>	633	4	9.2
	Bruce spanworm	<i>Operophtera bruceata</i>	353	2	5.8
	Lime swallowtail	<i>Papilio demoleus</i>	33	3	11.0
	Tufted apple bud moth	<i>Platynota idaeusalis</i>	242	2	3.7
	Fall armyworm	<i>Spodoptera frugiperda</i>	6	2	1.7
	Oak processionary moth	<i>Thaumetopoea processionea</i>	7	2	1.9
Orthoptera	Mormon cricket	<i>Anabrus simplex</i>	72	3	11.3
Thysanoptera	European flower thrips	<i>Frankliniella intonsa</i>	27	2	3.4
	Western flower thrips	<i>Frankliniella occidentalis</i>	457	4	3.9
	Chili Thrips	<i>Scirtothrips dorsalis</i>	233	12	18.0
	Melon thrips	<i>Thrips palmi</i>	212	2	13.0

Species with at least 5 publicly available sequences on BOLD were included in the analysis. Additional information is provided in Table S1.

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Table 3. Arthropod plant pests reported as representing a cryptic species complex following DNA barcode analysis.

Order	Common name	Species	Max. divergence (%)	NJ/phylogenetic Clades	Reference
Acari	Kanzawa spider mite	<i>Tetranychus kanzawai</i>	4.7 ^a	2	Matsuda et al. 2013
	NA	<i>Tetranychus parakanzawai</i>	5.1 ^a	2	“
Coleoptera	Bark beetle	<i>Crypturgus subcribrosus</i>	6.7 ^a	2	Jordal and Kambestad 2014
	Bark beetle	<i>Crypturgus hispidulus</i>	6.8 ^a	2	“
	Hairy spruce bark beetle	<i>Dryocoetes autographus</i>	9.8 ^a	3	“
	Bark beetle	<i>Dryocoetes hectographus</i>	5.2 ^a	3	“
	Lesser spruce shoot beetle	<i>Hylurgops palliatus</i>	5.7 ^a	3	“
	Engraver beetle	<i>Ips acuminatus</i>	9.7 ^a	2	“
	Bark beetle	<i>Orthotomicus suturalis</i>	5.6 ^a	2	“
	Striped Ambrosia Beetle	<i>Trypodendron lineatum</i>	4.6 ^a	2	“
	Fruit-tree pinhole borer	<i>Xyleborinus saxeseni</i>	12.5 ^a	2	“
	Ambrosia beetle	<i>Xyleborus affinis</i>	20.1 ^b	3	Chang et al. 2014
	Wireworm	<i>Hypnoidus bicolor</i>	3.0 ^a	3	Etzler et al. 2014
	Yellow toadflax stem weevil	<i>Mecinus janthinus</i>	2.4 ^a	2	ToŠevski et al. 2011
	Coffee berry borer	<i>Hypothenemus hampei</i>	11.8 ^a	4	Gauthier 2010
	Coconut leaf beetle	<i>Brontispa longissima</i>	3.0 ^b	2	Takano et al. 2011
	Root weevil	<i>Diaprepes abbreviatus</i>	14.9 ^a	3	Ascunce et al. 2008
Diptera	Hessian fly	<i>Mayetiola destructor</i>	3.0 ^b	2	Johnson et al. 2012
	African fig fly	<i>Zaprionus indianus</i>	11.2 ^a	2	Yassin et al. 2008
	Blueberry gall midge	<i>Dasineura oxycoccana</i>	10.7 ^c	2	Mathur et al. 2012
	Glasshouse Striped Sciarid	<i>Bradysia ocellaris</i>	2.4 ^b	2	Shin et al. 2015
Hemiptera	Citrus mealybug	<i>Planococcus citri</i>	NA	2	Abd-Rabou et al. 2012
	Solenopsis mealybug	<i>Phenacoccus solenopsis</i>	3.0 ^b	2	Dong et al. 2009
	Apple mealybug	<i>Phenacoccus aceris</i>	5.6 ^b	2	Park et al. 2011a
	Matsumoto mealybug	<i>Crisicoccus matsumotoi</i>	4.0 ^b	2	“
	Cyanotis scale	<i>Aspidiotus excises</i>	4.6 ^b	2	“
	Silverleaf whitefly	<i>Bemisia tabaci</i>	20 ^b	15	Ashfaq et al. 2014
	Mottled arum aphid	<i>Neomyzus circumflexus</i>	3.1 ^b	2	Footitt et al. 2008
	Leaf curl plum aphid	<i>Brachycaudus helichrysi</i>	2.5 ^b	2	Rebijith et al. 2013
	Cabbage aphid	<i>Brevicoryne brassicae</i>	3.8 ^b	2	“
	Asian sowthistle aphid	<i>Hyperomyzus carduellinus</i>	3.0 ^b	2	“
	Aphid	<i>Toxoptera aurantii</i>	3.1 ^b	2	Wang and Qiao 2009

Lepidoptera	Bronze bug	<i>Thaumastocoris peregrinus</i>	8.7 ^b	3	Nadel et al. 2010
	Grapewine leafminer	<i>Antispila hydrangaeella</i>	5.2 ^b	2	Van Nieukerken et al. 2012
	Durian fruit borer	<i>Conogethes punctiferalis</i>	5.8 ^b	2	Shashank et al. 2014
	Leaf worm	<i>Copitarsia decolora</i>	4.2 ^a	2	Simmons and Scheffer 2004
Thysanoptera	Asian gypsy moth	<i>Lymantria dispar</i>	3.1 ^b	2	Ball and Armstrong 2006
	Pink gypsy moth	<i>Lymantria mathura</i>	4.7 ^b	2	“
		<i>Lymantria sinica</i>	2.9 ^b	2	deWaard et al. 2010
	Beet armyworm	<i>Spodoptera exigua</i>	NA	2	Dumas et al. 2015
	Paddy armyworm	<i>S. mauritia</i>	NA	2	“
	Western flower thrips	<i>Frankliniella occidentalis</i>	4.4 ^b	2	Rugman-Jones et al. 2010
	Melon thrips	<i>Thrips palmi</i>	19.9 ^b	4	Rebijith et al. 2014; Kadirvel et al. 2013; Iftikhar et al. 2016
	Onion thrips	<i>T. tabaci</i>	10.4 ^b	3	“
	Chili thrips	<i>Scirtothrips dorsalis</i>	20.8 ^b	11	Dickey et al. 2015; Iftikhar et al. 2016
	Black flower thrips	<i>Haplothrips reuteri</i>	3.7 ^b	2	Iftikhar et al. 2016

The citations were collected by literature survey on the Web of Science with search terms “DNA barcoding pest cryptic” (accessed 12 January 2016). The citations were further restricted by only considering studies explicitly COI-5’ and reporting cryptic species. Species also included in the five pest databases (Table S1) are bold faced.

^a p-distances; ^b K2P distances; ^c GTRpG; NA = Information not available

Table S1. Arthropod plant pests listed on multiple databases and their DNA barcoding status on BOLD (

Common name	Species	Order	Barcode records o
City longhorn beetle	<i>Aeolesthes sarta</i>	Coleoptera	7
Small Hive Beetle	<i>Aethina tumida</i>	Coleoptera	5
St. Johnswort Borer	<i>Agrilus hyperici</i>	Coleoptera	4
Emerald Ash Borer	<i>Agrilus planipennis</i>	Coleoptera	16
Jewel Beetle	<i>Agrilus sulcicollis</i>	Coleoptera	16
Wireworm	<i>Agriotes sputator</i>	Coleoptera	24
Wireworm	<i>Agriotes ustulatus</i>	Coleoptera	25
Asian Longhorned Beetle	<i>Anoplophora glabripennis</i>	Coleoptera	443
Brown mulberry longhorn beetle	<i>Apriona germari</i>	Coleoptera	13
na	<i>Apriona rugicollis</i>	Coleoptera	1
Red Neck Longhorn Beetle	<i>Aromia bungii</i>	Coleoptera	2
Oak Timberworm	<i>Arrhenodes minutus</i>	Coleoptera	4
Coconut hispid beetle	<i>Brontispa longissima</i>	Coleoptera	124
Plum curculio	<i>Conotrachelus nenuphar</i>	Coleoptera	13
European Chestnut Weevil	<i>Curculio elephas</i>	Coleoptera	9
Great Spruce Bark Beetle	<i>Dendroctonus micans</i>	Coleoptera	8
Mountain Pine Beetle (MPB)	<i>Dendroctonus ponderosae</i>	Coleoptera	110
Douglas-fir beetle	<i>Dendroctonus pseudotsugae</i>	Coleoptera	4
Cucurbit Beetle	<i>Diabrotica speciosa</i>	Coleoptera	5
Spotted cucumber beetle	<i>Diabrotica undecimpunctata</i>	Coleoptera	24
Western Corn Rootworm	<i>Diabrotica virgifera</i>	Coleoptera	19
Potato Flea Beetle	<i>Epitrix cucumeris</i>	Coleoptera	17
na	<i>Epitrix similaris</i>	Coleoptera	4
Western Potato Flea Beetle	<i>Epitrix subcrinita</i>	Coleoptera	1
Tuber Flea beetle	<i>Epitrix tuberis</i>	Coleoptera	5
Black pine bark beetle	<i>Hylastes ater</i>	Coleoptera	1
Large Pine Weevil	<i>Hylobius abietis</i>	Coleoptera	17
Redhaired Pine Bark Beetle	<i>Hylurgus ligniperda</i>	Coleoptera	6
Pine Engraver Beetle	<i>Ips pini</i>	Coleoptera	3
Colorado Potato Beetle	<i>Leptinotarsa decemlineata</i>	Coleoptera	25
Lily Leaf Beetle	<i>Lilioceris lili</i>	Coleoptera	12
Argentine Stem Weevil	<i>Listronotus bonariensis</i>	Coleoptera	20
Asiatic Garden Beetle	<i>Maladera castanea</i>	Coleoptera	1
Corn wireworm	<i>Melanotus communis</i>	Coleoptera	1
Japanese Pine Sawyer	<i>Monochamus alternatus</i>	Coleoptera	14
Northeastern sawyer	<i>Monochamus notatus</i>	Coleoptera	1
Sakhalin Pine Sawyer	<i>Monochamus saltuarius</i>	Coleoptera	1
White-spotted sawyer	<i>Monochamus scutellatus</i>	Coleoptera	27
Whitefringed Weevil	<i>Naupactus leucoloma</i>	Coleoptera	74
Fruit tree weevil	<i>Naupactus xanthographus</i>	Coleoptera	116
Lemon tree borer	<i>Oemona hirta</i>	Coleoptera	3
European Elm Flea Weevil	<i>Orchestes alni</i>	Coleoptera	83
Mediterranean Pine Engraver	<i>Orthotomicus erosus</i>	Coleoptera	2
Coconut Rhinoceros Beetle	<i>Oryctes rhinoceros</i>	Coleoptera	1
white pine weevil	<i>Pissodes strobi</i>	Coleoptera	3

Oak Ambrosia Beetle	<i>Platypus quercivorus</i>	Coleoptera	8
Four-eyed fir bark beetle	<i>Polygraphus proximus</i>	Coleoptera	4
Japanese Beetle	<i>Popillia japonica</i>	Coleoptera	24
Viburnum Leaf Beetle	<i>Pyrrhalta viburni</i>	Coleoptera	41
New Guinea sugarcane weevil	<i>Rhabdoscelus obscurus</i>	Coleoptera	1
South American Palm Weevil	<i>Rhynchophorus palmarum</i>	Coleoptera	2
Poplar Borer	<i>Saperda calcarata</i>	Coleoptera	9
Morawitz's bark beetle	<i>Scolytus morawitzi</i>	Coleoptera	4
European Elm Bark Beetle	<i>Scolytus scolytus</i>	Coleoptera	1
Mango seed weevil	<i>Sternochetus mangiferae</i>	Coleoptera	5
Brown Spruce Longhorn Beetle	<i>Tetropium fuscum</i>	Coleoptera	7
Pine Shoot Beetle	<i>Tomicus destruens</i>	Coleoptera	1
Pine Shoot Beetle	<i>Tomicus piniperda</i>	Coleoptera	20
Velvet Longhorned Beetle	<i>Trichoferus campestris</i>	Coleoptera	6
Khapra Beetle	<i>Trogoderma granarium</i>	Coleoptera	31
Pear Blight Beetle	<i>Xyleborus dispar</i>	Coleoptera	83
Redbay Ambrosia Beetle	<i>Xyleborus glabratus</i>	Coleoptera	4
Rustic Borer	<i>Xylotrechus colonus</i>	Coleoptera	11
Oak Splendour Beetle	<i>Agrilus biguttatus</i>	Coleoptera	7
Ambrosia Beetle	<i>Anisandrus maiche</i>	Coleoptera	4
Alfalfa Weevil	<i>Hypera postica</i>	Coleoptera	16
Sixtoothed Bark Beetle	<i>Ips sexdentatus</i>	Coleoptera	6
European spruce bark beetle	<i>Ips typographus</i>	Coleoptera	15
White clover weevil	<i>Ischnopterapion virens</i>	Coleoptera	10
Small white-marmorated	<i>Monochamus sutor</i>	Coleoptera	15
Alfalfa Snout Beetle	<i>Otiorhynchus ligustici</i>	Coleoptera	6
Banded Elm Bark Beetle	<i>Scolytus schevyrewi</i>	Coleoptera	3
Lesser Pine Shoot Beetle	<i>Tomicus minor</i>	Coleoptera	4
Citrus long-horned beetle	<i>Anoplophora chinensis</i>	Coleoptera	33
Boll Weevil (BW)	<i>Anthonomus grandis</i>	Coleoptera	119
Strawberry Clipper	<i>Anthonomus signatus</i>	Coleoptera	12
Northern Corn Rootworm	<i>Diabrotica barberi</i>	Coleoptera	32
Cereal Leaf Beetle (CLB)	<i>Oulema melanopus</i>	Coleoptera	16
Granulate Ambrosia Beetle	<i>Xylosandrus crassiusculus</i>	Coleoptera	5
The spruce beetle	<i>Dendroctonus rufipennis</i>	Coleoptera	10
Lesser Spruce Shoot Beetle	<i>Hylurgops palliatus</i>	Coleoptera	21
Ambrosia Beetle	<i>Limonius californicus</i>	Coleoptera	81
Sixtoothed Spruce Bark Beetle	<i>Pityogenes chalcographus</i>	Coleoptera	14
European spruce longhorn bee	<i>Tetropium castaneum</i>	Coleoptera	12
European Oak Bark Beetle	<i>Scolytus intricatus</i>	Coleoptera	17
Diaprepes Root Weevil	<i>Diaprepes abbreviatus</i>	Coleoptera	79
Pepper Weevil	<i>Anthonomus eugeniei</i>	Coleoptera	2
Nut weevil	<i>Curculio nucum</i>	Coleoptera	1
Roundheaded pine beetle	<i>Dendroctonus adjunctus</i>	Coleoptera	3
Western pine beetle	<i>Dendroctonus brevicomis</i>	Coleoptera	2
Southern Pine Beetle	<i>Dendroctonus frontalis</i>	Coleoptera	2
Coffee berry borer	<i>Hypothenemus hampei</i>	Coleoptera	26

West Indian Cane Weevil	<i>Metamasius hemipterus</i>	Coleoptera		1
Red palm weevil	<i>Rhynchophorus ferrugineus</i>	Coleoptera		314
Chinese rose beetle	<i>Adoretus sinicus</i>	Coleoptera	na	
Bronze Birch Borer	<i>Agrilus anxius</i>	Coleoptera		14
Goldspotted Oak Borer	<i>Agrilus auroguttatus</i>	Coleoptera	na	
Oriental Beetle	<i>Anomala orientalis</i>	Coleoptera		5
Chafer beetle	<i>Anomala sulcatula</i>	Coleoptera	na	
strawberry weevil	<i>Anthonomus bisignifer</i>	Coleoptera		1
Poplar Stem Borer	<i>Apriona cinerea</i>	Coleoptera	na	
Oriental beetle	<i>Blitopertha orientalis</i>	Coleoptera	na	
Rough Sweetpotato Weevil	<i>Blosyrus asellus</i>	Coleoptera	na	
Japanese Cedar Longhorned Be	<i>Callidiellum rufipenne</i>	Coleoptera		1
Brown Fir Longhorned Beetle	<i>Callidiellum villosulum</i>	Coleoptera		1
Bamboo Borer	<i>Chlorophorus annularis</i>	Coleoptera	na	
Slender-Banded Pinecone Long	<i>Chlorophorus strobilicola</i>	Coleoptera	na	
Click beetle	<i>Conoderes rufangulus</i>	Coleoptera	na	
Small avocado seed weevil	<i>Conotrachelus aguacatae</i>	Coleoptera	na	
Avocado stem weevil	<i>Copturus aguacatae</i>	Coleoptera	na	
Pecan Weevil	<i>Curculio caryae</i>	Coleoptera		5
Soybean Stem Borer	<i>Dectes texanus</i>	Coleoptera	na	
Western balsam bark beetle	<i>Dryocoetes confusus</i>	Coleoptera		5
Fijian ginger weevil	<i>Elytroteinus subtruncatus</i>	Coleoptera	na	
Mexican Bean Beetle	<i>Epilachna varivestis</i>	Coleoptera		1
West Indian sweet potato wee	<i>Euscepes postfasciatus</i>	Coleoptera	na	
Leaf beetle	<i>Exosoma lusitanica</i>	Coleoptera	na	
Tuberous pine weevil	<i>Geniocretnus chilensis</i>	Coleoptera	na	
Western hemlock wood staine	<i>Gnathotrichus sulcatus</i>	Coleoptera	na	
Eucalyptus snout beetle	<i>Gonipterus gibberus</i>	Coleoptera	na	
Eucalyptus snout beetle	<i>Gonipterus scutellatus</i>	Coleoptera	na	
Avocado seed weevil	<i>Heilipus lauri</i>	Coleoptera	na	
Black Maize Beetle	<i>Heteronychus arator</i>	Coleoptera	na	
White grub	<i>Holotrichia mindanaona</i>	Coleoptera	na	
Loosestrife Root Weevil	<i>Hylobius transversovittus</i>	Coleoptera	na	
Sixspined Ips	<i>Ips calligraphus</i>	Coleoptera	na	
Pinyon Ips Beetle	<i>Ips confusus</i>	Coleoptera		1
Five-spined bark beetle	<i>Ips grandicollis</i>	Coleoptera		3
Kyrgyz mountain engraver	<i>Ips hauseri</i>	Coleoptera	na	
Arizona five-spined engraver	<i>Ips lecontei</i>	Coleoptera	na	
California pine engraver	<i>Ips plastographus</i>	Coleoptera	na	
Scolytid Beetle	<i>Ips subelongatus</i>	Coleoptera	na	
Chilean vegetable weevil	<i>Listroderes subcinctus</i>	Coleoptera	na	
Ambrosia beetle	<i>Megaplatypus mutatus</i>	Coleoptera		1
Hemlock Borer	<i>Melanophila fulvoguttata</i>	Coleoptera		12
Pine sawyer beetle	<i>Monochamus carolinensis</i>	Coleoptera		15
Balsam fir sawyer	<i>Monochamus marmorator</i>	Coleoptera		5
Spotted Pine Sawyer	<i>Monochamus mutator</i>	Coleoptera		4
Japanese pine sawyer beetle	<i>Monochamus nitens</i>	Coleoptera	na	

Flat-faced longhorn beetle	<i>Monochamus obtusus</i>	Coleoptera	3
Southern Pine Sawyer	<i>Monochamus titillator</i>	Coleoptera	6
Locust Leafminer	<i>Odontota dorsalis</i>	Coleoptera	10
Wingless Weevil	<i>Otiorhynchus dieckmanni</i>	Coleoptera	na
Eastern pine weevil	<i>Pissodes nemorensis</i>	Coleoptera	na
Lodgepole terminal weevil	<i>Pissodes terminalis</i>	Coleoptera	1
Bark Beetle	<i>Pityoborus comatus</i>	Coleoptera	na
Walnut Twig Beetle	<i>Pityophthorus juglandis</i>	Coleoptera	3
Andean potato weevil	<i>Premnotrypes latithorax</i>	Coleoptera	na
Andean potato weevil	<i>Premnotrypes suturicallus</i>	Coleoptera	na
Andean potato weevil	<i>Premnotrypes vorax</i>	Coleoptera	na
Twobanded Japanese Weevil	<i>Pseudocneorhinus bifasciatus</i>	Coleoptera	na
Small oak bark beetle	<i>Pseudopityophthorus minutissimus</i>	Coleoptera	2
European Chafer (EC)	<i>Rhizotrogus majalis</i>	Coleoptera	na
Roundheaded Appletree Borer	<i>Saperda candida</i>	Coleoptera	10
Hemlock Woolly Adelgid Lady E	<i>Sasajiscymnus tsugae</i>	Coleoptera	na
Ladybird Beetle	<i>Stethorus punctum</i>	Coleoptera	na
Thin-antenna spruce borer	<i>Tetropium gracilicorne</i>	Coleoptera	na
Altai larch longhorn beetle	<i>Xylotrechus altaicus</i>	Coleoptera	na
Mulberry Borer	<i>Xylotrechus chinensis</i>	Coleoptera	na
Namangan longhorn beetle	<i>Xylotrechus namanganensis</i>	Coleoptera	na
Longhorned Beetle	<i>Xylotrechus pyrrhoderus</i>	Coleoptera	na
Coffee White Stem Borer Beetl	<i>Xylotrechus quadripes</i>	Coleoptera	na
South American cucurbit fruit f	<i>Anastrepha grandis</i>	Diptera	3
Mexican fruit fly	<i>Anastrepha ludens</i>	Diptera	68
West indian fruit fly	<i>Anastrepha obliqua</i>	Diptera	52
Sapote fruit fly	<i>Anastrepha serpentina</i>	Diptera	8
Fruit fly	<i>Bactrocera caryeae</i>	Diptera	1
Guava Fruit Fly	<i>Bactrocera correcta</i>	Diptera	54
Cucumber fruit fly	<i>Bactrocera cucumis</i>	Diptera	2
Melon Fly	<i>Bactrocera cucurbitae</i>	Diptera	221
Fruit fly	<i>Bactrocera kandiensis</i>	Diptera	17
Malaysian Fruit Fly	<i>Bactrocera latifrons</i>	Diptera	81
Chinese citrus fly	<i>Bactrocera minax</i>	Diptera	58
Fruit fly	<i>Bactrocera occipitalis</i>	Diptera	30
Asian Papaya Fruit Fly	<i>Bactrocera papayae</i>	Diptera	64
Fruit fly	<i>Bactrocera philippinensis</i>	Diptera	19
Queensland fruit fly	<i>Bactrocera tryoni</i>	Diptera	48
Japanese orange fly	<i>Bactrocera tsuneonis</i>	Diptera	21
Natal fruit fly	<i>Ceratitis rosa</i>	Diptera	40
Lesser pumpkin fly	<i>Dacus ciliatus</i>	Diptera	40
Spotted Wing Drosophila	<i>Drosophila suzukii</i>	Diptera	133
Sout American leaf miner	<i>Liriomyza huidobrensis</i>	Diptera	13
Blotch leaf miner	<i>Nemorimyza maculosa</i>	Diptera	2
Eastern Cherry Fruit Fly	<i>Rhagoletis cingulata</i>	Diptera	23
Black cherry fruit fly	<i>Rhagoletis fausta</i>	Diptera	1
Blueberry Maggot	<i>Rhagoletis mendax</i>	Diptera	2

papaya fruit fly	<i>Toxotrypana curvicauda</i>	Diptera		6
Guava fruit fly	<i>Anastrepha striata</i>	Diptera		18
Carambola Fruit Fly	<i>Bactrocera carambolae</i>	Diptera		109
Asian fruit fly	<i>Bactrocera invadens</i>	Diptera		230
Mediterranean fruit fly, Medfly	<i>Ceratitis capitata</i>	Diptera		199
Vegetable leaf miner	<i>Liriomyza sativae</i>	Diptera		38
American serpentine leafminer	<i>Liriomyza trifolii</i>	Diptera		12
Apple Maggot	<i>Rhagoletis pomonella</i>	Diptera		23
European Crane Fly	<i>Tipula paludosa</i>	Diptera		129
Olive Fruit Fly	<i>Bactrocera oleae</i>	Diptera		107
Peach fruit fly	<i>Bactrocera zonata</i>	Diptera		42
Oriental fruit fly	<i>Bactrocera dorsalis</i>	Diptera		645
Caribbean Fruit Fly; Carib Fly	<i>Anastrepha suspensa</i>	Diptera		2
Fruit fly	<i>Bactrocera pyrifoliae</i>	Diptera	na	
Swede Midge	<i>Contarinia nasturtii</i>	Diptera		3
South American Rice Miner	<i>Hydrellia wirthi</i>	Diptera	na	
Western Cherry Fruit Fly	<i>Rhagoletis indifferens</i>	Diptera	na	
Canadian larch cone fly	<i>Strobilomyia viaria</i>	Diptera	na	
Orange spiny whitefly	<i>Aleurocanthus spiniferus</i>	Hemiptera		1
Soybean Aphid	<i>Aphis glycines</i>	Hemiptera		205
Elm Seed Bug	<i>Arocatus melanocephalus</i>	Hemiptera		1
Bagrada Bug	<i>Bagrada hilaris</i>	Hemiptera		29
Japanese Wax Scale	<i>Ceroplastes japonicus</i>	Hemiptera		31
Cypress aphid	<i>Cinara cupressi</i>	Hemiptera		18
Asian citrus psyllid	<i>Diaphorina citri</i>	Hemiptera		10
Russian Wheat Aphid (RWA)	<i>Diuraphis noxia</i>	Hemiptera		129
Glassy-winged Sharpshooter	<i>Homalodisca vitripennis</i>	Hemiptera		6
Spotted Lanternfly	<i>Lycorma delicatula</i>	Hemiptera		7
Hibiscus (Pink) Mealybug	<i>Maconellicoccus hirsutus</i>	Hemiptera		3
Bean Plataspid	<i>Megacopta cribraria</i>	Hemiptera		47
Sugarcane spotted aleyrodid	<i>Neomaskellia bergii</i>	Hemiptera		1
San Jose scale	<i>Quadraspidiotus perniciosus</i>	Hemiptera		2
Pine Tortoise Scale	<i>Toumeyella parvicornis</i>	Hemiptera		2
Brown Citrus Aphid	<i>Toxoptera citricidus</i>	Hemiptera		8
Arrowhead Scale	<i>Unaspis yanonensis</i>	Hemiptera		8
Green scale	<i>Coccus viridis</i>	Hemiptera		5
Vine Mealybug	<i>Planococcus ficus</i>	Hemiptera		6
Brown Marmorated Stink Bug	<i>Halyomorpha halys</i>	Hemiptera		37
Hemlock Woolly Adelgid	<i>Adelges tsugae</i>	Hemiptera		150
Sweetpotato Whitefly (SPWF)	<i>Bemisia tabaci</i>	Hemiptera		918
Grass Sharpshooter	<i>Draeculacephala minerva</i>	Hemiptera		1
Blue-green Sharpshooter	<i>Graphocephala atropunctata</i>	Hemiptera		16
Mealybug	<i>Hypogeococcus pungens</i>	Hemiptera		1
Coffee Mealybug	<i>Planococcus lilacinus</i>	Hemiptera		1
Passionvine Mealybug	<i>Planococcus minor</i>	Hemiptera		2
Blue grey fly	<i>Aleurocanthus woglumi</i>	Hemiptera	na	
Psyllid	<i>Bactericera cockerelli</i>	Hemiptera	na	

Soft Wax Scale	<i>Ceroplastes destructor</i>	Hemiptera	5
Iceryine Scale	<i>Crypticerya multicatrices</i>	Hemiptera	na
Cocoa Mealybug	<i>Exallomochlus hispidus</i>	Hemiptera	na
Elongate Hemlock Scale	<i>Fiorinia externa</i>	Hemiptera	na
Coconut red scale	<i>Furcaspis oceanica</i>	Hemiptera	na
Pallid cane leafhopper	<i>Haplaxius crudus</i>	Hemiptera	na
Egyptian fluted scale	<i>Icerya aegyptiaca</i>	Hemiptera	1
Cottony Cushion Scale	<i>Icerya purchasi</i>	Hemiptera	5
Ussuri oystershell scale	<i>Lepidosaphes ussuriensis</i>	Hemiptera	na
Paddy bug	<i>Leptocoris acuta</i>	Hemiptera	7
Brown Chilean leaf-footed bug	<i>Leptoglossus chilensis</i>	Hemiptera	na
Japanese maple scale	<i>Lopholeucaspis japonica</i>	Hemiptera	3
Margarodid	<i>Margarodes prieskaensis</i>	Hemiptera	na
Grape ground pearl	<i>Margarodes vitis</i>	Hemiptera	na
Ground pearl	<i>Margarodes vredendalensis</i>	Hemiptera	na
Wheat Bug	<i>Nysius huttoni</i>	Hemiptera	4
Cotton seed bug	<i>Oxycarenus Hyalinipennis</i>	Hemiptera	na
Lobate Lac Scale	<i>Paratachardina pseudolobata</i>	Hemiptera	na
Black Parlatoria Scale	<i>Parlatoria ziziphi</i>	Hemiptera	5
Cassava mealybug	<i>Phenococcus manihoti</i>	Hemiptera	na
Euphorbia Pit Scale	<i>Planchonia stentae</i>	Hemiptera	14
White Peach Scale	<i>Pseudaulacaspis pentagona</i>	Hemiptera	12
Cottony Citrus Scale	<i>Pulvinaria polygonata</i>	Hemiptera	na
Mealybug	<i>Ripersiella hibisci</i>	Hemiptera	na
White-banded elm leafhopper	<i>Scaphoideus luteolus</i>	Hemiptera	na
Rice Stinkbug	<i>Tibraca limbativentris</i>	Hemiptera	1
Twospotted Citrus Psyllid	<i>Trioza erytrae</i>	Hemiptera	na
Citrus snow scale	<i>Unaspis citri</i>	Hemiptera	na
Grapevine phylloxera	<i>Viteus vitifoliae</i>	Hemiptera	7
Red-headed sharpshooter	<i>Xyphon fulgidum</i>	Hemiptera	na
European Pine Sawfly	<i>Neodiprion sertifer</i>	Hymenoptera	4
Sirex Wasp	<i>Sirex noctilio</i>	Hymenoptera	33
Giant Wood Wasp	<i>Urocerus gigas</i>	Hymenoptera	3
Chestnut gall wasp	<i>Dryocosmus kuriphilus</i>	Hymenoptera	7
Green Alder Sawfly	<i>Monsoma pulveratum</i>	Hymenoptera	18
Tremex Woodwasp	<i>Tremex fuscicornis</i>	Hymenoptera	2
Scarlet Oak Sawfly	<i>Caliroa quercusoccineae</i>	Hymenoptera	na
Horned Oak Gall Wasp	<i>Callirhytis cornigera</i>	Hymenoptera	na
Erythrina Gall Wasp	<i>Quadrastichus erythrinae</i>	Hymenoptera	na
Blue-black horntail	<i>Sirex ermak</i>	Hymenoptera	1
Western black-headed bud wo	<i>Acleris gloverana</i>	Lepidoptera	1
Eastern black-headed budworn	<i>Acleris variana</i>	Lepidoptera	118
Leek Moth	<i>Acrolepiopsis assectella</i>	Lepidoptera	24
Black Cutworm (BCw)	<i>Agrotis ipsilon</i>	Lepidoptera	130
Fruit Tree Tortrix	<i>Archips podana</i>	Lepidoptera	9
Cherry Blossom Moth	<i>Argyresthia pruniella</i>	Lepidoptera	19
Polyphagous leaf roller	<i>Argyrotaenia ljungiana</i>	Lepidoptera	6

Silver Y Moth	<i>Autographa gamma</i>	Lepidoptera	31
Cactus Moth	<i>Cactoblastis cactorum</i>	Lepidoptera	9
Geranium bronze	<i>Cacyreus marshalli</i>	Lepidoptera	14
Peach Fruit Moth	<i>Carposina sasakii</i>	Lepidoptera	82
Large aspen tortrix	<i>Choristoneura conflictana</i>	Lepidoptera	316
Eastern spruce budworm	<i>Choristoneura fumiferana</i>	Lepidoptera	111
The oblique banded leaf roller	<i>Choristoneura rosaceana</i>	Lepidoptera	157
Golden Twin Spot Moth	<i>Chrysodeixis chalcites</i>	Lepidoptera	11
Cocoa pod borer	<i>Conopomorpha cramerella</i>	Lepidoptera	106
Hickory Shuckworm (HSw)	<i>Cydia caryana</i>	Lepidoptera	13
Codling Moth (CM)	<i>Cydia pomonella</i>	Lepidoptera	141
Nut fruit tortix	<i>Cydia splendana</i>	Lepidoptera	11
Nettle Caterpillar	<i>Darna pallivitta</i>	Lepidoptera	1
Pine-tree Lappet	<i>Dendrolimus pini</i>	Lepidoptera	28
Sakhalin Silk Moth	<i>Dendrolimus superans</i>	Lepidoptera	24
Yellow peach moth	<i>Dichocrocis punctiferalis</i>	Lepidoptera	1
Zimmerman Pine Moth	<i>Dioryctria zimmermani</i>	Lepidoptera	1
European Pepper Moth	<i>Duponchelia fovealis</i>	Lepidoptera	3
Onion carpenter worm	<i>Dyspepsa ulula</i>	Lepidoptera	1
Spotted bollworm - cotton	<i>Earias vittella</i>	Lepidoptera	7
Cherry Bark Tortrix	<i>Enarmonia formosana</i>	Lepidoptera	3
Light Brown Apple Moth	<i>Epiphyas postvittana</i>	Lepidoptera	1433
Mottled Umber Moth	<i>Erannis defoliaria</i>	Lepidoptera	29
Fruit Piercing Moth	<i>Eudocima fullonia</i>	Lepidoptera	7
European Grape Berry Moth	<i>Eupoecilia ambiguella</i>	Lepidoptera	6
Plum fruit moth	<i>Grapholita funebrana</i>	Lepidoptera	14
European Poplar Shoot Borer	<i>Gypsonoma aceriana</i>	Lepidoptera	31
Corn earworm	<i>Helicoverpa zea</i>	Lepidoptera	165
Fall Webworm	<i>Hyphantria cunea</i>	Lepidoptera	152
Tomato Pinworm	<i>Keiferia lycopersicella</i>	Lepidoptera	1
Brinjal Fruit and Shoot Borer	<i>Leucinodes africensis</i>	Lepidoptera	28
na	<i>Leucinodes pseudorbonalis</i>	Lepidoptera	1
na	<i>Leucinodes rimavallis</i>	Lepidoptera	2
Satin Moth	<i>Leucoma salicis</i>	Lepidoptera	77
European Grapevine Moth	<i>Lobesia botrana</i>	Lepidoptera	1
Okinawa gypsy moth	<i>Lymantria albescens</i>	Lepidoptera	14
Asian Gypsy Moth	<i>Lymantria dispar</i>	Lepidoptera	343
Nun Moth	<i>Lymantria monacha</i>	Lepidoptera	85
Hokkaido gypsy moth	<i>Lymantria umbrosa</i>	Lepidoptera	21
Iris Borer	<i>Macronoctua onusta</i>	Lepidoptera	8
Eastern tent caterpillar	<i>Malacosoma americanum</i>	Lepidoptera	46
Forest Tent Caterpillar	<i>Malacosoma disstria</i>	Lepidoptera	116
Sweetpotato vine borer	<i>Omphisa anastomosalis</i>	Lepidoptera	1
Winter Moth	<i>Operophtera brumata</i>	Lepidoptera	379
Douglas-fir tussock moth	<i>Orgyia pseudotsugata</i>	Lepidoptera	172
Asian Corn Borer	<i>Ostrinia furnacalis</i>	Lepidoptera	29
European Corn Borer	<i>Ostrinia nubilalis</i>	Lepidoptera	74

Spring Cankerworm	<i>Paleacrita vernata</i>	Lepidoptera	85
Chestnut leafroller	<i>Pammene fasciana</i>	Lepidoptera	5
Stalk Borer	<i>Papaipema nebris</i>	Lepidoptera	16
Palm moth	<i>Paysandisia archon</i>	Lepidoptera	2
Pink bollworm - cotton	<i>Pectinophora gossypiella</i>	Lepidoptera	20
Pink-spotted bollworm	<i>Pectinophora scutigera</i>	Lepidoptera	3
Poinciana Looper	<i>Pericyma cruegeri</i>	Lepidoptera	5
Potato Tuberworm	<i>Phthorimaea operculella</i>	Lepidoptera	12
Large White Butterfly - brassic	<i>Pieris brassicae</i>	Lepidoptera	78
European Pine Shoot Moth(EP	<i>Rhyacionia buoliana</i>	Lepidoptera	5
Southern armyworm	<i>Spodoptera eridania</i>	Lepidoptera	41
Egyptian Cottonworm	<i>Spodoptera littoralis</i>	Lepidoptera	26
Cotton Cutworm	<i>Spodoptera litura</i>	Lepidoptera	80
Western Bean Cutworm	<i>Striacosta albicosta</i>	Lepidoptera	7
Red-belted Clearwing	<i>Synanthedon myopaeformis</i>	Lepidoptera	4
False codling moth	<i>Thaumatotibia leucotreta</i>	Lepidoptera	36
Green Oak Tortrix	<i>Tortrix viridana</i>	Lepidoptera	11
Tomato Leaf Miner	<i>Tuta absoluta</i>	Lepidoptera	34
Apple Ermine Moth (AEM)	<i>Yponomeuta malinellus</i>	Lepidoptera	18
Mexican Rice Borer	<i>Eoreuma loftini</i>	Lepidoptera	8
Oriental Fruit Moth (OFM)	<i>Grapholita molesta</i>	Lepidoptera	56
Old World Bollworm - cotton	<i>Helicoverpa armigera</i>	Lepidoptera	433
Bean butterfly	<i>Lampides boeticus</i>	Lepidoptera	126
Soybean Pod Borer	<i>Leguminivora glycinivorella</i>	Lepidoptera	17
Pear leaf blister moth	<i>Leucoptera malifoliella</i>	Lepidoptera	5
Rosy Gypsy Moth	<i>Lymantria mathura</i>	Lepidoptera	41
Squash Vine Borer	<i>Melittia cucurbitae</i>	Lepidoptera	3
Tomato Fruit Borer	<i>Neoleucinodes elegantalis</i>	Lepidoptera	4
Bruce Spanworm	<i>Operophtera bruceata</i>	Lepidoptera	350
Tufted Apple Bud Moth (TABM	<i>Platynota idaeusalis</i>	Lepidoptera	242
Fall Armyworm	<i>Spodoptera frugiperda</i>	Lepidoptera	6
Oak Processionary Moth	<i>Thaumetopoea processionea</i>	Lepidoptera	7
Summer fruit tortrix moth	<i>Adoxophyes orana</i>	Lepidoptera	23
Asiatic Rice Borer	<i>Chilo suppressalis</i>	Lepidoptera	57
Yellow Peach Moth; Castor Ca	<i>Conogethes punctiferalis</i>	Lepidoptera	202
Hemlock Looper	<i>Lambdina fiscellaria</i>	Lepidoptera	566
Lime Swallowtail	<i>Papilio demoleus</i>	Lepidoptera	33
Legume pod borer	<i>Maruca vitrata</i>	Lepidoptera	633
Eggplant borer	<i>Leucinodes orbonalis</i>	Lepidoptera	159
Pecan Nut Casebearer	<i>Acrobasis nuxvorella</i>	Lepidoptera	6
Apple Tortrix	<i>Archips fuscocupreanus</i>	Lepidoptera	21
Variegated Golden Tortrix	<i>Archips xylosteanus</i>	Lepidoptera	na
Carnation Leaf Roller	<i>Cacoecimorpha pronubana</i>	Lepidoptera	25
Leafroller	<i>Capua tortrix</i>	Lepidoptera	na
Peach fruit moth	<i>Carposina niponensis</i>	Lepidoptera	na
Carpenter Worm	<i>Chilecomadia valdiviana</i>	Lepidoptera	7
Western Spruce Budworm	<i>Choristoneura freemani</i>	Lepidoptera	na

Cabbage Cluster Caterpillar	<i>Crocidolomia binotalis</i>	Lepidoptera	na	
Bud Borer	<i>Crocidosema aporema</i>	Lepidoptera		59
Manchurian fruit moth	<i>Cydia inopinata</i>	Lepidoptera	na	
Cherry fruitworm	<i>Cydia packardi</i>	Lepidoptera	na	
Lesser appleworm	<i>Cydia prunivora</i>	Lepidoptera	na	
Siberian coniferous silk moth	<i>Dendrolimus sibiricus</i>	Lepidoptera	na	
Walnut moth	<i>Erschoviella musculana</i>	Lepidoptera	na	
White-winged gypsy moth	<i>Lymantria postalba</i>	Lepidoptera	na	
Mountain tent caterpillar	<i>Malacosoma parallela</i>	Lepidoptera	na	
Pear fruit moth	<i>Numonia pyrivorella</i>	Lepidoptera	na	
Banana Moth	<i>Opogona sacchari</i>	Lepidoptera		10
Citrus pock caterpillar	<i>Prays endocarpa</i>	Lepidoptera	na	
Avocado seed moth	<i>Stenoma catenifer</i>	Lepidoptera		19
Potato tuber moth	<i>Tecia solanivora</i>	Lepidoptera		1
Mormon Cricket	<i>Anabrus simplex</i>	Orthoptera		72
Southern Mole Cricket	<i>Scapteriscus borellii</i>	Orthoptera		4
Grasshopper	<i>Trimerotropis fratercula</i>	Orthoptera	na	
Pear Thrips	<i>Taeniothrips inconsequens</i>	Thysanoptera		2120
South African citrus thrips	<i>Scirtothrips aurantii</i>	Thysanoptera		2
California citrus thrips	<i>Scirtothrips citri</i>	Thysanoptera		2
Rice Thrips	<i>Stenchaetothrips biformis</i>	Thysanoptera		2
European Flower Thrips	<i>Frankliniella intonsa</i>	Thysanoptera		28
Western flower thrips	<i>Frankliniella occidentalis</i>	Thysanoptera		455
Melon Thrips	<i>Thrips palmi</i>	Thysanoptera		220
Chilli Thrips; Yellow Tea Thrips	<i>Scirtothrips dorsalis</i>	Thysanoptera		249
Thrips	<i>Haplothrips chinensis</i>	Thysanoptera	na	
Myoporum thrips	<i>Klambothrips myopori</i>	Thysanoptera	na	
Fruit tree spider mite	<i>Amphitetranychus viennensis</i>	Trombidiformes		7
Chile false red mite of grapes	<i>Brevipalpus chilensis</i>	Trombidiformes	na	
Litchi mite	<i>Eriophyes litchii</i>	Trombidiformes	na	
Cassava mite	<i>Mononychellus tanajoa</i>	Sarcoptiformes	na	
Fuchsia gall mite	<i>Aculops fuchsiae</i>	Trombidiformes	na	
Citrus brown mite	<i>Eutetranychus orientalis</i>	Trombidiformes		1
Tetranychid mite	<i>Oligonychus perditus</i>	Trombidiformes		1
Two-spotted Spider Mite	<i>Tetranychus evansi</i>	Trombidiformes		6

Pests identified to genus only

Scarab beetles	Adoretus spp.	Coleoptera
Longhorned Beetle	Anoplophora spp.	Coleoptera
lily weevils	Brachycerus spp.	Coleoptera
Weevils	Conotrachelus spp.	Coleoptera
Bromeliad weevils	Metamasius spp.	Coleoptera
Cerambycid Sawyer Beetle	Monochamus spp.	Coleoptera
May-June beetles	Phyllophaga spp.	Coleoptera
Popillia beetles	Popillia spp.	Coleoptera
Wood-borers	Xyleborus spp.	Coleoptera
Cerambycid Beetle	Xylotrechus spp.	Coleoptera

Old world fruit flies	Ceratitisspp.	Diptera
Fruit flies	Pterandrus spp.	Diptera
Cuckoo wasps	Chrysis spp.	Hymenoptera
Cuckoo bees	Coelioxys spp.	Hymenoptera
Noctuid Moth	Copitarsia spp.	Lepidoptera
Seed worms	Cydia spp.	Lepidoptera
Red Pine Shoot Moths	Dioryctria spp.	Lepidoptera
Tortricid moths	Proeulia spp.	Lepidoptera

Arthropod pest species not included in the five pest databases

Kanzawa spider mite	<i>Tetranychus kanzawai</i>	Trombidiformes
NA	<i>Tetranychus parakanzawai</i>	Trombidiformes
Bark beetle	<i>Crypturgus subcribrosus</i>	Coleoptera
Bark beetle	<i>Crypturgus hispidulus</i>	Coleoptera
Hairy spruce bark beetle	<i>Dryocoetes autographus</i>	Coleoptera
Bark beetle	<i>Dryocoetes hectographus</i>	Coleoptera
Engraver beetle	<i>Ips acuminatus</i>	Coleoptera
Bark beetle	<i>Orthotomicus suturalis</i>	Coleoptera
Striped Ambrosia Beetle	<i>Trypodendron lineatum</i>	Coleoptera
Fruit-tree pinhole borer	<i>Xyleborinus saxeseni</i>	Coleoptera
Ambrosia beetle	<i>Xyleborus affinis</i>	Coleoptera
Wireworm	<i>Hypnoidus bicolor</i>	Coleoptera
Yellow toadflax stem weevil	<i>Mecinus janthinus</i>	Coleoptera
Coffee berry borer	<i>Hypothenemus hampei</i>	Coleoptera
Hessian fly	<i>Mayetiola destructor</i>	Diptera
African fig fly	<i>Zaprionus indianus</i>	Diptera
Blueberry gall midge	<i>Dasineura oxycoccana</i>	Diptera
Glasshouse Striped Sciarid	<i>Bradysia ocellaris</i>	Diptera
Citrus mealybug	<i>Planococcus citri</i>	Hemiptera
Solenopsis mealybug	<i>Phenacoccus solenopsis</i>	Hemiptera
Apple mealybug	<i>Phenacoccus aceris</i>	Hemiptera
Matsumoto mealybug	<i>Crisicoccus matsumotoi</i>	Hemiptera
Cyanotis scale	<i>Aspidiotus excises</i>	Hemiptera
Mottled arum aphid	<i>Neomyzus circumflexus</i>	Hemiptera
Leaf curl plum aphid	<i>Brachycaudus helichrysi</i>	Hemiptera
Cabbage aphid	<i>Brevicoryne brassicae</i>	Hemiptera
Asian sowthistle aphid	<i>Hyperomyzus carduellinus</i>	Hemiptera
Aphid	<i>Toxoptera aurantii</i>	Hemiptera
Bronze bug	<i>Thaumastocoris peregrinus</i>	Hemiptera
Grapewine leafminer	<i>Antispila hydrangaeella</i>	Lepidoptera
Leaf worm	<i>Copitarsia decolora</i>	Lepidoptera
NA	<i>Lymantria sinica</i>	Lepidoptera
Beet armyworm	<i>Spodoptera exigua</i>	Lepidoptera
Paddy armyworm	<i>Spodoptera mauritia</i>	Lepidoptera
Onion thrips	<i>Thrips tabaci</i>	Thysanoptera
Black flower thrips	<i>Haplothrips reuteri</i>	Thysanoptera

[na = not available)

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