Inventory of Important Insect Pests, Diseases and the Beneficial Insects in Fruits and Vegetables in West Central Bhutan

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ABSTRACT

Bhutan, an agrarian country gearing towards food self-sufficiency and food security is challenged by pests and diseases in crops. New pests emerge on old crops or known pests become adapted to new crops as a result of climatic change. These shifting in crop insectpests, pathogens and their hosts range result in outbreaks and crop losses which results in food insecurity. Pest outbreaks and crop losses can be addressed through integrated insect pests and diseases management specific to local environment. However, the comprehensive knowledge on occurrence and habitat range of beneficial and harmful organisms required for development of integrated pests and disease management is limited in the country. Therefore, we conducted the survey to monitor and inventorize the occurrence of major insect pests and diseases in fruit trees and vegetables, and their natural enemies in the west central Bhutan.

The Chinese citrus fruit fly (Bactrocera minax Enderlein*), trunk borer (Anoplophora versteegi* Rits.*) and citrus leaf miner (Phyllocnistis citrella* Stainton*) were the three important insect pests of citrus while Huanglongbing was the important disease of citrus crops in the west central Bhutan. Mango fruits in the region were infested by two insect pests i.e., trunk borer (Batocera rufomaculata* Dejan*) and Oriental fruit fly (Bactrocera dorsalis* Hendel*). Grapes were infested by the leaf beetle (Scelodonta strigicollis). Insect pests of chilli were solanum fruit fly (Bactrocera latifrons* Hendel*) and armyworm (Mythimnia separate* Walker*.) while phytopthora blight (Phytopthora capcisi) was its major disease. The bean pod borer (Muruca vitrata* Fabricius*) and armyworm were the two major insect pests of beans in west central Bhutan. The important natural enemies observed during the study period were ladybird beetles (Coccinellidae), assassin bugs (Family: Reduviidae), parasitic wasps (Family: Braconidae), dragon flies (Order: Odonate), spiders (Order: Araneae), mantis (Family: Mantidae), hoverflies (Family: Syrphidae) and big-eyed bug (Family: Geocoridae). The first hand information from this study confirmed the occurrence of the insect pests and diseases of major fruit and vegetable crops grown in the west central Bhutan.*

Keywords: *Chinese citrus fruit fly, Oriental fruit fly, Trunk borers, Bean pod borer, Natural enemy*

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1. Introduction

Bhutan comprises an agrarian society, with majority relying on agriculture for their livelihood. The major horticultural crops in the west central Bhutan are mandarin (*Citrus reticulate* Blanco), areca nut (*Areca catechu* L.), banana (*Musa spp.*), chilli (*Capsicum annum* L.), kidney bean (*Phaseolus vulgaris* L.), and radish (*Raphanus sativus* L.) (DoA, 2016). With climatic change, new pests emerge on old crops or known pests get adapted to new crops (Oso & Borisade, 2017). These shift in crop insect pests, pathogens and their hosts range result in outbreaks and crop losses (Coakley, Scherm & Chakraborty, 1999) leading to food insecurity. Farmers in the west central Bhutan reported insect pests and diseases as a major challenge in horticultural crop cultivation (Dorji, Sasaki, Jigme & Chofil, 2017). Similarly, pests and diseases were reported as a major challenge for food security and food self-sufficiency in Bhutan (CIAT; World Bank, 2017). In the past, Bhutan relied on plant protection chemicals to contain or control the major pests and diseases in crops.

However, starting 1992, managing these pests and diseases in the country geared towards safe guarding the environment with centralization of pesticide distribution (FAO, 2012), banning import of toxic chemicals (NPPC, 2015a), and declaring agriculture to become organic (Tashi, 2015). The Bhutanese government promotes organic agriculture in the country by discouraging the use of chemical inputs and intends to phase out the use of harmful plant protection chemicals (RGoB, 2010). However, in the absence of effective control options for pests and diseases in organic agriculture, the government's policy to achieve food self-sufficiency through higher crop yields remains a primary challenge.

The "Pesticide Act of Bhutan" enacted in 2000 has emphasized Integrated Pest Management (IPM). IPM is the preferred method for pest management that foster conservation and protection of ecosystems given the current scenario where agriculture development still focus on crop promotion, increasing production and productivity using chemicals (NPPC, 2015a). IPM, an ecosystem based strategy that focuses on the long term prevention of pests or their damage (FAO, 2017) uses a combination of techniques: cultural, biological, physical and chemical. For successful IPM, one basis is the pest identification; distinguish between pest, beneficial organisms through monitoring the insect pest and natural enemies. It is important to know the occurrence of various insect pests, their natural enemies, diseases and their vectors (Fake, 2011). IPM requires information on potential loss, pathogen biology, ecology, epidemiology, and basic concepts of plant disease management (Razdan & Sabitha, 2009).

The knowledge and understanding of the occurrence of various insect pests and diseases in Bhutan is limited as there is very limited information on level of crop damage or losses caused by insect pest and diseases (NPPC, 2015b). Therefore this survey was conducted to inventorize various insect pests and their natural enemies, diseases and their vectors in fruits orchards and vegetable farms in west central Bhutan. The first hand information from the study should serve as a basis for determination of effective IPM control measures under the current climatic

conditions in the region and as a step towards organic agriculture and in achieving food self-sufficiency and food security.

2. Materials and Methods

2.1. Survey site

The study sites were selected in consultation with the district agriculture officers of the region and research officers of the Agricultural Research and Development Center - Bajo (ARDC-Bajo). The study sites include a total of 35 farms and/or orchards in the elevation of 300 masl to 2,150 masl in west central Bhutan. The crops surveyed at different farms and orchards are tabulated against the farm or orchard name (Table 1).

Table 1.Investigation points of the survey

Elevation (m)	Point	Fruit plants	Vegetable
1,220	Bajo, WangduePhodrang	Citrus, Grape, Mango, Papaya, Pear, Persimmon	Beans
1,220	Bajo, WangduePhodrang	Apple, Citrus, Mango	Beans, Chilli, Indian mustard, Radish, Tomato
1,220	Bajo, WangduePhodrang	Apple, Citrus, Grape, Mango, Papaya, Pear	Beans, Chilli, Indian mustard, Radish, Tomato
1,250	Phuntsho, Pelri, Punakha	Mango	-
1,250	Phuntsho, Pelri, Punakha	Avocado	Indian mustard, Radish
1,920	Noobgang, Talo, Punakha	Peach, Persimmon, Plum	-
1,840	Laptsakha, Talo, Punakha	Pear	Beans, Broccoli, Chilli
1,520	Wolakha, Talo, Punakha	Citrus, Mango, Peach, Pear	Chilli
1,340	Damchoe, Kabjisa, Punakha	Citrus	Beans
1,370	Rimchu, Goenshari, Punakha	Citrus	-
1,740	Jazikha, Shangana, Punakha	Persimmon	-
1,610	Silna, Toepisa, Punakha	Avocado, Citrus, Peach, Pear, Persimmon	-
1,280	Chimipang, Baap, Punakha	Avocado, Citrus	-
610	Gewog, Daga, WangduePhodrang	Avocado, Citrus, Guava	-
640	Dohamchey, Athang, WangduePhodrang	-	Chilli, Eggplant, Indian mustard
1,510	Talidoho, Nahi, WangdiPhodrang	Citrus	Broccoli, Indian mustard

1,630	Doltochen, Nahi, WangdiPhodrang	Walnut	-
2,070	Tshokothanglca, Nahi, WangdiPhodrang	Apple, Citrus, Pear, Persimmon,	Beans, Cabbage, Chilli, Eggplant, Indian mustard, Radish

Table 1 contd…

Elevation (m)	Point	Fruit tree	Vegetable
2,190	Bjaktey, Kazhi, WangdiPhodrang	-	Cabbage, Chilli, Eggplant, Beans, Radish
2,150	Bjaktey, Kazhi, WangdiPhodrang	-	Beans, Chilli, Eggplant, Radish
1,840	Jagatokha, Kazhi, WangdiPhodrang	Citrus, Persimmon	-
1,190	Pangthang, Beteni, Tsirang	Citrus	Beans, millet
1,180	Damphu, Kilkorthang, Tsirang	Citrus	Radish
1,180	Damphu, Kilkorthang, Tsirang	Citrus	-
440	Southern area, Tsirang	Citrus	-
300	Southern area, Tsirang	Citrus	-
850	Noorbuthang, Phuentenchhu, Tsirang	Citrus	Beans, Chilli
690	SergithangMaeg, Tsirangtoe, Tsirang	-	Beans, Chilli
580	GaiceyKharka, Tsirangtoe, Tsirang	-	Beans
760	Trashiding, Dagana	-	Beans, Chilli, Indian mustard
980	Khagochen, KalidzingKha, Dagana	Citrus	-
870	Baleygang, Gozhi, Dagana	Guava	Beans, Indian mustard, Millet
880	Baleygang, Gozhi, Dagana	-	Broccoli
924	Baleygang, Gozhi, Dagana	Citrus	-
1,030	Lower Gozhi, Gozhi, Dagana	-	Beans, Chilli
1,280	Middle Gozhi, Gozhi, Dagana	Citrus	Chilli
836	Lower Tsendagang, Tsendagang, Dagana	-	Beans, Chilli
845	Lower Gesarling, Gesarling, Dagana	Citrus	Chilli

2.2. Sampling method

The simple random sampling method (Mead, Curnow & Hasated, 2002) was used to select the trees in an orchard for survey followed by stratified random sampling to inspect the leaves for presence of insect pests or disease symptoms. In an orchard, 5 random trees were selected from which 5 old and 5 new leaves were randomly inspected for the presence of insect pests, beneficial insects, and the disease symptoms. For vegetable farms, simple random sampling method was used where 25 plants were inspected for insect pests, beneficial insects and disease symptoms.

2.3. Data collection

In the months of September to October 2017, a total of 35 farms and/or orchards were surveyed (Table 1). Insect pests, disease incidence and their severity were visually rated in the farms. The disease incidence in an orchard or farm was calculated as below:

$$Disease\ incidence = \frac{\text{Number of disease plantsdenc}}{\text{Total number of plants}}$$

The percent infestation of different pests was calculated based on number of insects per leaf or fruit or stem or the whole plant. To analyze and rank the incidence of a pest across the region, frequency distribution was used. The insect pests and diseases for important fruit and vegetable crops were categorized in ranks according to the frequency of occurrence across the region.

To investigate the fruit fly damage in tomato, citrus, eggplant, pear, chilli, pear, guava, and persimmon; 20 numbers of fruits were sliced and investigated for fruit fly larvae. The fruits were collected from the local markets in Punakha and Wangdue districts and from the survey farms and orchards of the region and stored at room temperature for a week or two before investigating the presence of larvae.

To investigate the vectors of citrus greening disease, careful visual inspection on the leaves of the citrus plants and alternate hosts was carried out. Insect pests and natural enemies were also investigated by a sweeping method. Using the sweep net, 20 sweepings were carried out in an investigation on weeds that were growing near the different crops. Yellow sticky traps were also used for trapping insect pests. The yellow sticky traps were appropriately changed and data on different insects trapped were recorded for analysis.

2.4. Tools and equipment

A sweep net (Shiga Konchu Fukyusya, 35 cm in diameter and stick with 120 cm in length) was used to catch the insects. Insect samples were collected in vials (17*27*55mm) and preserved in 70% ethanol for identification with the help of microscope (MIZAR-TEC.SW-20). Yellow sticky traps (Arysta Life Science, 257*100mm) were used to trap insect pests and natural enemies.

3. Results and discussion

3.1. Major insect pests and diseases of important fruit crops of the west central Bhutan

Mandarin, mango, and pear are the top three fruit crops in west central Bhutan. Grapes, persimmon, subtropical apple, papaya, kiwi, walnut, pecan, peach and apricot are other fruit crops cultivated in the region (DoA, 2016). Pests and diseases of these crops are ranked in descending order (Figure 1).These ranks are based on the frequencies observed under each crop.

3.2. Incidence/occurrence of citrus insect pests and diseases in the region

Citrus leaf miner, HLB and trunk borer were the top three frequently observed pests or disease in the region during this study. Of the 20 citrus orchards surveyed, we found leaf miner in 11 orchards; HLB symptoms in nine orchards and trunk borer in six orchards.

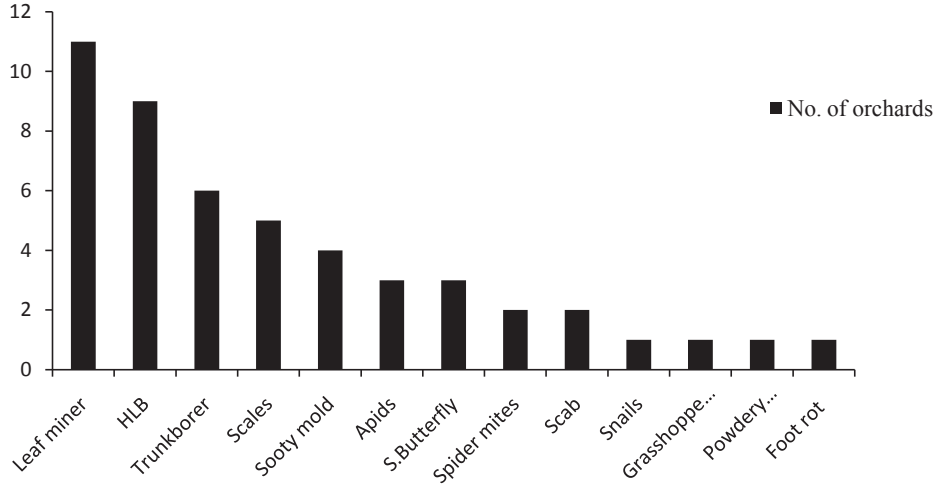

Figure 1.Incidence of citrus insect pests and diseases in the west central Bhutan (September-October, 2017)

3.2.1. Citrus leaf miner

We observed citrus leaf miner in 11 of the 16 citrus orchards surveyed. Citrus leaf miner percent infestation on citrus leaves ranged from 6% to 60% in Punakha, 12% to 59% in Wangdue and 0.4% to 56% in Tsirang. NPPC reported that citrus leaf miner is present in all mandarin orchards in the country (NPPC, 2017a). Citrus leaf miner is potentially a serious pest of citrus and its related Rutaceae family species, and some related ornamental plants (Beattie, 1989; Clausen, 1993). Citrus leaf miner favours spread of citrus canker (Ando et al., 1985; Hill, 1918) because of leaf damage from the miner. The information on spread of diseases by this pest in Bhutan is limited.

3.2.2. Citrus greening disease and its vector

Of the 22 citrus orchards surveyed, nine showed HLB symptoms. Ranging from 90% to 100% of the mandarin trees investigated in orchards in Dagana district was showing symptoms of HLB while it ranged from 22% to 100% in Tsirang district and 40% to 67% at Wangdue. NPPC reports that HLB disease is present in almost all citrus growing districts of Bhutan (NPPC, 2017b). *Diaphorina citri i*s the vector of the citrus greening disease. We did not find *D. citri* on citrus trees and collateral hosts. However, *Diaphorina communis,* a relative psyllid was observed on curry leaf trees at Dagana and Wangdue. Donovan et al. (2012) also reported *Diaphorina communis* inhabitation on curry leaf.

3.2.3. Citrus trunk borer

The percent infestation of citrus trunk borer ranged from 3.1% to 24% per trees in our study. It ranged from 8.3% to 24% per tree in Tsirang district and 3.1% to 16% in Dagana district. Citrus trunk borer is present in all the citrus growing regions and mainly problematic in poorly managed or neglected orchards (NPPC, 2017c). The orchard sanitation was poor across the region.

3.2.4. Fruit fly

Mandarin (*Citrus reticulate* Blanco) is the most important citrus crop in Bhutan. No fruits were available during the survey period. In Tsirang, 100% of the lime fruits investigated was infested by Chinese citrus fruit fly (*Bactrocera minax)*. NPPC reports Chinese citrus fruit fly as the most serious insect pest of citrus causing losses up to 70% through late fruit drop (NPPC , 2017d). Chinese citrus fly causes more than 50% fruit drop in mandarin (Dorji, et al., 2006). However, during this study, fruit dropcaused by fruit fly in mandarin was not studied.

3.2.5. Other pests and diseases of citrus

Other pests observed during the study were scales (*Aonidillae auranntii*), swallowtail butterflies (*Papilio aegeus*), cutworm (*Spodoptera litura)*, whiteflies (*Dialeurodes citri* Ashmead)), black citrus aphid (*Toxoptera aurantii)*, and snails. The percent infestation of these pests ranged from 0.02% to 6% on few separate incidences. Sooty mold was observed in most of the citrus orchards. The most severe sooty mold with 100% infestation on leaves was observed in Damphu, Tsirang. The sooty mold infestations on leaves in other orchard trees ranged from 14% to 30%. One orchard in Tsirang was infested with 36% powdery mildew, while 20% fruits investigated in Toepisa, Punakha had scab disease**.**

3.3. Incidence of mango insect pests and diseases in west central Bhutan

The incidence of mango insect pests and diseases is shown in Figure 2. Trunk borer was observed in two orchards out of four orchards surveyed. In Punakha, an unidentified weevils and black spot disease were observed in two different orchards, respectively.

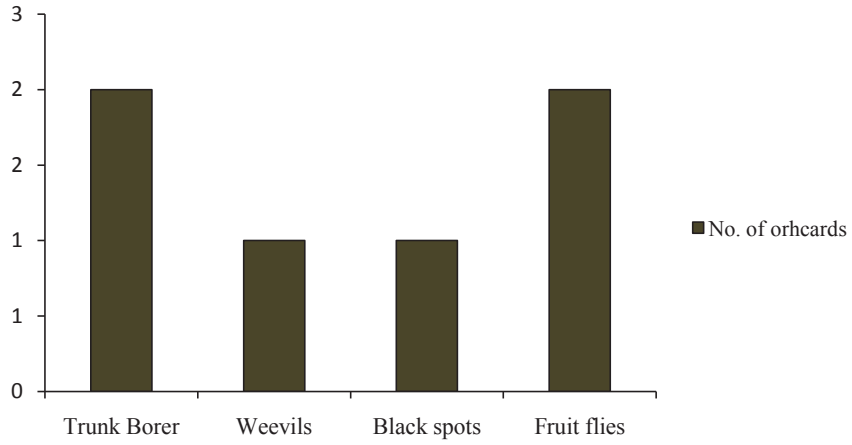

Figure 2.Incidence of mango insect pests and diseases inthewest central Bhutan (September-October, 2017)

3.3.1. Mango trunk borer

Of the four orchards surveyed, trunk borer (*Batocera rufomaculata* DeGeer) infestation was observed only at ARDC-Bajo.About 4% of the mango trees were observed infested by the pest.

3.3.2. Fruit fly (Bactrocera dorsalis)

Although no fruits were available during the study period, there were adult flies trapped on the yellow sticky traps. An average of 4 flies was trapped in a week during the survey period. Two studies reported that fruit fly (*Bactrocera dorsalis*) densities are very high in Bhutan (Ghalley, Lham & Wangdi, 2014; Moriya, Phuntsho, Gyeltshen & Penjor, 2014).

3.3.3. Black spots

The mango trees at Phuntsho Pelri, Punakha was infested by black spots. The disease incidence on leaves was about 68%.

3.4. Pear pests and diseases in west central Bhutan

No major pest was detected during the study period. Minor pests such as green apple aphid (*Aphis pomi* DeGeer), red spider mite (*Tetranychus urticae*) and oriental moth (*Grapholita molesta*) were observed. The highest aphid density or percent infestation was 5.4% per leaf at Talo, Punakha. The percent infestation for rest of the pests was less than one.

3.5. Grape pests in west central Bhutan

Grapes are relatively a new crop cultivated in Bhutan and information on its pests and diseases is

limited. At ARDC-Bajo, the leaf beetle (*Scelodonta strigicollis*) had infected about 50% of the leaves. There is no previous report on this pest in Bhutan. The adults of the *Scelodonta strigicollis* feed on the foliage and sprouting buds while the larvae feed on roots of the vine (Jeyaseelan & Mikunthan, 2004). The damage on foliage initially began on the small netted veins and then to veins and midrib. The adult feeds first on the leaf veins from the lower side and later may feed on the other parts of the leaves. The females lay eggs in the soil or underneath the split bark. ARDC-Bajo with the current Japan International Cooperation Agency (JICA) funded Integrated Horticulture Promotion Project (IHPP) distribute many grape seedlings as out-reach programs in the region. Chances of eggs dispersal/transportation of the pest (eggs) in the split barks of grape seedlings is high, although the seedlings distributed are pruned before distribution. With the percent hatchability of 95.0±2.4 (Jeyaseelan & Mikunthan, 2004), *S. strigicollis* pose a threat to the relatively new crop in the country if not controlled at the earliest.

3.6. Important vegetable insect pests and diseases in the west central Bhutan

Chilli, beans and radish are the top three vegetable crops grown in west central Bhutan. For the study, 14 chilli farms, 17 bean farms and seven radish farms were surveyed. Other vegetable crops grown in the region are broccoli, cabbage, mustard green, eggplant, tomato, etc.

3.7. Incidence of chilli insect pests and diseases in west central Bhutan

The incidence of chilli insect pests and diseases is shown in Figure 3.The most frequently observed disease of chilli was blight with seven farms out of 14 farms surveyed. Although aphid infestation was observed only in one farm, unknown disease symptoms were observed in four farms of the 14 farms.

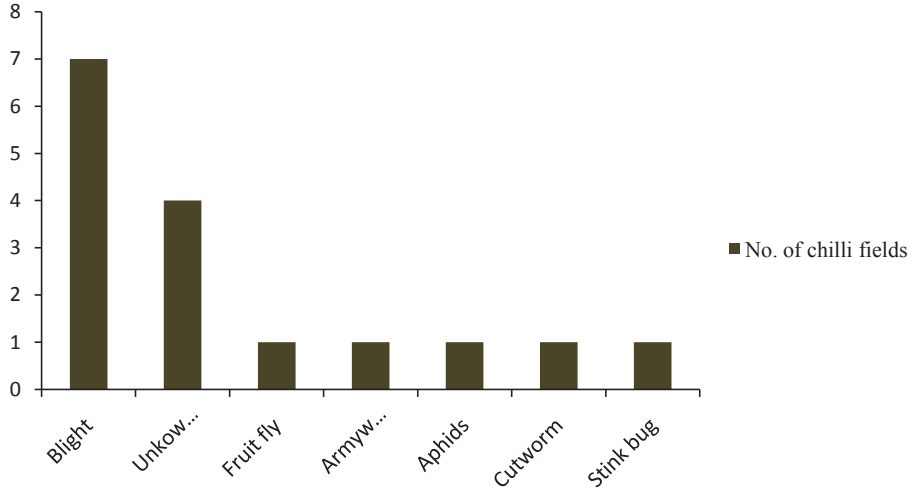

Figure 3.Incidence of chilli insect pests and diseases inthewest central Bhutan (September-October, 2017)

3.7.1. Chilli blight, damping off and foot rot symptoms

Chilli plants in the region were showing damping off and foot rot symptoms. The disease incidence ranged from 1% to 96% in the west central Bhutan. At Kazhi, the disease incidence on the small Indian chilli cultivar was 90% while the local chilli cultivar had about 24% infestation. NPPC reports that chilli blight is the most serious disease of chilli in Bhutan (NPPC, 2017e).

3.7.2. *Solanum f ruit fly* **(***Bactrocera latifrons* Hendel)

The fruit fly percent infestation was highest inWangdue district with 20% (field condition) followed by Punakha (9%). We found solanum fruit fly (*Bactrocera latifrons*) infesting tomato at ARDC Bajo in September, 2017. Moriya et al. (2014) reported that chilli is infected by solanum fruit fly in Bhutan.

3.7.3. Other pests of chilli

The chilli crop at Sergithang, Tsirang was affected by *Mythimna spp.*The percent infestation was 13%.Other pests such as aphids, termites, ants and cutworms (*Agrotis segetum*) were observed during the study. The density of aphids, cutworms and termite in Dagana was 1.5% per leaf, 2% per plant and 1% per plant, respectively.

3.8. Incidence of bean insect pests and diseases in the west central Bhutan

The incidence of bean insect pests and diseases is shown in Figure 4. A total of 16 bean farms were surveyed for the study. Armyworm (*Mythimna spp.*) was observed only at Sergithang under Tsirang district. Bean pod borer (*Maruca vitrata*) was observed in two farms under Dagana district. There were several pests and diseases observed but only in one or two spots of the region with percent infestation and disease incidence less than 1%.

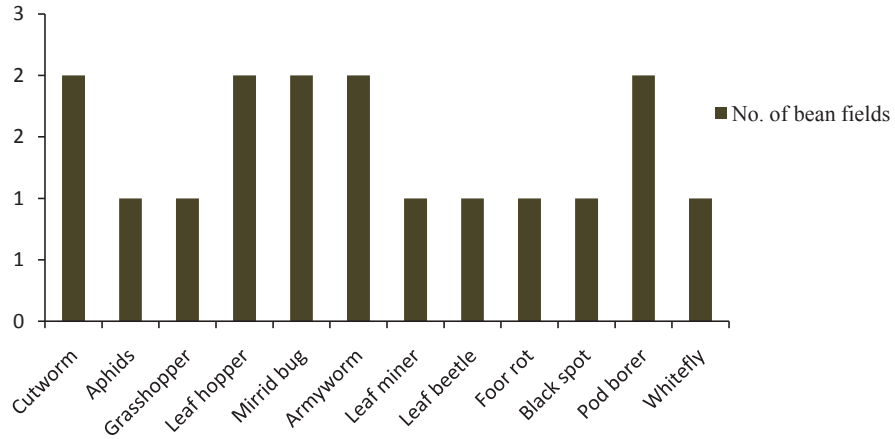

Figure 4.Incidence of bean insect pests and diseases inthe west central Bhutan (September-October, 2017)

3.8.1. Armyworms (Mythimna spp.)

The beans at Sergithang were affected (10% of the pods) by armyworms. The beans at other places were not affected by armyworm.

3.8.2. Bean pod borer (Maruca vitrata)

The bean pod borer was observed only in two villages under Dagana district. The percent infestation of the pest was 8% of the pods surveyed at Tashidhing and 6.7% at lower Gozhi.

3.8.3. Unidentified diseases in beans

Beans at Bjaktey, Wangdue were affected by a kind of black spot disease while the beans at Tashidhing, Dagana were showing foot rot symptoms. In Tashidhing, 2% of the beans were showing foot rot symptoms. The causal organism of the foot rot and black spots were unknown.

3.9. Incidence of insect pests and diseases in radish in the region

The incidence of radish insect pests and diseases is shown in Figure 5. The most commonly observed insect pests were aphids and armyworms. However, the percent infestation of these insect pests was minimal.

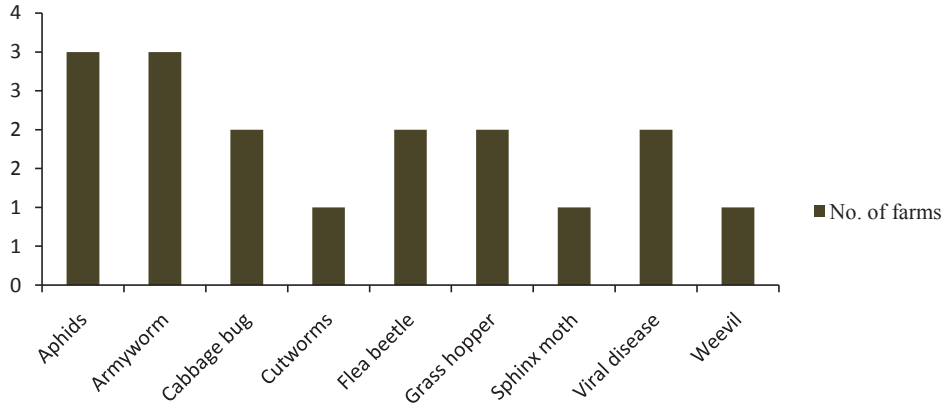

Figure 5.Incidence of radish insect pests and diseases in the west central Bhutan (September-October, 2017)

At ARDC-Bajo, 3% of the transplanted radish seedlings were affected by cutworms (*Agrotis segetum*). At Kazhi, the radish crop was affected by flea beetles of about 0.52% per leaf while 16% of plants were affected by an unknown viral disease. The percent infestation of other pests was less than 1% in all the farms surveyed.

3.10. Other vegetables pests

Other minor vegetable crops such as tomato and eggplants were also infested by several pests. In Tsirang and Dagana, 100% of mung beans were infested by armyworm (*Mythimna spp.*)

3.11. Major native natural enemies collected from fruit trees, vegetables and weeds in the cultivated fields

Natural enemies against their preys observed during the survey are shown below (Table 2). In this study, ladybird beetles belonging to subfamily Epilachninae and family Coccinellidae (i.e. *Henosepilachna indica* and *Henosepilachna vigintioctopunctata)* were observed along with the beneficial lady beetles. Dorji, Loday and Vorst (2017) reports that as high as 33 species of lady beetles were observed in the western region with 21 species in Wangdue dzongkhag alone. Ladybird beetles are well known for their predation for soft bodied arthropod pests (especially aphids and scales which are agriculture pests) and considered beneficial. However, these Epilachnae beetles are rather leaf feeding herbivores than predators. *Henosepilachna vigintioctopunctata,* commonly known as 'Hadda beetle' cause damage to solanaceous crops.

Table 2.Natural enemies in the west central Bhutan (September-October, 2017)

Major target insect pests	Natural enemy
Aphids	Lady beetles, Parasitic wasps, Predacious godflies, Spiders, Hoeverflies
Armyworms	Lady beetles, Brachonidae wasps
Spider mites	Predacious mites
Cabbage bugs and weevils	Big eyed bugs
Tussock moths and Grasshoppers	Spiders
Longhorn beetles	Spiders
Bagworm moths	Spiders
Stink bugs	Assassin bugs

In our study, parasitoid wasps belonging to subfamily Braconinae, family Braconidae, and several others wasps were found in the west central Bhutan. The parasitoid wasps in Braconinae attack nearly the entire range of lepidopteran insects, and are used for biological control of agriculture lepidopteron pests (Whitefield, 2002). Om et al. (2017) reported that a kind of a wasp called *Tamarixia drukyulensis,* the parasitoid nymphs of *Diaphorina communis* was observed in Wangdue dzongkhag. In Reunion Island, it is reported that parasites such as *Tamarixia dryi* and *T. radiata* Waterson significantly reduced the psyllid populations and lessened the damage of HLB (Gottwald, da Graca & Bassanezi, 2007). However, the wasp *Tamarixia drukyulensis* was

not observed in this study and the information on the effects of this wasp on psyllid populations is limited.

Other beneficial insects recorded were assassin bugs, dragon flies, earwigs, mantis, hoverflies and big eyed bugs. These bugs show predatory behavior as reported by several authors worldwide. The assassin bugs and mantises feed on a wide variety of arthropods (Hurd, 1999; Ambrose, 2003). The dragonflies' diet mainly constitutes small dipterans (Pritchard, 1964). Hoverflies and earwigs feed on aphids while the big eyed bugs feed on more than 60 preys in three classes of arthropods (Sadeghi & Gilbert, 2000). These beneficial organisms are probably of great importance in preventing pests as bio-control agents in agriculture.

4. Conclusion

The survey result produced an extensive inventory of the occurrences of insect pests, their natural enemies, diseases, and their vectors in fruits orchards and vegetables farms in the west central region of Bhutan. The major pests observed in fruit crops such as citrus, mango and pear were fruit flies and trunk borers. HLB and its vector, citrus psyllid (*Diaphorina citri*) were found to be the major pests on citrus. Armyworm was the major insect pest in vegetable crops such as chilli, beans and radish. *Phytopthora* blight was reported as the major disease on chilli. Important beneficial insects observed during the survey were ladybird beetles, assassin bugs, parasitic wasps, dragon flies, spiders, earwigs, mantis, hoverflies and big-eyed bugs.

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