

Original Research Article

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Diversity of Aphid Pests (Homoptera: Aphididae) and their Natural Bio-Control Agents in Vegetable Crop Ecosystems of Jammu & Kashmir, India

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ABSTRACT

The aphids (Homoptera: Aphididae) are one of major pests of agriculturally important crops, including vegetables, across the world. They suck plant sap, cause leaf curling, yellowing and stunted growth of the host plants. They also act as vectors of many viral diseases in plants. In order to explore aphid pests and their naturally occurring bio-control agents (parasitoids and predators), an extensive field survey was conducted in different vegetable ecosystems of the Kashmir valley during the years from 2014-2019. Moreover, a through literature survey pertaining to aphids, reported from Jammu and Kashmir, was also done. Accordingly, based on these studies, it was concluded that as many as 18 species of aphids belonging to 12 genera infest as many as 26 species and 30 varieties of vegetable crops in Jammu and Kashmir (J&K). It was also concluded that at least 29 species of insect predators and 17 species of parasitoids occur naturally to suppress these aphid pest species in vegetable ecosystems in J&K. In sum, through this study, a comprehensive account of aphids and their natural enemies with reference to vegetable crops in J&K is presented. This work will be useful for the studies concerning the devising of strategies for Integrated Control Program of aphids, especially through utilization of natural bio-control agents.

Keywords

Aphidiinae, Aphids, Coccinellidae, Jammu & Kashmir, Parasitoids, Predators

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Introduction

Aphids or 'plant lice' are minute pear-shaped, soft-bodied organisms. They belong to Class Insecta, order Homoptera and family Aphididae. They may be winged (alate) or wingless (apterous). Their life cycle is

completed through egg, nymphal and adult stages. Apart from sexual reproduction, they can also reproduce through a process of parthenogenesis (Dixon, 1987 and 1998). Aphids are an important group of plant insect pests having a high biotic potential as reflected by their parthenogenicity, viviparity

and fast development. They are found to inflict direct (sucking) and indirect (transmission of viruses and honeydew secretion) damage to different types of vegetations and are considered the most potent and worldwide enemies of many crops (Blackmon and Eastop, 2007).

Aphids are an extremely successful group which occurs throughout the world, with the greatest number of species in the temperate regions (Blackmon and Eastop, 2007). Out of 4702 aphid species so far known world over (Remaudiere and Remaudiere, 1997), about 1015 species occur in Oriental region (Agarwala and Gosh, 1984), among which, about 750 species belonging to 208 genera represent Indian Aphididae (Gosh and Gosh, 2006).

In Jammu and Kashmir region (India), more than 31 species of aphids have been reported on wide range of host-crop species of agricultural, horticultural and forest ecosystems, with varying degree of host specificity (Bhagat, 2012). Among these aphids, some species had earlier been reported on vegetable crops and the significant studies in this regard have been conducted by Ahmad and Bhat (1986); Bhagat (1986, 2012); Zaz (2001); Pandey *et al.*, (2006); Bhat (2008, 2017); Khan *et al.*, (2009, 2017); Bhat *et al.*, (2011); Bhat and Bhagat (2017) and Bhat and Ahanger (2018).

Some natural enemies (parasitoids/predators) had earlier been reported on aphid pests on some vegetable crops in J&K region and the important studies in this connection were done by Ahmad and Bhat (1986); Bhagat and Lone (1984); Bhagat & Masoodi (1986); Bali (1987); Bhagat & Matta (2002); Bhat (2008a); Khan *et al.*, (2009, 2017); Shah and Khan (2013); Bhat (2017) and Bhat & Bhagat (2017). Similarly, some parasitoid species were earlier recorded to suppress the aphid

population in vegetable ecosystems in J&K region and the key researchs in this regard were conducted by Rao *et al.*, (1969); Shujaiddin (1973); Stary and Bhagat (1978); Takada & Rishi (1980); Bhagat (1982 a, 1982b, 1986, 2008); Bhagat & Ahmad (1991); Bhat (2008a), Khan *et al.*, (2017) and Bhat *et al.*, (2017).

However, all the aforementioned studies pertaining to aphids and their natural enemies in J&K were scattered in different journals and, hitherto, there was no consolidated checklist available concerning aphids and their natural enemies on vegetable crops in J&K. Therefore, in sum, this paper by way of adding new information and consolidating the previous works pertaining to aphids and their natural enemies, gives a clearer picture regarding this subject area. Accordingly, a comprehensive account of the systematic position, host-crop range and natural bio-control agents of 18 species of aphids along with their 45 species of natural enemies (parasitoids and predators) in J&K is provided through this work. This study will be helpful in future for understanding of biodiversity of aphids and their natural enemies, particularly from this region. Moreover it would also be useful for the studies concerning the devising of strategies of integrated control program for aphids, especially through utilization of natural enemies (as bio-control agents).

Materials and Methods

Literature survey and preparation of compendium/checklist of aphid pests

A comprehensive literature survey of all the available published works/ research papers etc., published from time to time pertaining to aphid pest and their natural bio-control agents (parasites and predators) in J&K regions, was done in order to collect the information. Besides consulting previous published papers,

the other vital e-resources and abstracting services, particularly, CAB, NISCAIR, AGRI, Biological abstracts, etc., were also consulted for obtaining the required information.

Field and laboratory studies

The data presented in this paper is also based on extensive field surveys of aphids and their natural bio-control agents (parasites and predators), in different vegetable farms, floating gardens, kitchen gardens etc in different localities of J&K region, conducted by the present authors over the years from 2007-2019, appended as under:-

Study area (Fig. 62)

Regular fortnightly random and extensive field surveys were conducted at 7 study sites across the length and breadth of Kashmir Valley viz. Danderkhah in District Srinagar (34.0687° N, 74.7783° E), Zazuna in District Ganderbal (34.2301° N, 74.6854° E), Bugam in District Budgam (33.6911° N, 75.0231° E), Bangidar in District Anantnag (33.7265° N, 75.1443° E), Chaklu in District Baramulla (34.2004° N, 74.3969° E), Sumlar in District Bandipora (34.4111° N, 74.7235° E) and Murran in District Pulwama (33.8664° N, 74.8639° E).

Sampling method and rearing

The vegetable farms/ vegetable gardens/ kitchen gardens in above cited study areas were surveyed. Three fields at every site were selected randomly and sampling procedure was based on standardized sampling techniques. The field data regarding aphid pests, their host-plant, predators (natural enemy) was recorded in field diary. The immature stages (nymphs) of aphids were taken to laboratory, along with predatory larvae, if any and were reared on the host plant in glass / plastic jars for the

development of their adults and for the recovery of their parasitoids. The adults of aphids, their parasitoids and predators which emerged after rearing were identified and preserved.

Presentation of data in the form of checklist

The necessary data, pertaining to aphid is documented and presented in this paper in the form of checklist. The aphid species are listed sub family-wise & systematically, with details given on their host-plant range (followed by references), insect predators (family wise and followed by references) and parasitoids (followed by references).

Results and Discussion

The results obtained during this work are highlighted through a below mentioned checklist, well supported by field photography (Fig. 1-61) and table 1. The checklist reveals that as many as 18 species of aphids (See Section b) belonging to 12 genera under 2 subfamilies (Aphidiinae and Lachinae) of family Aphididae (Order: Homoptera) infest at least 26 species and 30 varieties of vegetable crops (See Section a) in J&K.

The checklist also reveals that at least 29 species of insect predators (natural enemies) (See Section c), belonging to 25 genera under 5 families (Anthocoridae, Coccinellidae, Ceccidomyiidae, Syrphidae, Chrysoperlidae) under 4 Insect orders (Coleoptera, Hemiptera, Diptera Neruoptera) commonly occur and feed on afore-mentioned aphid species. Apart from this, 17 species of parasitoids (Hymenoptera: Braconidae: aphidiinae) (See Section d), belonging to 7 genera which parasitize these aphids on vegetable crops, have been documented in this checklist.

Summary of vegetable plant host-range of aphid pests in J&K

As highlighted above, 26 species and 30 varieties of vegetable crops (both cultivated and wild) have been found infested by Aphid pests. These vegetable plants are: *Brassica napus* (Linn.) (= *Brassica campestris* L.), *Brassica juncea* Linn., *Brassica napus* (Linn.), *Brassica oleracea* (Linn.)- *Brassica oleracea* var. *acephella* (kale), *Brassica o.* var. *botrytis* (Cauliflower), *B. oleracea* var. *capitata* (cabbage), *B. o.* var. *kashmiriana*, *B. o.* var. *gongylodes* (knolkhol), *Brassica rapa* L. (turnip), *Capcicum annum* L. (capsicum), *Coriandrum sativum* L. (Corriander), *Cucumis sativus* (Linn.) (Cucumber), *Cucurbita maxima* Duchensc (large pumpkin), *Cucurbita pepo* L. (Marrow), *Daucus carota* L. (carrot), *Dolichos lablab* L. (Lablab bean), *Helianthus tuberosus* L. (artichoke), *Hibiscus esculentus* L. (Okra), *Lagenaria siceraria* (Molina) (bottle gourd), *Lycopersicon esculentum* Mill (tomato), *Phaseolus coccineus* (Linn.) (runner bean), *Phaseolus vulgaris* (common bean/French beans), *Pisum sativum* Linn. (pea), *Raphanus sativus* L. (radish), *Rumex acetosa* (Linn.), *Rumex nepalensis* Spreng *Rumix* sp. (rumex), *Solanum tuberosum* (Linn.), *Solanum melongena* L., *Taraxacum officinale* (L.).

Summary of aphid pest species of vegetable crops in J&K

The 18 species of Aphids (Family Aphididae) belonging to 12 genera, which have been reported to infest vegetable crops in J&K are: *Aphis craccivora* Koch, *Aphis fabae solanella* Theobald, *Aphis gossypii* Glover, *Aphis rumicis* Linnaeus, *Aphis spiraecola* (Patch), *Acyrtosiphon pisum* Harris, *Aulacorthum solani* (Kaltenbach), *Brachycaudus helichrysi* (Kaltenbach), *Brachycaudus rumexicolens* (Patch), *Brevicoryne brassicae* (Linnaeus),

Cavariella aegopodii Scopoli, *Hyadaphis coriandri* (Das), *Lipaphis (Lip.) erysimi* (Kaltenbach), *Lipaphis pseudobrassicae* (Davis), *Myzus persicae* (Sulzer), *Macrosiphum euphorbiae* (Thomas), *Semiaphis heraclei* (Takahashi), *Protrama penecaea* Stryon

Summary of insect predator species (natural bio-control agents) of aphid pests on vegetable crops in J&K

The 29 species of insect predators distributed over 25 genera, which have been reported on aphid pests in vegetable ecosystems in J&K, include 12 species of Coccinellidae (Coleoptera), 10 species of Syrphidae (Diptera), 2 species of Cecidomyiidae (Diptera), 3 Species of Chrysoperilidae (Neuroptera) and 2 species of Anthocoridae (Hemiptera) and are highlighted as under:-

Order-coeloptera (family coccinellidae)

Adalia tetraspilota (Hope), *Calvia punctata* (Mul.), *Coccinella septempunctata* L., *Coccinella undecempunctata* Linnaeus, *Cheilomenes sexmaculatus* Fabricius, *Hippodamia variegata* (Goe.), *Harmonia dimidiata* (Fabricius), *Oenopia conglobata* (Goe.), *Platynaspidius saundersi* (Crotch) (= *Platynaspis saundersi*), *Priscibrumus uropygialis* (= *Exochomus uropygialis*) (Mulsant), *Propylea luteopustulata* (Mulsant), *Scymnus* sp.

Order-diptera (family syrphidae)

Betasyrphus serarius (Wiedemann), *Episyrphus balteatus* DeGeer, *Eupeodes (Macrosyrphus) confrater* (Wiedemann), *Ischiodon scutellaris* (Fabricius), *Melanostoma univittatum* (Wiedemann), *Metasyrphus corolla* (Fabr.), *Paragus tibialis* (Fallén, 1817), *Sphaerophoria scripta* (Linnaeus), *Syrphus confractor* Weid,

(=*Metasyrphus confractor*), *Syrphus* sp.,

Order- diptera (family cecidomyiidae)

Aphidoletes aphidimyza (Rondani), *Leucopis* sp.

Order- Hemiptera (Anthocoridae): *Anthocoris* sp., *Orius* sp.

Order-neuroptera (family chrysopidae)

Chrysoperla zastrowi Sillemi (Esben-Petersen), *Chrysoperla* (= *Chrysopa*) *carnea* Stephens, *Chrysoperla* (= *Chrysopa*) *orestes* Banks

Summary of parasitoid species (natural bio-control agents) of aphid pests on vegetable crops in J&K region

The 17 species of aphid parasitoids (Hymenoptera: Braconidae: Aphidiinae) belonging to 7 genera reported on aphid pests of vegetable crops in J&K are: *Aphidius colemani* Viereck, *Aphidius eglanteriae* Haliday, *Aphidius matricariae* Haliday, *Aphidius salicis* Haliday, *Aphidius smithi* Sharma and Subbarao, *Aphidius* sp., *Diaeretiella rapae* (McIntosh), *Ephedrus persicae* Froggatt, *Ephedrus plagiator* (Nees), *Lysaphidus erysimi* Stray, *Lysiphlebus* (*Phelbus*) *fabarum* (Marshall), *Toxares zakai* Shujauddin, *Trioxyx kahmirensis* (Takada), *Trioxyx* (*Binodoxys*) *jaii*, Bhagat, *Trioxyx* (*Binodoxys*) *indicus*, *Trioxyx rubicola* Shujauddin, *Trioxyx* (*Trioxyx*) *complanatus* Quilis

Check list of family aphididae on vegetable crops in J&K

The 18 species of Aphids (Family Aphididae), which have been reported on vegetable crops in J&K are appended in the following

checklist. The Aphid species in this checklist are documented subfamily-wise, & systematically, with details given on their host-plant range (followed by references), insect predators (family wise and followed by references) and parasitoids (followed by references).

Sub-family: aphidinae

Tribe-aphidini Latreille, 1802

Aphis craccivora Koch, 1854

Aphis craccivora is commonly known as cow pea aphid.

Host vegetable plants in J&K/ references

Cucumis sativus, *Dolichos lablab*, *Lycopersicon esculentum*, *Phaseolus vulgaris*, *Rumex acetosa*, *Rumex nepalensis*, *Solanum melongena*, *Solanum tuberosum* / (Bhagat, 2012; Bhat, 2017; Bhat and Bhagat, 2017; Khan *et al.*, 2017; Bhat and Ahanger, 2018)

Predatory natural enemies in J&K/ references

Coleoptera (Coccinellidae)

Adalia tetraspilota, *Cheilomenes sexmaculata*, *Hippodamia variegata*, *Platynaspidium saundersi* (= *Platynaspis saundersi*), *Scymnus* sp., *Oenopia conglobata*, *Propylea luteopustulata*;

Diptera (Syrphidae)

Eupeodes (*Macrosyrphus*) *confrater*, *Ischiodon scutellaris*, *Melanostoma univittatum*, *Sphaerophoria scripta*, *Paragus tibialis* / (Bhat, 2017; Khan *et al.*, 2017; Bhat and Bhagat, 2017)

Parasitoid natural enemies in J&K/ references

(Hymenoptera: Braconidae: Aphidiinae): *Diaeretiella rapae* / (Bhagat & Ahmad, 1991; Bhagat, 2008); *Trioxys (Binodoxys) indicus* / (Bhagat, 2008), *Ephedrus persicae* Froggatt, *Trioxys jaii* Bhagat/ (Stary and Bhagat, 1978; Bhagat, 1982 a, 1982b; Khan *et al.*, 2017)

Aphis fabae solanella Theobald, 1914

It is commonly known as Black bean aphid.

Host vegetable plants in J&K/ references

Phaseolus sp. (French beans), *Rumex acetosella*, *Rumex nepalensis* / (Bhat & Lone, 1984; Bhat, 2017; Khan *et al.*, 2017; Bhat and Ahanger, 2018)

Predatory natural enemies in J&K/ references

Coleoptera (coccinellidae)

Adalia tetraspilota, *Coccinella septempunctata*, *Chrysoperla z. sillemi*, *Hippodamia dimidiata*, *Hippodamia variegata*, *Oenopia conglobata* (Goe.); Diptera: (Chamaemyiidae): *Aphodoletes aphidomyzae*, *Leucopis* sp. / (Bhagat and Lone, 1984; Bhagat and Matta, 2002; Bhat, 2017; Khan *et al.*, 2017); Hemiptera (Anthocoridae): *Anthocoris* sp., *Orius* sp.

Parasitoid natural enemies in J&K/ references

(Hymenoptera: Braconidae: Aphidiinae): *Aphidius matricariae* Haliday (Bhagat and Ahmad, 1991; Bhat *et al.*, 2017); *Lysiphelebus (Phelbus) fabrum*, *Trioxys (Binodoxys) indicus* (Bhagat, 2008)

Aphis gossypii Glover, 1802

Aphis gossypii is commonly known as cotton aphid.

Host vegetable plants in J&K/ references

Capsicum annum, *Cucumis sativus*, *Cucurbita maxima*, *Cucurbita pepo*, *Lagenaria siceraria*, *Rumex* sp., *Solanum melongena*, *S. tuberosum*, *Taraxacum officinale* (Bhagat and Masoodi, 1986; Bhat *et al.*, 2011; Khan *et al.*, 2017; Bhat, 2017; Bhat and Bhagat, 2017; Bhat & Ahanger, 2018).

Predatory natural enemies in J&K/ references

Coeloptera (Coccinellidae)

Adalia tetraspilota (Hope), *Coccinella septempunctata* L., *Cheilomenes sexmaculatus*, *Hippodamia variegata* (Goe.), *Symnus* sp., *Priscibrumus uropygialis* (= *Exochomus uropygialis*), *Propylea luteopustulata* (Mulsant); Neuroptera (Chrysopidae): *Chrysoperla sillemi* (Esben-Petersen), *Chrysopa arestes*; Diptera (Syrphidae): *Episyrphus balteatus* DeGeer (Ahmad and Bhat, 1986; Bhat, 2017; Bhat and Bhagat, 2017; Khan *et al.*, 2017); Hemiptera (Anthocoridae): *Anthocoris* sp., *Orius* sp. (new records)

Parasitoid natural enemies in J&K/ references

(Hymenoptera: Braconidae: Aphidiinae): *Ephedrus plagiator* (Nees), *Trioxys sruvicola* Shujaiddin (Rishi, 1976; Shujaiddin, 1973; Khan *et al.*, 2017)

4. *Aphis rumicis* Linnaeus, 1758

Host vegetable plants in J&K/ references

Rumex sp. (Khan *et al.*, 2017)

Natural enemies and authors reporting

Predatory natural enemies in J&K/ references

Coeloptera (Coccinellidae)

Adalia tetraspilota (Hope), *Hippodamia variegata* (Goe.), *Propylea luteopustulata* (Mul.) (Khan *et al.*, 2017).

Parasitoid natural enemies in J&K/
references: not known

***Aphis spiraecola* (Patch, 1914)**

Aphis spiraecola is commonly known as
spirea aphid.

Host vegetable plants in J&K/ references

Cucumis sativus (Khan *et al.*, 2017)

Natural enemies and authors reporting

Predatory natural enemies in J&K/ references

Coeloptera (Coccinellidae)

Adalia tetraspilota, *Coccinella septempunctata*, *H. dimidiata*, *Hippodamia variegata* (Goe.); Neuroptera (Chrysopidae): *Chrysoperla z. sillemi* (Khan *et al.*, 2017)

Parasitoid natural enemies in J&K/ references

(Hymenoptera: Braconidae: Aphidiinae): *Aphidius matricariae* Haliday (Stary and Bhagat, 1978; Khan *et al.*, 2017)

Tribe-Macrosiphini Wilson, 1910

***Acyrtosiphon pisum* Harris, 1776**

Host vegetable plants in J&K/ references

Phaseolus sp., *Pisum sativum* Linn (Ahmad and Bhat, 1986; Bhagat, 1986, 2012; Bhat *et al.*, 2011; Khan *et al.*, 2017; Bhat and Ahanger, 2018)

Predatory natural enemies in J&K/ references

Coeloptera (Coccinellidae)

Adalia tetraspilota (Hope), *Hippodamia variegata* (Goe.); Diptera (Syrphidae):

Episyrphus balteatus, *Melanostoma univittatum* (Ahmad and Bhat, 1986; Bhat *et al.*, 2011; Bhat and Bhagat, 2017)

Parasitoid natural enemies in J&K/ references

(Hymenoptera: Braconidae: Aphidiinae): *Aphidius eglanteriae* (Bhagat, 2008); *Aphidius smithi* Sharma and Subbarao (Takada and Rishi, 1980); *Trioxys Trioxys complanatus* Quilis (Bhagat, 2008).

***Aulacorthum solani* (Kaltenbach, 1843)**

Host vegetable plants in J&K/ references

Hibiscus esculentus (Okra) (khan *et al.*, 2017)

Predatory natural enemies in J&K/ references

Coeloptera (Coccinellidae)

Adalia tetraspilota (Hope), *Coccinella septempunctata*, *Hippodamia variegata* (Goe.) (khan *et al.*, 2017).

Parasitoid natural enemies in J&K/ references

(Hymenoptera: Braconidae: Aphidiinae): *Aphidius* sp. (khan *et al.*, 2017).

***Brachycaudus helichrysi* (Kaltenbach, 1843)**

Brachycaudus helichrysi is commonly known as green peach aphid.

Host vegetable plants in J&K/ references

Brassica oleracea (Khan *et al.*, 2017)

Predatory natural enemies in J&K/ references

Coeloptera (Coccinellidae)

Adalia tetraspilota (Hope), *Coccinella*

septempunctata L., *Hippodamia variegata* (Goe.), *Propylea luteopustulata*; Neuroptera (Chrysopidae): *Chrysoperla sillemi* E. & P. (Khan *et al.*, 2017)

Parasitoid natural enemies in J&K/ references

(Hymenoptera: Braconidae: Aphidiinae): *Aphidius matricariae* Haliday (Khan *et al.*, 2017)

***Brachycaudus rumexicolens* (Patch, 1917)**

Host vegetable plants in J&K/ references

Rumex sp. (Khan *et al.*, 2017)

Predatory natural enemies in J&K/ references

Coeloptera (Coccinellidae)

Adalia tetraspilota, *Calvia punctata* (Mul.), *Hippodamia variegata* (Goe.); Neuroptera (Chrysopidae): *Chrysoperla sillemi* E. & P. (Khan *et al.*, 2017)

Parasitoid natural enemies in J&K/ references: not known

***Brevicoryne brassicae* (Linnaeus, 1758)**

It is commonly known as cabbage aphid.

Host vegetable plants in J&K/ references

Brassica oleracea (Linn.), *Brassica oleracea* var. *acephella*, *Brassica o.* var. *botrytis*, *B. oleracea* var. *capitata*, *B. o.* var. *kashmiriana*, *Brassica oleracea* var. *gongylodes* (Ahmad and Bhat, 1986; Bhagat, 1986, 2012; Zaz, 2001; Pandey *et al.*, 2006; Khan *et al.*, 2009, 2017; Bhat *et al.*, 2011; Bhat, 2017; Bhat & Bhagat, 2017; Bhat and Ahanger 2018).

Predatory natural enemies in J&K/ references

Coeloptera (Coccinellidae)

Adalia tetraspilota (Hope), *Cheilomenes sexmaculata*, *Coccinella septempunctata*, *Hippodamia variegata* (Goe.), *Propylea luteopustulata* (Mul.); Diptera (Syrphidae): *Episyrphus balteatus*, *Sphaerophoria scripta* (Bhagat and Lone, 1984; Ahmad and Bhat, 1986; Khan *et al.*, 2009, 2017; Bhat, 2017; Bhat and Bhagat, 2017; Khan *et al.*, 2017)

Parasitoid natural enemies in J&K/ references

(Hymenoptera: Braconidae: Aphidiinae): *Aphidius matricariae* Haliday, *Diaeretiella rapae* (M'Int) (Rao *et al.*, 1969; Bhagat and Amad, 1991; Stary & Bhagat, 1978; Bhagat, 1986; Bhat, 2008; Bhat *et al.*, 2017; Bhagat and Ahmad, 1991)

***Cavariella aegopodii* Scopoli 1763**

Host vegetable plants in J&K/ references

Daucus carota (Bhat, 2017; Bhat and Ahanger, 2018)

Predatory natural enemies in J&K/ references

Diptera (Syrphidae): *Episyrphus balteatus* (Bhat and Bhagat, 2017)

Parasitoid natural enemies in J&K/ references: Not known

***Hyadaphis coriandri* (Das, 1918)**

Host vegetable plants in J&K/ references

Coriandrum sativum (Corriander) (Khan *et al.*, 2017)

Predatory natural enemies in J&K/ references

Coeloptera (Coccinellidae)

Adalia tetraspilota (Hope), *Calvia punctata* (Mul.), *Coccinella septempunctata* L., *Hippodamia variegata* (Goe.); Neuroptera (Chrysopidae): *Chrysoperla z. sillemi* E. & P. (Khan *et al.*, 2017)

Parasitoid natural enemies in J&K/ references

(Hymenoptera: Braconidae: Aphidiinae): *Aphidius matricariae* H. (Khan *et al.*, 2017)

***Lipaphis* (*Lip.*) *erysimi* (Kaltenbach, 1843)**

Host vegetable plants in J&K/ references

Brassica napus (Linn.) (= *Brassica campestris* L.), *Brassica campestris* L., *Brassica napus* (Bhagat, 1986; Bhat *et al.*, 2011; Bhagat, 2012; Bhat and Ahanger, 2018)

Predatory natural enemies in J&K/ references: Coeloptera (Coccinellidae)

Adalia tetraspilota (Hope), *Calvia punctata*, *Cheilomenes sexmaculata*, *Coccinella septempunctata* L., *Coccinella undecimpunctata*, *Hippodamia variegata* (Goe.), *Oenopia congoblata*; Diptera (Syrphidae): *Sphaerophoria scripta*, *Melanostoma univittatum*, *Ischiodon scutellaris*, *Metasyrphus corolae*, *Metasyrphus confractor*, *Paragus seratus*, *Betasyrphus serarius*, *Syrphus sp.* (Bhagat and Lone, 1984; Ahmad and Bhat, 1986; Bali, 1987; Bhagat and Matta, 2002; Khan *et al.*, 2009; Bhat, 2017; Bhat and Bhagat, 2017)

Parasitoid natural enemies in J&K/ references

(Hymenoptera: Braconidae: Aphidiinae): *Diaertiella rapae* (Rao *et al.*, 1969; Rishi, 1976; Bhagat, 1986; Bhagat and Ahmad, 199; Bhat *et al.*, 2017)

***Lipaphis pseudobrassicae* (Davis, 1914)**

Host vegetable plants in J&K/ references

Brassica oleracea *Brassica juncea* *Brassica oleracea var capitata*, *B. rapa*, *Raphanus sativa* (Khan *et al.*, 2017)

Predatory natural enemies in J&K/ references: Coeloptera (Coccinellidae):

Adalia tetraspilota (Hope), *Coccinella septempunctata* L., *Propylea luteopustulata* (M.), *Hippodamia variegata* (Goe.); Neuroptera (Chrysopidae): *Chrysoperla sillemi* E.& P. (Khan *et al.*, 2017)

Parasitoid natural enemies in J&K/ references

(Hymenoptera: Braconidae: Aphidiinae): *Lysaphidus erysimi* Stray (Khan *et al.*, 2017)

***Myzus persicae* (Sulzer, 1762)**

Myzus persicae is commonly known as green peach aphid.

Host vegetable plants in J&K/ references

Capicum annum, *Cucurbita maxima* *Lycopersicon esculentum* *Solanum melongena*, *Solanum tuberosum* (Bhat, *et al.*, 2011; Bhagat, 2012; Khan *et al.*, 2017; Bhat and Ahanger, 2018)

Predatory natural enemies in J&K/ references

Coleoptera (Coccinellidae)

Adalia tetraspilota (Hope), *Cheilomenes sexmaculata*, *Coccinella septempunctata*, *Hippodamia variegata* (Goe.), *Propylea luteopustulata* (Mul.), *Scymnus* sp.; Diptera (Syrphidae): *Episyrphus balteatus* (Bhat, 2017; Bhat and Bhagat, 2017; Khan *et al.*, 2017); Hemiptera (Anthocoridae): *Anthocoris* sp., *Orius* sp. (new record) ; Neuroptera (Chrysopidae): *Chrysopa* (*Chrysoperla carnea*) Stephens (Bhat, 2008a)

Parasitoid natural enemies in J&K/ references

(Hymenoptera: Braconidae: Aphidiinae): *Aphidius matricariae* Haliday (Bhagat, 2008), *Aphidius colemani* Viereck, *Toxares zakai* Shujauddin (Shujauddin, 1973)

***Macrosiphum euphorbiae* (Thomas, 1878)**

Host vegetable plants in J&K/ references

Solanum melongena (khan *et al.*, 2017)

Predatory natural enemies in J&K/ references

Coleoptera (Coccinellidae)

Adalia tetraspilota (Hope), *Coccinella septempunctata*, *Hippodamia variegata* (Goe.) (khan *et al.*, 2017); Hemiptera (Anthocoridae): *Anthocoris* sp. (new record)

Parasitoid natural enemies in J&K/ references

(Hymenoptera: Braconidae: Aphidiinae): *Trioxys kahmirensis* (Takada) (Takada and Rishi, 1980; Khan *et al.*, 2017)

***Semiaphis heraclei* (Takahashi, 1921)**

Host vegetable plants in J&K/ references

Daucus carota (Bhagat, 1986, 2012; Bhat and Ahanger, 2018)

Predatory natural enemies in J&K/ references: Not known

Parasitoid natural enemies in J&K/ references

(Hymenoptera: Braconidae: Aphidiinae): *Aphidius salicis* (Bhagat, 1986; Bhagat, 2008)

Sub-family-Lachinae Herrich-Schaeffer, 1854

The tribe- Tramini

***Protrama penecaea* Stryon 1998**

Host vegetable plants in J&K/ references

Helianthus tuberosus (Artichoke) (Khan *et al.*, 2017)

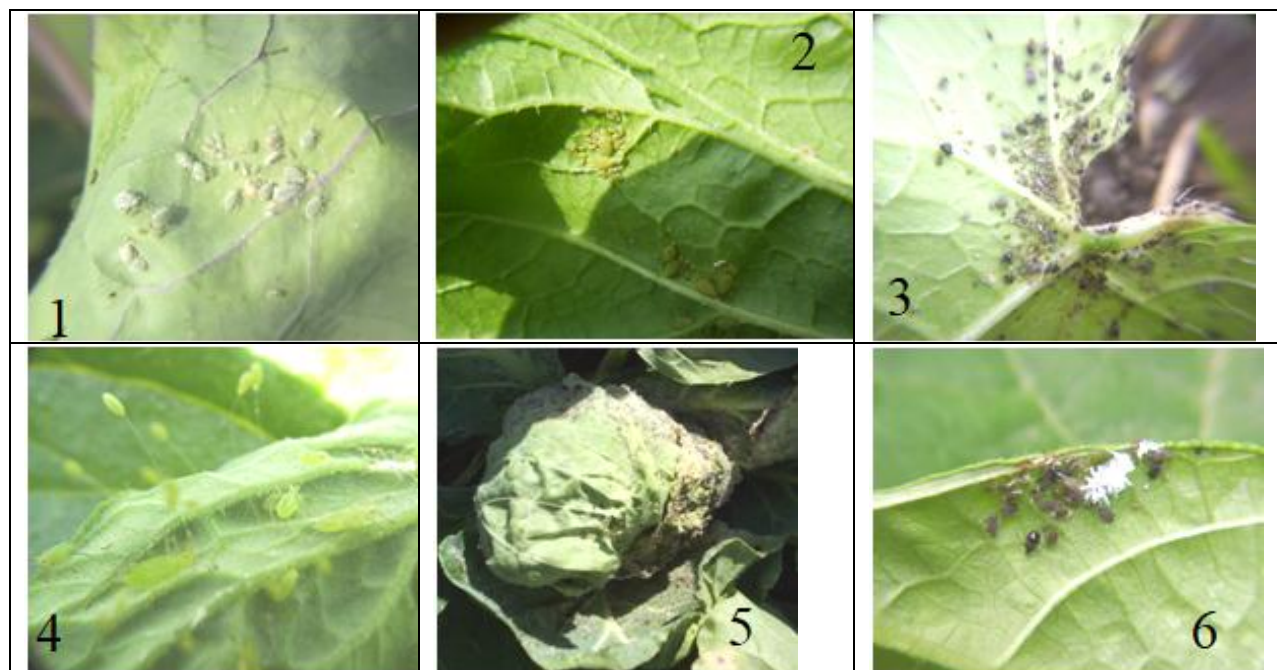
Predatory natural enemies in J&K/ references

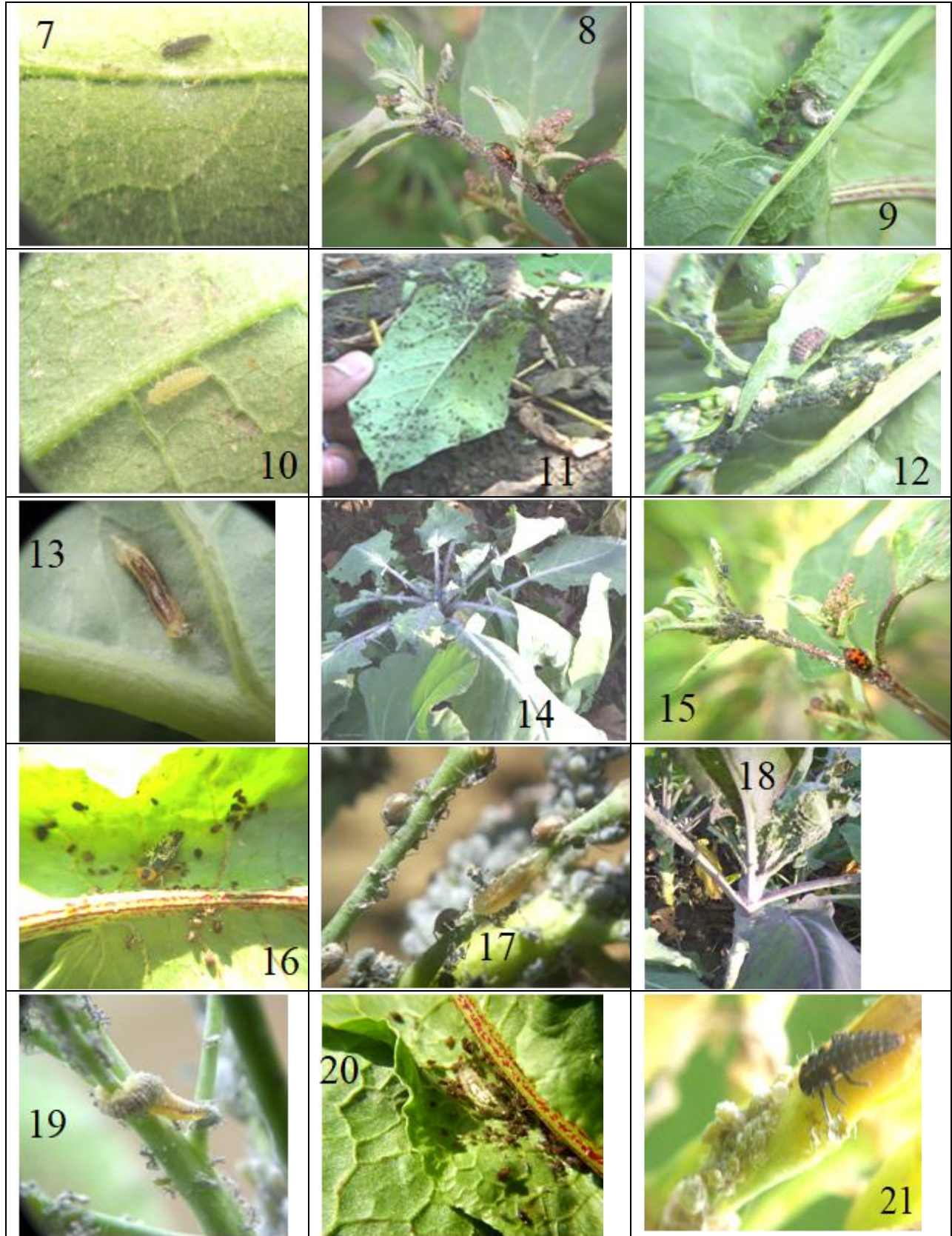
Coleoptera (Coccinellidae): *Adalia tetraspilota* (Hope), *Calvia punctata* (Mul.), *Hippodamia variegata* (Goe.); Neuroptera (Chrysopidae): *Chrysoperla* z. *Sillemi* E. & P. (Khan *et al.*, 2017). Parasitoids / references: Not known.

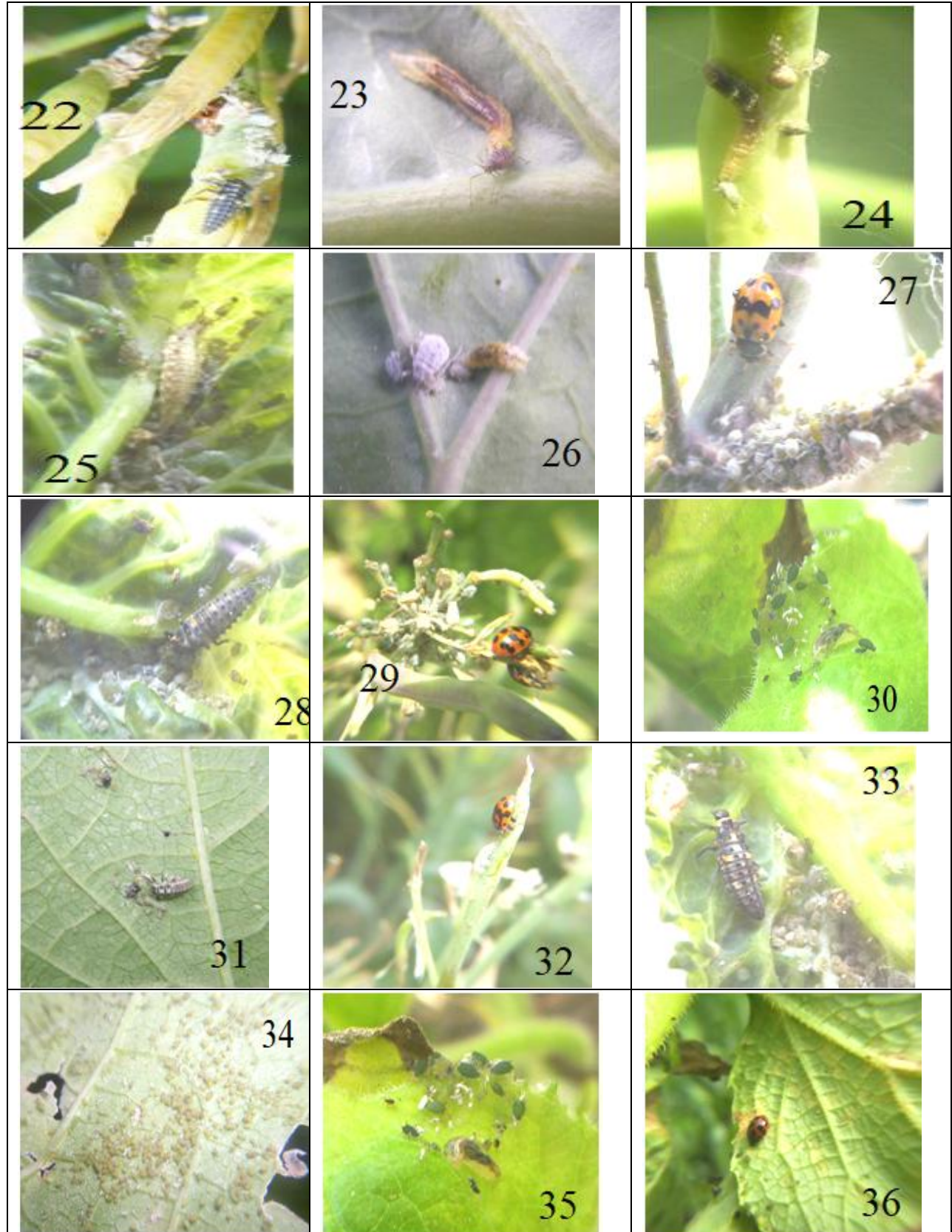
Table.1 Species richness of Aphids and their natural enemies on vegetable crops in J&K

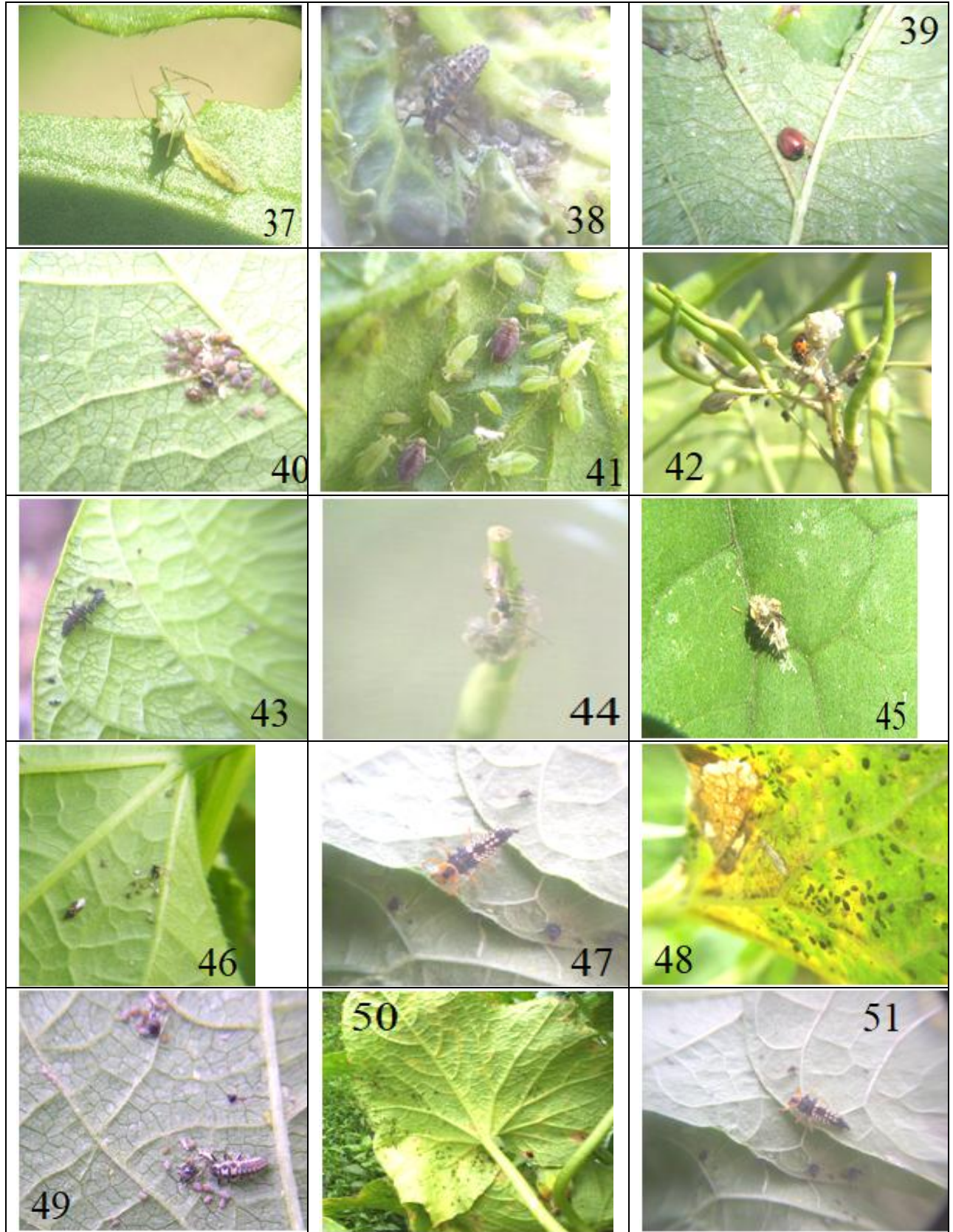
Aphids			Natural enemies															
			Predators				Parasitoids											
2	No. of Aphid sub-families (Aphidiine, Lachinae)		4	No. of Insect predator Orders (Coleoptera, Diptera, Hemiptera Neuroptera)	5	No. of Insect predator families (Anthocoridae, Cecidomyiidae, Chrysoperilidae, Coccinellidae, Syrphidae,	25	No. of insect predator Genera (see sec. c in the text)	29	No. of insect predator species (See Sec. c in the text)	1	No. of Insect parasitoid orders (Hymenoptera)	1	No. of insect parasitoid families (Braconidae: Aphidiinae)	7	No. of insect parasitoid Genera (see sec. d in the text)	17	No. of insect parasitoid species (see sec. d in the text)
	10	No. of Aphid Genera (see sec. b in text)																
	18	No. of Aphid species (see sec. b in the text)																

Legends to Figures (Photo credit Deen Mohd.)









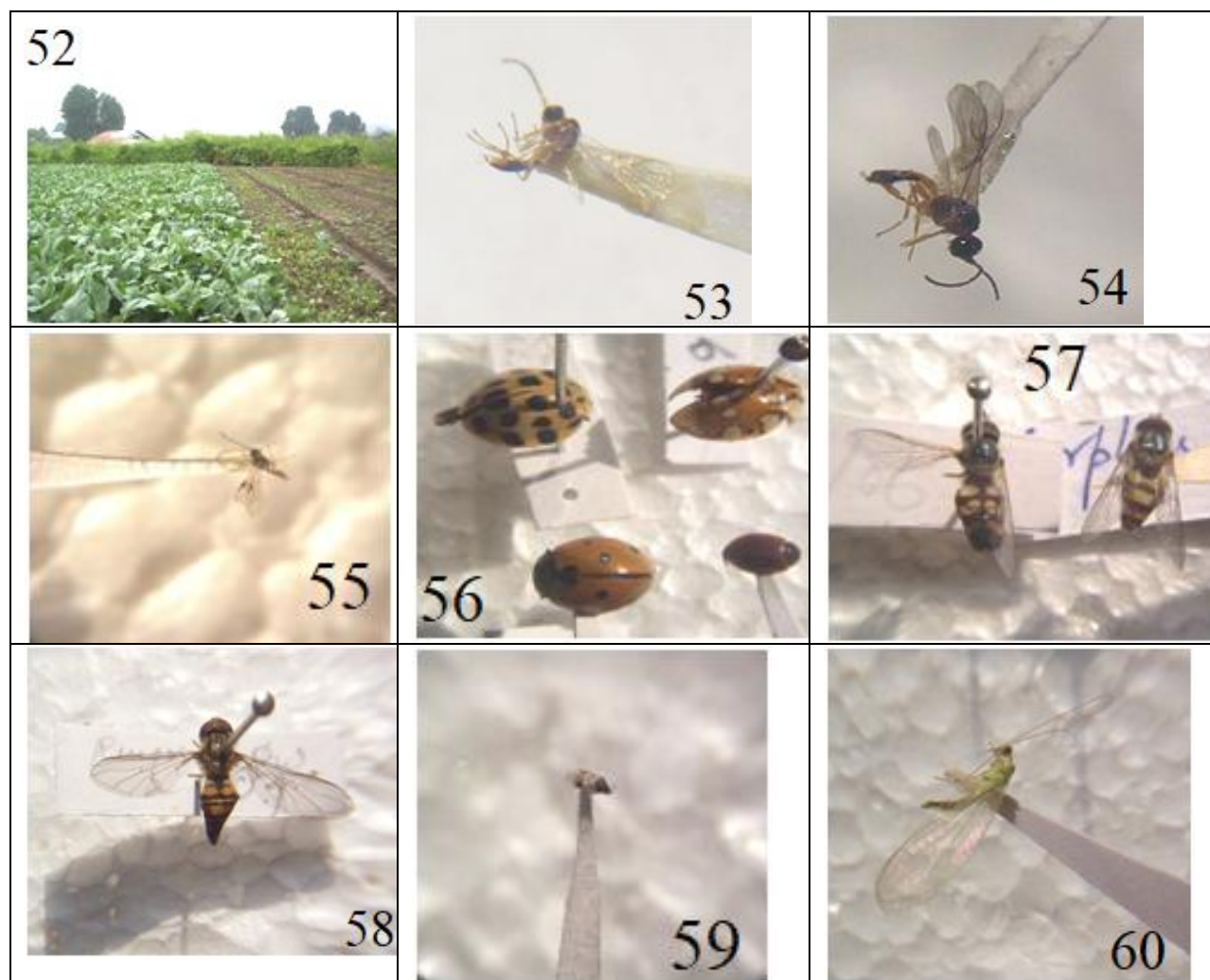


Fig.1-5, 11, 12, 14, 18, 34, 40, 48, 50 Aphid infestations on different vegetable plants in Kashmir
Fig.6, 7, 9, 10, 16, 21, 22, 28, 31, 33, 38, 43, 45, 47, 49, 51 Larvae of coccinellid beetles (predators) feeding on aphid pests on different vegetable plants in Kashmir
Fig.13, 17, 19, 20, 23, 24, 26, 30, 35, 37 larvae of syrphid flies (predators) feeding on aphid pests on different vegetable plants in Kashmir
Fig.8, 15, 27, 29, 32, 36, 39, 42 adult coccinellid beetles (predators) feeding on aphid pests on different vegetable plants in Kashmir
Fig.25 larva of *Chrysoperla* feeding on aphids in vegetable fields in Kashmir
Fig.51 Predatory bug *Anthocoris* sp. recovered from vegetable fields while feeding on aphids in Kashmir
Fig.53 Parasitoid *Trioxys* sp. recovered from aphids in Kashmir
Fig.54-55 Parasitoid *D. rapae* recovered from aphid *B. brassicae* in Kashmir
Fig.57 Adult syrphid fly *Metasyrphus* sp. (Syrphidae), predator of aphids, collected after rearing of its larvae in Kashmir
Fig.60 Adult *Chrysoperla* recovered after rearing of its larvae on aphids in Kashmir



Fig.61 Adult syrphid fly *Sphaerophoria scripta*, predator of aphids, collected after rearing of its larvae in Kashmir

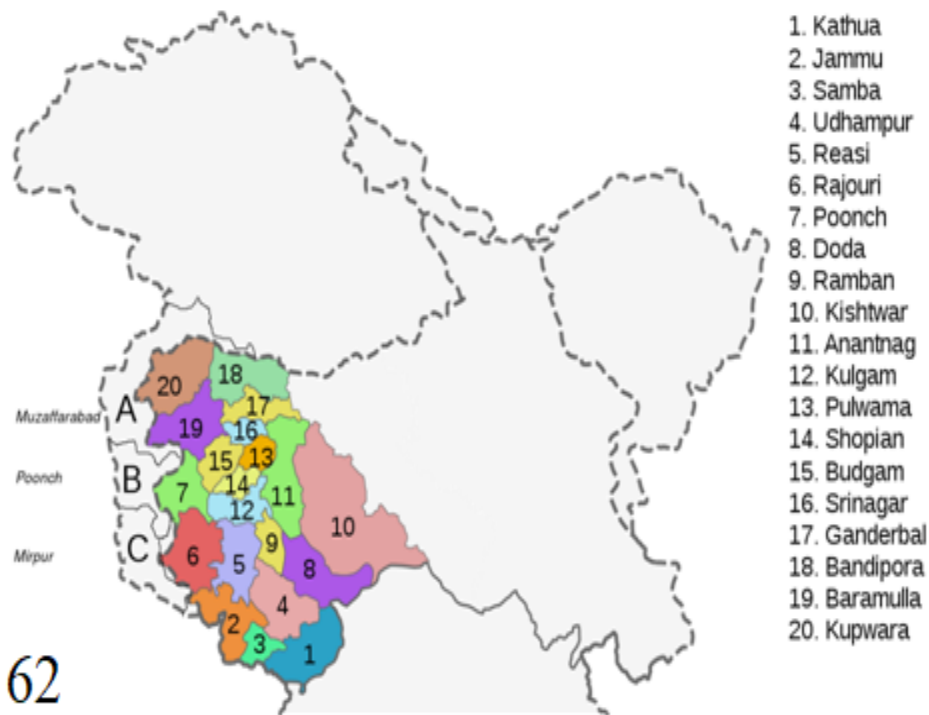


Fig.62 Map of J&K showing study areas (Districts) in Kashmir

Since, the complete knowledge of aphids is crucial for understanding their pest nature and for formulating a proper control and management strategy in order to mitigate their damage on vegetable crop ecosystems, So, the present work, based on field and literature survey provided a base line data pertaining aphid pests and their natural bio-control agents in vegetable ecosystems in J&K. Based on this work, it is understood that there are

large number of aphid species (at least 18) which attack various types of vegetable crops in this region.

However there are even more diverse kinds of natural bio-control agents of these aphid pests represented by 17 species of parasitoids and 29 species of predators, which mitigate the damage caused by aphids in vegetable ecosystems of this region.

Thus, it is concluded that it is important to preserve and conserve the existing diversity of such natural enemies so that efforts of integrated control program, if planned for vegetable crop ecosystems in this region, can materialize and be successful.

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