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Study of distribution and morphological characters of aphids occurred in major *Kharif* and *Rabi* crop ecosystems from the region, Akola, Maharashtra, India

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Abstract
The present investigation entitled "Aphid diversity and associated predatory fauna in different crop-ecosystems of Akola" was carried out during the year 2017-2018. During study period total 1810 specimens of aphids and 205 specimens of predatory fauna associated with aphids collected from various *Kharif* and *Rabi* crops agro-ecosystem. Pictorial key was developed during the course of investigation based on morphological characters facilitates to identify the aphid fauna from different crop-ecosystems up to species level. The aphids, *Aphis gossypii* (Glover) was found in three crops viz. Cotton, Okra and Sunflower. *Aphis craccivora* species was found on Cowpea, Bean and Citrus crops. The results of this study indicate that both *Aphis gossypii* (Glover) and *Aphis craccivora* have a wide range of host and vertical distribution from low to high. *Hysteroneura setariae* species of aphids were first time recorded for this locality. Pictorial key developed during the investigations based on morphological characters is useful in insect pest management. This investigation may helpful to the farmers as well as researchers and students for awareness, identification, distribution and characterization studies of the different aphids species found in various kharif and rabi crop agro-ecosystem in Akola district of Maharashtra.

Keywords: Aphids, ecosystem, *Kharif*, *Rabi*

Introduction
Aphids also known as plant lice are small sap-sucking insects and members of the super family Aphidoidea (Order: Hemiptera). Globally, over 4400 species of aphids are known to attack many plant species of cultivated and wild flora (Favret, 2016) [6]. An aphid is important pests of different crops all over the world, (Ibrahim, 1994) [8]. About 1000 species are injurious to crops throughout the world (Singh *et al*., 2015) [21]. World over about 5000 species of aphid have been described and of these, some 450 species have colonized food and fibre crops (Emden *et al*., 2017) [5]. In India, A. gossypii infest about 569 species belonging to 103 plant families (Singh *et al.*, 2014) [20].

An aphid causes both direct and indirect damage to the plants. The direct damage is caused by feeding on phloem sap, thereby adversely affecting plant vigour, quality of the harvested product and yield. In addition to this, the aphids also cause indirect damage by vectoring about 80 different kinds of virus diseases in economically important crops, e.g. cotton leaf roll virus, banana mosaic virus, papaya mosaic virus, papaya ring spot virus, citrus tristeza virus, passion fruit woody virus, etc. (Miyazaki, 2001) [14].

Even though aphids are the key pests of many important crop; however, they are extremely important hosts for a number of parasitoids, predators and an essential meal for numerous other insects, as well as birds (Singh *et al*., 2000) [22]. Aphid's different species was studied by previous workers *viz*. (Jarosik *et al*., 2003) [9] studied 11 aphid species in India from wheat crop. Report of (Saxena, 1978) [18] stated that an aphid's species *Aphis craccivora* Koch was mainly feed on several crops like cowpea, groundnut, pigeon pea, green gram, black gram, soybean, broad bean and pea which hamper the market value of several crops.

Insect fauna of Vidharbha region is unexplored and undescribed. Largest part of insect fauna are still waiting to describe and as well as to identify. However, due to lack of resource presence, expertise in taxonomical work there is certain limitations to carry out such type of investigation.

Therefore, the Study of morphological characters of prevailing aphids in Akola vicinity having more significant and also broad scope so as to classify the Aphids fauna into proper place. Nevertheless, efforts have been made to explore and carryout the characterization studies of aphids having economic importance. The present study would more informative and will act as ready reckoners to IPM workers to decide management tactics involving biocontrol of this important pest.

Materials and Methods

i. Study areas: The present study "Study of morphological characters of Aphids and Associated Predatory fauna occurred in Major Kharif and Rabi Crop Ecosystems from the region, Akola, Maharashtra, India" was carried out at Department of Entomology, Post Graduate Institute Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola during 2017-18.

ii. Collection of specimens: Aphids as well as its associated predatory fauna were collected periodically from kharif and Rabi crops of Akola, Maharashtra between July and December 2017. Aphid's collection done by cutting infested plant parts along with aphid colony in small plastic containers (12x7 cm) or polyethylene bags. The Sometimes the aphids were collected directly from the plants using a camel hairbrush. Aspirators are among the most effective and easiest to use devices for collecting winged aphid. The beetles were collected as per procedure adopted by (Sharma, 1987) [19], (Joshi and Sharma, 2008) [10] which included the use of sweep nets, insect collection tubes and jars depending upon the habitat. Adults of coccinelids beetles were collected randomly by "Sweep Sampling Method" as per (Gadakar *et al*., 1990) [7], aspirator and hand picking depending upon height of Kharif crop. Different aphid predators such as green lacewing, syrphid fly of these adults were collected by using sweep net and grub and maggot of these predators were transfer into small plastic containers (12x7 cm). Predatory spiders were collected in small plastic containers (12x7 cm) containing 70% ethyl alcohol with the help of sweep net. Insect collecting net made up of wooden handle with collecting bag made up of ordinary mosquito net cloth was used for collecting insects. The insect were collected by sweeping the net on the crop.

iii. Preservation of specimens: The specimens were then processed for identification for which they were killed in killing jar and spread and pinned properly. The aphids thus collected were preserved in 70% ethyl alcohol in small plastic vials (2.5 ml). Each vial was furnished with data on locality, host plant, date and collector's name on thin paper using a soft (2B) pencil. The label was inserted into each of the vials. Spiders specimens were preserve by using 70% ethyl alcohol. Collected specimens were preserved, labeled, and characterization study was carried out in insect biosystematics laboratory ICAR-NPIB Project of Entomology Department, Post Graduation Institute, Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola during 2017-18.

iv. Identification of specimens: The aphids and some predators were sent to NBAIR, Bengaluru for identification. Spiders specimens collected during the course of investigations have been identified upto generic level by Dr. M.V. Shirbhate, Asstt. Professor of Zoology, Shankarlal Khandelwal Arts, Science and Commerce College, Akola. By adjusting the magnifying Knob, zooms, characters were studied under microscope so as aphid's specimen were categorize up to species level with the help of taxonomic key as per (Blackman and Eastop, 2006) [4]. Genus level identification of all predatory fauna which were collected during the present investigations was carried out in NPIB lab, Department of Agril. Entomology, Post Graduate Institute Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.

v. Integrated Identification Key to the aphid species

Based on the taxonomic key given by (Blackman and Eastop, 2006) [4], the aphid specimens collected during the present investigation have been characterized and categorized into Species of Aphididae (Order: Hemiptera, Sub-order: Sternorrhyncha).

Results

A. Distribution of Aphids: During the study period total 12194 specimens of aphids collected from various *Kharif* and *Rabi* crops agro-ecosystem from Akola vicinity. The collected data revealed that total seven species of aphids were collected from different crop agro-ecosystem from Akola vicinity. The aphids, *Aphis gossypii* (Glover) was found in three crops *viz*. Cotton, Okra and Sunflower. *Aphis craccivora* species was found on Cowpea, Bean and Citrus crops. The results of this study indicate that both *Aphis gossypii* (Glover) and *Aphis craccivora* have a wide range of host and vertical distribution from low to high. The aphids species namely *Rhopalosiphum maidis*, *Aphis* (*Taxoptera*) *citricidus*, *Hysteroneura setariae*, *Lipaphis erysimi*, *Uroleucon* compositae has a single host plant and found on sorghum, citrus, wheat, mustard, safflower, respectively. Results stated that among the various species of aphids collected from various kharif and rabi crops Aphis craccivora collected maximum specimens during study period. Recorded observation also stated that maximum aphid's specimens collected from citrus crop agro-ecosystem during observation period (Table 1).

Table 1: Distribution of Aphid's species found on various kharif and Rabi crops ecosystems from the region, Akola, Maharashtra, India.

Crops	Aphids Species							Number of specimen collected
	Aphis gossypii (Glover)	***Aphis craccivora***	***Rhopalosiphum maidis***	***Aphis (Taxoptera) citricidus***	***Hysteroneura setariae***	***Lipaphis erysimi***	***Uroleucon compositae***	
Cotton	+	-	-	-	-	-	-	1300
Cowpea	-	+	-	-	-	-	-	1430
Okra	+	-	-	-	-	-	-	892
Sorghum	-	-	+	-	-	-	-	535
Bean	-	+	-	-	-	-	-	1683
Citrus	-	+	-	+	-	-	-	3238
Sunflower	+	-	-	-	-	-	-	271
Wheat	-	-	-	-	+	-	-	37
Mustard	-	-	-	-	-	+	-	72
Safflower	-	-	-	-	-	-	+	2736
Total	2463	5416	535	935	37	72	2736	12194

B. Morphological characterization of aphid species: *Aphis gossypii* (Glover) distinguishing morphological characters of *A. gossypii* encounter during *kharif* and *rabi*, 2017 is described as below. Most of the nymphs are light green mottled with darker green. Adults are dark green, almost black but adults produced in crowded colonies at high temperature found very pale yellowish to almost white.

1. *Aphis gossypii* (Glover): Body length 1.508 mm. Antennae 6 segmented with 1.106 mm in length, all segments are pale or dusky. Antennal tubercles weakly developed. ANT III 0.247 mm in length. ANT VI consisting of base length 0.093 mm and processus terminalis 0.297 mm in length. Rostrum tip reach upto 3rd coxa on ventral side of body. Ultimate rostral segment 0.107 mm in length. Siphunculi are dark with 0.260 mm. cauda pale or dusky in contrast siphunculi, caudal length 0.125 mm which is more than caudal base width 0.086 mm. Cauda bearing 5-7 hairs. Hind tibia is pale for more than half of length. Second segment of Hind tarsus are 0.088 mm in length (Fig 1).

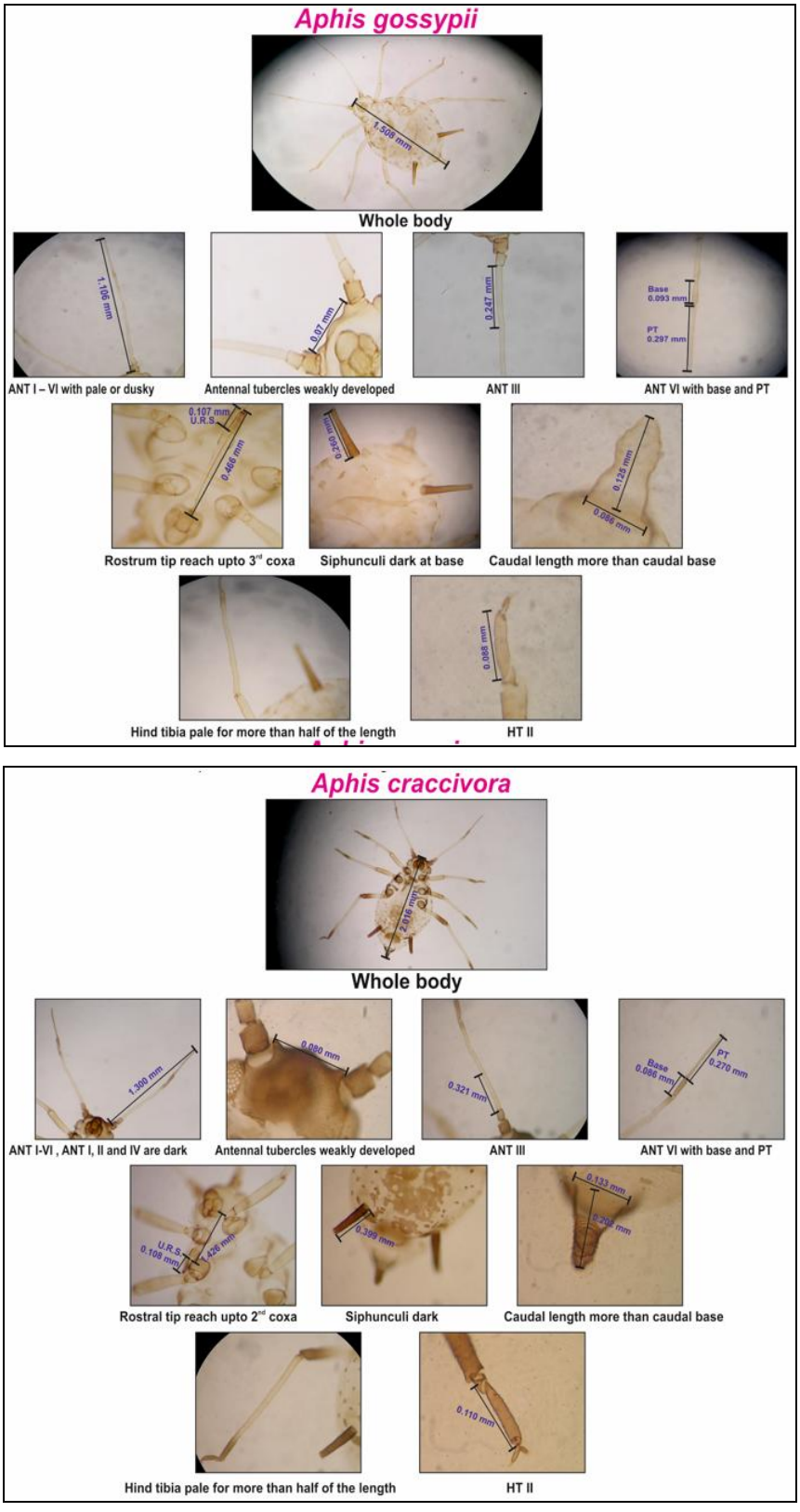
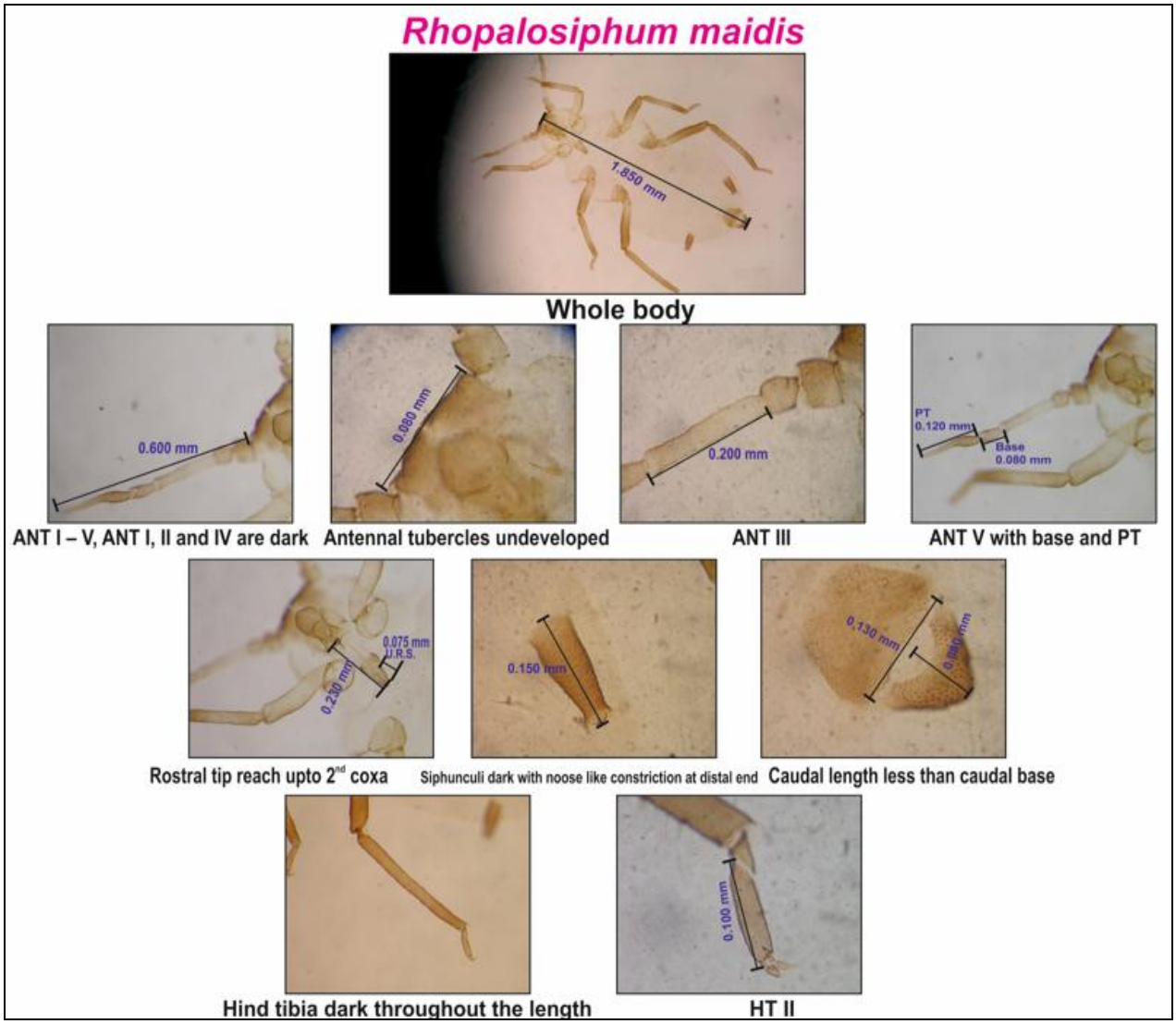


Fig 1. Morphological characterization of *Aphis gossypii* and *Aphis craccivora*

2. *Aphis craccivora* (Koch): Results sated that various distinguishing morphological characters of *A. craccivora* encounter during *kharif* and *rabi*, 2017. Nymphs are lightly dusted with wax and light brownish, adults are shiny black. Body length 2.016 mm. Antennae 6 segmented with length are 1.300 mm, ANT I, II and VI are dark. Antennal tubercles weakly developed. ANT III 0.321 mm in length. ANT VI consisting of base length 0.086 mm and processus terminalis 0.270 mm in length. Rostrum tip reach upto 2nd coxa on ventral side of body. Siphunculi are dark with 0.399 mm. Ultimate rostral segment 0.108 mm in length. Caudal length 0.202 mm which is more than caudal base width 0.133 mm. Cauda bearing 4 hairs. Hind tibia is pale for more than half of length. Second segment of Hind tarsus 0.110 mm in length (Fig 1).

3. *Rhopalosiphum maidis* (Fitch): Our recorded observation stated various distinguishing morphological characters of *R. maidis*. Nymphs and adults are olive green to bluish green in colour. Body length 1.850 mm. Antennae 5 segmented with length are 0.600 mm and ANT I, II and V are dark. Antennal tubercles undeveloped. ANT III is 0.200 mm. ANT V consisting of base length 0.080 mm and processus terminalis 0.120 mm. Rostrum tip reach upto 2nd coxa on ventral side of body. Ultimate rostral segment are 0.075 mm. Siphunculi are dark, broad at base with noose like constriction at distal end and length are 0.150 mm. Hind tibiae are dark throughout the length. Caudal length 0.080 mm which is less than caudal base width 0.130 mm. Second segment of Hind tarsus are 0.100 mm (Fig 2).



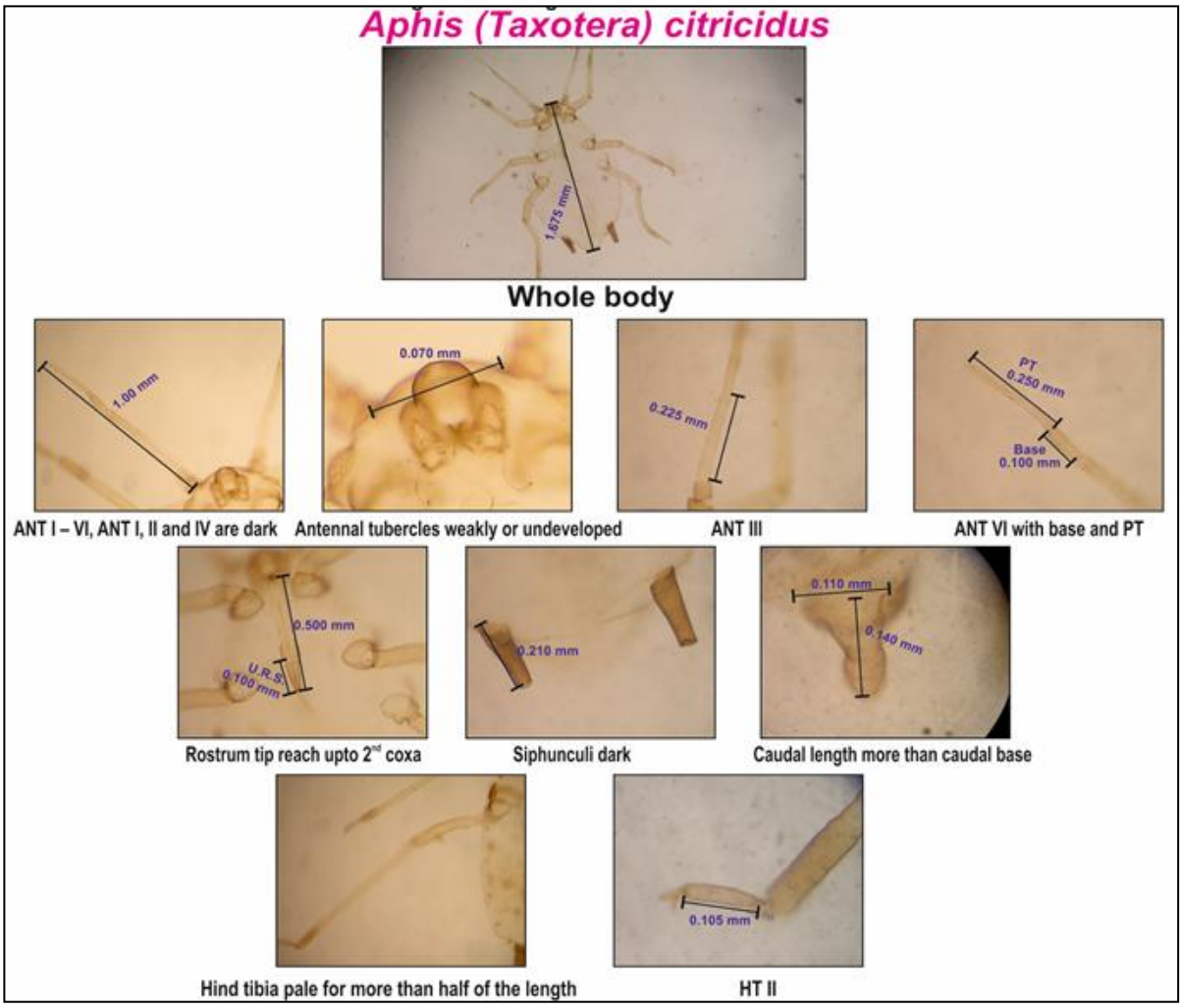
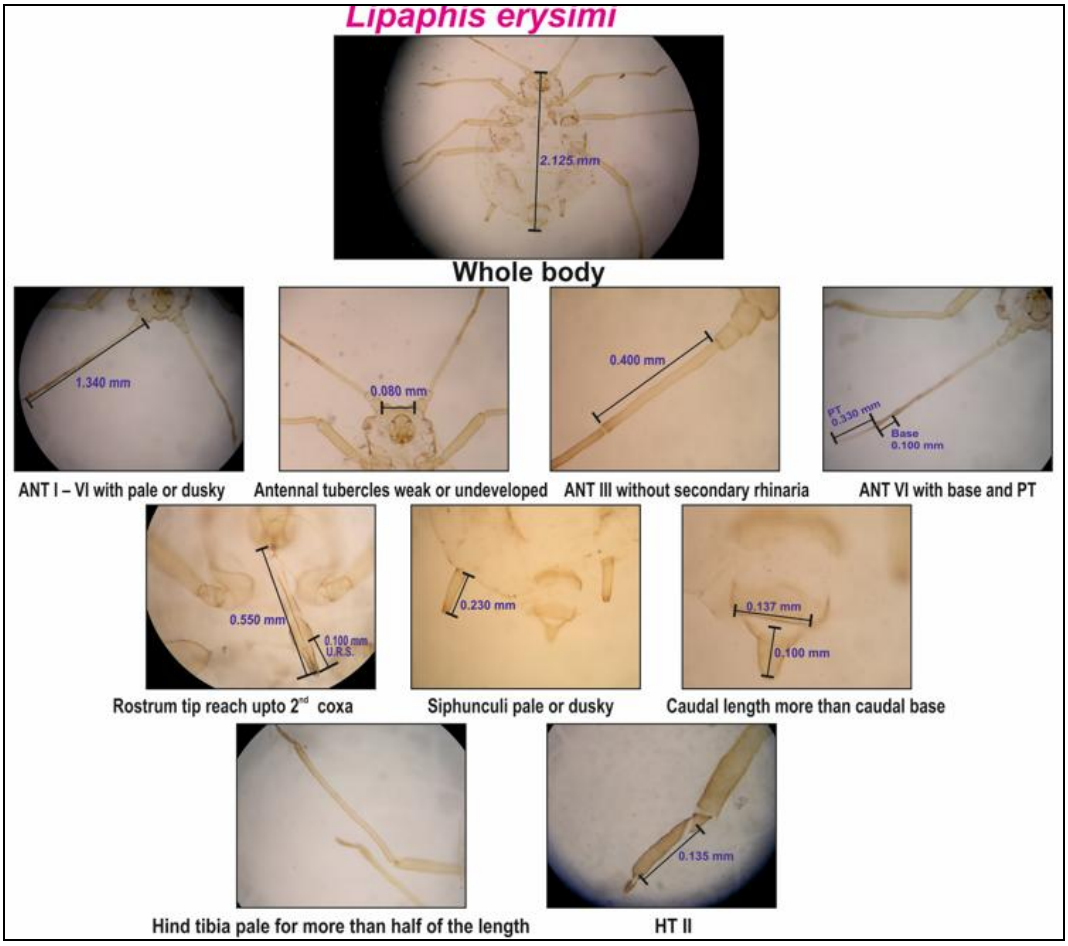


Fig 2: Morphological characterization of *Rhopalosiphum maidis* and *Aphis (Taxoptera) citricidus*

4. *Aphis* (*Taxoptera*) *citricidus* (Kirkaldy): The observation stated that *A.* (*Taxoptera*) *citricidus* posses various distinguishing morphological characters *viz.* Nymphs are brown, dark green and adults are dark green to shiny black in colour. Body length 1.675 mm. Antennae is 6 segmented and length is 1.00 mm and ANT I, II and VI are dark. Antennal tubercles weak or undeveloped. ANT III are 0.225 mm. ANT VI consisting of base length 0.100 mm and processus terminalis 0.250 mm. Rostrum tip reach upto 2nd coxa on ventral side of body. Ultimate rostral segment are 0.100 mm. Siphunculi are dark and length are 0.210 mm. Caudal length 0.140 mm which is more than caudal base 0.110 mm. Hind tibiae are pale for more than half of length. Second segment of Hind tarsus are 0.105 mm (Fig 2).

5. *Lipaphis erysimi* (Kaltenbach): Distinguishing morphological characters of *L. erysimi* encounter during *rabi* 2017 is as described below (Plate 14). Nymphs and adult are yellowish green, grey green with a white wax bloom. Body length 2.125 mm. Antennae is 6 segmented and lengths are 1.340 mm and all antennal segments are pale. Antennal tubercles weak or undeveloped. ANT III is 0.400 mm without secondary rhinaria. ANT VI consisting of base length 0.100 mm and processus terminalis 0.330 mm. Rostrum tip reach up to 2nd coxa on ventral side of body. Ultimate rostral segment are 0.100 mm. Siphunculi are pale or dusky with length 0.230 mm. Caudal length 0.100 mm which is less than caudal base 0.137 mm. Hind tibiae are pale for more than half of length. Second segment of Hind tarsus are 0.135 mm (Fig 3).

6. *Hysteroneura setariae* (Thomas): Various distinguishing morphological characters of *H. setariae* encounter during *rabi* 2017 is as described below (Fig 3). Nymphs and adults are brown colour Body length 1.825 mm. Antennae is 6 segmented and length are 1.500 mm and all antennal segments are dark. Antennal tubercles well developed. ANT III are 0.330 mm with 16 secondary rhinaria are present. ANT VI consisting of base length 0.100 mm and processus terminalis 0.610 mm. Rostrum tip reach upto 2nd coxa on ventral side of body. Ultimate rostral segment are 0.150 mm. Siphunculi are more dark at base with length 0.217 mm. Caudal length 0.162 mm which is more than caudal base 0.112 mm. Hind tibiae are pale for more than half of length. Second segment of Hind tarsus are 0.090 mm (Fig 3)



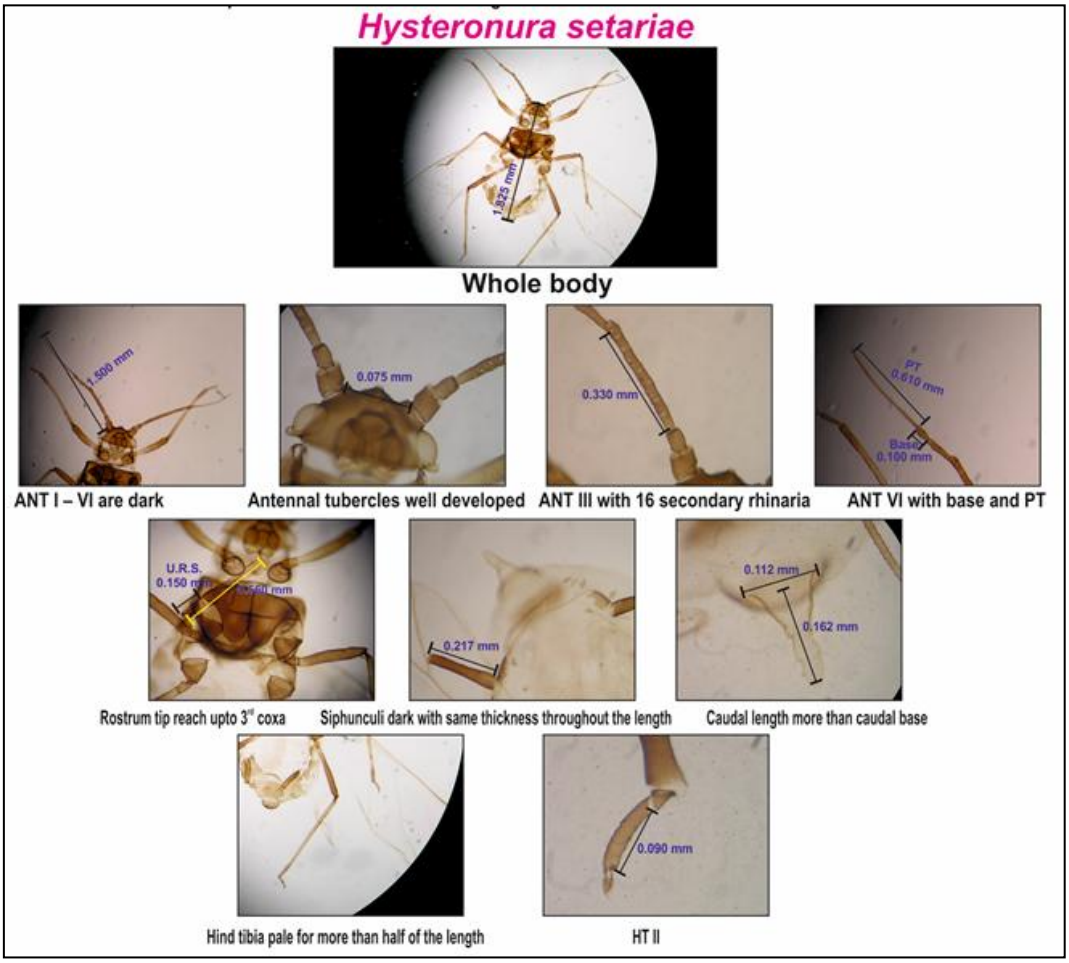


Fig 3: Morphological characterization of *Lipaphis erysimi* and *Hysteroneura setaria*

7. *Uroleucon compositae* (Theobald): Distinguishing morphological characters of *U. compositae* encounter during *rabi* 2017 is as described below (Plate 15). Adults are medium to large sized, broadly spindle shaped, almost black in colour. Body length 3.950 mm. Antennae is 6 segmented and lengths are 3.750 mm and all antennal segments are dark. Antennal tubercles well developed. ANT III is 1.070 mm with more than 45 secondary rhinaria are present. ANT VI consisting of base length 0.130 mm and processus terminalis 0.920 mm. Rostrum tip reach upto 3rd coxa on ventral side of body. Ultimate rostral segment are 0.200 mm. Siphunculi are more dark at base with length 1.200 mm. Caudal length 0.630 mm which is more than caudal base 0.340 mm. Hind tibiae are pale for more than half of length. Second segment of Hind tarsus are 0.160 mm.

Discussion

A. Distribution of Aphids: Our results showed various types of aphid's species found in various kharif and Rabi crops agro-ecosystem. Total of seven species of aphids were found during investigation at near Akola vicinity. Our results revealed that in *kharif* and *Rabi* agro-ecosystem various aphids' species *viz*. *Aphis gossypii* (Glover), *Aphis craccivora* (Koch), *Rhopalosiphum maidis* (Fitch), *Aphis* (*Taxoptera*) *citricidus* (Kirkaldy), *Lipaphis erysimi* (Kaltenbach), *Hysteroneura setariae* (Thomas) and *Uroleucon compositae* (Theobald) were recorded in Akola vicinity. Our results are in line with results of (Kale *et al.*,2020) [11] who reported diversity study of aphids and associated predatory fauna occurred in major *Kharif* and *Rabi* crop ecosystems of Akola; however, his data revealed that total seven species of aphids and sixteen species of predators were collected from different crop agro-ecosystem. In aphids seven species *viz*; *Aphis gossypii* (Glover), *Aphis craccivora* (Koch), *Rhopalosiphum maidis* (Fitch), *Aphis (Taxoptera) citricidus* (Kirkaldy), *Lipaphis erysimi* (Kaltenbach), *Hysteroneura setariae* (Thomas) and *Uroleucon compositae* (Theobald). Similarly, (Nagrare *et al.*, 2019) [15] reported that cotton aphid, *Aphis gossypii*, is a major sap sucking insect of cultivated cotton, *Gossypium sp.* and also investigated the effects of temperature on the biological parameters of *A. gossypii* by fitting different non-linear models. Similar work done by (Naikwadi *et al.*,2020) [17] who studied spatial distribution of important predatory fauna found in *Kharif* agro-ecosystem from the region, Akola, Maharashtra, India.

B. Morphological characterization of aphid species

Our results stated that various distinguishing morphological characters of seven species of aphids encounter during *kharif* and *rabi*, 2017. Based on the typical morphological characters as defined in the taxonomic key the microscopic colour images of prominants morphological characters of different species of aphids are depicted in the form of pictorial key. For easy identification and classification of aphid fauna important and typical morphological characters of concerned species have been studied (Fig 1-3) and depicted in pictorial form facilitated comparative studies to differentiate aphids at species level.

Similarly, study of morphological characters of important predatory fauna found in *kharif* Agro-ecosystem from the region, Akola, Maharashtra, India done by (Naikwadi *et al.*, 2019) [16]. Our results are based on the taxonomic key given by (Blackman and Eastop, 2006) [4], the specimen collected during the present investigation have been characterized and categorized into Species (Order: Hemiptera, Family: Aphididae).

1. *Aphis gossypii*: Rostrum tip reach upto 3rd coxa on ventral side of body (BL 1.508 mm, Cauda pale or dusky in contrast SIPH, cauda bearing 5-7 hairs, ANT PT/BASE 3.11. R IV+V long than 1.25X HT II, SIPH 1.59X cauda. SIPH 0.08X ANT III).

2. *Aphis craccivora*: Rostrum tip reach upto 2nd coxa on ventral side of body (BL 2.016 mm. cauda as dark as siphunculi, bearing 4 hairs. ANT PT/BASE 3.3. R IV+V less 1.25X HT II, SIPH 2X cauda. SIPH 1.23X ANT III).

3. *Rhopalosiphum maidis*: Hind tibiae pale for more than half of the length: Hind tibiae are uniformly dark (BL 1.85 mm, BW 0.65 mm. Antennae 5 segmented, ANT (I-V) 0.60 mm, ANT III 0.20 mm. Rostrum Length 0.23 mm. Siphunculi dark with broad at bases and noose like constriction at distal end, siphunculi longer than1.8X cauda. Cauda length much shorter than 0.615X caudal base width).

4. *Aphis (Taxoptera) citricidus*: Siphunculi less than 0.933X ANT III: Siphunculi long than 0.933X ANT III (BL 1.67 mm, BW 0.90 mm. ANT PT 0.597X base of ANT VI. R IV+V usually 0.952X HT II, Cauda/BL 0.083, Cauda longer than 1.272X base width, SIPH dark and distally tapering).

5. *Lypaphis erysimi*: Siphunculi uniformly dark: Siphunculi mainly pale or dusky, only dark towards distal end. (Body length 2.13 mm, body width 1.30 mm. Antennae length 1.34 mm, ANT III 0.40 mm. Cauda length 0.10 mm. ANT/BL 0.630, ANT PT/Base 3.2. SIPH long than 2.3X cauda, cauda/BL 0.047).

6. *Hysteroneura setariae*: SIPH broad at base and tapering towards tip: SIPH thickness same throughout the length (BL 1.825 mm, BW 0.85 mm. Antennae dark with ANT III and ANT IV bearing 16-18 and 2 secondary rhinaria respectively, antennal processus terminalis longer than X 7.625 base of ANT VI. Cauda pale, contrasting with dark SIPH, which are longer than 1.339× cauda. Trochanto- femure suture width 0.042 mm, U.R.S./HT II 1.66).

7. *Uroleucon compositae*: ANT I is dark, but ANT II is pale or dusky, concolorous with basal half of ANT III: ANT I, II and III are dark (BL 3.95 mm, body with numerous pigmentation on dorsal side. ANT tubercle well-developed with divergent inner faces, ANT(I-VI) 3.75 mm, ANT III 1.07 mm, ANT VI 1.05 mm, ANT III and ANT IV bearing 47 and 4 secondary rhinaria respectively. R IV+V 1.25X HT II with 8 Accessory hairs. Cauda almost dark as SIPH, which are longer than 1.9X cauda, cauda with 14 hairs. Coxa dark).

Our results are in line with the results of (Stoetzel and Miller, 2001) [23] who noted taxonomic characters, usual hosts, and distribution within the United States for each species. Which were *Aphis craccivora* Koch, *Aphis fabae* Scopoli, *Aphis gossypii* Glover, *Aphis Maidiradicis* Forbes, *Hysteroneura setariae* (Thomas), *Macrosiphum euphorbiae* (Thomas), *Metopolophium dirhodium* (Walker), *Myzus persicae* (Sulzer), *Rhopalosiphum Maidis* (Fitch), *Rhopalosiphum padi* (L.), *Sipha flava* (Forbes), *Schizaphis graminum* (Rondani), and *Sitobion avenae* (Fabricius). Pictorial and dichotomous keys were prepared for each aphid species. Our results similar

to some previous workers (Kaygin *et al.*, 2008 [12]; Bhagat, 2012[3]; Ali and Mzhr, 2012) [1] which recorded various aphids species which has economic significance.
Similar observation recorded by (Ali, 2014) [2], who recorded five aphid species belong to Subfamily Aphidinae recorded: *Brevicoryne brassica* (Linnaeus), *Brachycaudus helichrysi* (kaltenbach), *Lipaphis lepidii* (Nevsky), *Lipaphis pseudobrassicae* (Davis), *Myzus persicae* (Sulzer) were recorded. Similarly, (Khan and Shah, 2017) [13] were recorded 13 species and 4 genera of aphid's recorded first time from Jammu and Kashmir based on taxonomic keys.

Conclusion
During study period total 1810 specimens of aphids collected from various *Kharif* and *Rabi* crops agro-ecosystem. During the course of investigation seven species of aphids were recorded and classify upto species level with the help of taxonomic key.
Among different species of aphids *Uroleucon compositae* and *Aphis craccivora* proved its dominance in this locality and *Hysteroneura setariae and Rhopalosiphum maidis* had low population in Akola vicinity. *Hysteroneura setariae* species of aphids were first time recorded for this locality. For the characterization of aphid fauna up to species level morphological characters *viz*; Body length, antennae length, antennal III, V and VI segment, antennal tubercles, rostrum length with ultimate rostral segment. Siphunculi, cauda, hind tibia and second segment of hind tarsus are found to be the most distinguishing characters for identification. Pictorial key developed during the investigations based on morphological characters is useful in insect pest management. This investigation may helpful to the farmers as well as researchers and students for awareness, identification, distribution and characterization studies of the different aphids species found in various *kharif* and *rabi* crop agro-ecosystem in Akola district of Maharashtra.

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