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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

MAIN PESTS OF SUBTROPICAL PLANTS AND THEIR ENTOMOPHAGOUS IN LANKARAN – ASTARA REGION

Speciality: 2413.01. – "Entomology"

Field of science: Biology

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INTRODUCTION

The relevance of the topic and the depth of the degree of its study: The non – oil field is getting more important in the development of the economy of the Republic of Azerbaijan. The agriculture is one of the fields that increase the budget because of exportation, as well as surround the demanded output of the population owing to the unique environment and geograpichal condition of the country. The biological measures on the protection of plants from pests and diseases in order to enlarge the list of export countries of citrus fruit planted in Azerbaijan should be taken more.

The insect complex whose lifecycle is related o the subtropical plants is big enough. Here, the pests include in the first group and the predators and parasitoides that can affect the number of the first group include in the second group. In the modern biology, the study of interrelations in the phytophagous – entomophagous system allows defining the correlation of both components of this system; in this case it is possible to keep the number of the pests in a secure level. It also helps to minimize the usage of chemicals or to refuse them totally in the protection of flora. The economically – useful and ecologically-protective measures of subtropical plants on the pests led to the increase of the productivity, as well as, its quality.

The subtropical climate of our country – Lankaran – Astara region has extremely rich flora. The citrus plants and tea plantations are planted in the large areas of Lankaran – Astara region and this sphere is increased. The protective measures for the pests are one of the essential issues in order to get high productivity from the subtropical plants. In this regard, the purpose and objectives set for the implementation of work is urgent.

The purpose and objectives of the research. The discover of species of pests in subtropical plants, the study of bioecological characteristics of economically important species and the determination of damage rate of them, the evaluation of productivity of parasitoids regulated the number of pests.

1. To determine the species of the pests of subtropical plants, the economical importance and spread over the territory of various taxon representatives in Lankaran – Astara region.

2. To determine the food plants of the pests, to detect specialized and common pest species on various food plants.

3. To study some bioecological characteristics of ecomically important species.

4. To determine the damage rate of dominant species.

5. To determine the species composition of entomophagous.

6. To evaluate the productivity of entomophagous for its quality in the regulation of the pests.

Research methods. The collection of material was carried out by generally accepted entomological methods: by entomological netting and was composed of shaking of trees and shrubs, collection of insects (imago, larvae) by hand, excavator. Insects' behavior was also observed, and their numbers and damage to various organs of the plant (leaves, branches, flowers, fruits) were calculated. 5 stationary areas were selected in each region. 5-10 model plants were taken in each stationary area. The cuts were kept between layers of filter paper or cotton. When preparing the microscopic preparation, the samples from the cuts were immersed in 70% alcohol solution. When the citrus mealybugs are collected, they are immediately immersed in 70% alcohol solution.

The main points put forward for defense

1. The taxonomic structure of the pest complex of subtropical plants in the Lankaran – Astara region was studied, trophic connections and their adaptation to food plants were analyzed.

2. Distribution, morphology, biology, ecology, phenology, food plants, frequency of occurrence of 10 most common species were studied, symptoms of infection were found in plants.

3. 6 of the 10 species of entomophagous are parasitoids and 4 are Coleoptera predators.

4. During an experimental study of the behavioral response of a parasitoid to a change in the number of pests, was determined that it corresponds functional reactions of 1st type. The parasitoid pest can be effective at both low and high levels of population density.

Scientific novelty of the research: For the first time, the pests of subtropical plants, the species compositions and damage rate of them have been complexly studied in Azerbaijan, Lankaran – Astara

region. As a result of the study of behavioral responses against the density of the pest population of parasitoids, more effective species have been detected and the importance of them have been defined in the regulation of the number of main pests. For the first time, 4 species of pests - *Pseudococcus viburni* Signoret 1875, *Aonidiella auranti* (Mask,1879), *Ceroplastes destructor* Newstead, (1917), *Pseudococcus calceolariae* (Maskell, 1879) have been recorded for the fauna of Azerbaijan; 10 species - *Ps.viburni*, *A.auranti, C.destructor, Ps.calceolariae, Aphis punicae* (Pass.), *Aonidiella citrina* (Craw), *Chrysomphalus dictyospermi* (Morgan), *Lepidosaphes beckii* (Newman), *Lepidosaphes granati* (Koroneos), *Euzophera bigella* (Zeller) have been recorded for the subtroical plants of Lankara-Astara fauna. 10 species (6 species of parasitoids, 4 species of predators) of entomophagous have been detected during the studies.

The behavioral response of *Coccophagus lysimnia* parasitoid to the change of number of *Coccus hesperidum* L. pest has been experimentally studied.

The molecular genetic study of *Coccophagus sp*ecies paratisoid detected in th fauna of Azerbaijan have been conducted by means of sequencing of DNA barcode field of molecular identification cytochromoxidase I (COI – 5) mitochondrial genus.

The internal structure of *Dialeurodes citri* Ashmed (Citrus whitefly) that is a dominant pest of citrus plants has been studied for the first time.

The toretical and practical significance of the research:

The mathematical assessment of damage rate of hazardous pests of the subtropical plants in Lankaran – Astara economic region, the determination of mass flying period of them will lead to prepare the protective measures for pests and to define the danger rate for the productivity. Information obtained for the productivity of parasitoids will allow getting a ratio for keeping the number of pests at the economically secure level in the pest – parasitoid system.

Approbation and application of the study: The main results of research work were discussed in the following international and republic scientific – practical conferences.

– International Research and Practice Conference "Biotechnological Production Systems and Appilcation of Agriculture Biologization" dedicated to the 45th anniversary of the ETİ "Biotechnics"Odessa, 2016

– International Artvin symposium 2018 held in Artvin, (Turkey, 2018)

– International Scientific and Practical Conference Ecosystem Services and Management of Natural Resources (Tyumen, 2019)

– Protection of ecology and life activities: achievements, problems Republic Conference, (Sumgayit, 2020)

Based on research materials, 11 articles (in journals included in national and international index databases) and 3 theses reflecting the main content of the dissertation were published in the Republic and abroad.

Name of the organization where the dissertation work is performed. The research work was carried out in the "Center of Applied Zoology" of the Institute of Zoology of ANAS.

The volume and structure of dissertation. The total volume of the dissertation consists of 200 pages of computer writing and 202293 characters. Dissertation consists of 2 parts – main part and appendices. The main part consists of Introduction, 6 Chapters, Conclusions, Practical Implications, and the list of used literature (222) (Introduction - 9017, 6 chapters - 187820, Conclusions - 4010, Practical Implications - 1446). The main part contains 1 graph, 5 histograms, 23 tables, 9 equations and 25 figures. The appendices contain original photos of the pest species taken by the author (Figure 1 - 24).

CHAPTER I. Research area and physical – geographical characteristics

The research work was carried out in Lankaran geographical region located in the southern – west of our republic. Lankaran region is bordered with Iran from west and south, with the Caspian Sea from east. Lankaran physical – geographical region is surrounded by Jalilabad, Masalli,

Lankaran and Astara districts. Lankaran physical-geographical region is 606.9 thousand ha; consist of 7.0 % of the area of our republic[1].

CHAPTER II. Review of literature

In this chapter, the review of the literature datas on the study of pests of subtropical plants and their entomophagous complex in various regions of the world was given. The studies carried out in the neighborhood countries of Azerbaijan create a special interest for us. A general review to the literature information given related to the study shows that pest complex of subtropical and citrus plants especially in Lankaran-Astara region was not studied enough.

CHAPTER III. Material and methods of study

The study has been conducted in 2017 - 2021. The expeditions in field (natural) condition and agrocenosis were carried out in southern – east part of Azerbaijan, Lankaran – Astara region during the entomological monitorings in 2017 - 2019.

The samples collected during the expeditions in 2020 - 2021 were elaborated in laborator condition. In order to study an impact of parasitoid on the population density of pests, the experience series were set at the Center for Applied Zoology of the Institute of Zoology of ANAS in 2020 - 2021[2].

The internal structure of Citrus whitefly was researched in the electronic microscope of in 2021. The digital photo files were obtained by ITEM software and Veleta 2 × 2 k CCD camera.

The experimental works consisted of experimental series to study the behavioral responses against the population density of pests of parasitoids. Conduction condition and time of experiments and the number of female individuals were standardized. Regression equation is: y = a + вх a and в parameters and stability are calculated with the following formula:

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[1] Заповедники СССР. Заповедники Кавказа / общ.ред. В.Е.Соколов. – Москва: – 1990. –с. 1 – 365

[2] Фасулати, К.К. Полевое изучение наземных беспозвоночных / К.К.Фасулати. – Москва: Изд – во Высшая школа, – 1971. – с. 123 – 160.

$r = \Sigma xy - M_x \bullet M_y \bullet n / C_x \bullet C_y \bullet \Delta r = C_y / C_x \sqrt{1-r^2}/n-2$

$b = r \bullet C_y / C_x \; a = M_y - b \; M_x \; \Delta a = b \; C_x \; \Delta b = rb / \Delta r$

During the research work, as a result of amplification and secventation of genues fragment of I cytochromoxidaza, species relation of 1 representative of *Coccophagus species of Aphelinidae* family was specified. COI Barcode fragments were amplified by means of Polymer chain reaction (PCR).

The fragments of COI genus were amplified by universal primers: Forward primer LCO1490 (5' – GGTCAACAAATCATA AAGATATTGG – 3') and reverse primer: HCO2198 (5' – TAA-ACTTCAGGGT – GACCAAAAAATCA – 3').

CHAPTER IV. Pests' complex of subtropical plants of Lankaran – Astara region

4.1. Factors that affect to the formation of phytophagous complex

Factors that affect to the formation of phytophagous complex: 1.abiotic factors - climate, relief; 2.biotic factors – useful entomofauna; 3. Anthropogenic factors, introduction and planting materials, intensivity of construction.

All these factors are deeply related to each other, have impact together and cause to the formation of characteristic phytophagous complex.

4.2. Dominant phytophagous in subtropical agrocenosis

During our reaserches in Lankaran – Astara region, in 2017 - 2019, subtropical plants, 3 classification, 4 groups, 10 families and 16 species were observed. Table 1 gives information on the occurrence of pests belonging to the various families in different plants. As observed in Table, 24 species (89%) belong to Hemiptera families.

12 dominant species among them belong to *Diaspididae* family, scale insects. One types beetles (*Curculionidae*, *Scarabaeidae*) and lepidopteran families (*Papilionidae, Gracillariidae, Pyralidae).*

Polyxenus lagurus is a single species that is not a pest among the pests indicated in Table 1. However, this species is included into a table. It can be explained that *Polyxenus lagurus* is an indicator species of *Ps.viburni* pest. Therefore, it is included into a table as an indicator species.

Table 1

Taxonomic structure of subtropical pests' complex of Lankaran-Astara region of Azerbaijan

Taxon	Total	Subtropical plants											Infected plant organs
		Citrus plants				loquat	kiwi	feijoa	pomegranate	persimmon	tea	bay laurel	
		Lemon	mandarin	orange	kumquat								
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Group: Coleoptera	**2**												
Family: *Curculionidae*	1												
1.Pantomorus fulleri Perkins			+					+					Leaves
Family: *Scarabaeidae*	1												
2.Tropinota hirta (Poda)			+										Flowers
Group: Hemiptera	**24**												
Family: *Aleyrodidae*	1												
3.Dialeurodes citri (Ashmead)		+	+	+	+					+			Leaves

Continued in Table 1

Family: *Aphididae*	2												
4.Toxoptera theaecola (Buckt)											+		Leaves, buds
5.Aphis punicae (Pass.)**						+			+				Flowers, Fruit
Family: *Coccidae* –	4												
6.Ceroplastes destructor (Newstead)*		+	+	+	+	+		+		+		+	Branches, buds, leaves
7. Ceroplastes japonicus (Green)			+		+	+		+		+		+	Branches, buds, leaves
*8.Coccus hesperidum (*L.)		+	+	+	+								Branches, buds, leaves, fruit
9.Pulvinaria aurantii (Cockerell)		+	+	+	+	+						+	Branches, buds, leaves, fruit
10. Pulvinaria floccifera (Westwood)		+	+	+	+						+	+	Branches, buds, leaves, fruit
Family: *Diaspididae*	12												
11. Aonidiella citrina (Craw)**		+	+	+		+							Buds, leaves, fruit

Continued in Table 1

*12. Aonidiella auranti (*Mask)*		+	+	+								+	Buds, leaves, fruit
*13.Aspidiotus nerii (*Bouché)		+	+	+	+							+	All organs of plant
*14. Aspidiotus destructor (*Siqnorett)		+	+	+	+						+	+	Branches, buds, leaves
*15.Chrysomphalus dictyospermi (*Morg)**		+	+	+	+			+				+	Branches, buds, leaves, fruit
*16.Lepidosaphes beckii (*Newman)**		+	+	+	+								Branches, buds,
*17. Lepidosaphes gloveri (*Packard)		+	+	+									Branches, buds,
18. Lepidosaphes granati (Koroneos)**									+				Branches, buds,
19.*Lopholeucaspis japonica* (Cockerell)										+		+	Branches, buds, leaves, fruit
20.*Parlatoria ziziphi* (Lucas)		+	+		+								Branches, buds, leaves

Continued in Table 1

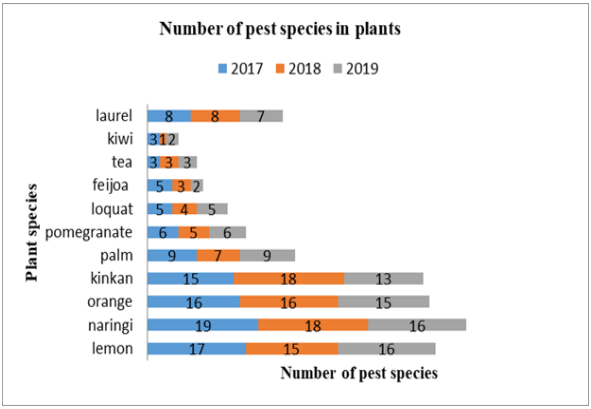
21.*Pseudaulacaspis pentagona* (Targ. – Tozzetti)							+						Branches, leaves,
22.*Diaspidiotus perniciosus* (Comstock)										+			All organs of plant
Family: *Margarodidae*													
23.*Icerya purchasi* (Maskell)		+	+	+	+			+		+	+		Branches, buds, leaves, fruit
Family: *Pseudococcidae*	3												
24. *Pseudococcus calceolariae* (Mask) *		+	+	+	+								Branches, buds, leaves,
25. *Pseudococcus comstocki* (Kuwana)		+	+	+	+			+		+	+	+	All organs of plant
26. *Pseudococcus viburni (Signoret)**		+	+	+	+					+			Branches, buds, leaves, fruit
Group: *Lepidoptera*	**2**												
Family: *Papilionidae*	1												
27. *Papilia demoleus* L.			+										Flowers

Continued in Table 1

Family:***Gracillariidae***													
28.*Phyllocnistis citrella* Stainton		+	+	+	+								Leaves
Family: *Pyralidae*	1												
29.*Euzophera bigella* (Zeller)**									+				Leaves, flowers, Fruit
Class Arachnida Family:*Tetranychidae*	**2**												
30.*Tetranychus urticae* (Koch)	1						+		+	+			Branches, buds, leaves, fruit
31. *Tuckerella.sp.*	1						+			+			Leaves, Fruit
Class *Diplopoda*	1												
Family: *Polyxenidae*	1												
32.*Polyxenus lagurus*	1							+	+	+			Branches, buds,fruit

Note: the species with "*" were recorded as the first time for Azerbaijani fauna and with "**" were recorded as the pest of subtropical plants in Lankaran – Astara region for the first time.

Adaptation to the host plant. The analysis of pests of subtropical plants in region showed that most of the pests were recorded in citrus plants: 17 species – lemon, 19 species- mandarin orange, 16 species – orange, 15 species – kumquat were observed. In other subtropical plants, the number of pests was as following: min. 3 species - tea and kiwi, max. 9 species – persimmon were observed (histogram 1.). As the studies were carried out in stationary fields, and the planting field and density of trees were almost same, that's why the number of pests didn't differ more. In comparison with other plants, few numbers of pests on kiwi are explained so that cultivation of these plants begins in recent years and the pest complex is not yet completely formed.

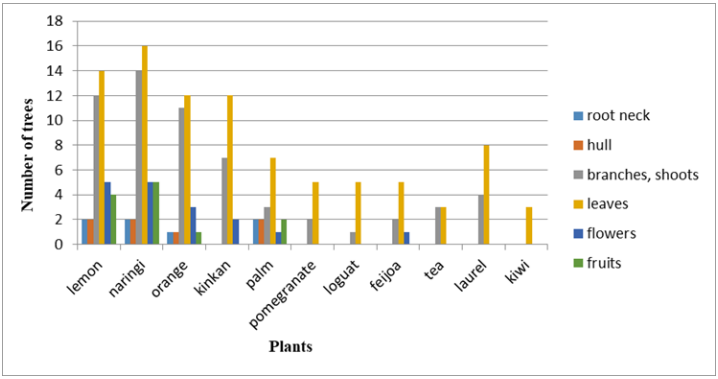


Histogram 1. Distribution of pests for the host plant

Most of the pest species recorded in subtropical plants is polyphagous organisms (95%). Most of them pass through other plants to subtropical plants. However, there are monophagous species such as for example *Lepidosaphes granati* among the pests.

The pests are distributed unequally according to the damaged parts (organs) of plants (histogram 2).

In histogram 2, a number of plants are indicated in ordinate axis, and the species of pests are indicated on any parts (organ) of the plant in abscissa axis. All organs of the plants getinfected then only a few pests are observed in the root of the plant (*Ps. comstocki*).



Histogram 2. Distribution of subtropical plant pests for the plant parts (organs)

The pests mainly damage the leaves and new buds of the plant. Thus, citrus whitefly (*D.citri*) is observed only on the leaves of the plant. The pests (*A. nerii*, L.beckii, *L.gloverii*, *L. japonica*, *Ps.calceolariae*, *Ch.dictyospermi*, *C.hesperidum*) are observed nearly in all fruit of the citrus plants. *T. hirta* species are observed in the flowers of mandarin orange and pomegranate, but *P. fulleri* species are observed in the leaves of mandarin orange (Diagram 1).

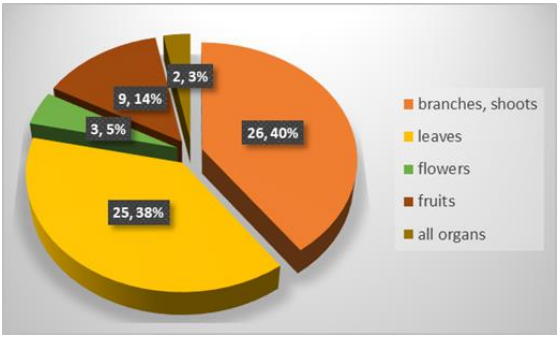


Diagram 1. A number of pest species recorded in different organs of plants

Among the pests, most of species have been recorded in the leaves, branches, buds and fruit of the plants. Information on the number of the recorded pests in various organs of plants is given in diagram 1.

As indicated, most species of pests have been recorded in the leaves, new buds and branches of plant.

The activity period of pests is different. According to our observations, activity period of subtropical pests occurs in summer-spring months in contrast to other fruit plants. Among these pests, *T.theaecola, A. punicae* aphid species are observed in spring and summer months. The flying of adult individual of Citrus whitefly (*D.citri*) is followed after hibernation in early April. The peak of the acitivity period of most species of scale insects happens in autumn months. The most of yearly-active species are indicated in diagram 2. One of the main reasons for a large number of yearly-active species is that many of the subtropical plants are evergreen.

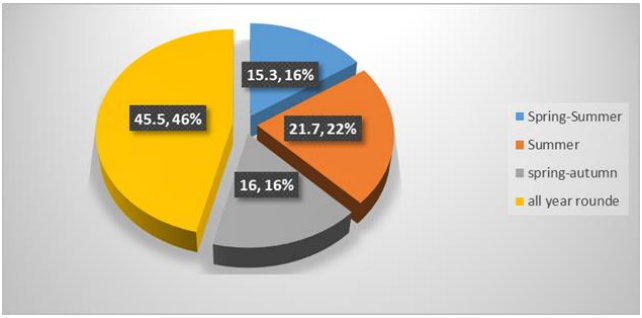
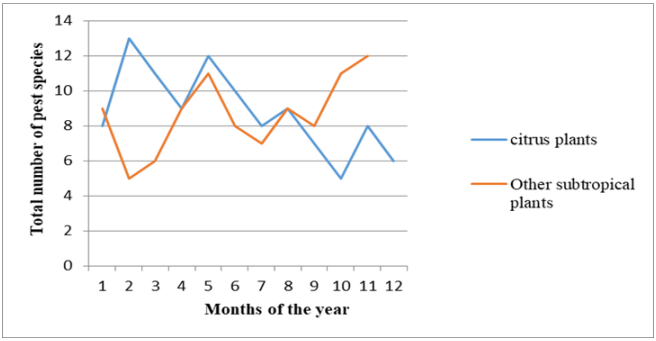


Diagram 2. The distribution of pest species according to their seasonal activity. Let look through each pest complex species of researched plants.

4.3. Comparative analysis of pest complex of citrus and other subtropical plants

The comparative analysis of pest complex of 4 species of citrus plants (lemon, mandarin orange, orange, and kumquat) prevailed in Lankaran – Astara economies and other 7 subtropical plants (persimmon, pomegranate, loquat, feijoa, tea, kiwi, bay laurel) were performed. All the studied citrus plants belong to the same family and are evergreen, but other subtropical plants belong to different families and are deciduous or evergreen. Also, distribution of the studied plants of pest species was not same. However, 8 species of pests on citrus

plants, 10 species on subtropical plants were recorded. Total number of the pests found in citrus and other subtropical plants was 14 species. A large number of pests infecting both groups of plants and the rapid infection of plants with pests are explained by the density of plants in the area and the presence of a large number of polyphagous among the pests. The compliance of certain plants that are typical for the species of monophagous and polyphagous pests belongs to *T. theaecola* və *L.granati* specie. It should be noted that a number of species exposed to the dangerous quarantine are quite enough among the proper pests and they contains 18,7 % of total number: *D.citri*, *I.purchasi*, *P.comstocki*, *L. japonica*, *Ps.pentagona*, *D. perniciosus* belong to these species. As scale, false oleander scale and scale insects have protective layer, the preventive measures don't have much affect to their number. Dominant pest species of citrus plants belong to *D.citri*, *Ch.dictyospermi*, *Ps.comstocki*, *L.beckii*, *and L.gloveri*. These species become in trophic relation with evergreen citrus plants in all seasons and grow the whole year. According to results of our studies, the pests dominated for other studied subtropical plants are: *Ps.comstocki*, *P.floccifera* species. These species have a very high frequency.



Histogram 3. Change of total number of pest species in citrus and subtropical plants in various months of a year

The change of total number of pests on plants studied in various months of a year is indicated as a chart in histogram 3. It is obvious from the chart that a maximum indicator of the total number of pests in plants showed in February, but in other subtropical plants the least

number of pests were recorded. However, the opposite is observed in autumn, so there are few indicators in subtropical plants, but the highest indicators in other subtropical plants in autumn.

Such a change of the number of pests, biological and phonological characteristics of these species are related to the number of species that are in the development period the whole year and have hibernation phases.

CHAPTER V. Bioecological characteristics of some dominant pests of subtropical plants and the evaluation of damage rate of them

5.1. Family: Aleyrodidae Westwood, 1840-Whiteflies

Dialeurodes citri (Ashmead, 1885)

Information on the damage rate of the bioecological characteristics of citrus whitefly allows giving information that these species are more dangerous than other pests of subtropical plants in Lankaran-Astara.

I age larval period of citrus whitefly lasts from II ten-days of September to II ten-days of October, II age larval period from II ten-days of October to November, III age larval period from November to II ten-days of December.

Table 2

Development period of *D.citri* in the southern part of Azerbaijan

Development cycle of generation from imago to imago	Development period of a generation (Day)
2017 – 2018 - 2019	
1. From the beginning of April to II decade of June	78 - 83 (days)
2. From III decade of June to the beginning of August	45 - 46 (days)
3. From the beginning of August to the end of March (following year)	239 - 245 (days)

As indicated in this table, a short development period of second generation last from 45-46 days in the middle of summer months-in the hottest period. Long-term development period of third generation lasts from 239-245 days in winter months. The humidity of suitable

weather condition is 80-85% for the growth of citrus whitefly. The emergence days of imagoes are given in Table 3.

Table 3

Growth days of *D. citri* for various generations

Generations	Stage period (day)	Average
I generation imago	11 - 16	12.0
II generation imago	31 - 46	35.8
III generation imago	16 - 21	17.5

Female imagoes reach to the maturity of laying eggs in 1-4 days. Female individuals lay their eggs on the lower part of fresh leaves.

Table 4

Infection rate of subtropical and citrus plants with citrus whitefly in Lankaran-Astara region of Azerbaijan (in 2017-2019)

Plant name	Total infected plants in the area (%)	Total infected leaves (in one plant) (%)	Maximal density of a pest on one leaf
Lemon	46	25	50 - 60
mandarin orange	41	20	30 - 40
Orange	39	20	30 - 40
Kumquat	32	15	20 - 30
Persimmon	28	20	20 - 30

According to the study of five species of plants, lemons and mandarin oranges are more higly infected with a pest in all areas (46 and 41%). Thus, 12 of 25 lemons have been infected with whitefly in one of the stationary areas. The average number (more than 25%) of leaves in which larvae of a pest or adult individuals are observed has been evaluated by 5-point scale with 3 points. During the analysis of the lower part of the leaves, unequal distribution of the pest was observed, ranging from a few individuals to dozens of individuals. The density of pests was high in other leaves and reached to 50 - 60 indi-

viduals in each leaf. Based on these indicators, the damage rate obtained as a result of our studies can be similar to the economical damage rate, and it shows the importance of control measures.

First information on the anatomical composition and ultrastructural characteristics of an adult female individual of citrus whitefly was given by means of light and electronic microscopic methods (Figure 1).

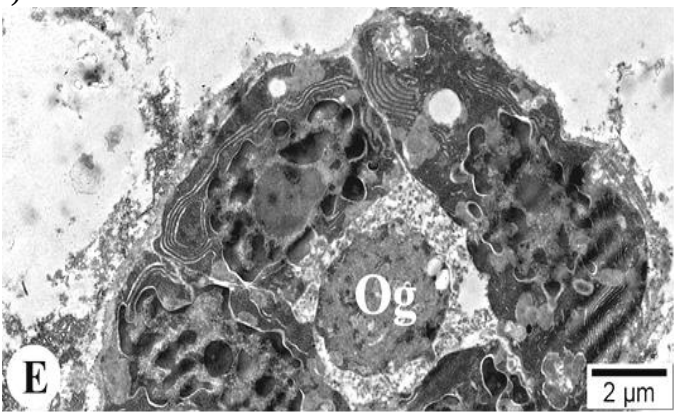


Figure 1. Ultrastructural characteristics of the composition of an adult individual of citrus whitefly. Ultrasonic dissections (50-70 mm).

Pigment: uranyl acetate and lead-citrate.

5.2. Family: Aphididae Latreille, 1802 – Aphids

Species: *Aphis punicae* Pass., 1863

A. punicae is a monophagous pest and grows with a non-complete transformation. It damaged on lower part of the leaves of a pomegranate, through streaks, trunks, buds, flowers and fruit. As a result of studies, infection of regions and gardens with pests and the spread of pests and the average density are defined from the second half of May. It is calculated by using this calculation method. For this reason, the trees are selected from each diagonal of the garden[3]. Five buds from each tree, the samples with 20-30 cm long have been collected from sides and inside.

[3] Avasthi, R.K., Shafee, S.A. Species of Ceroplastinae (Homoptera: Coccidae) from India // Journal of the Bombay Natural History Society, – 1986. 83(2), –p. 327 – 338.

1. According to our samples we can say that 46 of 62 pomegranates get infected with *A.punicae* in the gardens of Lankaran. According to our results, the highest population density was observed in pomegranates of Shilavar village, but the lowest population density was observed in pomegranates of Viyan village.

2. There was infection with *A.punicae* in 35 of 68 pomegranates in gardens of Astara. According to our results, the highest population density was observed in pomegranates of Archivan village, but the lowest population density was observed in pomegranates of Siyaku village.

During the studies, the population density of *A. punicae* on the pomegranates in gardens was relatively observed higher in April-July. In this period, there was damage in both vegetative and generative organs of pomegranate. At the end of the study, the prevalence of *A. punicae* infection in cenosis was observed in some areas of Lankaran-Astara region. As the high population density of a pest infected the buds, flowers and fruit of the pomegranate and damaged it, it caused to decrease the productivity.

Damage: Counting (recordings) was carried out seasonal every ten days. The average number of colonies in infected trees in stationary areas, the average number of aphids in one colony in laboratory was defined. A Table of damage rate for the aphids was used. This rate is calculated as 15 colonies for 100 leaves. 30 % (average) infection of leaf blade with aphids is evaluated by 5-point scale with 3 points.

Species: *Toxoptera aurantii* B.d.f., 1841

This pest is observed on the plants as a colony.

The hazardous impact of tea aphids becomes especially more in seedlings, immature plantations and seed fields. The consecutive protective measures in tea plantations don't allow an intensive increase of the number of aphids.

We have studied the population density of *T. aurantii* on the loquat in Lankaran, in 2017 - 2019. We have observed the alternation of 9 generations of a pest that overlap in a year. The number of a pest reaches to the maximal degree in June – July. At this time, temperature is 2 2- 27°C that is suitable for a pest. It was decided that the preventive

measures for a pest should be made from the last ten – days of May to the second ten – days of June.

According to the results of calculations, the average number of the colonies for 100 leaves is 9 - 11, the number of individuals in a colony is 100 - 150.

A table of damage rate for aphids is used. This rate is equal to 15 colonies for 100 leaves. 35 % (average) of the upper part of the leaf blade get infected with aphids. It is also evaluated by 5-point scale with 4 points.

5.3. Family: Coccidae Fallen, 1814

Order: Ceroplastes Gray, 1828

Species: *Ceroplastes destructor* Newstead, 1917

Based on our studies, we observed *C.destructor* imago and their hibernation in III age larval period as a ratio of 3 (larvae):7 (imago).

The development of a pest is related to host plants, temperature and humidity. During our studies, *C.destructor* is oberved on the leaves and branches of persimmon, loquat, bay laurel, orange and lemon plants. The pest decrease vital processes of the plants feeding with their juice and prevent the increase of their height[4].

It was observed that *C. destructor* damaged on subtropical and citrus plants belonging to 5 families and 6 species in different areas of Lankaran – Astara region of Azerbaijan in 2017 - 2019.

It is observed that, the damage rate of *C. destructor* pest is as 3 - 7 larvae in 10 cm branch or 20 - 30 individuals in 1 leaf blade, and is equal to 3 points by 5 – point scale. According to the severity table, this indicator for coccidia is 5 - 10 larvae in 10 cm branch or 10 colonies in 100 leaf blades. The number of leaves infected by a pest is 33 from 100.

As it is seen, according to the results of studies, the infection degree of subtropical plants by this pest is higher than citrus plants in Lankaran – Astara region, and in comparision persimmon, feijoa and loquat are more infected.

[4] Abasova, N. M. Phenological monitoring of subtropical plants in the Lankaran-Astara region of Azerbaijan on infestation with false scale insects (Ceroplastes destructor Newstead, 1917; c. Japonicus green, 1921) // Agrarian scientific journal, - 2020. №10, - p. 4-8.

Table 5

Phenological table of C. destructor

Sp. name	Months and decades of a year																				
C. destructor	January	February	March	April	May	June	July	August	September			October			November			December		
									1	2	3	1	2	3	1	2	3	1	2	3
	*	*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		
	c	c							•	•	•	•	•	•	•	•	•	•		
										a	a	a	b	b	b	c	c	c	*	*
																			c	c

Note: * – hibernated imago; + imago; • - egg; a- I age larvae; b- II age larvae; c – III age larvae.

Species: *Ceroplastes japonicus* Green, 1921

It was observed during our studies in 2017 - 2019 that, *C. japonicus* hibernated as a female individual. We recorded monocyclic development of a pest in Lankaran – Astara region.

Damage. The damage rate of both coccidia is defined according to the method descrbed in the chapter of materials and methods.

Damage rate of C. japonicus is 2-6 larvae in10 cm branch or 25 - 40 individuals in 1 leaf blade and it is evaluated by 5 – point scale with 3 points. According to the severity table, this indicator for coccidia is 5 - 10 larvae in 10 cm branch or 10 colonies in 100 leaf blades. According to the analysis of results on study of infection degree of various plants by *C. japonicus* in Lankaran-Astara region, it infects 7 species of subtropical and citrus plants belonging to 5 families.The number of leaves infected by a pest is 28 from 100.

5.4. Family *Diaspididae* Targioni Tozetti, 1868

Species: *Diaspidiotus perniciosus* Comstock, 1881

California red scale is an intensive increasing pest. They gather on plants for a short period and make colonies. As these colonies suck juice, the trunk and shell of the branches break, the sprouts get pale and sometimes the whole plant destroys.

Siyaku village of Astara region differs from other selected areas because of its altitude and density of trees. The development of a pest in this area has been a special focus. Here, an infection in trees was 35%. In comparison with other areas, an infection rate of persimmons with a pest was lower. There was decrease in the number of a pest after harvest.

5.5. Family: Pseudococcidae Heymons, 1903

The family of Pseudococcidae is represented by 3 species – *Ps.comstocki, Ps.viburni* and *Ps.calceolariae*. All of three were observed in lemons, mandarin oranges, oranges, *Ps.comstocki, Ps.viburni* were in persimmons, but only *Ps.comstocki* was in pomegranates.

For Ps.comstocki sucking pest species, the critical amount of a pest consists of 5 - 10 larvae for 10 cm branch before the formation of buds and 10 colonies for 100 leaves after the formation of buds. These indicators are lower in our studies and there are 3 - 5 larvae in 10 cm branch and 4 - 5 colonies in 100 leaves. Damage rate of *Ps.viburn* was 2 - 3 larvae for 10 cm branch, 3 - 4 colonies for 100 leaves in the blossoming period. The egg laying process of *Ps.calceolariae* lasts from 8 - 10 in early spring. I age larvae begin to be born in June. Female individuals of I generation continue from a month a half – 2 months. The egg laying process of II generation begins from the end of July and lasts from the end of September. The egg laying process of III generation starts from the beginning of October. Female individuals and larvae of this generation go to the hibernation.

Ps.calceolariae lays in various number of eggs for the generations. The female individuals of I generation lay approximately 600 eggs. Also, we have observed up to 1000 eggs. Female individuals of II generation lay approximately 300 eggs. However, female individuals of III generation lay up to 150 eggs.

Table 6

Distribution of egg – laying process of *Ps.calceolariae* for months of a year

Pseudococcus calceolariae	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Adult individual	H			EL								
I generation						ILB						
II generation	H						EL					
III generation	H									H		H

Note: H – hibernation, EL – egg laying, ILB – I generation larval period birth

5.6. Class: *Lepidoptera* Linnaeus, 1758

Family: *Gracillariidae*

Species: *Phyllocnistis citrella* Stainton, 1856

A generation period of citrus leafminer lasts from 25 days to 62 days. As a result of our studies, the number of imagoes of a pest was 3 - 6 individuals b shaking the trees. The miners in one leaf blade were 0.2 - 0.4. Based on the results of a study, immature citrus plants, especially newn – build gardens should be always under control. These observations should be started from early spring, about from May. When there is hazard for 15 - 20% in gardens, the preventive measures should be started. When a pest is in I and II age larval period, the disinfection measures should be taken. After this period, the plants are under control in gardens. If infection is detected again, the disinfection measures should be repeated after 7 - 8 days.

5.7. Comparable analysis of the studied pest species

The assessment of damage rate obtained during a study was carried out according to V.I. Tanskiy[5]. The identified damage rates for these pests were given in Table 7.

[5] Танский, В.И. Биологические основы вредоносности насекомых / В.И.Танский. – Москва: ВО Агропроиздат, – 1988. – 132 - 150 с.

Table 7

Damage rate indicators of the studied pests

№	Pest name	Maximal number of infected trees	Recorded damage	Infection rate
1	*Dialeurodes citri*	25 of 46 lemons	50 - 60 individuals for 1 leaf blade	10 imagoes for 1 leaf blade or 400 imagoes for 1 plant
2	*Aphis punicae*	46of 62 pomergranates	7 - 9 colonies for 100 leaf blade	15 colonies for 100 leaf blade or 100 flowers
3	*Toxoptera aurantii*	23 of 51 persimmons	10 - 11 colonies for 100 leaf blade	"------"
4	*Ceroplastes destructor*	7 of 46 lemons, 25 of 46 feijoas	3 - 7 larvae for 10 cm branch or 20 - 30 individuals for 1 leaf blade	5 - 10 larvae for 10 cm branch or 10 colonies for 100 leaf blades
5	*Ceroplastes japonicas*	8 of 25 feijoas	2-6 larvae for 10 cm branch or 25 - 40 individuals for 1 leaf blade	"------"
6	*Diaspidiotus perniciosus*	23 of 51 persimmons	3 - 4 larvae for 1 m branch, 5% of fruit	II - III score infection sources; 0,5 larvae / m 2-3% of fruit in branches
7	*Pseudococcus comstocki*	26 of 46 lemons	3 - 5 larvae for 10 cm branch, 4 - 5 colonies for 100 leaf blade in blossoming period	5 - 10 larvaes for 10 cm branch after falling of buds, 10 colonies for 100 leaves after formation of buds

Continued in Table 7

8	*Pseudococcus viburni*	19 of 51 mandarin oranges	2 - 3 larvae for 10 cm branch, 3 - 4 colonies for 100 leaf blade in blossoming period	"------"
9	*Pseudococcus calceolariae*	22 of 46 lemons	2 - 3 larvae for 10 cm branch, 2 - 3 colonies for 100 leaf blade in blossoming period	"------"
10	*Phyllocnistis citrella*	32 of 46 lemons	3 - 6 imagoes for 100 branches, 0,2 - 0,4 miner for 1 leaf	8 - 10 beetles for 100 branches/ (in the process of shaking) /0,5 - 1,0 miner for a leaf

According to our results, the highest damage indicator is indicated for whitefly and citrus leafminer.

CHAPTER VI. Correlation in phytophagous and entomophagous system and quantifying of parasitoid productivity

In this chapter, there were results of studies conducted by finding out the main pests of subtropical plants in Lankaran – Astara region, in 2017 - 2020. The goal of our research, in addition to identifying natural regulators of the number of pests, was to determine the processes that take place in it under experimental conditions, to quantify its productivity in a species sample using mathematical modeling methods.

6.1. Main entomophagous of subtropical plant pests

10 species entomophagous of subtropical plant pests collected during the research years of 2017 - 2020 in Lankaran – Astara region

of Azerbaijan. 6 species of these entomophagous were parasitoids and 4 species were wild insects. Parasitoid species belong to Aphelinidae, but wild entomophagous belong to Coccinellidae family.

Class: Hymenoptera Linnaeus, 1758

Family: Aphelinidae Thomson, 1876

Order: *Aphytis* Howard,1900

1.*Aphytis proclia* Walker.

A proclia is an exogen entoparasitoid species. It lays eggs under the body of scale insects. This parasitoid goes to the hibernation under the pot and in the pupation period. The larvae emerged from eggs feed with the body of scale insect and turn into pupas. I generation parasitoids fly in May. The total development period of I generation lasts from30 - 35days in spring. Parasitoid breeds 4 - 5 times in a year[6].

D. perniciosus come out of the California red scale that we collected from the persimmon.

Species: Aspidiotiphagus Howard

2. *As. citrinus* Graw.1891.

As.citrinus is an endoparasitoid species increased inside the scale insect. *As citrinus* hibernates in the pupation period. The individuals exited from hibernation fly in III ten – days of May. They give 4 - 5 generations in the vegetation period. The following pests were collected from lemon, mandarin orange and persimmon in the laboratory condition: *A.nerii, D.perniciosus, Ch.dictyospermi, and L.gloverii*.

Species: Encarsia Foerster, 1878

3. E. aurantii (Howard, 1894)

Ch.dictyospermi and *L.gloverii* are pest species that we collect from lemon and bay laurel.

Order: *Coccophagus* Westwood.

4. *C.lysimnia* Walker. (Walker, 1839)

C. hesperidum and P.floccifera are pest species that we collect from bay laurel and citrus plants.

[6] Mustafayeva,G.Ə. Çanaqlı yastıcaların parazitəri – afelinidlər (Hymenoptera, Aphelinidae) // Kimya, biologiya elmləri və təhsilinin aktual problemləri, Respublika elmi konfransının materialları, – Bakı: – 2001, – s. 10 - 151.

5. *Coccophagus sp.* – parasitoid species emerged from *C.hesperidum* pest collected from citrus plants.

Family: Encyrtidae Walker, 1837

Species: Encyrtus Latreille, 1809

6. *Encyrtus lecaniorum* (Mayr, 1876) emerged from *C. hesperidum* pest species collected from lemon.

Class: Coleoptera Linnaeus, 1758

Family: Coccinellidae Latreille, 1807

7. *Scymnus frontali* (Fabricius, 1787)

The beetles and their larvae feed with aphids and scale insects that are dangerous pests. During the development period, one beetle ruins more than 600 pest individuals.

8. *Oenopia conglobata* (Linnaeus, 1758)

As many of the ladybirds, the larvae and adult individuals of *O.conglobata* predators feed with aphids.

9. ***Adalia bipunctata L.***

It is a polyphagous predator. Along with different types of aphids, acarids feed with eggs and larvae of scale insects and with other insects.

10. *Coccinella sephtempunctata*

It is a polyphagous predator and has a widespread areal. It feeds with acarids and scale insects beside the aphids. It is almost widespread in all areas of Republic.

6.2. Molecular – genetic studies of *Coccophagus* species

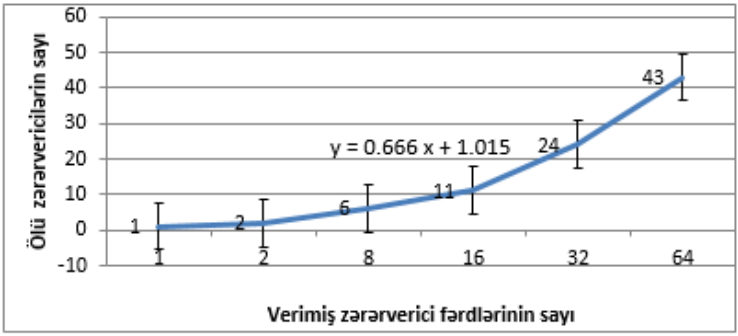
Molecular – genetic studies have more important role in modern science. The importance and necessity of comparable analysis of various groups of insects with DNA nucleotide structure is explained that they are addition to the systematic indicator and allow defining the correct taxonomic status. Information on exact diagnostics and ecological characteristics of species is an essential factor for choosing the preventive measures for pests. As a result of amplification and sequencing of cytochromoxidase I gene fragment of *Coccophagus species of Aphelinidae family*, their species relations are specified. Nucleotide sequence is considered right, because their straight and reverse sequences are coincided. The sudy is ongoing.

6.3. Quantifying of the productivity of parasitoids

During the study of functional reaction of *C.lycimnia* parasitoids – behavioral reaction of female individual, the change of population density of *C.hesperidum* pest, an increase of number of eggs with an increase of the number of pests were defined. If the number of dead pests was in ratio of 100 % in the places where there are few pests, the number of dead pests was fewer with the increase of their number in samples and this number was 68.75%, 75%, 67.1% with participation of 16, 32, 64 pests. In other word, the relative decrease of the number of pests is observed by the increase of dead individuals. The full solution of equitation is carried out by computer program https://math.semestr.ru/corel/corel.php. According to the cross – correlation, the hypothesis (general content) on linear character of coherence between all possible X and Y values can be proposed.

Linear regression: $y = bx + a$

$y = 0.666\ x + 1.0149$



Graph. 1. Relation of eggs of *C.lysimnia* females with the number of pests

The character of reaction is appropriate to 1st type of functional reaction according to the Holling classification, so it shows the number of laid eggs is increasing with the increase of host[7]. In equation of

[7] Holling, C.S. Some Characteristics of Simple Types of Predation and Parasitism //- Canada: Canadian Entomol. – 1959. Vol. 91, № 7, – p. 385-398.

a = 1.0151, a positive independent correlation "a" provides a regulatory importance of functional reaction. The thought is that females of the parasitoid actively infect individual hosts and high – density pests. This species of (parasitoid) a pest can be effective in lower – density, also can find the areas where a pest is dense and show common (aggregate) behave (Graph 1).

The directly proportional of the reaction indicates that the parasitoid is characteristic of estimating the density of the pest and spreading its eggs in proportion to its number. The ability to estimate the number of pests in parasitoids is reflected in the difference in their strategic option in the distribution of eggs. At lower density, they try to lay as many eggs as possible on an individual of host plant. At higher density, an egg is distributed to an individual of host plant.

This behavior is an indicator of the generational care providing his maximum survival period.

As the calculated tolerance for correlation and regression coefficients is less than 1, the regression equation is considered valid.

RESULTS

1. During the analysis of taxonomix structure of pest complex of subtropical plants in Lankaran – Astara region, 32 species of 3 families were found out. They include – *Diplopoda* (*Polyxenidae*) – 1 species, Arachnida (*Tetranychidae*) – 2 species, Insecta – 30 species, as well as, among them 3 families Coleoptera (family: *Scarabaeidae – 1, Curculionidae – 1*) 24 species of Hemiptera family (family: *Aleyrodidae* – 1, *Aphididae* – 2. *Coccidae* – 5, *Diaspididae* – 12, *Margarodidae* – 1, *Pseudococcidae* – 3), and 3 species of Lepidoptera family (family: *Papilionidae* – 1, *Gracillariidae* – 1, *and Pyralidae* – 1). The pest complexes of studied plants include the following: lemon – 17, mandarin orange – 19, orange – 16, kumquat – 15, persimmon – 9, pomergranate – 6, loquat – 5, feijoa – 5, tea – 3, bay laurel– 8 and kiwi – 3 species. Four species – *Ps.viburni, A.auranti, C.destructor, Ps.calceolariae* were first for Azerbaijani fauna and 10 species – *Ps.viburni, A.auranti, C.destructor, Ps.calceolariae, Aphis punicae* (Pass.), *Aonidiella citrina* (Craw), *Chrysomphalus dictyospermi* (Morgan), *Lepidosaphes beckii*

(Newman), *Lepidosaphes granati* (Koroneos), *Euzophera bigella* (Zeller) were observed firstly as a pest of subtropical plants in Lankaran – Astara region.

2. The analysis of pest complexes of different plants indicated that the number (min.15 – max. 19) of pests detected in citrus plants is more twice than the number (min. 3 – max. 9) of pest species in other subtropical plants. The maximum number of pest species is noted on mandarin orange and there are 19 species. It is determined that a pest complex of two groups differs for its quality and quantity. There are 8 species – having relation only with citrus plants; 10 species – only in other studied subtropical plants; and 14 species – in both groups of plants. The most of determined species is polypagous (95%), two species are monophagous (*A. punicae*, *L.granati)*, and the others are oligophagous.
3. Dominant species of pests such as *D.citri, Ch.dictyospermi, Ps.comstocki, L.beckii, L.gloveri* were defined in citrus plants. In other studied subtropical plants *Ps.comstocki, P.floccifera* species were more observed.
4. Most species are found on leaves and young buds (25 species) due to their adaptation to plant organs. It was defined that the majority of pests (45.5%) have the whole year growth period synchronized with the vegetation of evergreen citrus plants. The peak of development of other species occurs in the autumn months, the period of crop productivity.
5. Distribution, morphology, biology, ecology, phenology, food plants, frequency of occurrence of 10 most common species were studied, symptoms of infection were found in plants, and 4 of them are dangerous quarantine pests. This information can be used in protective measures.
6. For the first time, the indicators of damage rate of 10 species of a pest were obtained. According to the study results, the highest damage index that was close to the economic damage rate for citrus whitefly *D.citri* and citrus leafminer *P.citrella* were obtained.
7. Among identified 10 species of entomophagous, 6 were parasitoids of larval period of pests, 4 were predator species Hymenoptera and Coleoptera groups fed with larvae, eggs and imagoes of pests.

Hymenoptera group is represented by two families – *Aphelinidae* (4 sorts, 5 species) and *Encyrtidae* (1 sort, 1 species). Coleoptera group is represented by *Coccinellidae* – 4 sorts, 4 species.

8. The sequence of nucleotides of the COI gene was obtained by molecular genetic methods for the Coccophagus species which was discovered for the first time in Azerbaijan, and it will help to determine the exact species for the future studies.
9. *During the experimental study of behavioral reaction of C.lysimnia* parasitoid for change of the number of *C.hesperidum* L. pest, the coherence of independent member with functional reaction displayed with $y = 0.666 x + 1.015$ linear regression has been defined. It can be effective impact on both lower level of and higher level of population density of parasitoid pest.
10. With the help of light and electron microscopes (TEM), the anatomical structure and ultrastructural features of the adult female of the citrus organ were studied for the first time.

PRACTICAL IMPLICATIONS

1. It is important to control the quality of imported planting material to prevent the entry of invasive pest species into the country. Only accurate species identification will allow effective control measures to be taken.
2. Doing continuous monitorings has a great important in order to determine the quality and quantity of pest complex of subtropical and citrus plants. Quantitative report should be conducted at different stages of pest development. If there is a sharp increase in the number of pests, mechanical preventive measures should be taken, infected branches should be pruned, then burned and other agro – technical measures should be taken.
3. As a result of research conducted in the Lankaran – Astara region during 2017 - 2020 the phenology of 10 species of dominant pests was studied. Measures to control these dangerous pests should be taken on the basis of this phenological calendar.
4. The use of various insecticides should be strictly conducted, considering accurate quantitative assessments of the degree of pest. For

this purpose, it is necessary to use tables of damage limits of pest species.

5. In modern condition, biological means of plant protection are becoming increasingly important. The use of the method of quantitative and qualitative assessment of the effectiveness of parasitoids will lead to strengthen the application of the method of biological protection of subtropical plants, to include new perspective agents to control the number of pests.

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