



T.C.

TOKAT GAZIOSMANPASA UNIVERSITY

GRADUATE SCHOOL

DEPARTMENT OF PLANT PROTECTION

Ph.D OF SCIENCE PROGRAM

**DETERMINATION OF THRIPS (THYSANOPTERA) SPECIES AND
EFFECT OF SOME CONTROL METHODS ON ABUNDANCE OF
THRIPS IN PEPPER FIELD IN TOKAT PROVINCE**

Ph.D Thesis

SARAH DISKO YOUNUS

Supervisor: Prof. Dr. Dürdane YANAR

Co-supervisor: Prof. Dr. Ekrem ATAKAN

TOKAT- 2023

ETHICS CONTRACT

According to the thesis writing guide of the Graduate Education Institute at Tokat Gaziosmanpaşa University, I have prepared an original version of the Ph.D. thesis titled “Determination of Thrips (Thysanoptera) Species and the Effect of Some Control Methods on the Abundance of Thrips in Pepper Fields in Tokat Province.” This work was conducted under the supervision of Prof. Dr. Dürdane YANAR, and co- supervision by Prof. Dr. Ekrem ATAĞAN. I hereby declare that I accept all legal sanctions in the event it is determined that my work violates established rules and scientific ethical values.

/ /2023

Sarah Disko YOUNUS

COMMITTEE ACCEPTANCE AND APPROVAL

Defense of the thesis titled 'Determination of Thrips (Thysanoptera) Species and the Effect of Some Control Methods on the Abundance of Thrips in Pepper fields in Tokat Province, prepared by Sarah Disko Younus, was conducted in 2023. It was accepted as a Ph.D. thesis by the jury listed below by unanimous vote at Tokat Gaziosmanpaşa University Graduate Education Institute, Department of Plant Protection.

Committee MEMBERS

Signature

Chairman Committee: Prof. Dr. Dürdane YANAR
Tokat Gaziosmanpaşa University

Committee member: Prof. Dr. Hüseyin GÖÇMEN
Akdeniz Üniversitesi University

Committee member: Prof. Dr. Celal TUNCER
Ondokuz Mayıs University

Committee member: Prof. Dr. Naif GEBOLOĞLU
Tokat Gaziosmanpaşa University

Committee member: Associate Prof. Turgut ATAY
Tokat Gaziosmanpaşa University

Approved by

...../...../.....

Associate Prof. Dr. Yusuf TEMÜR
Graduate Institute Chair

ACKNOWLEDGMENT

First of all, I want to express my gratitude and thanks to Almighty and Merciful (God) for providing me with the capability to complete this work.

I wish to express my sincere and deepest gratitude to my supervisor Prof. Dr. Dürdane YANAR for supervision and providing the required facilities during the achievement this work.

With sincere thanks and gratitude to my co-supervisor Prof. Dr. Ekrem ATAKAN for helping us to complete this research

Thanks to the Dean of the Agriculture College/ Gaziosmapasa university Prof. Dr. Rüstem CANGI and Head of Plant Protection Department prof. Dr. Yusuf YANAR for supporting and facilitating everything related to the accomplishment of this thesis.

With many thanks and gratitude to prof. Dr. Akram Othman, prof. Dr. Hassan S. Al asady and Dr. Yalçın TAHTALI for providing me with assistance and support.

I would like to express my thanks to every member, especially to Neslihan KARA, Hakan KARTAL and summer training students.

I am very grateful to my father and mother who supported me for the road to success.

My deepest thanks for my husband.

Sarah Disko YOUNUS

ÖZET

Tokat ili biber yetiştirilen alanlarda görülen trips türleri (Thysanoptera)nin belirlenmesi, yaygın bazı mücadele yöntemlerinin trips yoğunluğu üzerine etkisinin

Sarah Disko YOUNUS

Tokat Gaziosmanpaşa Üniversitesi Lisansüstü Eğitim Enstitüsü
Bitki Koruma Anabilim Dalı

1.Tez Danışmanı: Prof. Dr. Dürdane YANAR

2.Tez Danışmanı: Prof. Dr. Ekrem ATAKAN

Bu çalışma Türkiye'nin Tokat ilinde 2021-2022 yıllarında yürütülmüştür. Tokat ili biber ekim alanlarında görülen trips türleri belirlenmiştir. Biber üretim döneminde 2021-2022 yıllarında Haziran ayından itibaren Ekim ayına kadar Tokat'ın Merkez, Erbaa, Niksar, Turhal, ve Pazar ilçelerinde bulunan tarlaları temsil edecek şekilde örneklemeler yapılmıştır. Bu çalışmada toplam 7 tür tespit edilmiştir. Bu türler; Thripidae familyasından *Frankliniella occidentalis* (Priesner, 1932), *Thrips tabaci* (Lindeman), *Thrips meridionalis* (Priesner 1926), *Chirothrips manicatus* (Haliday, 1836), *Aeolothrips intermedius* (Bagnall, 1934), *Aeolothrips fasciatus* (Linnaeus, 1758) ve Phlaeothripidae familyasından *Haplothrips aculeatus* (Fabricius, 1803) dur. Bu çalışmada, Tokat ili biber tarlalarında baskın trips türünün *F. occidentalis* olduğu tespit edilmiştir. Çalışmanın ikinci bölümü ise trips mücadelesinde farklı yöntemlerinin kullanımına yöneliktir. Bu çalışma tarla koşullarında açık alanda Esen ve Gama tatlı biber çeşitleri üzerinde yürütülmüştür. Denemelerde uygulama olarak: kontrol, *Orius laevigatus* (Fieber), *Amblyseius swirskii* Athias Henriot, Azadirachtin 790 g/l + Neem yağı 0,3 g/l (bitkisel kökenli insektisit) , Spinosad 240 g/l, Formetanat hidroklorür %50 ve feromon+ mavi yapışkan tuzak kullanılmıştır. Deneme tesadüf parselleri deneme desenine göre, parsel büyüklükleri 360x270cm, parseller arası 100cm , 4 tekerrürlü olarak kurulmuştur. Denemede kontrol uygulamasında herhangi bir işlem yapılmamıştır. 2021 ve 2022 yıllarında yürütülen çalışmalarda trips yoğunluğu ekonomik zarar eşiği (3 trips/çiçek) seviyesinin altında kalmıştır. Uygulamalarda sırasıyla, *O. laevigatus* uygulamasında, 1 trips/çiçek *A. swirskii* uygulamasında 1,6 trips/çiçek, Azadirachtin 790 g/l + Neem yağı 0,3 g/l (Bitkisel preparat)'ın uygulamasında, 0,2 trips/çiçek, Spinosad 240 g/l ve Formetanat hidroklorür %50 uygulamalarında 0,6 trips/çiçek, Feromon+ mavi yapışkan tuzak uygulamalarında, 0,3 trips/çiçek seviyesinin altında kalmıştır. Bu çalışma entegre zararlı yönetimi sistemlerinde biyolojik preparatların ve tuzakların açık alanda da tripslere karşı kullanılabileceğini ortaya koymuştur.

ANAHTAR KELİMELER

Trips, Biyolojik mücadele, Tuzak, Kimyasal Mücadele, *Orius*

ABSTRACT

Determination of thrips (Thysanoptera) species and effect of some control methods on abundance of thrips in pepper field in Tokat Province

Sarah Disko YOUNUS

Ph.D

Tokat Gaziosmanpasa University Institute of Graduate Studies

Department of Plant Protection

Supervisor: Prof. Dr. Dürdane YANAR

Co-supervisor: Prof. Dr. Ekrem ATAKAN

This study was conducted in Tokat province of Turkey in 2021-2022. Thrips species seen in pepper cultivation areas in Tokat province were determined. During the pepper production period, from June to October in 2021-2022, samplings were performed to represent the fields in the Merkez, Erbaa, Niksar, Turhal, and Pazar districts of Tokat. A total of 7 species were identified in this study. These species are as follows; *Frankliniella occidentalis* (Priesner, 1932), *Thrips tabaci* (Lindeman), *Thrips meridionalis* (Priesner 1926), *Chirothrips manicatus* (Haliday, 1836), *Aeolothrips intermedius* (Bagnall, 1934), *Aeolothrips fasciatus* (Linnaeus, 1758) from Thripidae family and *Haplothrips aculeatus* (Fabricius, 1803) Phlaeothripidae family. In this study, it was determined that the dominant thrips species in pepper fields in Tokat province was *F. occidentalis*. The second part of the study is about the use of different control methods in thrips management. Esen and Gama sweet pepper varieties were used in this study under field conditions. Treatments were control, *Orius laevigatus* (Fieber), *Amblyseius swirskii* Athias Henriot, Azadirachtin 790 g/l + Neem oil 0.3 g/l (plant-based insecticide), Spinosad 240 g/l, Formetanate hydrochloride 50% and pheromone blue sticky trap. The trial was set up according to the randomized plot design, with plot sizes of 360x270cm, 100cm between plots, and 4 replications. Blank control was used to evaluate the efficacy of the treatments. In studies conducted in 2021 and 2022, thrips density remained below the economic damage threshold (3 thrips/flower). The thrips density in *O. laevigatus*, *A. swirskii*, Azadirachtin 790 g/l + Neem oil 0.3 g/l (Herbal preparation), Spinosad 240 g/l and Formetanate hydrochloride 50% applications were 1 thrips/flower, 1.6 thrips/flower, 0.2 thrips/flower also, in Pheromone+ blue sticky trap applications density remained below 0.3 thrips/flower. This study revealed that biological preparations and traps can be used against thrips under field conditions in integrated pest management systems.

KEYWORDS

Thrips, Biological control, Chemical control, Traps, *Orius*

LIST OF CONTENTS

ETHICS CONTRACT	I
COMMITTEE ACCEPTANCE AND APPROVAL	II
ACKNOWLEDGMENT	III
ÖZET	IV
ABSTRACT	V
LIST OF CONTENTS	VI
LIST OF TABLES	IX
LIST OF FIGURES	XIII
1. INTRODUCTION	1
2. LITERATURE REVIEW	7
2.1. Thrips definition.....	7
2.2. The biology and life cycle.....	8
2.3. Distribution.....	9
2.4. Economic importance.....	10
2.4.1. Direct damage.....	10
2.4.2. Vectoring of plant diseases.....	11
2.5. Host plants.....	14
2.6. Thrips species.....	14
2.7. Thrips species recorded in Türkiye.....	15
2.8. Pest Management.....	18
2.8.1. Cultural Control.....	18
2.8.2. Physical control.....	19
2.8.3. Mechanical control.....	19
2.8.4. Trapping.....	19
2.8.5. Biological control.....	20
2.8.5.1. <i>Amblyseius swirskii</i> Athias-Henriot (Acari: Phytoseiidae).....	21
2.8.5.2. <i>Orius laevigatus</i> (Fieber, 1860) (Hemiptera: Anthocoridae).....	23
2.8.6. Chemical control.....	25
2.8.6.1. Azadirachtin 790 g/l Neem oil + 0.3 g/l.....	26
2.8.6.2. Spinosad 240 g/l.....	27
2.8.6.3. Formetanate hydrochloride% 50	28
2.8.7. Biotechnic control.....	28
2.8.8. Integrated pest management (IPM).....	30
3. MATERIALS AND METHODS	32
3.1. Materials.....	32
3.2. Methods.....	32
3.2.1. Experimental design.....	32
3.2.2. Climatic characteristics of the trial area.....	34
3.2.3.1. Survey studies for thrips	36
3.2.3.2. Field studies.....	37
3.2.4. Sampling of thrips species.....	38
3.2.5. Thrips identification.....	39
3.2.6. Characteristics of pesticides, traps and predatory insect used in the field trials	40

3.2.6.1. Control.....	40
3.2.6.2. <i>Orius laevigatus</i>	40
3.2.6.3. <i>Amblyseius swirskii</i>	40
3.2.6.4. Azadirachtin 790 g/l Neem oil + 0.3 g/l.....	41
3.2.6.5. Spinosad 240 g/l.....	41
3.2.6.6. Formetanate hydrochloride% 50.....	41
3.2.6.7. Blue sticky trap with pheromones.....	42
3.2.7. The harvesting procedure	45
3.2.8. Statistical analysis.....	45
4. RESULTS AND DISCUSSION.....	46
4.1. Survey Studies.....	46
4.2. Thrips species detected in pepper fields of Tokat Province in 2021 and 2022...	46
4.2.1. Thrips species detected in pepper fields of Tokat Province.....	46
4.2.1.1. <i>Frankliniella occidentalis</i> (Priesner, 1932) (Western Flower thrips).....	48
4.2.1.2. <i>Thrips tabaci</i> (Ozel, 1895) (Onion thrips).....	53
4.2.1.3. <i>Thrips meridionalis</i> (Priesner, 1926) (peach thrips).....	56
4.2.1.4. <i>Chirothrips manicatus</i> (Haliday, 1836).....	58
4.2.1.5. <i>Aeolothrips intermedius</i> (Bagnall, 1934).....	60
4.2.1.6. <i>Aeolothrips fasciatus</i> (Linnaeus, 1758).....	62
4.2.1.7. <i>Haplothrips aculeatus</i> (Fabricius, 1803).....	65
4.3. Thrips Survey on the <i>Solanum nigrum</i> in the 2021 and 2022.....	67
4.3. Management in field experiments.....	69
4.3.1. Thrips population in control treatments.....	69
4.3.1.1. Mean densities of <i>Frankliniella occidentalis</i> in pepper flowers in untreated plots of pepper varieties, Gama and Esen.....	69
4.3.1.1.1. Mean densities of <i>Frankliniella occidentalis</i> in pepper flowers in 2021...	69
4.3.1.1.2. Mean densities of <i>F. occidentalis</i> in pepper flowers in 2022.....	70
4.3.1.2. Mean densities of <i>Thrips tabaci</i> in pepper flowers in untreated pepper varieties, Gama and Esen.....	71
4.3.1.2.1. Mean densities of <i>Thrips tabaci</i> in pepper flowers in 2021.....	71
4.3.1.2. Mean densities of <i>Thrips tabaci</i> in pepper flowers in 2022.....	72
4.3.2. Thrips population in <i>Orius laevigatus</i> treatment.....	73
4.3.2.1. The effect of <i>Orius laevigatus</i> on density of <i>Frankliniella occidentalis</i> in pepper flowers.....	73
4.3.2.1.1. The effect of <i>Orius laevigatus</i> on density of <i>Frankliniella occidentalis</i> in 2021.....	73
4.3.2.1.2. The effect of <i>Orius laevigatus</i> on density of <i>Frankliniella occidentalis</i> in 2022.....	75
4.3.2.2. The effect of <i>Orius laevigatus</i> on density of <i>Thrips tabaci</i> in pepper flowers.....	76
4.3.2.2.1. The effect of <i>Orius laevigatus</i> on density of <i>Thrips tabaci</i> in 2021.....	76
4.3.2.2.2. The effect of <i>Orius laevigatus</i> on density of <i>Thrips tabaci</i> in 2022.....	77

4.3.3. Thrips population in <i>Amblyseius swirskii</i> treatment.....	79
4.3.3.1. The effect of <i>Amblyseius swirskii</i> on density of <i>Frankliniella occidentalis</i> in pepper flowers.....	79
4.3.3.1.1. The effect of <i>Amblyseius swirskii</i> on density of <i>Frankliniella occidentalis</i> in 2021.....	79
4.3.3.1.2. The effect of <i>Amblyseius swirskii</i> on density of <i>Frankliniella occidentalis</i> in 2022.....	80
4.3.3.2. The effect of <i>Amblyseius swirskii</i> on density of <i>Thrips tabaci</i> in pepper flowers.....	81
4.3.3.2.1. The effect of <i>Amblyseius swirskii</i> on density of <i>Thrips tabaci</i> in 2021....	81
4.3.3.2.2. The effect of <i>Amblyseius swirskii</i> on density of <i>Thrips tabaci</i> in 2022....	82
4.3.4. The effect of Azadirachtin 790 g/l Neem oil + 0.3 g/l.....	83
4.3.4.1. The effect of Azadirachtin 790 g/l Neem oil + 0.3 g/l on density of <i>Frankliniella occidentalis</i> in pepper flowers.....	83
4.3.4.1.1. The effect of Azadirachtin 790 g/l Neem oil + 0.3 g/l on density of <i>Frankliniella occidentalis</i> in 2021.....	83
4.3.4.1.2. The effect of Azadirachtin 790 g/l Neem oil + 0.3 g/l on density of <i>Frankliniella occidentalis</i> in 2022.....	85
4.3.4.2. The effect of Azadirachtin 790 g/l Neem oil + 0.3 g/l on density of <i>Thrips tabaci</i> in pepper flowers.....	86
4.3.4.2.1 The effect of Azadirachtin 790 g/l Neem oil + 0.3 g/l on density of <i>Thrips tabaci</i> in 2021.....	86
4.3.4.2.2 The effect of Azadirachtin 790 g/l Neem oil + 0.3 g/l on density of <i>Thrips tabaci</i> in 2022.....	87
4.3.5. The effect of spinosad 240 g/l.....	88
4.3.5.1. The effect of spinosad 240 g/l on density of <i>Frankliniella occidentalis</i> in pepper flowers.....	88
4.3.5.1.1. The effect of spinosad 240 g/l on density of <i>Frankliniella occidentalis</i> in 2021	88
4.3.5.1.2. The effect of spinosad 240 g/l on density of <i>Frankliniella occidentalis</i> in 2022.....	89
4.3.5.2. The effect of spinosad 240 g/l on density of <i>Thrips tabaci</i> in pepper flowers.....	89
4.3.5.2.1 The effect of spinosad 240 g/l on density of <i>Thrips tabaci</i> in 2021.....	89
4.3.5.2.2 The effect of spinosad 240 g/l on density of <i>Thrips tabaci</i> in 2022.....	90
4.3.6. The effect of Formetanate hydrochloride% 50.....	91
4.3.6.1. The effect of Formetanate hydrochloride% 50 on density of <i>Frankliniella occidentalis</i> in pepper flowers.....	91
4.3.6.1.1. The effect of Formetanate hydrochloride% 50 on density of <i>Frankliniella occidentalis</i> in 2021	91

4.3.6.1.2. The effect of Formetanate hydrochloride % 50 on density of <i>Frankliniella occidentalis</i> in 2022.....	92
4.3.6.2. The effect of Formetanate hydrochloride% 50 on density of <i>Thrips tabaci</i> in pepper flowers.....	93
4.3.6.2.1. The effect of Formetanate hydrochloride% 50 on density of <i>Thrips tabaci</i> in 2021.....	93
4.3.6.2.2. The effect of Formetanate hydrochloride% 50 on density of <i>Thrips tabaci</i> in 2022.....	94
4.3.7. The effect of blue sticky traps with pheromones.....	95
4.3.7.1. The effect of blue sticky traps with pheromones on density of <i>Frankliniella occidentalis</i> in pepper flowers.....	95
4.3.7.1.1. The effect of blue sticky traps with pheromones on density of <i>Frankliniella occidentalis</i> in 2021.....	95
4.3.7.1.2. The effect of blue sticky traps with pheromones on density of <i>Frankliniella occidentalis</i> in 2022.....	96
4.3.7.2. The effect of blue sticky traps with pheromones on density of <i>Thrips tabaci</i> in pepper flowers.....	97
4.3.7.2.1. The effect of blue sticky traps with pheromones on density of <i>Thrips tabaci</i> in 2021.....	97
4.3.7.2.2. The effect of blue sticky traps with pheromones on density of <i>Thrips tabaci</i> in 2022.....	98
4.4. Calculated the number of Thrips inside sticky trap with pheromone.....	99
4.4.1. Calculated the number of Thrips inside sticky trap with pheromone in 2021...	99
4.4.2. Calculated the number of Thrips inside sticky trap +pheromone in 2022.....	101
4.5. Interaction between treatments and thrips density.....	102
4.7. The effect of different treatments on the total yield.....	105
4.6.1. The effect of different treatments on the total yield of the Gama pepper cultivar.....	105
4.6.2. The effect of different treatments on the total yield of the Esen pepper cultivar	107
5. CONCLUSIONS AND RECOMMENDATION.....	109
6. REFERENCES.....	111
RESUME.....	122

LIST OF TABLES

Table 1.1. Pepper production in Tokat province (ton) (TUIK, 2023).....	1
Table 1.2. Cultivation area of pepper field in Tokat province (Decares) (TUIK,2023)..	2
Table 2.3. Thrips species associated with pepper and vegetable crops plants in Türkiye.....	18
Table 2.4. Natural enemies (<i>Amblyseius swirskii</i> and <i>Orius laevigatus</i>) and plant name used as biological control (Koppert, 2023).....	25
Table 2.5. Insecticide registered (azadiractin 0,3 g/l + 790 g/l neem oil) for the pest thrips on some vegetables in Türkiye (Anonim, 2023a).....	27
Table 2.6. Insecticide registered (spinosad 240 g/l) for the pest thrips on some vegetables in Türkiye (Anonim, 2023b).....	27
Table 2.7. Insecticide registered (Formetanate hydrochloride% 50) for the pest thrips on some vegetables in Türkiye (Anonim, 2023c).....	28
Table 2.8. Active substances and application doses of insect traps registered for the pest arthropods in peppers in Türkiye (Anonim, 2023d).....	29
Table 3.9. The date of treatments applications in the pepper field.....	44
Table 4.10. Thrips species individuals, order and family in pepper fields of Tokat province in 2021-2022.....	47
Table 4.11. Species composition of thrips and their numbers in pepper flowers during 2021-2022.....	48
Table 4.12. <i>Frankliniella occidentalis</i> survey in the pepper fields of Tokat Province.....	52
Table 4.13. <i>Thrips tabaci</i> survey in the pepper fields of Tokat Province.....	56
Table 4.14. <i>Thrips meridionalis</i> survey in the pepper fields of Tokat Province.....	58
Table 4.15. <i>Chirothrips manicatus</i> survey in the pepper fields of Tokat Province.....	60
Table 4.16. <i>Aeolothrips intermedius</i> survey in the pepper fields of Tokat Province.....	62
Table 4.17. <i>Aeolothrips fasciatus</i> survey in the pepper fields of Tokat Province.....	64
Table 4.18. <i>Haplothrips aculeatus</i> survey in the pepper fields of Tokat Province.....	67
Table 4.19. Thrips species individuals, order, sub order and family and sub family in <i>Solanum nigrum</i> of Tokat province.....	68
Table 4.20. <i>Frankliniella occidentalis</i> survey in the <i>Solanum nigrum</i> of Tokat Province.....	68
Table 4.21. Numbers of thrips caught on blue sticky traps + (Pheromone) settled in pepper plots of two varieties in 2021.....	100
Table 4.22. Numbers of thrips caught on blue sticky traps + (Pheromone) in settled in pepper plots of two varieties in 2022.....	101
Table 4.23. Interaction between treatments, pepper variety and thrips density.....	102
Table 4.24. Effect of treatment on <i>Frankliniella occidentalis</i> density in varieties of pepper (Gama and Esen) in 2021.....	103
Table 4.25. Effect of treatment on <i>Frankliniella occidentalis</i> density in varieties of pepper (Gama and Esen) in 2022.....	103

Table 4.26. Effect of treatment on <i>Thrips tabaci</i> density in varieties of pepper (Gama and Esen) in 2021.....	104
Table 4.27. Effect of treatment on <i>Thrips tabaci</i> density in varieties of pepper (Gama and Esen) in 2022.....	105
Table 4.28. The effect of different treatments on the total yield of the Gama pepper cultivar in 2021- 2022.....	106
Table 4.29. The effect of different treatments on the total yield of the Esen pepper cultivar in 2021- 2022.....	107



LIST OF FIGURES

Figure 2.1. Adult of <i>Amblyseius swirskii</i>	23
Figure 2.2. <i>Orius laevigatus</i> a. Immature stage b. Adult stage.....	24
Figure 3.3. Some views of the field trials a. Soil preparation b. Area processed c. Seedling d. Experimental design.....	34
Figure 3.4. Monthly average of temperature (°C) (Anonim, 2023 e).....	35
Figure 3.5. Monthly average of relative humidity (Anonim, 2023 e).....	35
Figure 3.6. Total rain (mm) (Anonim, 2023 e).....	36
Figure 3.7. Map for sampling locations in Tokat Province, Türkiye	37
Figure 3.8. Samples of thrips collected from field trials.....	39
Figure 3.9. Applied biological control (<i>Amblyseius swirskii</i> and <i>Orius laevigatus</i>) in the pepper field	40
Figure 3.10. Application of pesticides by use of back sprayer in the pepper plots	42
Figure 3.11. Blue sticky traps with pheromones in the pepper trial	43
Figure 3.12. The harvested of pepper fruits in field trials	45
Figure 4.13. <i>Frankliniella occidentalis</i> (Priesner, 1932) a. Adult b. Thorax c. Abdominal setae d. Antennae segments.....	49
Figure 4.14. <i>Frankliniella occidentalis</i> damage symptoms on flower.....	50
Figure 4.15. <i>Thrips tabaci</i> (Ozel, 1895) a. Adult b. Abdominal setae c. Antennae segments.....	54
Figure 4.16. <i>Thrips tabaci</i> damage symptoms on leaves.....	55
Figure 4.17. <i>Thrips meridionalis</i> (Priesner, 1926) a. The abdominal setae b. The antennae segments c. Thorax.....	57
Figure 4.18. <i>Chirothrips manicatus</i> (Haliday, 1836) a. Adult b. Antennae segments c. Abdominal setae.....	59
Figure 4.19. <i>Aeolothrips intermedius</i> a. Adult b. Antennae segments c. Abdominal setae.....	61
Figure 4.20. <i>Aeolothrips fasciatus</i> (Linnaeus, 1758) a. Adult b. Abdominal setae c. Antennae segments d. Wings.....	64
Figure 4.21. <i>Haplothrips aculeatus</i> a. Adult b. Antennae segments c. Abdominal setae	66
Figure 4.22. Mean densities of <i>F. occidentalis</i> in pepper flowers in untreated plots of pepper varieties Gama and Esen in 2021.....	70
Figure 4.23. Mean densities of <i>F. occidentalis</i> in pepper flowers in untreated plots of pepper varieties Gama and Esen in 2022.....	71
Figure 4.24. Mean densities of <i>T. tabaci</i> in pepper flowers in untreated plots of pepper varieties Gama and Esen in 2021.....	72
Figure 4.25. Mean densities of <i>T. tabaci</i> in pepper flowers in untreated plots of pepper varieties Gama and Esen in 2022.....	73
Figure 4.26. The effect of <i>Orius laevigatus</i> on density of <i>Frankliniella occidentalis</i> in pepper flowers in 2021.....	74
Figure 4.27. The effect of <i>Orius laevigatus</i> on density of <i>Frankliniella occidentalis</i> in pepper flowers in 2022.....	76

Figure 4.28. The effect of <i>Orius laevigatus</i> on density of <i>Thrips tabaci</i> in pepper flowers in 2021.....	77
Figure 4.29. The effect of <i>Orius laevigatus</i> on density of <i>Thrips tabaci</i> in pepper flowers in 2022.....	78
Figure 4.30. The effect of <i>Amblyseius swirskii</i> on density of <i>Frankliniella occidentalis</i> in pepper flowers in 2021.....	79
Figure 4.31. The effect of <i>Amblyseius swirskii</i> on density of <i>Frankliniella occidentalis</i> in pepper flowers in 2022.....	81
Figure 4.32. The effect of <i>Amblyseius swirskii</i> on density of <i>Thrips tabaci</i> in pepper flowers in 2021.....	82
Figure 4.33. The effect of <i>Amblyseius swirskii</i> on density of <i>Thrips tabaci</i> in pepper flowers in 2022.....	83
Figure 4.34. The effect of Azadirachtin 790 g/l Neem oil + 0.3 g/l on density of <i>Frankliniella occidentalis</i> in pepper flowers in 2021.....	84
Figure 4.35. The effect of Azadirachtin 790 g/l Neem oil + 0.3 g/l on density of <i>Frankliniella occidentalis</i> in pepper flowers in 2022.....	85
Figure 4.36. The effect of Azadirachtin 790 g/l Neem oil + 0.3 g/l on density of <i>Thrips tabaci</i> in pepper flowers in 2021.....	86
Figure 4.37. The effect of Azadirachtin 790 g/l Neem oil + 0.3 G/l on density of <i>Thrips tabaci</i> in pepper flowers in 2022.....	87
Figure 4.38. The effect of Spinosad 240 g/l on density of <i>Frankliniella occidentalis</i> in pepper flowers in 2021.....	88
Figure 4.39. The effect of Spinosad 240 g/l on density of <i>Frankliniella occidentalis</i> in pepper flowers in 2022.....	89
Figure 4.40. The effect of Spinosad 240 g/l on density of <i>Thrips tabaci</i> in pepper flowers in 2021.....	90
Figure 4.41. The effect of Spinosad 240 g/l on density of <i>Thrips tabaci</i> in pepper flowers in 2022.....	91
Figure 4.42. The effect of Formetanate hydrochloride on density of <i>Frankliniella occidentalis</i> in pepper flowers in 2021.....	92
Figure 4.43. The effect of Formetanate hydrochloride on density of <i>Frankliniella occidentalis</i> in pepper flowers in 2022.....	93
Figure 4.44. The effect of Formetanate hydrochloride on density of <i>Thrips tabaci</i> in pepper flowers in 2021.....	94
Figure 4.45. The effect of Formetanate hydrochloride on density of <i>Thrips tabaci</i> in pepper flowers in 2022.....	95
Figure 4.46. The mean numbers of <i>Frankliniella occidentalis</i> on blue sticky traps with pheromones in peppers 2021.....	96
Figure 4.47. The mean numbers of <i>Frankliniella occidentalis</i> on blue sticky traps with pheromones in peppers 2022.....	97
Figure 4.48. The mean numbers of <i>Thrips tabaci</i> on blue sticky traps with pheromones in peppers 2021.....	98
Figure 4. 49. The mean numbers of <i>Thrips tabaci</i> on blue sticky traps with pheromones in peppers 2022.....	99
Figure 4.50. The mean numbers of thrips on blue sticky traps with pheromones in	

peppers 2021.....	100
Figure 4.51. The mean numbers of thrips on blue sticky traps with pheromones in	
peppers 2022.....	101



1. INTRODUCTION

Pepper (*Capsicum annuum* L.) is an important vegetable crop, is grown both commercially and by small farmers in Asia, Africa, and South America. The genus *Capsicum* encompasses over 40 species, but *Capsicum annuum* L. is the most well-known, the fruits of this plant can be found in various colors, such as red, yellow, orange, green, white, and purple, bell peppers, which are milder in flavor compared to other chili peppers, are sometimes referred to as "sweet peppers" (Shilpa and Singh, 2020). To cultivate sweet peppers and chilies in commercial agriculture, growers often initiate the process by sowing hybrid seeds in a regulated indoor environment, while they wait for the seedlings to mature; they prepare the soil for the upcoming plantation season. Fresh market peppers are best grown in soil that has good drainage, can retain water, and has a pH ranging from 5.8 to 6.6, pepper plants are started in greenhouses, and after six to eight weeks, they are transplanted into the fields. Since peppers thrive in warm weather, it is recommended to move them only when the soil temperature 7.62 cm below the surface reaches 15.5C° providing drip irrigation to the plants is crucial for optimal growth and yields, and also allows the use of fertilizers during the growing season. According to (2021) statistics, global pepper production reached 42137899 tons, with Turkey being the second-largest producer after Mexico, and the United stat was third (FAO, 2020). Total production of pepper was 36286643 ton in 2021 in Turkey (FAO, 2023, Table 1.1).

Table 1.1. Pepper production in Tokat Province (tonne) (TUIK, 2023)

Region	2018	2019	2020	2021	2022
Almus	338	178	180	180	180
Center	8 800	10 850	12 375	12 375	1 3072
Erbaa	48 325	40 050	37 250	22 900	14 063
Niksar	2 824	5 327	5 725	2 495	2 570
Pazar	5 385	5 395	4 000	3 245	2 097
Resadiye	32	234	844	9	7
Turhal	8 360	9 020	9 438	8 866	8 874
Zile	1 045	285	285	285	248

According to TUIK statistics on the production of pepper in the province of Tokat from 2018 to 2022 in (Table 1.1), it was found that the largest area for pepper production was Erbaa. Pepper production was 48 325 tons in 2018, but this production decreased to 40050 tons in 2019 and it continued to decline until reaching 14 063 tons in 2022.

TUIK statistics also showed that the lowest area for pepper production was Reşadiye. Pepper production was 32 tons in 2018, and then it increased to 234 tons and 844 tons in 2019 and 2020, respectively. However, it started to decline again in 2021, reaching 9 tons and in 2022 7 tons.

As for the city center, pepper production was 8800 tons in 2018. It started to increase in 2019, reaching 10850 tons. In 2020 and 2021, it reached even greater production, with 12375 tons.

The production of pepper in the rest of the regions varied. In some years, it decreased to the lowest production, such as in Zile, where it was 1 045 tons in 2018. In other years, the production was at a low rate (TUIK, 2022).

Table 1.2. Cultivation area of pepper field in Tokat Province (Decares) (TUIK, 2023)

Region	2018	2019	2020	2021	2022
Almus	178	178	180	180	180
Center	2 810	6 695	3 545	3 545	3 745
Erbaa	7 905	6 555	6 500	3 800	2 180
Niksar	808	1 109	780	715	713
Pazar	2 050	2 050	1 500	1 250	750
Resadiye	40	40	16	13	10
Turhal	3 800	4 105	4 290	4 030	4 030
Zile	150	150	150	150	130

According to TUIK statistics from a survey of areas cultivated with pepper (Table 1.2), it was found that the most planted area with pepper plants was 7 905 decares in Erbaa in 2018. In 2021 and 2022 the highest region of cultivation was in Turhal with 4030 hectares, while in Reşadiye, the cultivated area was very low. It was 40 decares in 2018, and 2019, and then decreased further to 13 decares in 2021. In the center, the highest cultivated area was reached in 2019, when it was 6695 hectares. However, in 2021, it decreased to 3545 decares. Also, in the Pazar region, the cultivated areas were in good proportions. They were

2342 decares and 2050 decares in the years 2018, and 2019, while in 2021-2022 decreased to 750- 1250 decares.

Pepper production can be limited by various abiotic such as salinity, drought and biotic factors, such as pests and diseases. Insects are a major problem in pepper production, aphids, flea beetles, pepper maggots, thrips, and European corn borers can lead to significant crop damage, additionally, several pepper diseases, such as bacterial leaf spot (*Xanthomonas campestris* pv. *vesicatoria*), phytophthora blight (*Phytophthora infestans*), anthracnose fruit rot (*Colletotrichum* spp.) , bacterial soft rot (*Erwinia chrysanthemi*), and viruses like Potato virus (PVY) and Tobacco mosaic virus (TMV), Tomato spotted wilt virus (TSWV), can also result in crop losses, these diseases can be controlled through the use of disease-resistant or disease-tolerant cultivars, proper crop rotation, growing in areas with good air circulation, and planting in soil with good water permeability (Kime et al., 2017). Thrips can harm many crops and spread various plant viruses, they are small insects, with a slender, elongated body measuring about 1 mm or less in length, two pairs of fringed wings, and a pale yellow to light brown color, adult males are usually smaller than adult females, thrips belong to the insect order Thysanoptera, which refers to their fringed wings as the wings of adult thrips have long hairs, this order encompasses over 5,000 species, most of which are small and slender in body, with a length that typically ranges from 1-2.5 mm in temperate regions (Palmer et al., 1989). Thrips have been found on over 500 host species from 29 different plant orders, including cotton, berries, flowers, field crops, grasses, legumes, vines, privet hedges, roses, trees, truck crops, and weeds (Buitenhuis et al., 2010; Manoliu et al., 1993). Thrips can affect both the quantity and quality of flower production in greenhouse and field-grown host plants, making efficient control measures necessary, both larvae and adults cause damage by sucking plant sap from buds, flowers, and leaves, resulting in distorted and discolored plant parts that take on a gray or silver scars, the empty cells in the damaged parts of the plant, after the sap has been sucked, are filled with air and appear silvery with black spots (Bethke and Bates, 2013). Thrips can spread several viruses, including tomato spotted wilt virus (TSWV), which has a very wide host range and infects plants from over 50 families (Flint, 1998). Thrips species like *Thrips tabaci* (Lindeman) and *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) can

cause stippled and scarred petals, leaves, and other plant parts, as well as distorted terminals and those thrips are also important vectors of TSW viruses. The development of thrips typically takes 20-30 days from egg to adult and its growth ceases at 35°C, thrips have 12 to 15 generations in a year during the warmer months, female thrips lay their eggs within the plant, on leaves, stems or undersides of leaves, which are small in size about 0.2mm. Each female lays 2 to 200 eggs after mating, the color of the eggs is white or pale yellow, the thrips life cycle is composed of an egg stage, two larval stages, prepupal stage, pupal stage, and adult stage, with the prepupal and pupal stages taking place in protected places or in soil, Thrips thrive better on flowering plants like sweet peppers compared to plants without flowers (Hoddle and Paris, 2008). *Frankliniella occidentalis* become active in the early spring and lay their eggs on plant tissue, these punctures resulting brown or discoloration on the white petals. The time required for the egg to develop an adult range from 11 to 17 days, depending on the temperature (Anonymous, 2002). Controlling thrips can be challenging and typically involves the use of chemical insecticides, insecticide sprays can be applied in sequence to manage thrips populations when they reach 15-20 thrips per plant (Pandey et al., 2019). The use of chemical control to manage thrips may not always be effective due to certain ecological traits of the thrips species, including their tendency to seek shelter, high reproductive capacity, and resistance to insecticides (Tompos, 2006). Therefore, the most efficient method of controlling thrips involves utilizing a comprehensive approach that combines cultural practices, utilizing natural predators, and applying the most selective or least harmful insecticides (Bethke and Bates, 2013). Adults thrips can be monitored by using bright blue sticky traps that are placed near or on host plants, the traps have a sticky yellow or blue surface, with blue sticky traps being particularly useful for catching thrips that have landed on flowers (Cho et al., 1995). Biological control involves utilizing other organisms to manage pests such as insects, mites, weeds, and plant diseases, this method is based on natural processes such as predation, parasitism herbivore, and others, agricultural crops can benefit from beneficial insects like pollinators, pest predators, and parasites, keeping a healthy population of these biological control organisms can be achieved through various techniques, including using

low-risk pesticides, preserving native natural predators like predatory mites and stinkbugs, and supporting a diversity of parasitoid flies and wasps (Jones and Gillett, 2005).

The control of thrips in sweet pepper crops can be enhanced through the use of predatory arthropods like the *Amblyseius swirskii* Athias-Henriot (Arachnida: Mesostigmata: Phytoseiidae) mite and the flower bug *Orius laevigatus* (Fieber) (Hemiptera: Anthocoridae). These organisms are a cost-effective alternative to chemical pest control methods (Van and Bueno, 2003). *Amblyseius swirskii* mites and *O. laevigatus* are commonly employed to manage pests, both the larvae and adults feed on a range of small insect pests including thrips, spider mites, insect eggs, aphids, and small caterpillars, the pests' soft bodies are typically consumed, leaving only the exoskeleton behind, *Orius* species and mites are particularly significant predators, feeding on both the adult and larval stages of thrips, as well as their eggs (Hodges et al., 2009).

The *O. laevigatus* is a small predatory insect that feeds on a wide range of prey, including thrips, aphids, whiteflies, and mites. It measures about 3 mm in length, is oval-shaped, and has black and white wing patches, with wings extending beyond its body, the nymphs are small, wingless, and vary in color from yellow to brown, the most widely used *Orius* species for biological thrips control is *O. laevigatus*, under normal conditions, female *O. laevigatus* consume around 12 thrips daily, feeding by sucking out the body contents and leaving behind only the empty skin, both the nymphs and adult bugs can consume up to 30 or more thrips in a single day (Flint, 1998). Both adult and nymph stages of the bug feed by extracting the bodily substances of thrips (Moritz et al., 2009).

Amblyseius swirskii is a beneficial predatory mite species known for its generalist feeding habits, including the consumption of small, soft-bodied pests like thrips. The adult mite has four pairs of legs and measures 0.4 mm in length, with a pale color, the eggs are typically laid on the underside of leaves, and the larvae, which are much paler than the adults, are very small and difficult to spot (Flint, 1998).

This study is unique due to its integration of various control methods for thrips management in pepper production areas under field conditions, additionally; the population dynamics of thrips in pepper crops were studied in open field conditions.

The aim of study was:

1. Determination of thrips species in pepper production areas of Tokat Province, Türkiye.
2. Evaluation of efficiency of different control methods against thrips under open field conditions.



2. LITERATURE REVIEW

2.1. Thrips definition

Thrips can reproduce through both sexual and asexual means, in the sexual method, females are diploid and males are haploid, similar to other bisexual species, the sexes mate within two or three days after their final pupal molt, with each male capable of fertilizing multiple females, they locate each other through a sensory cone on the top of their antennae, oviparity is common in thrips (Lewis, 1973). Female thrips can mate with a male to lay fertilized eggs, or they can lay eggs without mating through a process called parthenogenesis, female adults lay their eggs in living plant tissue using their ovipositor, the eggs hatch within 2 to 4 days, marking the start of the first of two larval stages, which are minute, white or yellowish, elongate, cylindrical or kidney-shaped and partially embedded in host tissue by the female (Shimat et al., 2019). The larval stage of thrips is composed of two different developmental stages, during this time, they feed and mature on the leaves, flowers, and fruit (Bunn, 2014). The first instar larvae are about 0.5-1.0 mm long, this stages where they actively feed, they have a white to pale yellow color, with a long and slender body, similar in appearance to adults but lacking wings, the antennae are short, and their eyes are dark in color, they primarily feed on new leaves in the center of the leaf stem (Bunn, 2014). The second stage larva about 1.0-1.2 mm in length, it has the light yellow to brown body with antennae bent towards the head and wing buds that are visible, it can be found in the soil near the plant (Bunn, 2014). The pupal stage is a non-feeding and immobile period, the pupae have thin tubes on their backs, which are the developing wings, this stage typically occurs in the soil or near the host plants, under fallen and decayed plant matter (Mound and Teulon, 1995). The development of the prepupal stage often occurs on the soil or on leaf litter or lodge within plant crevices or galls, but it can also occur on the plant (Mound and Teulon, 1995). Thrips are tiny insects, typically measuring 1.2-1.5mm in length, with slender bodies and fringed wings, they have a simple morphology, with short antennae consisting of 6-9 segments and three ocelli located on the top of the head, the legs of thrips have single or double-segmented tarsi ending in a vesicle, and they have a

compact rostrum with asymmetrical suctorial mouthparts and only one functional mandibular stylet (Morse and Hoddle, 2006). The first region of the body behind the head, the pronotum, has several setae (hairs) and the number of pairs of setae between the compound eye and simple eyes (ocelli) on the thrips head, as well as the presence of two complete rows of setae on the wings, can be used to identify thrips (Mound and Kibby, 1998). The abdomen of thrips consists of 11 segments, of which only 10 can be seen, in female Terebrantia, the end segments are usually cone-shaped, and in males they are rounded off without a point (Mound and Teulon, 1995).

2.2. The biology and life cycle

Thrips eggs usually takes from 3 to 5 days to hatching, the larvae feed for 1 to 3 weeks and then rest to molt for another 1 to 2 weeks, thrips can have up to 15 generations in a year and increasing in warmer conditions, both larvae and adult thrips feed on pollen and cell sap within flowers, causing discoloration, malformed buds, and loss of fruit (Mound and Marullo, 1996). The success of thrips as pests can be attributed to both their anatomy and life cycle, their rapid reproduction and generation time allows their populations to grow quickly (Georghiou and Taylor, 1977). The life cycle of thrips consists of five stages: egg, two larval stages, two pupal stages, and adult, males are smaller than females, and females use a sharp egg-laying tube to insert their eggs into plant tissue, the eggs hatch after 6 days and the two larval stages take an additional 6 days to complete, prepupal and pupal stages, which occur in the soil, the average lifespan of a mated female is 35 days, with each capable of producing 50 or more eggs, thrips can reproduce both sexually and asexually, with mated females producing both male and female offspring while unmated females produce only males, the life cycle can be completed in two weeks under favorable conditions, thrips populations peaking in the spring and early summer, the number of adult and larva thrips varies during the months of April and May, with the highest concentration typically occurring in early April (Edelson et al., 1986). The larvae tend to be found in groups more frequently than the adults (Theunissen and Legutowska, 1991). The seasonal distribution of the western flower thrips *Frankliniella occidentalis* and *Thrips tabaci* was

observed more abundant in the spring while the latter was more abundant in the fall, both species were found in higher numbers in the upper part of the plant compared to the lower part, and recorded a higher population of male thrips in the upper part of the plant, while immature thrips were found in the lower part (Reitz, 2002). The resistance to pesticides in thrips can be increased when female thrips that mate with haploid males to produce offspring, thrips can reproduce either through parthenogenesis or through mating, and they are either arrhenotokous or thelitokous, according to most researchers, females are diploid while males are haploid, males mate with females within 2 to 3 days after the last pupal molt and can fertilize multiple females, the sexes locate each other through a sensory cone on their antennae (Lewis, 1973).

2.3. Distribution

Thrips has a global distribution, as its presence is reported in over 120 countries (Wu et al., 2021). Thrips are found in a wide range of locations, from tropical and subtropical regions to temperate areas (Pourian et al., 2009). Dry weather with high temperature can be the increasing factor of thrips population. *Frankliniella occidentalis* which originated from western North America, and has become a dominant thrips species in many of the areas it has invaded, *F. occidentalis* is naturally found in many wildflowers across western North America, including southern California, Mexico, and Canada, in the late 1970s, it began to spread eastward across the USA and Canada, in 1983, it had reached and spread throughout Europe (Kirk and Terry, 2003). *F. occidentalis* become well established in Europe and Israel, it spread to the highlands of eastern Africa and subsequently entered New Zealand in 1992 and Australia in 1993. In Australia it has spread through agricultural areas of eastern Australia, and it is present in southern Brazil (Monteiro et al., 1999). *Bradinothrips musae* species of thrips have been recorded as banana pests in Brazil (Sutil et al., 2022). Also Thrips species present in the Cameron Highlands of Peninsular Malaysia (Fauziah and Saharan, 1991). In Costa Rica and Colombia, this pest is mostly found in green houses, however, in Guatemala, it has been reported as a pest of field- crops (Reitz, 2002). Chilli thrips, (*Scirtothrips dorsalis*), is an economically important pest of vegetable, fruit, and

ornamental crops throughout Asia, Africa, Oceania, the Caribbean and some parts of South America and is an invasive pest in several US states, chilli thrips were first observed in Florida in 1991 (Kumar et al., 2013).

2.4. Economic importance

Thrips have piercing-sucking mouthparts that enable them to puncture different parts of plants, such as leaves, flowers, seeds, pollen grains, and fruit, they can also feed on open liquids like nectar, water, and even insect secretions (Kirk, 1995). When the head is thrust downward, the mandible is driven down, and the mouth cone is pulled back, resulting in a feeding hole in the plant (Mound, 2005). The two maxillary stylets hold a channel for feeding, which is used to inject saliva into plant cells (Espinosa et al., 2002). The cibarial muscles generate enough suction to extract the contents of the plant cell through the feeding tube, causing necrotic scars to remain (Frank, 2014). If present tospoviruses are spread to the plant when it is being Thrips fed upon (Takacs et al., 2008). Different species of thrips have a preference for specific parts of plants, such as flowers, leaves, or fruit, this may be because these areas have different nutrient levels, young or growing parts of the plant usually have a higher concentration of amino acids and amides in their sap compared to mature parts, making them a more attractive food source (Kirk, 1995). The *Frankliniella* species is recognized as a pest that attacks seedlings during the early growing season (Reed et al., 2006). Adults feed on the new growth at the tips of the plant and the underside of leaves, causing the plant tissue to become silvery and decreasing photosynthesis (Kirk, 2002). Plants that have been harmed by thrips can exhibit stunted growth and misshapen leaves. The *Frankliniella* species of thrips can be found in the blooms of eggplant, pepper, and tomato plants (Demirozer et al., 2012).

2.4.1. Direct damage

Thrips have a significant impact on agriculture as they cause direct harm to plants during both their egg laying and feeding processes, they have a preference for succulent plant

tissues and feed by piercing the cells with their mouthparts and draining their contents, they can feed on leaves, flowers, and even pollen, with light-colored flowers being a preferred target, the most typical damages caused by thrips include discoloration and yellowing of leaves and flowers, as well as malformations of fruits, they may also damage the delicate tissues of developing foliage and flowers by feeding on the bud scales, this results in scarring, which manifests as small scars or silvered patches and can lead to deformed plant growth, flower deformation, or unsightly flecking on leaves, damaged leaves become bleached and dry, while the skin of damaged fruit appears sanded with underlying tissues that can have off flavors, be hard, or dry, thrips can also cause new leaves growth spotted and thickened curls, making the plant unsightly and unmarketable if not detected and controlled early, the evidence of their feeding activities is more visible in the form of dark fecal pellets and the dried, whitened material they leave behind (Sutherland, 2006). Some plants exhibit a dead or discolored area in the vicinity where thrips have laid their eggs on the plant's tissue (Allen and Matteoni, 1991). The feeding of thrips causes petals to become misshapen, take on a discolored appearance, and display extensive streaks, the feeding cause's new leaves to grow abnormally, with a curled upward shape and white bumps on the upper surface (Tommasini and Maini, 1995).

2.4.2. Vectoring of plant diseases.

All thrips of the order Thysanoptera that have been identified as vectors of plant viruses are described, these thrips transmit viruses belonging to the Tospovirus, Ilarvirus, Carmovirus, Sobemovirus, and Machlomovirus groups (Abad et al., 2003). Tospoviruses are the source of numerous significant and growing diseases globally, and thrips are held accountable for serious outbreaks in various crops, resulting in billions of dollars in control expenses and lost yield for growers (Ullman et al., 1997). Thrips are known to transmit numerous plant diseases, with two viruses in the *Tospovirus* genus being particularly significant for greenhouse and field crop producers, these viruses are impatiens necrotic spot virus (INSV) and tomato spotted wilt virus (TSWV) (Ullman et al., 1997). Over the last 20 years, tomato spotted wilt virus (TSWV) has spread globally in numerous crops and this is largely due to

the effective transmission capabilities of *Frankliniella occidentalis*. (German et al., 1992). Tomato spotted wilt virus (TSWV) is a devastating pathogen that affects fresh market pepper crops, causing stunted growth in leaves, necrosis of stems and petioles, and the appearance of concentric rings on the fruit, in some fields, the incidence of the disease was observed to be 30 to 50%, and it eventually increased to 50 to 80%, Thrips acquire TSWV from infected hosts when they are first instar larvae, this occurs when they puncture plant cells and feed on sap containing virus particles (Van de Wetering et al., 1996). Tospoviruses are only acquired by western flower thrips during their larval stage when they feed on infected plants, the viruses then reproduce in the thrips' salivary glands and other tissues and are subsequently transmitted to healthy plants when the infected thrips, feeds on them, once the virus has replicated within the thrips and is transported to their salivary glands, transmission becomes possible during the second larval instar or adult stage (Wijkamp et al., 1993). The virus only spreads to the salivary glands during the first and possibly early second instar stage, through direct contact between the mid-gut muscle cells and the salivary glands (Moritz et al., 2004). The transmission of the virus to a new host occurs when the salivary glands of the thrips move away from the mid-gut during feeding and transmit the virus through salivation (Ullman et al., 1992). Male thrips are much more effective in transmitting tomato spotted wilt virus (TSWV) compared to female thrips (Van de Wetering et al., 1996). For transmission to occur in healthy plants, a minimum of 15-30 minutes of feeding by thrips is necessary (Sakimura, 1962). Efficient transmission of the pathogen frequently occurs in commercial greenhouse crops such as ornamentals and vegetables, leading to significant economic losses (Allen and Broadbent, 1986). Viruses that affect plants can be highly destructive and pose a significant threat to agriculture, TSWV is considered to be one of the top ten economically impactful plant viruses, causing significant issues in a number of crops (Goldbach and Peters, 1994). The varying abilities of different thrips life stages to transmit TSWV may be attributed to genetic factors in both the thrips and the virus (Bandla et al., 1998). There has been much focus on the genetic differentiation of thrips in relation to TSWV transmission, however, it has also been established that genetic differences between TSWV strains play a role, numerous studies have demonstrated that the efficiency of transmission varies with the strain of the virus in

several different thrips species (Jenser et al., 2002). The capability of various thrips life stages to spread TSWV may be attributed to both genetic factors in the thrips and the virus (Bandla et al., 1998). The ability to transmit TSWV is also influenced by the thrips feeding on the host and the host's sensitivity or tolerance to the virus (Maris et al., 2003). It is believed that the capacity to transmit TSWV is controlled by factors such as the thrips' preference for and ability to feed on different hosts (Bautista and Mau, 1994). The virus TSWV, which is transmitted by thrips, has been identified in over 1100 plant species including crops grown for horticulture, ornamental plants, and weeds (Parella, 1995). TSWV has caused substantial harm to crops such as lettuce, capsicum, tomato, stonefruit, tobacco, peanuts, chickpea, eggplant, celery, rhubarb, and ornamental plants, leading to substantial losses in countries including Australia, New Zealand, the United States, Eastern, Western and Southern Europe, and Eastern and Southern Africa and Asia (Chatzivassiliou et al., 1996). The symptoms of TSWV vary in type, severity, and extent and can range from local chlorotic and necrotic lesions in plants with hypersensitive responses to irregular chlorotic and necrotic areas, ring spots, necrotic streaks, line patterns, stunting, mottling, and wilting when the virus is transported throughout the plant, other possible symptoms include bronzing, curling, dark brown streaks on leaf petioles and stems, stunted growth, and cessation of growth (Persley et al., 2007). Controlling pathogens transmitted by thrips is extremely difficult because even a few thrips can result in high rates of pathogen transmission, furthermore, many thrips species are not susceptible to pesticides due to resistance, growing plants that are resistant to pathogens can reduce disease spread in certain situations, but the thrips species known to transmit plant viruses are not closely related from a phylogenetic perspective, they do have similar ecological features such as feeding on multiple host plants and the ability to reproduce on various host plants (Ullman et al., 1992). Thrips effectiveness as vectors of Tospoviruses is also due to their way of feeding, which involves puncturing the plant and sucking its sap, Tospoviruses are a group of plant-affecting viruses transmitted by thrips and can cause diverse symptoms in plants, depending on the type of virus and the infected plant (Labuda, 1991). The diagnosis of this plant disease can be difficult and may vary depending on the type of plant, it may also be mistaken for other issues such as other diseases, fungi, bacteria, or nutritional problems,

symptoms include stunted growth, ring spots (spots on leaves or stems that are brown to purple), brown stems, flowers falling off the stems, and death, the use of certain pesticides can also lead to the elimination of biological control agents for thrips, potentially leading to outbreaks, some chemicals used for treatment work slowly and have limited effectiveness, and the virus can be spread to other plants through thrips before they die, using certain pesticides can also cause insects to become agitated and fly (Broadbent and Allen 1995). Thrips at both the adult and larval stage, after acquiring TSWV, can spread the virus (Tsuda et al., 1996). Populations of *Frankliniella occidentalis* and *Thrips tabaci* are capable of transmitting Tomato Spotted Wilt Virus (TSWV) (Wijkamp et al., 1995).

2.5. Host plants

Frankliniella occidentalis is a pest that affects the flowers of many agricultural crops including asparagus (*Asparagus officinalis* L.), blackberry (*Rubus subg Rubus*), cotton (*Gossypium hirsutum*), eggplant (*Solanum melongena* L.), peach (*Prunus persica* L.), pepper (*Capsicum annuum* L.), corn (*Zea mays* L.), soybean (*Glycine max* (L). Merr), strawberry (*Fragaria x ananassa* Duch.) and tomato (*Solanum lycopersicum* L.) (Funderburk et al., 2015). *Frankliniella* species can be found in ornamental plants like chrysanthemum and rose (Cluever and Smith, 2016). In addition to agricultural crops and ornamentals, *Frankliniella* species has been found in several species of flowering weeds including morning glory, dandelion, wood sorrel, and clover (Chellemi et al., 1994). In Türkiye, weeds host list of *Frankliniella* spp. and *Thrips tabaci* as well as their predatory insects has been published by (Atakan and Uygur, 2004, 2005).

2.6. Thrips species

Thrips is the biggest genus in the Thysanoptera order, there are over 280 species, mostly located in Europe, Africa, and Asia, the Thysanoptera order is comprised of two sub-orders, namely Tubulifera and Terebrantia, these two sub-orders are part of the Thysanoptera order, the defining characteristic of the thrips species can be found at the

end of their abdomen, members of the Tubulifera sub-order have a cylindrical, tube-like final segment of the abdomen, this group is referred to as Phlaeothripidae and is the only family within the sub-order, these thrips have tube-like tips and a few bristle-like protuberances at the end, unlike other thrips, Tubulifera species do not damage plants by laying eggs inside them as they lack the serrated ovipositor, in contrast to the Tubulifera sub-order, Thrips belonging to the Terebrantia sub-order have a pointed segment with a saw-like stinger called an ovipositor, there are numerous families within the Terebrantia sub-order, and the cone-shaped tip conceals a drill-like organ known as the ovipositor, in addition, thrips have bristles, however, they primarily protrude from the penultimate ring in the abdomen rather than the tip, as seen in species of the Tubulifera sub-order (Laurence, 2010).

2.7. Thrips species recorded in Türkiye

The species of Thysanoptera in Türkiye, samples of thrips were gathered from cereal crops at two separate times, the study area encompasses the regions of Afyonkarahisar, Antalya, Burdur, Konya, and Isparta (Kızılaslan, 2004). Thrips commonly feed in various locations including under the sheath of flag leaves, on the stem, on leaves, and on spikes. Both adults and larvae cause damage by feeding on plant tissues and draining cell contents, resulting in silvery staining (Gaafar et al., 2010). Numerous species of thrips (Thysanoptera) are known to attack various Citrus spp. across different regions of Turkey, these species typically cause damage by feeding on the flowers, fruits, and leaves of citrus varieties, the resulting damage is characterized by silvery scars on the tissues surrounding the calyx, which diminishes the market value, in Turkey, the composition of thrips species that inhabit citrus plants has been extensively documented. However, in the eastern mediterranean region of Turkey, *Frankliniella occidentalis* (Pergande), *Thrips major* (Uzel), and *Thrips tabaci* (Lindeman) were commonly found in citrus plantations, *F. occidentalis* is a versatile species that infests various crops and wild plants worldwide. Interestingly, this thrips species was first observed on certain ornamental and vegetable plants in Antalya, particularly in the Çukurova Region (Atakan et al., 2016). The Hawaiian flower thrips,

Thrips hawaiiensis (Morgan, 1913) (Thysanoptera: Thripidae), has been reported for the first time in Mersin province, Turkey, it was found infesting lemon trees, where it caused silvery spots on young fruits and damage to the fruit's structure, *T. hawaiiensis* was detected in lemon orchards from Turkey, additionally, the thrips affected both the plant tissue and fruits, causing them to appear silvered, this species of thrips has also been observed on various vegetables, ornamental plants, and field crops such as cotton, sunflower, maize, and sesame (Atakan et al., 2021). Thrips species damaged associated with strawberry in Adana and Mersin provinces, Turkey, the population densities of the thrips and damage symptoms due to thrips attacks on various plant parts like flower and fruits, this species including *Frankliniella occidentalis* (Pergande), *Frankliniella intonsa* (Trybom) and *Thrips tabaci* (Lindeman) (Atakan, 2008). *F. occidentalis* and *T. tabaci* were active in the alfalfa fields during the winter months, in Adana province of Turkey (Atakan and Tunc 2004). Thrips species *F. occidentalis* and *T. tabaci* Occurring in winter vegetable crops in Çukurova region of Turkey, *F. occidentalis* was the predominant thrips infesting broad bean, lettuce and parsley, while *T. tabaci* was more abundant on leek, onion and pea (Atakan, 2008). *Frankliniella occidentalis* and *Thrips major* were the most fruit pests in fruit orchards in the Çukurova Region of Turkey, caused damage for peach, apple and plum (Atakan, 2008). Thysanoptera species on citrus orchards were surveyed in Adana, Mersin, Hatay and Osmaniye provinces in Eastern Mediterranean Region of Turkey, samples consisted of citrus flowers, species belong to families Thripidae, Phlaeothripidae and Aeolothripidae, thrips species were *Frankliniella occidentalis* (Pergande), *Thrips meridionalis* (Priesner), *Thrips major* (Uzel), *Thrips tabaci* (Lindeman), *Pezothrips kellyanus* (Bagnall), *Haplothrips reuteri* (Karny), *H. distinguendus* (Uzel), *Melanthrips* sp. *F. occidentalis* and *T. major* (Nas et al., 2007). Population densities of *Haplothrips tritici* (*H. tritici*) Kurdjumov (Thysanoptera: Phlaeothripidae) were studied in Kahramanmaraş, Turkey in bread wheat cultivars (Özsisli, 2011). In Turkey, the (western thrips) *Frankliniella occidentalis* (Pergande) is a key pest affecting eggplants grown in greenhouses In Turkey, eggplants can greatly improve the efficiency of *A. swirskii* controlling thrips. The experiments were carried out in both greenhouse and low tunnel, used *A. swirskii* for controlling thrips (Kutuk, 2017). Thrips samples were collected at two

different periods of cereal crops in region of Turkey, most common species were *Haplothrips tritici* (Kurdjumov 1912), *Collemboothrips mediterraneus* (Priesner 1935), *Thrips angusticeps* (Uzel 1895), *Limothrips cerealium* (Haliday 1836) The *H. tritici*, *T. angusticeps*, *L. cerealium*, *Aeolothrips intermedius* (Bagnall, 1934), *Aptinothrips stylifer* (Trybom, 1894), The Lakes Region includes Afyonkarahisar, Antalya, Burdur, Konya, and Isparta in the west of the Mediterranean Region in cereals crops, Cereals provide an important contribution to the Turkish economy in agricultural production (Yiğit et al., 2022). Determine thrips species and population densities in different pepper varieties in Kahramanmaraş in 2019 Türkoğlu Hacıbebek village, Türkoğlu Kadioğlu village and Dulkadiroğlu Çiğli village, by used blue sticky trap and flower samples, leaf samples taked, determine thrips species *Frankliniella occidentalis* (Pergande 1895), *Frankliniella intonsa* (Trybom 1895), *Thrips dubius* (Priesner 1927), *Thrips tabaci* (Lindeman 1889), *Haplothrips aculeatus* (Fabricius 1803), *Haplothrips gowdeyi* (Franklin 1908), *Aplothrips intermedillna* (Franklin 1908) 7 species were identified. Among the detected species, the most common species in the spicy pepper variety *Frankliniella occidentalis*, respectively, *Haplothrips aculeatus*, *Thrips tabaci*, *Frankliniella intonsa*, *Aeolothrips intermedius*, *Thrips dubius*, *Haplothrips gowdeyi*, the most abundant species in the capia pepper variety, *Frankliniella occidentalis* *Haplothrips intermedius* aripoloth The most common species in *Frankliniella intonsa* and tomato paste were *Frankliniella occidentalis*, *Frankliniella intonsa*, *Aeolothrips intermedius* and *Thrips tabaci* (Table 2.3).

Table 2.3. Thrips species associated with pepper and vegetable crops plants in Türkiye

Family	Species	Host	Research related Thrips species in Türkiye
Thripidae	<i>Frankliniella occidentalis</i> (Pergande 1895)	Eggplants	(Kutuk, 2017)
	<i>Frankliniella occidentalis</i> (Pergande 1895) <i>Thrips tabaci</i> (Lindeman 1889)	Winter vegetable crops	(Atakan, 2008)
	<i>Frankliniella intonsa</i> (Trybom 1895) <i>Thrips dubius</i> (Priesner 1927), <i>Thrips tabaci</i> (Lindeman 1889), <i>Haplothrips aculeatus</i> (Fabricius 1803) <i>Haplothrips gowdeyi</i> (Franklin 1908) <i>Apllothrips intermedillna</i> (Franklin 1908)	Pepper	(Kozanoğlu, 2022)
Aeolothripidae	<i>Aeolothrips gloriosus</i> (Bagnall, 1914 <i>Aeolothrips gloriosus</i> (Bagnall))	green house vegetables	(Tunc, 1991)

2.8. Pest Management

2.8.1. Cultural Control

Cultural pest control options involve planting crops or cultivars that are less attractive to thrips, avoiding the rotation of susceptible hosts, properly managing vegetation in the field and at the edges, utilizing colored mulches that deter thrips, and limiting the use of high nitrogen fertilizers (Brodbeck et al., 2001). Other approaches to managing thrips are cultural techniques, for instance, postponing the planting time can decrease thrips damage, cultural pest control involves changing growing conditions to hinder the pest and its life cycle, these methods include planting resistant varieties, plowing, using mulch, manual weeding and hoeing, trimming, trapping and manual removal of insects and weeds, and utilizing physical obstacles such as row covers and sticky strips (Greene et al., 2020).

2.8.2. Physical control

Physical pest control is a primary method of protecting crops from insect damage, where insects are eliminated by killing, removing, or blocking their access to crops, this type of control is mainly utilized in crop cultivation (Vincent et al., 2003).

2.8.3. Mechanical control

Mechanical cleaning is a widely used post-harvest procedure, especially when required as a quarantine treatment, the importing regulatory agencies typically inspect the cleaning to confirm that unwanted pests and debris have been effectively removed, cleaning alone may not be sufficient and often requires additional treatment, one variation of cleaning is the soapy water and wax treatment, which has been shown to be effective against small pests that infest the surface of fruits and vegetables (Vincent et al., 2003).

2.8.4. Trapping

Trapping is an effective pest management strategy, particularly in the form of perimeter trapping, which has been successful in preventing flying insects from entering orchards from nearby host plants, success factors include low pest infestation, high trap density, availability of attractants, the absence of nearby host plants, and proper trap maintenance, Thrips can be monitored using sticky traps or the "trapping method", which can be used to detect their presence and estimate their numbers. Sticky traps can be placed randomly, such as above the crop, and both yellow and blue traps can be used, blue traps are more efficient, but yellow traps are also attractive to whiteflies and other flying greenhouse pests, making them useful for overall pest monitoring, pheromones produced by adult male thrips can attract both males and females and have been used commercially for monitoring and mass trapping as part of an integrated pest management program, pheromones have also been widely used for managing other insect pests and can be used in many ways (Howse et al., 1998). Pheromones play an important role in the behavior of thrips, a type of

pheromone known as a larval alarm pheromone has been identified in the western flower thrips, *Frankliniella occidentalis*, this pheromone has the potential to enhance the effectiveness of insecticides (Teerling et al., 1993). A pheromone produced by adult males has been identified in the western flower thrips, *Frankliniella occidentalis*, however, it only works through physical contact, so its potential for pest management is limited (Olaniran et al., 2013).

In the species *Echinothrips americanus*, anti-aphrodisiac pheromones have been found which could be used for mating disruption, aggregation pheromones have also been discovered in various species and hold the possibility of being utilized for trapping and altering behavior in different scenarios, the purpose of this paper is to examine the current understanding of aggregation pheromones in thrips and explore their potential for controlling pests (Krueger et al., 2016). The available evidence indicates that the production of pheromones is done by the sternal glands, which release them through the pore plates, although it is probable that the sternal glands produce aggregation pheromones, this has yet to be confirmed, the first aggregation pheromone was discovered in *Frankliniella occidentalis* (Hamilton and Kirk, 2013). The idea that the sternal glands are responsible for producing the aggregation pheromone was largely based on the fact that they were found only in males and were large enough to produce the large quantities needed for the pheromone to work at a distance, however, the discovery of a second adult-male-produced pheromone in *F. occidentalis* has complicated the matter (Olaniran et al., 2013). The finding of a second adult-male-produced pheromone in *Frankliniella occidentalis* has complicated the previous assumption that the sternal glands produce aggregation pheromone as both pheromones are produced in similar quantities (Dublon et al., 2008).

2.8.5. Biological control

The potential of various natural enemies to control thrips populations in greenhouse and field crops has been studied, these include green lacewings, minute pirate bugs (*Macrotracheliella nigra*), mites, and certain parasitic wasps, pathogenic fungi, and

nematodes, the management of thrips in sweet pepper crops can be improved through the use of predatory insects such as the predatory mite *Amblyseius swirskii* and the flower bug *Orius laevigatus*, minute pirate bugs of the *Orius* species are the main predatory insects found in association with thrips populations (Riudavets, 1995). Biological control which are cost-effective replacements for chemical pest management methods (Van Lenteren and Bueno, 2003). Several species of *Orius*, including *O. laevigatus*, *O. majusculus*, *O. armatus*, *O. heterorioides*, *O. tantillus*, and *O. insidiosus* have been documented as preying on thrips and have been employed for their control (Ferguson and Schmidt, 1996). Biological pest control is considered cost-effective in crops with long growing periods that can last for up to 8 to 10 months, two common biocontrol agents (Table 2.40), the predatory mite *Amblyseius swirskii* and the flower bug *Orius laevigatus*, are widely utilized by sweet pepper growers for managing thrips pests as part of their integrated pest management strategy (Molnar et al., 2008).



2.8.5.1. *Amblyseius swirskii* Athias-Henriot (Acari: Phytoseiidae)

Several species of phytoseiid mites have been documented as feeding on different developmental stages of thrips (Sabelis and van Rijn, 1997). Some commonly used species of *Amblyseius* as predators include *A. andersoni*, *A. barkeri*, *A. californicus*, *A. cucumeris*, *A. hibisci*, *A. limonicus*, and *A. scutalis* (Riudavets, 1995). *A. swirskii* is a helpful mite that preys on other insects and is originally from the eastern Mediterranean area (Ragusa and Swirski, 1977). many research studies have demonstrated that *A. swirskii*, a versatile predator, can consume and breed on a variety of food sources, including greenhouse whitefly, tobacco whitefly (*Bemisia tabaci*), acrid mite (*Tyrophagus putrescentiae*), broad mite (*Polyphagotarsonemus latus*), tomato russet mite (*Aculops lycopersici*), spider mite (*Tetranychus urticae*), and chilli thrips (*Scirtothrips dorsalis*), and also nourish themselves on the pollen of different plant species (Momen and El- Saway, 1993). Studies have shown that *A. swirskii* is a promising biological control agent due to its ability to feed on, reproduce and develop on both western flower thrips and onion thrips, the mite has been found to be effective in controlling *F. occidentalis* on vegetable crops, including sweet

pepper (Kutuk et al., 2011). *A. swirskii* is a highly mobile predator with good searching behavior, and is effective against various pest insects, including western flower thrips, onion thrips, and *F. occidentalis* on vegetable crops and sweet pepper, it is not susceptible to diapause, making it useful throughout much of the season, and is considered a generalist predator, feeding on small soft-bodied pests, pollen, and plant exudates, the species is native to Israel, Italy, Cyprus, Turkey, Greece, and Egypt, and can be found on various crops such as apples, apricots, citrus, vegetables, and cotton (Eppo, 2013). This predatory mite has been utilized or tested as a biological control agent in numerous regions, including Europe, North America, North Africa, China, Japan, and Argentina (Arthurs et al., 2009). The eggs of *Amblyseius swirskii* are small, oval-shaped, and light-colored, measuring about 0.15 mm, the female predatory mites lay their eggs on the bottom of leaves, often near leaf hairs and small tufts of hair known as domatia, possibly as a defense against egg predators (Ragusa and Swirski, 1975). The immature stages of *Amblyseius swirskii* include the larvae, protonymph and deutonymph, the larvae are light white with three pairs of legs, the second and third stages respectively, have four pairs of legs and are darker in color compared to the larvae, the adult mites are shaped like pears, measuring 0.5 mm (Arthurs et al., 2009). *Amblyseius swirskii* has the ability to subsist on various pollens and plant nectars, enabling them to maintain their population during times of low pest activity and enhancing their performance as a biological control agent, however, the predator is best suited for warmer and humid subtropical climates (Ragusa and Swirski, 1975). The growth and development of *A. swirskii* is impacted by the type of food it consumes, the amount of food available, and the environment, optimal conditions for development occur between 18°C and 36°C at 60% relative humidity, if feeding on prey, the time it takes for an egg to become an adult at 25°C is around five days (Park et al., 2010). Females laid 26 eggs on a pollen diet and 38 eggs on a mite diet, when not hunting, *A. swirskii* can typically be found on the underside of leaves (Park et al., 2010).



Figure 2.1. Adult of *Amblyseius swirskii*

2.8.5.2. *Orius laevigatus* (Fieber, 1860) (Hemiptera: Anthocoridae)

The genus *Orius*, known as the minute pirate bug, in family Anthocoridae, the bugs have an oval-shaped body, with adults measuring 2 to 5mm in length and having a brown-black color with gray spots, they have a piercing-sucking mouthpart and two pairs of wings, the first being partially rigid, and both wings are longer than the body, the female can be differentiated from the male by her pointed abdomen and the presence of an ovipositor, optimal conditions for the predator include temperatures between 21-27 degrees and 70% humidity, and they primarily feed on smaller insects, larvae, and eggs like spider mites, thrips, and jumping plant lice (Hérard, 1986). This genus of bugs, known as the minute pirate bug, will also consume pollen and sap from the plant's vascular system (Kiman and Yeargan, 1985). The *O. laevigatus* have ability to feed on a variety of pests, including whitefly larvae, spider mites, and moth eggs, but it has a preference for thrips, especially the western flower thrips, an adult predator can consume over 30 thrips per day, the flattened body of the nymphs and adults helps them move easily between petals, making *O. laevigatus* a great solution for thrips control, when there is a lack of pests or pollen, the bug can feed on predatory mites, gall midges, and parasitic wasps, but this does not cause significant harm to entomophage populations, *O. laevigatus* is commonly used to control thrips in a variety of crops, including vegetables, flower-ornamentals, and tree-shrub crops,

particularly in pollen-rich crops like sweet peppers, the female lays 60-150 transparent white eggs in a leaf or stem, which hatch into nymphs after 4-5 days and are not visible to the naked eye, the nymphs change color from yellow to orange and brown as they mature, the nymphs develop wing buds and become similar in color to adults, with favorable conditions, the nymphs grow and develop in 6-8 days, adults begin mating 3-5 days after emerging (Mouratidis et al., 2022). The lifespan of adults is 3-4 weeks, the body of the bug is oval in shape, reaches a length of 1.4-2.4 mm and has a characteristic brown-black color with gray spots, the bug has a piercing-sucking mouthpart and a pair of wings, both pairs of wings are longer than the body, the female differs from the male in a pointed abdomen due to the presence of an ovipositor, the optimal conditions for a predator are temperatures of 21-27 degrees and humidity of about 70% (Chambers et al., 1993).

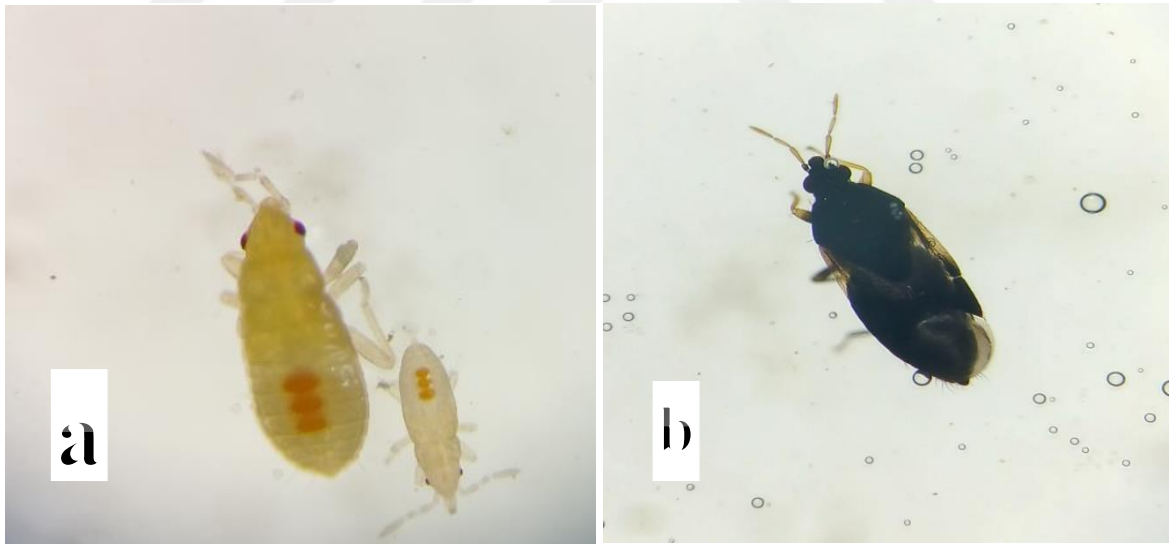


Figure 2.2. *Orius laevigatus* a. Immature stage b. Adult stage

Table 2.4. Natural enemies (*Amblyseius swirskii* and *Orius laevigatus*) and plant name used as biological control (Koppert, 2023).

Natural enemies	Plant name	Harmful organisms name (Purpose of usage)	Mode of action	Packaging content	Storage time after receipt	Storage temperature	Application
<i>Amblyseius swirskii</i>	Pepper Vegetable	Tobacco whitefly (<i>Bemisia tabaci</i>) Acrid mite (<i>Tyrophagus putrescentiae</i>) Broad mite (<i>Polyphagotarsonemus latus</i>) Tomato russet mite (<i>Aculops lycopersici</i>), Spider mite (<i>Tetranychus urticae</i>) Chilli thrips (<i>Scirtothrips dorsalis</i>) And young larvae and whitefly eggs and larvae of various thrips species	Predator mites pierce their prey with their sucking mouthparts and suck the contents.	25,000 predator mites (500ml bottle).	1-2 days	12-14°C In the dark, provide ventilation to prevent CO ₂ accumulation	Invert the bottle and shake it gently before use, open the dosing hole by pushing the center of the cap, scatter material on leaves or pour into Diboxes, ensure material is not disturbed for several days at the installation site
<i>Orius laevigatus</i>	Peppers Vegetable	Various types of thrips Smaller insects, larvae, and eggs spider mites, and jumping plant lice	Adults and nymphs <i>Orius laevigatus</i> pierce thrips larvae and adults with their sucking mouthparts and suck their contents. leaving only the empty skin	500- 2000 adults and nymphs.	1-2 days	10-15°C It should be stored horizontally, in the dark.	Shake the bottle gently before use, spread the material on clean rock wool sheets, leaves and/or in application boxes (Dibox), apply in groups of at least 50 insects to build populations and stimulate mating

2.8.6. Chemical control

Chemical control is the most commonly utilized method to manage thrips populations in greenhouses and fields (Helyer and Brobyn, 1992). Controlling thrips through the use of chemicals is a commonly utilized method, effective application of insecticides requires consideration of factors such as the type of pesticide, the extent of coverage, potential harm to plants, and resistance, when using foliar sprays, it's important to use equipment that produces small droplets to ensure complete coverage and effective penetration into areas where thrips feed, repeat applications should be done every five days for at least three

times, and the addition of pyrethrin-like insecticides such as resmethrin can increase the exposure of thrips to the residues, another alternative to foliage application is to apply pesticides directly to the soil, since thrips often pupate in the soil or potting media (Helyer et al., 1995). Even if strong measures are taken against a certain group, they will not effectively control it unless they are repeated often, also there are limited options for pesticide use in soil, and the use of pesticides can often lead to plant toxicity, especially in programs aimed at controlling thrips (Nasruddin and Smitley, 1991).

2.8.6.1. Azadirachtin 790 g/l Neem oil + 0.3 g/l

The molecular structure of Azadirachtin is intricate and includes secondary and tertiary hydroxyl groups, a tetrahydrofuran ether, and 16 stereogenic centers, 7 of which are tetrasubstituted, due to these complex features, synthesizing the compound using standard methods of synthetic organic chemistry is challenging, Azadirachtin can be found in the seeds of the neem tree (Veitch et al., 2007). Nimbecidine leads to the degeneration of neuroendocrine glands in pests, serving as an antifeedant by deterring feeding, Azadirachtin 790 g/l is a botanical insecticide based on neem oil that contains azadirachtin and other alkaloids with pesticide properties, it contains 300 ppm azadirachtin and other limonoids such as Meliantriol, Salanin, Nimbin, and terpenoids, the product effectively controls a variety of pests including white flies, aphids, thrips, mealybugs, caterpillars, and leafhoppers, it is safe for beneficial insects like parasites, predators, and honeybees, the product should be applied during the early stages of pest infestation, with 2-3 applications given every 10 days (Table 2.5), it functions as an antifeedant, repellent, insect growth regulator, and prevents egg-laying, additionally, it protects plants from viral infection by controlling pests such as sucking insects, leaf miners, thrips, spider mites, whiteflies, and caterpillars (Kilani et al., 2021).

Table 2.5. Insecticide registered (azadiractin 0,3 g/l + 790 g/l neem oil) for the pest thrips on some vegetables in Türkiye (Anonim, 2023a)

Plant name	Harmful organisms name	Application Dose	Time between last application and harvest
Pepper	(<i>Lobesia botrana</i>) European grapevine moth	500 ml /100 l water	3 days
Vegetable	(<i>Frankliniella occidentalis</i>) western flower thrips	500 ml/100 L water	3 days
	(<i>Thrips tabaci</i>) onion thrips	500 ml/da	3 days

2.8.6.2. Spinosad 240 g/l

Spinosad works both through contact and ingestion. It has a distinctive mode of action that distinguishes it from other insect control products, the product causes stimulation of the insect nervous system, resulting in involuntary muscle contractions, tremors, and eventual paralysis, this effect is due to activation of nicotinic acetylcholine receptors through a mechanism that is novel and exclusive among known insecticides, Spinosad is commonly used in fruit and vegetable crops such as cherry, peach, tomatoes, eggplants, cucumbers, and peppers (Table 2.6).

Table 2.6. Insecticide registered (spinosad 240 g/l) for the pest thrips on some vegetables in Türkiye (Anonim, 2023b)

Plant Name	Harmful Organism Name	Application Dose	Time Between Last Application and Harvest
Pepper	(<i>Frankliniella occidentalis</i>) Flower thrips	40 ml/da larva, adult	3 Days
Strawberry	(<i>Frankliniella occidentalis</i>) Flower thrips	40 ml/da larva, adult	3 Days
Cucumber	(<i>Frankliniella occidentalis</i>) Flower thrips	40 ml/da larva, adult	3 Days
Tomato	(<i>Tuta absoluta</i>) Tomato moth	50 ml/ 100 l water larva	3 Days

2.8.6.3. Formetanate hydrochloride (% 50)

A non-systemic insecticide with both contact and stomach action, used for controlling thrips, it acts on the insects' nervous system by inhibiting acetylcholinesterase (belonging to the carbamate group), and is available as a water-soluble powder, the insecticide is specifically designed to target thrips (mainly western thrips) in the cultivation of indoor ornamental plants, it works against both larvae and adult insects and has a surface effect on the plant (Table 2.7).

Table 2.7. Insecticide registered (Formetanate hydrochloride% 50) for the pest thrips on some vegetables in Türkiye (Anonim, 2023c)

Plant name	Harmful Organism Name	Application Dose	Time Between Last Application and Harvest
Pepper	(<i>Frankliniella occidentalis</i>) Western flower thrips	125 g / 100 L water larva, adult	14 days
Eggplant (Greenhouse)	(<i>Frankliniella occidentalis</i>) Western flower thrips	100 g / 100 L water larva, adult	7 days
Cucumber (Greenhouse)	(<i>Frankliniella occidentalis</i>) Western flower thrips	100 g / 100 L water larva, adult	7 days
Strawberry	(<i>Frankliniella occidentalis</i> , <i>F. intonsa</i>) Western flower thrips	100 g / 100 L water larva, adult	7 days

2.8.7. Biotechnical control

The primary traps utilized are those that use pheromones, substances unique to each species and secreted by individuals to lure the opposite gender for mating, these traps are crafted using the pheromones to enhance their attractiveness, the fragrance released by female insects as a mating signal is particularly effective in drawing males, with each insect species having a distinct scent, these scents can be either naturally extracted from the insects or artificially synthesized for use in trapping systems, the traps are designed in specific colors and shapes that appeal to the target species, and include a plate with a non-drying adhesive and a pheromone capsule, they are strategically placed in gardens or fields at suitable intervals and heights, depending on the specific needs of the species being targeted. The key aspect of a pheromone trap is its ability to emit the pheromone

consistently at an optimal rate throughout the trap's lifespan. Pheromone-laden sticky traps are also employed to control storage pests in warehouses and certain vegetable pests in greenhouses, in warehouse environments, they are primarily used to track the initial emergence, duration, and population levels of storage pests, the number of adults caught in these traps is tallied weekly, and this data aids in making decisions about pesticide application or assessing the effectiveness of pesticides used (Vick et al., 1990).

The blue sticky trap, featuring an entomological adhesive on both sides, is specifically designed for targeting thrips due to its high selectivity towards this pest. Ideally, these traps should be positioned about 20 cm above the ground, although this height may need adjustment based on the specific situation and pest population, as plants grow, the placement height of the traps should be raised accordingly. Flora sticky blue traps offer a straightforward and effective method for pest control, these traps, equipped with a double-sided adhesive, are highly effective in both monitoring and mass-trapping of insect pests. Resistant to environmental factors and UV radiation, flora sticky traps maintain their stickiness over prolonged periods. Blue sticky traps provide a safe, non-toxic method to control and monitor thrips including (*Frankliniella occidentalis* and *Thrips tabaci*) and Sciarids, the unique blue color of the traps attracts these pests, causing them to adhere to the long-lasting, non-drying glue on the trap's surface (Anonim, 2023f).

Table 2.8. Active substances and application doses of insect traps registered for the pest arthropods in peppers in Türkiye (Anonim, 2023d).

Active substance	Application Dose
Blue Sticky Trap	1 trap /50 m ² (for monitoring purposes) 30 cm x 100 m Blue Colored Sticky Strip Trap
2.9 g Methyl-isonicotinate + Blue Sticky Trap	150 traps/da 30 cm x 100 m Blue Colored Sticky Strip Trap

2.8.8. Integrated pest management (IPM)

Controlling thrips with pesticides is a major challenge due to their tendency to hide in cramped areas on plants and their quick development of resistance to insecticides (Gao et al., 2012).

The methods for managing and controlling thrips include use of chemicals, biological control, and integrated pest management (IPM). Thrips are challenging to control due to their fast reproductive rate and their ability to reproduce without mating (facultative parthenogenetic reproduction), resulting in a high number of eggs being laid (Brodsgaard, 1989). Integrated Pest Management (IPM) is an approach to controlling pests that prioritizes the use of environmentally friendly methods, it combines knowledge of the life cycle and environmental interactions of pests with the most cost-effective pest control techniques, aiming to minimize harm to other organisms and the environment (Andrews, 2011). Integrated Pest Management (IPM) is applied in both agricultural and non-agricultural settings, and it involves four steps: setting action thresholds, monitoring and identification of pests, prevention, and control, the action threshold is determined by the level of pest population or environmental conditions that indicate the need for control measures to prevent damage to the economic injury level (Parrella, 1995). The economic threshold for pest control can vary greatly depending on various factors such as crop growth stage, season, climate, pest type, market tolerance for damage, and more, for example, in ornamental crops, no damage is acceptable, which leads to heavy use of pesticides, however, simply observing a single pest does not necessarily mean that it will cause economic damage to the crop, proper identification and monitoring of pests is crucial as some of them may be harmless or beneficial, such as natural predators, this reduces the chances of applying unnecessary pesticides or using the incorrect treatment, effective crop management, such as crop rotation, proper timing of planting and harvesting, selection of pest-resistant varieties, planting healthy rootstock free of pests, promoting rapid plant growth, and keeping crops clear of weeds, can be used as a first line of defense against pest outbreaks (Parrella, 1995). Furthermore, techniques such as intercropping, planting companion crops, creating shelter for beneficial organisms, using cover crops, and planting

plants that deter pests can improve the population of beneficial organisms in the soil and on plants (Cast, 2003). Physical control methods can also be employed, this type of pest control that doesn't involve chemicals involves the use of barriers, screens, traps, etc, to manage pests, pesticides may only be resorted to when other population control methods have proven ineffective, the priority is to choose pest control methods that are less hazardous but still effective, these may include techniques such as disrupting the mating process with chemicals or using mechanical methods like weeding or trapping (Jacobson, 1995). Additionally, natural enemies like parasitoids, predators, pathogens, and entomophyllic nematodes, or biological control agents like gene products derived from living organisms that kill, disable, or change the behavior of pests can also be used, if the control methods prove to be insufficient in managing the pests, more targeted pesticide sprays may be applied, only as a last resort, when all other control options have been exhausted, will broad-spectrum pesticides be utilized (Cast, 2003).



3. MATERIALS AND METHODS

3.1. Materials

The study was performed to determine thrips (Thysanoptera) species in the pepper fields in the Tokat province from 2021 to 2022. Samples were collected randomly from pepper fields in the Center, Erbaa, Niksar, Turhal, and Pazar districts of Tokat to determine the thrips species present. We collected samples on a weekly basis in the experimental field at the Gaziosmanpaşa University, spanning from June to November, for a duration of two years. The study also has evaluated the impact of different control methods on the population of common thrips species in the field, in the Tokat Gaziosmanpaşa University experimental area.

3.2. Methods

3.2.1. Experimental design

Effects of different control tactics were performed for the pest thrips in peppers by the field trials established in Tokat Province, Türkiye, in May 2021 and 2022. The experiments were followed a randomized complete block design with eight replications with pepper (*Capsicum annum*) varieties namely Gama and Esen, commonly grown indeterminate hybrid variety in Türkiye that is widely used in soil-less cultivation. The flower samples were collected in pepper field during the 2021-2022 trial seasons in the Tokat Province/ Türkiye to identify thrips species. The trial was conducted at the Experimental and Research Farm of the Faculty of Agriculture, Gaziosmanpaşa University in Tokat in 2021 and 2022. Soil preparation began in the spring of 2021 and 2022 in the area where the research would be conducted (Figure 3.3.a). The trial area was plowed and then processed with a disc harrow and rake before planting the seedlings (Figure 3.3.b). Pepper production in open fields in Türkiye occurs from mid-May to November; the trial had eight

replications for each treatment. The trial plots, measuring 360×270 cm, were created after the completion of basic soil preparation in the trial area for growing the plants. The pepper seedlings were planted with a double row system and spaced 100 cm apart (Figure 3.3.c). Standard watering and fertilizing techniques using a drip irrigation system were employed. The harvest was collected from 10 pepper plants randomly of each replication (Figure 3.3.d). Daily temperature and relative humidity data were obtained from a meteorological station in Tokat.





Figure 3.3. Some views of the field trials; (a) Soil preparation (b) Area processed (c) Seedlings of peppers (d).Experimental design

3.2.2. Climatic characteristics of the trial area

The temperature and precipitation values for (2021-2022) years in the province of Tokat, where the experiment was conducted, were obtained from the MGM web page.

The meteorological data of (2021-2022), The temperature and precipitation values of the province of Tokat in (2021-2022), years are given in (Figures 3.4-3.6), when the data are examined, it was seen that there is a transition to continental climate besides the transition zone climate in the region.

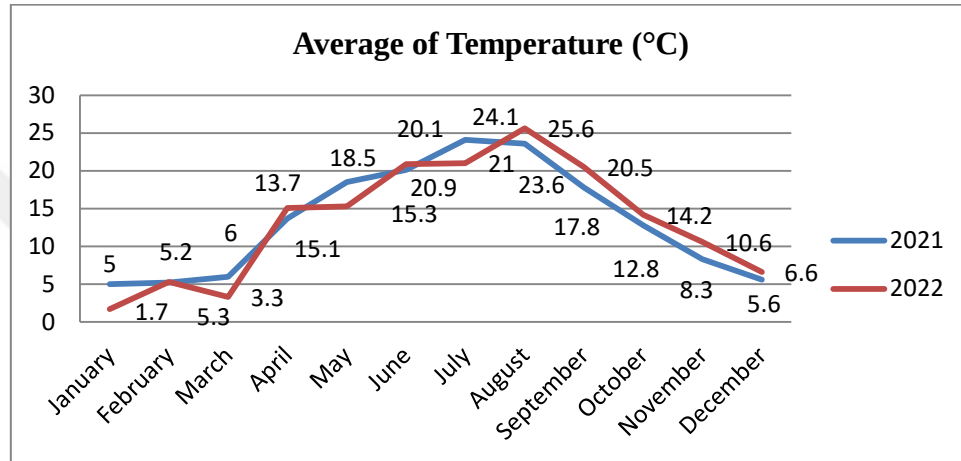


Figure 3.4. Montly average of temperature (°C) (Anonim, 2023 e)

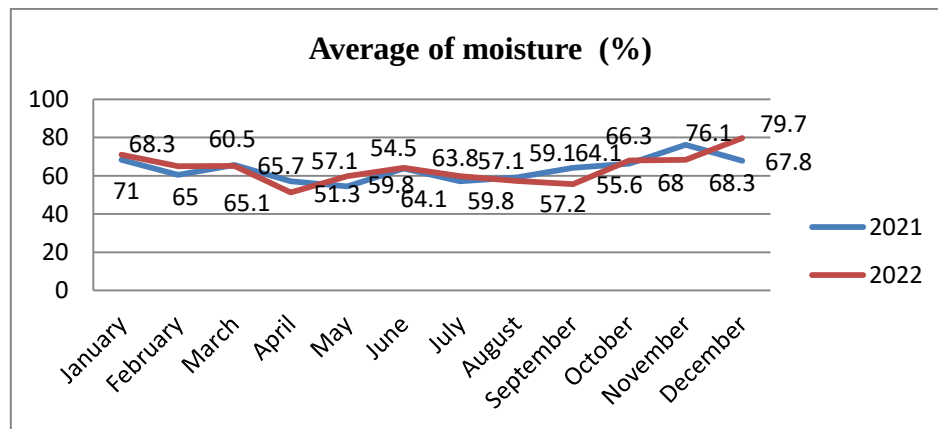


Figure 3.5. Montly average of relative humidity (Anonim, 2023e)

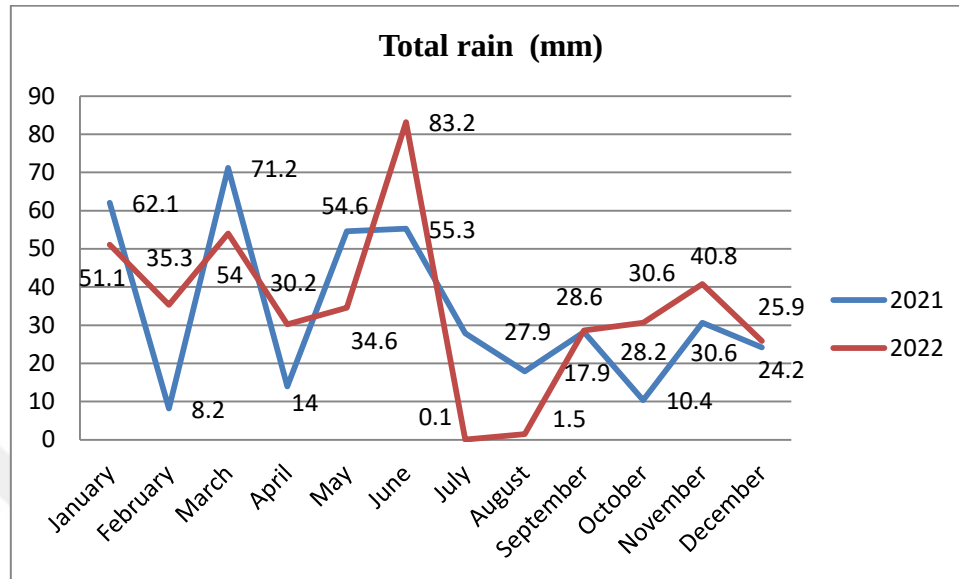


Figure 3.6. Total rain (mm) (Anonim, 2023e)

3.2.3.1. Survey studies for thrips

In this study was to identify the species of thrips present and their levels of population in the pepper fields located in the central region of Tokat and surrounding districts. The area comprised pepper cultivation sites in the districts of Tokat center, Erbaa, Turhal, Pazar and Niksar, where survey research was conducted. Thrips samplings took place in the pepper production areas of the Tokat province from June to October. The samples were randomly collected from flowers of pepper plants within the selected fields of Tokat Province and district. The flowers were carefully collected and filled with 60% ethyl alcohol before being placed in plastic tubes with a capacity of 50 ml. Plastic tubes were used to collect the samples, with 25 flowers collected from each field. The flower samples were transported to the laboratory and placed in glass petri dishes for examination.

3.2.3.2. Field studies

This research was carried out between 2021 and 2022 to determine the thrips species in pepper field growing areas in Tokat Province. The collected samples were placed in tubes and labeled, then transfer to laboratory.

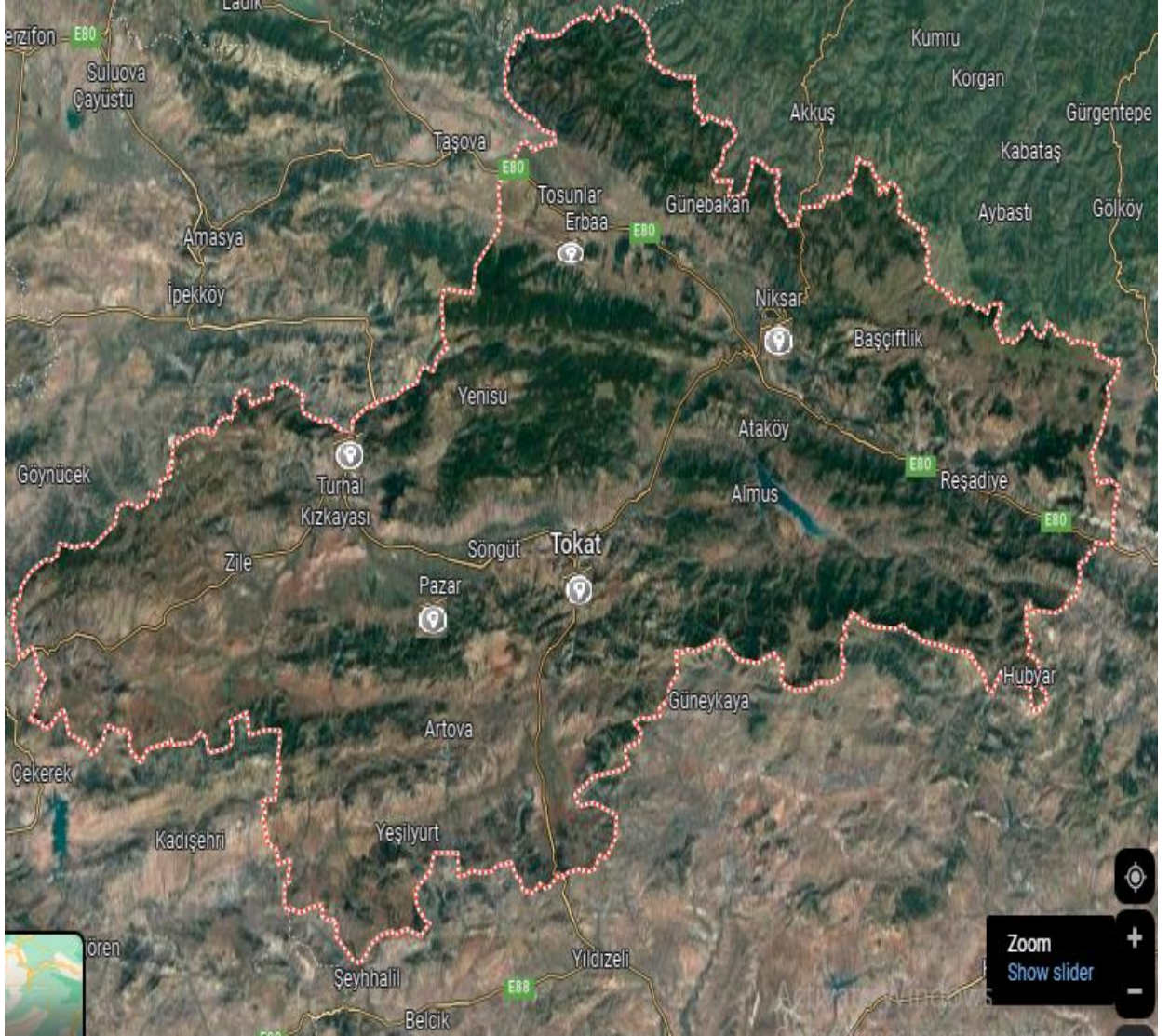


Figure 3.7. Map for sampling locations in Tokat Province, Türkiye

3.2.4. Sampling of thrips species in field trials

For the two-year period of 2021 and 2022, field trials were established with the seven treatments, using a randomized complete block design with four replications. Samples of thrips were collected from flowers during the flowering period (Figure 3.8). Samplings were beginning two weeks after the appearance of the seedlings and continued at weekly intervals until the flowering period of the pepper plants. The treatments were applied when the thrips populations exceed 3 thrips (adults and larval thrips) per flower in each treatment. According to the sampling method described by Funderburk et al., (2019), 10 flowers were randomly chosen from each total 40 flowers per treatment. To implement the flower thrips sampling procedure:

- 1- Prepare 50ml plastic or glass containers before visiting the test plots.
 - a. Mark each container with the sampling date.
 - b. Pour 30ml of 70% alcohol into each container.
 - c. Arrange the containers in a tray.
 - d. Carry the tray to the field where the experiment is being conducted.
- 2- Collect samples of thrips, minute pirate bugs, and mites, especially predatory mites, from the flowers.
 - a. Randomly select the pepper plants in each plot for sampling.
 - b. Carry out the sampling between mid-morning and mid-afternoon.
 - c. Take samples from the upper part of the plant.
 - d. Remove the container lid. Use scissors to snip the flower from the plant and quickly submerge it in the appropriately labeled alcohol-filled container. Ensure the flower is pressed well into the fluid.
 - e. Collect 10 flowers for each sample and confirm that every container is securely sealed. Gently agitate each container to ensure the flowers are thoroughly soaked in the alcohol. Bring back the trays containing the samples to the lab for preservation, to prevent the samples from deteriorating before processing, keep them cool and dry, if feasible, refrigerate them, especially for samples that will not be processed immediately (Funderburk et al., 2019).

Research on population trends reveals that thrips activity will be observed on a weekly basis, beginning two weeks post the planting of the pepper saplings and continuing through the conclusion of the flowering period. In every replication, ten flowers will be selected from each plot, and the established procedure for thrips sampling will be employed (Funderburk et al., 2019).



Figure 3.8. Samples of thrips collected from the field trials.

3.2.5. Thrips identification

In order to facilitate the preparation of the microscope slides, thrips specimens, which were kept in AGA liquid for 2 days after collection and then taken in alcohol (60% ethyl alcohol), were kept in 10% NAOH liquid on the hot plate at 47°C for approximately 1 hour until a slight color change occurred in the individuals. Then, this liquid was allowed to enter the thrips body, and the body contents were cleaned by the very fine needle. After the samples were kept in 96% ethanol for 5 minutes, they were taken to Hoyer medium and microscope slides were made. Thysanoptera species were identified by the second supervisor, Prof. Dr. Ekrem ATAKAN (Çukurova Üniversitesi, Ziraat Fakültesi Bitki Koruma Bölümü, Adana, Türkiye)

3.2.6. Characteristics of pesticides, traps and predatory insect used in the field trials

3.2.6.1. Control

The first treatment consisted of a control group, where only applied water to the pepper plants

3.2.6.2. *Orius laevigatus*

The second treatment involves the used of *Orius laevigatus* as a biological control method, with 25 individuals placed in each plot for a total of 100 individuals in four replications (Figure 3.9).

3.2.6.3. *Amblyseius swirskii*

The third treatment involved using *Amblyseius swirskii*. The product comed in bulk and contain between 10,000 to 125,000 mites, including all life stages, mixed with a material such as bran and vermiculite.



Figure 3.9. Applied biological control (*Amblyseius swirskii* and *Orius laevigatus*) in the pepper field

3.2.6.4. Azadirachtin (790 g/l Neem oil + 0.3 g/l)

The fourth treatment involves used of Azadirachtin 790 g/l Neem oil + 0.3 g/l, which contains both neem oil and azadirachtin. The treatment has been applied using an 18-liter electric knapsack sprayer.

3.2.6.5. Spinosad (240 g/l)

The fifth treatment is a reduced-risk insecticide called Spinosad that uses a combination of two neurotoxic macrolide compounds, spinosyn A and spinosyn D, to control thrips. It works by the insects ingesting it and is used at a rate of 40 ml per 100 liters of water / 100lt (Bret et al., 1997).

3.2.6.6. Formetanate hydrochloride (% 50)

In sixth treatment used the insecticide Formetanate hydrochloride is a powder that is mixed with water to make it soluble, and it is effective in controlling thrips in the cultivation of various crops (Dreistadt et al., 2004). Used 100gm /100 l + 100 g sugar.



Figure 3.10. Application of pesticides by use of back sprayer in the pepper plots

3.2.6.7. Blue sticky traps with pheromones

In last order to effect of blue stick traps (22 × 18 cm) (Figure 3.11), with pheromone (active subctanses is nanolux- manufacturing) to catching flower thrips (*F. occidentalis*), it was a pheromone used to combat the western flower thrips (*Frankliniella occidentalis*) and (*thrips tabaci*) pest, it is obtained from the scent of female thrips synthesized under laboratory conditions, male thrips are captured and their reproduction is reduced, thus ensuring a significant reduction in the thrips population, the blue sticky trap was card with a special entomological adhesive on both sides. Blue color is chosen specifically for thrips, because differs in high selectivity in relation to it, but at the same time blue color almost does not attract useful bugs. Sticky blue traps with a double-sided sticky layer have a strong trapping effect. Flora sticky traps are not subject to environmental conditions, do not lose their stickiness for a long time, they are resistant to sunlight (resistant to UV radiation).



Figure 3.11. Blue sticky traps with pheromones in the pepper trial

Treatment Applications

Controlling the pest became necessary after thrips were detected in the field as the peppers began to grow. The initial action taken was the application of chemical pesticides on July 8, 2021. This was followed by weekly sprays using the following insecticides: azadirachtin 790 g/l Neem oil + 0.3 g/l, Spinosad 240 g/l, and Formetanate hydrochloride 50%. Sticky traps infused with pheromones were utilized to attract thrips and minimize their population in the field. These traps were introduced on July 8, 2021, and replaced as needed. To control thrips, biological control agents such as *Orius laevigatus* and *Amblyseius swirskii* were employed. These measures were implemented on three separate dates: July 29, 2021, and August 17 and 25. Pesticide treatments, releasing of predatory insects/ acaries and settlement of blue stick traps were initiated when thrips reached economic threshold level (ETL) with 3 thrips per flower in plots. To address the issue, chemical pesticides

(azadirachtin 790 g/l neem oil + 0.3 G/l, spinosad 240 g/l, formetanate hydrochloride % 50) were initially applied on July 22, 2022, followed by weekly applications.

Traps application with pheromones was employed to reduce the population of thrips in the field. These traps were deployed on 8,25 July, 17 Augusts and 8 September in 2021, with 6, 25 July, 6, 30 August and 15 September in 2022.

Biological control agents such as *Orius laevigatus* and *Amblyseius swirskii* were employed. These applications were treated on 23 and 29 July, 25 August, and 9 September in 2022 (Table 3.9).

Table 3.9. The date of treatments applications in the pepper field

Year	Day- week	Natural enemies	Pesticide application	Stick blue traps + pheromone
2021	8.VII	-	+	+
	16.VII	-	+	-
	25.VII	-	-	+
	28.VII	-	+	-
	29.VII	+	-	-
	4.VIII	-	+	-
	10.VIII	-	+	-
	17.VIII	+	-	+
	8. IX	-	-	+
	25.IX	+	-	-
	9. IX	-	+	-
2022	6.VII	-	-	+
	22.VII	-	+	-
	23.VII	+	-	-
	25.VII	-	-	+
	29.VII	+	-	-
	6.VIII	-	-	+
	19.VIII	-	+	-
	25.VIII	-	+	-
	25.VIII	+	-	-
	30.VIII	-	-	+
	9.IX	+	-	-
	15.IX	-	-	+

The (+) marks refer to the dates when different controls were applied in the field

3.2.7. The harvesting procedure

After the pepper plants began to grow, pepper fruits were harvested at weekly intervals. For this aim, 10 plants in each plot were randomly sampled and fruits were harvested, then they were weighed (Figure 3.12).



Figure 3.12. The harvested of pepper fruits in field trials

3.2.8. Statistical analysis

Mean numbers, if treatment effect was important according to ANOVA data analysis were compared by using (ANOVA), one-way analysis with the Tukey test ($p \leq 0.05$) used to compare means between them. The correlation between the number of flowers and the density of adult thrips also analyzed ($p \leq 0.05$).

4. RESULTS AND DISCUSSION

4.1. Survey Studies

Thrips species collected from green pepper's leaf and flower samples were collected from Tokat districts (Center, Erbaa, Niksar, Turhal and Pazar) and their preparations were made. Identification of the preparation samples belonging to the sub order: Tubulifera, belong to three families (Thripidae, Aeolothripidae and Plaeothripidae).

4.2. Thrips species detected in pepper fields of Tokat Province in 2021 and 2022

To determine the Thrips species from several regions in Tokat province a survey was conducted in the pepper fields in the spring and summer periods of 2021 and 2022, thrips was appearance in spring, when the temperature (between 25-30 °C), population densities of the adults and larvae were increased. This result agreed with Bethke and Bates, (2013) who mentioned that the thrips have several generations (up to about eight) a year, when the weather is warm, the life cycle from egg to adult may be completed in as short a time as 2 weeks.

The researchers monitored the seasonal fluctuations and distribution of *F. occidentalis* and *T. tabaci* on various vegetables from April to August, during this period, noted the populations of both species highest density occurred in May; both species were found on leaves, not on flowers. This result agreed with Deligeorgidis et al., (2005) who mentioned the population of *F. occidentalis* and *T. tabaci* feeding on various types of vegetables from April to August or September, varied with the seasons.

4.2.1. Thrips species detected in pepper fields of Tokat province

A total of seven thrips species, belonging to three families: Thripidae, Aeolothripidae, and Phlaeothripidae, were identified. These species were *F. occidentalis* (Pergande, 1895), *T. tabaci* Lindeman, 1889, *T. meridionalis* (Priesner, 1926), and *C. manicatus* (Haliday,

1836), all of which belong to the family Thripidae. Although the majority of species were from the family Thripidae, the thrips were dominated by *F. occidentalis*. *A. intermedius* (Bagnall, 1934) and *A. fasciatus* (Linnaeus, 1758) belong to family Aeolothripidae were recorded; only one species of family Phleothripidae namely *H. aculeatus* (Fabricius, 1803) was found (Table 4.10).

Table 4.10. Thrips species found in pepper fields of Tokat province in 2021-2022

Order	Family	Species
Thysanoptera	Thripidae	<i>Frankliniella occidentalis</i> (Priesner, 1895)
		<i>Thrips tabaci</i> Lindeman, 1889
		<i>Thrips meridionalis</i> (Priesner, 1926)
		<i>Chirothrips manicatus</i> (Haliday, 1836)
	Aeolothripidae	<i>Aeolothrips intermedius</i> (Bagnall, 1934)
		<i>Aeolothrips fasciatus</i> (Linnaeus, 1758)
	Phleothripidae	<i>Haplothrips aculeatus</i> (Fabricius, 1803)

The species, along with their families, are listed based on their abundance (the total number of individuals collected for each species) in Table 4.11, while the major species were from the family Thripidae, the thrips were dominated by *Frankliniella occidentalis*, comprising (73.22%) of the total individuals, the percentages of *Thrips tabaci* comprising (21.58%), *Thrips meridionalis* and *Chirothrips manicatus* were (0.1%). The total number of *Haplothrips aculeatus* with (0.55) individuals. There were no individuals of thrips belonging to *Aeolothrips fasciatus* in 2021.

Table 4.11. Species composition of thrips and their total numbers in pepper flowers during 2021-2022

Family	Thrips species	2021 Numbers of thrips	2022 Numbers of thrips	Total numbers (2021+2022)	Proportion in total adults percent (%)
Thripidae	<i>Frankliniella occidentalis</i> (Priesner, 1895)	141	127	268	73.22
	<i>Thrips tabaci</i> Lindeman, 1889	61	18	79	21.58
	<i>Thrips meridionalis</i> (Priesner, 1926)	1	0	1	0.27
	<i>Chirothrips manicatus</i> (Haliday, 1836)	0	1	1	0.27
Aeolothripidae	<i>Aeolothrips intermedius</i> (Bagnall, 1934)	3	0	3	0.82
	<i>Aeolothrips fasciatus</i> (Linnaeus, 1758)	0	12	12	3.28
Plaeothripidae	<i>Haplothrips aculeatus</i> (Fabricius, 1803)	0	2	2	0.55
Total		206	160	366	

4.2.1.1. *Frankliniella occidentalis* (Priesner, 1895) (Western flower thrips)

Description: Both adult sexes (male and female) of *F. occidentalis* exhibit a variety of color variations, from light to dark, their abdomen displays grey bands on the segments, and their body length is approximately 1.5 mm in females and 1.1 mm in males, the wings display a yellow color and are equipped with two rows of setae, when these wings are folded, a dark stripe can be observed along the top surface (Figure 4.13.a), the insect possesses 8-segmented antennae (Figure 4.13.d), has five pairs of long setae on the top surface of the prothorax (Figure 4.13.b). This result agreed with Arthurs et al., (2009) who mentioned that the adult female of the *Frankliniella* species has an approximate length of 1.5 mm, with a color that ranges from light to dark, its abdomen features gray segmented bands, and it has yellow wings and 8-segmented antennae. *F. occidentalis* is characterized by a unique setal structure on its 8th abdominal tergite, featuring spines distributed across the abdomen (Figure 4.13.c) and posterior parts of the pronotum in *F. occidentalis* are adorned with long black setae on the thorax. This result agreed with Abd El-Wahab et al., (2011) who mentioned The 8th abdominal tergite of *F. occidentalis* a structure of bristles

featuring spines spread throughout the abdomen, contrasting with *T. tabaci* where such features are missing. The forepart and rear of the pronotum in *F. occidentalis* feature lengthy black bristles located on the thorax. All species belonging to the *Frankliniella* genus possess prominently evolved bristles on the anterior section of their thorax.

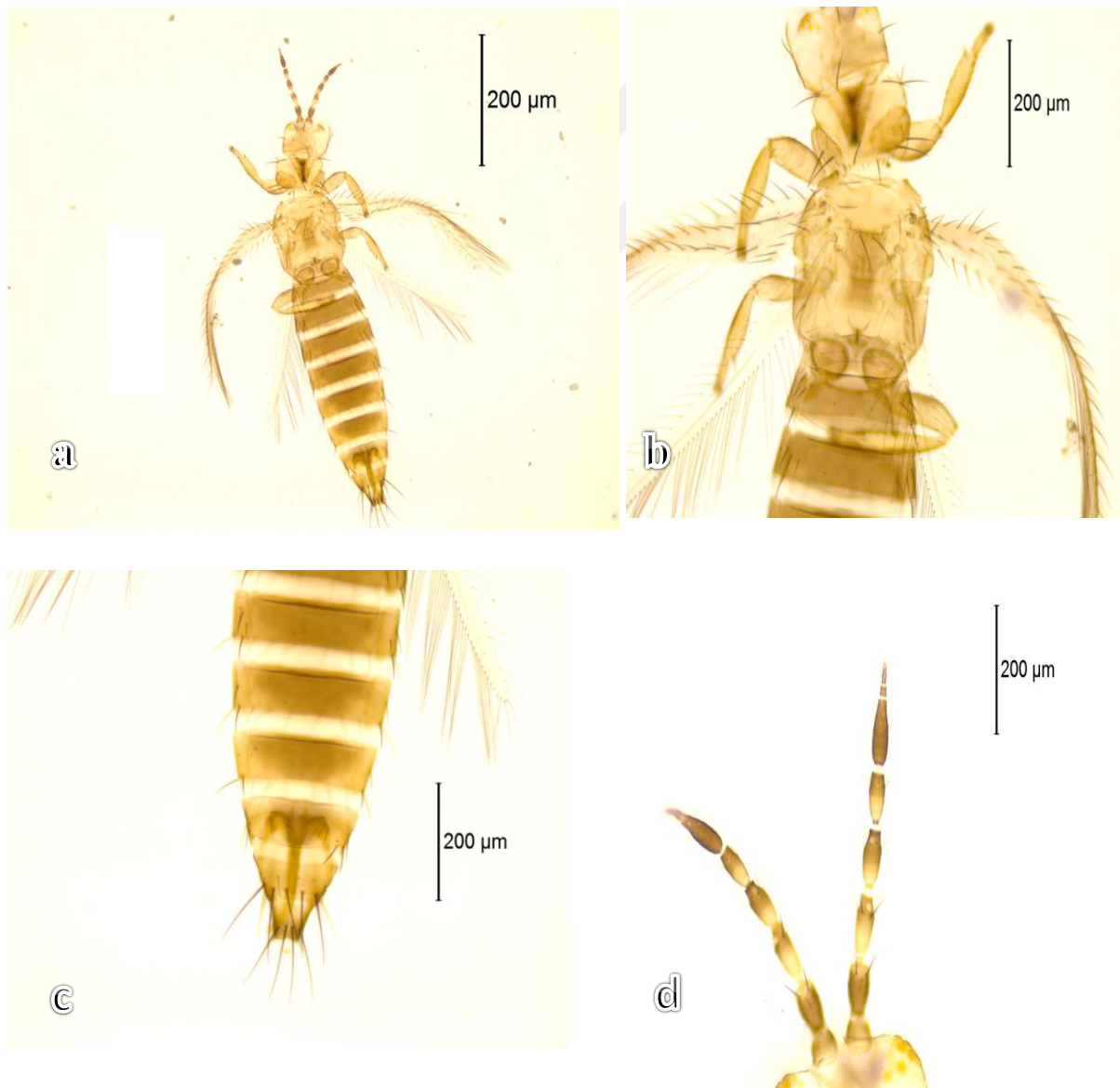


Figure 4.13. *Frankliniella occidentalis* (Priesner, 1932) a. Adult b. Thorax c. Abdominal setae d. Antennae segments

Damage symptoms: The plant quality is reduced by loss of chlorophyll, when infestations become serious the leaves themselves can shrivel. The western flower thrips (*F. occidentalis*) is the most important vector for both tomato spotted wilt virus (TSWV) and impatiens necrotic spot virus (INSV) in pepper fields (Figure 4.14). This result agreed with Atakan et al., (2016) who mentioned *F. occidentalis* (Pergande) (Thysanoptera: Thripidae) this insect caused a major problem to a variety of crops around the world and is widely known as a primary pest in able crops grown in open-fields, it inflicts damage through its mouthparts that pierce and extract plant fluids, subsequently leading to scar formation on plant tissues. Consequently, this pest's activities result in harm, including the bronzing of flowers and fruits and the distortion of fruits.



Figure 4.14. *Frankliniella occidentalis* damage symptoms on flower

Common hosts: Wide host range, but most damaging on tomatoes (*Solanum lycopersicum*), peppers (*Capsicum annuum*), cotton (*Gossypium hirsutum*), lettuce (*Lactuca*

sativa), other leafy vegetables, and flowering greenhouse, especially roses and chrysanthemums, and Gerber daisies are preferred (Hodges et al., 2009).

Distribution: Western flower thrips (*F. occidentalis*): is a native of western North America, it remained confined to western North America until the 1960s, present in greenhouse pest in the U.S., and capable of overwintering in the Mid-Atlantic, Southern, and Western U.S., present in Asia and Africa (Kirk and Terry 2003).

In this study, the biggest group of thrips species belonging to the suborder Thripinae, the dominant species in this group was *F. occidentalis* (Priesner, 1932) and *Thrips tabaci* (Lindeman, 1895) in the pepper fields. This result is agreed with findings of Deligeorgidis et al., (2005) who mentioned that the population of *F. occidentalis* and *Thrips tabaci* feeding on various types of vegetables from April to August or September, varied with the seasons. *Frankliniella occidentalis* species were identified in various locations, including the central area of Tokat, Erbaa, Niksar, Pazar, and Turhal. The samples collected indicated variations in population density; In Table (4.12), the number of larvae and adult individuals (males and females) of *F. occidentalis* were presented. The largest samples of individuals were collected in the central area of Tokat, with a total of 21♀ and 10♂ in 2021, and 18♀ and 7♂ in 2022. The lowest numbers of individuals were collected in Turhal, with 6♀ and 0♂ in 2021, and the lowest sum was found in Niksar, with 6♀ and 2♂ in 2022. This result is agreed with the findings of Kirk and Terry, (2003) who mentioned that the (*F. occidentalis*) is a native of western North America, greenhouse pest in the U.S and capable present in Asia. The dominant species was *Frankliniella occidentalis* in pepper fields in Tokat province. This result agreed with (Ertürk, 2018), who mentioned that the *F. occidentalis* which is an important pest in tomato and green pepper growing areas in Türkiye, the trials were conducted in Mersin, due to infestations of *F. occidentalis* damaging the export quality of tomatoes and green peppers.

Table 4.12. *Frankliniella occidentalis* survey in the pepper fields of Tokat Province

Number of sample	Region	Province/ District	Coordinated		Altitude (meters)	Day-Month-year	No. of species
			North	East			
1	Tokat	Center	40° 55' 24''	37° 39' 21''	610	20.VII.2021	20♀ 5♂
2	Tokat	Center	40° 55' 24''	37° 39' 21''	610	15.VIII.2022	18♀ 7♂
3	Tokat	Gumeneç	40° 42' 24''	36° 32' 21''	201	15.IX.2021	1♀ 5♂
4	Erbaa	Kaleköyü	40° 44' 55''	36° 31' 22''	208	4.VIII.2022	3♀ 3♂
5	Erbaa	Karaağaç	40° 35' 31''	36° 55' 47''	317	4.VIII.2022	4♀ 3♂
6	Erbaa	Kızılçubuk	40° 40' 39''	36° 32' 49''	192	30.IX.2021	5♀
7	Erbaa	Kızılçubuk	40° 44' 31''	36° 35' 24''	189	4.VIII.2022	4♀
8	Erbaa	Kızılköyü	40° 21' 35''	36° 38' 22''	628	4.VIII.2022	8♀ 2♂
9	Erbaa	Kızılköyü	40° 22' 33''	36° 40' 59''	624	4.VIII.2022	18♀ 4♂
10	Erbaa	Kızılköyü	40° 22' 21''	36° 41' 20''	625	4.VIII.2022	7♀ 1♂
11	Erbaa	Tebe kışlı	40° 42' 24''	36° 32' 39''	201	30.IX.2021	5♀ 1♂
12	Erbaa	Tebe kışlı	40° 41' 28''	36° 32' 19''	199	30.IX.2021	5♀ 1♂ 3l
13	Erbaa	Tepe kışla	40° 40' 4''	36° 38' 21''	220	4.VIII.2022	6♀ 1l
14	Erbaa	Tosunlar	40° 34' 26''	36° 54' 50''	296	30.IX.2021	14♀ 1♂ 7l
15	Erbaa	Tosunlar	40° 44' 52''	36° 25' 8''	134	30.IX.2021	2♀
16	Erbaa	Tosunlar	40° 41' 28''	36° 32' 19''	199	30.IX.2021	2♀ 1l
17	Niksar	Hamidiye	40° 35' 29''	36° 56' 10''	277	30.IX.2021	5♀ 3l
18	Niksar	Hayderbey	40° 33' 57''	36° 54' 27''	500	4.VIII.2022	6♀ 2♂ 1l
19	Niksar	Şahinli	40° 35' 29''	36° 56' 10''	277	30.IX.2021	8♀ 1♂ 18l
20	Pazar	Center	40° 14' 88''	36° 12' 07''	553	15.IX.2021	8♀ 2♂ 2l
21	Pazar	Center	40° 16' 32''	40° 16' 34''	561	11. XI.2022	2♀ 1♂
22	Pazar	Köprübasi	40° 17' 12''	36° 21' 78''	554	15.IX.2021	2♀ 1♂
23	Pazar	Ovayurt	40° 18' 40''	36° 14' 59''	539	11. XI.2022	4♀ 1♂
24	Pazar	Üzümlören	40° 16' 50''	36° 10' 59''	537	11. XI.2022	8♀
25	Pazar	Center	40° 21' 35''	36° 38' 59''	569	15.IX.2021	2♀
26	Pazar	Center	40° 16' 56''	36° 18' 19''	549	15.IX.2021	2♀
27	Turhal	Dökmetepe	40° 18' 19''	36° 18' 4''	549	11. XI.2022	7♀ 6♂
28	Turhal	Kat	40° 21' 35''	36° 38' 59''	569	15.IX.2021	3♀ 3l
29	Turhal	Kat	40° 21' 35''	36° 38' 31''	636	15.IX.2021	3♀

*(l) Letter indicated to the larvae number.

4.2.1.2. *Thrips tabaci* (Lindeman, 1889) (Onion thrips)

Description: The adult *T. tabaci* measures about 1.3 mm and its color ranges from yellow to dark brown (Figure 4.15.a), they possess prominent hairs or setae on the front section of their thorax, setting them apart from thrips species that do not have these features. *T. tabaci* are smaller than *F. occidentalis* and exhibit gray eyes and 7-segmented antennae (Figure 4.15.c). *T. tabaci* can be distinguished from *F. occidentalis* by its larger size and lighter hue, *T. tabaci* has long black setae only on the back (Figure 4.15.b). This result agreed with Arthurs et al., (2009) who mentioned that the adult *Thrips tabaci* typically measures around 1.3 mm in size and its colors ranging from yellow to dark brown, *T. tabaci* are smaller in size and have gray eyes and they have 7-segmented antennae. *T. tabaci* was considered one of the dominant species in the field. This result agreed with (Atakan, 2008), who mentioned that *F. occidentalis* and *T. tabaci* are dominant species in vegetable crops in Türkiye. They have been recorded in winter vegetables in the Çukurova region, the most thrips were collected from flowers or heads of vegetables in early spring.

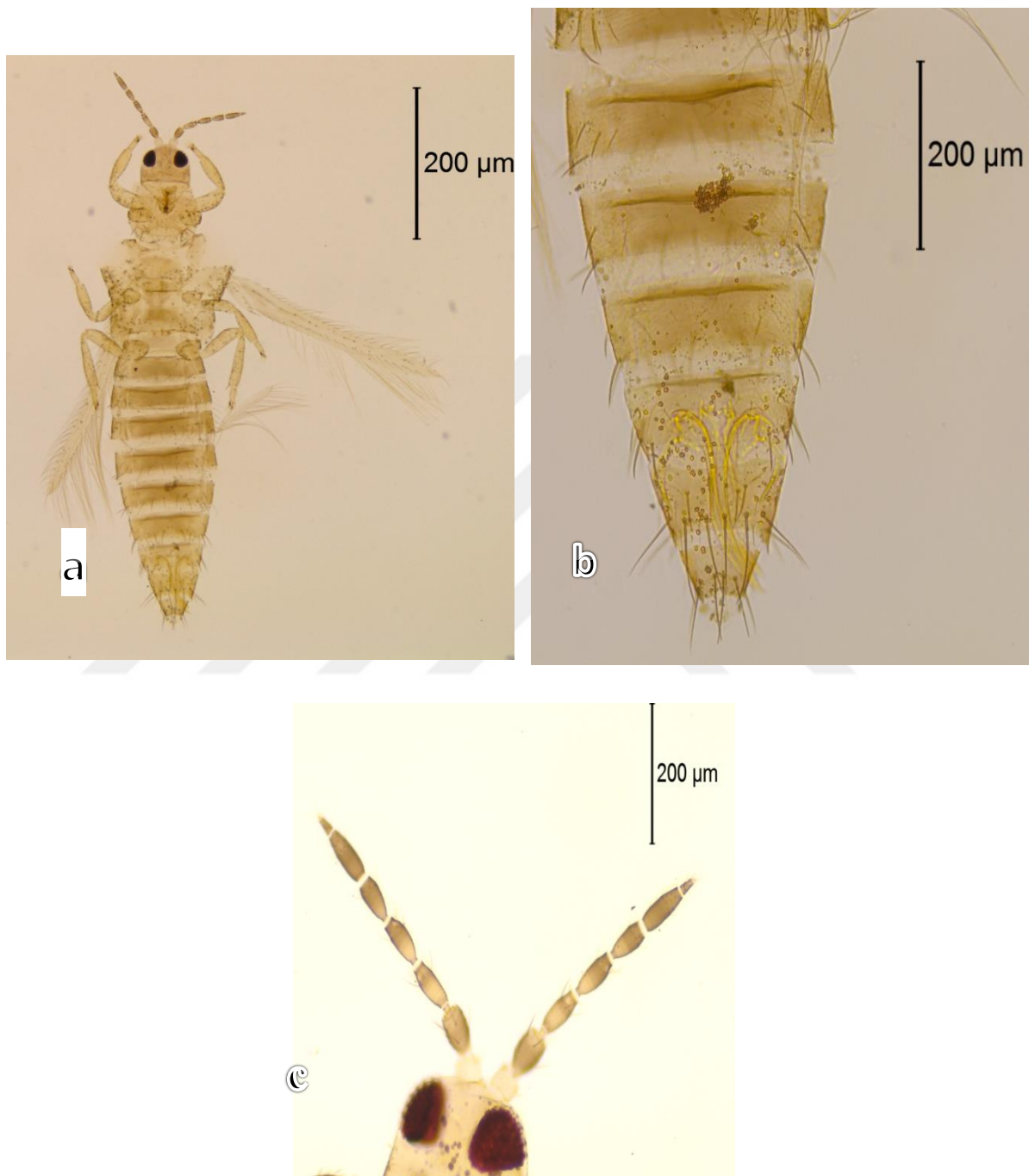


Figure 4.15. *Thrips tabaci* (Ozel, 1895) a. Adult b. Abdominal setae c. Antennae segments

Damage symptoms: The feeding behavior of *T. tabaci* primarily takes place on new plant growth, causing silvery, flecking, and curling of leaves (Figure 4.16), while dense populations may also feed on fruit, which can lead to scarring, dieback of terminal buds, and even death of the plant, the damage caused during the early bulbing stage is particularly economically devastating, this pest is known to transmit Iris yellow spotted virus (IYSV) and tomato spotted wilt virus (TSWV). (Hodges, 2009).



Figure 4.16. *Thrips tabaci* damage symptoms on leaves

Common hosts: Onion (*Allium cepa* L), tomatoes (*Solanum lycopersicum*), potatoes (*Solanum tuberosum*), cabbage (*Brassica oleracea*), cucumber (*Cucumis sativus*), melons (*Cucumis melo*), garlic (*Allium sativum*), squash (*Cucurbita* sp.), strawberries (*Fragaria × ananassa*), ornamental plants and some crucifer crops particularly if potential overwintering sites such as small grains, clover (*Trifolium* sp.), or alfalfa fields (Hodges, 2009).

Distribution: Occurs in tropical to subtropical climates (Hodges, 2009).

Table (4.13) showed the data for individual *T. tabaci*, the results indicated that the highest numbers of males and females had been found in the center and Erbaa, with approximately 21♀ and 9♂ in 2021, and in Erbaa, with 22♀ and 1♂. However, the lowest number of individuals had been observed in Pazar. This result agreed with Atakan, (2008) who mentioned that *Frankliniella occidentalis* and *Thrips tabaci* are dominant species in vegetable crops in Turkey. They have been recorded in winter vegetables in the Çukurova region.

Table 4.13. *Thrips tabaci* survey in the pepper fields of Tokat Province

Number of sample	Region	Province/ District	Coordinated		Altitude (meters)	Day-Month-year	No. of species
			North	East			
1	Tokat	Center	40° 55' 24''	37° 39' 21''	610	15.VIII.2021	21♀ 9♂
2	Erbaa	Kale	40° 40' 16''	36° 38' 19''	224	30.IX.2021	8♀
3	Erbaa	Kızılköyü	40° 22' 14''	36° 34' 21''	632	4.VIII.2022	2♀ 1♂
4	Erbaa	Tosunlar	40° 40' 22''	36° 29' 17''	193	30.IX.2021	14♀ 1♂
5	Pazar	Center	40° 16' 59''	36° 17' 23''	553	15.IX.2021	1♀ 7♂
6	Pazar	Center	40° 16' 7''	36° 74' 9''	545	4.VIII.2022	5♀
7	Pazar	Ovayurtköyü	40° 16' 58''	36° 12' 2''	540	4.VIII.2022	6♀
8	Pazar	Üzümlören	40° 16' 50''	36° 10' 59''	537	4.VIII.2022	1♀
9	Turhal	Dökmetepe	40° 18' 23''	36° 17' 37''	555	11. XI.2022	3♀

4.2.1.3. *Thrips meridionalis* (Priesner, 1926) (peach thrips)

Description: Both adult males and females have a similar appearance, but males tend to have a slightly paler, and have a long black setae on the back on the abdomen (Figure 4.17.a), their body and thorax displays a mix of brown and black colors, has hairs in the posterior corner of the prothorax (Figure 4.17.c). The antennae are composed of eight segments (Figure 4.17.b). This result agreed with Alford, (2007) who mentioned that Adult females and males have a similar shape, but the males typically show a paler than female, their body color blends brown and black, and their antennae has eight segments and include

two segmented styles. *T. meridionalis* undergoes three successive generations in a single year.



Figure 4.17. *Thrips meridionalis* (Priesner, 1926) a. The abdominal setae b. The antennae segments c. Thorax

Distribution: Found in Europe and the Mediterranean region (Hodges, 2009).

Hosts: Peach (*Prunus persica*), apricot (*Prunus armeniaca*), almond (*Prunus dulcis*), plum (*Prunus domestica*), cherry (*Prunus avium*), apple (*Malus* spp.), pear (*Pyrus communis*), and many other plants (Hodges, 2009).

The species *T. meridionalis* had appeared in very low numbers, with only 1 female having been observed in Pazar in 2021 (Table 4.14). These results agreed with Aydın, (2020) who mentioned that the *T. meridionalis* (Priesner, 1926) species were studied in three different orchards located in Isparta province/ Türkiye. The orchards selected included apple orchards, cherry tree orchards, and walnut orchards. The active period of *T. meridionalis* had been determined to be between March 15th and April 1st, indicating that this variety had appeared for only a short period. In contrast, Kaplan et al. (2016) found that *T. meridionalis* was an infrequent species (0.8%) in Mardin Province, Türkiye. However, *T. meridionalis* had been observed in large numbers even though it seemed to be active only a short time each year. This could be related to the seasonal blooming of its host plants and other environmental conditions (Alford 2007).

Table 4.14. *T. meridionalis* survey in the pepper fields of Tokat Province

Number of sample	Region	Province/ District	Coordinated		Altitude (meters)	Day-Month-year	No. of species
			North	East			
1	Pazar	Center	40°14'88''	36°12'07'	553	15.IX.2021	1♀

4.2.1.4. *Chirothrips manicatus* (Haliday, 1836)

Description: The body and wings have a brown color, with the fore wings being a lighter shade of brown (Figure 4.18.a). The antennae are comprised of eight segments (Figure 4.18.b). The head, being small, protrudes forward beyond the eyes. There are three sets of ocellar and two sets of posteroangular setae. The fore wing narrows to a pointed tip, and the first vein of the wing features two setae on its latter half, while the second vein is adorned with four setae. There are a structure of bristles featuring spines spread throughout the

abdomen (Figure 4.18.c). This result agreed with Bhatti, (1990) who stated that the antennae consist of eight segments, the head is small and elongated in front of the eyes.



Figure 4.18. *Chirothrips manicatus* (Haliday, 1836) a. Adult b. Antennae segments
c. Abdominal setae

Hosts

Cereal crops (Funderburk et al., 2015).

Distribution

Described from Europe (Chellemi et al., 1994).

The *C. manicatus* appeared in very few numbers, with only 1 female observed in Pazar in 2022 (Table 4.15). Additionally, this species was not found in the central location. This result agreed with Yiğit, (2022) who mentioned that the *C. manicatus* species and *Aeolothrips* sp. studied in Afyonkarahisar, Antalya, Burdur, Konya, and Isparta in the west of the Mediterranean region about cereals crops, this provide an important contribution to the Turkish economy in agricultural production, nutrition, domestic and foreign in cereal production, there were many important pests damaged these crops, which caused economic loss in cereal crops are the main food source for humanity, by thrips species in two suborders, Terebrantia and Tubulifera.

Table 4.15. *Chirothrips manicatus* survey in the pepper fields of Tokat Province

Number of sample	Region	Province/District	Coordinated		Altitude (meters)	Day-Month-year	No. of species
			North	East			
1	Pazar	Kaledere	40 ⁰ 19'20''	36 ⁰ 13'18''	541	11. XI.2022	1 ♀

4.2.1.5. *Aeolothrips intermedius* (Bagnall, 1934)

Description: The female's fore wings exhibit two distinct dark bands, and the vein that shapes the ring at the wing's end, the body, legs, and antennae of both sexes are brown (Figure 4.19.a), the antennae are composed of nine segments (Figure 4.19.b), the male's fore wings bear a close resemblance to the female's. There are structures of bristles featuring spines spread throughout the abdomen (Figure 4.19.c). This result agreed with Chiasson, (1986) who mentioned both male and female specimens have fully grown wings, in females, the fore wings showcase two dark bands running horizontally, and the vein at the

wing's tip isn't darker than its adjacent membrane, the body, legs, and antennae of both sexes are brown, and the antennae are consist of nine segments.

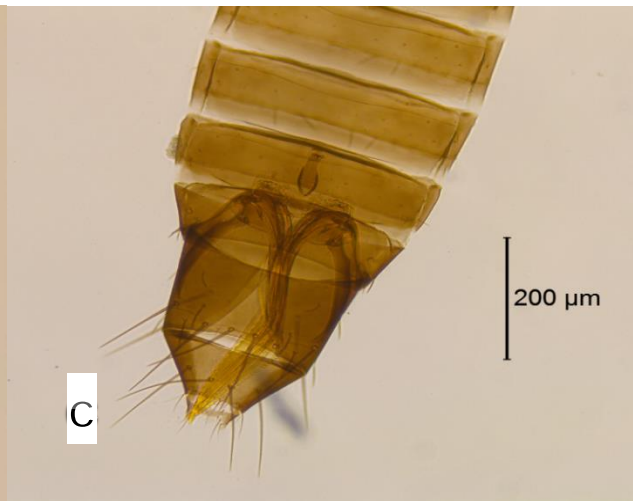
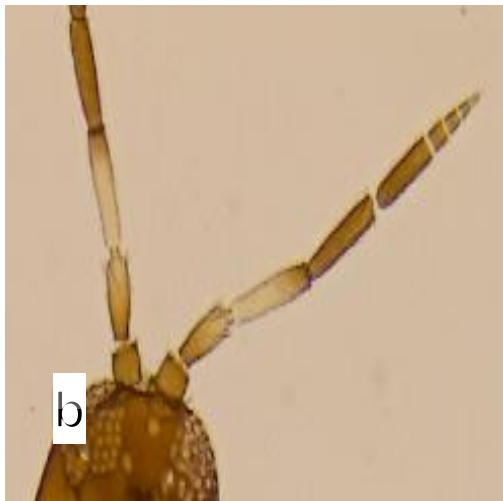
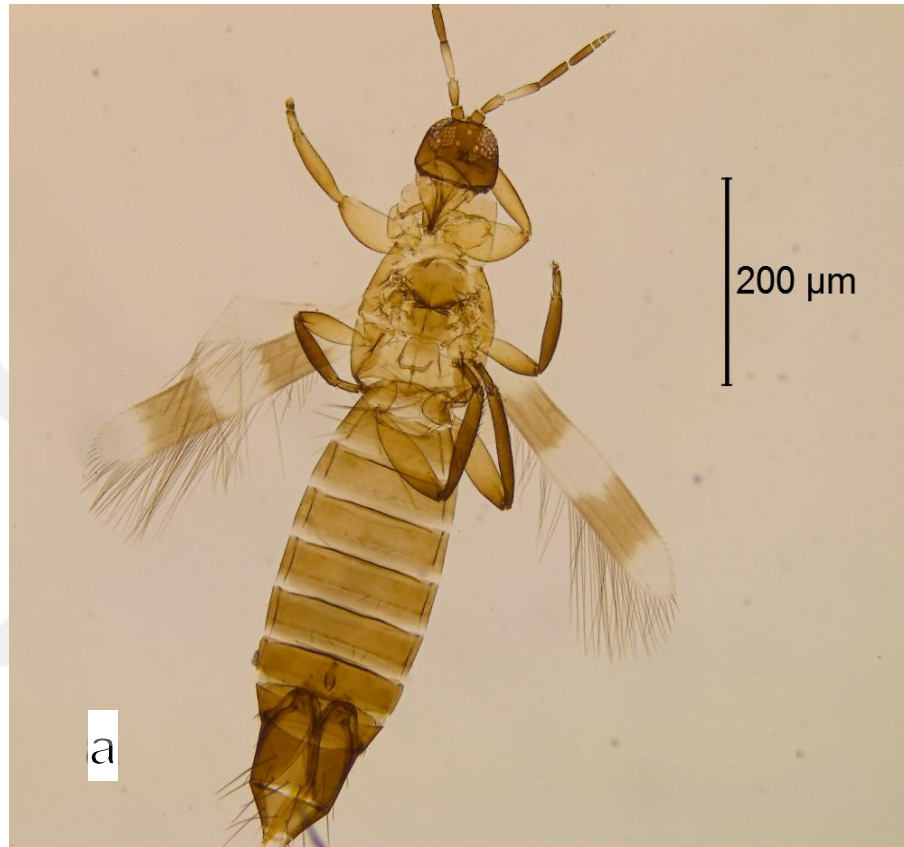


Figure 4.19. *Aeolothrips intermedius* a. Adult b. Antennae segments c. Abdominal setae

A. intermedius is a native predator of *T. tabaci*, *A. intermedius* used against *T. tabaci* adults, can be considered a promising resource for the biological control of onion thrips (Abenaim et al., 2022).

Distibution: Widespread in Europe also in Palearctic Asia (Chellemi et al., 1994).

The species *A. intermedius* was found in low numbers, approximately 1♀ and 2♂, in the center and Erbaa in 2021 (Table 4.16), *A. intermedius* found in pepper flowers. This result agreed with Trdan et al., (2005), mentioned that the *A. intermedius*, which inhabit flowers, observed on a wide range of 30 host plant species across 16 different botanical families, particularly on the vegetative portions of cultivated plants. Research on the Thysanoptera fauna in Türkiye's Aegean region was conducted in the spring seasons of 1993 and 1995, the study covered several provinces, including Afyonkarahisar, Aydın, Denizli, İzmir, Manisa, Muğla, and Uşak, and resulted in new findings for both the region and the country, newly recorded species for the Turkish fauna included *T. meridionalis* (Priesner), *T. tabaci* (Lindeman), *A. intermedius* (Bagnall), and *H. reuteri* (Trybom).

Table 4.16. *Aeolothrips intermedius* survey in the pepper fields of Tokat Province

Number of sample	Region	Province/District	Coordinated		Altitude (meters)	Day-Month-year	No. of species
			North	East			
1	Tokat	Center	40°55'24''	37°39'21''	610	16.IX.2021	1♀
2	Erbaa	Tosunlar	40°40'16''	36°38'19''	224	30.IX.2021	2♀

4.2.1.6. *Aeolothrips fasciatus* (Linnaeus, 1758)

Description: The mature individual has a brown color, extending its legs, its antennal section is primarily yellow but darkens at both the very tip and base, and the clavus primarily exhibits a light tone but has two dark horizontal stripes, the light-colored band in the center is shorter than the adjacent dark one near the end, the head's area behind the eye is as long as the eye itself (Figure 4.20.a), the maxillary palp is made up of three parts,

while the antennae comprise nine segments (Figure 4.20.c). The first abdominal tergite has subtle horizontal lines towards the front and middle, the hair-like structures on segment are not bigger than the base of the primary bristles on that segment, the lower plates feature four sets of bordering bristles, but there aren't any significant bristles in the central part (Figure 4.20.b), The forewings feature two distinct dark stripes, with a white tip, the very base has a subtle hue, while the vein remains unshaded in the light-colored section (Figure 4.21.d). This result agreed with Labanowski and Soika, (2010) who stated that both males and females have mature wings, the female and her legs are brown-toned, the segment of the antenna is yellow, darkening at both its tip and base, the clavus is light-colored, the female's forewings feature two dark cross bands, and the light band in between is not as long as the dark band near the end, the wingtips are transparent, with a faint ring vein, the head's area behind the eye matches the eye's length, the maxillary palp has three sections, and the antennae consist of nine parts.



Figure 4.20. *Aeolothrips fasciatus* (Linnaeus, 1758) a. Adult b. Abdominal setae c. Antennae segments d. Wings

A. fasciatus is a native predator of *T. tabaci* and *F. occidentalis*. It is insufficient to control severe outbreaks of *T. tabaci* on onion (Ferrari, 1980). It has two generations per year, it

can live temporarily on plants, but it needs an arthropod diet to complete its preimaginal development (Lenteren and Loomans 1995).

Distibution: Described from Europe, this species has been recorded in various parts of the world (Chellemi et al., 1994).

The species of *A. fasciatus* was found in varying numbers, with 1♀ and 1♂ in Erbaa, 2♀ and 1♂ in Niksar, and 5♀ and 2♂ in Turhal in 2022 (Table 4.17).

Table 4.17. *Aeolothrips fasciatus* survey in the pepper fields of Tokat Province

Number of sample	Region	Province/District	Coordinated		Altitude (meters)	Day-Month-year	No. of species
			North	East			
1	Erbaa	Kaleköyü	40° 45' 0''	36° 31' 21''	207	4.VIII.2022	1♀ 1♂
2	Niksar	Hayderbey	40° 33' 13''	36° 54' 53''	315	4.VIII.2022	2♀ 1♂
3	Turhal	Center	40° 18' 19''	36° 18' 4''	549	11. XI.2022	5♀ 2♂

4.2.1.7. *Haplothrips aculeatus* (Fabricius, 1803)

Description: The body and legs range in color from brown to dark brown, while the tarsi and fore tibiae have a yellowish-brown, the fore wings are light in shade with a shaded base, and the major setae are pale (Figure 4.21.a), the antennae are brown in color and consist of eight segments, and the head is longer than it is wide (Figure4.21.b), the maxillary stylets are approximately one-third the width of the head, positioned apart from each other. Abdominal segment are complete tube in both sexes, and the abdominal tergites consist of curved wing-retaining setae (Figure4.21.c). This result agreed with Mound and Minaei (2007) who mentioned that the body color and the antennae are brown. The antennae consist of eight segments.

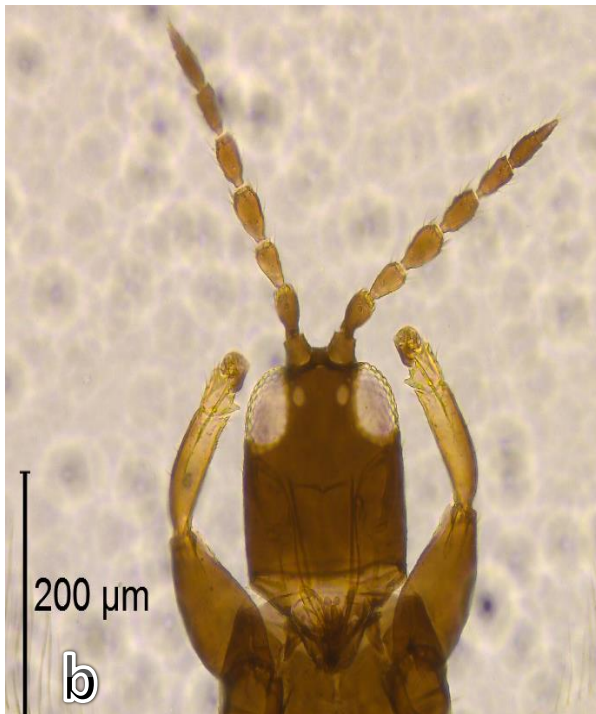


Figure 4.21. *Haplothrips aculeatus* a. Adult b. Antennae segments c. Abdominal setae

Hosts: various species of Poaceae, Cyperaceae and Juncaceae (Chellemi et al., 1994).

Distribution: Britain, Cambridgeshire, Oxfordshire, Norfolk and Suffolk, Iceland south east to Turkey, Iran, China and Japan (Okajima, 2006).

The species *H. aculeatus* recorded in Pazar and Turhal in rate 1♂: 1♂ in 2022 (Table 4.18). This result agreed with Çinkul, (2021) who mentioned that the *Haplothrips* sp. studied was carried out to identify species belonging to Thysanoptera in stone and pome fruit orchards in the districts (Balya, Bandırma, Bigadiç, Burhaniye, Dursunbey, Erdek, Gönen, Havran, Kepsut and Manyas) of Balıkesir Province, Türkiye in 2018 and 2019. The survey revealed 32 Thysanoptera (thrips) species. Thrips were examined in 9900 flowers, leaves, and fruits species were, *H. reuteri* (Karny) (Phlaeothripidae: Thysanoptera), *T. meridionalis* (Priesner).

Table 4.18. *Haplothrips aculeatus* survey in the pepper fields of Tokat Province

Number of sample	Region	Province/District	Coordinated		Altitude (meters)	Day-Month-year	No. of species
			North	East			
1	Pazar	Kaledere	40°19'20"	36°13'18"	541	11. XI.2022	1♀
2	Turhal	Şatroba	40°17'12"	40°81'2"	541	11. XI.2022	1♀

4.3. Thrips Survey on the *Solanum nigrum* in the 2021 and 2022

In summer 2021-2022, a survey was conducted in various locations of Tokat province (Erbaa, Niksar, Pazar, Turhal and the center) to identify thrips species in the wild plants surrounding pepper fields (Table 4.19), the results revealed that all the species found in these areas were *F. occidentali* (Table 4.20). This result agree with Suganthi and Sakthivel, (2012) who mentioned that the *Solanum nigrum* Linn. is an annual herbaceous plant belongs to the family Solanaceae, it is commonly known as black nightshade, attacked different species of insect pests, like *Thrips* spp.

Table 4.19. Thrips species individuals, order, sub order and family and sub family in *Solanum nigrum* of Tokat province

Order	Suborder	Family	Subfamily	Species
Thysanoptera	Terebrantia	Thripidae	Thripinae	<i>Frankliniella occidentalis</i>
(Priesner, 1932)				

Table 4.20. *Frankliniella occidentalis* survey in the *Solanum nigrum* of Tokat Province

Number of sample	Region	Province/ District	Coordinated		Altitude (meters)	Day-Month-year	No. of species
			North	East			
1	Center	Gumeneek	40° 21' 35''	36° 38' 31''	636	15.IX. 2021	11♀ 1♂
2	Center	Gumeneek	40° 21' 39''	36° 38' 59''	603	15.IX. 2021	12♀ 1♂
3	Center	Kaleköyü	40° 40' 39''	36° 32' 49''	192	30.IX. 2021	2♀ 1♂
4	Erbaa	Kaleköyü	40° 40' 39''	36° 32' 49''	192	30.IX. 2021	3♀ 1♂
5	Erbaa	Kaleköyü	40° 44' 55''	36° 31' 22''	208	4.VIII.2022	21♀ 5♂
6	Erbaa	Karaağaç	40° 35' 31''	36° 55' 47''	317	4.VIII.2022	3♀
7	Erbaa	Kızılcubuk	40° 44' 52''	36° 25' 87''	134	30.IX. 2021	18♀ 10♂
8	Erbaa	Kızılcubuk	40° 21' 35''	36° 38' 22''	628	4.VIII.2022	4♀ 1♂
9	Erbaa	Tosunlar	40° 41' 28''	36° 32' 19''	199	30.IX. 2021	2♀ 1♂
10	Niksar	Hamidiye	40° 34' 26''	36° 54' 50''	296	30.IX. 2021	11♀ 1♂
11	Niksar	Hayderbey	40° 33' 57''	36° 54' 27''	500	4.VIII.2022	11♀ 1♂
12	Niksar	Şahinli	40° 35' 29''	36° 56' 10''	277	30. IX.2021	9♀
13	Niksar	Şahinli	40° 35' 29''	36° 56' 10''	277	30. IX.2021	6♀ 1♂
14	Pazar	Center	40° 16' 32''	40° 16' 34''	561	11. XI.2022	6♀ 1♂
15	Pazar	Ovayurtköyü	40° 18' 40''	36° 14' 59''	539	11. XI.2022	4♀
16	Pazar	Center	40° 16' 50''	36° 10' 59''	537	11. XI.2022	1♀
17	Pazar	Center	40° 17' 12''	40° 21' 78''	554	15.IX.2021	6♀ 1♂
18	Turhal	Dökmetepe	40° 18' 19''	36° 18' 40''	549	11. XI.2022	9♀

4.3. Management in field experiments

4.3.1. Thrips population in control treatments

4.3.1.1. Mean densities of *Frankliniella occidentalis* in pepper flowers in untreated plots of pepper varieties, Gama and Esen

4.3.1.1.1. Mean densities of *Frankliniella occidentalis* in pepper flowers in 2021

In the control, where *F. occidentalis* was observed, and no pesticides or other materials were used in this treatment, *F. occidentalis* began to appear at the beginning of July in 2021, with a number of 0.95 per flower in Gama varieties and 1.025 individual per flower in Esen, the number then increased in the middle of July, reaching 1.15 in both Gama and Esen varieties by July 28th, it reached its peak in August, temperatures played a role in reducing the number of thrips, which began to decline in September, the number continued to decrease in September and October until it reached zero per flower (Figure 4.22), and the numbers of *F. occidentalis* decrease when the temperature drops (less than 15 °C), in 27th October. All species of thrips identified as carriers of plant viruses were included. Thrips spread plant viruses belonging to the genera Tospovirus, Ilarvirus, Carmovirus, Sobemovirus, and Machlomovirus. Tospoviruses were responsible for several notable new diseases, with adult thrips typically being the ones that transmitted these viruses. The transmission of these viruses to plants happened during the thrips' feeding process, and infection in plants with these viruses led to a decrease in their crop yield. This result agreed with the findings of Jones (2005) who mentioned the pepper plants infected with plant viruses experience reduced production and yield fruits of poor quality.

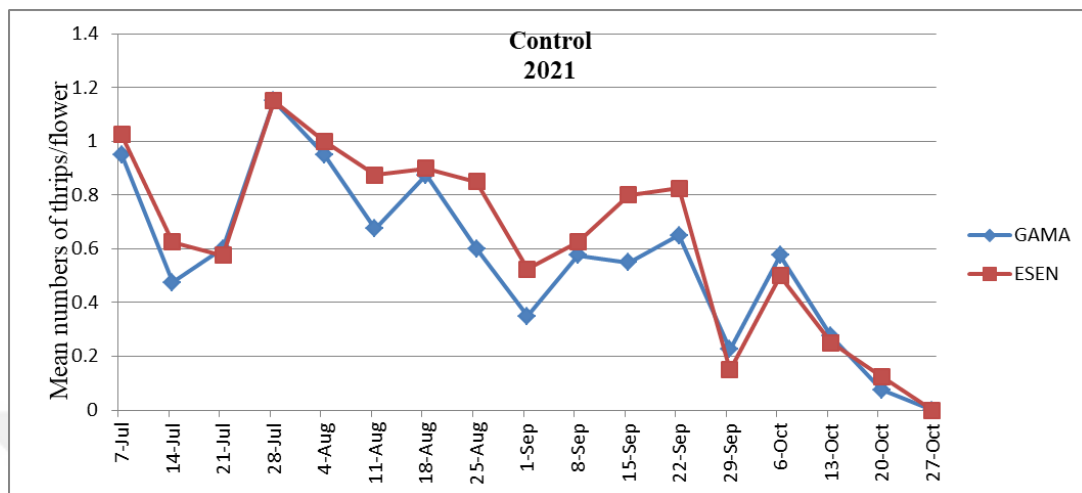


Figure 4.22. Mean densities of *Frankliniella occidentalis* in pepper flowers in untreated plots of pepper varieties Gama and Esen in 2021

The number of thrips in both types of peppers (Gama and Esen) had decreased to zero, suggesting either the conclusion of the thrips life cycle or the end of these peppers growing season. This result agreed with the findings of Kaur et al., (2017) who mentioned the total duration of the larval and adult stages was notably longest at temperatures between 30-35°C, as temperatures dropped in the months of September and October, a corresponding decrease in thrips numbers was observed.

4.3.1.1.2. Mean densities of *F. occidentalis* in pepper flowers in 2022

Figure (4. 24) presents the number of thrips observed in Gama and Esen pepper plants, collected over time from 1 July to 7 October. On 1 July, there were 0.15 individual thrips per flower observed per Gama pepper and 0.125 individual per flower in Esen pepper, the number of thrips increased over time, peaking in August. Specifically, on 12 August, there were 1.65 thrips observed in Gama peppers and 1.525 in Esen peppers, after that peak, there's a gradual decrease in thrips in both Gama and Esen peppers, in 2 September, there were 1.2 thrips per Gama pepper and 0.725 individual per flower in Esen pepper, the number continued to decrease over September, and in 30 September it was down to 0.125

in Gama and 0.075 in Esen peppers. In 7 October, the count reached zero for both varieties of peppers (Figure 4. 23), this may be due to changes in temperature.

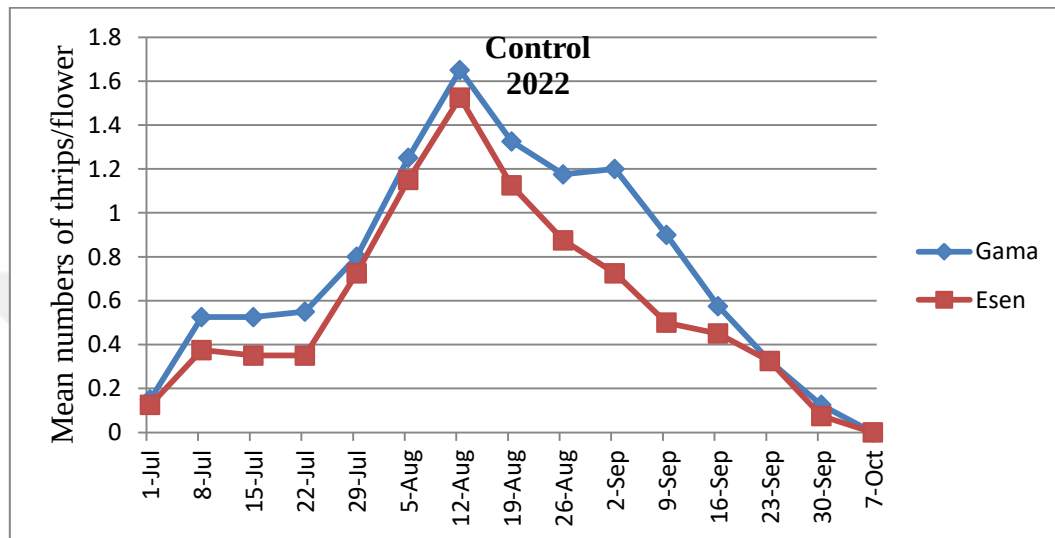


Figure 4. 23. Mean densities of *Frankliniella occidentalis* in pepper flowers in untreated plots of pepper varieties Gama and Esen in 2022

4.3.1.2. Mean densities of *Thrips tabaci* in pepper flowers in untreated pepper varieties, Gama and Esen

4.3.1.2.1. Mean densities of *Thrips tabaci* in pepper flowers in 2021

Figure (4.25), represents the population densities of *T. tabaci* in two different varieties of pepper plants, Gama and Esen, the *T. tabaci* first appeared at the beginning of July, with a rate of 0.325 individual per flower in Gama and 0.35 individual per flower in Esen per flower across all replications, by the middle of July, the rate had reached 0.15 in Gama and 1.175 individual per flower in Esen. On August 25th, the densities in abundance had reached 0.4 individual per flower in Gama and 0.45 individual per flower in Esen. In September, the number of *T. tabaci* began to decline, reaching 0.3 in Gama and 0.325 in Esen by September 22th, in the end of October, the *T. tabaci* count had dropped to zero in both replications (Figure 4. 24). This result agreed with the finding of Kaur et al., (2017) who mentioned that the development span from egg to adult in *T. tabaci*, is significantly

influenced by environmental conditions, particularly suitable temperature, development of *T. tabaci* may have affected by temperature, which ideally should not fall below 5-6°C for optimal survival and completion of its life cycle, the optimal temperature for *T. tabaci*'s growth is around 30°C, as it exhibits maximum growth at this temperature.

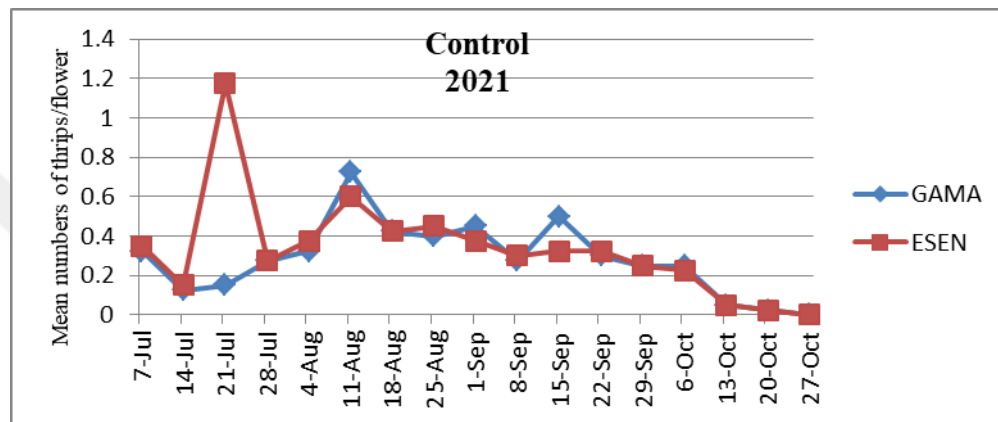


Figure 4.24. Mean densities of *Thrips tabaci* in pepper flowers in untreated plots of pepper varieties Gama and Esen in 2021

4.3.1.2.2. Mean densities of *Thrips tabaci* in pepper flowers in 2022

Figure (4.25), displays the population density of *T. tabaci*, in two varieties of peppers, (Gama and Esen), over a period from July to October, the numbers appear to represent the average number of thrips found on a single flower of each pepper variety on a given date. The data indicates that the *T. tabaci* first observed at the start of July with population density in Gama 0.075 and 0.025 individual per flower in Esen, in 5 Augusts the *T. tabaci* numbers was 0.35 in one flower in both varieties (Gama and Esen), in September 2, 9 and 16 *T. tabaci* numbers were 0.225, 0.225 and 0.25 thrips/flower respectively in both varieties.

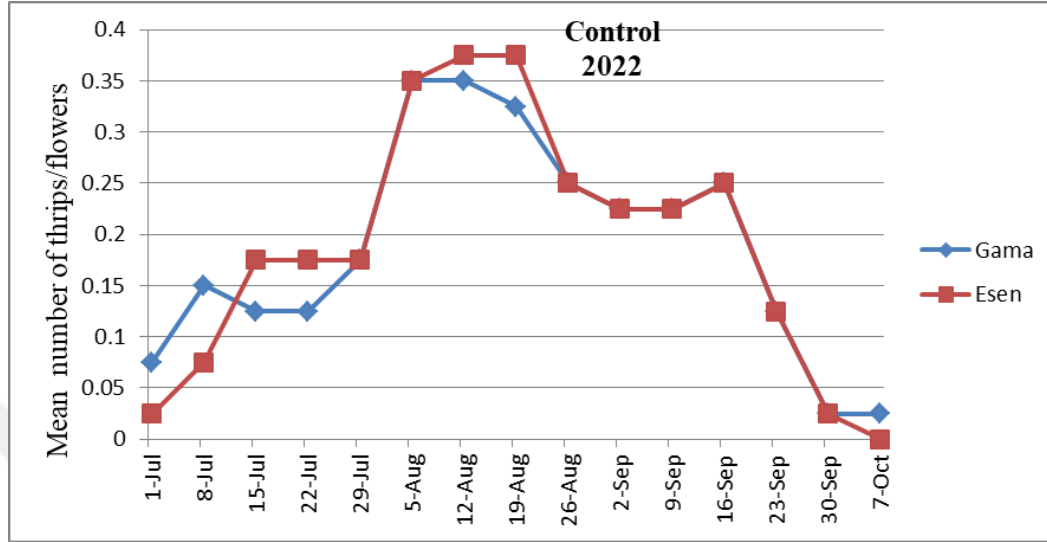


Figure 4.25. Mean densities of *Thrips tabaci* in pepper flowers in untreated plots of pepper varieties Gama and Esen in 2022

In the control treatment, it was observed the number of thrips was lower than economic threshold. The reason of this due to the spread proliferation of predatory insect *Orius laevis* in the control parcels in two years.

4.3.2. Thrips population in *Orius laevis* treatment

4.3.2.1. The effect of *Orius laevis* on density of *Frankliniella occidentalis* in pepper flowers

4.3.2.1.1. The effect of *Orius laevis* on density of *Frankliniella occidentalis* in 2021

In the second treatment (GAMA and ESEN), *Orius laevis* bug was used as a biological control agent, this predatory insect preys on adult thrips as well as thrips larvae, the data in the figure corresponds to a specific collection date, starting from 7th July and ending on 27th October. It was observed that the number of *F. occidentalis* significantly increased

before the application of *Orius laevigatus* in July. The first treatment occurred on 29th July when it was noted that the number of *F. occidentalis* began to decrease. In August, the numbers of *F. occidentalis* reduced drastically, with 0.1-0.1 individual per flower in Gama and 0.05-0.025 in Esen per flower, but was 0.95 per flower in Gama varieties and 1.025 individual per flower in Esen in control treatment. The population of *F. occidentalis* continued to decline, and did not increase after *Orius laevigatus* was applied for the second time on 17th August, the number of *O. laevigatus* increased in the replicates to be by 0.6 in Gama and 0.8 individual per flower in Esen, and the last treatment was 25 Augusts (Figure 4.26), the number of *F. occidentalis* in both Gama and Esen peppers decreased to zero level, indicating successful pest presures due to *Orius*'s attacks.

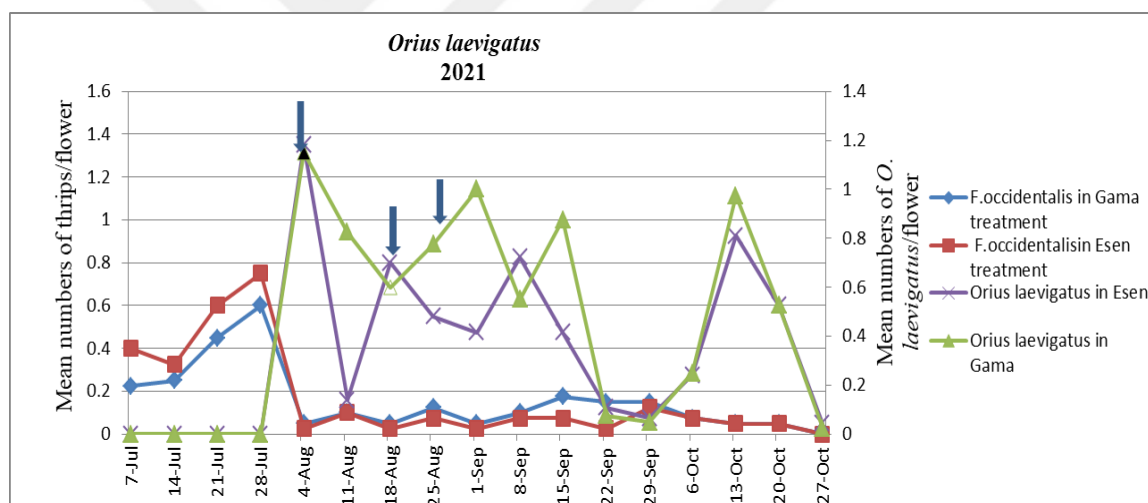


Figure 4.26. The effect of *Orius laevigatus* on density of *Frankliniella occidentalis* in pepper flowers in 2021

The arrow indicates the date of release of *Orius laevigatus*.

The *Orius laevigatus* populations remained until September and October, when they were still giving good results in controlling *F. occidentalis*. However, in September, the number of *F. occidentalis* increased slightly to 0.1 in Gama and 0.075 individual per flower in Esen. In October, the numbers were very low, with the last reading taken on the 27th showing zero in both replications (Gama and Esen). The results suggested that this

predatory insect, *Orius laevigatus* was highly efficient at controlling thrips. These results agreed with Van and Loomans (1995) who mentioned that the insect predator, *Orius laevigatus*, demonstrated a high level of effectiveness in managing thrips, with *F. occidentalis* as their prey, the nymphs of *O. laevigatus* consume an average of 1.95 ± 0.75 larvae or 2.10 ± 0.03 adult thrips daily.

4.3.2.2. The effect of *Orius laevigatus* on density of *Frankliniella occidentalis* in 2022

In 1st July, there were *F. occidentalis* in Gama and 0.075 individual per flower in Esen, the numbers fluctuated in both varieties over the following weeks, in 29th July, the *F. occidentalis* count had significantly dropped in both replications, with 0.05 thrips in Gama and 0.075 individual per flower in Esen. In August, after the *Orius laevigatus* application in 23th, 29th July and in 25th Augusts, it can be seen that their numbers have increased significantly where they were 1.275 individual per flower in Esen replication in 12-Aug and 1.025 individual per flower in Gama with 1.05 individual per flower in Esen in 2th September, the *F. occidentalis* population decreased to zero level, even further in both varieties, in 5th August in Gama and in 12th August in Esen, the counts remained low through September, with a slight increase to 0.05 *F. occidentalis* in both replications in 30th September.

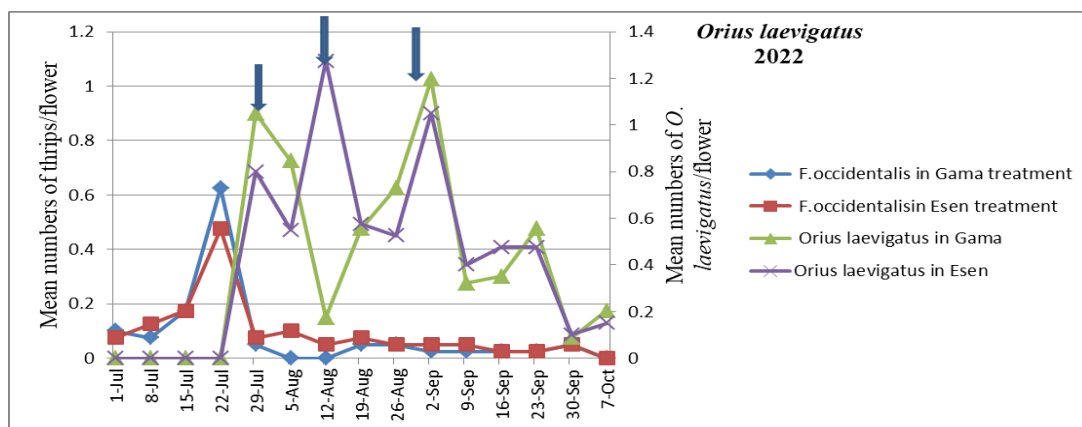


Figure 4.27. The effect of *Orius laevigatus* on density of *Frankliniella occidentalis* in pepper flowers in 2022

In October, there were no *F. occidentalis* found in either replications in the 7th and 20th. However, in 7th October, no thrips were found in Gama and Esen (Figure 4. 27). This result agreed with the findings of Arnaouty et al., (2020) who mentioned that the biological control methods could significantly reduce pest populations and related damage to levels that are economically tolerable, this approach often takes longer than chemical pesticides to bring pest populations down to acceptable threshold level, *Orius laevigatus* is able to decrease the population of *F. occidentalis* in commercially grown sweet peppers.

4.3.2.2. The effect of *Orius laevigatus* on density of *Thrips tabaci* in pepper flowers

4.3.2.2.1. The effect of *Orius laevigatus* on density of *Thrips tabaci* in 2021

Orius laevigatus was used as a biological control agent, with 25 individuals placed in each plot for a total of 100 individuals in whole trial, the application of *Orius laevigatus*, the initial readings of the *T. tabaci* count, taken on July 7th, were 0.225 individual per flower in Gama and 0.175 individual per flower in Esen per flower, but in control treatment was 0.325 individual per flower in Gama and 0.35 individual per flower in Esen, the first treatment was applied on 29th July, and showed the numbers of *Orius laevigatus* increased, and the number of thrips was 0.825: 0.16 individual per flower in Gama and Esen, after which a decrease in the number of *T. tabaci* was observed. In August, the mean numbers of *T. tabaci* were notably low, with counts of 0 to 0.1 in Gama and 0 to 0.05 individual per flower in Esen (Figure 4.28), the population of *T. tabaci* continued to decline and did not rise in August after *Orius laevigatus* was applied for the second time on 17th August, after that in 25th August, where observed increase in mean numbers of *Orius laevigatus* in rate 0.825 individual per flower in Gama replication.

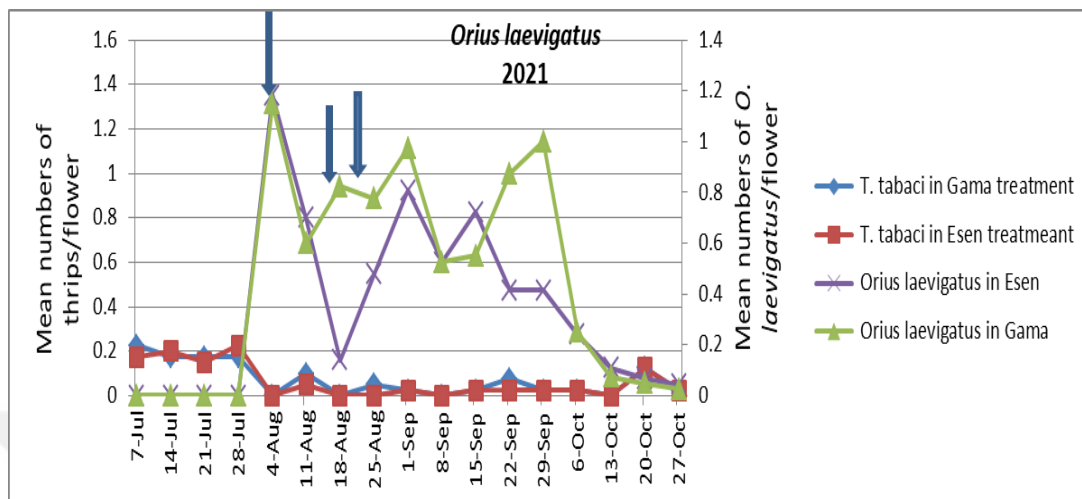


Figure 4.28. The effect of *Orius laevigatus* on density of *Thrips tabaci* in pepper flowers in 2021

The arrow indicates the date of release of *Orius laevigatus*.

In 1st September, the mean of *T. tabaci* number/ flower had fallen to 0.025 individual per flower in both Gama and Esen. In October, the counts were very low, with the last reading taken on the 27th indicating a count of 0.025 individual per flower in both Gama and Esen.

4.3.2.2.2. The effect of *Orius laevigatus* on density of *Thrips tabaci* in 2022

In 1st July, there were 0.05 *T. tabaci* in Gama and 0.025 individual per flower in Esen. The *Orius laevigatus* applied in this treatment in 23, 29th July and in 25th Augusts. The mean number of *T. tabaci* showed fluctuations over the following weeks with an increase 0.15 individual per flower in Gama and 0.25 individual per flower in Esen on 22nd July, and decrease to 0.025 individual per flower in both varieties in 29th July. In August, the thrips count dropped to zero in both replications on the 5th and fluctuated between zero and 0.025 individual per flower for the rest of the month. In September, there were very few thrips in both replications with the count remaining at zero for most of the month, except for a slight increase to 0.025 individual per flower in both Gama and Esen on the 2nd September.

There were no *T. tabaci* recorded in either replication until the 7th October, 0.025 individual per flower *T. tabaci* was noted in Gama while Esen remained at zero (Figure 4.29). These results were compatible results reported by Atanasova et al., (2022) who mentioned that the biological control was implemented, the density of thrips per flower was decreased to an economically acceptable level within three weeks after the initial release of *Orius laevisgatus* at a rate of one adult per square meter, following the second and third introductions of *O. laevisgatus*, the population of thrips per flower continued to decrease.

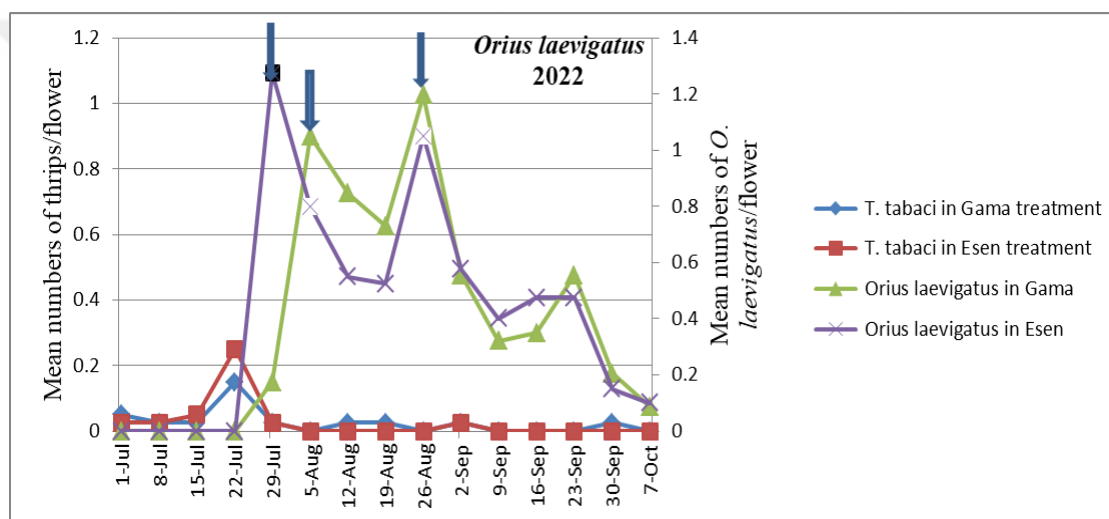


Figure 4.29. The effect of *Orius laevisgatus* on density of *Thrips tabaci* in pepper flowers in 2022

The arrow indicates the date of release of *Orius laevisgatus*.

4.3.3. Thrips population in *Amblyseius swirskii* treatment

4.3.3.1. The effect of *Amblyseius swirskii* on density of *Frankliniella occidentalis* in pepper flowers

4.3.3.1.1. The effect of *Amblyseius swirskii* on density of *Frankliniella occidentalis* in 2021

In the third treatment biological control by predatory mite against pest thrips was utilized, specifically, the predatory mite *Amblyseius swirskii*, which is becoming increasingly vital in controlling thrips pests such as *F. occidentalis*, with 100 individuals released to each plot, a total of 1125,000 mite individuals in whole trial, including all life stages before was deployed. After 29th July, when *Amblyseius swirskii* was first introduced, the account of *Amblyseius swirskii* populations increased arrived to 1.025 individual per flower in Gama replication and 0.9 individual per flower in Esen replication in 11-Aug and a significant reduction in the number of *F. occidentalis* was observed, this mite was used in 29th July, 17th and 25th August. Consequently, the number of thrips was low in both August and September. By September 15th, the number of thrips had fallen to 0.1 in the Gama treatment and 0.05 individual per flower in Esen. Finally, in 27th October.

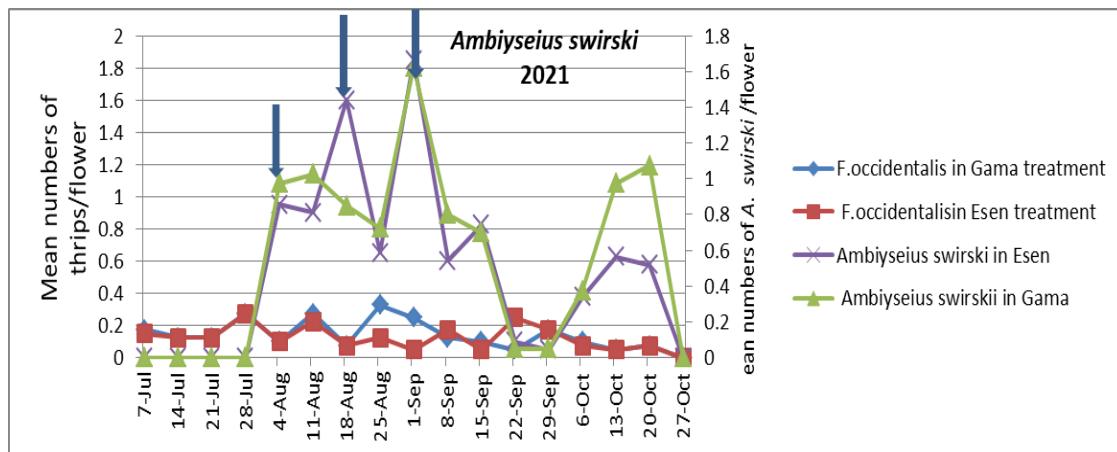


Figure 4.30. The effect of *Amblyseius swirskii* on density of *Frankliniella occidentalis* in pepper flowers in 2021

The arrow indicates the release of *Amblyseius swirski*.

The number of thrips reached its lowest level, with zero thrips reported in both Gama and Esen. In October, densities of the thrips in both pepper's flowers of Gama and Esen dropped to zero level (Figure 4.30), this could indicate the end of the thrips life cycle, effective pest control measures, or the end of the growing season for these peppers. This result was agreed with the findings of Cindy et al., (2009) who mentioned that the predators of *Amblyseius swirskii* fed on larvae and adults were the preferred prey for both species, consuming on average 1.1–1.7 adults/day and (1.3 eggs/day), in greenhouse tests with infested pepper plants, and reduced thrips mean numbers significantly over 28 days following a single release (30 mites/plant).

4.3.3.1.2. The effect of *Amblyseius swirskii* on density of *Frankliniella occidentalis* in 2022

In figure (4.31) presents data of *F. occidentalis* population densities in Gama and Esen, mite was used in 29th July, 17th and 25th August. From 1st July, there were 0.075 thrips individual per flower in Gama and 0.025 in Esen. The mean number of thrips increased in both varieties over the next few weeks showing a peak with 0.75 individual per flower in both Gama and Esen on 22nd July. After peak densities, there was a significant decrease in the abundance of thrips in both varieties on 29th July, with 0.05 thrips individual per flower in Gama and 0.025 in Esen. The *Amblyseius swirskii* applied in 23, 27th July and 25th August. In August, the thrips count fluctuated, reaching 0.325 thrips individual per flower in Gama and 0.3 in Esen in 26th August. In September, the count continued to fluctuate with a decline to 0.025 individual per flower in both varieties in 23rd September. In 7th October, no thrips were recorded in either varieties.

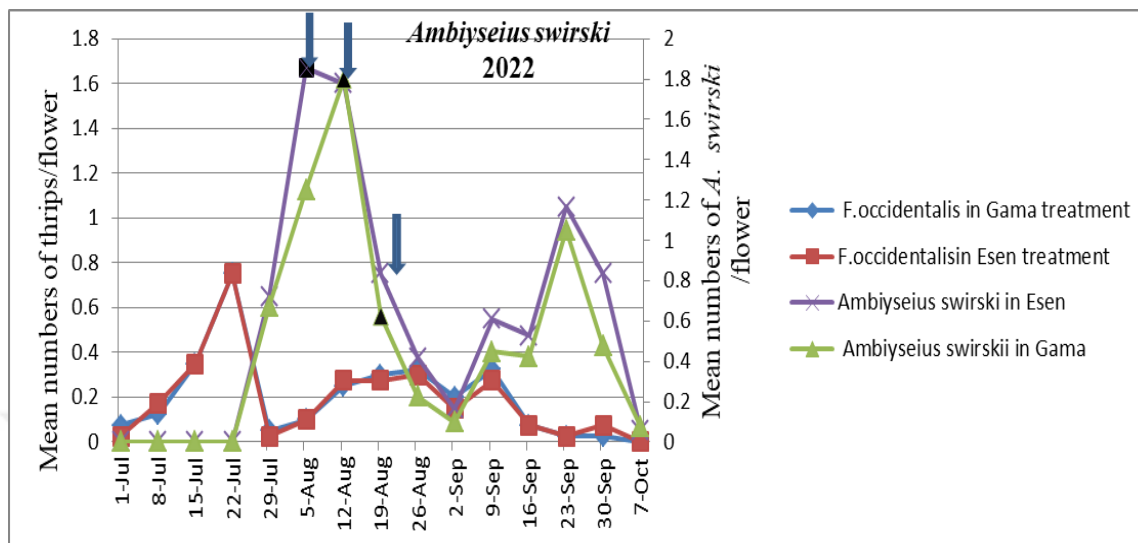


Figure 4.31. The effect of *Amblyseius swirskii* on density of *Frankliniella occidentalis* in pepper flowers in 2022

The arrow indicates the release of *Amblyseius swirskii*.

4.3.3.2. The effect of *Amblyseius swirskii* on density of *Thrips tabaci* in pepper flowers

4.3.3.2.1. The effect of *Amblyseius swirskii* on density of *Thrips tabaci* in 2021

In the third treatment (GAMA and ESEN replication) to control *T. tabaci* species, using the predatory mite *Amblyseius swirskii* as biological control, *T. tabaci* was reduced to low level after 29 July, when *Amblyseius swirskii* were released to representative plots, were used in 29 July and 17,25 August, the mean numbers of *T. tabaci* were low on the August and September, in 1 September arrived to (0.2 in Gama treatment and 0.1 individual per flower in Esen), in 29 September it increased by a little bit as it reached to (0.6 in Gama and 0.175 individual per flower in Esen), in 20 October the mean number of *T. tabaci* arrived the lowest level (0.075 in Gama and 0.025 in Esen), and in 27 October the readings *Thrips tabaci* numbers were 0 in Gama and Esen (Figure 4.32).

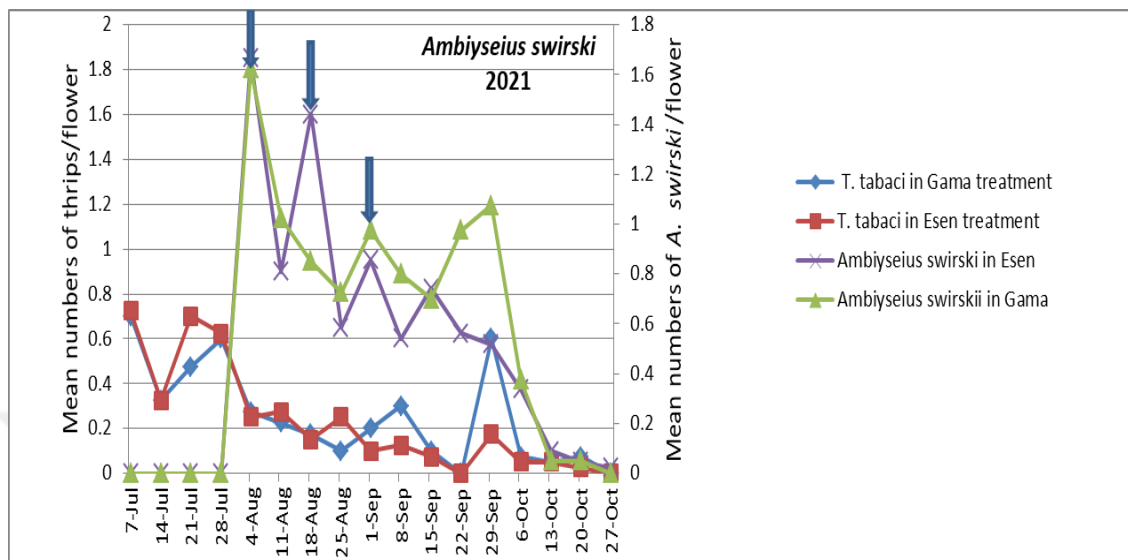


Figure 4.32. The effect of *Amblyseius swirskii* on density of *Thrips tabaci* in pepper flowers in 2021

The arrow indicates release of *Amblyseius swirskii*.

4.3.3.2.2. The effect of *Amblyseius swirskii* on density of *Thrips tabaci* in 2022

In figure (4.33) showed in 1st July, there were 0.05 *T. tabaci* observed in Gama and no thrips in Esen. The mean number of *T. tabaci* generally increased in both varieties over the course of July, peaking at 0.175 individual per flower in Gama and 0.125 in Esen in 22th July. In 29th July, after treatment with an *Amblyseius swirskii*, it was observed that it was abundant in the field, where it was in the percentage of 1.25: 1.67 thrips individual per flower in August 5th, and the mean number of *T. tabaci* per flower dropped to zero level in both varieties. In August, the *T. tabaci* count fluctuated, reaching as 0.175 thrips individual per flower in both varieties in 19th August. In September, the *T. tabaci* density again experienced fluctuations, falling to zero in Gama and Esen in 23rd September. The count increased slightly in 30th September, with 0.075 *T. tabaci* in Gama and 0.025 individual per flower in Esen. In 7th October, no thrips were observed in either replication. This result agreed with the findings of Buitenhuis et al. (2008) who mentioned that the *Amblyseius*

swirskii plays a significant part in thrips control and serves as a more cost-efficient biological control agent under prevalent climate conditions. Its usage in greenhouse crops in North America has shown notable success.

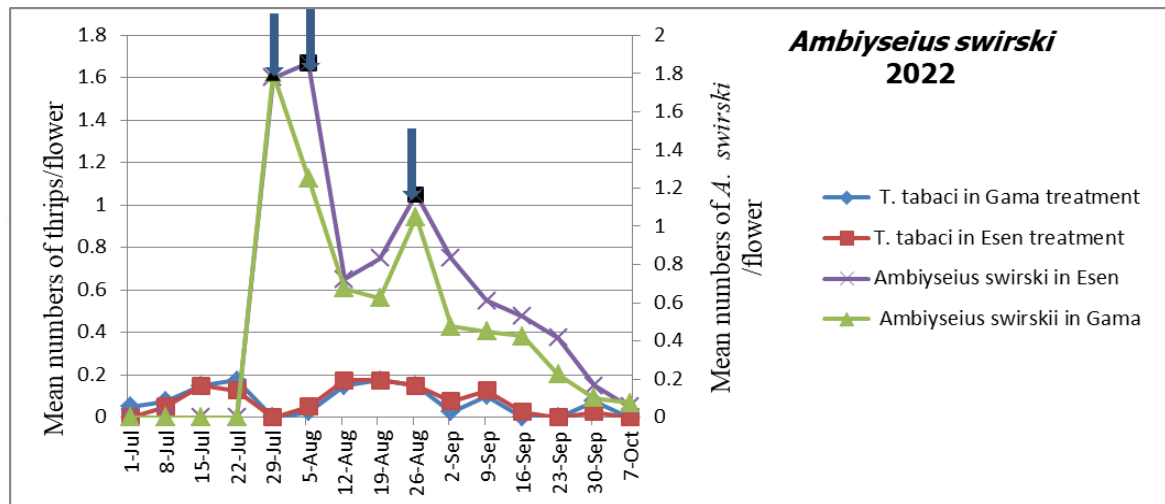


Figure 4.33. The effect of *Amblyseius swirskii* on density of *Thrips tabaci* in pepper flowers in 2022

The arrow indicates the release of *Amblyseius swirskii*.

4.3.4. The effect of Azadirachtin 790 g/l Neem oil + 0.3 g/l

4.3.4.1. The effect of Azadirachtin 790 g/l Neem oil + 0.3 g/l on density of *Frankliniella occidentalis* in pepper flowers

4.3.4.1.1. The effect of Azadirachtin 790 g/l Neem oil + 0.3 g/l on density of *Frankliniella occidentalis* in 2021

In figure (4.35) showed the data collected from 7th July to 27th October, for the treatment applying the botanical or plant-derived chemical/ (active ingredient) (azadirachtin 790 g/l Neem oil + 0.3 G/l) (Gama and Esen varieties), where started the treatment in 8 July, where were the numbers of *F. occidentalis* before treatment (1.025 in Gama and 1.1

individual per flower in Esen), then after spraying the pesticide arrived the *F. occidentalis* number to 0.05 in Gama and Esen in 14 July.

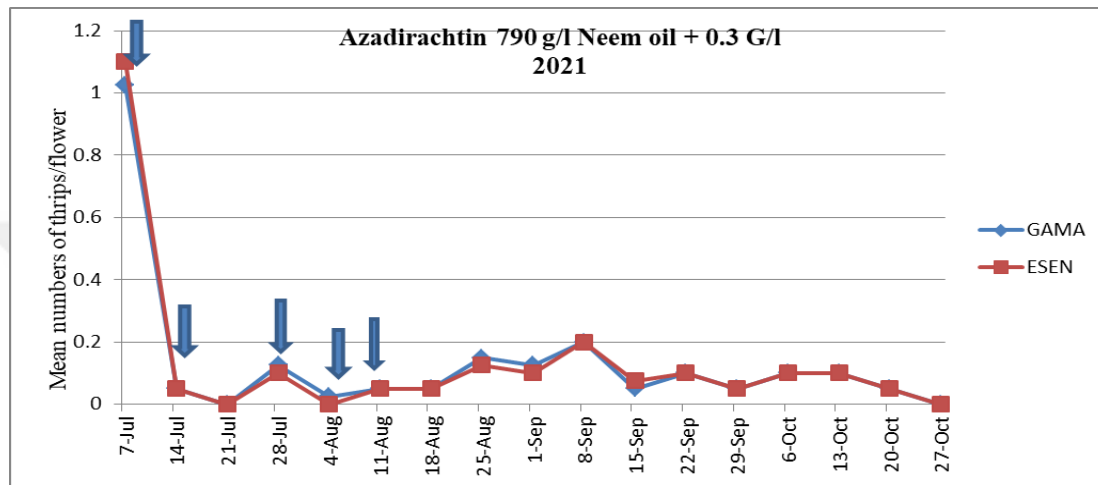


Figure 4.34. The effect of Azadirachtin 790 g/l Neem oil + 0.3 G/l on density of *Frankliniella occidentalis* in pepper flowers in 2021

The arrow indicates the application of Azadirachtin 790 g/l Neem oil + 0.3 G/l

Then used the pesticide again at the following appointments 16, 28 July and 4, 10 Augusts, where the use of this pesticide gave good results, as the number of the insect did not increase, as it was the highest in 8 September as 0.2 in Gama and Esen treatment, then it looked down in 20- 27 October to arrived 0.05-0 individual per flower in both varieties (Gama and Esen) (Figure 4.34). Through the use of this specific insecticide, it was found that it had the capability to reduce quickly the number of *F. occidentalis* to acceptable density level delivers quick results, the efficacy of azadirachtin against adult insects and larvae of thrips over a 24-hour period depends on the dosage applied. This result was agreed with Balaško (2021) who mentioned that the Colorado potato beetle and western flower thrips (*F. occidentalis*) are agricultural pests that pose control challenges due to their developed resistance to numerous types of insecticides, alternative for managing these pests could be the botanical insecticide azadirachtin, in this study, we examined the effectiveness

of azadirachtin on the mortality and feeding intensity of the Colorado potato beetle and *F. occidentalis*, as well as thrips' egg-laying behavior, the insecticide was tested at three different doses in lab trials, the findings revealed that azadirachtin was effective against the larval stages of the Colorado potato beetle and minimized the damage on the treated leaves. Moreover, it was observed that azadirachtin reduced the overall population of *F. occidentalis* by affecting their larvae, feeding intensity, and oviposition.

4.3.4.1.2. The effect of Azadirachtin 790 g/l Neem oil + 0.3 g/l on density of *Frankliniella occidentalis* in 2022

In figure (4.35) the populations of thrips in both Gama and Esen seem to peak around the 22th of July, with 0.6 in Gama and 0.55 individual per flower in Esen, after that, there was a general trend of decrease in the thrips population in both varieties, with some fluctuations, in 7th October, no thrips was reported in either Gama or Esen. (Azadirachtin 790 g/l Neem oil + 0.3 G/l) applied in 22 July, 19, 25 August and 9 September.

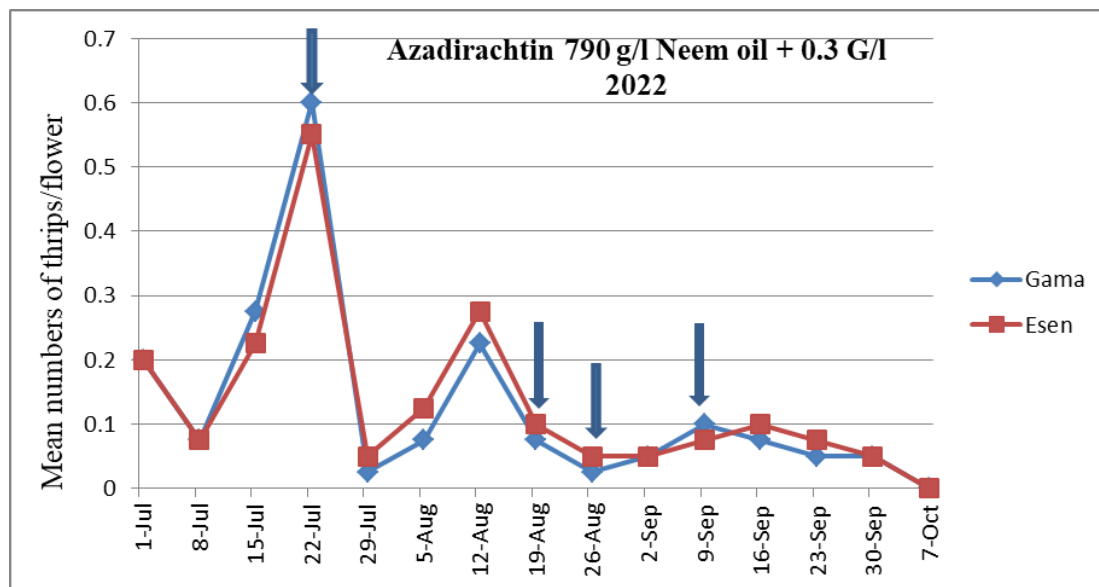


Figure 4.35. The effect of (Azadirachtin 790 g/l Neem oil + 0.3 g/l) on density of *Frankliniella occidentalis* in pepper flowers in 2022

4.3.4.2. The effect of Azadirachtin 790 g/l Neem oil + 0.3 g/l on density of *Thrips tabaci* in pepper flowers

4.3.4.2.1 The effect of Azadirachtin 790 g/l Neem oil + 0.3 g/l on density of *Thrips tabaci* in 2021

In the fourth treatment, for controlling *Thrips tabaci* species, applied azadirachtin (790 g/l Neem oil + 0.3 G/l) to both the Gama and Esen varieties. This substance affects the insect's nervous system. Treatment began on 8 July, with the numbers of *T. tabaci* before treatment being 0.2 in Gama and 0.125 individual per flower in Esen.

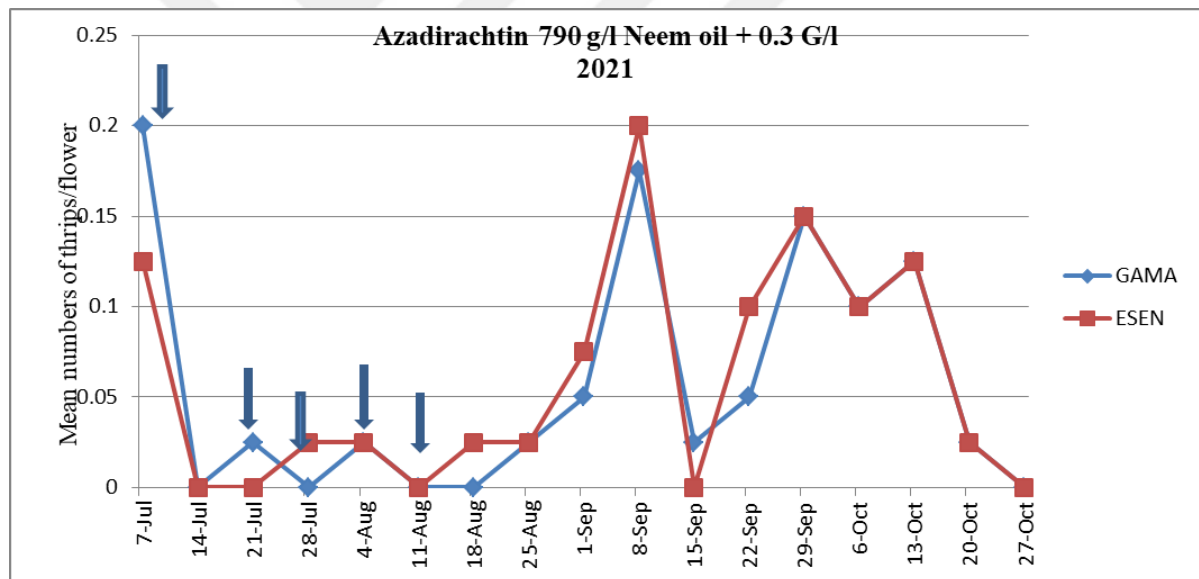


Figure 4.36. The effect of Azadirachtin 790 g/l Neem oil + 0.3 G/l on density of *Thrips tabaci* in pepper flowers in 2021

The arrow indicates the application of Azadirachtin 790 g/l Neem oil + 0.3 G/l

After the pesticide was sprayed, the *T. tabaci* count dropped to 0 in 14 July in both Gama and Esen varieties. The pesticide was applied again on the following dates: 16,21,28 July and 4, 10 August. The highest count was observed on 8 September, with 0.175 mean thrips number/ flower in Gama and 0.2 in the Esen treatment. Subsequently, the mortality rate

began to decline from October 20 to 27, eventually reaching a count of 0.025 to 0 in both the Gama and Esen treatments (Figure 4.36).

4.3.4.2.2 The effect of Azadirachtin 790 g/l Neem oil + 0.3 g/l on density of *Thrips tabaci* in 2022

On the 8th of July, mean thrips number/ flower of *T. tabaci* is 0 in Gama replication, while in Esen is 0.05 individual/ flower. Both in Gama and Esen have the highest number of *T. tabaci* on the 22nd of July, with in Gama at 0.15 and in Esen at 0.175 individual per flower. The 29th of July is interesting as both Gama and Esen have 0 of *T. tabaci*. From the 5th of August to the 30th of September, both entities seem to have similar values on the same dates, with a few exceptions (like on 9-Sep and 16-Sep) was (0, 0.025) individual per flower in Gama and (0.025, 0) in Esen individual per flower (Figure 4.38).

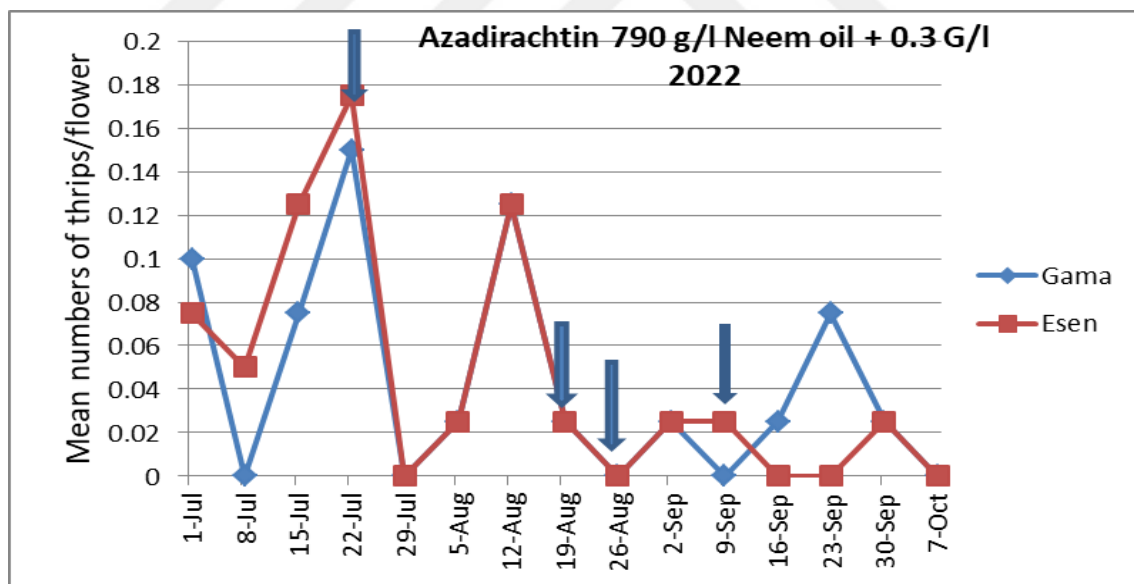


Figure 4.37. The effect of Azadirachtin 790 g/l Neem oil + 0.3 g/l on density of *Thrips tabaci* in pepper flowers in 2022

The arrow indicates the application of Azadirachtin 790 g/l Neem oil + 0.3 g/l

4.3.5. The effect of Spinosad 240 g/l

4.3.5.1. The effect of Spinosad 240 g/l on density of *Frankliniella occidentalis* in pepper flowers

4.3.5.1.1. The effect of Spinosad 240 g/l on density of *Frankliniella occidentalis* in 2021

In fifth treatment, for controlling *Frankliniella occidentalis* species applying (Spinosad 240 g/l) in (Gama and Esen varieties), where started the treatment on 8 July, where were the mean thrips numbers/ flower of *F. occidentalis* before treatment (0.35 in Gama and 0.25 in Esen) (Figure 4.38), after using the pesticide in 8th, 16th, 28th July and 4th, 10th August, insecticide was not capable to reduce, the abundance of *F. occidentalis* to desired density levels. It was noticed that the pesticide did not well control, where the readings of *F. occidentalis* were as follows (0.675, 0.15, 0.25, 0.15) individual per flower in Gama treatment and (0.625, 0.25, 0.275, 0.15) in Esen treatment in 28- Jul, 4-Aug, 18-Aug and 1-Sep (Figure 4.38). This result agreed with the findings of Jones et al. (2005) who mentioned that the (Spinosad 240 g/l) is effective, but not very well, as the number of insects mortality is not many.

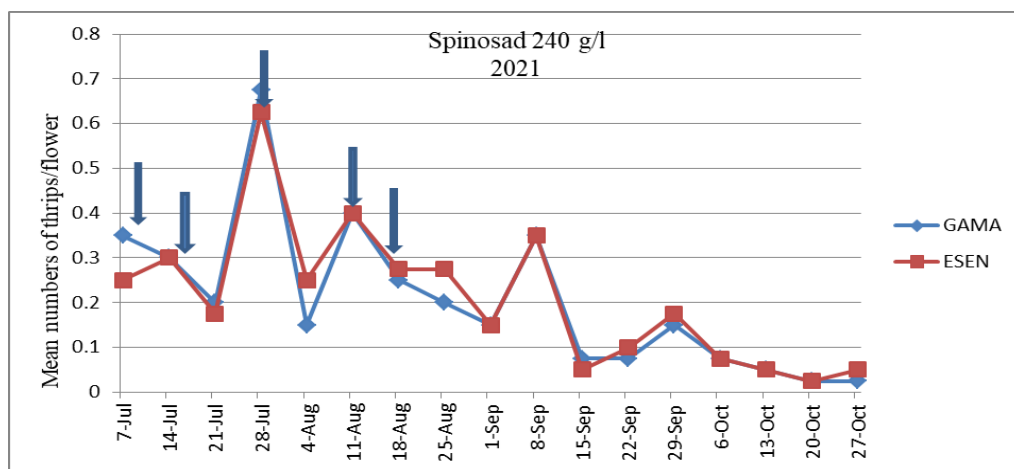


Figure 4.38. The effect of Spinosad 240 g/l on density of *Frankliniella occidentalis* in pepper flowers in 2021

4.3.5.1.2. The effect of Spinosad 240 g/l on density of *Frankliniella occidentalis* in 2022

The *Frankliniella occidentalis* samples gives a specific date from 1-Jul to 7-Oct in Gama and Esen replications, in 1-Jul, 15-Jul, 22-Jul, 2-Sep, and 30-Sep, both Gama and Esen have the same numbers of *F. occidentalis*, in 23- Sep the samples arrived to 0.2 in Gama and 0.25 individual per flower in Esen replication, in 7-Oct the *Frankliniella occidentalis* numbers decreased to 0.05 individual per flower in Gama and 0.025 in Esen (Figure 4.39). (Spinosad 240 g/l) applied in 22th July, 19, 25th August and 9th September.

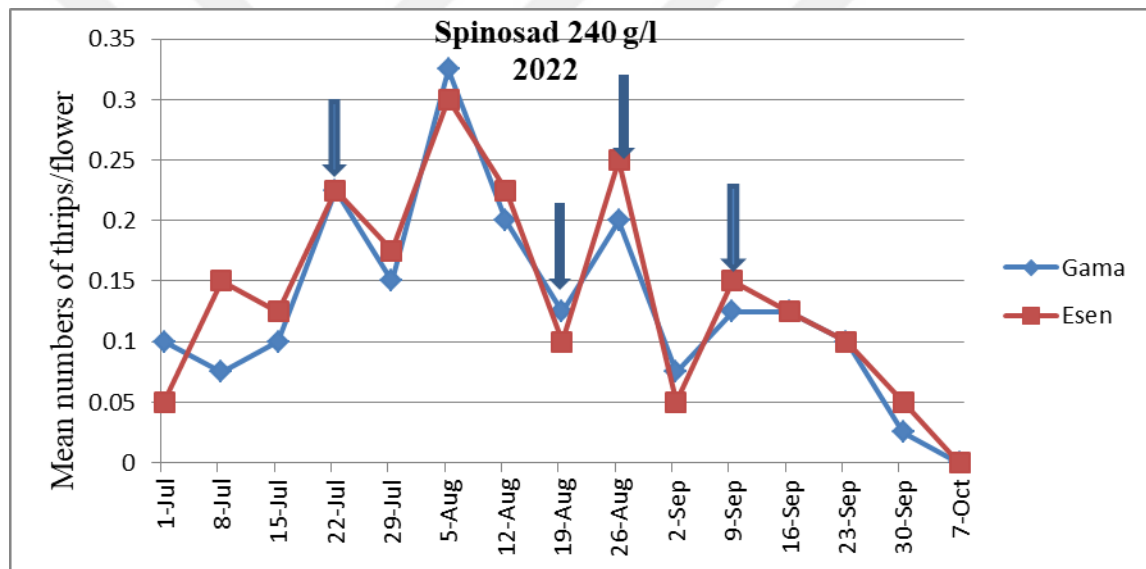


Figure 4.39. The effect of Spinosad 240 g/l on density of *Frankliniella occidentalis* in pepper flowers in 2022

The arrow indicates the application of spinosad

4.3.5.2. The effect of Spinosad 240 g/l on density of *Thrips tabaci* in pepper flowers

4.3.5.2.1 The effect of Spinosad 240 g/l on density of *Thrips tabaci* in 2021

In fifth treatment, for controlling *Thrips tabaci* species applying (Spinosad 240 g/l) in (Gama and Esen) both varieties, the counts were made at period of 7th July to 27th October, where started the treatment on 8 July, where were the numbers of *T. tabaci* before

treatment (0.05 in Gama and 0.15 in Esen), after using the pesticide (Figure 4.40), Spinosad did not reduce numbers of this thrips to acceptable level. It was noticed that the pesticide did not have good results, where the numbers of *T. tabaci* remained in varying proportions in the months of the study.

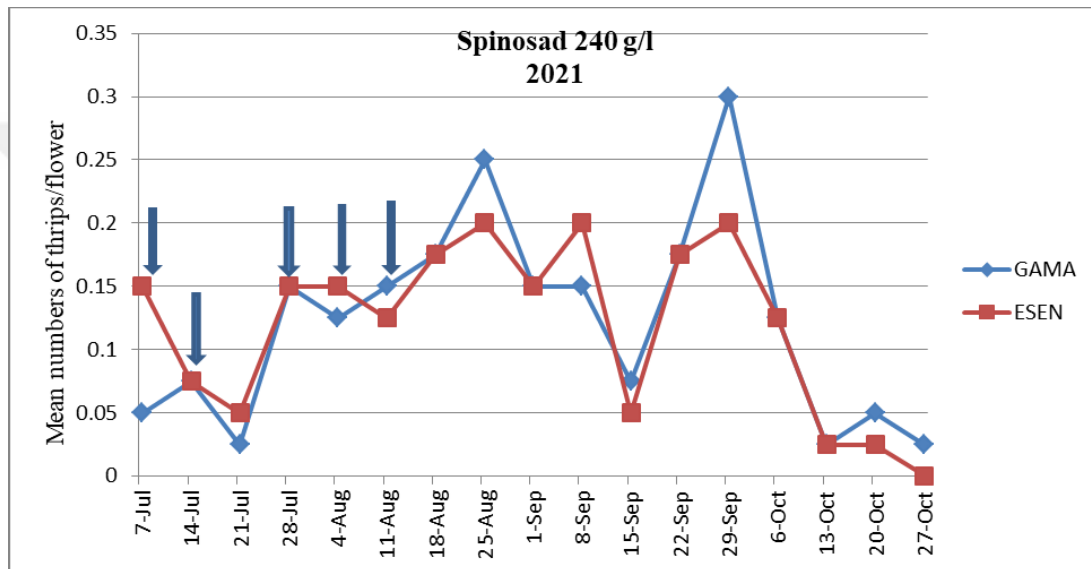


Figure 4.40. The effect of Spinosad 240 g/l on density of *Thrips tabaci* in pepper flowers in 2021

The arrow indicates the application of Spinosad

4.3.5.2.2 The effect of Spinosad 240 g/l on density of *Thrips tabaci* in 2022

In the 1st of July, in Gama the *T. tabaci* numbers starts with 0.1 individual per flower, while in Esen was 0.05 individual per flower, which is half number in Gama's replication. In 22-Jul, both in Gama and Esen varieties have the same number of 0.225 individual per flower, indicating a point where their metrics converged. The highest number of *T. tabaci* in Gama is 0.325 founded in 5-Aug, and in Esen 0.25 in 26-Aug, and reaching the lowest number in 7-Oct where both are at 0 (Figure 4.41). (Spinosad 240 g/l) applied in 22th July, 19, 25th August and 9th September.

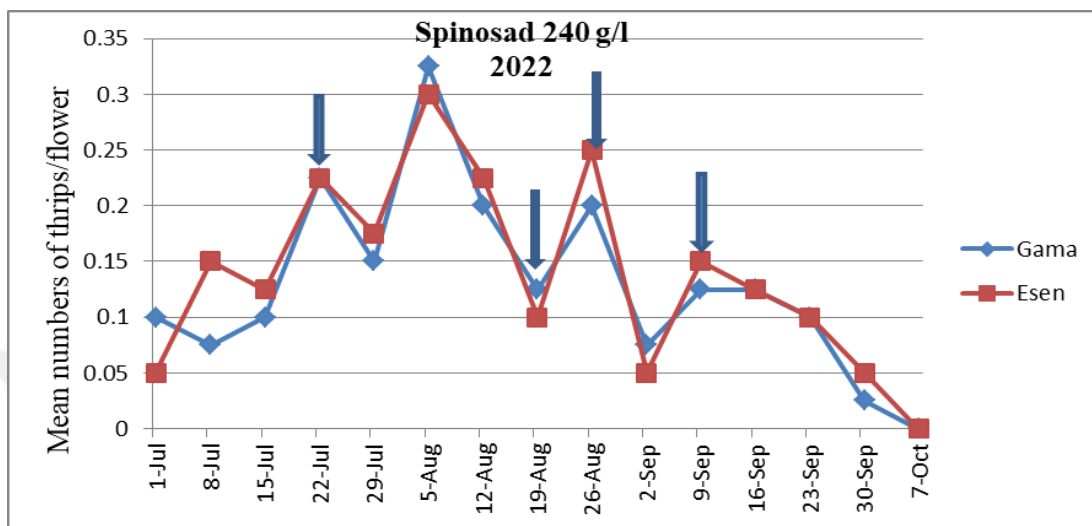


Figure 4.41. The effect of Spinosad 240 g/l on density of *Thrips tabaci* in pepper flowers in 2022

The arrow indicates the application of spinosad

4.3.6. The effect of Formetanate hydrochloride % 50

4.3.6.1. The effect of Formetanate hydrochloride % 50 on density of *Frankliniella occidentalis* in pepper flowers

4.3.6.1.1. The effect of Formetanate hydrochloride % 50 on density of *Frankliniella occidentalis* in 2021

In sixth treatment used Formetanate hydrochloride% 50 in (Gama and Esen varieties), applied on developing stages and adults to reduce the populations numbers of *F. occidentalis*, that the maximum rate of *F. occidentalis* in 28 July was 0.675 in Gama and 0.625 in Esen, applying the treatment at the following appointments 16,28 July and 4, 10 Augusts, in 27 October the mean thrips number/ flower of *F. occidentalis* was 0.025 in Gama and 0.05 individual per flower in Esen treatment), the treatment was done with

Formetanate hydrochloride% 50 on the following dates (8, 16, 28) July and (4, 10) August (Figure 4.42).

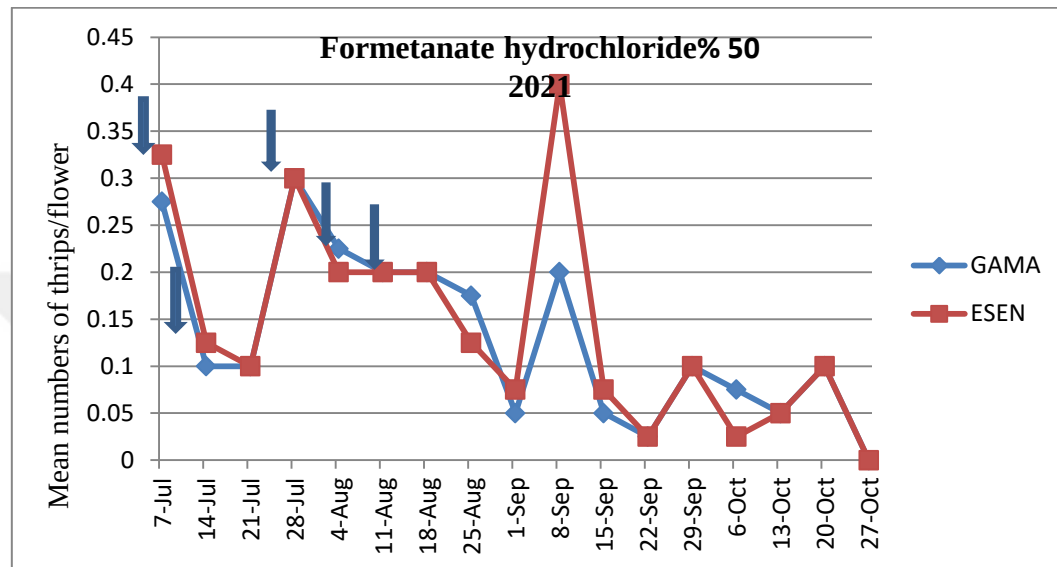


Figure 4.42. The effect of Formetanate hydrochloride % 50 on density of *Frankliniella occidentalis* in pepper flowers in 2021

The arrow indicates the application of formetanate hydrochloride

4.3.6.1.2. The effect of Formetanate hydrochloride% 50 on density of *Frankliniella occidentalis* in 2022

The samples collected in dates from 1-Jul to 7-Oct, weekly basis. The number of *Frankliniella occidentalis* range between 0 and 0.675. On 1-Jul, Gama begins with a number of 0.175 individual per flower, slightly more than Esen's 0.15 individual per flower. Gama reaches its peak on 22-Jul with a number of 0.675, while in Esen peak is slightly less at 0.625 on the same date, in both varieties Gama and Esen reach their lowest point on 7-Oct with a value of 0, the treatment was done with (Formetanate hydrochloride) on the following dates 22 July, 19, 25 August and 9 September (Figure 4.43).

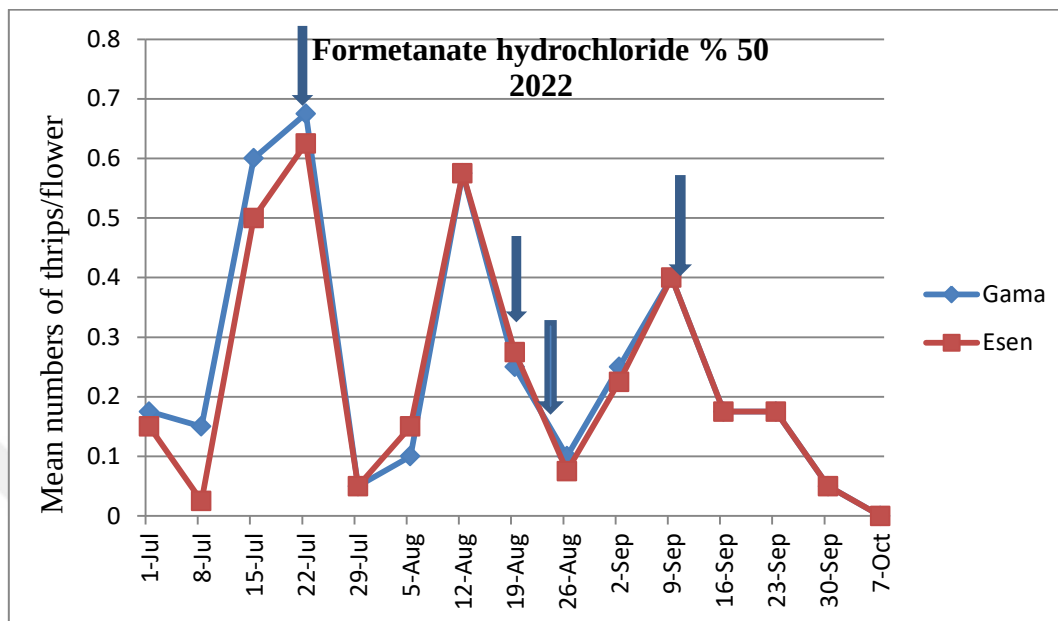


Figure 4.43. The effect of Formetanate hydrochloride on density of *Frankliniella occidentalis* in pepper flowers in 2022

4.3.6.2. The effect of Formetanate hydrochloride% 50 on density of *Thrips tabaci* in pepper flowers

4.3.6.2.1. The effect of Formetanate hydrochloride% 50 on density of *Thrips tabaci* in 2021

This treatment is one of the best methods to control thrips species and has quick results, it can be seen that very few numbers after using Formetanate hydrochloride, where the numbers of the insect were low then decreased. to 0.175 individual per flower in Gama and Esen varieties in 22 Sep, then it started to go down to (0.025 in Gama and 0 individual per flower in Esen) in 27 October (Figure 4.44). This result agreed with Manucci et al., (2014) who mentioned during 2012-2013, two variants of formetanate – one being formetanate 50% and the other formetanate hydrochloride 10.5% were trialed at various doses and benchmarked against chemical standards for their effectiveness against thrips.

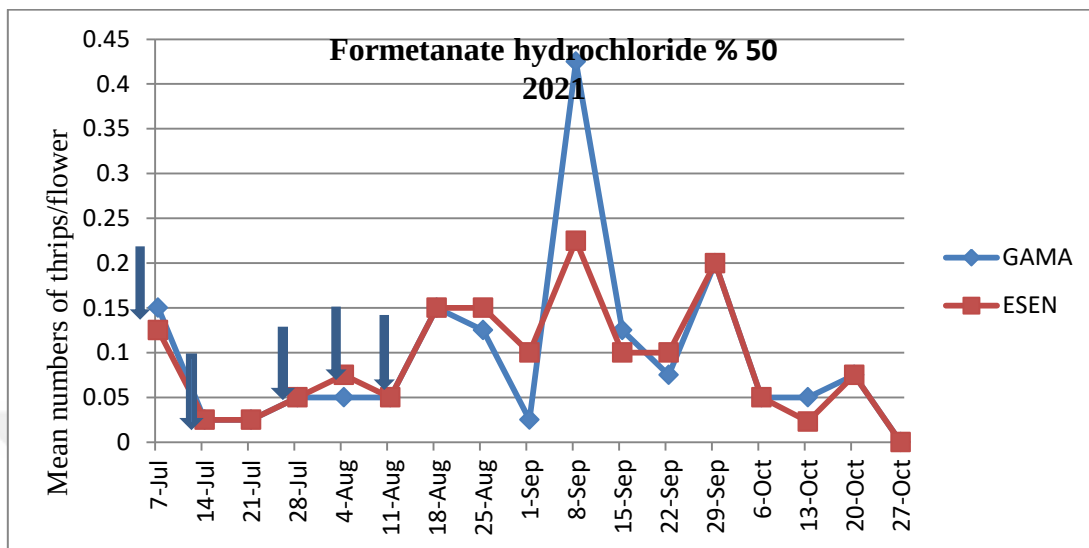


Figure 4.44. The effect of Formetanate hydrochloride on density of *Thrips tabaci* in pepper flowers in 2021

The arrow indicates the application of formetanate hydrochloride

The testing procedure involved three successive applications of the respective product at intervals of 7-10 days. Effectiveness was measured by tallying the overall count of thrips. Post this two-year period, formetanate demonstrated strong effectiveness against thrips, showing a notable correlation between dosage and results.

4.3.6.2.2. The effect of Formetanate hydrochloride% 50 on density of *Thrips tabaci* in 2022

The samples collected from 1st of July to the 7th of October, probably on a weekly basis, each date provides a corresponding numbers for both Gama and Esen varieties, the number of *T. tabaci* seem to be in a range from 0 to 0.25 individual per flower, in 1-Jul, Gama starts off with a mean *Thrips tabaci* numbers/ flower 0.1, while Esen is slightly lower at 0.075, the highest number for Gama varieties was 0.2 on both 22-Jul and 12-Aug. Esen peaks at 0.25 in 15-Jul, both Gama and Esen have the lowest value of 0 in 29-Jul and 7-Oct, there are instances where Gama and Esen show different behaviors, for example, in 15-Jul,

while Gama is at 0.175, Esen spikes to 0.25. On 30-Sep, Gama registers a value of 0.075, while Esen drops to 0 (Figure 4.45).

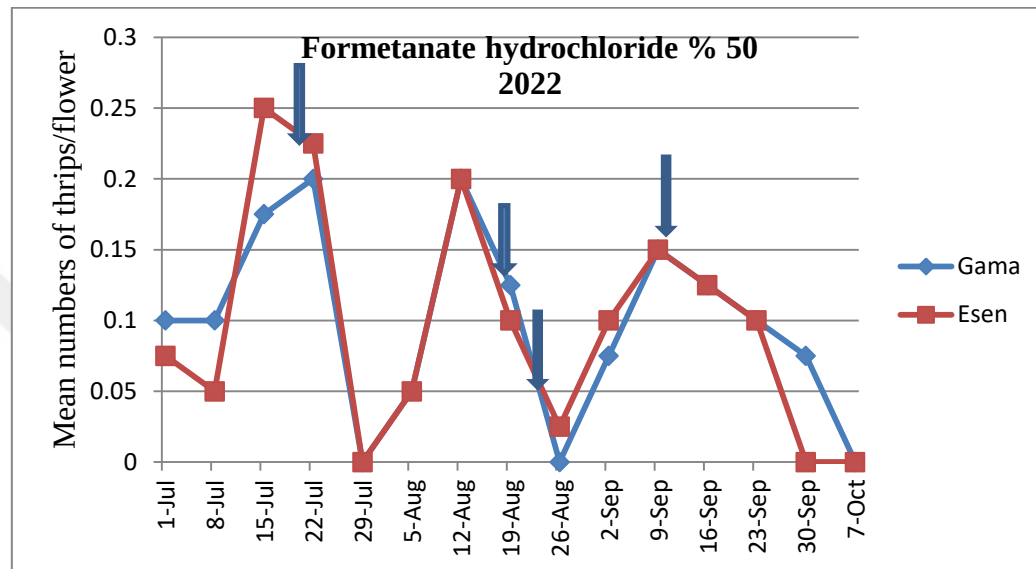


Figure 4.45. The effect of Formetanate hydrochloride on density of *Thrips tabaci* in pepper flowers in 2022

4.3.7. The effect of blue sticky traps with pheromones

4.3.7.1. The effect of blue sticky traps with pheromones on density of *Frankliniella occidentalis* in pepper flowers

4.3.7.1.1. The effect of blue sticky traps with pheromones on density of *Frankliniella occidentalis* in 2021

In the last treatment was used blue sticky trap with pheromones, where it gave quick and good results in attracting the *Frankliniella occidentalis*, where the blue sticky trap with pheromones was used the trap for the first time in 8 July, after that used again in 25 July, 17 August and 8 September. The highest population density was reached at 0.35 in Gama varieties and 0.375 individual per flower in Esen varieties in 7 July, after the blue sticky traps with pheromones was applied, the mean of *F. occidentalis* number/ flower did not

increase and remained in low populations, as the readings were as follows: (0.1, 0.1, 0, 0, 0.025) in Gama treatment and (0.15, 0.05, 0.025, 0,0) in Esen in 8-September, 15-September, 29-September, 20-October and in 27-October (Figure 4.46). This result agreed with the findings of Pobozniak (2020) who mentioned to study discussed the control of thrips using traps, noting positive outcomes, it assessed the efficiency of three trap colors (blue, yellow, and white) to determine the best color for monitoring thrips species such as *F. intonsa*, *T. tabaci*, *T. fuscipennis*, and *Aeolothrips intermedius*, the trap color significantly influenced the number of thrips caught, most *F. intonsa*, *T. fuscipennis*, and *T. tabaci* individuals were attracted by the blue and yellow traps, while *A. intermedius* showed a preference for yellow traps, blue traps were overall the most effective for thrips monitoring.

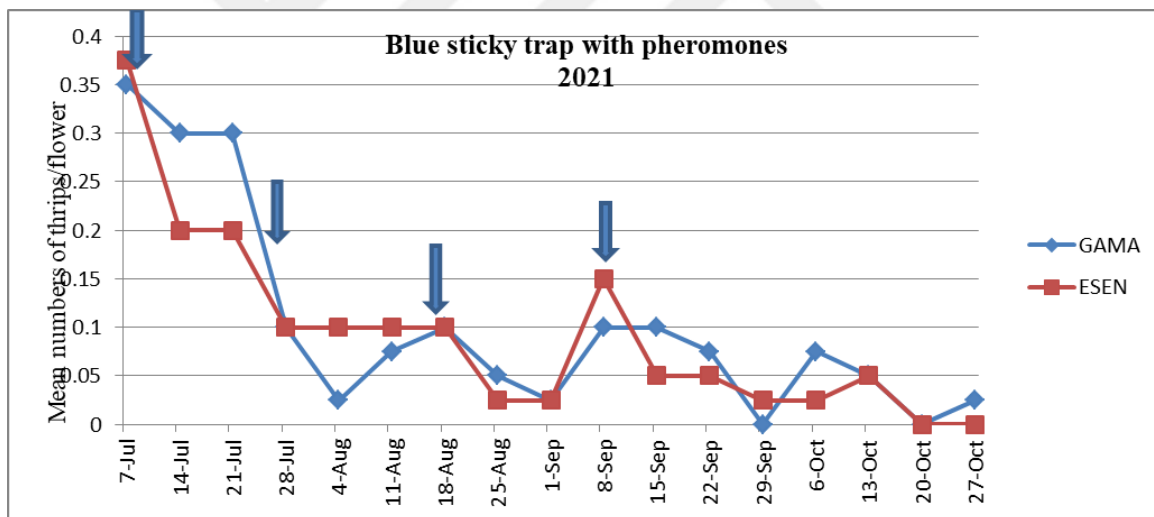


Figure 4.46. The mean numbers of *Frankliniella occidentalis* on blue sticky traps with pheromones in peppers 2021

4.3.7.1.2. The effect of blue sticky traps with pheromones on density of *Frankliniella occidentalis* in 2022

The populations of *Frankliniella occidentalis* between 0 and 0.3, in 1-Jul, Gama starts with a number of 0.075 individual per flower, while the number of *F. occidentalis* in Esen variety was 0.1, the highest mean thrips number/ flower in Gama was 0.3 in 15-Jul, this

trap applied in 22th July, 19, 25 August and 9th September, with both treatments (Gama and Esen) reaching 0 in 7-Oct (Figure 4.47), where this trap had good results in controlling thrips.

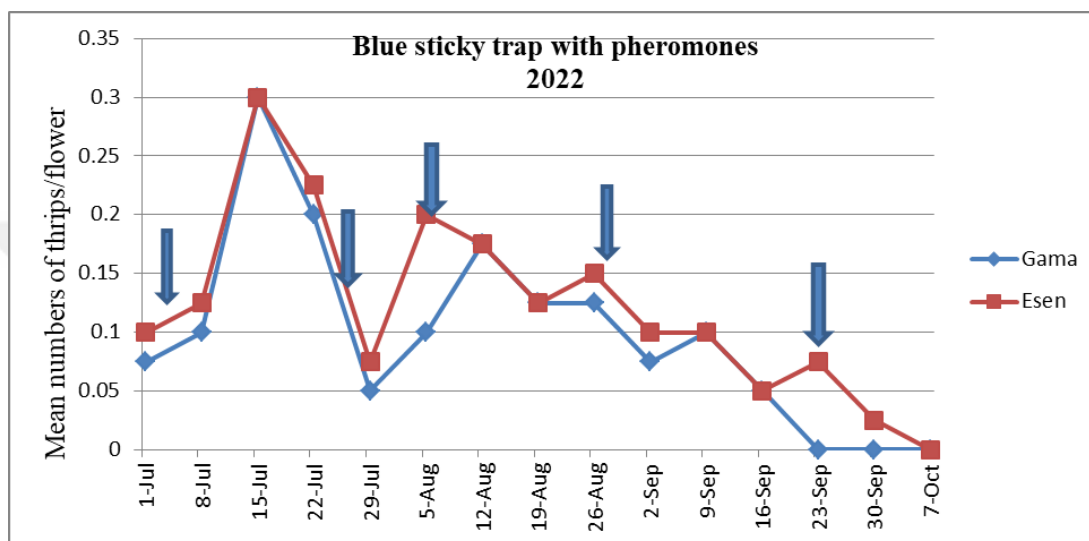


Figure 4.47. The mean numbers of *Frankliniella occidentalis* on blue sticky traps with pheromones in peppers 2022

4.3.7.2. The effect of blue sticky traps with pheromones on density of *Thrips tabaci* in pepper flowers

4.3.7.2.1. The effect of blue sticky traps with pheromones on density of *Thrips tabaci* in 2021

In the last treatment was used blue sticky trap with pheromones, where it gave quick and good results in attracting the *Thrips tabaci*, where the blue sticky trap with pheromones was used for the first time in the treatment in 8 July, after that used again in 25 July, 17 Augusts and 8 September. When readings were taken before applying the blue sticky trap with pheromones, they were the numbers of the *T. tabaci* 0.2 in Gama and 0.175 in Esen, after application, the number of *T. tabaci* decreased to 0 in both replications (Gama and Esen)

for three consecutive weeks 14-Jul, 21 Jul and 28 Jul. Even in the months of September and October, the number of *Thrips tabaci* did not exceed 0.05 in both varieties (Figure 4.48).

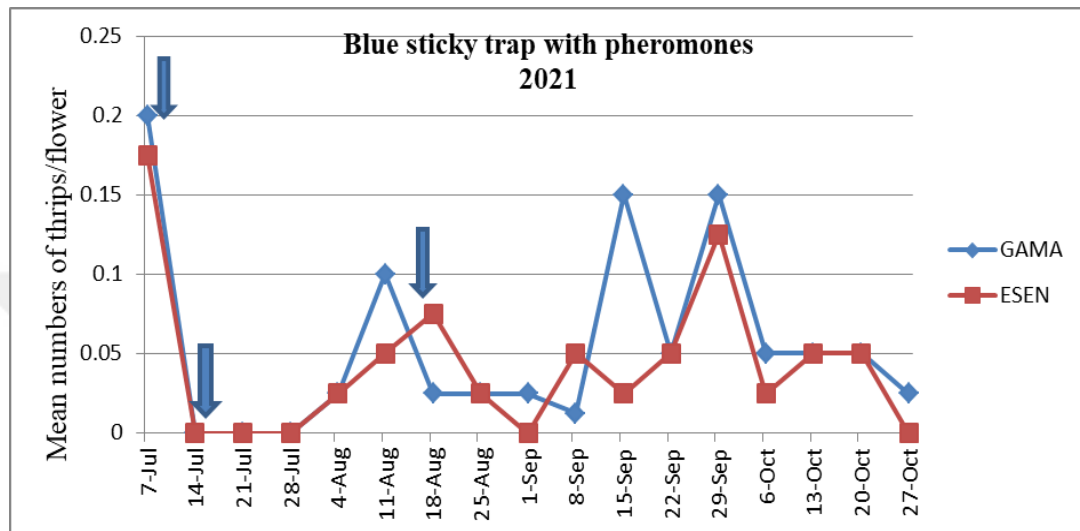


Figure 4.48. The mean numbers of *Thrips tabaci* on blue sticky traps with pheromones in peppers 2021

4.3.7.2.2. The effect of blue sticky traps with pheromones on density of *Thrips tabaci* in 2022

The range of populations *T. tabaci* for Gama and Esen between 0 and 0.125 in this treatment, in 1-Jul the number of *T. tabaci* 0.025 in Gama, while Esen begins at a slightly higher value of 0.1 individual per flower. In 15-Jul, in Gama was 0.1, which slightly less than Esen's value of 0.125. It was notable that from 2-Sep onwards (Figure 4.50), both Gama and Esen register very low or zero values, this trap applied in 22th July, 19, 25 August and 9th September.

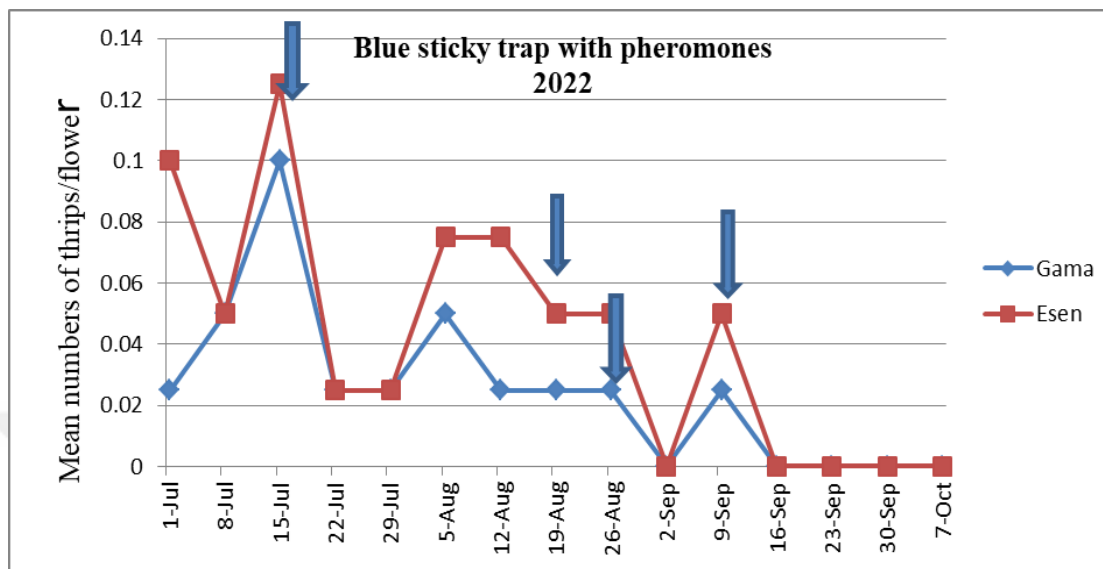


Figure 4.49. The mean numbers of *Thrips tabaci* on (blue sticky traps with pheromones) in peppers 2022

4.4. Calculated the number of Thrips inside sticky traps with pheromone

4.4.1. Calculated the number of Thrips inside sticky traps with pheromone in 2021

After placing the sticky traps with Pheromone between varieties in the pepper field, the number of thrips caught on it was counted weekly, additionally, the trap was replaced on this dates (8, 25July, 17 August and 9 September).

Calculated the number of Thrips inside each sticky pheromone traps per week for each varieties in (2021), and the result was as follows (Table 4.20).

Table 4.21. Numbers of thrips caught on blue sticky traps + (Pheromone) settled in pepper plots of two varieties in 2021

Date	Esen Variety	Gama Variety
10-July	21	36
16-July	32	36
18-July	47	50
25-July	26	25
3-August	40	38
10-August	40	35
17-August	31	30
24-August	28	26
2-September	13	12
9-September	10	17
16-September	14	13
23-September	13	9
29-September	16	4
5-October	2	11

In figure (4.50), the numbers of thrips are depicted on the blue traps, readings were taken weekly after the trap was initially installed, subsequent readings were taken from the date of 10 July to October in 2021.

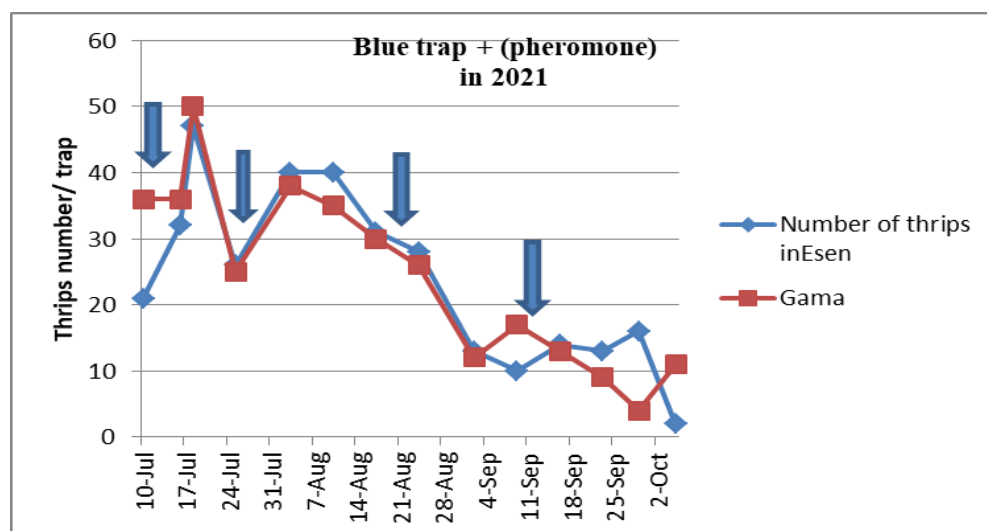


Figure 4.50. The mean numbers of thrips on (blue sticky traps with pheromones) in peppers 2021

4.4.2. Calculated the number of Thrips inside sticky traps +pheromone in 2022

The number of thrips calculated inside each sticky pheromone traps per week for each varieties in (2022), and the result was as follows (Table 4.21), the traps were replaced on 6, 25 July, 6,30 August and 15 September.

Table 4.22. Numbers of thrips caught on blue sticky traps + (Pheromone) in settled in pepper plots of two varieties in 2022

Date	Esen variety	Gama variety
8-July	65	55
16-July	50	52
23-July	42	40
30-July	52	50
6- August	48	50
13- August	38	44
20- August	34	30
27- August	42	40
3-September	68	74
10September	33	29
17September	30	38
24September	40	44
29September	23	19
5-October	10	14
10- Octer	8	10

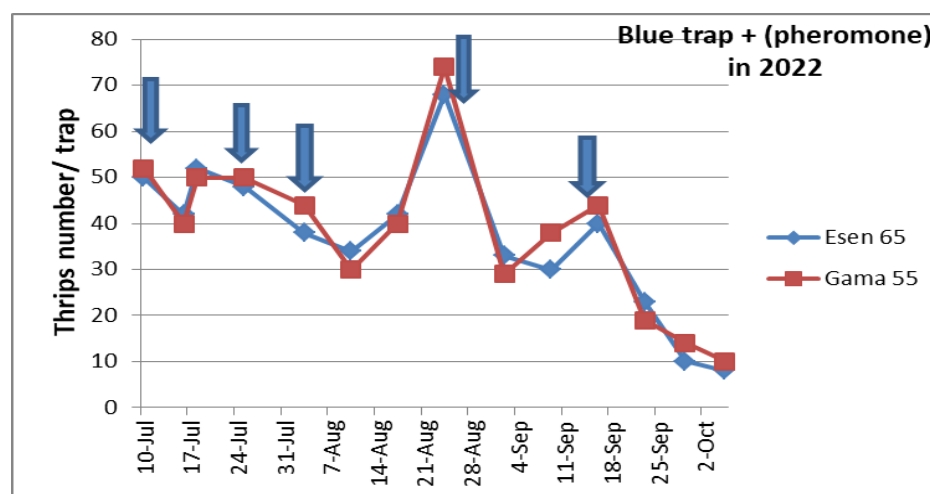


Figure 4.51. The mean numbers of thrips on (blue sticky traps with pheromones) in peppers 2022

In figure (4.51), the blue trap displays the count of thrips. After its first installation, readings were recorded on a weekly basis, with subsequent measurements taken from 10 July to 2 October in 2022.

4.5. Interaction between treatments and thrips density

Table 4.23. Interaction between treatments, pepper variety and thrips density

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	58.369 ^a	45	1.297	25.870	.000
Intercept	87.380	1	87.380	1742.755	.000
Species	1.425	1	1.425	28.415	.000
Pepper variety	1.177	1	1.177	23.483	.000
Treatment	11.127	6	1.855	36.987	.000
Year	20.138	1	20.138	401.653	.000
Month	2.999	3	1.000	19.938	.000
Replication	.047	3	.016	.314	.816
Species * Pepper variety	1.113	1	1.113	22.189	.000
Species * Treatment	8.170	6	1.362	27.159	.000
Species * Year	.455	1	.455	9.083	.003
Species * Month	.136	3	.045	.905	.438
Species * Replication	.029	3	.010	.195	.900
Pepper variety * Treatment	1.246	6	.208	4.140	.000
Pepper variety * Year	.196	1	.196	3.919	.048
Pepper variety * Month	1.286	3	.429	8.553	.000
Species * Pepper variety * Treatment	10.461	6	1.743	34.773	.000
Error	177.391	3538	.050		
Total	342.600	3584			
Corrected Total	235.760	3583			

a. R Squared = ,248 (Adjusted R Squared = ,238)

Table (4.23) showed that Species * Treatment with an ($F = 27.159$ and $df = 6$, $p \leq 0.001$), while Species * Pepper variety with ($F = 22.189$ and $df = 1$, $p \leq 0.00$). However, Species * Pepper variety * Treatment with an ($F = 34.773$ and $df = 6$, $p \leq 0.001$). Suggests a significant interaction effect between Species and Treatment, Species * Pepper variety and Species * Pepper variety * Treatment.

Table 4.24. Effect of treatment on *Frankliniella occidentalis* density in varieties of pepper (Gama and Esen) in 2021

Pepper	Control	<i>O. laevigatus</i>	<i>A.swirskii</i>	Azadirachtin 790 g/l Neem oil + 0.3 G/l	Spinosad 240 g/l	%50formetanate hydrochloride	Blue sticky trap +pheromones	df
Gama	0.608 a	0.158 b	0.207 b	0.130 b	0.213 b	0.155 b	0.088 b	6
Esen	0.633 a	0.165 b	0.232 b	0.130 b	0.207 b	0.140 b	0.075 b	6
Mean	0.620	0.161	0.220	0.130	0.210	0.148	0.081	

** : Indicates that the differences between treatments are significant at 0.01 level.

LSD 0.05 for (a) = 0.39 LSD 0.05 for (b) = 0.003

Table (4.24) explains the significant influence of a treatments on *F. occidentalis*, the highest population of thrips appeared in the first treatment (control), where nothing was used, in rate 0.608: 0.633, while the percentage was low in treatments were used *O.laevigatus*, Azadirachtin 790 g/l Neem oil + 0.3 G/l and Blue sticky trap +pheromones. The interaction between treatments and thrips influenced significantly at $p \leq 0.05$ on value. This result agreed with the findings of Blumthal et al., (2005) who mentioned the control of thrips through different techniques like: used biological control and chemical treatments results in a reduction of both their numbers and rates of infection, subsequently lessening the damage they cause.

Table 4.25. Effect of treatment on *Frankliniella occidentalis* density in varieties of pepper (Gama and Esen) in 2022

Pepper	Control	<i>O. laevigatus</i>	<i>A.swirskii</i>	Azadirachtin 790 g/l Neem oil + 0.3 G/l	Spinosad 240 g/l	%50formetanate hydrochloride	Blue sticky trap +pheromones	Df
Gama	0.655 a	0.063 b	0.160 b	0.098 b	0.350 b	0.198 b	0.083 b	6
Esen	0.517 a	0.065 b	0.150 b	0.105 b	0.360 ab	0.188 ab	0.090 ab	6
Mean	0.586	0.064	0.155	0.101	0.355	0.193	0.085	

s.n: Indicates that the differences between treatments are insignificant.

* : Indicates that the differences between treatments are significant at 0.05 level.

LSD 0.05 for (a) = 0.210 LSD 0.05 for (b) = 0.020 LSD 0.05 for (ab) = 0.26

In table (4.25) showed the lowest population of *F. occidentalis* was found in the second treatment explains, used *O.laevigatus*, where the numbers were limited between 0.063-0.065. These results agreed with Van and Loomans (1995) who mentioned that the insect

predator, *Orius laevigatus*, demonstrated a high level of effectiveness in managing thrips. with *Frankliniella occidentalis* as their prey, these bugs can completely controlling thrips species, whether in the open field or in greenhouses. Also, in the last treatment, where used blue sticky trap with pheromones, the number of thrips was very low, as the sticky traps effectively reduced their population. This result agreed with the findings of Pobożniak (2020) who mentioned that the control of thrips by using traps, noting positive outcomes, it assessed the efficiency of three trap colors (blue, yellow, and white), and blue traps were overall the most effective for thrips monitoring.

Table 4.26. Effect of treatment on *Thrips tabaci* density in varieties of pepper (Gama and Esen) in 2021

Pepper	Control	<i>O. laevigatus</i>	<i>A. swirskii</i>	Azadirachtin 790 g/l Neem oil + 0.3 G/l	Spinosad 240 g/l	%50 formetanatehy drochloride	Blue sticky trap +pheromones	Df
Gama	0.278 a	0.070 b	0.138 b	0.052 b	0.115 b	0.095 b	0.055 b	6
Esen	0.330 a	0.063 b	0.120 b	0.050 b	0.112 b	0.080 b	0.032 b	6
Mean	0.304	0.066	0.129	0.051	0.113	0.087	0.044	

* : Indicates that the differences between treatments are significant at 0.05 level.

*** : Indicates that the differences between treatments are significant at 0.001 level.

LSD 0.05 for (a) = 0.076 LSD 0.05 for (b) = 0.007

Table (4.26) explains the significant influence of a treatments and *T. tabaci*. The highest and lowest density were (0.304 and 0.044), where the density was higher in the control treatment that did not use anything and the lowest population of *T. tabaci*, in the last treatment that used blue traps.

Table 4.27. Effect of treatment on *Thrips tabaci* density in varieties of pepper (Gama and Esen) in 2022

Pepper	Control	<i>O. laevigatus</i>	<i>A. swirskii</i>	Azadirachtin 790 g/l Neem oil + 0.3 G/l	Spinosad 240 g/l	%50 formetanate hydrochloride	Blue sticky trap +pheromones	df
Gama	0.165 a	0.018 b	0.060 b	0.030 b	0.107 ab	0.073 ab	0.019 b	6
Esen	0.163 a	0.019 b	0.060 ab	0.033 b	0.110 ab	0.074 ab	0.032 b	6
Mean	0.164	0.018	0.060	0.031	0.109	0.074	0.026	

s.n : Indicates that the differences between treatments are insignificant.

* : Indicates that the differences between treatments are significant at 0.05 level.

LSD 0.05 for (a) = 0.165 LSD 0.05 for (b) = 0.033 LSD 0.05 for (ab) = 0.060

Table (4.27) shows the significant influence of treatments in 2022, the highest population of thrips 0.164 was in control and lowest thrips populations 0.018 in *O.laevigatus* treatment, Where the results showed that the numbers of thrips were very few in the treatment of *O.laevigatus*, where the ratio 0.018: 0.019, the ratio was was also low in blue sticky trap + pheromones, around 0.019: 0.032. The interaction between pepper and treatments influenced significantly at $p \leq 0.05$.

4.6. The effect of different treatments on the total yield

4.6.1. The effect of different treatments on the total yield of the Gama pepper cultivar

Once the pepper plants started to mature, collected them on a weekly basis, randomly selected samples from each replication, and from each of these, picked 10 plants, afterward, weighed the harvested pepper fruits from these plants.

Table 4.28. The effect of different treatments on the total yield of the Gama pepper cultivar in 2021- 2022

Treatment	Fruit weight per plant (g)	GAMA 2021 Total yield (kg)	Fruit weight per plant (g)	GAMA 2022 Total yield (kg)
Control	350,5 c	42,060 c	664,3 d	79,719 d
<i>O.laevigatus</i>	1498,7 a	179,847 a	1382,7 a	165,924 a
<i>A.swirskii</i>	906,4 b	108,771 b	966,9 b	116,028 b
Azadirachtin	1373,7 a	164,808 a	998,5 b	119,823 b
Spinosad 240	959,3 b	115,119 b	664,1 d	79,701 d
%50formetanate	839,3 b	100,716 b	789,8 c	94,785 c
Blue stickytrap	1391,7 a	167,004 a	1007,9 b	120,954 b
Averages	1045,6	125,475	924,9	110,990
	***	***	***	***

*** : Different letters within a column shows that the difference between applications are significant at the 0.01% level ($P \leq 0.001$).

In table (4.28) shows the average weight of harvested pepper fruits (Gama) per plant for each treatments, in control treatment shows the lowest amount of other treatments, as its production of pepper was low, the production pepper between 42,060 kg, because in the control treatment, where no applications are used to control thrips, it appeared in high populations, this can lead to significant damage, the feeding habits of thrips can distort plant growth, deform flowers, and reduce photosynthetic capacity, thereby lowering yields, additionally, when thrips feed on pepper fruit, they cause bronzing and silvering of the skin, which reduces its market quality. This result agreed with the findings of Tommasini and Maini (1995) who mentioned that the feeding patterns of thrips can lead to the deformation of plant structures, the malformation of flowers, and a reduction in the capacity for photosynthesis, ultimately resulting in decreased yields. While in the second treatment was the largest yield of pepper, because in this treatment, the numbers of thrips were low after using *Orius laevigatus*, in this treatment production of pepper 179,847 in 2021 and 165,924 in 2022, in the fourth treatment, where an insecticide (Azadirachtin 790 g/l Neem oil + 0.3 G/l) was used, it effectively controlled thrips, as their numbers were reduced, leading to positive

results in the production of the pepper crops, where production was limited 164,808-119,823 (kg), also in the last treatment, we used blue sticky trap with pheromones, which proved effective in controlling thrips and significantly impacted the increased production of the pepper crop, where pepper production was between 167,004 in 2021 kg and 120,954 kg in 2022. Where the results appeared, treatment involving either natural enemies, pesticides and sticky trap led to a decrease in the number of thrips, and therefore resulting in an increase the production of pepper. This result agreed with the findings of Blumthal et al., (2005) who mentioned that the control of thrips by various methods and chemical pesticides leads to a decrease in its populations, and decrease in infection rates, then reduction in its damage.

4.6.2. The effect of different treatments on the total yield of the Esen pepper cultivar

Table 4.29. The effect of different treatments on the total yield of the Esen pepper cultivar in 2021- 2022

Treatment	Fruit weight per plant (g)	Esen 2021 Total yield (kg)	Fruit weight per plant (g)	Esen 2022 Total yield (kg)
Control	416,8 d	50,025 d	488,3 e	58,599 e
<i>O.laevigatus</i>	1422,6 a	170,718 a	1256,7 a	150,810 a
<i>A.swirskii</i>	740,8 c	88,902 c	1078,6 b	129,438 b
Azadirachtin	1160,4 b	139,251 b	1056,8 b	126,822 b
Spinosad 240 g/l	762,2 c	91,467 c	709,0 d	85,083 d
%50formetanate	695,2 c	83,427 c	836,4 c	100,368 c
Blue sticky trap	1064,1 b	127,698 b	1062,1 b	127,461 b
Averages	894,6	107,355	926,842	111,225
	***	***	***	***

*** : Differents letter within a column shows that the difference between applications are significant at the 0.01% level ($P \leq 0.001$).

In table (4.29) shows the average weight of harvested pepper fruits (Esen) per plant for each traetments, in control treatment shows the lowest amount of other treatments, the

production of pepper was low, around 50,025 in 2021 and 58,599 in 2022 , while the percentage of pepper production was very high in the second treatment, where applied biological control *Orius laevigatus*, where was the percentage of pepper production 170,718 kg in 2021 and 150,810 kg in 2022, also, in the last treatment, the production of pepper was good, as the sticky traps had an effective role in reducing the numbers of thrips, and therefore the results were positive for the production of the pepper crop.



5. CONCLUSIONS AND RECOMMENDATIONS

In this study, was the determination of the Thysanoptera order in Tokat Province/ Türkiye, among the seven species identified across different families in this study, two thrips species *F. occidentalis* and *T. tabaci* were determined as main thrips inhabiting the green pepper fields surveyed.

There was another section which of this study applied various methods to control thrips species in the open field, like biological control, insecticides and blue trap with pheromone, where beneficial predators like *Orius laevigatus* and *Amblyseius swirskii* were used, the results surpassed those of certain pesticides, studies showed that these predators can persist in the field for extended periods and are also capable of reproduction. *Orius laevigatus* bugs had a great effect in controlling thrips insects of both species (*F.occidentalis* and *T. tabaci*), for example, the mean density in varieties pepper (Gama and Esen) of *F.occidentalis* were 0.161 in 2021 and 0.064 in 2022 (Tables 4.24- 4.25), the mean density of *T. tabaci* 0.066 in 2021 and 0.018 in 2022 (Tables 4.26- 4.27). Chemical pesticides were also used in the study. In Azadirachtin treatment the mean numbers of *F.occidentalis*/ flower was 0.130 in 2021 and 0.101 in 2022 (Tables 4.24- 4.25), and Formetanate hydrochloride were effective in controlling thrips, the mean numbers of *F.occidentalis*/ flower was 0.148 in 2021 and 0.193 in 2022, also used blue sticky traps with pheromone, which were one of the best ways to attract thrips species, and the results were quick, effective, and easy in use, the mean density in varieties pepper (Gama and Esen) of *F.occidentalis* were 0.081 in 2021 and 0.085 in 2022 (Tables 4.24- 4.25), and the mean number of *T. tabaci* was 0.044 in 2021 and 0.026 in 2022 (Tables 4.26- 4.27). Thrips density remained below the economic damage threshold (3 thrips/flower) in all treatments. For the first time in the region, various types of pest control methods were studied for their effectiveness against thrips in an open field. One recommended approach is to control thrips species immediately upon their emergence and before their numbers increases. Implement resistance measures, including the use of natural predators like the *Orius laevigatus* and blue trap + pheromone, which offer rapid and effective results; this is considered one of the best and easiest ways for reducing thrips damage. Additionally, there

are several pesticides available, but it must be chosen carefully to minimize the negative effects of the pesticide to the environment and other organisms.



6. REFERENCES

- Abad, J. A., Speck, J., Mohan, S. K., and Moyer, J. W. 2003. Diversity of the Iris yellow spotvirus gene in the USA. *Phytopathology* 93: No. 6
- Abenaim, L., Bedini, S., Greco, A., Giannotti, P., and Conti, B. 2022. Predation Capacity of the Banded Thrips *Aeolothrips intermedius* for the Biological Control of the Onion Thrips *Thrips tabaci*. Department of Agriculture, Food and Environment, University of Pisa, Via del Borghetto 80, 56126 Pisa, Italy. 13(8), 702
- Alford, D. V. 2007. Pests of Fruit Crops: A Color Handbook-A Color Handbook. Academic Press, 461 pp.
- Allen, W. R., and Broadbent, A., B. 1986. Transmission of tomato spotted wilt virus in Ontario greenhouses by the western flower thrips *Frankliniella occidentalis* (Pergande). *Canadian Journal of Plant Pathology* 8: 33-38.
- Allen, W. R., and Matteoni, J. A. 1991. Petunia as an indicator plant for use by growers to monitor for thrips carrying the tomato spotted wilt virus in greenhouses. *Plant Disease* 75: 78-82.
- Andrews, H. E. 2011. Monitoring and management of thrips populations in vegetables, row crops, and greenhouse crops in Virginia. Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of Master of Science in Life Sciences in Entomology.
- Anonim, 2023a. Zararlı Organizma Detay. Tütün tripsi (*Thrips tabaci*) Tarım ve Orman Bakanlığı. Gıda ve Kontrol Genel Müdürlüğü. <https://www.tarimorman.gov.tr/GKGM/Sayfalar/Detay.aspx?SayfaId=8>. Erişim tarihi: 22.11.2023. Ürünleri Daire Başkanlığı. Ankara.
- Anonim, 2023b. Plants and Organism used. <https://agrobtestgrup.com/bitki-koruma-urunleri/nimbecidine>. Erişim tarihi: 1.9.2023. Ürünleri Daire Başkanlığı. Ankara.
- Anonim, 2023c. Plants and Organism used. <https://agrobtestgrup.com/bitki-koruma-urunleri/nimbecidine>. Erişim tarihi: 1.6.2023. Ürünleri Daire Başkanlığı. Ankara.
- Anonim, 2023d. Zararlı Organizma Detay. Tarım ve Orman Bakanlığı. Gıda ve Kontrol Genel Müdürlüğü. <https://bku.tarimorman.gov.tr/Kullanım/TavsiyeArama>. Erişim tarihi: 20.10.2023. Ürünleri Daire Başkanlığı. Ankara.
- Anonim, 2023e. Meteoroloji Genel Müdürlüğü. Tokat. <https://mgm.gov.tr/veridegerlendirme/ive-ilceler-istatistik.aspx?k=undefined&m=TOKAT>. Erişim tarihi: 2.7.2023.
- Anonim, 2023f. Flora biological kontrol system, <https://floraipm.com/en/>. Antalya Esnafı Kucuk Sanayi Sitesi, Gaziler Mah. 252 Sk. No: 1/11, 07112, Antalya - Turkey. Erişim tarihi: 24.11.2023.
- Anonymous, 2002. Interstate Movement of Gardenia from Hawaii, Federal Register, Volume 67, Number 94, Wednesday, May 15: pp. 34626–34630.
- Arnauty, S. A., El-Heneidy, A. H., Heikal and Kortam, M. N. 2020. Comparative study between biological and chemical control programs of certain sweet pepper pests in greenhouses. *Egyptian Journal of Biological Pest Control*. 30: 28-34.

- Arthurs, S. McKenzie, C. L., Chen, J., Doğramaci, M., Brennan, M., Houben, K., and Osborne, L. 2009. Evaluation of *Neoseiulus cucumeris* and *Amblyseius swirskii* (Acari: Phytoseiidae) as biological control agents of chilli thrips, *Scirtothrips dorsalis* (Thysanoptera: Thripidae) on pepper. *Biological Control* 49: 91-96.
- Atakan, E. 2008. Thrips (Thysanoptera) species and thrips damage associated with strawberry in Adana and Mersin provinces, Turkey. *Türk. entomol. derg.* 32 (2): 91-101. ISSN 1010- 6960.
- Atakan, E., Ölçülü, M., Pehlivan, S., and Özgür, O. 2016. An analysis of western flower Thrips *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) in lemons: Its abundance, distribution
- Atakan, E., and Tunç, İ. 2004. Adana ilinde yonca tarlasında Thysanoptera faunası ve bazı önemli türlerin ve predatör böceklerin populasyon değişimleri. *Türkiye Entomoloji Dergisi*, 28: 181-192.
- Atakan, E., Ölçülü, M., Pehlivan, S., and Satar, S. 2021. A new thrips species recorded in Turkey: *Thrips hawaiiensis* (Morgan, 1913) (Thysanoptera: Thripidae) 5(2): 77-84.
- Atakan, E., and Uygur, S. 2004. Seasonal abundance of the some thrips species and their predators on weeds. *Turkey Journal of Entomology*, 28(2): 123-132.
- Atakan, E., and Uygur, S. 2005. Winter and Spring Abundance of *Frankliniella* spp. and Thrips tabaci Lindeman (Thysan., Thripidae) on Weed Host Plants in Turkey. *Journal of Applied Entomology*, 129(1): 17-26.
- Atanasova, B., Spasov, D., Spasova D., and Ilievski, M. 2022. Use of *Orius laevigatus* to control *Frankliniella occidentalis* (Thysanoptera: Thripidae) population in greenhouse pepper. Faculty of Agriculture, Goce Delcev University – Stip, Krste Misirkov 10-A, 2000 Stip, Republic of North Macedonia. *Journal of Agriculture and plant sciences, Japs*. Vol 20. ISSN 2545-4447.
- Alford, D. V. 2007. *Pests of Fruit Crops: A Color Handbook-A Color Handbook*. Academic Press, 461 pp.
- Aydin, G., Şlachta, M., and Karaca, I. 2020. Detection and monitoring of Thrips meridionalis (Priesner, 1926) (Thysanoptera: Thripidae) with the colored sticky traps. *Türk. entomol. Derg.* 44 (3): 285-294 ISSN 1010-6960 E-ISSN 2536-491X.
- Balaško, M. K., Karla, N., Borna, N., Bažok, R., Drmić, Z., and Čačija, M. 2021. Azadirachtin efficacy in colorado potato beetle and western flower thrips control. University of Zagreb, Faculty of Agriculture, Department of Agricultural Zoology, Svetošimunska cesta 25, Zagreb, Croatia. DII 2067-5720 RAR 2021-36.
- Bandla, M. D., Campbell, L. R., Ullman, D. E., and Sherwood, J. L. 1998. Interaction of Tomato spotted wilt tospovirus (TSWV) glycoproteins with a thrips midgut protein, a potential cellular receptor for TSWV. *Phytopathology* 88: 98-104.
- Bautista, R. C., and Mau, R., F., L. 1994. Preferences and Development of Western Flower Thrips (Thysanoptera: Thripidae) on plant hosts of tomato spotted wilt tospovirus in Hawaii. *Environmental Entomology* 23: 1501- 1507.
- Bethke, J. A., and Bates, L. 2013. *Pest Notes: Myoporum Thrips*. Oakland: Univ. Calif. Agric. Nat. Res. Publ. 74165.
- Bhatti, J.S. 1990. On some genera related to *Chirothrips* (Insecta: Terebrantia: Thripidae). *Journal of Pure and Applied Zoology*. 2: 194–200.

- Blumthal, M. R., Cloyd, R. A., Spomer, L. A. and Warnock, D. F. 2005. Flower color preferences of Western Flower Thrips. *Horttechnology* 15: 846-853.
- Broadbent, A. B., and Allen, A. R. 1995. Interactions within the western flower thrips/ tomato spotted wilt virus/ host plant complex on virus epidemiology, pp. 185-196. In B. L. Parker, M. Skinner and T. Lewis [eds.], *Thrips Biology and Management*. Plenum Press, New York, NY.
- Brodbeck, B. V., Stavisky, J., Funderburk, J. E., Andersen, P. C., and Olson, S. M. 2001. Flower nitrogen status and populations of *Frankliniella occidentalis* feeding on *Lycopersicon esculentum*. *Entomologia Experimentalis et Applicata* 99: 165-172.
- Brodsgaard, H. F. 1994. Effect of photoperiod on the bionomics of *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae). *Journal of Applied Entomology* 117: 498-507.
- Brodsgaard, H. F. 1989. *Frankliniella occidentalis* (Thysanoptera: Thripidae)—a new pest in Danish glasshouses. *Tidsskrift foer Planteavl* 93, 83–91.
- Buitenhuis, M., Shipp, R. G., and Scott-Dupree, L. C. 2015. *Amblyseius swirskii* in greenhouse production systems: a floricultural perspective. *Exp Appl Acarol* (this issue).
- Buitenhuis, R., Shipp, J. L., Scott-Dupree, C. 2008. Intra-guild extra-guild prey: effect on predator fitness and preference of *Amblyseius swirskii* (Athias- Henriot) and *Neoseiulus cucumeris* (Oudemans) (Acari: Phytoseiidae). *Bulletin of Entomological Research* 100: 167-173.
- Bunn, B. 2014. Utah vegetable production and pest management guide 2014. Utah State University Extension, Utah.
- Cast, 2003. Integrated pest management: current and future strategies. Council for Agricultural Science and Technology.
- Chambers, R. J., Long, S., and Helyer, N. L. 1993. Effectiveness of *Orius laevigatus* (Hem.: Anthracoridae) for the control of *Frankliniella occidentalis* on cucumber and pepper in the U.K. *Biocontrol Science and Technology* 3: 295–307.
- Chatzivassiliou, E. K., Nagata, T., Katis, N. I. and Peters, D. 1996. The transmission of tomato spotted wilt tospovirus (TSWV) by *Thrips tabaci* Lind. (Thysanoptera: Thripidae) populations originating from leek. *Plant Pathology* 48: 700-706.
- Chellemi, D. O., Funderburk, J. E., and Hall, D. W. 1994. Seasonal Abundance of flower in habiting *Frankliniella* species (Thysanoptera: Thripidae) on wild plant species. North florida. Research and Education center. University of florida. IFAS, Box 4370.
- Chiasson, H. 1986. A synopsis of the Thysanoptera (thrips) of Canada. *Lyman Entomological Museum and Research Laboratory Memoir*: 1–153.
- Cho, K. C., Eckel, S., James, F., George, W. and Kennedy, G. 1995. Comparison Of Colored Sticky Traps for Monitoring Thrips Populations (Thysanoptera: Thripidae) in Staked Tomato Fields. *Journal of Entomological Science* .130 (2): 176–190.
- Cindy, L., Jianjun, M., b., Dogramaci, M., Brennan, M., Houben, K., and Osborne, L. 2009. Evaluation of *Neoseiulus cucumeris* and *Amblyseius swirskii* (Acari: Phytoseiidae) as biological control agents of chilli thrips, *Scirtothrips dorsalis* (Thysanoptera: Thripidae) on pepper. *Biological Control*. 49 91–96.

- Çinkula, B., Atakan, E., and Varlic, SV. 2021. Determination of thrips (Thysanoptera) fauna on stone and pome fruit trees in Balıkesir province, Türkiye. *Plant Protection Bulletin*, 61(4) : 38-45.
- Deligeorgidis, P., Ipsilandis, C., Fotiadou, C., Kaltsoudas, G., Giakalis, L., and Garsen, A. 2005. Fluctuation and distribution of *Frankliniella occidentalis* (Pergande) and *Thrips Tabaci* Lindeman (Thysanoptera: Thripidae) populations in greenhouse cucumber and Tomato. *Pak. J. Biol. Sci.* 8 (8): 1105-1111.
- Demirozer, O., Tyler-Julian, K., Funderburk, J., Leppla, N., Reitz, S. 2012. *Frankliniella Occidentalis* (Pergande) integrated pest management programs for fruiting vegetables in Florida. *Pest Management Science* 68: 1537–1545.
- Dublon, I. A. N., Hamilton, J. G. C., and Kirk, W. D. J. 2008. Quantification of the release rate of the aggregation pheromone of the western flower thrips, *Frankliniella occidentalis* (Pergande), using solid-phase microextraction (SPME). *Acta Phytopathologica et Entomologica Hungarica* 43, 249–256.
- El-Deen El-Wahab, A., Abdel-Kader, M. El., and Elnagar, S. 2011. First Record of *Frankliniella Occidentalis* and Impatiens Necrotic Spot Virus in Egypt. Department of Economic. Entomology and Pesticides, Faculty of Agriculture, Cairo University, Cairo 12613, Egypt EPPO (European and Mediterranean Plant Protection Organization). 2013. Commercially used biological control agents - Arachnida, Acarina.
- Ertürk, S., Şen, F., Alkan, M., and Ölcülu, M. 2018. Effect of different phosphine gas concentrations against *Frankliniella occidentalis* (Pergande, 1895) (Thysanoptera: Thripidae) on tomato and green pepper fruit, and determination of fruit quality after application under low-temperature storage conditions. *Türk. entomol. derg.*, 2018, 42 (2): 85-92.
- Espinosa, P. J, Bielza, P., Contreras, J., Lacasa, A. 2002. Insecticide resistance in field populations of *Frankliniella occidentalis* (Pergande) in Murcia (south-east Spain). *Pest Management Science*, 58 (9): 967-971.
- FAO STAT; 2020. Available: www.fao.org/faostat/en/#data/QC.
- FAO STAT; 2023. Available: www.fao.org/faostat/en/#data/QC.
- Fauziah, I. and Saharan, H. A. 1991. Research on thrips in Malaysia. Thrips in Southeast Asia. AVRDC Publication Bangkok, Thailand, 29–33.
- Ferguson, G. M., and Schmidt, J. S. 1996. Effect of selected cultivars on *Orius insidiosus*. *Bulletin IOBC/WPRS* 19(1): 39-42.
- Flint, M. L. 1998. *Pests of the Garden and Small Farm: A Grower's Guide to Using Less Pesticide*. Oakland: Univ. Calif. Agric. Nat. Res. Publ. 3332.
- Frank, S. 2014. How thrips evade insecticides. *Grower talks*, insecticide and fungicide guide (2014–2015), pp 4–11.
- Funderburk, J. E., Adkins, S., Freeman, J., Stansly, P., Smith, H., Demirozer, O., Snodgrass, C., Paret, M. and Leppla, N. 2015. Managing thrips and tospoviruses in tomato. Document ENY-859 (IN859). UF/IFAS EDIS, Electronic Data Information Source.

- Funderburk, J., Martini, X., Freeman, J., Strzyzewski, I., Traczyk, E., Skarlinsky, T., and Adkins, S. 2019. Sampling for Estimating *Frankliniella* Species Flower Thrips and *Orius* Species Predators in Field Experiments.
- Gaafar, N., El-Wakeil, N., and Volkmar, C. 2010. Susceptibility of spring wheat to infestation with wheat blossom midges and thrips. *Journal of Plant Diseases and Protection*, 117 (6), 261–267, ISSN 1861-3829. © Eugen Ulmer KG, Stuttgart J.Plant Dis.Protect. 6/2010.
- Gao, Y., Lei, L. Z., and Reitz, S. R. 2012. Western flower thrips resistance to insecticides: detection, mechanisms and management strategies. *Pest Management Science* 68, 1111–1121.
- Georghiou, G. P. and Taylor, C. E. 1977. Operational influences in evolution of Insecticide resistance. *Journal of Economic Entomology* 70: 653-658.
- German, T. L., Ullman, D. E., and Moyer, J. W. 1992. Tospoviruses: Diagnosis, molecular biology, phylogeny, and vector relationships. *Annual Review of Phytopathology* 30: 315-348.
- Goldbach, R., and Peters, D. 1994. Possible causes of the emergence of tospovirus diseases. *Seminars in Virology* 5: 113-120.
- Greene, J. K., Reay-Jones, F., and Conzemius, S. 2020. Best Management Practices for Thrips (Thysanoptera: Thripidae) in Cotton.
- Hamilton, J. G. C. and Kirk, W. D. J. 2013. A male-predominant cuticular hydrocarbon, 7-methyltricosane, is used as a contact pheromone in the western flower thrips *Frankliniella occidentalis*. *Journal of Chemical Ecology* 39, 559–568.
- Helyer, N. L. and Brobyn, P. J. 1992. Chemical control of western flower thrips (*Frankliniella occidentalis* [Pergande]). *Annals of Applied Biology* 121: 219-231.
- Helyer, N. L., Brobyn, P. J., Richardson, P. N., and Edmondson, R. N. 1995. Control of Western flower thrips (*Frankliniella occidentalis* [Pergande]) pupae in compost. *Annals of Applied Biology* 127: 405-412.
- Hérard, F. 1986. Annotated list of the entomophagous complex associated With pear *psylla pyri* (L.) (Hom: psyllidae) in France *Agronomie*. 6: 1- 34 do.: 10 1051/ agro: 19860101.
- Hoddle, M. S., Mound, L. A. and Paris, D. 2008. Thrips of California (CD- ROM) Australia: The University of Queensland.
- Hodges, A., Ludwig, S., Osborne, L. and Edwards, G. B. 2009. Pest Thrips of the United states: Field Identification Guide. USDA- CSREES Regional. Integrated Pest menegment Centers. <https://www.FAO.org>.
- Howse, P., Stevens, I., and Jones, O. 1998. Insect Pheromones and their Use in Pest Management. Chapman and Hall, London. 369 pp.
- Jacobson, R. J. 1995. Resources to implement biological control in greenhouses, pp. 211-219. In B. L. Parker, M. Skinner and T. Lewis [eds.], *Thrips Biology and Management*. Plenum Press, New York.
- Jones, G.A., and Gillett, J.L. 2005. Intercropping with sunflowers to attract beneficial insects inorganic agriculture. *Fla Entomologist*. 88(1):91- 96.
- Jones, T., Scott-Dupree, C. D., Harris, R. and Shipp, L. 2005. *Pest Management Science*. 61(2):179-85. DOI:10.1002/ps.939.

- Kaplan, M. E., Bayhan and Atakan, E. 2016. Determination of Thysanoptera species, their seasonal abundance and distribution in vineyard areas of Mardin Province. Turkish Bulletin of Entomology, 6 (2): 161-168.
- Kaur, S., Kular, J. S., and Chandi, R., S. 2017. Effect of Temperature on Growth and Development of *Thrips tabaci* Lindeman in BT Cotton. Department of Entomology, Punjab Agricultural University, Ludhiana, Punjab, India. Int.J.Curr.Microbiol.App.Sci 6(5): 2553-2560 2553.
- Kilani, M., Morakchi, S. G., and Karima, H.,S. 2021. Azadirachtin-Based Insecticide: Overview, Risk Assessments, and Future Directions". Frontiers in Agronomy. 3: 676208.
- Kim, TJ., Choi, J., Kim, KW., Ahn, SK. H. SH., and Choi, Y. P. 2017. Metabolite profiling of peppers of various colors reveals relationships between tocopherol, carotenoid, and phytosterol content. J Food Sci 82:2885–2893
- Kiman, Z. B., and Yeargan, K. V. 1985. "Development and reproduction of the predator Orius insidiosus (Hemiptera: Anthocoridae) reared on diets of selected plant material and arthropod prey". Annals of the Entomological Society of America. 78 (4): 464–467
- Kirk, S. D. J. 1995. Feeding behavior and nutritional requirements, pp. 21-29. In B. L. Parker, M. Skinner and T. Lewis [eds.], Thrips Biology and Management. Plenum Press, New York, NY.
- Kirk, W. D. J. 2002. The pest and vector from the west: *Frankliniella occidentalis*. Thrips and Tospoviruses: Proceedings of the 7th International Symposium on Thysanoptera (Eds. Marullo R, Mound L), pp. 33-42. Australian National Insect Collection, Canberra, Australia.
- Kirk, W. D., and Terry, L. I. 2003. The spread of the western flower thrips *Frankliniella occidentalis* (Pergande). Agricultural and Forest Entomology 5, 301–310.
- Kızılaslan, H. 2004. Dünya’da ve Türkiye’de buğday üretimi ve uygulanan politikaların karşılaştırılması. Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi 21(2): 23-38.
- Krueger, S., Moritz, G., Lindemann, P., Radisch, D., and Tschuch, G. 2016. Male pheromones influence the mating behavior of *Echinothrips americanus* (Insecta, Thysanoptera, Thripidae). Journal of Chemical Ecology 42, 294–299.
- Kumar, V., Kakkar, G. McKenzie C. L., Seal, D. R. and Osborne, L. S. 2013. An Overview of Chilli Thrips, *Scirtothrips dorsalis* (Thysanoptera: Thripidae) Biology, Distribution and Management. Intech Open.
- Kutuk, H. 2011. Performance of the predator *Amblyseius swirskii* (Acari: Phytoseiidae) on greenhouse eggplants in the absence and presence of pine *Pinus brutia* (Pinales: Pinaceae) pollen. Abant İzzet Baysal University, Faculty of Agriculture and Natural Science, Bolu, Turkey. 263–269
- Kutuk, H., Yigit, A., Canhilal, R., and Karacaoglu, M. 2011. Control of western flower thrips (*Frankliniella occidentalis*) with *Amblyseius swirskii* on greenhouse pepper in heated and unheated plastic tunnels in the Mediterranean region of Turkey. African Journal of Agricultural Research Vol. 6 (24), pp. 5428-5433. Plant Protection Research Institute, PK 21 01321 Adana, Turkey.

- Labanowski, G., and Soika, G. 2010. Beneficial organisms associated with ornamental pests (Organizmy pożyteczne związane ze szkodnikami roślin ozdobnych.). Progress in Plant Protection, 50(4):2003-2007.
- Labuda, M. 1991. Arthropod vectors in the evolution of Bunyaviruses. Acta Virologica 35: 98- 105.
- Lenteren, J.,C., and Loomans, J. M. 1995. Biological control of thrips pests. papers 95-1. Department of Entomology. Wageningen Agricultural University, Wageningen, the Netherlands.
- Lewis, T. 1973. Thrips. Their biology, ecology and economic importance. Acad. Press London and New York, 349pp.
- Manucci, F., Allegri, A., Alessandri, S. and Alegi, S. 2014. Efficacia di una nuova formulazione di formetanate hydrochloride (Dicarzol®) nei confronti di *Thrips tabaci* su cipolla in Emilia Romagna. 2014 pp.209-214 ref.7. Italy.
- Molnar, A., Pap, Z. Z. and Fail, J. 2008. Observing population changes of thrips (Thysanoptera) species damaging forced pepper and their natural enemies. International Journal of Horticultural Science 14(4): 55–60.
- Momen, F. M., and El- Saway, S. A. 1993. Biology and feeding behaviour of the predatory mite, *Amblyseius swirskii* (Acari: Phytoseiidae). Acarologia 34(3): 199–204.
- Monteiro, R. C., Mound, L. A., Zucchi, R. A. 1999. Thrips (Thysanoptera) as pests of plant production in Brazil. Revista Brasileira de Entomologia 43: 163–171.
- Moritz, G., Donnell, C. A. and Parrella, M. 2009. Pest Thrips of North America – associated with domestic and imported crops. Centre for Biological Information Technology, The University of Queensland. DVD ISBN 978-1-86499-940-2.
- Moritz, G., Mound, L. A., Morris, D. C., and Goldarazena, A. 2004. Pest Thrips of the World Visual and Molecular Identification of Pest Thrips. CD- rom published by CBIT, Brisbane.
- Morse, M. S. and Hoddle, M. S. 2006. Invasion biology of thrips. Annual Review of Entomology 51:67–89.
- Mound, L. A. 2005. Thysanoptera: diversity and interactions. Annual Review of Entomology 50: 247-269.
- Mound, L. A. and Kibby, G. 1998. Thysanoptera, an Identification Guide, 2nd edition. CAB International, United Kingdom.
- Mound, L. A. and Marullo, R. 1996. The thrips of Central and South America: An Introduction (Insecta: Thysanoptera). Memoirs on Entomology, International 6: 1–487.
- Mound, L. A. and Teulon, D. A. J. 1995. Thysanoptera as phytophagous opportunists, pp. 319. In B. L. Parker, M. Skinner and T. Lewis [eds.], Thrips Biology and Management. Plenum Press, New York.
- Mound, L.,A., and Minaei, K. 2007. Australian insects of the Haplothrips lineage (Thysanoptera – Phlaeothripinae). Journal of Natural History 41: 2919–2978.
- Mouratidis, A., de Lima, A. P., Dicke, M., and Messelink, G. J. 2022. Predator-prey interactions and life history of *Orius laevigatus* and *O. majusculus* feeding on flower and leaf-inhabiting thrips. Biological Control, 104954.
- Nas, S., Atakan, E., and Eleçloğlu, N. 2007. Thysanoptera species infesting the citrus in eastern Mediterranean region of Türkiye. Turk J. Ent, 31: 307-316.

- Nasruddin, A., and Smitley, D. R. 1991. Relationship of *Frankliniella occidentalis* (Thysanoptera: Thripidae) population density and feeding injury to the frequency of insecticide applications to gloxinia Journal of Economic Entomology 84: 1812-1817.
- Okajima, S. 2006. The Suborder Tubulifera (Thysanoptera). The Insects of Japan 2: 1–720.
- Olaniran, O. A., Sudhakar, A. V. S., Drijfhout, F. P., Dublon, I. A. N., Hall, D. R., Hamilton, J. G. C., and Kirk, W. D. J., (2013). A male-predominant cuticular hydrocarbon, 7- methyltricosane, is used as a contact pheromone in the western flower thrips *Frankliniella occidentalis* . Journal of Chemical Ecology 39, 559–568.
- Ortega-Jiménez, Victor, M., Arriaga-Ramirez S., and Dudley, R. 2016. Meniscus ascent by thrips (Thysanoptera). Biology Letters. 12 (9).
- Özsisli, T. 2011. Population densities of wheat thrips, Haplothrips tritici Kurdjumov (Thysanoptera: Phlaeothripidae), on different wheat and barley cultivars in the province of Kahramanmaraş, Turkey. African Journal of Biotechnology Vol. 10(36), pp. 7063-7070.
- Palmer, J.M. Mound, L. A. and Heaume, G. J. 1989. Thysanoptera, CIE guides to insects of importance to man, Ed: Betts CR., CAB Int. Inst. Entomol.,The Cambrian News Ltd, Aberystwyth, UK: 73pp.
- Pandey, S., Pathak, M. K., Dubey, B.K. and Gupta, P. K. 2019. Chemical control of onion thrips with insecticides through sequential sprays. Journal of Entomology and Zoology Studies 2020; 8(1): 517-521.
- Park, H. H., Shipp, L., and Buitenhuis, R. 2010. Predation, development and oviposition the Predatory mite *Amblyseius swirskii* (Acari: Phytoseiidae) on tomato russet mite (Acari: Eriophyidae). Journal of Economic Entomology 103: 563-569.
- Parrella, M. P. 1995. Thrips biology and management. guide part II. Proper identification. GrowerTalks 59 (July): 82-94.
- Persley, D. M., Sharman, M., Thomas, J., Kay, I., Heisswolf, S., and McMichael, L. 2007. Thrips and Tospovirus – A Management Guide. Cooperative Research Centre for Tropical Plant Pathology.
- Pobozniak, M., Tokarz, K., Musynov, K. 2020. Evaluation of sticky trap colour for thrips (Thysanoptera) monitoring in pea crops (*Pisum sativum* L.). Journal of Plant Diseases and Protection. <https://doi.org/10.1007/s41348-020-00301-5>.
- Pourian, H. R., Mirab-balou, M., Alizadeh, M. and Orosz, S. 2009. Study on biology of onion thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) on cucumber (var. Sultan) in laboratory conditions. J. Plant Prot. Res. 49 (4): 390-394.
- Ragusa, S., Swirski, E. 1975. Feeding habits development and oviposition of the predaceous mite *Amblyseius swirskii* Acarina Phytoseiidae on pollen of various weeds. Israel Journal of Entomology. 15: 55-62.
- Ragusa, S., Swirski, E. 1977. Feeding habits, post embryonic and adult survival, mating, virility and fecundity of the predacious mite *Amblyseius swirskii* (Acarina: Phytoseiidae) on some Coccids and Mealybugs. Entomophaga 22(4): 383–392.
- Reed, J. T., Allen, C., Bagwell, R., Cook, D., Burris, E., Freeman, B., Leonard, R. and Lentz, G. 2006. A key to the thrips (Thysanoptera: Thripidae) on seedling cotton in the mid- Southern. United States. Mississippi Agricultural and Forestry Experiment Station Information Sheet. pp. 1–26.

- Reitz, S. R. 2002. Seasonal and within plant distribution of *Frankliniella* thrips (Thysanoptera:Thripidae) in north Florida tomatoes. Fla. Entomol. 8 (3): 431-439.
- Riudavets, J. 1995. Predators of *Frankliniella occidentalis* (Perg.) and *Thrips tabaci* Lind.: a review, pp. 43-87. Biological Control of Thrips Pests. Wageningen Agricultural University Papers 95-1, printed by Veenman Drukkers, Wageningen, The Netherlands.
- Sabelis, M. W., and van Rijn, P. C. J. 1997. Predation by insects and mites, pp. 259- 354 In Lewis, T. (ed.) Thrips as Crop Pests. CAB International, United Kingdom.
- Sakimura, K. 1962. *Frankliniella occidentalis* (Thysanoptera: Thripidae), a vector of the tomato spotted wilt virus with special reference to the color forms. Annals of the Entomological Society of America 55: 387-389.
- Shilpa, P. B., and Singh, S. 2020. Effect of mulching on crop production under rainfed conditions: A review. Int. J. Chem. Stud., 8, 2268–2271.
- Shimat V., Joseph, Kris Braman, Will Hudson, and Shakunthala Nair. 2019. Biology and Management of Thrips affecting the production nursery and landscape .University of Georgia Extension. Department of Entomology . extension.uga.edu.
- Suganthi, M., and sakthivel, P. 2012. Efficacy of botanical pesticides against major pests of black nightshade, *Solanum nigrum* linn. International Journal of Pharma and Bio Sciences. Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore,India. ISSN 0975- 6299.
- Sutherland, C. A. 2006. Extension and State Entomologist Thrips. New Mexico State University is an equal opportunity/affirmative action employer and educator. NMSU and the U.S. Department of Agriculture cooperating.
- Sutil, W. P., Barbosa, R. B., Santos, R. S., Fancelli, M., and Lima, É. F. B. 2022. Unravelling the identity of pest thrips (Thysanoptera: Thripidae) of bananas (Musaceae) in Brazil. The Canadian Entomologist, 154.
- Takacs, A., Kazinczi, G., Horvath, J., Gaborjanyi, R., and Varga, L. 2008. Relationships Between Thysanoptera species and tomato spotted wilt virus (TSWV). Cereal Research Communications 36: 95-98.
- Teerling, C. R., Pierce, H. D., Borden, J. H. and Gillespie, D. R. 1993. Identification and bioactivity of alarm pheromone in the western flower thrips, *Frankliniella occidentalis*. Journal of Chemical Ecology 19, 681–697.
- Theunissen, J. and Legutowska, H. 1991. *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) in leek: symptoms, distribution and population estimates. J. Appl. Entomol. 112 (1-5):163-170.
- Tommasini, M. G. and Maini, S. 1995. *Frankliniella occidentalis* and other thrips harmful to vegetable and ornamental crops in Europe, pp. 1-42. In Loomans, A. J. M., J. C. van Lenteren, M. G. Tommasini, S. Maini, And J. Riudavets (eds.). Biological Control of Thrips Pests. Wageningen Agricultural University Papers 95-1, printed by Veenman Drukkers, Wageningen, The Netherlands.
- Tompos, D. 2006. Certain technological elements and economic relationships of Greenhouse pepper production on rockwool. PhD thesis. Corvinus University of Budapest (mscr.). (in Hungarian).

- Trdan, S., Andjus, L., Raspudić, E., and Kač, M. 2005. Distribution of *Aeolothrips intermedius* Bagnall (Thysanoptera: Aeolothripidae) and its potential prey Thysanoptera species on different cultivated host plants. *Journal of Pest Science*, 78, 217–226.
- Tsuda, S., Fujisawa, I., Ohnishi, J., Hosokawa, D., and Tomaru, K. 1996. Localization of tomato spotted wilt tospovirus in larvae and pupae of the insect vector *Thrips setosus*. *Phytopathology* 86: 1199-1203.
- TUIK, 2021. Türkiye İstatistik Kurumu, Bitkisel üretim istatistikleri. <https://biruni.tuik.gov.tr/bitkiselapp/bitkisel.zul>.
- TUIK, 2023. Türkiye İstatistik Kurumu, Bitkisel üretim istatistikleri. <https://biruni.tuik.gov.tr/bitkiselapp/bitkisel.zul>.
- Ullman, D. E., Cho, J. J., Mau, R. F. Westcot, D. M., and Custer, D. M. 1992. A midgut barrier to tomato spotted wilt virus acquisition by adult western flower thrips. *Phytopathology* 82: 1333-1342.
- Ullman, D. E., Sherwood, J., L., and German, T., L. 1997. Thrips as vectors of plant pathogens, pp.539-565. In Lewis, T. (ed.) *Thrips as Crop Pests*. CAB International, United Kingdom. New York.
- Van de Wetering, F., Goldbach, R., and Peters, D. 1996. Transmission of tomato spotted wilt Virus by *Frankliniella occidentalis* after viral acquisition during the first larval stage. *Horticultur.* 431: 350-358.
- Van, J. C. L., and Loomans, A. J. M. 1995. Biological control of thrips pests. Department of Entomology, Wageningen Agricultural University, Wageningen, The Netherlands. 95-1.
- Van, L. J. C., and Bueno, V. H. P. 2003. Augmentative biological control of arthropods in Latin America. *BioControl* 48(2): 123–139.
- Veitch, G., Beckmann, E., Burke, E., Boyer, A., and Maslen, S., L. 2007. Synthesis of azadirachtin: a long but successful journey. *Angew. Chem. Int. Ed. Engl.* 46 (40): 7629–32.
- Vincent, C., Hallman, G., Panneton, B., and Fleurat-Lessard, F. 2003. Management of agricultural insects with physical control methods. *Annual Review of Entomology*, 48(1), 261–281.
- Vick, K. W., Mankin, R. W., Cogburn, R. R., Mullen, M. J., Throne, E., Wright, V. F., and Cline, L. D. 1990. Review of Pheromone Baited stick traps for detection of *Sto* Product. *Entomol. Soc.*, 63: 526-532.
- Wijkamp, I. J., Van Lent, R., Kormelink, R. G., and Peters, D. 1993. Multiplication of tomato spotted wilt virus in its insect vector, *Frankliniella occidentalis*. *J. Gen. Virol.* 74: 341-349.
- Wijkamp, I., Almarza, N., Goldbach, R., and Peters, D. 1995. Distinct levels of specificity in thrips transmission of tospoviruses. *Phytopathology* 85: 1069-1074.
- Wu, S., Xing, Z., Ma, T., Xu, D., Lei, Z., and Gao, Y. 2021. Competitive interaction between *Frankliniella occidentalis* and locally present thrips species: a global review *Journal of Pest Science*, 94, 5–16.

Yiğit, A. U., Demirozer, O., and Minaei, K. 2022. Thrips species associated with cereals of the Lakes Region of Turkey with new records. Department of Plant Protection, Faculty of Agriculture, Isparta University of Applied Sciences, Turkey Department of Plant Protection, College of Agriculture, Shiraz University, Shiraz, Iran. 35(1): 15- 19.



RESUME

Name and surname Sarah Disko YOUNUS

Personal
Information

[REDACTED]

Contact information

[REDACTED]

Education

[REDACTED]

[REDACTED]
Bachelor of Agriculture Engineering Sciences,
[REDACTED]

[REDACTED]
[REDACTED]

Work experience

[REDACTED]



