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MONITORIZAREA DINAMICII UNOR AGENŢI DE DĂUNARE DIN POMICULTURĂ ÎN CONTEXTUL SCHIMBARILOR CLIMATICE DIN ULTIMUL DECENIU
THE DYNAMIC MONITORING OF SOME DAMAGING AGENTS IN FRUIT GROWING RELATED TO CLIMATE CHANGES OF LAST DECADE

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Abstract

Nowadays, the average values of the main parameters of the local climate and microclimate have changed significantly compared to the pre-industrial period. The immediate consequences are quite obvious, namely: the earlier initiation of vegetation of the most fruit tree species (with about 2 weeks), the increase in the frequency of damages caused by late spring frosts, the prolongation of periods of water stress into the soil and in the atmosphere, accompanied by the blocking photosynthetic activity and increased cell respiration, increased frequency and severity of burns on fruits through the combined effect of insolation and extremely high temperatures, earlier ripening and decreased fruit firmness and acidity. Changes have become obvious in the biological cycle of pests, harmful for fruit growing, especially by the appearance of additional generations with high aggressiveness, the increase of the risk, frequency, intensity and duration of the attack of pathogens. In fruit growing, the depletion of the level and quality of the harvest is caused by bacterial and fungal pathogens (over 155; 41%), pests (over 132; 35%), viruses, viroids and mycoplasmas (over 67; 17%) and dominant mono- and dicots (over 26; 7%). In the last 20 years, technical means have appeared, which allow the monitoring the physico-chemical and humidity parameters of the soil, the local microclimate, as well as the physiological and health status of the plants. The paper presents the results obtained in the period 2018-2022 at RIFG Pitesti-Mărăcineni, in the monitoring of some harmful agents, using independent analog or digital devices, automatic or semi-automatic weather stations with software for real-time data collection and processing, forecasting and warning modules of the risk of attack. These assets allowed the highlighting of the dynamics of some of the damaging agents in fruit growing, the professional scheduling and carrying out of phytosanitary actions in bearing orchards, the reduction of the allocated resources consumption and the protection of the environment.

Cuvinte cheie: pomicultură, schimbari climatic, dăunători, boli, monitorizare.
Key words: fruit growing, climatic changes, pests diseases, monitoring.

1. Introduction

Nowadays, the average values of the main parameters of the local climate and microclimate have changed significantly compared to the pre-industrial period. The year 2022 was the sixth warmest year since global records began in 1880 with 0.86°C above the 20th century average of 13.9°C. This value is 0.13°C less than the record set in 2016 and it is only 0.02°C higher than the last year's (2021) value. The 10 warmest years in the 143-year record have all occurred since 2010, with the last nine years (2014–2022) ranked as the nine warmest years on the record.

Europe had above-average monthly temperatures throughout the year, with the highest monthly temperature departure of +3.12°C occurring in February. Despite it being the highest monthly temperature for the year, February 2022 was ranked as the seventh-warmest February on record. The months of August and October had a temperature departure that ranked as the warmest for respective months. The smallest monthly temperature departure for the year was +0.80°C in September. The year as a whole ranked as the second warmest for Europe, behind the record year of 2020 by 0.23°C. The year 2022 was also the 26th consecutive year with temperatures above average, Europe's 10 warmest years have occurred since 2007. The annual temperature for Europe has increased at an average rate of 0.15°C per decade since 1910; however, it has tripled to 0.46°C since 1981. (NOAA-NCEI, Monthly Global Climate Report, for 2022, published online January 2023).

In Romania, climate change involves adaptation of ecological systems to the effects of climate variability.

The years of 2018 and 2019 had mild winters, and dry autumns. More over 2019 is considered the warmest year since 1900. The immediate consequences of climatic changes are quite obvious, namely: the earlier enter into vegetation of most fruit tree species (with about 2 weeks), the increase in the frequency of damages, caused by late spring frosts, the prolongation of periods of water stress into the soil and in the atmosphere, accompanied by the blocking photosynthetic activity and increased cell respiration, increased frequency and severity of burns on fruits, through the combined effect of insolation and extremely high temperatures, earlier ripening and decrease of fruit firmness and acidity.

Changes have become obvious in the biological cycle of pests, harmful for fruit growing, especially by the appearance of additional generations with high aggressiveness, the increase of the risk, frequency, intensity and duration of the pathogens attack.

Pest and disease forecast is based on the biology of the damaging agents, their presence in the orchard, the oscillations of local condition of microclimate conditions and the fruit trees phenology and physiological status.

This situation leads to the need for a complex and interdisciplinary approach to monitoring the physico-chemical parameters of the soil, the local microclimate, as well as the physiological and health status of plants, using semi-automatic and automatic weather stations and professional software, independent monitoring devices and pheromonal products to increase the performance of farmers and the quality of local fruits.

2. Material and methods

The researches were carried out during 2018-2022 inside the experimental and demonstrative plots organized at RIFG Pitesti Romania. The area where the researches were done belongs to national second climatic area, with solar radiation 114-128 Kcal/cm^2, mean temperatures between 9.8-11.2°C, 3400-4100 degrees over 0°C, 2800- 3500 degrees over 10°C, mean precipitations 450-700 mm, in dry years, from April until October. The experimental plots were located on poor loam-clay soil with over 30% clay (albeluvisoil). Deep into the profile, the soil has sandy structure and includes a variable amount of coarse material. Soil surface is prismatic and friable. Soil organic matter represents 1.8% and drop with the deep. The soil is poor in nitrogen and phosphorus (nitrogen index 0.33-1.43; PAL 1.3-2.5 mg per 100g) and potassium supply is good up to 40 mg per 100g. The cationic exchange capacity (CEC) was 68.4, the water holding capacity was 50 and the soil solution pH 5.6. The experimental and demonstrative plots included: apple planted at 4 x 1 and 3 x 1 m (2500-3333 trees/ha), plums and cherries planted at 4.0 x 2.0 and 4.0 x 1.5 m (1250-1666 trees/ha); blueberry planted at 3 x 1 m (3333 plants/ha) and red currant planted at 3 x 0.75 m (4444 plants/ha).

Analogic, semi-automatic and automatic weather stations and professional software and independent monitoring devices were used. The weather data were collected with two types of weather stations WatchDog from Spectrum LLC Plainfield Illinois - USA and Pessl - Austria with their dedicated software Specware Pro and iMetos 3.3.

To assess the seasonal dynamic of some pathogens and pests, forecast modules compatible with Specware Pro and iMetos 3.3. were purchased, installed and used, to indicate the damaging attack risk and period.

In order to estimate some pests dynamic and their potential damages (frequence F% intensity I-notes and DD%) into the experimental and demonstrative plots were calculated.

Independent monitoring devices TrapView and iTrap and the feromonal traps (AtraPOM for apple codling moth - *Cydia pomonella*; AtraFUN for plum fruit moth - *Cydia funebrana*; AtraCERAS and DecisTrap for cherry fruit fly - *Rhagoletis cerasi*, and AtraTYP for twig borer *Sesia typuliformis* on red currant) were used and the readings were done daily or twice per week.

For some other important damaging agents, the monitoring was done by orchard scouting, lab assessment and evaluation of their potential damages (frequence F%, intensity I-notes and DD%).

In the lab pathogens were identified using an Optika 383 PL microscope and the aphids, mites and leaf rollers were identified under Zeiss Stemi 508 stereo magnifier.

The performances and operational advantages and disadvantages of the assets used for monitoring were compared with other some other platform and independent devices released on the market. All the data obtained were used for more precise scheduling and application of phytosanitary treatments.

3. Results and discussions

Results obtained in collecting and assessment of the weather data.

The databases built between 2018 and 2022 revealed that both types of weather stations and their dedicated software Specware Pro and iMetos 3.3 are reliable and offer synthesis and many details about orchard microclimate during the study period. (See tables 2-6).

In this sense, in 2018, the months May and June were rich in precipitations, the leaf wetness period ranged between 130.8 and 198.5 h/month, while the monthly temperature average ranged between 17.5 and 21.0 ºC.

As regard 2019, the minimum temperature was -14.3 ºC, registered in February and the maximum temperature of 31.5 ºC was registered in August. The average monthly temperatures from May to August, ranging between 10.8 and 22.8 ºC, were favorable both for pests and diseases attack. The precipitation sum of 599.0 mm, which was under the area normal value with 197.0 mm.

In 2020, the minimum temperature was -10.2 ºC, registered in January and the maximum temperature of 35.3 ºC was registered in July. The average monthly temperatures from April to August, ranging between 10.9 and 22.2 ºC, were optimum both for pests and diseases attack development. The precipitation sum of 679.0 mm was over the area normal value with 197.0 mm and the most rainy months were May and June, with 104.1 and 166.2 mm.

The weather conditions of 2021 were very favorable to the micotic and bacterian infections and pathogenesis development. In this sense, in June, the precipitation sum was 225.0 mm and the air humidity ranging between 70% and 99%. The leaf wet period was 196.2 h (with 43.2 h more than the average of the previous five years). Moreover, the hail fallen in June, accentuated the trees and fruits vulnerability to diseases.

In 2022, the minimum temperature was -12.0 ºC, registered in January and the maximum temperature of 38.3 ºC was registered in July. The monthly average values from April to July (10.1-22.8ºC) were very favorable to the pest and disease attack. Also, till September, the precipitations sum was 440 mm, under the area normal value, the rainiest month was August, with 142.1 mm.

Results obtained in monitoring of some damaging pathogens using two types of weather stations and their forecast modules.

In our area, the microclimate conditions of the last decade lead to an increased risk of infection with fireblight- *Erwinia amylovora* on apples, especially in the last five years. Assessment of the figures 1 and 2 generated with the warning module of iMetos 3.3 software reveal that, the infection risk (Cougar scale 0-4) starts in the mid or end of April from first flowers open-petal fall (BBCH 63-69) Cougar risk was 1-2, increased in May from fruit formation (BBCH 71-72) -Cougar risk 2-3, and remain higher during the vegetation (Cougar risk 3-4).

Also, in the case of the stone fruits, especially sweet cherry the infection risk with - *Pseudomonas syringae pv. mors prunorum* bacteria increased especially on some valuable varieties as 'Lapins', 'Sweetheart', 'Regina' and 'Folfer'. In this situation the preventive phytosanitary treatments and an integrated management approach became mandatory.

From the figures 3 and 4 generated with the warning module of iMetos 3.3 software it can be seen that, apple scab -*Venturia inaequalis* remains a very damaging pathogen for the apples with a fast emergence of the ascospores from mouse ear stage (BBCH 10) till May (BBCH 69-71) and even rapid spread of conidia during all summer, in the period of shoot leaves and fruit increase (BBCH 71-81).

We observed that the infection with scab were difficult to be contained especially under 2021 weather conditions. In this situation the preventive and curative phytosanitary treatments and integrated management approach are obvious. The preventive and curative phytosanitary interventions were better positioned in time when the warning module of iMetos 3.3 software was used as supplementary decision tool.

Assessment of the figures 5 and 6 generated with the Specware 9 warning module, highlight that on sensitive apple varieties, the powdery mildew - *Podosphaera leucotricha* is a serious threat that must be monitored, with a fast occurence of the ascospores from bud brake (BBCH 07), or mouse ear stage (BBCH 10), till May (BBCH 69-71) and even rapid spread of conidia during all summer in the period of shoot leaves and fruit increase (BBCH 71-81), when the conidial severity index ranged very often between 80 and 100, except late August and the month of September.

Assessment of the figures 7 and 10 generated with the warning module of iMetos 3.3 software reveal that, for the infection risk of shoot hole - *Stigmina carpophilla* and brown rot - *Monilia laxa* on stone fruits, the most favorable conditions were met since April till late July sometime in August and were related with the amount of precipitations fallen and air relative humidity.

The most difficult year was 2021 when brown rot attacked very severe the cherry varieties 'Lapins', 'Karina' and 'Tamara', during the ripening and harvest, therefore additional phytosanitary interventions with short activity period fungicides (1-3 days) were necessary between the ripening and the harvest sessions.

A deep look in the figures 11 and 12 generated with the Specware 9 warning module, highlight that, on cherry, the anthracnosis - *Blumeriella jaapii* menaced sensitive varieties, between May and June, or even later in September when leaf wet period was higher than 4.5-7.0 hours per day.

The figures 11 and 12 generated with the Specware 9 warning module, put in evidence that on blueberry, a berry with a high increase as planted surfaces, production and market demand, the twigs blight (*Phomopsis putrefaciens*) attack risk was higher when monthly leaf wet hours exceeded the sum of 20-40, and lesion number are more than 100.

The assessments carried out in the experimental device lead to the conclusion that the varieties 'Huron', Elliot and Top Shelf were vulnerable also to other infections with micotic pathogens, since the planting moment.

As regard the red currant, the assessments carried out in the experimental device highlighted that, 'Rovada' and 'Junifer' varieties were sensitive to powdery mildew - *Sphaeroheca mors-uvae*. Their sensitivity to powdery mildew qualifies them as indicator varieties to trigger the phytosanitary interventions in currant plots, starting with leaf occurrence (BBCH 54-55).

For all berry species, the grey mold - *Botrytis cinerea* is a very damaging pathogen which strike fast under the most favorable conditions for infections which were met since April till late July and sometime in August, when daily leaf wet hour is higher than 10 hours (figures 15 and 16) therefore additional phytosanitary interventions with short activity period fungicides (1-3 days) or biological ones, are necessary between the ripening and the harvest sessions.

Results obtained in monitoring of apple codling using automatic weather station and its forecast module and independent monitoring devices.

Assessment of the figures 17 and 18 generated with the warning module of iMetos 3.3 software, reveal some year-by-year changes in the flight dynamic of the apple coldling moth - *Cydia pomonella*.

In this sense, in 2018 the first generation G1, lasted from April to June with an average capture of 2-3 adults/trap/day while the second generation G2, lasted from July till September with an average capture of 3-5 adults/trap/day, and the third generation G3 emerged in October with an average capture of 3 adults/trap/day.

In 2019 and 2020, the first generation G1, lasted from April to June with an average capture of 2-3 adults/trap/day while the second generation G2, lasted from July till September with an average capture of 3-5 adults/trap/day, and the third generation G3 emerged in October with an average capture of 3-5 adults/trap/day as well.

In 2021 and 2022, the flight dynamic of apple coldling moth - *Cydia pomonella* was pretty much the same.

These facts were confirmed by the data delivered in real time by independent monitoring devices TrapView and iTrap and the catches with the pheromonal traps AtraPOM.

Results obtained in monitoring of some damaging pests using the feromonal traps and orchard scouting.

Examination of the figures 19 and 20 drawn based on the captures in the pheromonal trap AtraFUN highlight that on plum in 2018-2020, plum codling moth - *Cydia funebrana*, has two distinct generations. The first generation G1, lasted from 17 April till 11 June and the highest capture was in the period 06-12 May, with an average of 11 adults/trap/day. The second generation lasted from 12 June till 24 August, but the flight amplitude was lower, the average captures were 3.5 and 3.0 adults/trap/day at 9 July and 20 August.

In 2021 and 2020, plum codling moth - *Cydia funebrana*, has two distinct generations as well. The first generation G1, lasted from 10 April till 18 June and the highest capture was in the period 01-05 May, with an average of 4 adults/trap. The second generation lasted from 12 May till 24 August, the average captures were 6.0 and 3.5 adults/trap/day at 12 July and 26 July.

Assessment of the figures 21 and 22, drawn based on the captures in the pheromonal trap AtraCERAS suggest that, on sweet cherry in 2018-2020, the fruit fly - *Rhagoletis cerasi* was very active between 6 May and 21 July. The highest captures were registered between 3-9 June and 10-16 June 6.0 adults/trap/week and respectively 5.0 adults/trap/week.

In 2021-2022, the fruit fly - *Rhagoletis cerasi*, was very active between 6 May and 22 July. The highest captures were registered between 4-10 June and 11-18 June, 7.0 adults/trap/week and respectively 6.5 adults/trap/week.

Results obtained in monitoring other damaging pests by orchard scouting and lab assessments.

In 2019 on red currant the yellow aphids-*Criptomysus ribis* and twig borer *Sesia tipuliformis* were detected. For yellow aphids, the treatments were applied at occurrence of the first infested twigs, and for twig borers at first catches in AtraTYP pheromonal traps.

Under 2020 conditions, by apple orchard plot scouting, wooly aphid - *Eriosoma lanigerum* was detected and was the most difficult pest to be controlled, because of higher number of generations than in the past (11-12 generations/season vs. 8-10 generations/season) and limited options for chemical control. In this situation the treatments were applied at the beginning and the end of the vegetation period. The most sensitive apple variety to the wooly aphid attack were Red ′Braeburn′ and ′Jonagold Boerenkamp′.

In 2021, on red currant, twig borer *Sesia tipuliformis* were detected, the attack frequency F% on some plants was 35%, which lead to necessity and opportunity of sanitation prunings.

Under 2022 conditions, on some blueberry plants *Partenolecanium corni* scale was detected, the heavy attacked plants being removed, other healthy ones being planted.

Number of treatments needed and effected during the study period.

The number of the phytosanitary treatments needed and carried out during the study period, were variable according the species, damaging agents, weather and microclimate conditions, forecast and warning systems, the need to diminish the pests and pathogens reserve from the previous year and the need for reduction of the impact of the fruit growing activities on the environment.

On top fruits, on apples between 12 and 18, on sweet cherry between 10 and 14 and on plum, according the age between 4 and 10 interventions, were deployed. On blueberry, including the sanitation interventions, between 6 and 12 and on red currant between 8 and 12 interventions were carried out. (See Table 7).

3.6. *Operational advantages of the monitoring systems and devices tested at RIFG Piteşti Romania*

Operational advantages of the monitoring systems and devices tested at RIFG Piteşti Romania are presented in the Table 8, in comparation with other system existent on the market and operating in some fruit growing research units.

The use of the automatic and semiautomatic weather stations gives to the users the possibility to collect store integrate and assess of a wide range of weather data. The specific forecast models transform them is investigation tools for the changes in the pest and pathogens populations dynamic and biological cycle.

To operate such kind of platforms, a strong biological, technical and IT training is necessary and must be done according to the hardware and software improvements, pheromone formulation or new varieties release.

After many years of use it can be concluded that automatic weather stations are more accurate, some data being delivered in real-time, while the semi-automatic ones, must be periodically ′downloaded′, but their interface is more user-friendly. Both types of stations are safe and stable, but their real performances in pest and diseases forecast, depend also on the specific modules acquired, which must be in accordance with the farmer problems and needs for its orchard and crops.

The independent monitoring devices are reliable to. They have specific software but can monitor only one pest and eventually fewer parameters. However, they are versatile and by changing the pheromone type, other damaging pest can be monitored. According the crops structure, many independent devices can be used. The data collected are delivered in real time on the supplier web page, and accessed by user name and ID.

Nowadays, the utility of the pheromonal traps can be not put into the question as long as they were tested for many decades and enters into the configuration of the independent monitoring devices, both systems being useful for monitoring many pests living in the orchards and scheduling of treatments with insecticides.

Use of such kind of technical platforms and independent devices allows better positioning of the phytosanitary interventions, better use or plant protection products, reduction of the impact of the fruit growing activities on the environment and increase of the farmers presence and efficiency on the fruits market.

4. Conclusions

Monitoring microclimate conditions using automatic weather stations, expert programs and independent devices are modern tools for early warning of the risk of attack by pests and pathogens in modern orchards.

The equipment tested or studied allowed the collection, organization, processing and interpretation of an important volume of data organized in default databases regarding biocenotic stress caused by harmful agents.

Independent devices collect in real time certain specific indicators of physiological and biocenotic stress.

The use of all forecasting and warning systems and modules requires the operation of the systems by qualified personnel with experience in the use of automatic systems, periodic training being required depending on the updating of sensors, hardware and software components.

Forecasting and warning systems and modules independent devices, pheromone traps orchard scouting and lab assessments complement each other in a happy way, increasing the accuracy of monitoring, forecasts and decisions.

The systems allow the collection and processing of data in real time, the forecasting and warning modules allow the management in a professional manner of programming and carrying out phytosanitary and technological actions in fruit orchards, to reduce the consumption of imputations, protect the environment and increase of the farmer’s presence and efficiency on the fruits market.

Due the climatic changes, assortment completion, and technology advances, the number damaging species and phytosanitary interventions applied in order to control the most damaging ones increased in the period 2018-2022 vs. 2013-2017 an each studied species: 16 vs. 12 treatments/year on apple, 12 vs. 9 treatments/year on cherry, 10 vs. 8 treatments/year on plum, 8 vs. 4 treatments/year on blueberry and 10 4 treatments/year on red currant.

References

1. Amzar Valentina, 2002. Prevenirea şi combaterea integrată a agenţilor fitopatogeni şi a dăunătorilor în pomicultură, Revista Sănătatea Plantelor, nr. 2: 33.
2. Brun L., Gomez Christelle, Dumont Estelle, 2005. Prophylaxie contre la tavelure du pommier. Intérêts de la diminuation de l'inoculum primaire de tavelure en vergers de pomiers, Phytoma. La Défence de Végétaux N. 581: 16-18.
3. Chmielewski F.M., Metz Reinhart, 2005. Încălzirea globală a climei. Urmările pentru faună şi floră. Curierul Bayer 1: 15-17.
4. Drosu S., 2001. Monitorizarea populaţiilor de microlepidoptere dăunătoare din livezi cu ajutorul capcanelor cu feromoni. Sesiunea ştiinţifică anuală "Tehnologii Anuale în Protecţia Plantelor. Alinierea la cerinţele europene şi mondiale, ICDPP Bucureşti-Băneasa.
5. Halbrendt J.M. et all, 2012-2013. Pennsylvania Tree Fruit Production Guide, Pennsylvania State University, College of Agricultural Sciences, 340 pp.
6. Ionescu L.M., Mazăre A.G., Visan D., Liţă Al., Liţă I., Şerban G., 2020. Embedded Image Analysis System Based on B-ANN, 43th International Spring Seminar on Electronics Technology (ISSE) 1-6, Demänovska Valley, Slovakia, web-based conference, 14 - 15 May 2020.
7. Ionescu L.M., Mazăre A.G., Şerban G., Chiţu E., Liţă Al., 2019. Intelligent monitoring and analysis system of soil moisture parameters and trunk diameter used in fruit tree culture, IEEE 25th International Symposium for Design and Technology 3-26 Octomber 2019, Cluj Napoca, Romania.
8. Mazăre A.G., Ionescu L.M., Visan D., Belu N., Liţă Al., 2019. Pests detection system for agricultural crops using intelligent image analysis, IEEE 25th International Symposium for Design and Technology 3-26 Octomber 2019, Cluj Napoca, Romania.
9. Murray Marion, Larsen H. et all., 2012. Commercial Tree Fruit Production Guide Utah-Colorado States Universities, USDA NIFA Extension IPM Program, 183 pp.
10. Oprean Ioan. 2008, Feromonii insectelor. Capcanele cu feromoni-Instructiuni de folosire, Institutul de Cercetare-Dezvoltare Raluca Ripan, Cluj-Napoca.
11. Păltineanu Cristian şi colab., 2008. Pomicultura Durabilă: de la genotip la protecţia mediului şi sănătătea umană, Editura Estfalia, Bucureşti, 414 pp., ISBN-978-973-7681-43-0, WP IV Protecţia Plantelor în Pomicultura Durabilă pp.313-317.
12. Sumedrea Dorin Ioan, Tănăsescu N., Chiţu E., Moiceanu D., Marin F.C., Ţintarcu G., 2009. Prezent şi perspectivă în tehnologiile pomicole din România în condiţiile schimbărilor climatice globale. Scientific Papers of the R.I.F.G. Pitesti, Vol. XXV: 45-79.
14. Şerboiu Albertina, Şerboiu L., Bolbose Cecilia, 2001. Posibilităţi actuale de reducere a costurilor şi poluării chimice, Sesiunea ştiinţifică anuală "Tehnologii Anuale în Protecţia Plantelor. Alinierea la cerinţele europene şi mondiale", ICDPP Bucureşti-Băneasa, 19 Aprilie 2001.
15. Teodorescu Georgeta, Trandafirescu M., E. Cîrdei, I. Man, Frăsin L., 2003. Protecţia fitosanitară a ecosistemelor pomicole, Editura, TIPARG, ISBN 973-8029-79-1.
16. Teodorescu Georgeta, 2000. Prognoza şi avertizarea bolilor şi dăunătorilor plantelor de cultură. Editura, TIPARG, ISBN 973-8029-16-3.
17. Tomşa M., Tomşa Elena, 2003. Protecţia Integrată a Pomilor şi Arbuştilor Fructiferi la Început de Mileniu, Editura Geea, Bucureşti, 162 pp., ISBN 973-85232-9-X.
18. Ward L. Daniel, 2014. New Jersey Commercial Tree Fruit Production Guide, New Jersey Agricultural Experiment Station, Rutgers Cooperative Extension, 234 pp.
19. *** INMH, Clima. Adaptarea la schimbările climatice, https://www.meteoromania.ro/clima/adaptarea-la-schimbarile-climatice/
20. *** IoT Catalogue 2021. For Real-Time Continuous Monitoring of: Natural, Built & Agricultural Environments, Australia, 184pp, www.ictinternational.com.
21. *** SpecWare 9 User Guide (Pro & Basic) - Product manual, SpecWare Software © 1997-2012 Spectrum Technologies, Inc., IL, USA, 52 pp.
22. *** SpecWare 9 Pro Advanced Features - Product manual, SpecWare Software © 1997-2012. Spectrum Technologies, Inc., IL, USA, 13 pp.
23. *** Specware 7.0 Profesional. Disease and Insect Guide, Spectrum Technologies Inc., 2005, Plainfield IL 60544, Web. www. specmeters.com.
24. ***, 2005. Spectrum Technologies Inc., Specware 7.0 Profesional. Disease and Insect Guide, Plainfield IL 60544, Web. www. specmeters.com.
25. *** iMetos TNS, iMetos CP Manual, 2011. Pessl Instruments GmbH. Werksweg 107, 8160 Weiz, Austria, August 2011, Version 01.2011, 28 pp.
26. *** iMetos Eco Manual 2011. Pessl Instruments GmbH. Werksweg 107, 8160 Weiz, Austria, August 2011, 24 pp.
27. *** iMetos Field Climate user Manual, 2009. Pessl Instruments GmbH. Werksweg 107, 8160 Weiz, Austria, 8 pp.

28. *** iMetos AG, iMetos SM, 2005. Pessl Instruments GmbH. Werksweg 107, 8160 Weiz, Austria, Version 01.2010, 21 pp.
29. *** https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/202213
30. *** RootSense Stations, Viridix Technology, NaanDanJain Technology, Israel, www.naandanjain.ro.
31. *** NOAA National Centers for Environmental Information, Monthly Global Climate Report for Annual 2022, published online January 2023, retrieved on June 3, 2023.
32. *** Data sources: ERA5 (ECMWF Copernicus Climate Change Service, C3S); GISTEMPv4 (NASA); HadCRUT5 (Met Office Hadley Centre); NOAAGlobalTempv5 (NOAA), JRA-55 (JMA); Berkeley Earth; Copernicus Climate Change Service/ECMWF.

Tables and Figures

Table. 1 Working steps with the monitoring systems

N	Working steps	WatchDog	Pessl	Adcon* Telemetry	Delta T Devices	TrapView/ iTrap	Pheromones traps
1	Installation of the station in a representative area.	Yes	Yes	Yes	Yes	Yes	Yes
2	Buying a data transmission card.	Yes	Yes	Yes	Yes	Yes	No
3	Specific software installation.	Specware Pro 9	iMetos Field Climate 3.3 or superior	addVantage 6.4 or superior	DataLink 3.2 or superior	TrapView	No
4	Purchase and installation of warning software modules for the attack of diseases and pests in fruit growing.	Disease Management (apple scab, powdery mildew, apple scab, antrachnosis grey mold etc.)	Disease Management, apple scab, fireblight, brown spot, entomosporiosis, moniliose, shoot hole, mildew, peach clock, grey mold	Disease Management, specific module	Disease Management, specific module	No	No
		Insect Management, (*Psylla pyricola*; codling moth; red mite; gipsy moth; San Jose scale, peach fruit fly, peach moths plum moth, etc.	Insect Management, specific module	Insect Management, specific module/ (Degree Day)	Insect Management, specific module/ (Degree Day)	No	No
5	Purchase and installation of warning software modules for irrigation management.	Yes	Yes	Yes	Yes	No	No
6	Installing a free photo editor (IrfanView 4.4.5, XnView, PhotoFiltre 7.1.2. or superior), for screen captures.	Yes	Yes	Yes	Yes	Yes	Yes
7	Purchase and installation of soil and microclimate sensors and micro photovoltaic panels.	Yes	Yes	Yes	Yes	No	No
8	The monitoring itself, the collection, processing, interpretation of the data and the transmission of the results.	Yes	Yes	Yes	Yes	Yes	Yes
9	Making decisions regarding phytosanitary risk and carrying out phytosanitary treatments, fertigation, etc.	Yes	Yes	Yes	Yes	Yes	Yes

Table 2 Montly dynamic of meteo parametres at RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m, 1.01.-31.10.2018

2018	Temperature			Degree Days [n]	Wet Hours [n]	Wet Days [n]	Rain Fall [l/m2]	Rain Days [n]
Month	**High**	**Low**	**Mean**					
Jan	15.8	-13.1	0.6	2.9	0.0	24.0	36.1	20.0
Feb	13.1	-16.1	0.6	0.7	0.0	21.0	42.8	16.0
Mar	21.4	-19.8	3.7	22.2	3.8	23.0	89.0	19.0
Apr	29.4	-1.1	15.3	173.7	67.5	17.0	5.0	7.0
May	30.8	7.4	17.5	23.5	130.8	25.0	112.5	15.0
Jun	32.0	7.7	20.2	306.0	172.8	26.0	198.5	20.0
Jul	31.2	9.7	21.0	340.4	198.5	28.0	90.9	16.0
Aug	33.9	12.1	22.2	374.9	184.5	30.0	36.2	8.0
Sep	32.6	-1.5	17.1	225.8	78.5	23.0	14.3	7.0
Oct	26.4	1.7	12.1	107.1	27.8	21.0	2.0	3.0
Nov	18.3	-11.1	4.7	16.3	10.0	25.0	39.0	15.0
Dec	11.8	-9.6	-0.3	0.2	0.0	25.0	79.2	22.0
AVG_18	**24.73**	**-2.81**	**11.23**	**132.81**	**72.85**	**24.00**	**62.13**	**14.00**
STDEV	*8.184*	*10.890*	*8.768*	*145.34*	*78.816*	*3.411*	*55.923*	*6.223*
VAR	*33.10*	*-387.8*	*78.11*	*109.43*	*108.19*	*14.21*	*90.02*	*44.45*

Table 3 Montly dynamic of meteo parametres at RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 1.01.-31.10.2019

2019	Temperature			Degree Days [n]	Wet Hours [n]	Wet Days [n]	Rain Fall [l/m2]	Rain Days [n]
Month	**High**	**Low**	**Mean**					
Jan	10.4	-13.5	-1.2	0.0	0.0	19.0	63.7	17.0
Feb	19.2	-14.1	2.6	10.1	0.0	14.0	14.8	8.0
Mar	23.6	-4.4	7.8	53.2	1.3	12.0	21.2	6.0
Apr	26.3	-0.1	10.0	70.2	54.8	22.0	35.6	11.0
May	28.3	2.4	15.7	186.0	107.0	27.0	46.3	19.0
Jun	32.2	11.2	21.2	335.9	188.3	30.0	197.1	19.0
Jul	34.9	7.9	21.1	340.9	135.8	26.0	93.4	10.0
Aug	35.1	10.2	22.8	386.9	386.9	12.0	9.7	3.0
Sep	33.0	1.3	17.5	232.0	232.0	13.0	11.9	5.0
Oct	27.9	0.8	12.2	59.8	59.8	16.0	26.2	7.0
Nov	21.4	-1.1	9.3	45.8	74.3	30.0	56.2	19.0
Dec	19.4	-7.9	2.8	6.9	3.3	23.0	15.5	7.0
AVG_19	**26.0**	**-0.6**	**11.8**	**148.3**	**103.9**	**21.4**	**50.0**	**11.5**
STDEV	*7.50*	*8.31*	*8.00*	*143.24*	*117.48*	*7.19*	*52.71*	*5.92*
VAR	*28.87*	*-13.66*	*67.69*	*96.57*	*113.05*	*33.58*	*105.50*	*51.44*

Table 4 Montly dynamic of meteo parametres at RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 1.01.-31.10.2020

2020	Temperature			Degree Days [n]	Wet Hours [n]	Wet Days [n]	Rain Fall [l/m2]	Rain Days [n]
Month	**High**	**Low**	**Mean**					
Jan	15.0	-10.2	0.2	2.6	0.0	12.0	1.8	4.0
Feb	19.3	-8.5	4.2	14.5	0.0	12.0	22.5	7.0
Mar	23.3	-6.1	7.6	45.5	2.3	13.0	30.0	8.0
Apr	25.3	-3.9	10.9	101.4	11.3	79.0	21.1	6.0
May	30.1	4.3	15.0	169.0	79.0	168.8	104.1	14.0
Jun	32.8	4.3	19.6	290.2	168.8	98.3	166.2	14.0
Jul	35.3	11.6	22.0	368.9	98.3	94.0	52.0	11.0
Aug	35.2	11.0	22.2	372.8	94.0	94.0	29.2	10.0
Sep	33.8	0.2	18.9	269.7	81.0	81.0	68.2	6.0
Oct	27.4	-0.4	12.4	113.5	177.8	30.0	92.7	15.0
Nov	17.6	-4.9	4.7	8.0	0.0	26.0	8.8	12.0
Dec	12.9	-7.9	3.1	0.4	0.0	29.0	81.9	18.0
AVG_20	**25.67**	**-0.88**	**11.73**	**146.38**	**59.38**	**19.42**	**56.54**	**10.42**
STDEV	*8.04*	*7.38*	*7.81*	*144.28*	*66.90*	*7.67*	*48.18*	*4.32*
VAR	*31.33*	*-843.1*	*66.56*	*98.57*	*112.68*	*39.50*	*85.22*	*41.43*

Table 5 Montly dynamic of meteo parametres at RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 1.01.-31.10.2021

2021	Temperature			Degree Days [n]	Wet Hours [n]	Wet Days [n]	Rain Fall [l/m2]	Rain Days [n]
Month	High	Low	Mean					
Jan	13.3	-14.1	0.5	0.8	0.0	25.0	73.0	21.0
Feb	22.3	-10.3	3.0	13.9	2.0	18.0	12.4	7.0
Mar	18.8	-6.2	4.1	16.7	0.0	17.0	66.8	15.0
Apr	25.3	-3.3	8.6	47.4	8.3	22.0	38.4	12.0
May	28.4	2.5	15.6	184.0	132.0	25.0	65.4	16.0
Jun	34.0	7.0	19.3	278.2	225.0	29.0	104.0	18.0
Jul	36.8	12.5	23.5	408.6	66.0	18.0	33.5	9.0
Aug	36.4	9.0	22.4	372.4	82.3	16.0	74.0	9.0
Sep	30.4	2.7	15.6	178.4	62.3	27.0	14.3	6.0
Oct	22.7	-2.0	8.6	112.9	29.5	23.0	36.1	9.0
Nov	22.7	-2.0	8.6	27.5	29.5	23.0	36.1	9.0
Dec	26.3	-2.2	6.7	25.4	8.8	26.0	25.6	11.0
AVG_21	13.1	-11.6	1.6	0.6	0.5	25.0	91.9	16.0
STDEV	**25.65**	**-1.33**	**10.79**	**129.50**	**51.39**	**22.58**	**52.95**	**12.42**
VAR	*8.07*	*8.40*	*8.19*	*151.24*	*69.01*	*4.34*	*30.26*	*4.72*

Table 6 Montly dynamic of meteo parametres at RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 1.01.-31.10.2022

2022	Temperature			Degree Days [n]	Wet Hours [n]	Wet Days [n]	Rain Fall [l/m2]	Rain Days [n]
Month	High	Low	Mean					
Jan	17.8	-12.0	0.8	4.4	0.0	13.0	6.4	6.0
Feb	17.8	-7.6	3.1	7.8	0.3	12.0	11.0	9.0
Mar	22.1	-9.3	3.6	29.1	2.5	14.0	19.4	10.0
Apr	24.5	-3.8	10.1	75.2	38.5	20.0	88.0	13.0
May	31.5	2.9	16.4	211.3	96.5	23.0	72.6	13.0
Jun	36.8	11.0	21.1	329.3	154.3	25.0	25.6	10.0
Jul	38.3	8.7	22.8	383.7	92.8	17.0	25.3	12.0
Aug	35.2	12.9	22.6	384.3	128.3	25.0	142.1	15.0
Sep	29.4	2.3	15.6	184.0	189.8	29.0	49.6	11.0
Oct	27.1	1.2	12	104.5	46	30.0	4.3	3
Nov	26.7	-3.7	7.6	31.9	7.5	27.0	40.8	13
Dec	16.9	-7.1	2.8	5.8	8.8	28.0	40.4	16
AVG_22	**27.01**	**-0.38**	**11.54**	**145.95**	**63.78**	**21.92**	**43.79**	**10.92**
STDEV	*7.50*	*8.22*	*8.12*	*149.18*	*66.84*	*6.52*	*40.23*	*3.68*
VAR	27.1	1.2	12	104.5	46	30.0	4.3	3

Table 7 The main pathogens and pest surveyed and number of treatments effected during the study period. RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m

N.	Species	Pathogens	Pests	Year					
				2018	2019	2020	2021	2022	AVG
1	**Apple**	*Venturia inaequalis; Podosphaera leucotricha; Erwinia amylovora**	*Cydia pomonella; Dysaphis devecta; Dasineura mali; Operophtera brumata; Tetranychus spp.; Eriosoma lanigerum.*	12	15	18	16	13	15
2	**Cherry**	*Pseudomonas syringae pv. morsprunorum; Monilia laxa.*	*Rhagoletis cerasi; Operophtera brumata; Myzus cerasi*	10	14	14	10	10	12
3	**Plum**	*Stigmina carpophylla; Monilia laxa.*	*Cydia funebrana; Hyalopterus pruni; Acalitus phloeocoptes; Tetranychus spp.*	-	4	9	10	10	8
4	**Blueberry**	*Phomopsis spp.; Botryosphaeria corticis; Fusicoccum putrefaciens; Botrytis cinerea.*	*leaf rollers, sporadic attack*	9	12	7	8	6	8
5	**Red currant**	*Sphaerotheca mors-uvae Pseudopeziza ribes* Botrytis cinerea**	*Synanthedon tipuliformis; Cryptomyzus ribis.*	9	12	9	8	9	10

Note *Preventive treatments.

Table 8. Operational advantages of the monitoring systems and devices tested at RIFG Piteşti Romania

N	Operational Advantages & Disadvantages	Watch Dog	Pessl	Adcon* Telemetry	Delta T* Devices	TrapView/ iTrap	Pheromone traps
	ADVANTAGES						
1	Ease of installation and operation.	+	+	+	+	+	+
2	Accuracy and fast transmission of data collected through the GPRS mobile network.	+	+	+	+	+	-
3	Quick access to results based on user ID and password.	+	+	+	+	+	-
4	Friendly and easy to use graphical interface.	+	+	+	+/-	+	-
5	The possibility of querying the database and importing data as Excel files, for additional analyses, etc.	+/-	+	+	+/-	+	+/-
6	Chance to install a wide range of soil and microclimate sensors.	+	+	+	+	-	-
7	Chance to install a wide range of sensors to monitor the physiologic status of the trees.	+	+	+	+	-	-
8	Each system's default software or higher versions are compatible with forecasting and warning modules for key diseases and pests, which can be purchased and configured separately, depending on local needs.	+	+	+	+	-	-
	DISADVANTAGES						
9	The need to operate the systems by qualified personnel with experience in the use of automatic systems.	+	+	+	+	+	-
10	The need for periodic training depending on the improvement of sensors, hardware and software components and forecasting and warning systems.	+	+	+	+	+	+

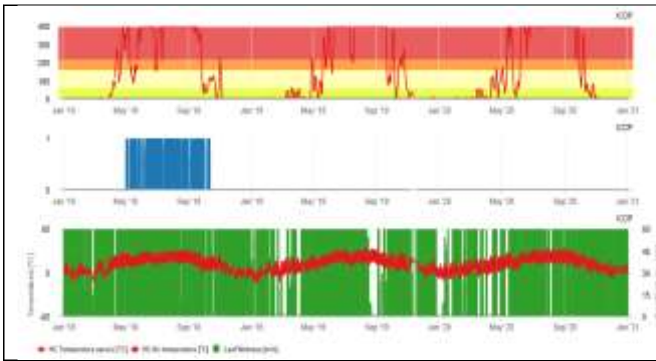

Fig. 1. Fireblight (*Erwinia amylovora*) infection risk RIFG Piteşti Romania, Lat. N 44.513; Long. E 24.52; Alt. 287m 2018-2020

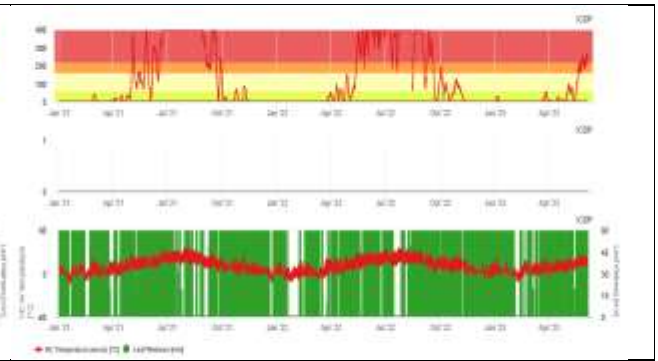

Fig. 2. Fireblight (*Erwinia amylovora*) infection risk RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 2021-2022

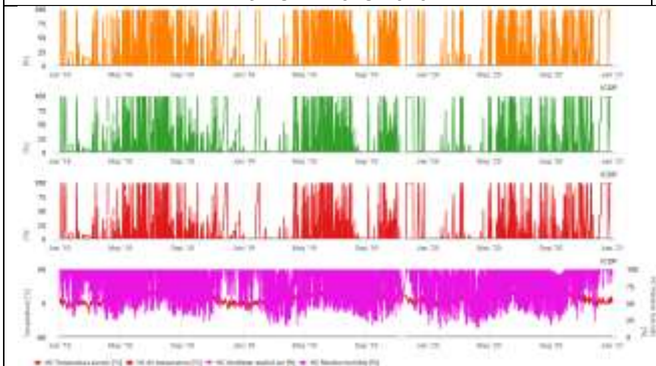

Fig. 3. Apple scab (*Venturia inaequalis*) infection risk RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 2018-2020

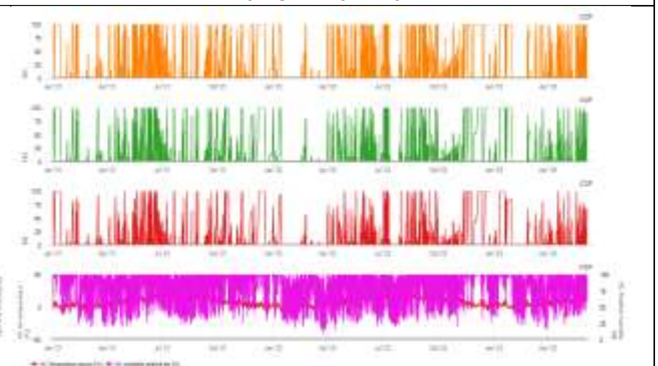

Fig. 4. Apple scab (*Venturia inaequalis*) infection risk RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 2021-2022

 DOI 10.33045/fgr.v39.2023.13

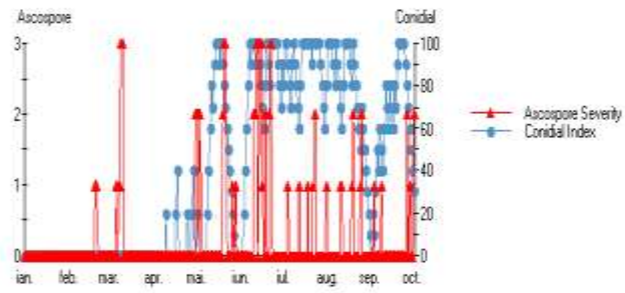

Fig. 5. Powdery mildew (*Podosphaera leucotricha*) infection risk RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 2020

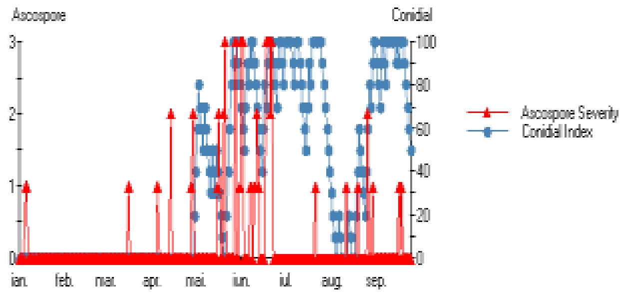

Fig. 6. Powdery mildew (*Podosphaera leucotricha*) infection risk RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 2022

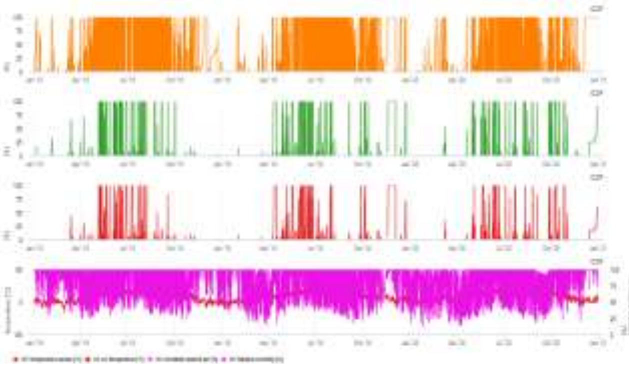

Fig. 7. Shoot hole (*Stigmina carpophylla*) infection risk RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 2018-2020

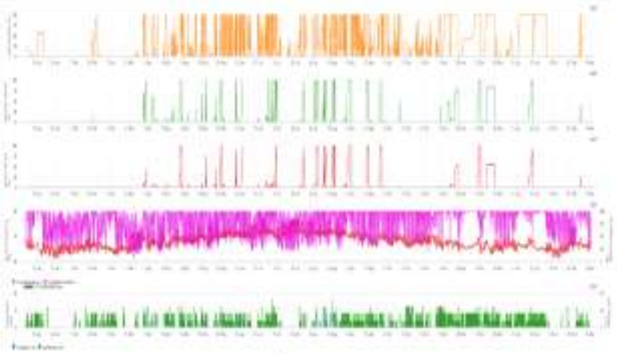

Fig. 8. Shoot hole (*Stigmina carpophylla*) infection risk RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 2021-2022

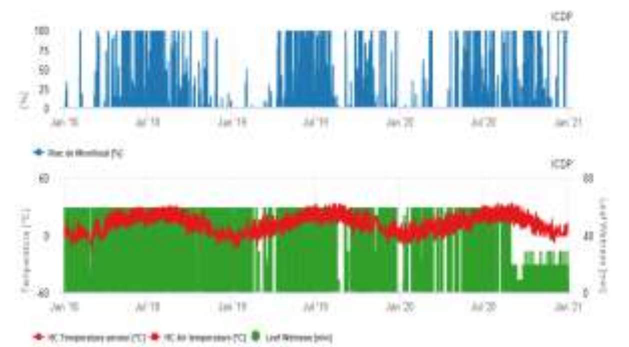

Fig. 9. Brown rot (*Monilia laxa*) infection risk RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 2018-2020

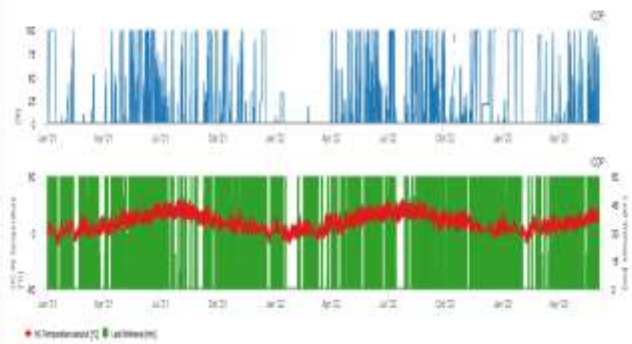

Fig. 10. Brown rot (*Monilia laxa*) infection risk RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 2021-2022

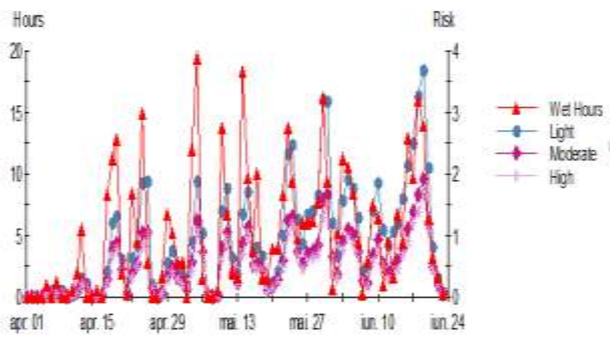

Fig. 11. Cherry anthracnose (*Blumeriela jaapii*) infection risk RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 2020

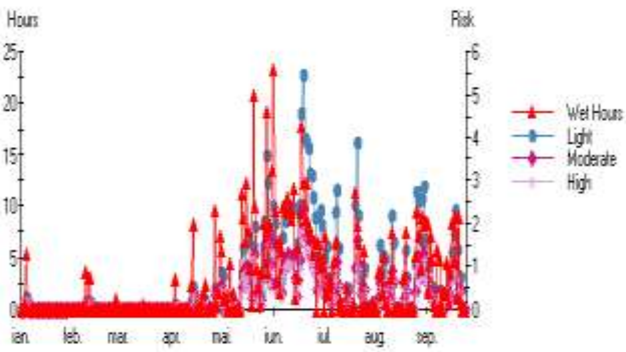

Fig. 12. Cherry anthracnose (*Blumeriela jaapii*) infection risk RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 2022

 DOI 10.33045/fgr.v39.2023.13

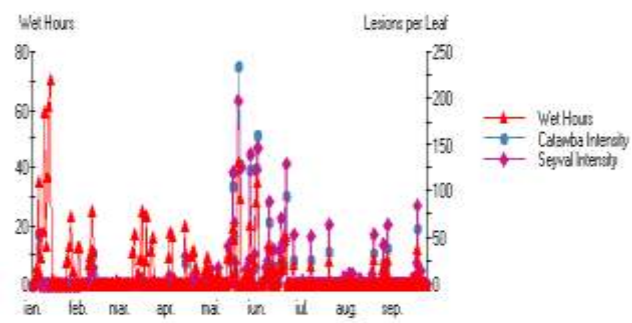

Fig. 13. Twig blight (*Phomopsis putrefaciens*) infection risk RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 2020

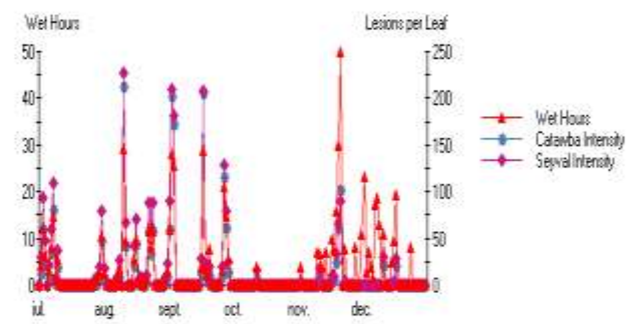

Fig. 14. Twig blight (*Phomopsis putrefaciens*) infection risk RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 2022

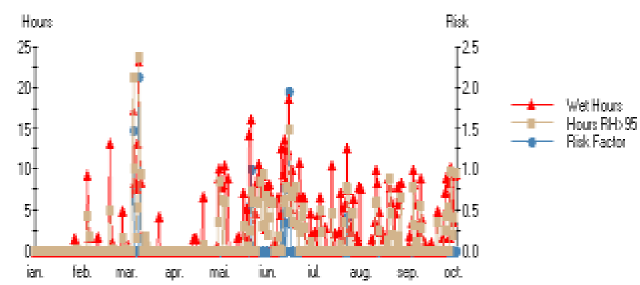

Fig. 15. Grey mold (*Botytis cinerea*) infection risk RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 2020.

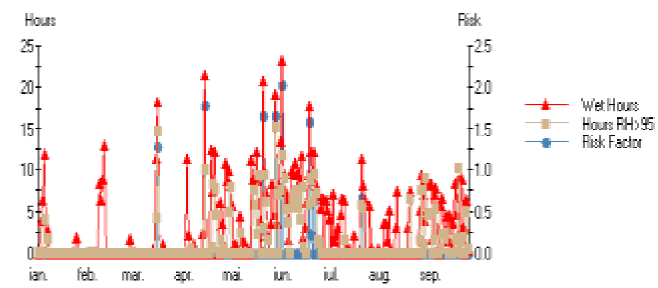

Fig. 16. Grey mold (*Botytis cinerea*) infection risk RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 2022.

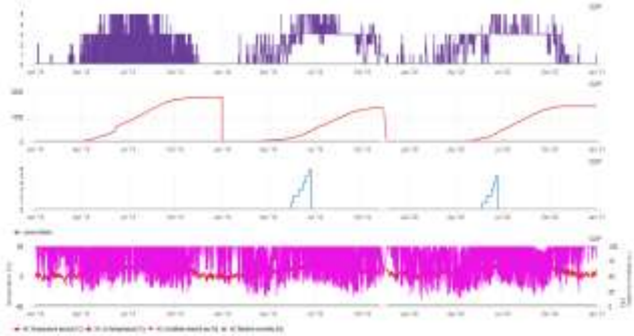

Fig. 17. Apple codling moth (*Cydia pomonella*) flight dynamic RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 2018-2020

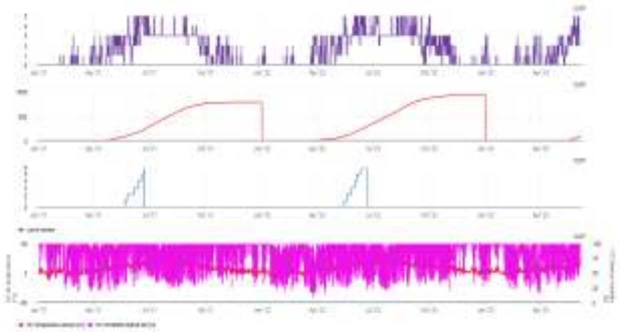

Fig. 18. Apple codling moth (*Cydia pomonella*) flight dynamic RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 2021-2022

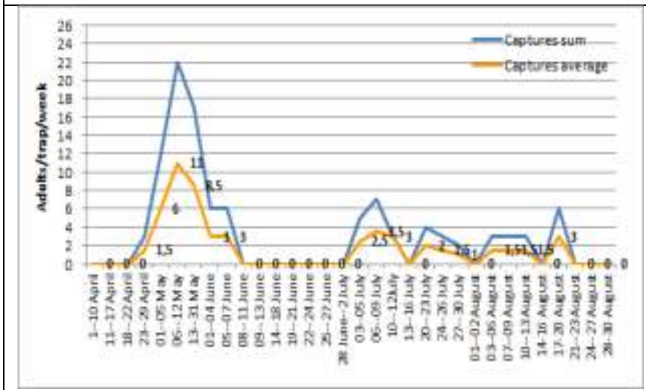

Fig. 19. Plum fruit moth (*Cydia funebrana*) flight dynamic RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 2018-2020

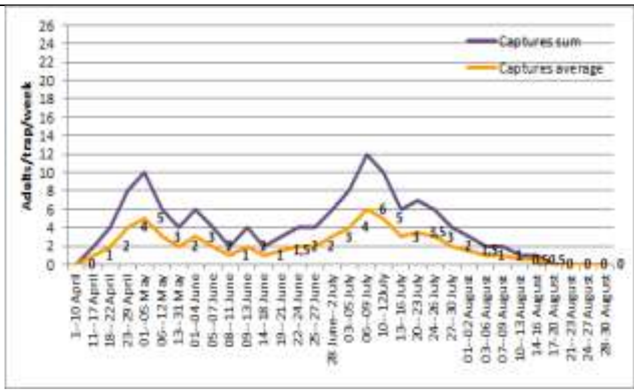

Fig. 20. Plum fruit moth (*Cydia funebrana*) flight dynamic RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 2021-2022

 DOI 10.33045/fgr.v39.2023.13

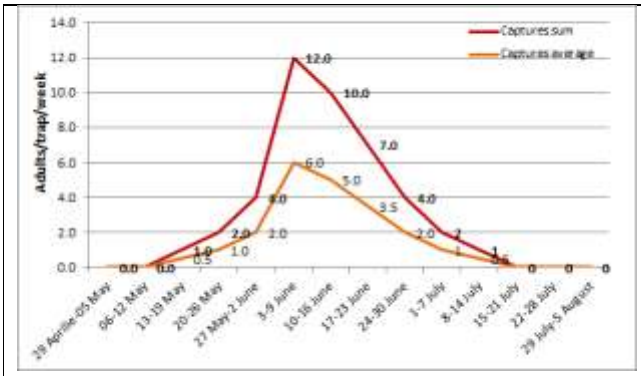

Fig. 21. Cherry fruits fly (*Rhagoletis cerasi*) flight dynamic RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 2018-2020

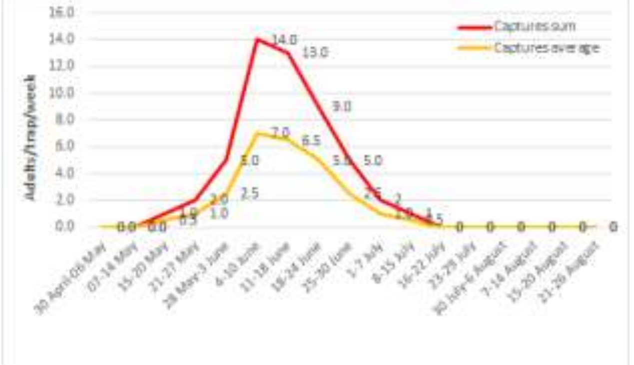

Fig. 22. Cherry fruits fly (*Rhagoletis cerasi)* flight dynamic RIFG Piteşti Romania Lat. N 44.513; Long. E 24.52; Alt. 287m 2021-2022