Goji Berry Gall Mite Expansion in Europe, with Emphasis on Southeastern Part of Romania

Roxana CICEOI¹, Vasilica LUCHIAN², Andrei Florin TABACU³, Minodora GUTUE⁴ and Mala-Maria STAVRESCU-BEDIVAN⁴*

¹ Research Center for Studies of Food Quality and Agricultural Products, University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59, Mărăști Bd., Bucharest, 011464, Romania,
² Faculty of Horticulture, University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59, Mărăști Bd.
³ Didactic, Research and Development Station for Viticulture and Fruit Growing Pietroasa - Istrița, University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59, Mărăști Bd., Bucharest, 011464, Romania
⁴ Faculty of Agriculture, University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59, Mărăști Bd., Bucharest, 011464, Romania
*Corresponding author: M. STAVRESCU-BEDIVAN e-mail: mala.stavrescu@agro-bucuresti.ro

SHORT COMMUNICATION

Abstract
In Europe, the goji crop is expanding rapidly, to satisfy the increased market demand for functional foods, with effects in chronic diseases treatment (cancer, diabetes, atherosclerosis, etc.). Romania has become in recent years one of the most important growers of goji berry, especially for organic production, as the species was quite resistant to main pests and diseases. Still, in 2008, a non-indigenous species of Eriophyid mites, called Aceria kuko, was identified on goji plants in UK and spread rapidly throughout the EU. The plant protection institutions took eradication measures, however the pest continued to spread in new plantations and recently on spontaneous plants. Based on GBIF, iNaturalist, personal observations and communication, the paper presents the current distribution of goji berry gall mite in Europe and in Romania and also suggests the use of new citizen science tool - ProtectGoji maps, that aims both to increase awareness of goji producers and consumers about this pest and to geolocate the species expansion in Romania for a better containment and control strategy.

Keywords: Aceria kuko; citizen science; Lycium barbarum, L. chinense; distribution maps.

INTRODUCTION
The closely related Lycium barbarum and L. chinense solanaceous species are known in Europe and Romania as Goji or Goji berry and their use increased exponentially in the last decades, being promoted as superfruits and functional foods (Wetters et al., 2018). The Goji has been used for millennia in China and neighboring countries for maintaining good health through traditional medicine and cuisine, and the recent attention in western countries is due to the high amounts of functional components, such as sugars, carotenoids, and essential fatty acids from plants (Yossa Nzeuwa et al., 2019, Chen et al., 2020). According to various authors, the genus Lycium includes globally more than 100 (Hummer et al. 2012), 80 (Zeng et al., 2014), or 70 species (Mocan et al., 2014) of deciduous or evergreen woody shrubs, but only three species are considered having high commercial value, L. barbarum, L. chinense and L. ruthenicum. The chemical diversity of L. barbarum fruits provide many opportunities in the worldwide polyphenol market (Mocan et al., 2019). Lycii Fructus, the dried goji berries, contain high amounts of polysaccharides that may prevent and even treat diverse...
chronic diseases, as cancer, diabetes atherosclerosis, and male infertility because of their high antioxidative properties (Chen et al., 2020, Ilic et al., 2020). For instance, the anti-diabetic effects seem to be given by the uracil, rutin, and ascorbic acid contents from fruits, while betaine was found responsible for hepatoprotective, hypotensive, and anti-diabetic effects (Ryu et al., 2020). Lycii Radicis Cortex, the dried bark of goji roots has been used in treating hypertension and reducing serum glucose and lipids (Cho et al., 2011) while the complex root extract inhibits hepatic damage and protects the skin from UVB radiation (Chen et al., 2020). Lycii folium, the dried goji berry leaves, also possesses multiple pharmacological effects, including antimicrobial, antioxidant, anti-inflammatory and anti-diabetic effects (Mocan et al., 2014, Mocan et al., 2017, Xiao et al., 2019, Lee et al., 2021).

Besides China, goji berry has been commercially produced in other Asian countries such as Japan, Korea or India and also by the farmers in Canada and the US, being postulated that the demand for these fruits has become greater than the supply (Chen et al., 2018). Due to the nutritional values and health benefits of L. barbarum fruits, the different Goji berry products such as juice, cake, pastry, snacks, or herbal teas were considered as a superfood in Europe and North America (Pop et al., 2013, Ma et al., 2019, Ye and Jiang, 2020). Nevertheless, food safety and food quality aspects are to be considered in relation with goji derived products.

From the food safety perspective, in Romania there is still confusion related to which goji fruits are edible and which are toxic, because goji’s Latin name L. hamifolium is a synonym of L. barbarum, but people consider that the species are different. The wild goji growing in Romania, also known as `cătina de garduri` (fence sea buckthorn), is believed or even intentionally presented in social media and online journal articles as being toxic (Karaman et al., 2019, Agrointel, 2017). L. barbarum might have Mediterranean origin, as proved also by the Italian name “licio d’Europa” (EPPO, 2021), and represents 90% of the world production (Zhang et al., 2016), therefore a careful analysis of the wild biotypes that grow in different corners of Romania or Europe needs to be performed prior to advising which fruits are good for consumption.

From the food quality perspective, goji is a quite resistant species, being cultivated in the northwest part of China for over 5 millennia due to its strong resistance to abiotic stress as well as its economic value (Gong et al., 2016). In Romania, the fruits quality and production are mostly affected by mildew and two invasive pest species, Halyomorpha halys and Aceria kuko. The marmorated stink bug H. halys was first introduced in Romania in 2014, and first damages on goji crops were found in 2016 in the northern area of Bucharest. Very often, on goji plants H. halys and Nezara viridula coexist (Ciceoi et al., 2017).

Aceria kuko, the goji berry gall mite, recently invaded Europe and extended to Romania. In 2008, the non-indigenous species of Eriophyid mites A. kuko was identified on goji plants in Guernsey, UK, and spread rapidly. This mite is a pest of goji berries, but some reports indicate this species is also damaging sweet peppers or infesting solanaceous weeds (Anderson and Ostoja-Starzewski, 2010). It causes small blisters on the leaves and damages young shoots of the plants, preventing flowers and fruits from forming (Halbert, 2019). The induction of galls on Goji leaves reduces their photosynthetic ability and fruit yield, which raise their farming costs, thereby leading to economic loss (Chen et al, 2020). It is known that eriophyid mites reproduce extremely quickly, being able to build up millions of individuals within a single season (Marini et al., 2021). Considering the increasingly popular goji berry cultivation, the goji berry mite expanded its distribution in Europe and North America by plant material for planting. EU plant protection institutions took eradication measures, but the pest continued to spread (Suvák, 2020), even though in some countries the removal of all infested plants is practiced (Trajcevs, 2018). Based on current evidence provided by the EPPO Database, Aceria kuko (Kishida, 1927) is present in four Asian countries (China, Japan, Korea, Republic Taiwan), in the United States (only Florida is referenced) and in 16 countries from Europe (EPPO, 2021).

To answer the challenges related with both food safety and food quality perspectives, a new project intends to develop tools for easier prevention and control of this pest. The paper presents one of the tools to be developed, the maps depicting the current distribution of goji berry gall mite in Romania and the risks for expansion, represented both by the spontaneous and planted goji berry plants. The novelty of this future research consists in developing a citizen science tool that intends to increase awareness of goji producers and consumers about this pest and to geolocate the species expansion in Romania for a better containment and control strategy. Maps including the data provided by the database GBIF, iNaturalist and social media illustrate in real time the goji mite expansion in Romania and the reservoirs of spontaneous Lycium spp. plants.

MATERIALS AND METHODS

The ProtectGoji project aims to develop three pest prevention and control methods to be used in goji berry production technology to grant a high-quality fruit production. These methods target the optimal intervention time for curative treatments, the elaboration of the distribution maps and identification of goji mite-resistance using molecular markers. The most important, the three maps were designed as preventive tools: the distribution of cultivated plants, the distribution of goji wild plants and the updated distribution of goji berry gall mite.
To build the Aceria kuko distribution maps, directs reports, the GBIF and iNaturalist datasets and scientific data started to be used. For the future development of these maps, a project webpage having an integrated forum and social media accounts (Facebook, Twitter, Wordpress based blog and Whatsapp) will be launched and developed according to the best practices in developing citizen science projects. The direct reports are the field observation already made by the project members. Data generated through these observations are the foundation of defining the citizen science campaign and releasing the “ProtectGoji Tutorial: how to identify the goji berry plant mite and its spontaneous hosts”. The GBIF stands for the Global Biodiversity Information Facility (www.gbif.org), an international network and data infrastructure funded by the world’s governments and aimed at providing anyone, anywhere, open access to data about all types of life on Earth. It also incorporates the validated datasets from iNaturalist (GBIF, 2021).

iNaturalist (www.naturalist.org) is an online social network of people sharing biodiversity information, the observations being recorded for numerous reasons, as participation in citizen science projects, school projects, and personal fulfillment (Ueda, 2021). Although its main goal is to connect people to nature, iNaturalist functions as a crowdsourced species identification system and an organism occurrence recording tool, that generates scientifically valuable biodiversity data from the personal encounters. ProtectGoji encourage the volunteers to personally upload their data on iNaturalist platform, raising awareness among Romanians about collecting biodiversity data. Currently Romania has only one citizen science project listed on the EU citizen science platform (EU Citizen science, 2021) therefore this type of approach is needed both for biodiversity studies and citizen involvement in science.

The maps for Romanian distribution were built in Google My Maps and MapChart applications using the GPS coordinates of the record, the pictures taken in the field work, several aspects related to the number of hosts plants, the degree of attack and special mentions.

RESULTS AND DISCUSSIONS

Since 2016, when only seven countries were reporting the first occurrences of A. kuko on their territories (Ciceoi and Mardare, 2016), the mite continued to spread, its presence being confirmed now in Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, France, Germany, Greece, Hungary, North Macedonia, Romania, Serbia, Slovakia, Slovenia, and United Kingdom (EPPO, 2021) and reported in another four countries on biodiversity platforms or citizens reports (Table 1), rising the number of EU reporting countries to 20 (Figure 1). In 2020, Suvák also reviewed A. kuko distribution, counting 14 countries and adding Slovakia on the host’s map. An important new record concerns Estonia, the first Nordic country reporting the pest in 2017, (Marvet and Voolma, 2017). All these reports were related to cultivated plants, that have been usually introduced from abroad, mainly by the hobby gardeners. In Romania, in 2021, the pest was found on spontaneous goji berry shrubs in Bucharest and 4 counties (Constanta, Giurgiu, Ilfov and Prahova), but its presence is not excluded from other administrative divisions, considering the mite spreading potential.

Table 1. Citizen scientist’s occurrence reports in European countries where Aceria kuko has not been officially reported yet

<table>
<thead>
<tr>
<th>Country</th>
<th>Location (City and GPS Coordinates)</th>
<th>Reporting Date</th>
<th>Host Plant</th>
<th>Platform</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>Wien, 8.1871979871: 16.397508122</td>
<td>2019-09-13</td>
<td>Lycium barbarum</td>
<td>GBIF</td>
<td><a href="https://www.inaturalist.org/observations/69460779">https://www.inaturalist.org/observations/69460779</a></td>
</tr>
<tr>
<td>Italy</td>
<td>Rho (Milan), 45.5326°, 9.0396°</td>
<td>2017-07-04</td>
<td>Lycium chinense</td>
<td>forum.giardino.it</td>
<td><a href="https://forum.giardino.it/threads/problema-con-goji.240302/">https://forum.giardino.it/threads/problema-con-goji.240302/</a></td>
</tr>
<tr>
<td>Spain</td>
<td>Huelva, 37°13’11.9” 6°30’58.6”</td>
<td>2021-03-06</td>
<td>Lycium sp.</td>
<td>Global tribe, pers comm.</td>
<td><a href="https://www.global-tribe.org/">https://www.global-tribe.org/</a></td>
</tr>
<tr>
<td>Ukraine</td>
<td>Kiev, 50.4062937665 30.5641519278</td>
<td>2018-07-10</td>
<td>Solanum nigrum</td>
<td>GBIF</td>
<td><a href="https://www.inaturalist.org/photos/112723679">https://www.inaturalist.org/photos/112723679</a></td>
</tr>
<tr>
<td>Ukraine</td>
<td>Kiev, 50.4062937665 30.5641519278</td>
<td>2018-08-30</td>
<td>Lycium chinense</td>
<td>GBIF</td>
<td><a href="https://www.inaturalist.org/observations/69469300">https://www.inaturalist.org/observations/69469300</a></td>
</tr>
</tbody>
</table>

**Reported as Aceria eucricotes** (Nalepa, 1892)

<table>
<thead>
<tr>
<th>Country</th>
<th>Location (City and GPS Coordinates)</th>
<th>Reporting Date</th>
<th>Host Plant</th>
<th>Platform</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>Wien, 48.30436: 16.414481</td>
<td>2021-06-27</td>
<td>Lycium barbarum</td>
<td>iNaturalist</td>
<td><a href="https://www.inaturalist.org/observations/84724329">https://www.inaturalist.org/observations/84724329</a></td>
</tr>
</tbody>
</table>

*Taxonomic studies are required, considering the identification was only based on host plant

95| VOLUME 78 ISSUE 2 | NOVEMBER
Current distribution of Aceria kuko in Europe

The current official distribution of A. kuko includes 16 countries, mentioned above. Still, some biodiversity reports from Austria, Italy, Spain, and Ukraine require scientific deeper analysis (Table 1).

Aceria is the largest genus of Eriophyidae, with more than 900 species worldwide, hosted by many plant families. Usually, Aceria spp. mites are restricted to a single species of host plant, but some species feed on multiple species within the same plant genus, or related plant genera (Ripka and Sánchez, 2017). Considering Tajaddod et al. (2020) work, there are currently nine different mite species belonging to Aceria genus, that attack Lycium species. Of these, A. eucricotes is known to infest the European goji (L. europaeum), A. kendalli infests L. barbarum while A. kuko attack L. chinense. However, several authors noticed that A. kuko is hosted both by L. barbarum and L. chinense, making the pest identification even more complicated (Ciceoi and Mardare, 2016, Ripka and Sánchez, 2017). The current geographical distribution of A. eucricotes includes Spain, Canary Islands, Sardinia and Sicily (Ripka and Sánchez, 2017), still, iNaturalist provides 13 observations from Austria, Slovakia, Germany, Spain, while GBIF platforms contain six mentions from Hungary, Spain and USA, both on L. barbarum and L. chinense, that may cause confusion. Considering the above, there is still uncertainty regarding goji gall mite current distribution, a complex task that requires collaboration between taxonomist from different countries (Figure 1).

According to Halbert (2019), the taxonomy of Aceria genus is continuously evolving, some scientists asking for revision, and many records now belonging to Aceria kuko might be reassigned to A. tjyingi (Mason, 1973) or A. kendalli (Baker, 1996).

Current distribution of Aceria kuko in Romania

In Romania, in 2021, the pest was found in 5 counties and the capital (Figure 2), of which in 4 locations on spontaneous goji berry shrubs (Constanta, Giurgiu, Ilfov and Prahova) and in two locations on cultivated plants (Bucharest and Buzau). In Ilfov county, the wild plants are at about 5 km direct flying distance from the known infested site from Bucharest, on shrubs growing on an artificial waterway (canal and lake).

Up to date, goji cultivars and marketing brands for Lycium barbarum were registered in the following Romanian counties: Bihor, Brașov, Călărași, Cluj, Constanța, Dâmbovița, Hunedoara, Prahova, Satu Mare, Sibiu and Vaslui, counties distributed all over the country, with the most appreciated cultivars being “Erma”, “Transilvania” and “Kronstadt”. Considering the difficult identification of mites on plant material intended for new plantations, it is mandatory that all goji producers be advised and aware of the symptoms, in such a way that the spread be limited and contained.
The recent identification of the pest on wild plants on the Southeastern part of Romania (Figure 2), far away of any cultivated sources, in the context of recent climate changes and previous mentions of symptoms on other solanaceous plants, bring into the light uncertainty and threats, both for goji berry crops and other economic important solanaceous crops.

![Figure 2. The current distribution of *Aceria kuko* in Romania, including the counties where reports must be verified by taxonomists](image)

It has been noted that Citizen science projects are important for science education, concerning both general methods and specific knowledge about the taxa (Roetman and Daniels, 2011, Palmer, 2017). The contributions of citizen science are significant in conservation and biodiversity research, since professional scientists can train a global interdisciplinary network to accomplish faster their tasks (Soteropoulos et al., 2021).

A throughout citizen science campaign is foreseen to be launched in October 2021, under the name ProtectGoji, to identify other possible infested sites and raise awareness among goji growers and hobby gardeners. Without citizens reports, the real distribution of the pest might pass unnoticed until a generalized spread, with high economic and biodiversity costs.

**CONCLUSIONS**

This paper provides the first data concerning the distribution of *Aceria kuko* on spontaneous plants, in Romania and new insights on possible distribution in EU. Out of the eight Romanian counties in which the presence of wild goji plants was reported, four also include reports about the mite pest. The goji berry gall mite is expanding its range, with unknown consequences on the cultivated and spontaneous plants, and geolocation of infested spots is proposed as a measure of containment. Further studies will focus on the potential risk of mite distribution in *Lycium* spp. cultivars, due to the increased interest for health benefits of goji berry consumption.

**Author Contributions:** R.C. and M.M. S-B. Conceived and designed the paper; R.C., V. P., M.T., A.T., M.M. S-B Collected the data; R.C. and M.M. S-B. Wrote the paper.
**Funding Source:** This research work was carried out with the support of a grant of University of Agronomic Science and Veterinary Medicine of Bucharest, project number 1268/30.07.2021, acronym ProtectGoji, within IPC 2021.

**Acknowledgments**
We would like to express our gratitude to those who helped identifying new occurrences of Aceria kuko in Romania, as USAMV Bucharest student Ionela Sion and Cătălin Mihai Croitoru, responsible for ecological education in Comana Natural Park Administration.

**Conflicts of Interest**
The authors declare that they do not have any conflict of interest.

**REFERENCES**


8. EU Citizen science. Projects [Internet]. [cited 2021 September 12], https://eu-citizen.science/projects

9. GBIF. What is GBIF? [Internet]. [cited 2021 September 12], https://www.gbif.org/what-is-gbif


