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POPULATION DYNAMICS AND SPATIAL DISTRIBUTION OF *Panaphis juglandis* (Goeze, 1778) (Hemiptera: Aphididae) ON COMMON WALNUT (*Juglans regia* L.)

DYNAMIKA POPULACJI I ROZKŁAD PRZESTRZENNY *Panaphis juglandis* (Goeze, 1778) (Hemiptera: Aphididae) NA ORZECHU WŁOSKIM (*Juglans regia* L.)

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Streszczenie. W Polsce orzech włoski ze względu na swój pokrój i okazałe liście zdobył uznanie jako drzewo zdobiące otaczającą nas przestrzeń. Celem pracy było prześledzenie rozkładu przestrzennego *Panaphis juglandis* (Goeze) zasiedlającej drzewa *Juglans regia* L. w różnych siedliskach, w odniesieniu do warunków pogodowych. Badania prowadzono na orzechu włoskim (*Juglans regia* L.) w Siedlcach w latach 2010–2012. Do obserwacji wytypowano trzy stanowiska w ogrodach przydomowych (H1, H2, H3) oraz jedno stanowisko przyuliczne (H4). Badania wykazały, że więcej populacji szkodnika występowało w miejskich zadrzewieniach w pobliżu ulic, niż w przypadku badanych drzew z ogrodów przydomowych. *P. juglandis* zawsze występowała na górnej stronie liści złożonych orzecha włoskiego i formowała kolonie w pobliżu nerwu głównego tylko na pierwszych trzech zewnętrznych listkach w liściu złożonym orzecha włoskiego.

Key words: aphids, *Panaphis juglandis*, walnut, population dynamics.
Słowa kluczowe: mszyce, *Panaphis juglandis*, orzech włoski, dynamika populacji.

INTRODUCTION

Walnut (*Juglans regia* L.) tree cultivation is widely distributed around of Northern Hemisphere. Common walnut is one of the most cultivated species throughout Northern Africa, Eastern Asia and Southern Europe. This species grows well in virtually all parts of the world with a temperate climate. Recently, there has been an increasing demand for walnut since its nuts are considered one of the most nutritional and healthy food (Christopoulos and Tsantili 2015; Copolovici et al. 2017; Pollegioni et al. 2017). Thus the tree has great socio-economic importance being frequently cultivated in temperate zones of the world mainly because of its oil is rich in unsaturated fatty acids, phytosterols and tocopherols (Amaral et al. 2003, 2005) and whose consumption has been recently related to health benefits (Sabaté et al. 1993; Anderson et al. 2001; Fukuda et al. 2004). Moreover, its non-edible parts such as

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leaves, husks and wood also find broad application as flavour liqueurs (Jakopic et al. 2007), cosmetics (Tsamourisa et al. 2002), dyes (Park et al. 2005), furniture and in traditional medicine product (Amaral et al. 2008).

Walnut leaf has been widely used in folk medicine for treatment of venous insufficiency and haemorrhoidal symptomatology, and for its antidiarrheic, antihelmintic, depurative and astringent properties (Bruneton 1993). Keratolytic, antifungal, hypoglycaemic, hypotensive, anti-scrofulous and sedative activities have been also described. Several of these traditionally attributed actions may be due to tannins known to occur in these leaves, but also to several phenolic compounds (Amaral et al. 2008). Among then phenolic acids, flavonoids and naphthoquinones are the most important phenolic compounds within walnut leaf tissues (Jakopic et al. 2008; Chrzanowski et al. 2011; Nour et al. 2013). In fact, several pharmacological effects have been ascribed to flavonoids, such as anti-inflammatory, antihepatotoxic, antitumor, antimicrobial, antiviral, and enzyme inhibition (Cai et al. 2004).

Two species of aphids colonize walnut, large walnut aphid *Panaphis juglandis* (Goeze 1778) and small walnut walnut aphid *Chromaphis juglandicola* (Kaltenbach 1843) (Jaśkiewicz and Kmieć 2007; Karczmarz 2012; Leszczyński et al. 2012; Wani and Ahmad 2014; Krzyżanowski 2017). Walnut aphid is native to the Old World and invaded California at the beginning of the 20th century. It is supposed that its homelands were Central Asia and South-Eastern Europe. Distribution of this tree includes a narrow but quite long strip of land, passing through Asia Minor, Persia, Caucasus, along the Himalayas through Tibet, up to China (Debach 1974; Karczmarz 2010).

P. juglandis has been also widely known under the name of *Callaphis juglandis*, but the generic name *Callaphis* Walker has been suppressed by the opinion No. 147 of the ICZN following the plea of Quednau (l983) on the grounds of potential confusion with *Callaphis* Walsh. The species was originally described from Germany (Goeze 1778), and it is common throughout Europe from Spain (Nieto Nafría and Mier Durante 1998), Italy (Barbagallo et al. 1995), Serbia (Petrovič 1998) to Denmark, Sweden (Heie 1982) and Poland (Szelęgiewicz 1972). *P. juglandis* colonize only the top side of the walnut leaf, establishing characteristic colonies along the main vascular vein (Jaśkiewicz and Cichocka 2004), but *Ch. juglandicola* was observed on the bottom part of the leaf blade (Jaśkiewicz 2003; Krzyżanowski 2017). *P. juglandis* is much larger than the *Ch. juglandicola* and works entirely on the upper surface of leaves while *Chromaphis* feeds on lower surface of the walnut leaves. Both aphids are phloem feeders and reduce tree vigour, nut size, yield, and its quality. In addition to direct feeding damage, they excrete copious amounts of honey-dew that falls onto nuts, leaves and shoots. Honey-dew supports growth of the black sooty mould fungus. This fungus reduces light penetration to the leaf surface and reducing its photosynthetic capacity. Being black, it also absorbs heat to predispose nuts to sunburn and subsequent kernel quality loss due to high temperatures. High populations of the aphids may also cause leaf drop, and exposing more nuts to sunburn. If heavy populations are allowed to develop (i.e. > 15 aphids per walnut leaflet) and remain for at list 14 days uncontrolled, current season's nut quality is reduced along with a substantial reduction in the following season's crop (Wani and Ahmad 2014).

There is no data in the literature on the detailed spatial distribution of the large walnut aphid on leaflets in walnut composite leaf. The aim of three-year studies was to establish the population dynamics and spatial distribution of *P. juglandis* settling the different leaflets on composite leaf in trees of *J. regia* in Siedlce stands.

MATERIAL AND METHODS

Studies were conducted in the area of Siedlce during 2010–2012. Four observation trees of *J. regia* were designated:

A. Home gardens location – situated in a single family housing estate (H1, H2, H3).
B. The street-side location was situated at the crossing of busy roads (H4).

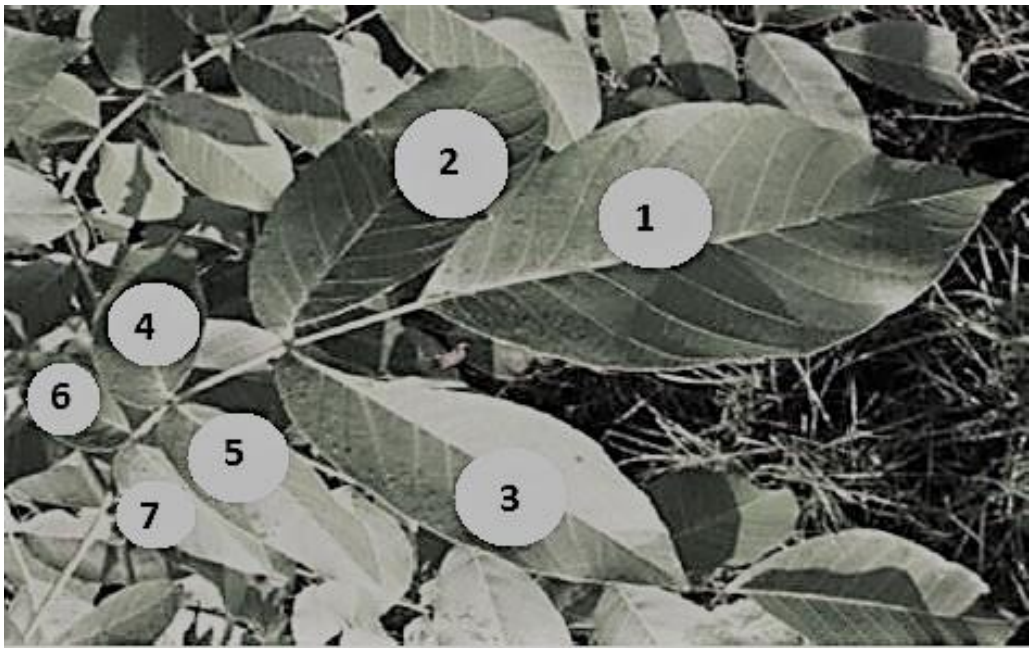

Fig. 1. Diagram of leaflets in composite leaf of walnut
Source: after Krzyżanowski (2017).
Ryc. 1. Schemat oznaczenia pojedynczych listków w liściu złożonym orzecha włoskiego
Źródło: wg Krzyżanowskiego (2017).

In each of the selected stands a sample of 25 composite leaves was collected. The samples were taken every 10 days from May to September. The collected material was viewed in a laboratory, under a stereoscopic microscope. Identification of this aphid as to species was conducted on the basis of durable slides. Blacman and Eastop (2000) and Cichocka (1980) keys were used for determinations.

Results were the basis for the determination spatial distribution of *P. juglandis* for leaflets, which are marked with the following symbols 1–7 (Fig. 1). Results for the individual dates are presented in the form of the average number of aphids per composite leaf of walnut.

Whether conditions (temperature, relative humidity) in year 2010–2012 were measurement by Kestrel 4000 (Nielsen-Kellerman, USA) with Kestrel Communicator Software ver.2.5/2014 (Nielsen-Kellerman, USA) – Fig. 5–6.

RESULTS

During the 2010, a single specimens of *P. juglandis* appeared on stand H4 at the first decade of May. At the home garden stands H1–H3, the first single specimens of plant lice was observed in the third decade of May (Fig. 4), and always development of the aphid population started on external leaflets (1–4). At the H4 street stand a higher number of alatae females occurred between the first and the third decade of May (leaflets 1–2). Moderately warm May up to the first decade June (15–20°C), with an average rainfall, enhanced development of the aphid population (Fig. 2).

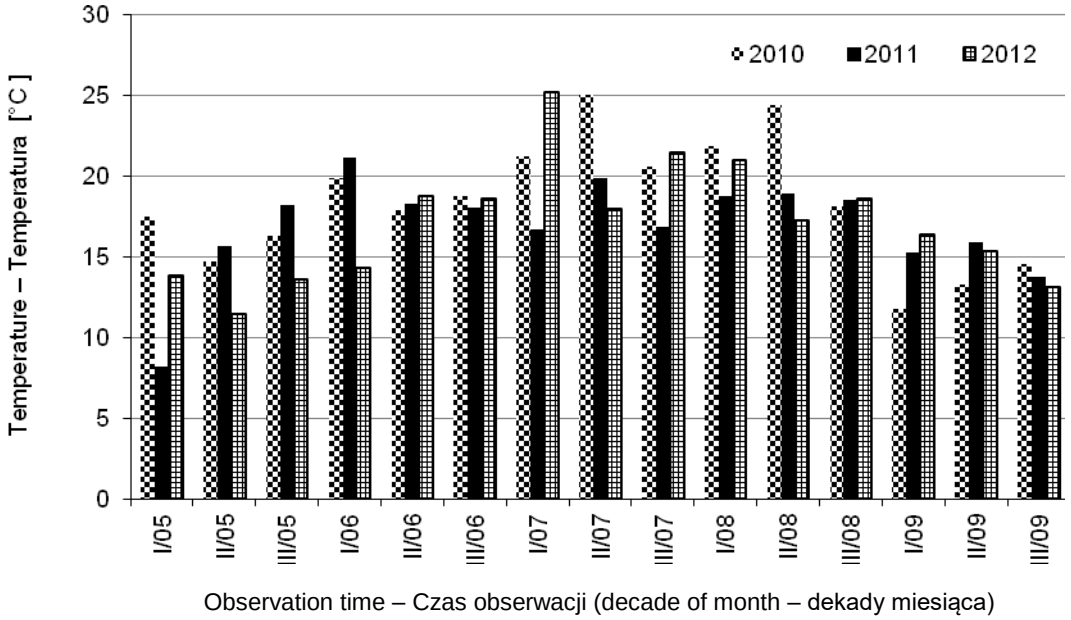

Fig. 2. Temperature measurement in the years 2010–2012
Ryc. 2. Pomiar temperatury w latach 2010–2012

Next, the number of the aphids suddenly increased and the peak population, was reported in the second decade of June for H4 stand and third decade of June for H1 stand (Fig. 4). The home garden stands showed a higher number of alatae females during the first decade of June on three first external leaflets. In the subsequent observations, when the temperature increased up to 25°C and the rainfall was more intensive, the number of plant lice significantly decreased to third decade of July and in the first decade of August no aphids were found to be present on the leaves of *J. regia* in the home garden trees (Fig. 2). *P. juglandis* stayed on the examined tree H4 to third decade of August and remained on the tree to second decade of September. In third decade of September, decrease at high temperatures (less than 15°C), no aphids were observed on the examined four leaflets (1–4) (Fig. 4).

Since the early start of vegetation, in the year 2011, the first apterae of *P. juglandis* were found on stand H2 in the third decade of April. Then, cool spring (temperature about 7°C), with low level of precipitation and persistent in a given period of constant humidity (about

80%) appeared (Fig. 3). It stopped development of the aphid population on the stand H1-H3, but on suddenly increased on the stand H4 on the all studied leaflets (1–4). The peak population occurred, when the temperature was less than 20 °C, in all examined trees at the second decade of June (Fig. 5). In the next 10-days period the aphid population radically decreased. Finally, the last specimens of *P. juglandis* were reported in the third decade of August (H1–H3). However, the aphids detected in H4 stand were still present there August and the up to the second decade of September, when the temperature decreased to about 15°C (Fig. 2–3).

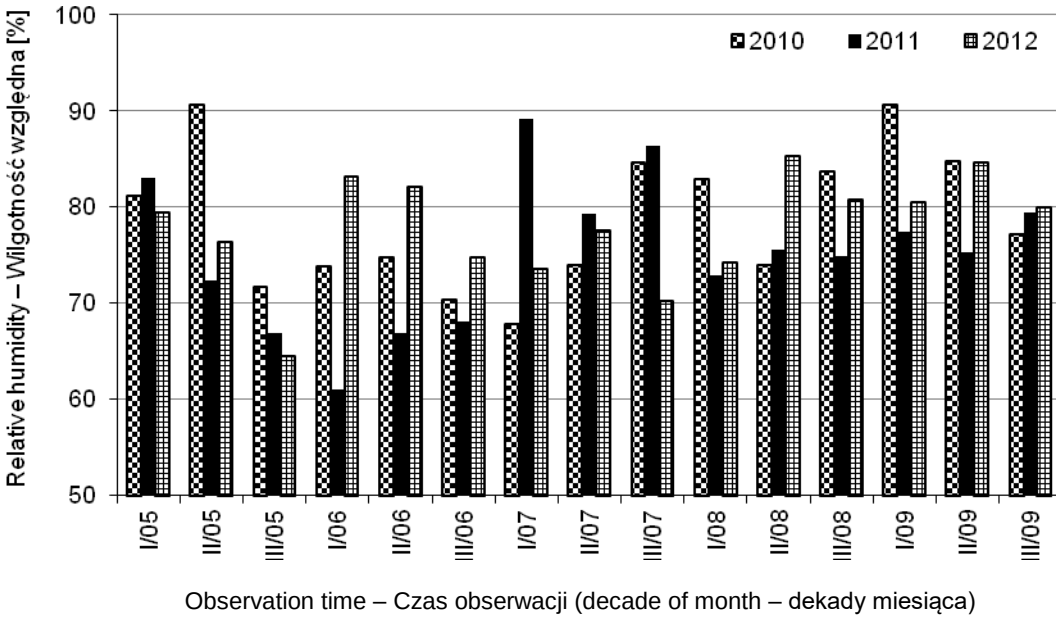

Fig. 3. Relative humidity conditions during 2010–2012
Ryc. 3. Pomiar względnej wilgotności w latach 2010–2012

In the last year of the observations (2012), the first aphids on the H4 trees was observed in the first decade of May (Fig. 6), instead the highest number of alatae females occurred there between the third decade of April and the first decade of June (leaflets 1–3). Maximum of the aphid populations were observed at the second decade of June (H1–H3 stands) on first external leaflets (1) and in H4 tree on three leaflets (1–3). In subsequent observations the population of *P. juglandis* significantly decreased and systematically was reduced up to third decade July. Results of the observations were seriously affected by weather conditions, including such decrease in level of precipitation and humidity during the third decade of July, and increase of daily temperature up to 20°C between the second and the third decade of July (Fig. 2–3). At the beginning of August aphid population radically decreased. However, when the daily temperature decreased (temperature under 20°C), the second peak of the walnut aphid population appeared at the third decade of August (stands H1 and H4), on four leaflets (1–4) (Fig. 6). The followed observations between August and September showed further decrease of daily temperature and decrease of aphid number in this (Fig. 2–3).

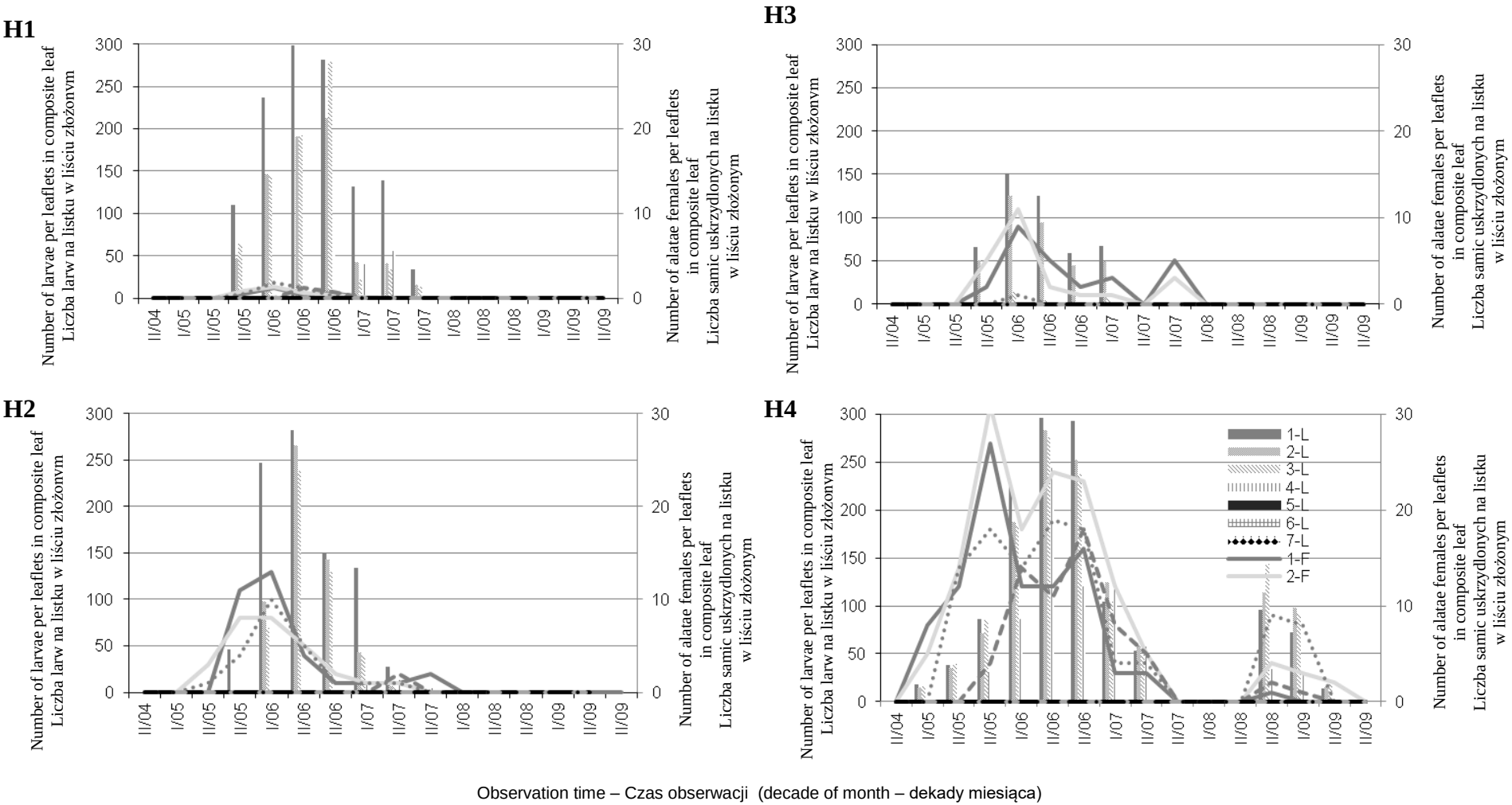

Fig. 4. Spatial distribution of *Panaphis juglandis* population on the examined walnuts H1, H2, H3 and H4 in 2010 (symbol of leaflets 1-L, 2-L, 3-L, 4-L, 5-L, 6-L and 7-L relate to spatial distribution of larvae and symbols of leaflets 1-F, 2-F, 3-F, 4-F, 5-F, 6-F, and 7-F relate to spatial distribution of alatae females)
Ryc. 4. Rozkład przestrzenny *Panaphis juglandis* na badanych orzechach H1, H2, H3 i H4 w 2010 (oznaczenia listków 1-L, 2-L, 3-L, 4-L, 5-L, 6-L i 7-L dotyczą rozkładu larw na listkach, a oznaczenia listków 1-F, 2-F, 3-F, 4-F, 5-F, 6-F i 7-F dotyczą rozkładu samic uskrzydlonych

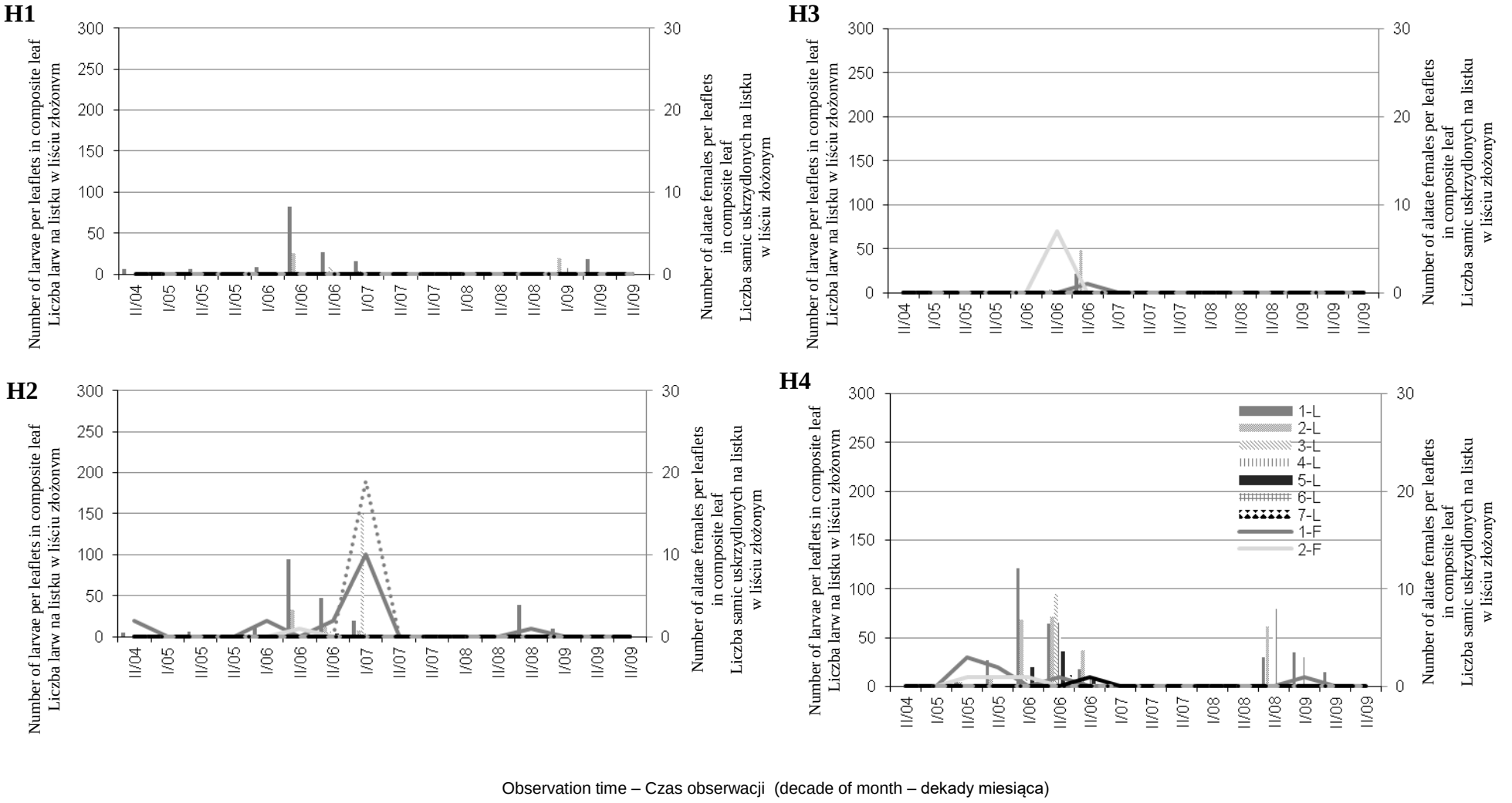

Fig. 5. Spatial distribution of *Panaphis juglandis* population on the examined walnuts H1, H2, H3 and H4 in 2011 (symbol of leaflets 1-L, 2-L, 3-L, 4-L, 5-L, 6-L and 7-L relate to spatial distribution of larvae and symbols of leaflets 1-F, 2-F, 3-F, 4-F, 5-F, 6-F, and 7-F relate to spatial distribution of alatae females)
Ryc. 5. Rozkład przestrzenny *Panaphis juglandis* na badanych orzechach H1, H2, H3 i H4 w 2011 (oznaczenia listków 1-L, 2-L, 3-L, 4-L, 5-L, 6-L i 7-L dotyczą rozkładu larw na listkach, a oznaczenia listków 1-F, 2-F, 3-F, 4-F, 5-F, 6-F i 7-F dotyczą rozkładu samic uskrzydlonych

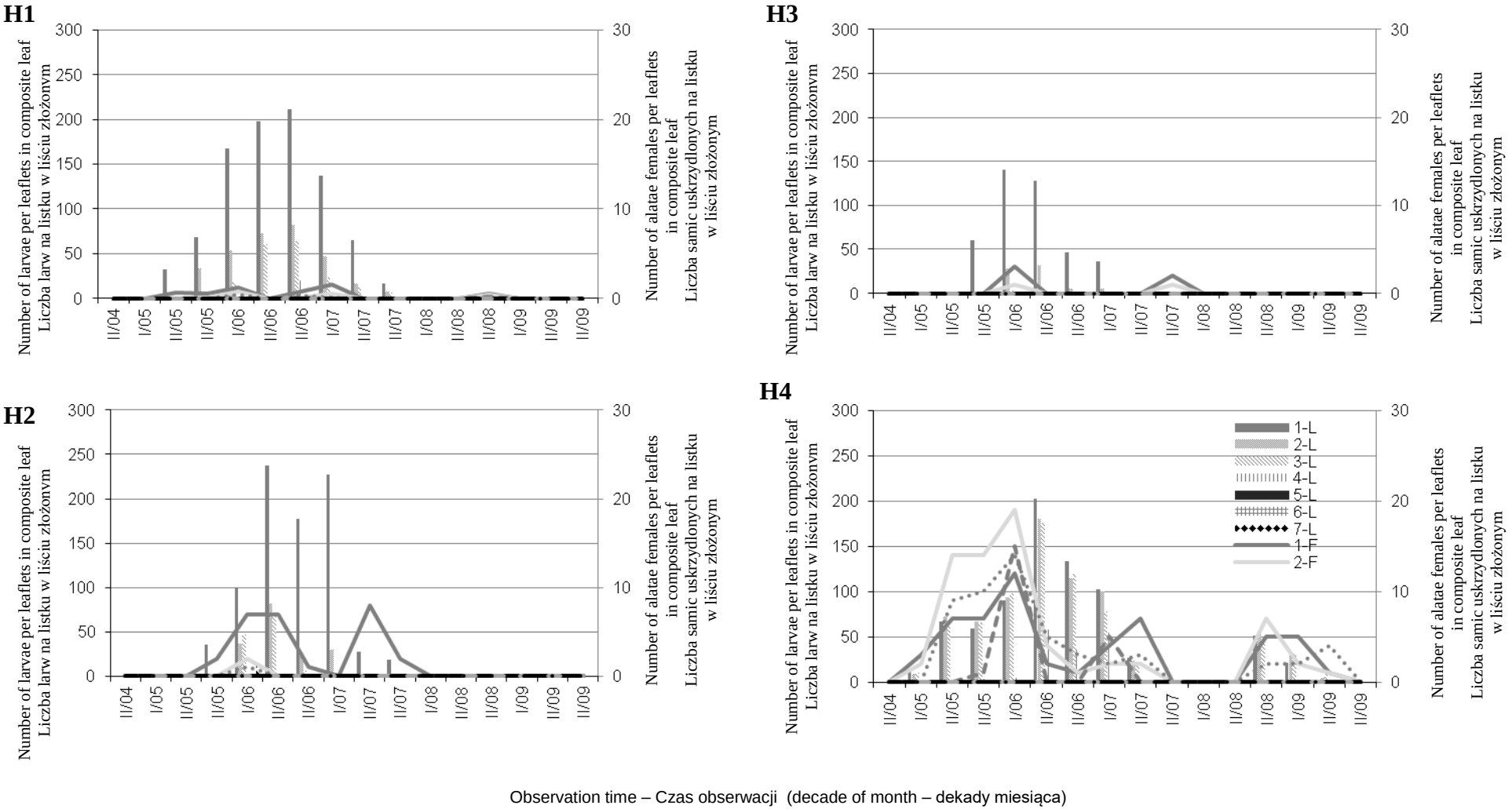

Fig. 6. Spatial distribution of *Panaphis juglandis* population on the examined walnuts H1, H2, H3 and H4 in 2012 (symbol of leaflets 1-L, 2-L, 3-L, 4-L, 5-L, 6-L and 7-L relate to spatial distribution of larvae and symbols of leaflets 1-F, 2-F, 3-F, 4-F, 5-F, 6-F, and 7-F relate to spatial distribution of alatae females)
Ryc. 6. Rozkład przestrzenny *Panaphis juglandis* na badanych orzechach H1, H2, H3 i H4 w 2012 (oznaczenia listków 1-L, 2-L, 3-L, 4-L, 5-L, 6-L i 7-L dotyczą rozkładu larw na listkach, a oznaczenia listków 1-F, 2-F, 3-F, 4-F, 5-F, 6-F i 7-F dotyczą rozkładu samic uskrzydlonych

DISCUSSION

The occurrence of two aphid species was observed on walnut: *Panaphis juglandis* (Goeze 1778) and *Chromaphis juglandicola* (Kaltenbach 1843). Aphids *P. juglandis* colonize only the top side of the walnut composite leaf, establishing characteristic colonies along the vascular vein. *P. juglandis* has always been the predominant species on studied stands of walnut in the Siedlce area. Similar results were reported earlier for the Lublin region by Jaśkiewicz and Cichocka (2004), as well as Cichocka (1980). Results of the studies by Krzyżanowski 2016 indicated that sometimes *Ch. juglandicola* may predominate, as well.

In the present study this aphid was present in each year in the all investigated locations. It occurred in greater number in the street-side stand, which is consistent with the conclusions reached by Cichocka et al. (1998) and Halbert et al. (1998); Milevoj and Kravanja (1999); Wilkaniec (1999); Lubiarz (2009); Karczmarz (2012), reported that insects with stinging-sucking mouthparts occur in greater numbers in the areas that undergo strong anthropopressure.

Panaphis juglandis was feeding on the examined trees from spring to early autumn, and peak density was mostly observed at June. This is consistent with the previous results, published by Jaśkiewicz and Cichocka (2004). However, Jaśkiewicz and Kmieć (2007) report that walnut trees during 2003–2005 were mostly infested by the aphids between June and July.

Based on the conducted observations it was shown that development of *P. juglandis* population on composite leaf of the walnut began on external leaflets. Next the *P. juglandis* spreads on the all leaflets of the walnut. In addition, Olson (1974) has shown that shortly after the aphids began building up their population on the leaflets, darkening of the midrib occurred. Such discoloration remains distinct even after the aphid colonies have gone. The significance of this discoloration was investigated by examining thin cross sections of midrib with the aid of light microscope. This examination revealed that the discoloration extended into the conductive tissues of the leaflet. However, Krzyżanowski (2017), reported that average length of individual leaflets was the largest in external leaflets. Other leaflets the maximum size attained in the second and third decade of June.

The dynamics of *P. juglandis* population was also significantly affected by the course of whether conditions. Among the studied whether factors, such as daily temperature, humidity and rainfall, the temperature was the most important in development of the walnut aphid population. There was a strong positive correlation between daily temperature and number of the *P. juglandis* on the walnut trees. The weather conditions, including temperature and humidity have been also reported earlier as important factors affecting development of the large walnut aphid (Karczmarz 2012) and common walnut aphid (Karczmarz 2010, 2012).

RECAPITULATION

Summarizing, *P. juglandis* was preying on *Juglans regia* L. trees at the home-gardens and street-side stands, in Siedlce area. More numerous colonies of *P. juglandis* were observed on trees growing in street-side stand, where it formed colonies along the main vascular vein on the top part only of the first three external leaflets.

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Abstract. Common walnut (*Juglans regia* L.) has gained recognition in Poland as an ornamental species in city environments. More frequent use of walnut in the city landscape has induced a more thorough analysis of the factor that causes a significant decrease in the decorative values of this tree. The aim of this paper was to trace population dynamics and spatial distribution of *Panaphis juglandis* (Goeze 1778) occupying the *J. regia* trees. The studies were conducted on walnut trees (*J. regia*) in Siedlce in the years 2010–2012. Three tree stands in home gardens were selected for observation (H1, H2, H3) and one near the street (H4). Results showed that higher aphid population was found on the studied tree at the street stand in relation to the home gardens trees. *P. juglandis* were observed on trees growing in street-side stand, where it formed colonies along the main vascular vein on the top part only of the first three external leaflets.

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