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The station of the hoptree (*Ptelea trifoliata* L. ssp. *trifoliata*) in the forests of the Wyszków Forest District

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Abstract. This paper presents the results of studies carried out on *Ptelea trifoliata* populations in the Wyszków Forest District in 1998 and 2013. *P. trifoliata* is a native species of North America (United States of America, northern part of Canada) and has a wide ecological range. However, it prefers fertile, wet soils and moderate light. In Europe, it is planted for its decorative value and is mainly found in synanthropic habitats (parks, graveyards, roadsides, fortifications) in Poland. The station of *P. trifoliata* is situated in the oak-hornbeam forest, *Tilio–Carpinetum typicum*, with a significant fraction of the stand consisting of *Pinus sylvestris*. Hop trees occur mainly along forest section lines and are rarely found inside the sections. In the last 15 years, an increase in the number and size of *P. trifoliata* clusters has been observed. The species spreads along forest section lines, which form a convenient migration route by creating favourable conditions for the germination and growth of seedlings (good access to light, fragments of bare soil). The presence of new individuals far from the pre-existing clusters indicates that the generative way of propagation dominates. Biometric measures indicate significant differences in length and width of whole leaves as well as leaflets, with leaves and leaflets of vegetative specimens significantly larger than generative ones.

As a consequence of the high rate of *P. trifoliata* expansion along forest section lines and occurrence of single specimens inside the forest sections, we assume this species to be potentially invasive.

Keywords: *Ptelea trifoliata*, Wyszków Forest District, spreading of species, biometric studies

1. Introduction

The hoptree (*Ptelea trifoliata* L.) is a perennial plant of the Rutaceae family. Its typical subspecies (*P. trifoliata* L. ssp. *trifoliata*) occurs mainly in the mixed and deciduous forest communities in the south-eastern part of the United States. From there, this taxon has spread to the north - in the direction of the Great Lakes and Canada, and to the south - in the direction of Mexico (Bailey et al. 1970). Currently, its natural range extends from the Great Lakes and southern Canada, where it can be found on the shady forest edges and rocky slopes, to Texas and northern Florida (Ambrose 2002). Some isolated clusters of the subspecies can also be encountered in southern Mexico. The occurrence of other subspecies (*P. trifoliata* L. ssp. *Angustifolia*, *P. trifoliata* L. ssp. *pallida*, *P. trifoliata* L. ssp. *polyadenia*) is limited to the southern regions of the United States and Mexico.

P. trifoliata was introduced to Poland in the early 19th century. Currently, the species is considered locally domesticated (neophyte) in anthropogenic, semi-natural and natural communities (Tokarska-Guzik et al. 2012).

During the field studies conducted in the state-owned forests of the Wyszków Forest District in 1998, *P. trifoliata* individuals were recorded in the Uroczysko Wyszków Leszczydół wilderness. The attempts to determine their origin and age have failed. On the basis of the number of annual growth rings, the age of the oldest individuals was estimated at over 30 years.

The paper presents changes in the population size of the hoptree that took place from 1998–2013 and the results of biometric measurements of the leaves of individuals from vegetative and generative propagation.

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Table 1. Number of *P. trifoliata* clusters in 1998 and 2013

Forest section line	Area of cluster (m^2)								In total	
	< 10		10–50		50–150		>150			
	1998	2013	1998	2013	1998	2013	1998	2013	1998	2013
170/175	3	14	2	5	2	3	1	1	8	23
171/172	-	3	-	-	-	-	-	-	-	3
171/176	2	9	1	2	-	1	-	-	3	12
176/177	4	14	3	4	1	2	-	-	8	20
In total	9	40	6	11	3	6	1	1	19	58

2. The study area

P. trifoliata occurs in the territory of the Wyszków Forest District (Mazowieckie Province) on the southern edge of the Biała Primeval Forest (Atlas of Poland "ATPOL" – square EC79). According to Trampler's natural-forest regionalisation (1990), this study area lies in the Mazowsze-Podlasie Natural-Forest Region IV, in the Podlasie Natural-Forest Subregion situated in the Podlasie Lowland and the Siedlce Upland, in the Łomża Upland mesoregion. According to Kondracki's physicogeographical classification (2013), the study area - a moraine upland, lies in the Międzyrzecze Łomżyńskie mesoregion between the Dolna Narew and Dolny Bug valleys (North Mazowsze Lowland macroregion).

The study area is located in the Podlasie Natural-Forest Subregion, being under the influence of the central uplands climate (Romer 1949). The main climatic characteristics are as follows: mean annual air temperature – 7.7°C, annual precipitation – 550 mm, prevalence of westerly or south--westerly winds. The snow cover lies for 50–80 days, the growing season lasts for 200–220 days. In comparison to the climatic conditions of the central part of Mazowsze, the Biała Primeval Forest is under the continental climate influences. This is confirmed by significantly higher amplitude of annual temperatures (25°C) than that in the Warsaw area (22°C). The latitudinal position of the Bug river valley results in the prevalence of westerly winds.

3. Research methods

Field studies on *P. trifoliata* in the Biała Primeval Forest were conducted twice: in 1998 and 2013. The distribution of hoptree individuals in both study periods was drawn on a map. A tape measure was used to determine the location of individuals. Eight phytosociological relevés of 400 m^2 were made in accordance with the Braun-Blanquet method (Pawłowski 1972).

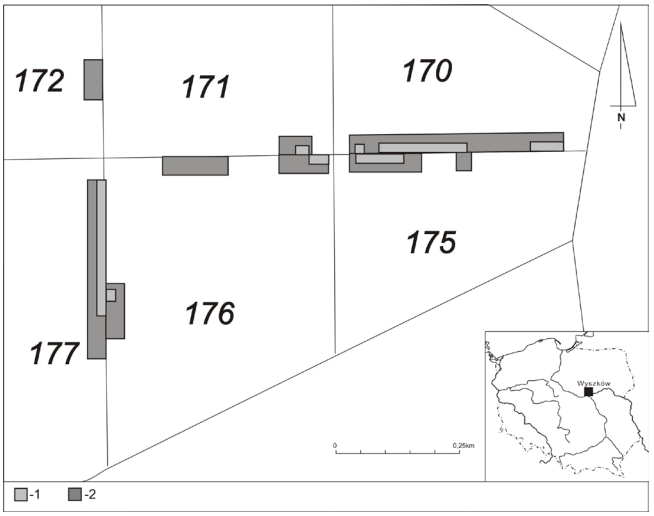

Figure 1. Distribution of *P. trifoliata* clusters in 1998 and 2013. 1 – 1998, 2 – 2013.

Areas where *P. trifoliata* occurred were selected at a distance of 20–30 m from the compartment boundary. Species coverage was determined using the Braun-Blanquet seven-grade scale r - 1–2 individuals, + - few individuals, sparse coverage, 1 - 1–5% 2 - 5–25% 3 - 25–50%, 4 - 50–75%, 5 - 75–100%. The phytosociological relevés were the basis for determining the type of forest plant community. The nomenclature of vascular plant species was adopted after Mirek et al. (2002), and their syntaxonomic classification - after Matuszkiewicz (2005). As a result of the observed differences in the leaf size between vegetative (non-flowering) and generative (flowering and fruiting) individuals, their biometric measurements were taken (10 leaves from 10 randomly selected individuals). Measurements (width and length of the whole leaf as well as of apical and lateral leaflets) were taken from live specimens in August, selecting the leaves outgrowing from the central section of the shoot. The significance of the differences in the biometric characteristics

of the vegetative and generative leaves was determined using the Mann–Whitney non-parametric U test (Statistica 10) designed for comparing two independent samples.

4. Research results

In 1998, *P. trifoliata* individuals were observed on the boundaries of forest compartments 170/175, 176/177, and sporadically on the boundaries of compartment 171/176 (Figure 1). Then, a total of 19 hoptree clusters, including 15 clusters with an area of up to 50 m^2 and 4 larger ones, were identified (Table 1). Fifteen years later, a significant increase in the hoptree population was reported: 51 hoptree clusters with an area of 50 m^2 and 7 with a larger area. The total area of the *P. trifoliata* population increased from 2500 m^2 in to 4300 m^2 in 2013. The expansion of hoptree individuals along the boundaries of compartment 171/176 was particularly noticeable. In 2013, the first hoptree individuals were also found on the boundary of compartment 171/172.

Almost all *P. trifoliata* individuals grew close to the compartment boundaries. Some hoptree clusters occurred sporadically in the interior of forest compartments (up to 10 m from the compartment boundary).

The *P. trifoliata* clusters grew in a typical oak-hornbeam forest (*Tilio–Carpinetum typicum*) with a significant share of *Pinus sylvestris,* which was causing the ousting of the species typical of this association ('pinetisation'). The stand with a crown closure of about 60–80% was composed of *P. sylvestris* and *Quercus robur*, with the participation of *Carpinus betulus* in the lower tree layer (20–70%). The shrub layer (ca a 40% closure) was dominated by *C. betulus* and *Corylus avellana*, with a smaller share of *Frangula alnus*. However, in the herbaceous layer (a 90–100% closure), species of the class *Querco-Fagetea* and the order *Fagetalia sylvaticae* (*Anemone nemorosa*, *Carex digitata*, *Melica nutans*, *Milium effusum*, *Viola reichenbachiana*) predominated. Less frequent were species of oak (*Hieracium murorum*, *Melittis melissophyllum*) and pine (*Vaccinium myrtillus*) forests. The relevés made in the vicinity of compartment boundaries showed a higher species richness than in the interior of the forest. This was associated with the presence of synanthropic (*Stellaria media*, *Oxalis stricta*, *Lupinus polyphyllus*) and thermophilic species (*Hieracium caespitosum*, *Stachys recta*, *Aquilegia vulgaris*).

A detailed phytosociological description of *P. trifoliata* clusters is given below:

The Wyszków Forest District, compartments 170, 171, 175, 176, 177 (8 phytosociological relevés); date: 05.06.2013 r.; layer closure: a - 60–80%, a_1 - 50–60%, a_2 - 20–70%, a_3 - 10–30%, b - 30–60%, c - 70–100%, d - 0–10%; relevé area: 200–400 m^2. *P. trifoliata* b - V^{1-3}; trees and shrubs: *P. sylvestris* a_1 - V^{2-3}, *Q. robur* a_1 - V^{1-2}, *Q. robur* a_2 - IV^{1-2}, *Q. robur* b – IV^{+-1}, *C. betulus* a_2 - V^{1-3}, *C. betulus* a_3 - III^{1-2}, *C. betulus* b - V^{1-3} *C. betulus* c - V^{1-2}, *C. avellana* b - V^{1-3}, *C. avellana* c - V^{1-2}, *F. alnus* b - III^{+-1} *F. alnus* c - III^{+-1}, *Sorbus aucuparia* c - II^{+-1}, *Acer platanoides* c - II^{+-1}; harbaceous plants: ch. *Querco-Fagetea*: *A. nemorosa* - V^{2-4}, *M. nutans* - V^{+-3}, *C. digitata* - IV^{1-2}, *Aegopodium podagraria* - III^{+-2}, *M. melissophyllum* - III^{+-1}; ch. *Fagetalia sylvaticae*: *M. effusum* - V^{1-2}, *V. reichenbachiana* - IV^{r-2}, *Actaea spicata* - IV^{r-1}, *Phyteuma spicatum* - IV^{r-1}, *Sanicula europaea* - III^{+-1}, *Daphne mezereum* - II^{r-+}, *Lilium martagon* - II^{r-+}; accompanying: *Majanthemum bifolium* - V^{1-3}, *Oxalis acetosella* - V^{1-3}, *Moehringia trinervia* - V^{+-2}, *Dryopteris carthusiana* - V^{+-1}, *H. murorum* - IV^{+-2}, *Ajuga reptans* - IV^{+-2}, *Rubus saxatilis* - IV^{+-2}, *Pteridium aquilinum* - IV^{+-2}, *V. myrtillus* - IV^{+-2}, *Viola riviniana* - IV^{+-1}, *Mycelis muralis* - IV^{+-1}, *Luzula pilosa* - IV^{+-1}, *Dryopteris filix-mas* - IV^{+-1}, *Veronica chamaedrys* - III^{+-1}, *Urtica dioica* - III^{+-2}, *Melampyrum nemorosum* - III^{r-1}, *Galeopsis pubescens* - III^{r-1}, *Rubus caesius* - II^{+-1}, *Athyrium filix-femina* - II^{+-1}, *Dactylis glomerata* - II^{r-+}, *Gymnocarpium dryopteris* - II^{r-+}, *S. media* - I^{+-1}, *O. stricta* - I^{r-+}, *A. vulgaris* - I^{r-+}, *L. polyphyllus* - I^{+}, *S. recta* - I^{+}, *H. caespitosum* - I^{r}.

The analysis of biometric measurement results shows significant differences in the length and width of leaves

Table 2. The results of biometric measurements of vegetative and generative specimens of *P. trifoliata*

Leaf		Length (cm)			Width (cm)		
		mean	min.	max.	mean	min.	max.
Vegetative	the whole leaf	29.6	23.9	37.3	18.9	14.5	23.3
	middle leaflet	12.8	9.8	19.5	8.2	5.8	12.1
	lateral leaflet	15.4	9.2	22.8	9.0	5.5	13.7
Generative	the whole leaf	24.9	16.1	36.6	13.4	11.2	16.8
	middle leaflet	10.5	6.2	16.1	6.6	3.4	12.1
	lateral leaflet	11.7	6.0	22.8	6.9	3.1	13.7

between the vegetative and generative individuals of *P. trifoliata* (Table. 2). The average total length of vegetative leaves was 4.7 cm higher than that of the generative leaves (Mann–Whitney U test: $z = 7.51$, $p < 0.0001$). The average length of apical and lateral leaflets of the individuals from vegetative propagation was also higher (by 2.3 cm and 3.7 cm, $z = 6.79$, $p < 0.0001$ and $z = 8.22$; $p < 0.0001$) than that of generative individuals. The width of apical and lateral leaflets of the individuals from vegetative propagation was also significantly higher compared to generative individuals (by 1.8 cm and 2.1 cm; $z = 10.48$; $p < 0.0001$ and $z = 8.03$, $p < 0.0001$).

5. Discussion

P. trifoliata, is an ornamental plant species frequently planted in the parks and gardens in the temperate climate countries. In Poland, it was rarely planted, usually along roadsides and an element of park architecture. Werpachowski (2005) identified the hoptree as one of the plants growing around the fortification of the Ossowiec Fortress. Sudnik-Wójcikowska (1987) reports its occurrence in the Warsaw area (in allotments, around the airport). This paper is the first to present the characteristics and dynamics of the *P. trifoliata* population in the forest interior.

The population under study represents the typical subspecies *P. trifoliata* L. ssp. *trifoliata* usually introduced to Poland. This plant is recognised for its morphological and biometric characteristics of leaves (Bailey, 1960; Bailey et al. 1970). *P. trifoliata* is a frost-resistant plant. In spite of its high habitat tolerance, it prefers fertile, moist and permeable soils. The growth of seedlings is also stimulated by high temperatures and humidity during the early spring (McLeod, Murphy 1983).

In 1998–2013, the area of the *P. trifoliata* population increased by over 70%. The species spreads mainly along compartment boundaries, where it has the best conditions for germination (less vegetation cover, better access to light). They are the primary routes of hoptree seed dispersal, as it is an anemochoric species (Ambrose et al. 1985). As a result, single plants appear some distance away from the existing *P. trifoliate* clusters. Other propagation methods are less important, of which the expansion of the existing clusters is the most significant.

The hoptree meets the basic criteria of an invasive species. It is capable of expansion by increasing the area of the existing populations and colonising the new sites. At the current level of knowledge, it is difficult to establish to what extent the hoptree can reduce the biological diversity of plant communities (competition, shading of the herbaceous layer, soil damage during thinning operations and cleaning cuts).

The research confirmed differences in the size of leaves between the individuals from vegetative and generative propagation (vegetative leaves were significantly larger). These differences may be due to the fact that individuals from vegetative propagation are juvenile or mature; they grow in the shade, so their leaves have to be larger to compensate for the deficiency of light.

6. Conclusions

Based on the research results, the following conclusions can be drawn:

1. The examined *P. trifoliata* clusters growing in the natural oak-hornbeam community (*Tilio–Carpinetum typicum*) were described for the first time.
2. In 1998–2013, the expansion of the species was limited mainly to the boundaries of the forest compartment.
3. The results of biometric measurements of *P. trifoliata* leaves indicate significant differences in the size of leaves between individuals from vegetative and generative propagation. Significantly higher values (total length and width of leaves, length and width of apical and lateral leaflets) were observed in individuals from vegetative propagation.
4. The high expansion rate of *P. trifoliata* along the boundaries of forest compartments and the occurrence of individuals in the interior of the forest may raise concerns about the potentially high invasiveness of the species.

Conflict of interest

None declared.

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References

Ambrose J.D. 2002. Update COSEWIC Status Report on the Common Hoptree *Ptelea trifoliata* in Canada, Ottawa, Committee on the Status of Endangered Wildlife in Canada, 14 p. ISBN 0-662-34314-X.

Ambrose J.D., Kevan P.G., Gadawski R.M. 1985. Hop tree (*Ptelea trifoliata*) in Canada: population and reproductive biology of a rare species. *Canadian Journal of Botany*, 63: 1928–1935.

Bailey V.L. 1960. Historical review of *Ptelea trifoliata* in Botanical and Medical Literature. *Economic Botany,* 14: 180–188.

Bailey V.L., Herlin S.B., Bailey H.E. 1970. *Ptelea trifoliata* ssp. *trifoliata* (Rutaceae) in deciduous forest regions of Eastern North America. *Brittonia* 22: 346–358.

Kondracki J. 2013. Geografia regionalna Polski. Warszawa, PWN. ISBN 9788301160227.

Matuszkiewicz J. M. 2005. Przewodnik do oznaczania zbiorowisk roślinnych Polski. Warszawa, PWN. ISBN 83-01-14439-4.

McLeod K.W., Murphy P.G. 1983. Factors affecting growth of *Ptelea trifoliata* seedlings. *Canadian Journal of Botany*, 61(9): 2410–2415.

Mirek Z., Piękoś-Mirkowa H., Zając A, Zając M. 2002. Flowering plants and pteridophytes of Poland – a checklist, Biodiversity of Poland, 1, Kraków, W. Szafer Institute of Botany, Polish Academy of Sciences, 442 p. ISBN 83-85444-83-1.

Pawłowski B. 1972. Skład i budowa zbiorowisk roślinnych oraz metody ich badania, w: Szata Roślinna Polski T. 1 (eds. W. Szafer, K. Zarzycki). Warszawa, Państwowe Wydawnictwo Naukowe: 237–269.

Romer E. 1949. Regiony klimatyczne Polski. Wrocław, *Prace Wrocławskiego Towarzystwa Naukowego, Ser. B* 16: 1–28.

Sudnik-Wójcikowska B. 1987. Flora miasta Warszawy i jej przemiany w ciągu XIX i XX wieku. Część 2. Warszawa, Wydawnictwa Uniwersytetu Warszawskiego, 435 p. ISBN: 83-230-0475-7.

Tokarska-Guzik B,, Dajdok Z., Zając M., Zając A., Urbisz A., Danielewicz W. 2012. Rośliny obcego pochodzenia w Polsce ze szczególnym uwzględnieniem gatunków inwazyjnych. Warszawa, Generalna Dyrekcja Ochrony Środowiska, 107 p. ISBN 978-83-62940-34-9.

Trampler T., Kliczkowska A., Dmytreko E., Sierpińska A. 1990. Regionalizacja przyrodniczo-leśna na podstawach ekologiczno-fizjograficznych. Warszawa, Państwowe Wydawnictwo Rolnicze i Leśne, 155 p.

Werpachowski C. 2005. Świat roślin naczyniowych Kotliny Biebrzańskiej i Biebrzańskiego Parku Narodowego, w: Przyroda Biebrzańskiego Parku Narodowego. (eds. A. Dyrcz, C. Werpachowski). Osowiec-Twierdza, Wydawnictwo Biebrzański Park Narodowy: 87–106. ISBN: 83-921241-2.

Authors' contribution

M.C. – concept and schedule of research, methodological assumptions, fieldwork, literature review; J.K – fieldwork, literature review, analysis and interpretation of results, text preparation; R.S – fieldwork, manuscript preparation. All the authors have read and approved the final version of the manuscript.

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