Assessment of some invasive species photosynthetic acclimation to new habitat environment by the closed chamber system

Ligita Baležentienė

Institute of Environment and Ecology, Vytautas Magnus University, Lithuania; Studentų 11, LT-53361 Akademija, Kaunas distr., Lithuania, e-mail: ligita.balezentiene@vdu.lt

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Abstract. Photosynthetic response to environmental conditions of an invaded habitat were evaluated as indices of invasive species acclimation. Photosynthesis measurements of *Fallopia japonica*, *Heracleum sosnowskyi*, and *Rumex confertus* were performed every month along grassland or forest ecotones in Kaunas distr., Central Lithuania, during the plant vegetation period in 2016. Photosynthetic capacity and its positive relationship to environment tolerance confirmed that the assessed recently developed invasive species will also exhibit enhanced photosynthetic performance during their vegetative growth in new invaded habitats.

Key words: ecotone, environment, PAR, invasive species

Introduction

Numerous characteristics common to invasive plants have been identified to facilitate recognition and prediction of habitat invaders, specifically the high reproductive allocation, rapid vegetative growth rates, and high potential for acclimation (Rejmanek 1996). Physiological characteristics of the invasive plant species have also been identified by comparing the invasive species with unrelated non-invasive species (Mcdowell 2002). A possible mechanism by which invasive plants may achieve success is through exploiting the photosynthesis (Cavender-Bares & Bazzaz 2004).

Solar radiation is mainly assimilated in the leaf into photosynthetic energy and transpiration rate, which constitute the essential integrated functional system in plants (Rico & al. 2013; Woolfenden & al. 2018). The theories of the optimisation demands are based on the postulation that the plants target a maximum carbon (C) uptake and growth (subject to constraints) over a given period (McMurtrie & al. 2008; Franklin & al. 2012). The estimations of these components are essential for understanding the plants physiological conditions (Chen & al. 2011; Yahia & al. 2019) and water dynamics (Manzoni & al. 2013). Moreover, the growth and development of plant species are greatly affected by the process of photosynthesis. Herbaceous plants are generally regarded as photosynthate sinks, because they rely on energy provided by sugars (produced by photosynthesis) transported from leaves to carry out the highly demanding processes of growth, development, and maturation.

From ecological perspective, attention has mainly been focused on the yield of chemical energy assimilated from light energy and indicating the photosynthetic efficiency. However, photosynthesis is complex and also responds to many environmental factors (light intensity, vapour pressure deficit, CO_2 concentration, etc.) that step up the invasive plant acclimation success (Sugiura & Tateno 2014; Ramírez & al. 2016; Jiao & al. 2017; Cincera & al. 2019).

Consistent with these issues, the main objective of the present study was to evaluate the ratio of photosynthesis as indices of acclimation of the assessed invasive species to environmental conditions in an invaded habitat. The relations between the observed variability in photosynthesis during the time and the meteorological changes at different PAR (photosynthetically active radiation) ranging were evaluated.

Material and methods

Site and species setup. Lithuania is located in the cold temperate zone (5–6), with moderately warm summers and medium cold winters (Galvonaitė & al. 2007). The average temperature in July is approximately 17 °C, and in winter it is approximately −5 °C; the interval between the temperatures is about 20 °C.

Measurement of physiological parameters. Plant photosynthesis system LCpro+ Photosynthesis System (ADC BioScientific, UK) was applied for assessing the photosynthesis (A, μmol $m^{-2}s^{-1}$) and photosynthetically active radiation (PAR, μmol $m^{-2}s^{-1}$) parameters *in situ* of invasive plant species listed in the National List of Invasive Species (LR Ministry of Environment 2016). Environmental acclimation of four invasive species was assessed, namely *Fallopia japonica* (Houtt.) Ronse Decr., *F jap* (*Polygonaceae*), native of northern Japan (Hokkaido, Honshu) and NE Russia (Sakhalin, Kuril Islands), 54°54'01.3"N, 23°50'07.2"E; *Heracleum sosnowskyi* Manden., *H sosn* (*Apiaceae*) from Trans-Asia, 54°54'08.1"N, 23°50'10.5"E; *Rumex confertus* Willd., *R conf* (*Polygonaceae*) from Asia, 54°54'13.1"N, 23°49'11.1"E. The cosmopolite *Taraxacum officinale* L., *T offi*, 54°54'12.2"N, 23°51'29.5"E served as a control species. Measurements in 10 replications were performed every month along the grassland or forest ecotone in Kaunas distr., Central Lithuania, during the plant vegetation period in 2016.

Environmental conditions measurement. Meteorological data (temperature and precipitation) were taken from the Kaunas Meteorological Station, while physical soil parameters (temperature, moisture and electric conductivity) were evaluated using the integrated analyser HH-2 (AT Delta-T Devices Ltd, UK).

Meteorological conditions were averaged and compared with multi-annual averages throughout the vegetation period (APR-SEP) (Fig. 1). The fluctuations and differences in weather conditions could affect not only abiotic ecosystem parameters but also plant photosynthesis and respiration processes.

Mean temperatures of MAY-AUG exceeded multi-annual averages by 0.3–3.43 °C, and were equal to the multi-annual averages in APR and SEP. Nonetheless, precipitation exceeded multi-annual averages, with the exception of May. Therefore, the vegetation period was rather favourable for plant growth, due to the normally warm conditions, with higher than usual humidity.

Statistical evaluation. The level of statistical confidence, multivariate test of homogeneity, Box M of variances/covariances, Fisher test (F) , Kruskal–Wallis (KW-H) nonparametric H test of one-way ANOVA stochastic interactions between estimated A data, and the species measurement date and environmental conditions were calculated by the methods of variance and regression analysis, using the statistical package STATISTICA of StatSoft for Windows standards.

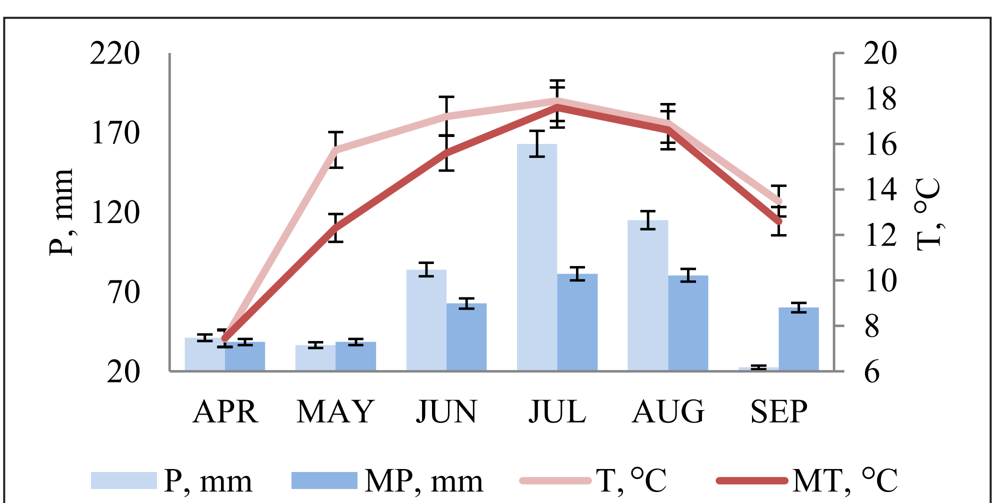

Fig. 1. Meteorological conditions throughout the vegetation period (APR-SEP) of 2016. P – monthly precipitation, MP – multi-annual average precipitation, T – monthly average temperature, MT – multi-annual average temperature (Kaunas Meteorological Station).

Results and discussion

Photosynthesis (A, r=0.8) initially responded to PAR intensity related to the habitat type and meteorological conditions during measurements (Fig. 1). Therefore, significantly (p=0.0000) the higher PAR rates up to 1056–1083.67 μmol $m^{-2}s^{-1}$ were available for *R conf* and *T offi*, which grew in open grasslands, than those for *F jap* and *H sosn* in shaded scrubland (Fig. 2). PAR values strongly correlated with temperature (r=0.6),

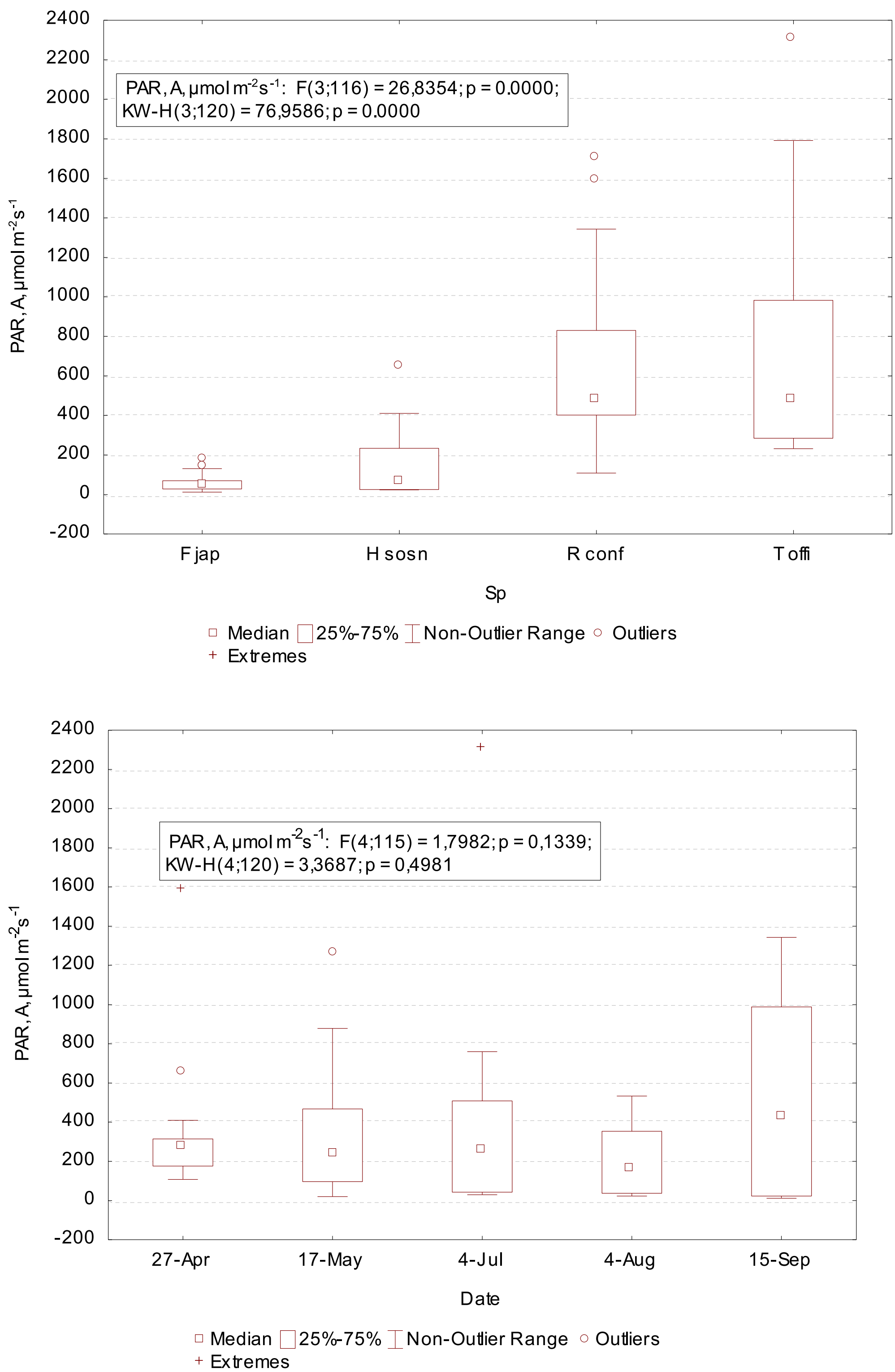

Fig. 2. Box Plot of PAR (μmol $m^{-2}s^{-1}$) grouped by assessed species and measurement date. *F jap – Fallopia japonica*, *H sosn – Heracleum sosnowskyi*, *R conf – Rumex confertus*, *T offi – Taraxacum officinale*. A – ANOVA, KW-H – Kruskal-Wallis H test.

slightly correlated (r=0.4) with precipitation rates, and corresponded to earlier findings (Vráblová & al. 2018). These data correspond to earlier results that PAR variations might be particularly credited for regulation of photosynthesis at canopy level (Baldocchi 2014; Sellers & al. 2018). Nonetheless, differences between PAR values recorded at particular dates varied insignificantly in the invaded habitats (2).

The recorded PAR values of various species determined their photosynthesis rates (r=0.8) during the growth period (Fig. 3). Significantly, the most intensive mean photosynthesis of 11.60 and 8.30 μmol $m^{-2}s^{-1}$

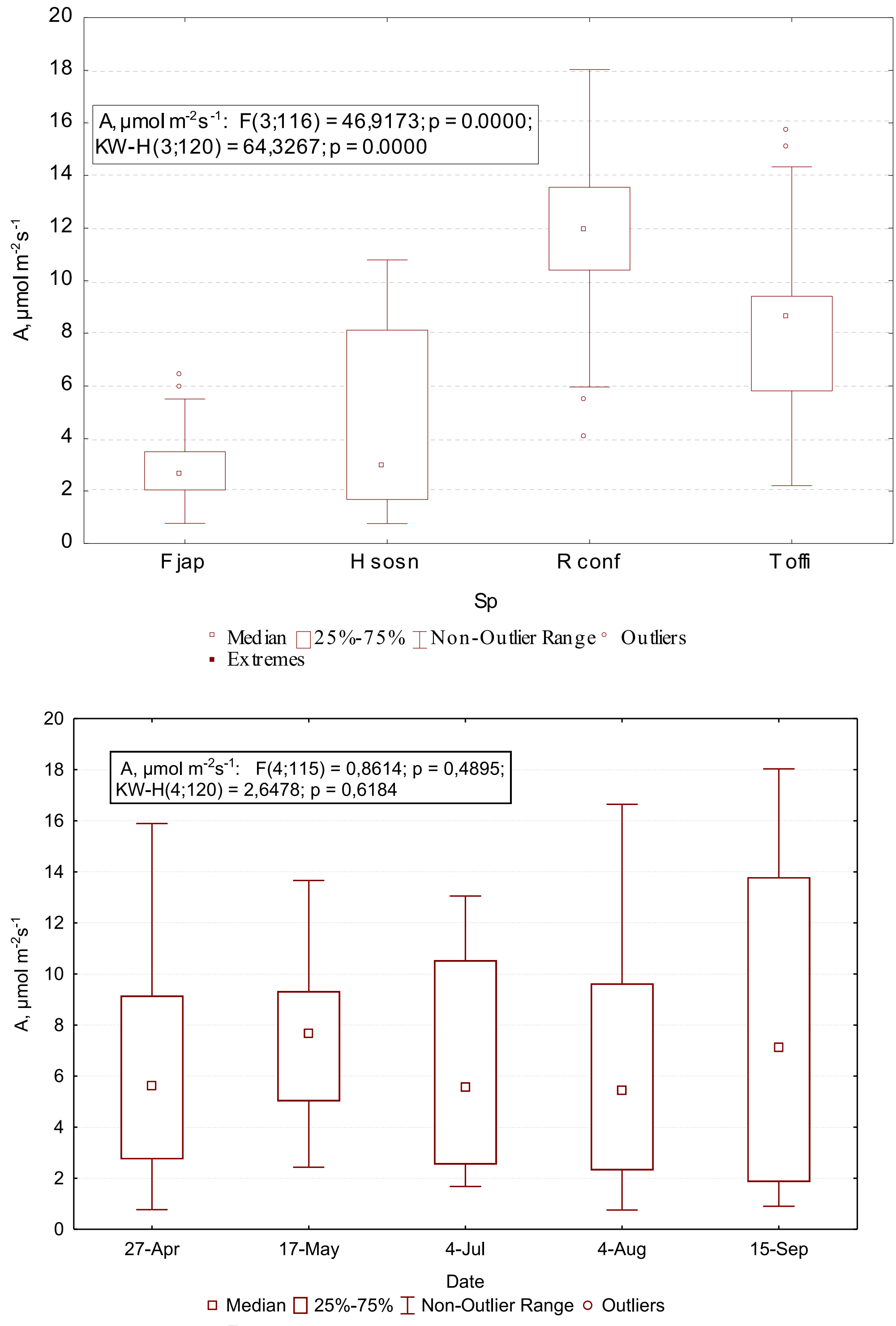

Fig. 3. Box plot of photosynthesis (A, μmol $m^{-2}s^{-1}$) grouped by species and measurement date. *F jap* – *Fallopia japonica*, *H sosn* – *Heracleum sosnowskyi*, *R conf* – *Rumex confertus*, *T offi* –*Taraxacum officinale*. F – Fisher and KW-H – Kruskal-Wallis H tests.

was recorded for *R conf* and *T offi* in open grassland habitats. While the mean photosynthesis of 3.02 and 4.52 μmol $m^{-2}s^{-1}$ for *F jap* and *H sosn* was lower than in the previous species, possibly due to canopy in the invaded shrub habitats. Correspondingly to PAR, the difference of photosynthesis ranging similarly remained insignificant between the species during the growth period.

Though the invasive species exhibited a different capacity for photosynthesis in invaded habitats, the light-access was sufficient for carbon assimilation maintaining the plants' growth and guaranteed their acclimation strategy in the temperate climate of Lithuania, making them resistant to the competition of native species. Acceptable gain of photosynthesis during the growth period contributed to the invasive plants success and, consequently, could be regarded as a useful indicator for predicting invasiveness within particular environments.

Conclusion

Acclimation of the invasive species was evaluated by means of their essential ecophysiological parameters, such as photosynthesis range in a new environment. The photosynthesis data confirmed that the assessed invasive species exhibited strong acclimation to invaded habitats. Nonetheless, photosynthesis can be limited by canopy or water availability. The obtained data revealed that quantifying photosynthesis may contribute to identification of acclimation potential of the invasive species.

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