Original Scientific paper
10.7251/AGRENG2202071B
UDC 630*44

EFFECT OF FALLOPIA JAPONICA ON SOIL MICROBIAL ACTIVITY DEPENDS ON VARIOUS CLIMATIC AREAS

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ABSTRACT

Biological invasions are one of the main threats to natural ecosystems and the impact of invasive plant species on native species, communities, ecosystems and soil biota has been widely recognized over the last decades. The number of invasive plants and their distribution is increasing in many parts of the world. *Fallopia japonica* (Houtt.) Ronse Decr. (Japanese knotweed) is considered to be one of 100 worst invasive species in the world. The aim of this study was to report that invasive plant species *F. japonica* had an impact on physico-chemical properties and microbial indices in soil ecosystems. The research was carried out in ten research sites in three different climatic areas of Eastern Slovakia. Soil reaction, soil moisture, soil organic carbon, soil basal respiration and soil enzyme activities (FDA, beta-glucosidase, acid and alkaline phosphatases) were determined. Obtained data were compared with uninvaded adjacent sites. Generally, the studied plant invader altered soil parameters, but those changes varied among selected localities. Correlation relationships were found between the individual parameters depending on the location and altitude. The results also suggested that large-scale invasion by *Fallopia* species was, therefore, likely to seriously affect biodiversity and reduce the quality of ecosystems.

Keywords: *Invasive species, Soil indices, Soil enzymes, Climate Areas.*

INTRODUCTION

Soil is a hardly renewable formation that needs to be protected and monitored in changes that would lead to its complete destruction. It is a crucial natural resource, producing food and raw materials, recycles waste, filters and retaining water, ensuring the circulation of substances in nature, maintaining the diversity of animals and plants and shapes the quality of the environment (Forman and Godron, 1986). Soil quality is the ability to maintain and affect the quality of the environment and healthy animal and plant development (Yakovchenko *et al.*, 1996). Soil quality needs to be derived from changes in its parameters - indicators (Wick *et al.*, 2002). As indicators of soil quality, are used microbiological characteristics because they allow an immediate response to different environmental changes (Bobuľská *et al.*, 2021). There are many factors that negatively affect soil quality and one of the factors is human influence (Meena *et al.*, 2020). Currently, biological invasions are critical to human activity. There are many anthropogenic activities that help to spread non-native plant species. Such plant invasions dramatically disrupt native ecosystems, have a massive impact on biodiversity, displace native species and form homogeneous communities and, last but not least, threaten human health. They can have a negative effect on soil properties and thus also affect soil conditions of microorganisms (Ehrenfeld, 2003; Belnap *et al.*, 2005).

Measuring and evaluating soil quality is a relatively big problem. As for indicators are often used biological characteristics that must be sensitive enough to reflect changes in the soil and had a high informative value (Fazekašová and Bobuľská, 2012). The most effective indices are microbiological characteristics, which thanks to their reactivity, distribution, generation time and diversity of the soil microflora allow for immediate response to various changes (Bobuľská *et al.*, 2021). Among the important microbial parameters include soil respiration, soil microbial biomass, soil enzyme activity, fixation of biological N_2, etc. (Fejér and Bobuľská, 2015). The activity and composition of the microbial community are directly affected by the abiotic factors (soil temperature and humidity, nutrient availability), and indirectly affected by biomass and plant diversity (Khan *et al.*, 2018). One of the important components of the soil ecosystem are soil microorganisms. Although microorganisms are the smallest living system, their activity it is very rich and important. They play an important role in the decomposition of plants and animal residues, organic mineralization, humus formation and soil aggregates, maintaining the balance of the soil ecosystem (Wang *et al.*, 2020) and are appropriate and sensitive a tool for predicting changes in the quality of monitored soils (Vinhal-Freitas *et al.*, 2017).

The objective of the study was to assess the impact of invasive plant species on soil properties, with an emphasis on biochemical indices, on soil ecosystems in various climatic areas.

MATERIAL AND METHODS

Site description

The research was carried out on three different climatic areas during May 2021. All research sites have been significantly invaded by *Fallopia japonica* (Japanese knotweed), which greatly affects the characteristics of the soil ecosystem.

Cold climatic area (49°18'06" N, 20°41'19" E) was characterized by annual rain precipitation of 800-900 mm with the average temperature of 6-7°C. The dominant soil type are Cambisols.
Middle climatic area (48°56'09" N, 21°54'24" E) climatic area relatively warm, slightly dry, highland, continental with an average annual rainfall of 700-800 mm with the average temperature of 8-9 °C.
Warm climatic area (48°22'52" N, 20°00'52" E) was characterized as warm, very dry, basin with an average annual rainfall of 600-700 mm with the average temperature 9-10 °C. The dominant soil types for the second and third research localities are skeletal Fluvisols.

Invasive species description
Fallopia japonica (Houtt.) Ronse Decr. (Japanese knotweed) belongs to Polygonaceae family, is considered to be one of 100 worst invasive species in the world. It was introduced into North America and Europe in the 19th century as an ornamental plant and cattle fodder. In its native range of Japan, Taiwan and Korea. This invasive plant is found growing in sunny places on hills, high mountains and along road verges and ditches. Considered an aggressive invader in Europe, the United States, and Canada, *F. japonica* spreads by clonal, rhizomatous growth and can quickly form a monoculture. *F. japonica* can survive very harsh conditions with a pH range of 3.0-8.5, and an ability to survive extreme heavy metal and salt pollution and areas with low available nitrogen (Abgrall *et al.*, 2018; Sołtysiak, 2020).

Soil sampling
At all three research sites (cold, middle and warm climatic areas), 20 localities were identified (10 for invaded and 10 for non-invaded sites) measuring 1m x 1m, which represented a total of 60 bulk of average soil samples. Each sample consisted of three subsamples taken from a depth of 0.1-0.2 m, which were subsequently homogenized. All soil samples were transferred to a laboratory in plastic bags, sieved with a mesh size of 2 mm and stored in a refrigerator before the analyzes. Part of the samples were air dried at the room temperature to determine selected chemical parameters.

Soil physico-chemical and microbial indices
Dry soil samples were completely crushed in a porcelain crucible. These soil samples were used to measure soil reaction, total nitrogen content and organic carbon content. Soil pH was detected in a 1:3 mixture of soil and 0.01 M $CaCl_2$ solution using a digital pH meter. Soil organic carbon (SOC) and total nitrogen content (Ntot) were determined by the Turin's method (Fiala *et al.*, 1999). Gravimetric soil moisture (SM) was calculated on 10 g of fresh subsamples after drying in a 105°C oven for 24 h. Soil basal respiration (SBR) was measured by the CO_2 released from field moist soil in hermetically sealed flasks at 25°C for 48

hours (Alef and Nannipieri, 1995). Enzymatic activity assays, beta-glucosidase (BGL) (Eivazi and Tabatabai, 1988), fluorescein diacetate (FDA) (Green *et al.*, 2006), acid phosphatase (PHOSac) and alkaline phosphatase (PHOSal) (Grejtovský, 1991), were determined using field-moist soil samples using specific substrates of each enzyme. All determinations were performed in duplicate. The corresponding controls were done for each soil and enzyme activity by the same analytical analysis described, but without the addition of the substrate at the moment of initiating the enzyme reaction. Activity of all enzymes was measured in a spectrophotometer crating a reference curve.
Statistical evaluation of the obtained data was performed using Statistica 12 programme. All statistical operations were performed in the PAST 4.03 programme. Data were transformed before log+1 analysis.

RESULTS AND DISCUSSION

Invasive plant species may have the strong impact on several soil properties. The results revealed that soil reaction did not significantly change between invaded (6.9) and non-invaded sites (6.2). The same trend was observed for total nitrogen content, where average values in invaded sites reached 0.39% and in non-invaded sites 0.34%. Statistically, the content of organic carbon and soil moisture showed significant impact of invasiveness. Selected invasive species was able to slightly increase soil moisture (20.7%) compared to the control sites (17.3%). Very important soil chemical parameter organic matter, that affects quality of soil ecosystems was also significantly affected by plant invasion. The content of organic carbon showed higher average values in invaded sites (3.1%) compared to the non-invaded sites (1.84%). Generally, invaded soils are characterized by increased C and N stores and microbial activity (Stefanowicz *et al.*, 2017) which partially corresponds to our results.
The results of soil microbial indices also showed some differences between invaded and non-invaded sites. The study of Čerevková *et al.* (2019) showed a decrease of soil respiration rate affected by *F. japonica*, that has also been demonstrated in our research (Figure 1). The average value of soil respiration was statistically significant lower in invaded soils compared to non-invaded. The study of Koutika *et al.* (2007) showed that invasion of F. japonica reduced the soil C respiration and created soil organic matter which decomposed slowly. Figure 1 represents soil microbial indices in invaded and control sites. The same trend was found for acid phosphatase; it was lower (but not significantly) in the invaded than the non-invaded sites. Alkaline phosphatase was affected by *F. japonica* invasion in different ways in the different climatic areas, but no significant differences were found. Similar trend was also observed with the activity of FDA and beta-glucosidase. Their values were higher under presence of invasive plant species compared to the non-invasive sites. The analysed microbial characteristics in our study revealed that enzymatic activity was slightly higher in all ecosystems invaded by *F. japonica* compared to the uninvaded ones, suggesting that invasion did not significantly affect microbial activity in soil ecosystem. This was in line

with the measured enzyme activities, which remained unaffected by *F. japonica* invasion probably due the unchanged soil acidity, a factor most affecting activity of soil enzymes (Dassonville *et al.*, 2011).

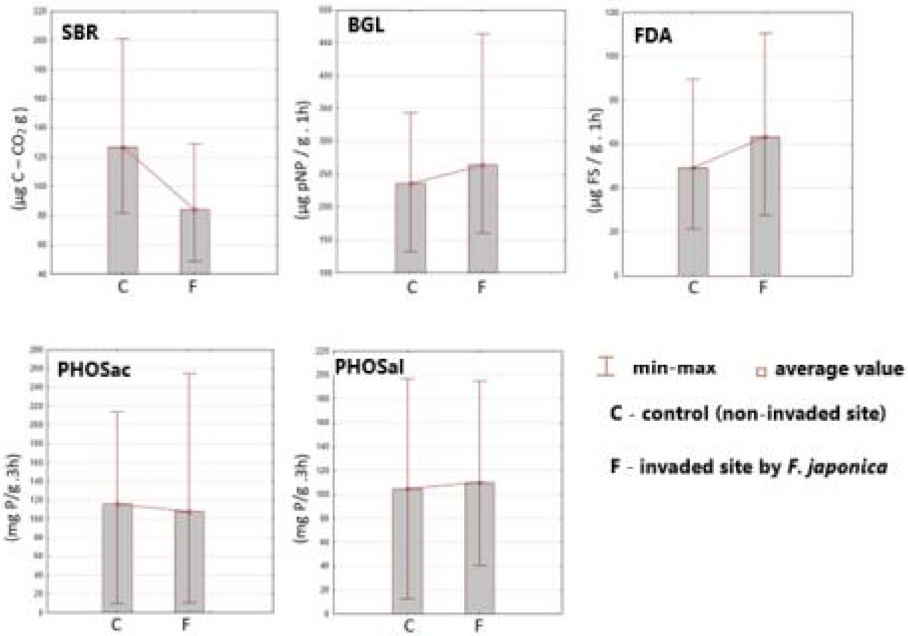

Figure 1. Average values of soil microbial indices in invaded and non-invaded (control) sites.

Native flora, as well as actual weather conditions, soil and ecosystem type, date of soil sampling, etc., are probably responsible for the variable impacts of invasion on soil acidity and moisture among studies. *F. japonica* forms dense stands that prevent other species from growing. The study of Kappes *et al.* (2007) and Čerevková *et al.* (2019) evaluated the impact of this plant exotic species on soil fauna and concluded that *F. japonica* significantly affect the faunal community, more that physical and microbial properties, regardless of selected habitat. Their study also concluded that large-scale invasion by *Fallopia* species is therefore likely to seriously affect biodiversity and reduce the quality of riparian ecosystems for amphibians, reptiles, birds and mammals whose diets are largely composed of arthropods.
Activity of microorganisms is also affected by climate that was also shown in our study. Figure 2 represents average values of microbial parameters according to different climatic regions. Statistically significant differences were shown for all monitored parameters according to the climatic area ($p<0.05$). The study of some authors (Rilling *et al.*, 2019, Zhou *et al*., 2019) show that climatic factors have big impacts on soil parameters development, especially soil organic carbon. Our study

revealed that soil microbial parameters, except activity of BGL, reached higher values in warm conditions compared to the cold region. This result corresponds with the finding of Misiak *et al.* (2021). Interestingly, the enzymatic activity, in which the enzyme activity such as FDA, acidic and alkaline phosphatase was lowest in the coldest climate region compared to others. High precipitation and low temperature may result in reduced activity of microorganisms. Statistically significant differences have been demonstrated in soil reaction, organic carbon content, soil respiration and the FDA in invaded soils compared to non-invaded regardless of climatic area. It follows that biological invasions affect the soil environment and are capable of significantly change soil properties.

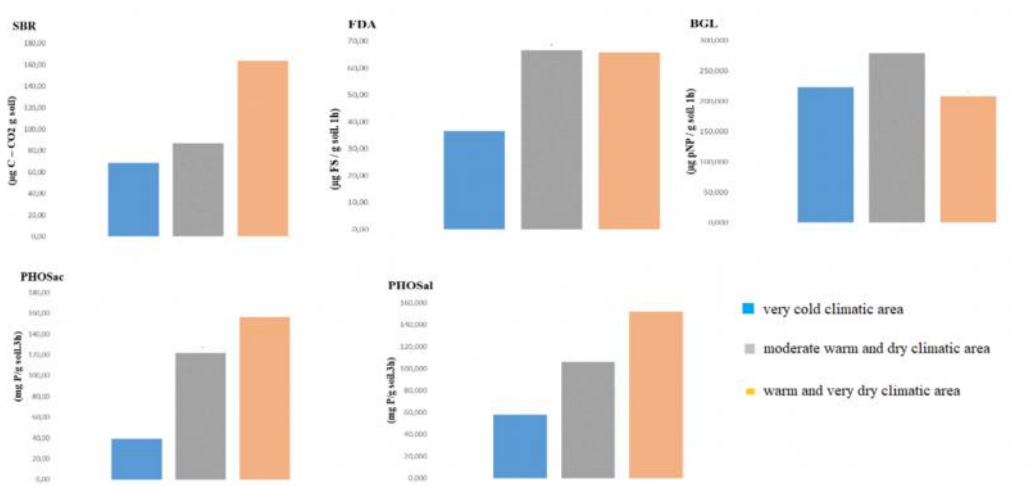

Figure 2 Average values of soil microbial indices in three different climatic regions.

CONCLUSION

The results showed that invasive *Fallopia japonica* have been able to alter the values of biochemical soil properties in soil ecosystem. There have also been recorded specific correlations among single parameters and region, which means that the effect of climatic conditions and different altitudes also impact microbial activity and other soil parameters.

ACKNOWLEDGMENTS

This study was supported by the project of Slovak Scientific Agency VEGA No. 2/0018/20.

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