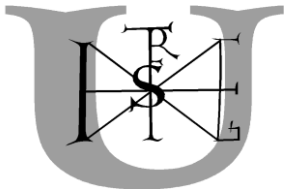

SZENT ISTVÁN UNIVERSITY

COMPLEX AND MAINPULATIVE ECOPHYSIOLOGICAL INNVESTIGATION OF WEED STANDS; THE EFFECT OF CERTAIN CLIMATE ELEMENTS ON ECOLOGICAL PARAMETERS

Theses of doctoral (PhD) dissertation

NÉMETH ZOLTÁN

Gödöllő
2019

1. Preliminary Experiments, Goals

One of the main goals of international ecosystem research is recently to measure the cycles of key greenhouse gases (CO_2, N_2O and CH_4) in different habitats. The European and national projects so far have focused on natural plant communities. However, such studies have not yet been carried out on weed species, although they are an inevitable part of agro-ecosystems and affect the production of cultivated plants. As one of the potential winners of climate change is the growing importance of weed species. Surprisingly, the greenhouse gas fluxes of weeds are hardly investigated, although they can affect the carbon balance of a given area due to their widespread distribution and continuous penetration. The ecological characteristics of many weed species have been well revealed, but their ecophysiological conditions, especially at the stand level, have hardly been studied. This work is basically a new approach at international and domestic level in the research on weeds. So far, such complex studies (parallel stand-level CO_2 flux measurements, phenological and production investigations) involving multiple weed species - including manipulative experiments – haven't been carried out on weed species. By studying weed taxa with different physiognomy, taxa belonging to different plant functional groups, archeophytes and neofphytes, we can learn about the supraindividual physiological diversity of their stands and the synphysiological function weed communities they dominate. The main objective of my research was the comparative eco-physiological, synphenetical and production biology examination of five in Middle Europe well spread weed species, *Amaranthus retroflexus*, *Ambrosia artemisiifolia*, *Artemisia vulgaris*, *Chenopodium album*, and *Sorghum halepense* at stand level. By selecting theese plant species, I took into account that both archaeophytons and neofitons, the different plant functional groups (C_3, C_4; therophytes, cryptophytes), as well as different plant families were represented. In addition to indigenous weeds, the study also includes species that are capable of biological invasion and, through their increasing proliferation, may be one of the most significant threats to biodiversity. Not only the invasive but also the indigenous weed species have an important nature conservation role in the distressed areas. The entire vegetation cycle covering study the of the selected weed species took place at the Botanical Garden of Szent István University in Gödöllő, with 27 plots in random block arrangement. As a result of global warming, changes in the frequency or intensity of extreme climatic events on a regional scale play an important role in the impact of the climate system on ecological and social systems. Thus, the modifications that can be traced in climatological extremes fundamentally determine the adaptability of these systems (BARTHOLY & PONGRÁCZ 2005). To investigate the effects of the extreme climate years predicted for the

Carpathian Basin, I have also carried out manipulative experiments with *Amaranthus retroflexus* (C_4) and *Chenopodium album* (C_3). From these weed species representing different plant functional groups, in addition to the control strains, partially precipitatin excluded, and irrigated plots were created in each of 3 to 3 repetitions per taxon and treatment. Changes in precipitation associated with climate change affect the adaptability of invasive species, and thus their impact on native species, which underlines the importance of manipulative experiments.

2. Materil and Methods

In the Botanical Garden of Szent Isván University Gödöllő monodominant plots (1m x 1m) were created of the five selected species (*Amaranthus retroflexus, Ambrosia artemisiifolia, Artemisia vulgaris, Chenopodium album, Sorghum halepense*), in 3-3 replicates to investigate the species-specific characteristics.

With *Chenopodium album* and *Amaranthus retroflexis* manipulative experiments were also carried ou, to which I created partial precipitation excluded (complete precipitation exclusio every second weeks) and irrigated (5mm a week).

Phenological sampling was done weekly. The number of new germs appearing, the current phenophase (appearance of flowers, yield), the maximum and average height of the stocks were recorded.

Biomass was measured on a weekly basis at individual level, and stocking at the end of the vegetation period.

The photosynthetic pigments (chlorophyll-a, -b and carotenoids) were determined by the method of LICHTENTHALER (1987). I took samples of the examined plant species and their different treatment spots at the time of full development.

Soil CO_2 flux (R_{eco}) was measured weekly using a LiCor-6400 (Lincoln, Nebrasca, USA) portable infrared gas analyzer with so called "Closed chamber method", with 3-3 repetitions per species and treatment, with additional soil temperature measurement.

The stand-level carbon dioxide gas exchange (NEE) is measured using a CIRAS-2 infrared gas analyzer (PP Systems, Hitchin, UK). I used the "open-chamber" technique on a weekly or bi-weekly basis, with transparent, clear, clear (60 cm diameter) plexiglas, corresponding to the current height of the files.

N_2O and CH_4 measurements were done on a two-week basis with closed chamber technique.

3. Results

The weed species are characterized by a similar growth curve or change in sowing rate (sigmoid), irrespective of whether they belonged to different plant function types and taxonomical groups. Preliminary and ex situ germination showed that among the examined taxa, *Ambrosia*'s germination rate is the lowest that the plant is likely to compensate for higher seed yields.

The C_4 species sprouted several weeks later than the white *Chenopodium album* and *Atemisia vulgaris*, which can be explained by the higher germination temperature demand. In the majority of species, I have experienced earlier flowering, which is due to the lack of favorable rainfall and late spring frosts. The earlier than expected flowering was even more pronounced in the vegetative flocks.

The investigated species achieved very significant production without exception, which is several times higher than the values of Hungarian herbaceous vegetation (eg grasslands) found in the literature. On the one hand, this can be explained by the favorable precipitation level, on the other hand, by the high CO_2 fixation lasting for several months. The above ground biomass of the examined C_3 taxa was - in most cases significantly- higher than the C_4 species', which can be explained mainly by their different physiognomy.

In the fully developed stage, the dominance of chlorophyll-a was not general, as the chlorophyll-b content was the highest for the two taxa representing the Asteraceae family. The measured pigments were in a wide range for the five species. It seems that the nearly balanced chlorophyll-a/b ratio resulted higer level of CO_2 fixation. The proportion of carotenoids and xanthophylls was higher in the partially precipitation excluded stands, which can be explained by the protective effect of these pigments.

The seasonal dynamics of soil respiration and CO_2 uptake were both represented by bell-curve in each species, but no statistically significant difference could be detected in the whole cycle. The low values measured in the plant-free control plots showed that the root respiration of the examined weeds and the effect of the microclimate formed by the cover can be decisive for the carbon balance of an area.

The stands of all five weeds had reasonable CO_2 fixation, which was maintained for several months despite the rising R_{eco} values and the drought in August. The maximal CO_2 fixation of the stands of the examined taxa reached several times higher values than other of grass types that have been measured by chamber technique in Hungary.

As a result of the manipulation experiments, I found that the number of plants, the average height of the shoots, the NDVI values, the total pigment content, the mean NEE and the biomass values were related to the precipitation conditions in both species. The effect of different

precipitation conditions also influenced the phenological phaze of the manipulated stands. As a result of irrigation, *Amaranthus retroflexus* shifted its flowering and harvesting dates two weeks later. There was an oposit trend observable in the stands of the C_3 species. The flowers occured later in the partialy precipitation excluded plots compared to control stands and yilding started about one month later as well. The R_{eco} value of *Amaranthus* decreased on average by 27% and by 12% of *Chenopodium* due to partial precipitation exclsion in 2008. Irrigation increased the R_{eco} by 19% in the *Amaranthu*s and 23% in the *Chenopodium* stands throughout the first vegetation periode. In the partially precipitation excluded *Amaranthus retroflexus* plots, based on the of our periodic measurements average values, the rate of CO_2 fixation decreased by nearly half (47.5%). In contrast, the average CO_2 uptake of irrigated stands were more than 1.6 times (161%) higher as the average value of the control stock. The average NEE values of the manipulated stands of the C_3 taxon did not reflect the different water regimes. The average CO_2 fixation of the reduced water stands was less than 10% lower than the untreated type, while the irrigated stock exceeded the average NEE of the control by 13%. The impact of manipulation on biomass, like CO_2 flux, was more pronounced in *Amaranthus* stands, where the rate of production change was almost fully harmonized with precipitation differences. Precipitation exclusion in the *Amaranthus retroflexus* stands resulted in a 53.5% decrease in biomass and 46.6% in the *Chenopodium*. As a result of irrigation, the amount of total biomass increased by 51% for *Amaranthus* and 29.3% for *Chenopodium*.

In 2009, the average biomass production of all 5 taxa fell significantly short of the values measured in 2008, due to the much lower rainfall supply compared to the previous year. In the case of C_3 species this difference was significant ($P < 0.05$). The decline was also significant for C_4 species, as *Sorghum halepense* and *Amaranthus retroflexus* reached only about half of the biomass production compared to the previous year.

The CH_4 and N_2O fluxes of the examined weed species did not show significant differences from other domestic vegetation (grasslands and wetlands) despite the different environmental conditions and biomass production. There were no clear and significant differences between the functional groups.

3. New Scientific Results

- The investigated species in monodominant flocks achieved a very significant production without exception, which is several times higher than the values of Hungarian herbaceous vegetation (eg. grasslands) found in the literature.

- Each of the five investigated taxa had a reasonable CO_2 fixation during the vegetation period. The maximum CO_2 fixation of the stands of the examined species is several times higher than the maximum limit values measured in other Hungarian grassland types..
- The order of carbon fixation of each species did not reflect the biomass of the stands.
- There was no significant difference between the 5 examined weed species and the C_4 and C_3 taxa examining the light dependence of NEE.
- Surprisingly, the C_3 *Chenopodium album*'s NEE values were less affected by lesser rainfall than C_4 *Amaranthus retroflexus*'s CO_2 capture.
- The CO_2 fixation of the stands, depending on the air temperature, showed a bell curve character. There is no clear difference between C_4 and C_3.
- Despite the different environmental conditions and biomass production, the CH_4 and N_2O fluxes of the examined weed species did not show significant differences from other domestic vegetation (grasslands and wetlands).
- There are no significant differences between methane and nitrous oxide fluxes in each functional group.
- Low Reco values measured in plant-free control spot showed how decisive the impact of the root weeds of the weeds and the microclimate of the cover on the carbon balance of an area.

4. Findings and Suggestions

Although the chosen species represented different functional groups, and had different shoot number and biomass, they were characterized by very similar dynamics regarding more parameters (stand height, shoot number, NDVI values, soil respiration and stand level CO_2 fixation). All the investigated taxa had a remarkable production, which was multiple times higher than the herbaceous plants in Hungary (for example grasses). It can be the result of the favorable water regimes and the elongated period of high CO_2 fixation. This intensive carbon dioxide fixation can be the key to the success of this plant group. Methane and dinitrogen-oxid fluxes had a bigger range in 2008 which year was a more balanced regarding the precipitation, signing their correlation with draught.

Regarding the manipulative experiments I have found remarkable even significant (for example biomass, shoot number) difference to the control plots about more parameters. The differences among the treatments started already during the germination, but got stronger during the dryer periods. The arid summer had stressed the stands at different level which was well measurable by the soil respiration and CO_2 flux variability. The manipulative experiments showed that there

was a correlation between the precipitation level and shoot number, mean height of the plants, NDVI values, pigment content, mean NEE and biomass values at the total development phase. These results are not only basic research like but can be used at synphenetical and synphysiological characterization or modeling of plant communities with similar dynamics. Furthermore the deeper knowledge of weed ecophysiology can allow developing new plant protection methods for the benefit of the economy and public health.

5. Publications relelant to the topic of the dissertation

International reviewed scientific journal articles with impact factor:

Németh Z., Skutai J., Pósa P., Szirmai O., Czóbel Sz. (2017): Stand level CO_2 flux examination of weed species with different origin and functional groups. *Applied Ecology & Environmental Research* **15** (4): 217-226.

Czóbel Sz., **Németh Z.**, Szirmai O., Gyuricza Cs., Tóth A., Házi J., Vikár D., Penksza K. (2013): Short-term effects of extensive fertilization on community composition and carbon uptake in a Pannonian loess grassland. Photosynthetica 51: 490-496. IF: 0,862

DOI: 10.1007/s11099-013-0052-z

Czóbel Sz., Szirmai O., **Németh Z.**, Gyuricza Cs., Házi J., Tóth A., Schellemberger J., Vasa L., Penksza K. (2012): Short-term effects of grazing exclusion on net ecosystem CO_2 exchange and net primary production in a Pannonian sandy grassland. *Notulae Bot Horti Agrobo* (*Notulae Botanicae Horti Agrobotanici Cluj-Napoca*) 40: 67-72.

Czóbel Sz., Horváth L., Szirmai O., Balogh J., Pintér K., **Németh Z.**, Ürmös Zs., Grosz B., Tuba Z. (2010): Comparison of N2O and CH4 fluxes from Pannonian natural ecosystems. *European Journal of Soil Science* 61: 671-682.

SCI-registered, Hungarian peer-reviewed periodicals:

Németh Z., Falvai D., Szirmai O., Czóbel Sz. (2017): Archeofiton és neofiton gyomfajok fitomassza vizsgálata. *Tájökológiai Lapok* 15: 21-29.

Czóbel Sz., Tuba Z., Szirmai O., **Németh Z.**, Nagy J., Szerdahelyi T., Péli E., Balogh J., Nagygyörgy E.D., Varga E., Valkó D. (2009): Különböző ökoszisztémák állományszintű, kamrás CO_2-fluxus méréseinek sajátosságai. *Botanikai Közlemények* 96: .13-14.

Németh Z., Czóbel Sz., Nagygyörgy E. D., Varga E., Szirmai O., Péli E. R. (2008): Erdei geofitonok ökológiai vizsgálata, valamint szerepük a magyarországi szénmérlegben. *Kitaibelia* **13**: 122.

International conference publications:

Németh Z., Vikár D., Penksza K., Czóbel Sz. (2012): Drought and wetness effect on production of weed taxa. p. 123. In: Willner W. (ed.) Book of Abstracts of the 21th International Workshop of European Vegetation Survey, Vienna, Austria, 24-27 May 2012. 165 p.

Németh Z., Vikár D., Penksza K., Czóbel Sz. (2012): The tolerance on draught stress in *Chenopodium album* and *Amaranthus retroflexus* stands considering ecophysiological parameters. p. 38. In: Touraev A., Schubert S., Rennenberg H. (eds.): Programme and Abstracts, International Conference Plant Growth, Nutrition & Environment Interactions, Vienna, Austria, 18-21 February 2012. 119 p.

Németh Z., Pap K., Szirmai O., Czóbel Sz. (2011): Differences in evapotranspiration characteristics in common weed species. Növénytermelés 60: 341-344. /In: Harcsa M. (ed.) Proceedings of the 10th Alps-Adria Scientific Workshop, Opatija, Croatia, 14-18 March 2011. 464 p./

Németh Z., Czóbel Sz., Németh Cs., Pásztor-Huszár K. (2010): Resilience in C_3 and C_4 weed stands, in response to different water regimes. Növénytermelés 59.: 461-464. In: Harcsa M. (ed.) Proceedings of the 9th Alps-Adria Scientific Workshop, Špičák, Czech Republic, 12-17 April 2010. *636* p./

Németh Z., Czóbel Sz. (2010): Ecological indicators vs. manipulation, an *ex situ* case study on selected weed taxa. p. 135. In: Botta-Dukát Z. & Salamon-Albert É. (eds.) Book of Abstracts of the 19th International Workshop of European Vegetation Survey, Pécs, Hungary, 29 April – 2 May 2010. 144 p.

Németh Z., Czóbel Sz. (2009): Comperative ecophysiological study of a C_3 and C_4 weed stands considering the climate change. In: Proceedings of the 8th International Carbon Dioxide Conference, Jena, Germany, September 2009. p.

Hungarian conference publications:

Czóbel Sz., Huszti E., Pap K., Szirmai O., Pándi I., **Németh Z.**, Vikár D., Penksza K. (2011): Védett nyílt és zárt homoki gyeptársulások magszórással és monolit áttelepítéssel végzett ex situ rekonstrukciójának első eredményei. p. 68 In: Lengyel Sz., Varga K., Kosztyi B. (eds.): VII. Magyar Természetvédelmi Biológiai Konferencia, Előadások és poszterek összefoglalói. Debrecen, 2011. november 3-6., 197 p.

Németh Z., Penksza K., Czóbel Sz. (2011): Neofiton és archeofiton gyomfajok csírázási karakterisztikája. 161-165. pp. In: Magyar Biológiai Társaság (ed.): VII. Kárpát-medencei Biológiai Szimpózium, Előadások és poszterek összefoglalói. Budapest, 2011. október 13-14.

Czóbel Sz., Szirmai O., Nagy J., Szerdahelyi T., Cserhalmi D., Balogh J., Valkó D., **Németh Z.**, Tuba Z. (2009): Hínárfajok dominálta növényközösségek szén-dioxid fluxusainak összehasonlító vizsgálata. p. 40 In: Körmöczi L. (ed.): 8. *Magyar Ökológus Kongresszus*, Előadások és poszterek összefoglalói. Szeged, 2009. augusztus 26-28., 248 p