STAND LEVEL CO_2 FLUX EXAMINATION OF WEED SPECIES WITH DIFFERENT ORIGIN AND FUNCTIONAL GROUPS

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Abstract. Although the ecological attributes of many weed species are well-known, their eco-physiological relations – particularly at stand level – are scarcely researched. Based on this the main objectives of our examination are to measure the stand level CO_2 flux (NEE) for 5 weed species generally widespread in Central Europe as well as to explore the dependence of NEE on air temperature, radiation and stand level evapotranspiration. The selected weed species represent archaeophyte and neophyte plants as well as different functional groups (C_3, C_4, therophytes and cryptophytes). The research covering an entire vegetation cycle of the weed species has been implemented *ex situ* in 15 patches of the Szent István University's Botanical Garden. Stands of the involved species showed really significant CO_2 uptake for months. This value is the multiple of what is indicated in literature regarding Central European herbaceous vegetation (e.g. grasslands) – this fact can be one of the key factors leading to the success of this plant group. By comparing the average CO_2 fluxes of these five weed species in the entire vegetation period it can be concluded that the values of the two endemic species are almost completely identical exceeding the average values of non-endemic C_4 weed species. Furthermore, significant linear regression ($P<0.05$) has been observed between the net ecosystem CO_2 gas exchange of *Ambrosia artemisiifolia* and *Chenopodium album* and the values of stand level evapotranspiration.
Keywords: *canopy chambers; weeds; net ecosystem; carbondioxide exchange; dependence*

Abbreviations: *Ama ret – Amaranthus retroflexus*; *Amb art – Ambrosia artemisiifolia*; *Art vul – Artemisia vulgaris*; *Che alb – Chenopodium album*; ET – evapotranspiration; LAI – leaf area index; NEE – net ecosystem CO_2 exchange; PPFD – photosynthetically active photon flux density; *Sor hal – Sorghum halepense*; T_{air} – air temperature

Introduction

One of the main objectives of recent international ecosystem researches is to measure the cycles of important greenhouse gases (including carbon dioxide) in different habitats (e.g. Yamuki et al., 1997; MacDonald et al., 1998; Dong et al., 2000; Papen et al., 2001; Hefting et al., 2003; Horváth et al., 2006). Such European projects have examined ecosystems of grasslands, shrubs, waters, watersides and forests together with their plant communities/stands. However it is surprising that stand level research regarding greenhouse gas fluxes of weed stands has not yet been conducted although they can have fundamental influence on the carbon balance of certain areas due to their wide range and constant expansion. Ecological characteristics of several weed species are well-explored (e.g. Holzner and Numata, 2013; Čekić and Kovačević, 2015; Kleunen et al., 2015) but their stand level ecophysiological relations are hardly examined.

Examinations implemented so far on greenhouse gases in relation with weeds mainly focused on the impacts of increased CO_2 concentration on the growth and production of

weed species instead of their CO_2 fluxes. Based on the responses given by different C_3 and C_4 weed species on increased CO_2 concentration in the air the highest growth rate among the involved taxa belonged to the C_4 *Amaranthus retroflexus*. In case of *Ambrosia* growth was more intensive under increased CO_2 concentration in the first half of the examination period while in the second half current atmospheric conditions (i.e. 350 ppm) resulted higher growth (Garbutt et al., 1990). The amount of reproductive biomass was increased in case of *Amaranthus retroflexus*, *Chenopodium album* and *Ambrosia artemisiifolia* when atmospheric CO_2 concentration was higher. Strong correlation can be observed between the change of leaf surface and accumulation of biomass in case of *Abutilon theophrasti* and *Amaranthus retroflexus* (Akerly et al., 1992). Development of leaves has been accelerated for these species by increasing either the air temperature or the CO_2 concentration.

 Other researchers examined the impacts of not only increased but also decreased carbon dioxide concentration on – among others – C_3 and C_4 weed species (Dipperey et al., 1994.). Regarding C_4 taxa CO_2 concentration had no effect on either growth rate or total biomass within the first 35 days following germination. In case of C_3 taxa biomass showed positive correlation with higher atmospheric CO_2 concentration.

The effect of aridity was different in the involved functional groups (Ward et al., 1999). Photosynthetic rate of plants with good availability rate has increased when atmospheric CO_2 concentration was higher but their leaf surface and biomass has not changed. As opposed to that both leaf level CO_2 uptake and biomass of C_3 taxa increased under the concentration of 700 ppm. Due to the aridity leaf surface of C_3 plants reduced significantly; as a consequence of that water potential value of remaining leaves became relatively high. The LAI of C_4 plants decreased in smaller extent. Lower water potential value was measured in their leaves. Under non-limiting nutrient provision whole individuals of C_3 taxa developed significantly as a result of increased CO_2 concentration while more moderate growth has been examined in case of C_4 plants (Bernacchi et al., 2000). In limiting environment neither types showed significant development. Shoot-root rate remained unchained or decreased in the observed taxa as a result of higher CO_2 concentration.

Considerable competition can occur among weeds in mixed communities as a result of which the amount of biomass – both above and below soil surface – change as well as the habit of the plants (e.g. Bazzaz et al., 1989). Interference of different species can be observed not only in competition for resources. For instance, *Artemisia vulgaris* has allelopathic characteristics among the examined weed species (Barney et al., 2005). In mixed vegetation species can influence not only negatively the development of other taxa. Weeds growing under higher plants can utilise absorbed and photosynthetically active radiation with higher efficiency (Gramig et al., 2006). Selected parameters can be examined in a taxon specific way (Borjigidai et al., 2008) in monodominant stands of the selected weed species.

By examining archaeophyte and neophyte weed species representing different physiognomy and functional groups the CO_2 balance of these stands and plant communities can be explored. Photosynthetic capacity of invasive plants is usually higher (Nielsen et al., 1993; Patterson et al., 1998) but their mass invasion is not a primary consequence of this feature (Brodersen et al., 2008).

Measurement of carbon dioxide fluxes in the weed stands can also provide a basis in the future for monitoring alterations occurring as a result of global climate change regarding these stands and plant communities dominated by these species. Due to

climate change extreme weather conditions become more frequent (Brodersen et al., 2008) to which taxa give different answers. Examining the success of adaptation to extreme precipitation conditions may help when establishing a prognosis in relation to the future range of certain weed species since different types of photosynthesis influence the water utilisation efficiency of plants (Niu et al., 2005; Sharkawy, 2009).

The main objective of our research is to implement comparative measurement of carbon dioxide fluxes at stand level in case of five weed species generally widespread in Central Europe (Lososová et al., 2006): *Amaranthus retroflexus, Ambrosia artemisiifolia, Artemisia vulgaris, Chenopodium album* and *Sorghum halepense.* Dependence of NEE on air temperature, radiation and stand level evapotranspiration has also been examined.

When selecting the species it has been taken into consideration that archaeophyte (*Artemisia vulgaris, Chenopodium album*) and neophyte (*Amaranthus retroflexus, Ambrosia artemisiifolia*, *Sorghum halepense*) plants as well as members of different functional groups /C$_3$ (*Ambrosia artemisiifolia, Artemisia vulgaris, Chenopodium album*), C$_4$ (*Amaranthus retroflexus, Sorghum halepense*); therophyte (*Amaranthus retroflexus, Ambrosia artemisiifolia, Artemisia vulgaris, Chenopodium album*), cryptophyte (*Sorghum halepense*)/ species and angiosperms (3 families and 5 genera) are all to be represented.

Materials and Methods

Site description

Examination covering the entire vegetation cycle of weed species have been implemented in the Experimental Site of Szent István Egyetem Botanical Garden (Gödöllő 19°14'E, 47°25'N, 250 m elevation) (Szirmai et al., 2014). Mean annual temperature is 10.5 °C; average amount of precipitation is 500 mm. The soil of the site is loose and moderately calcareous sand (Szente et al., 1993b). 15 homogenous stand patches have been created within the selected area. The size of the patches was 1 by 1 metre, with 3 repetitions by species and by examinations. Proper isolation distances have been kept among the stands. Parcels were established following random block pattern in order to avoid spot effect.

Stand level measurements

Measurements were conducted in the 2008 vegetation period by using CIRAS-2 infrared gas analyser (PP Systems, Hitchin, UK) and the so-called "open chamber" method. Measurements have been taken weekly or in every two weeks with the help of transparent, water-clear plexi chambers adjusted to the actual height of stands. The chamber used initially consisted of a cylinder wall with 60 cm diameter and a half-sphere shaped transparent part installed at the top airtight (in details see Czóbel et al., 2004). In order to harmonise the tools with the actual height of stands 70 cm and 200 cm high chambers were used. External fans ensured the consistent mixing of air within the chambers as well as air exchange. The same measurement technique has been applied regardless the size of the chambers. Measurements were taken between 11 am and 3 pm under cloudless and clean sky. Data recording took at least 30 minutes for each weed species and treatment. The equipment measured the difference in stand level CO$_2$ flux (in the incoming and outgoing tubes of the chamber) by taking 10 samples per

minute. It also recorded the photosynthetically active radiation (PPFD), air temperature (T$_{air}$) and evapotranspiration (ET) in the stand covered by chamber. Average temperatures of the given stand have been used for CO$_2$ flux calculations. The following differential equation has been applied when calculating CO$_2$ flux:

$$F=\Delta c * Q/A$$

where 'F' is the stand level flux /CO$_2$ uptake of the plant stand, vegetation and soil respiration in case of CO$_2$ flux; the resultant of the evaporation regarding soil surface covered by vegetation in case of evapotranspiration/ (mol m^{-2} s^{-1}), 'Δc' represents the difference in incoming and outgoing concentration /CO$_2$ or H$_2$O/ (mol m^{-3}), 'Q' stands for flowrate (m^{-3} s^{-1}) and 'A' is the soil surface covered by the chamber (m^2).

Following quality control raw data have been manually filtered where negative evapotranspiration values as well as outliers recorded at the initiating and final phases of the measurement (due to human respiration) have not been taken into account.

Parallel to CO$_2$ flux measurements ET, PPFD and T$_{air}$ have been recorded by patches with a portable infrared gas analyser /CIRAS-2 (PP Systems, Hitchin, UK)/

Statistics

Only significant correlations have been represented in the figures indicating the strength of the correlation. The strongest significant correlation has been fitted to the data in all cases. Values of regression have been calculated by SigmaPlot 8.0 software. In case of time series t-tests were implemented to check the level of significance regarding correlation values, impacts of manipulation experiments and the differences among the involved taxa. Standard deviance (SD) values are indicated in the figures.

Figures have been created by using SigmaPlot 8.0 software.

Results and Discussion

Net ecosystem CO$_2$ exchange (NEE) examinations

All five species reached considerable CO$_2$ exchange values until the time of cutting (*Fig. 1*). Significant values of standard deviance is connected to high CO$_2$ fluxes regardless of the species. Stands of *Ambrosia artemisiifolia* and *Sorghum halepense* reached the maximum of CO$_2$ uptake relatively late. Maximal value of CO$_2$ fixation, in case of both species, can be the multiple compared to that of either a fully developed loess grassland (Frank et al., 2002; Hunt et al., 2002; Czóbel, 2007; Czóbel et al., 2008) or a stand of spring forest geophytes (Barcza et al. 2011). Different functional groups cannot be significantly separate based on their NEE values. During spring both early germinating C$_3$ species (*Che alb*: -9.20; *Art vulg*: -6.28) produced remarkably high NEE values even from May while stands of C$_4$ weeds showed lower CO$_2$ uptake (*Ama ret*: -4.06; *Sor hal*: -2.53) in this period. Average net ecosystem exchange increased in a great extent (*Ama ret*: -8.29; *Sor hal*: -8.44) during summer. Stands of *Amb art* reached the highest value of the summer period (-15.95) by showing great increase in biomass and NEE. In this season average NEE value of *Art vul* also increased (-9.98) while in stands of white goosefoot it has been reduced (-7.66). Order of CO$_2$ fixation among the species has not reflected the amount of biomass. Following cutting CO$_2$ exchange of the weed species significantly decreased as a result of both losing the majority of foliage

and the poor regeneration due to aridity stress, therefore differences among taxa have been levelled off. During the autumn period *Ambrosia artemisiifolia* and *Sorghum halepense* showed the highest (-2.85) and the lowest (-0.85) average NEE value, respectively.

In case of *Amaranthus retroflexus* until uptake irrigated stand and no-precipitation stand showed the most intensive and lowest CO_2 uptake, respectively.

NEE averages of the examined weeds remarkably exceeded values measured in temperate grasslands (e.g. Frank et al., 2002; Hunt et al., 2002; Soussana et al., 2007). Compared to grasslands the examined weed species were characterised by high CO_2 fixation even in the arid summer period (Valentini et al., 1995; Suyker et al., 2003; Li et al., 2005; Pintér et al., 2008).
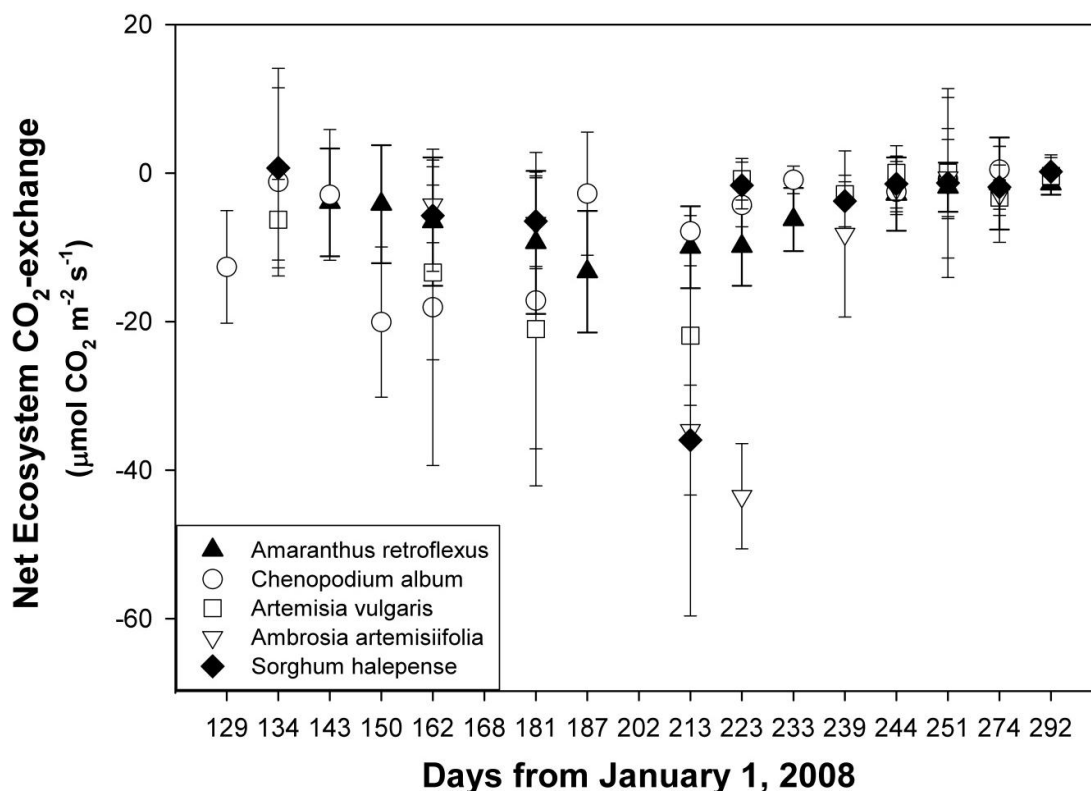

Figure 1. Seasonal dynamics of net ecosystem CO_2 exchange (NEE) regarding the examined weed species during an entire vegetation period

Dependence of NEE on light, temperature and evapotranspiration

As regards of NEE light dependence no significant difference could be observed among neither the 5 examined weed species nor C_3 and C_4 taxa (*Fig. 2*). Positive correlation was found between CO_2 uptake value of the stands and PPFD. In stands of *Chenopodium album* this relation was significant when using exponential fit (P<0.05). The most intensive CO_2 fixation was measured when PPFD value ranged between 1400 and 1600.

CO_2 fixation of the stands showed Gaussian curve when their dependence on air temperature has been examined (*Fig. 3*). No clear difference could be observed between C_4 and C_3 species. Correlation between the two parameters was significant in stands of *Chenopodium album* (P<0.05).
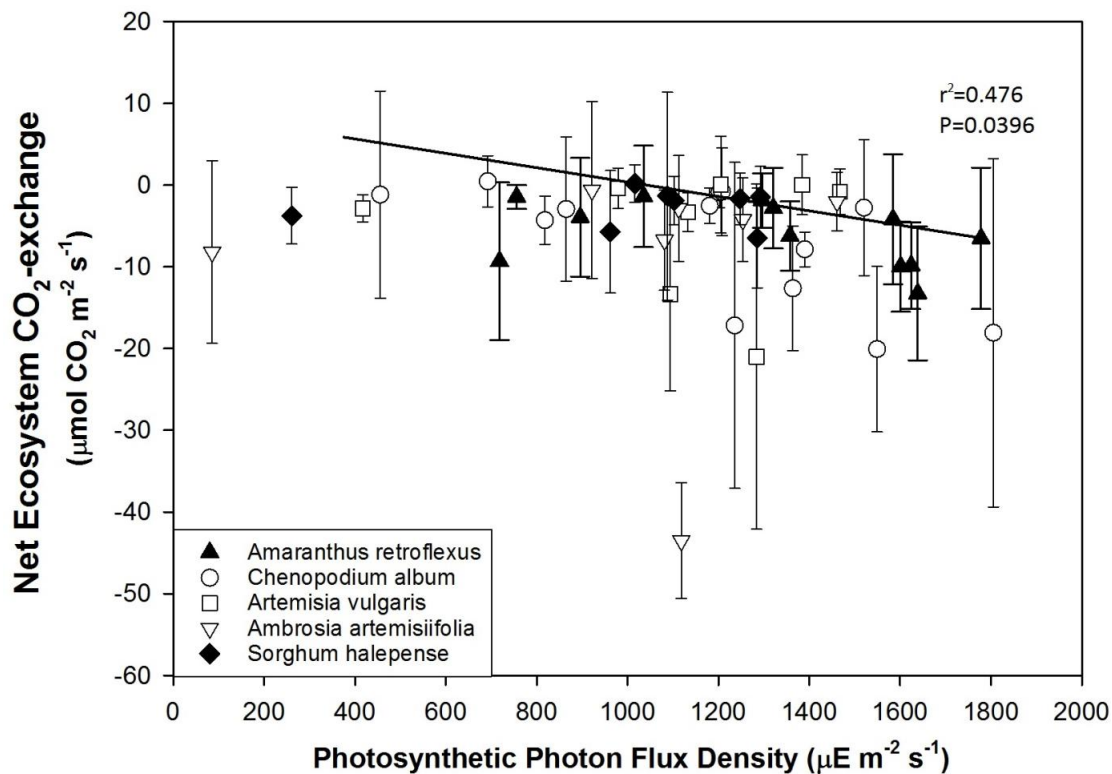
Figure 2. Dependence of net ecosystem CO_2 exchange (NEE) regarding the examined weed species on photosynthetically active radiation (PPFD)
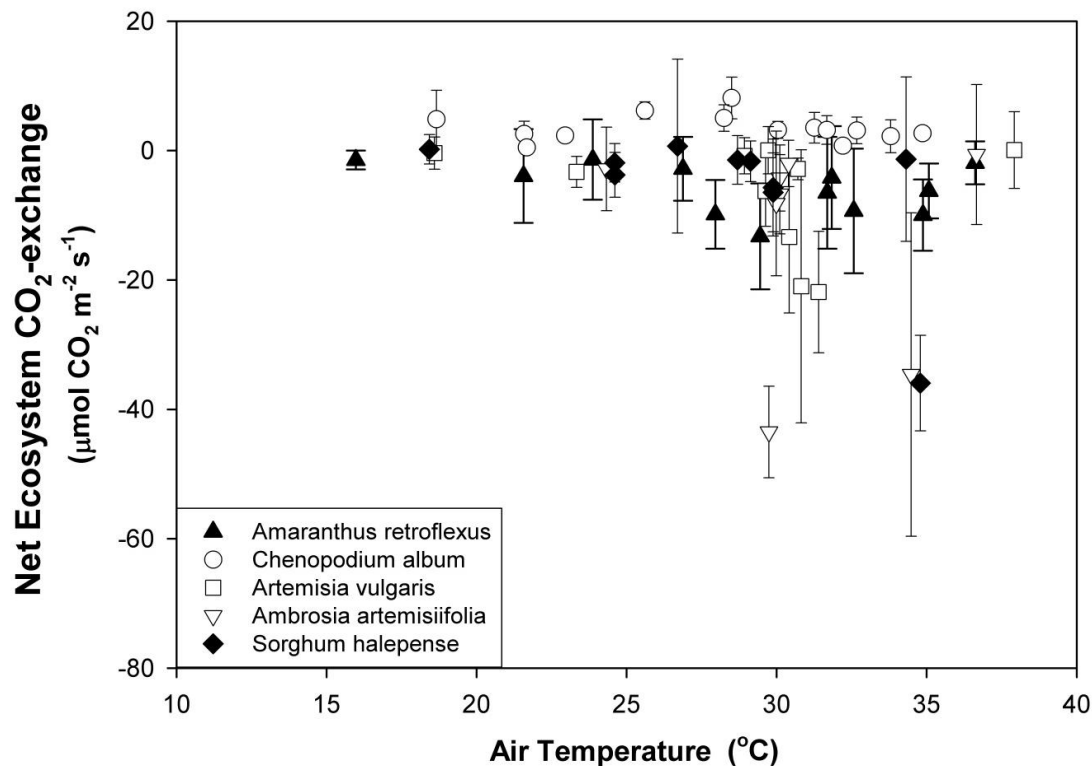

Figure 3. Dependence of net ecosystem CO_2 exchange (NEE) regarding the examined weed species on air temperature (T_{air})

Considering CO_2 fixation optimum heat ranged between 28 and 35 °C for all five species. Gas exchange intensity continuously increased up to 30 °C in case of each taxon while considerable retrogression was observed over 35 °C. Latter phenomenon was experienced for C_4 type weeds also, thus presumably not only stomatal closure (C_3) but also lover level of soil humidity contributed in its development.

Positive correlation could be noticed between CO_2 uptake and ET within the examined stands (*Fig. 4*). ET dependence of NEE did not show significant distinction regarding the plant species and functional groups. However, significant linear regression (P<0.05) could be observed between net ecosystem CO_2 exchange and stand level evapotranspiration in case of *Ambrosia artemisiifolia* and *Chenopodium album*. When conducting the measures increased ET was usually coupled with slightly higher CO_2 uptake.
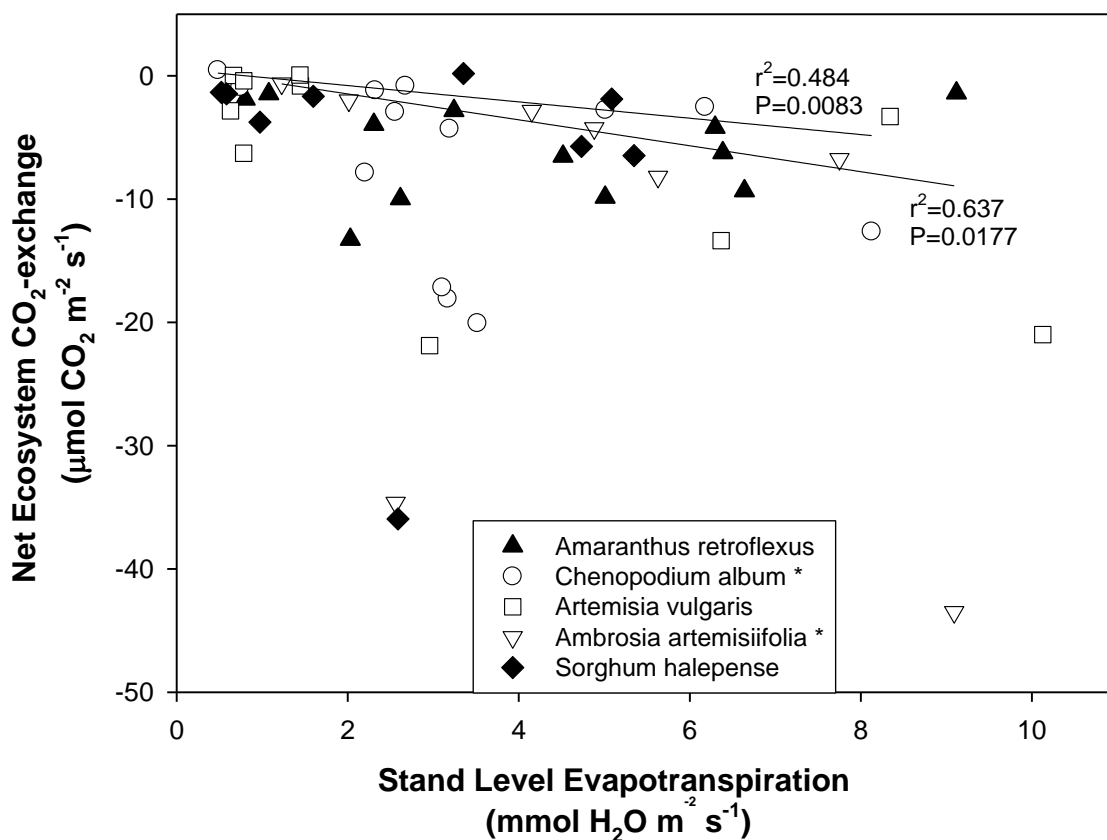

Figure 4. Dependence of net ecosystem CO_2 exchange (NEE) regarding the examined weed species on evapotranspiration (ET)

Conclusions

The examined species all reached remarkable production that is the multiple of values presented in literature regarding herbaceous vegetation (e.g. grasslands) in the Carpathian Basin. Despite the species represented different functional groups and characterised by different stem count and biomass they all showed very similar dynamics. This can be explained by the above-average precipitation of the examination year and by the high level of CO_2 fixation maintained for months. This latter feature can prove as one key feature leading to the success of this plant group.

By examining the stand level CO_2 fluxes of the five involved weed species regarding the entire vegetation period it can be concluded that values of two species endemic in Central Europe (*Chenopodium album* and *Arthemisia vulgaris*) are nearly identical while exceeding the average values of non-endemic C_4 weed species (*Amaranthus retroflexus*, *Sorghum halepense*). The latter two plants, despite their different morphological features, can be characterised by almost the same average regarding CO_2 uptake. The average CO_2 fixation of the neophyte ragweed significantly exceeded that of all other plants involved. As for C_3 weeds endemic species initiated more intensive CO_2 uptake compared to the also C_3 but invasive *Ambrosia arthemisiifolia*. C_4 taxa reached higher NEE values later, similar to *Ambrosia*.

Further study is needed to define and measure the effects of intraspecific and interspecific competitions.

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