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An analysis of weed floras in nurseries: Do polytunnels serve as ports of entry for alien plant species?

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ABSTRACT

The introduction of alien species into new regions has become a defining feature of global environmental change. It has been argued that greenhouses and polytunnels may serve as invasion foci for emerging plant invaders of agricultural ecosystems under future warmer climates. To test this hypothesis we selected 15 organically producing plant nurseries in lowland eastern Austria. There species coverage was recorded in 73 plots inside and in 60 plots outside polytunnels. In total, 109 species were identified (including plant seedlings which could only be determined to the genus level), consisting of 27 neophytes, 6 archaeophytes and 76 native plant species. Although average weed species numbers were significantly higher inside polytunnels compared to reference plots outdoor, nonmetric multidimensional scaling revealed no significant differences in species composition. Similarly, we found no differences in the weed community indices, i.e., the proportion of species preferring low or high temperatures, low or high precipitation, and low or high soil fertility, between plots located in polytunnels and outdoor. This holds true for total species number as well as for subsets of species of different residence time. The recorded neophytes are native to Asia, Europe, North and South America at almost equal proportions, most neophytes (22 species) are introduced intentionally, while unintentionally introduced species were more abundant on average. In polytunnels, neophyte species number was dependent on the crop category only, and archaeophyte species numbers were influenced by size of the polytunnels, whereas native and total species numbers were again influenced by the crop species. In outdoor plots, archaeophyte numbers were influenced by mean annual temperature. Overall, weed vegetation in polytunnels and outdoors differs only little in terms of species composition and abundance. We thus conclude that sheltered environments (as polytunnels), which mimic warmer climates, do not serve as entry points for emerging neophytes of agricultural ecosystems.

Introduction

Transport and establishment of species by human activities into regions beyond natural dispersal limits has become one of the defining features of global environmental change (Blackburn et al., 2014; Simberloff et al., 2013). Alien species – encompassing old ('archaeophytes', pre-1500 alien species) and new ('neophytes', post-1500 alien species) invaders – are already an important component of many ecosystems (Hobbs et al., 2013), in particular of those strongly modified by humans as ruderal habitats and agricultural fields (Chytrý et al., 2008a,b). These systems are exposed to particularly high levels of disturbance which create abundant colonization opportunities for many alien species (Chytrý et al., 2008b). In addition, propagule pressure due to contaminated seeds and soil transported by agricultural machinery often is high as well (Simberloff, 2009). Hence, ruderal and agricultural habitats are often the invasion foci for subsequent colonization of other ecosystems by spreading alien organisms (Hulme, 2003, 2011; Theoharides and Dukes, 2007).

During the recent decades, rates of naturalization of alien species have continuously increased and so have the ecological and economic impacts of these species (Blackburn et al., 2014; Vilà et al., 2011). For instance, 10% of the now naturalized alien plant species in Europe have been first recorded only after 1989 (Pyšek and Hulme, 2011). As niche filling in the new ranges may take several decades to hundreds of years (Williamson et al., 2009)

Abbreviations: ANOSIM, analysis of similarity; GLM, generalized linear model; GLMM, generalized linear mixed model; NMDS, non metric multidimensional scaling; WCI, weed community indices.

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many of these species will probably continue to spread for a long time into the future (Pyšek and Hulme, 2011). The recent acceleration of biological invasions and the effects they cause is driven by the reinforcing effects of other features of global change, notably the increase in trade and transport (Essl et al., 2011), land use change (Chytrý et al., 2012), and climate change (Walther et al., 2009), which jointly amplify propagule pressure and invasibility of ecosystems.

In temperate regions such as Central Europe most alien plant species are confined to warm lowlands (Chytrý et al., 2008a), and increasing temperatures are projected to increase the levels of invasion in most habitats. Greenhouses and polytunnels may provide climatic safe sites from which alien plant species could escape and invade agricultural ecosystems under future warmer climates, as it has been shown to be the case e.g., for alien bryophyte species from warmer climates (Essl et al., 2013).

Several studies on plant invasions have shown that introduction history may play a substantial role for the invasion success of alien plant species. For instance, the time elapsed since the introduction of an alien plant species (residence time, Pyšek et al., 2009) has been shown to be an important predictor of their current distribution (Essl et al., 2012). Similarly, different pathways of introduction may have differential effects on the likelihood that a species may become alien. For instance, plants cultivated in horticulture likely have particularly high chances to escape to adjacent sites because of high levels of propagule pressure (Dehnen-Schmutz et al., 2007a).

In this study we explored this idea by using paired plots in the weed vegetation of sheltered (polytunnels) and outdoor environments (open fields) in horticultural nurseries in the Austrian lowlands. Specifically, we posed the following questions: 1) Does the weed vegetation inside polytunnels show higher numbers and greater abundance of alien plant species than in outside reference plots? 2) Do climate and land use (i.e., size of nurseries or polytunnels, and crop species) modify alien plant species numbers and abundance? 3) Is the alien weed vegetation of polytunnels characterized by species adapted to warmer climates?

Material and methods

Study area and sites

We selected 15 plant nurseries in lowland eastern Austria (Fig. 1) which fulfilled the following criteria: i) polytunnels and outdoor fields are adjacent to each other, ii) crops are grown organically (no use of herbicides), iii) cultivated species are vegetables, and iv) crops are exclusively cultivated on soil (but not on artificial substrates). The climate of the region is temperate continental, with moderately cold winters and warm summers. Average annual mean temperatures vary between 8.5 and 10.2 °C, and average annual precipitation between 585 and 1010 mm (Supplementary Table 1).

Plant data sampling

We aimed to establish at least three plots inside polytunnels and three outdoors at each plant nursery. Plot sites were chosen randomly excluding areas which were not cultivated but ensuring that the same species were cultivated indoors and outdoors. At two small plant nurseries, only fewer plots could be established due to size limitations (Supplementary Table 1). Field sampling took place from June to August 2013.

In total, 131 plots were established, 71 in polytunnels and 60 outside of them (Supplementary Table 2). Plot size was kept constant ($7 \times 7\,m = 49\,m^2$), with few plots being smaller due to space limitations (six in polytunnels, two outdoors). Plant species coverage was estimated in each plot in percent. Plant species were identified using standard floras (Fischer et al., 2008) and special literature for the identification of weed species (Hofmeister and Garve, 1998; Holzner and Glauninger, 2005; Klaaßen and Freitag, 2004). In several cases, small seedlings could not be determined, and were excluded from the analyses. Taxonomy and nomenclature follow Fischer et al. (2008); for alien species not covered there, we followed the AliensAustria database (Umweltbundesamt, 2013).

Data preparation

All plant species were classified as natives, archaeophytes (=pre-1500 alien species) or neophytes (post-1500 alien species) based on information provided in the AliensAustria database (Umweltbundesamt, 2013). For each species, we extracted the Ellenberg indicator values for nitrogen, precipitation and temperature from Karrer and Wiedermann (2014). For each neophyte, we collected a set of additional variables: first record in Austria (as a proxy for the local residence time), region of origin (continents), and dominant pathways (intentional introduction [by horticulture]; unintentional introduction) based on the information provided in AliensAustria (Umweltbundesamt, 2013). The cultivated vegetables of the plots were divided into four crop categories: the three main crop species [pepper and chili species (A), tomatoes (B), cucumbers and pumpkins (C)], whereas the last category (D) encompassed all rarely cultivated crops (e.g., nasturtium, corn, aubergine, parsley and turnip). For each nursery, we compiled data on mean annual temperature and precipitation from 1961 to 1990 (ZAMG, 2001). Finally, information on size and age of the nursery and of polytunnels was collected by a questionnaire.

Data analysis

To test for differences in the species composition of alien weed communities within and outside polytunnels we first performed a non metric multidimensional scaling (NMDS) of the alien community matrix and subsequently compared interplot distances in ordination space using analysis of similarity (ANOSIM). To test for differences in species abundance, we calculated the mean proportion of neophyte and archaeophyte species.

To analyze the factors which might contribute to explaining species numbers of natives, archaeophytes and neophytes we fitted generalized linear mixed models (GLMMs) using the *lmer* function in the R package lme4 (Faraway, 2006). The GLMMs included random effect intercepts with nursery as the grouping variable and tested for fixed effects of crop category, size of the nursery or polytunnels, respectively, mean annual temperature and – for outdoor plots – mean annual precipitation. GLMMs were performed separately for plots in polytunnels and outdoors. No variable interactions or nonlinear effects were considered.

We calculated weed community indices (WCI) for temperature, precipitation and nitrogen for each plot (Devictor et al., 2008; Gottfried et al., 2012). This framework allows to calculate the proportion of species preferring low or high temperatures, low or high precipitation, and low or high soil fertility, between plots located in polytunnels and outdoor. We used the Ellenberg indicator values (Karrer and Wiedermann, 2014), which characterize the ecological preferences of plant species (Supplementary Table 2). Ellenberg indicator values for temperature, precipitation, and nitrogen range from 1 (=minimum value, i.e., species of cool climates or dry sites) to 9 (=maximum value, i.e., species of warm climates or wet sites). These Ellenberg indicator values were weighted by species abundance for each species occurring in a plot to calculate the plot WCI. In other words, the WCI characterizes the ecological preferences of the community for temperature, precipitation and nitrogen in a plot based on species Ellenberg indicator values. Subsequently, we used these values to test for differences between the WCIs of