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ORIGINAL PAPER

Is the flora of wildlife food plots similar to that of agricultural fields, or does it have its own specificity?

Aneta Czarna[(1)], Renata Nowińska[(1)✉], Wojciech Szewczyk[(2)]

[(1)] Department of Botany, Poznań University of Life Sciences, J.H. Dąbrowskiego 159, 60-594 Poznań, Poland

[(2)] Department of Forest Entomology and Pathology, Poznań University of Life Sciences, Wojska Polskiego 71c, 60-625 Poznań, Poland

ABSTRACT

Food plots are sites located usually in woodlands but sown or planted with species supposed to provide food and habitat for wildlife. As in the case of agroecosystems, wild plants accompanying crops appear in food plots. Knowing the wild plants in food plots helps in assessing their potential impact on the local environment. Since food plots were largely omitted in earlier studies of segetal flora, this paper fills this gap by presenting results from 226 food plots located in western Poland. In each food plot, all vascular plant species were recorded with cover-abundance. The floristic analysis included the plant life-form structure, geographic-historical structure, sociological-ecological structure, and flora synanthropization. The results obtained from food plots were compared with literature data on agroecosystems. In total, 313 plant species were found, including 28 cultivated ones and 67 segetal ones (field and garden weeds). In the case of food plots (unlike in agricultural fields), the line between cultivated plants and weeds may be blurred. The richness of uncultivated species was slightly higher than in agricultural fields, whereas their cover-abundance was clearly greater. The plant life-form structure was also similar, with a high contribution of annuals. Both habitat types were characterized by a dominant share of native species but in food plots many of them were forest species. Most of anthropophytes were archaeophytes. In this group there were two threatened species recorded on the Polish red list. However, also 24 alien species that are invasive at the national level were recorded in food plots. Assessment of the distribution and frequency of threatened weed species and invasive taxa in food plots can in the future facilitate the monitoring of transformations taking place in such ecosystems and aid in both preservation of threatened weed species and limitation of the spread of invasive taxa.

KEY WORDS

anthropogenic changes, cultivated plants, flora synanthropization, invasive plants, threatened plants, weeds

Introduction

Food plots are sites located usually in woodlands but sown or planted with species supposed to provide food for wildlife. They are intended to improve the availability of nutrients for game populations and to limit the extent of damage caused by game in agricultural fields. For wildlife

✉e-mail: renata.nowinska@up.poznan.pl

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management, the establishment of food plots ensures substantial amounts of forage both during the growing season and at the onset of winter (Månsson *et al.*, 2015). The increased availability of nutrients can positively influence wild ungulates in many ways, including weight, reproduction (both timing and recruitment), survival (adults, broods, and fawns), lactation rate, and antler development (Harper, 2019). Limiting the penetration of agricultural fields by game decreases the accumulation of pesticides in their organisms (Klich *et al.*, 2020), reducing the probability of health problems in the animals (Hoy *et al.*, 2015).

In patchy rural landscapes, composed of agroecosystems and wooded habitats, the proximity of shelter habitats to foraging habitats favours the impact of wild ungulates on agroecosystems (Hofman-Kamińska and Kowalczyk, 2012; Sobczuk and Olech, 2016). Thus the establishment of food plots is particularly important in such landscapes. The patchy agricultural-wooded landscapes are characteristic of many parts of Poland, especially western Poland. Four types of food plots are distinguished here: productive plots, browsing plots, barrier plots, and mid-forest meadows (Kubacki *et al.*, 2007). In productive plots, standard agricultural activity is aimed to provide food (especially fodder plants) to be used in winter, when natural food reserves are scarce. During the growing season, such plots can be fenced to force the animals to use the natural food base. This ensures proper growth of the planted or sown species. In autumn or late summer, the plots are opened to allow free grazing. Browsing plots are places where broad-leaved trees and shrubs are grown to provide a diverse food base for game animals. Beside native species, also some alien woody species are introduced sometimes in browsing plots (Danielewicz and Wiatrowska, 2012). Barrier plots are narrow belts of crop plants or special areas used to place food for game animals, aiming to keep them away from agroecosystems, to limit the damage caused by game in agricultural fields.

The management of food plots for wildlife is somewhat similar to the management of agricultural lands in terms of sowing/planting, maintenance, and monitoring. Among all types of food plots, productive plots are the most similar to agricultural areas. Establishing such plots requires a series of preparatory works typical of fields, such as ploughing, liming, and fertilizing the soil. A significant factor that distinguishes the management of food plots from conventional agriculture is the absence of pesticide use. Moreover, food plots often include a mix of plants specifically chosen to benefit wildlife (*e.g.* Kiepenkerl seed mixtures), whereas agricultural lands typically focus on crops for human consumption. The timing of sowing/planting food plots is often designed to align with the nutritional needs of wildlife.

Agricultural weeds became a serious focus for research internationally in the late 1950s (Ward *et al.*, 2014). Since the 1970s, extensive research on the distribution of segetal weeds was initiated in Poland, but no productive food plots were taken into account. The flora of food plots has not been studied in other countries either.

Our study aimed to assess the species composition of vascular flora and frequency of weeds and crop plants in productive food plots in Poland, based on the example of Wielkopolska Province. The second aim of the study was to identify and explain the similarities and differences between the floristic features of food plots and agricultural fields.

Material and methods

STUDY AREA. The study covered 37 forest districts and 108 forest ranges in Wielkopolska Province. Field research was carried out on 226 food plots.

Detailed locations of the studied food plots are provided below. For each food plot, the name of the forest district and forest range as well as subcompartment code and geographic coordinates are provided. The list is arranged alphabetically according to names of forest districts.

Antonin (Czarny Las, 162w, 51°30.925'N 17°48.661'E; Klady, 27b, 51°33.597'N 17°54.175'E; Wysokie Grądy, 197f, 51°29.856'N 17°50.582'E); Babki (Łękno, 61i, 52°09.196'N 17°07.976'E; Łękno, 70g, 52°08.935'N 17°08.777'E; Łękno, 129t, 52°06.295'N 17°09.170'E; Łękno, 118h, 52°07.393'N 17°09.995'E; Łękno, 123i, 52°07.532'N 17°09.325'E; Mechlin, 158g, 52°07.650'N 17°06.862'E; Mechlin, 162a, 52°07.555'N 17°06.257'E; Mechlin, 87h, 52°07.065'N 17°05.835'E); Bolewice (Grudna, 363j, 52°26.477'N 16°04.852'E; Kaliska, 138d, 52°29.704'N 15°58.593'E; Papiernia, 22m, 52°31.106'N 15°58.413'E; Papiernia, 21t, 52°31.237'N 15°59.008'E; Papiernia, 33g, 52°31.252'N 15°59.039'E; Papiernia, 45f, 52°30.834'N 16°01.007'E); Czerniejewo (Dzikowy Bór, 72g, 52°23.309'N 17°24.364'E; Dzikowy Bór, 81b, 52°23.449'N 17°26.802'E; Karw, 187f, 52°25.309'N 17°24.386'E; Linery, 92x, w, s, t, 52°27.296'N 17°26.187'E; Linery, 87h, 52°27.308'N 17°27.963'E; Linery, 57l, 52°28.359'N 17°29.117'E; Nekielka, 42c, 52°23.920'N 17°23.324'E; Nekielka, 44o,p, 52°24.234'N 17°28.319'E; Podstolice, 100f, 52°23.045'N 17°28.467'E); Durowo (Orla, 109h, 52°48.934'N 17°09.137'E; Rąbczyn, 297d, 52°46.047'N 17°20.965'E; Rąbczyn, 261g, f, 52°49.379'N 17°23.368'E; Wągrowiec, 73f, 52°50.534'N 17°13.906'E; Wągrowiec, 279b, 52°47.116'N 17°17.743'E); Gaj (Bugaj, 109h, 52°19.912'N 18°44.976'E; Bugaj, 118b, 52°19.479'N 18°44.811'E; Bugaj, 18b, 52°19.477'N 18°44.781'E; Rogóźno, 45l, 52°19.419'N 18°58.855'E; Rogóźno, 25k, 52°21.164'N 18°56.429'E); Grodziec (Borowice, 240j, 51°59.820'N 18°03.222'E; Józefów, 214l, 51°57.782'N 17°54.864'E; Kaźmierka, 84a, 52°01.663'N 17°49.961'E; Lipie, 26g, 51°56.718'N 18°03.511'E; Zbiersk, 111l, 51°58.001'N 18°04.618'E; Zbiersk, 95k, 51°58.182'N 18°04.510'E; Zbiersk, 90k, 51°58.371'N 18°06.758'E; Zbiersk, 90m, 51°58.385'N 18°06.794'E); Jarocin (Tarce, 32l, 51°00.833'N 17°37.409'E); Kaczory (Jeziorki, 262c, 53°10.252'N 16°54.143'E; Jeziorki, 236k, 53°10.275'N 16°53.967'E; Radacznica, 465d, 53°07.046'N 16°54.631'E); Kalisz (Wilcze Ługi, 424b, 51°32.964'N 18°18.286'E; Wilcze Ługi, 424c, 51°32.937'N 18°18.283'E; Wróbel, 324g, 51°33.308'N 18°20.489'E); Karczma Borowa (Książęcy Las, 111h,f, 51°47.504'N 16°33.746'E; Książęcy Las, 106r, 51°47.192'N 16°35.640'E; Książęcy Las, 116h, 51°46.958'N 16°34.369'E; Książęcy Las, 116f, 51°46.961'N 16°34.334'E; Książęcy Las, 116f, 51°46.959'N 16°34.300'E; Książęcy Las, 118h, 51°46.715'N 16°33.714'E; Tarnowa Łąka, 127Bj, Bk, 51°46.052'N 16°37.383'E; Tarnowa Łąka, 131f, 51°45.958'N 16°35.406'E); Konin (Bielice, 147c, 52°16.295'N 18°11.179'E; Grąblin, 258a, 52°15.081'N 18°17.623'E; Grąblin, 258b, 52°15.098'N 18°17.548'E; Grąblin, 224b, 52°17.767'N 18°20.468'E; Licheń, 158d, 52°22.055'N 18°22.750'E); Kościan (Turew, 139i, 52°03.271'N 16°54.280'E; Turew, 141d, 52°01.306'N 16°53.637'E; Wyderowo, 171j,k, 51°57.778'N 16°28.997'E; Wyderowo, 171 j,k, 51°57.808'N 16°29.040'E; Żegrowo, 255c, 51°59.379'N 16°24.706'E); Krotoszyn (Borowina, 87j, 51°38.880'N 17°34.290'E; Rochy, 136c, 51°41.036'N 17°19.806'E; Smoszew, 41j, 51°39.432'N 17°30.158'E; Smoszew, 95k, 51°37.690'N 17°28.641'E; Wisławka, 121d, 51°37.402'N 17°36.539'E; Wisławka, 158g, 51°35.598'N 17°35.228'E); Krucz (Goraj, 30p, 52°52.667'N 16°28.762'E; Goraj, 34 d,f, 52°52.725'N 16°27.768'E; Kruczlas, 178e, 52°48.925'N 16°26.479'E); Krzyż Wlkp. (Rzecin, 435i, 52°55.707'N 15°58.505'E; Rzecin, 523g, 52°55.161'N 16°00’503'E; Rzecin, 568k, 52°54.802'N 16°00’192'E; Zacisze, 75i, 52°59.721'N 15°58.871'E); Lipka (Kiełpin, 52c, 53°30.974'N 17°04.040'E; Lipka, 118l, 53°29.525'N 17°11.722'E; Lipka, 118l, 53°29.584'N 17°11.714'E; Osowo, 178i, 53°27.025'N 17°19.935'E; Potulice, 195c, 53°28.699'N 17°09.347'E; Potulice, 196a, 53°28.723'N 17°09.260'E; Potulice, 172p, 53°28.814'N 17°08.616'E); Międzychód (Przedlesie, 344h, 52°39.313'N 15°50.008'E); Oborniki (Żurawiniec, 1002b, 52°40.148'N 16°35.308'E; Żurawiniec, 1112d, 52°40.785'N 16°37.622'E; Żurawiniec, 1052d, 52°41.382'N 16°32.411'E); Okonek (Brokęcino, 155b, 53°32.108'N 16°49.270'E; Brokęcino, 178b, 53°31.915'N 16°48.441'E; Brokęcino, 137d, 53°32.570'N 16°48.651'E; Marianowo, 60f, 53°33.913'N 16°47.141'E; Marianowo, 61a, 53°34.250'N 16°47.024'E; Marianowo, 64c, 53°34.250'N 16°47.024'E; Marianowo, 126b, 53°33.840'N 16°45.291'E; Marianowo, 53o, 53°34.431'N 16°42.265'E; Marianowo, 150d, 53°33.485'N 16°44.580'E); Pniewy (Klemensowo, 298c, 52°37.394'N 16°23.340'E; Klemensowo, 313o, 52°36.533'N 16°23.654'E; Urbanówko, 175c, 52°28.947'N 16°03.829'E; Wielonek, 334m, 52°36.416'N 16°25.248'E; Wituchowo, 120c, 52°31.126'N 15°58.414'E; Wituchowo, 137j, 52°30.466'N 16°06.912'E; Wituchowo, 160d, 52°29.500'N 16°04'406'E); Podanin (Budzyń, 254p, 52°54.543'N 16°58.921'E; Budzyń, 270d, 52°54.424'N 16°59.616'E; Budzyń, 270b, 52°54.240'N 16°59.413'E; Budzyń, 251c, 52°55.059'N 16°59.493'E; Strzelecki Gaj, 198o, 52°56.360'N 16°56.938'E; Strzelecki Gaj, 204o, 52°56.360'N 16°56.938'E; Strzelecki Gaj, 212c, 52°55.564'N 16°57.448'E; Strzelecki Gaj, 199k, 52°56.233'N 16°57.266'E); Potrzebowice (Brody, 1b, 53°27.384'N 16°29.595'E; Brzeźnica, 204g, 53°27.141'N 16°42.713'E; Brzeźnica, 125c,d, 53°26.933'N 16°38.920'E; Brzeźnica, 385f,h, 53°24.136'N 16°10.596'E; Dziewanna, 91g, 52°51.237'N 16°11.329'E; Kamiennik, 331n, 52°50.510'N 15°59.947'E; Kamiennik, 379L 01, 52°49.096'N 16°00.627'E; Kamiennik, 379L 02, 52°49.096'N 16°00.627'E; Wądołek, 283d, 53°26.542'N 16°45.018'E; Wądołek, 281d, 53°26.541'N 16°45.668'E; Wądołek, 257r,s, 53°26.756'N 16°43.826'E; Wądołek, 259b, 53°27.060'N 16°42.671'E; Zacisze, 130s,t,w, 53°26.126'N 16°37.781'E; Zawada, 53f, 52°51.231'N 16°08.123'E); Przedborów (Aniołki, 57b, 51°26.987'N 17°52.240'E; Aniołki, 76b, 51°26.214'N 17°51.716'E; Aniołki, 98z, 51°25.588'N 17°51.285'E; Marydół, 65c, 51°28.180'N 17°55.033'E; Marydół, 42d, 51°27.865'N 17°52.683'E; Przytocznica, 330j, 51°26.332'N 18°00.866'E; Przytocznica, 310d, 51°27.535'N 18°00.162'E; Zmyślona, 197g, 51°23.977'N 17°45.434'E; Zmyślona, 219f, 51°22.822'N 17°46.006'E; Zmyślona, 218h, 51°22.839'N 17°46.232'E); Sarbia (Gębice, 181d, 156i, 52°55.225'N 16°44.624'E; Nówki, 254n, 52°53.799'N 16°46.537'E; Szklarnia, 248Ai, 52°54.319'N 16°47.964'E; Szklarnia, 248Bl, 52°54.480'N 16°47.221'E; Szklarnia, 223t, 52°54.493'N 16°47.221'E; Szklarnia, 270Ac, 52°53.869'N 16°46.849'E); Sieraków (Czaplinek, 314d, 52°36.045'N 16°25.201'E; Czaplinek, 229j, 52°36.123'N 16°25.016'E; Kukułka, 321g, 52°36.420'N 16°25.233'E; Lipin, 320l,k, 52°39.920'N 16°03.605'E); Syców (Czermin, 202h, 51°18.339'N 17°48.840'E; Darnowice, 19b, 51°12.879'N 17°54.543'E; Marcinki, 206d, 51°20.892'N 17°51.788'E; Marcinki, 106f, 51°20.859'N 17°51.689'E; Marcinki, 106d, 51°20.875'N 17°51.691'E; Marcinki, 106c, 51°20.928'N 17°51.819'E; Smardzew, 66c, 51°11.749'N 17°56.429'E; Smardzew, 50h, 51°11.896'N 17°56.710'E; Starogóra, 139f, 51°09.521'N 17°54.124'E; Starogóra, 151b, 51°08.927'N 17°54.093'E; Starogóra, 151b, 51°08.985'N 17°54.151'E); Taczanów (Gołuchów, 156k, 51°49.574'N 17°76.765'E; Koryta, 284i, 51°45.737'N 17°47.443'E; Nowy Staw, 259a,c, 51°47.226'N 17°54.866'E; Nowy Staw, 259f, 51°46.663'N 17°53.938'E; Nowy Staw, 307g, 51°44.290'N 17°52.297'E; Taczanów, 196b, 51°49.535'N 17°45.265'E; Wtórek, 389h, 51°39.646'N 17°54.776'E; Wtórek, 393e, 51°39.597'N 17°53.917'E; Wysocko, 459h, 51°36.560'N 17°52.499'E; Wysocko, 457g, 51°36.152'N 17°53.379'E); Trzcianka (Kochanówka, 245f, 53°05.185'N 16°27.173'E; Ogorzałe, 538g, 53°01.042'N 16°26.150'E; Ogorzałe, 508n, 53°00.902'N 16°22.890'E; Pańska Łaska, 224i, 53°05.257'N 16°24.718'E; Pańska Łaska, 290a, 53°04.713'N 16°25.274'E; Teresa, 635g, 53°00.564'N 16°30.292'E; Teresa, 637f, 53°00.430'N 16°29.620'E; Wrząca, 237g, 53°05.347'N 16°30.347'E; Wrząca, 55c, 53°05.826'N 16°33.852'E); Turek (Grzymiszew, 28j, 52°04.015'N 18°21.051'E; Uniejów, 108i, 51°59.502'N 18°41.105'E; Uniejów, 105l, 51°59.374'N 18°40.708'E); Włoszakowice (Koczury, 70m,l, 51°54.012'N 16°22.926'E; Koczury, 70m,l, 51°53.028'N 16°22.925'E; Krzyżowiec, 119g, 51°53.091'N 16°20.400'E; Krzyżowiec, 106a, 51°53.501'N 16°21.411'E; Krzyżowiec, 94h, 51°53.551'N 16°22.148'E; Krzyżowiec, 94i, 51°53.549'N 16°22.141'E; Papiernia, 47c, 51°55.350'N 16°17.848'E; Papiernia, 63w,x,t, 51°54.858'N 16°17.620'E; Papiernia, 64w,x, 51°54.856'N 16°17.609'E; Papiernia, 113c, 51°53.792'N 16°17.875'E); Wronki (Chojno, 363d, 52°43.746'N 16°12.058'E; Lubowo, 497f, 498f, 52°43.482'N 16°14.741'E; Lubowo, 326k, 52°44.100'N 16°14.375'E; Mokrz, 275b, 52°44.903'N 16°14.562'E; Mokrz, 266l, 52°45.017'N 16°17.025'E; Pustelnia, 632b, 52°42.080'N 16°10.115'E; Pustelnia, 635g, 52°41.674'N 16°08.692'E); Zdrojowa Góra (Leśny Dworek, 696f, 53°07.422'N 16°35.712'E; Leśny Dworek, 679c, 53°08.192'N 16°34.657'E; Leśny Dworek, 692b, 53°07.419'N 16°33.529'E; Skórka, 182c, 53°15.010'N 16°51.605'E; Skórka, 71f, 53°15.481'N 16°52.231'E; Zaciszów, 481g, 53°11.628'N 16°52.375'E; Zawada, 545k, 53°03.361'N 16°37.935'E); Złotów (Leśnik, 634r, 53°17.420'N 17°02.483'E; Wąsosz, 568h, 53°18.399'N 17°01.122'E; Wąsosz, 568b, 53°18.604'N 17°01.139'E; Wąsosz, 584j, 53°18.448'N 17°02.684'E; Wąsosz, 621c, 53°18.170'N 17°04.053'E; Wąsosz, 621d, 53°18.148'N 17°04.018'E; Wąsosz, 628e, 53°18.214'N 17°04.747'E; Wąsosz, 628a, 53°18.212'N 17°04.740'E; Wąsosz, 645a, 53°17.731'N 17°05.489'E); Grodzisk Wlkp. (Bukowiec Stary, 133d, 52°19.485'N 16°18.094'E; Bukowiec Stary, 146d, 52°19.181'N 16°18.147'E; Porażyn, 129b, 49°26.572'N 20°25.853'E; Porażyn, 128a, 52°19.375'N 16°19.012'E); Sława Śląska (Bagno, 124c, 51°59.347'N 16°04.897'E; Bagno, 130n, 51°58.847'N 16°02.425'E; Świętno, 55g, 52°01.245'N 16°04.082'E; Świętno, 81g, 52°00.484'N 16°05.758'E; Świętno, 89f, 52°00.126'N 16°05.736'E).

FIELD RESEARCH. The size of the examined food plots ranged from 0.04 to 6.00 hectares, with an average of 0.85 hectares. In each food plot, an area of ca. 400 m^2 was selected to record all vascular species. The following 7-point scale was used to determine the cover-abundance, *i.e.* the proportion of the area covered by a given species: r=1-2 specimens; '+'=several specimens covering less than 1% of the area; 1=species covering 1-5% of the area; 2=5-25%; 3=25-50%; 4=50-75%; 5=75-100%. In addition, the total cover-abundance was estimated separately for cultivated species and for accompanying species. Scientific names of the species follow Mirek *et al.* (2020).

DATA ANALYSIS. Regression analyses were initially used to assess whether there is a relationship between the number of observed species and food plot size (Nowińska *et al.*, 2020).

To compare the results with published studies of arable fields, the flora of the studied plots was analysed according to the classification of life-forms (Zarzycki *et al.*, 2002), geographic-historical classification (Chmiel, 2006), and socio-ecological classification (Chmiel, 1993; Czarna, 2009).

The following plant life-forms in the sense of Raunkiaer were used: F1=megaphanerophytes; F2=nanophanerophytes; Ch=chamaephytes; G=geophytes; H=hemicryptophytes; T1=annual therophytes; T2=biennial therophytes.

In the geographic-historical classification, the two major groups are: S=spontaneophytes (all native species); and A=anthropophytes (all alien species). Spontaneophytes are formed by three subgroups: Sp=non-synanthropic spontaneophytes (native species that do not show any permanent tendency to colonize transformed, anthropogenic habitats); Ap=apophytes (= synanthropic spontaneophytes; native species that permanently occupy strongly transformed, anthropogenic habitats); Sp/Ap=semi-synanthropic spontaneophytes (native species frequent in natural, semi-natural as well as anthropogenic habitats). Anthropophytes are also divided into three subgroups: Arch=archaeophytes (naturalized alien species introduced before ca. 1500); Ken=kenophytes (naturalized alien species introduced after ca. 1500); and D=diaphytes (casual alien species introduced after ca. 1500, occurring sporadically or for a short time within the study area).

The following socio-ecological groups of species were distinguished on the basis of their preference for different habitats: 1=fertile broad-leaved forests and shrub communities (*Fagetalia*, *Prunetalia*); 2=acidophilous or xerothermic oak forests, mixed coniferous forests and their substitute shrub, herb or grassland communities (*Quercion robori-petraeae*, *Quercion petraeae*, *Epilobion*, *Nardetalia*); 3=nitrophilous shrub or herb communities (*Sambuco-Salicion*, *Alliarion*); 4=xerothermic herb or grassland communities (*Trifolio-Geranietea*, *Festuco-Brometea*); 5=pine forests or sandy grasslands (*Dicrano-Pinion*, *Sedo-Scleranthetea*, *Corynephoretea*); 6=swamp alder forests, woodless fens, bogs, and intermediate mires (*Alnion*, *Magnocaricion*, *Caricetalia fuscae*, *Sphagnion fusci*); 7=riparian forests and thickets, reeds, and aquatic vegetation (*Salicion*, *Phragmition*, *Glycerio--Sparganion*, *Potamogetonetea*, *Lemnetea*, *Utricularietea*), 8=humid meadows and tall herb communities (*Molinietalia*); 9=fresh and moderately humid meadows (*Arrhenatheretalia*); 10=nitrophilous flood-plains and treaded communities (*Plantaginetea*); 11=salt marshes and halophilous grasslands (*Thero-Salicornietea*, *Asteretea trifolium*); 12=therophyte communities on wet and humid sites (*Bidentetea*, *Nanocyperion*); 13=mesophilous communities of tall perennials (*Arction*); 14=xerothermic, perennial ruderal communities (*Onopordon*); 15=short-term, pioneer ruderal communities (*Sisymbrion*, *Eragrostion*); 16=weed communities of gardens and root crop fields (*Polygono-Chenopodietalia*); 17=weed communities of cereal fields (*Aperetalia*); 18=epilithic communities (*Asplenietea*); 19=species of unknown phytosociological affiliation.

The following scale was applied to determine the frequency of occurrence of species: very rare (1-5 plots), rare (6-20 plots), moderately frequent (21-42 plots), frequent (43-85 plots), very frequent (86-110 plots), and common (111-226 plots).

Indices of anthropogenic changes of flora (adopted from Chmiel, 2006) are percentage contributions of specific geographic-historical groups to the total number of species.

- The *flora naturalness index* specifies the share of non-synanthropic spontaneophytes in the entire flora: N [%]=Sp/(S+A).
- The *proper synanthropization index* is the share of apophytes and anthropophytes in the flora: S_w [%]=(Ap+A)/(S+A). The *potential synanthropization index* takes into account also the presence of semi-synanthropic spontaneophytes: S_p [%]=(Sp/Ap+Ap+A)/(S+A).
- The *proper apophytization index* determines the share of apophytes in the flora: Ap_w [%] =Ap/(S+A). The *potential apophytization index* takes into account also the presence of semi-synanthropic spontaneophytes: Ap_p [%]=(Sp/Ap+Ap)/(S+A).
- The *index of proper apophytization of spontaneophytes* is the share of apophytes among native species: Aps_w [%]=Ap/S. The *index of potential apophytization of spontaneophytes* specifies the share of apophytes and semi-synanthropic spontaneophytes among native species: Aps_p [%]=(Sp/Ap+Ap)/S.
- The *general anthropophytization index* determines the share of anthropophytes in the flora: A_n [%]=A/(S+A).
- The *archaeophytization index* specifies the share of archaeophytes in the flora: A_r [%]=Ar/(S+A).
- The *kenophytization index* is the share of kenophytes in the flora: K_n [%]=Kn/(S+A).
- The *flora modernization index* determines the share of kenophytes in the flora of permanently established anthropophytes: M [%]=Kn/(Kn+Ar).
- The *index of stability of anthropophyte flora* specifies the share of permanently established species among anthropophytes: T_A [%]=(Ar+Kn)/A. The *index of stability of flora* is the share of relatively permanently established anthropophytes in the entire flora: T_C [%]=(Sp+ Sp/Ap+Ap+Ar+Kn/(S+A).
- The *index of floristic fluctuations of anthropophytes* determines the share of diaphytes among anthropophytes: FL_A [%]=D/A. The *index of floristic fluctuations* specifies the share of diaphytes in the entire flora: FL_C [%]=D/(S+A).

The list of alien invasive species was established on the basis of Tokarska-Guzik *et al.* (2012) and ‘Regulation of the Council of Ministers on the list of invasive alien species posing a threat to the European Union and the list of invasive alien species posing a threat to Poland, remedial actions, and measures aimed at restoring the natural state of ecosystems' (Rozporządzenie, 2022). The analysis of the share of protected species was based on the 'Regulation of the Minister of the Environment on protection of species of plants' (Rozporządzenie, 2014). The share of rare species was analysed on the basis of the Red List for Poland (Kaźmierczakowa *et al.*, 2016).

Herbarium materials from this study are deposited at the Herbarium of the Adam Mickiewicz University in Poznań (POZ).

Results and discussion

SPECIES RICHNESS. In the 226 wildlife food plots in Wielkopolska, 313 vascular plant species were recorded (Table 1). The number of species in individual plots ranged from 6 to 45 (16 on average). In about 60% of plots, 10-18 plant species were found (Fig. 1). There was no significant effect of plot size on the number of species detected ($F_{1.224}$=0.87800; p=0.35). For comparison, the average numbers of species in various segetal communities of Poland ranged from 9 to 37 (Kutyna and Młynkowiak, 2014; Chwastek *et al.*, 2016; Dąbkowska *et al.*, 2017). Therefore, the plant diversity of agricultural areas and food plots seems to be similar and they are characterized by a high variability in the number of species recorded. Such a large variation of species number can be determined by natural factors, like soil fertility and moisture, as well as agrotechnical factors. In the case of arable fields, it has been proven that intensive agriculture has contributed to the decline in the biodiversity of segetal communities (Richner *et al.*, 2015; Storkey and Neve, 2018; Fanfarillo *et al.*, 2019). The number of plant species in intensively farmed fields is on average 1/3-2/3 lower, compared to organic farming (Balcerkiewicz and Pawalak, 2000; Kutyna and Malinowska, 2014).

CULTIVATED PLANTS. The research showed that as many as 28 species were cultivated in wildlife food plots (Table 1). The use of many food plots was irregular, so that no crop species was found in 16% of the plots. A single cultivated species was recorded in 42% of the plots. A mixture of 2-3 cultivated species was present in 22% of the plots, whereas 4-8 such species were found in 9% of the plots. Unlike in arable fields, the average coverage of cultivated species was relatively low and amounted to 37%. Only 9% of the food plots had a crop species cover higher than 90%.

The most commonly grown crop species was Jerusalem artichoke – *Helianthus tuberosus* L. It is a valuable fodder plant but its numerous small tubers and rooted stem fragments, which are easily overlooked during harvest, can contribute to its unregulated expansion. In the last few decades, this species has markedly increased in abundance and occupied new sites in Poland (Zarzycki *et al.*, 2002), so it was classified as category II (*i.e.* medium) of invasive species here (Tokarska-Guzik *et al.*, 2012). It is invasive in Central Europe (Janikova *et al.*, 2020), showing a tendency to extend its geographic range (Pacanoski and Mehmeti, 2020).

Special attention should be paid also to annual corn spurry *Spergula arvensis* L., which is a weed in agricultural fields but can be cultivated in food plots (Łowiectwo, 2023). A species rarely found in food plots is *Avena strigosa* Schreb. It is cultivated as a fodder plant (for soilage and silage) or in pastures but mostly locally, in north-eastern Poland (Zając and Zając, 2001). It is a declining archaeophyte (Tokarska-Guzik *et al.*, 2012), threatened with extinction (Warcholińska, 2002; Kaźmierczakowa *et al.*, 2016). Very rare crops for food plots, such as *Panicum miliaceum* L. and *Trifolium resupinatum* L., are ancient crops that are now rarely cultivated.

SEGETAL (WEED) SPECIES. We recorded 285 species that co-occurred with crops in wildlife food plots (Table 1). This is a very large number, considering that 303 species accompanying crops

Table 1.

List of the recorded plant species, grouped according to frequency classes in food plots and habitat preferences; the number of species in each group is given in brackets

Frequency class	Species
Very rare	**Segetal species (25):** *Aethusa cynapium* L., *Agrostemma githago* L., *Anagallis arvensis* L., *Anthemis ruthenica* M. Bieb., *Arabidopsis thaliana* (L.) Heynh., *Chaenorhinum minus* (L.) Lange, *Chamomilla recutita* (L.) Rauschert, *Chenopodium hybridum* L., *Descurainia sophia* (L.) Webb ex Prantl, *Euphorbia helioscopia* L., *Fumaria officinalis* L., *Galeopsis ladanum* L., *Galeopsis terahit* L., *Hypericum humifusum* L., *Lamium amplexicaule* L., *Lamium purpureum* L., *Oxalis dillenii* Jacq., *Raphanus raphanistrum* L., *Sisymbrium officinale* (L.) Scop., *Sonchus arvensis* L., *Sonchus oleraceus* L., *Thlaspi arvense* L., *Veronica persica* Poir., *Vicia hirsuta* (L.) Gray, *Vicia tetrasperma* (L.) Schreb. **Species of forests and shrub communities (42):** *Acer pseudoplatanus* L., *Aegopodium podagraria* L., *Alnus glutinosa* (L.) Gaertn., *Anthoxanthum odoratum* L., *Astragallus glycyphyllos* L., *Betula pubescens* Ehrh., *Brachypodium sylvaticum* (Huds.) P. Beauv., *Calluna vulgaris* (L.) Hull, *Carex pilulifera* L., *C. sylvatica* Huds., *Carpinus betulus* L., *Clinopodium vulgare* L., *Crataegus monogyna* Jacq., *Deschampsia flexuosa* (L.) Trin., *Dryopteris carthusiana* (Vill.) H. P. Fuchs, *D. filixmas* (L.) Schott, *Equisetum sylvaticum* L., *Erechtites hiracifolia* (L.) Raf. ex DC., *Fagus sylvatica* L., *Festuca gigantea* (L.) Vill., *Fragaria vesca* L., *Frangula alnus* Mill., *Geranium robertianum* L., *Geum urbanum* L., *Hieracium laevigatum* Willd., *Lamium maculatum* L., *Luzula pallescens* Sw., *Melampyrum pratense* L., *Moehringia trinervia* (L.) Clairv., *Mycelis muralis* (L.) Dumort., *Populus nigra* L., *Potentilla erecta* (L.) Raeusch., *Pteridium aquilinum* (L.) Kuhn, *Quercus rubra* L., *Rubus caesius* L., *Scrophularia nodosa* L., *Senecio sylvaticus* L., *Solidago virgaurea* L., *Sorbus aucuparia* L. emend. Hedl., *Veronica officinalis* L., *V. sublobata* M. A. Fisch., *Viola canina* L. **Species of moist habitats (23)**: *Agrostis canina* L., *Agrostis stolonifera* L., *Barbarea vulgaris* R. Br., *Chenopodium polyspermum* L., *Epilobium ciliatum* Raf., *Juncus bufonius* L., *Lotus uliginosus* Schkuhr, *Lycopus europaeus* L., *Lysimachia vulgaris* L., *Lythrum salicaria* L., *Mentha* × *verticillata* L., *Myosoton aquaticum* (L.) Moench, *Plantago intermedia* Gilib., *Poa trivialis* L., *Polygonum lapathifolium* L. subsp. *brittingerii* (Opiz) Rech. fil., *Polygonum lapathifolium* L. subsp. *lapathifolium*, *Potentilla norvegica* L., *P. reptans* L., *Ranunculus flammula* L., *Sagina procumbens* L., *Salix aurita* L., *Scutellaria galericulata* L., *Veronica serpyllifolia* L. **Meadow species (27):** *Achillea ptarmica* L., *Arrhenatherum elatius* (L.) P. Beauv. ex J. Presl & C. Presl, *Bromus carinatus* Hook. & Arn., *Calystegia sepium* (L.) R. Br., *Carduus crispus* L., *Carex acutiformis* Ehrh., *C. disticha* Huds., *Centaurea jacea* L., *Centaurium erythraea* Rafn, *Festuca arundinacea* Schreb., *Galium mollugo* L., *G. verum* L., *G. verum* × *G. mollugo*, *Heracleum sphondylium* L., *Holcus lanatus* L., *Knautia arvensis* (L.) J. M. Coult., *Lathyrus pratensis* L., *Molinia caerulea* (L.) Moench, *Odontites serotina* (Lam.) Rchb., *Poa palustris* L., *P. pratensis* L., *P. subcaerulea* Sm., *Ranunculus acris* L., *Scirpus sylvaticus* L., *Symphytum officinale* L., *Tragopogon pratensis* L., *Trifolium dubium* Sibth. **Ruderal species (26):** *Amaranthus lividus var. ascendens* (Loisel.) Thell., *Arctium lappa* L., *A. tomentosum* Mill., *Artemisia absinthium* L., *Atriplex patula* L., *Bromus hordeaceus* L., *B. inermis* Leyss., *B. tectorum* L., *Cichorium inthybus* L., *Cirsium vulgare* (Savi) Ten., *Cynoglossum officinale* L., *Datura stramonium* L., *Eragrostis minor* Host, *Euphorbia esula* L., *Lactuca virosa* L., *Lolium multiflorum* Lam., *Malva neglecta* Wallr., *Melilotus officinalis* (L.) Pall., *Panicum capillare* L., *Picris hieracioides* L., *Portulaca oleracea* L., *Rumex obtusifolius* L., *R. thyrsiflorus* Fingerh., *Sisymbrium loeselii* L., *Solidago canadensis* L., *Verbascum phlomoides* L. **Species of treaded habitats (4):** *Chamomilla suaveolens* (Pursh) Rydb, *Juncus tenuis* Willd., *Lotus corniculatus* L., *Tussilago farfara* L.

Table 1. continued (2)

Frequency class	Species
	Species of dry grasslands (23): *Arenaria serpyllifolia* L., *Artemisia campestris* L., *Berteroa incana* (L.) DC., *Centaurea stoebe* L., *Chondrilla juncea* L., *Corynephorus canescens* (L.) P. Beauv., *Echium vulgare* L., *Erigeron acris* L., *Festuca trachyphylla* (Hack.) Krajna, *Filago minima* (Sm.) Pers., *Gypsophila muralis* L., *Leontodon saxatilis* Lam., *Petrorhagia prolifera* (L.) P. W. Ball & Heywood, *Potentilla argentea* L., *P. collina* Wibel., *Prunus spinosa* L., *Sarothamnus scoparius* (L.) Wimm. ex W. D. J. Koch, *Scleranthus perennis* L., *Senecio jacobaea* L., *Spergularia rubra* (L.) J. Presl & C. Presl, *Tessdalea nudicaulis* (L.) R. Br., *Verbascum lychnitis* L., *Viola tricolor* L., **Cultivated species (10):** *Hordeum vulgare* L., *Lathyrus tuberosus* L., *Lycopersicon esculentum* Mill., *Medicago staiva* L., *Panicum miliaceum* L., *Raphanus sativus* L., *Solanum tuberosum* L., *Trifolium resupinatum* L., *Triticum aestivum* L., *Vicia sativa* L. **Others (7):** *Agrimonia eupatoria* L., *Agrostis gigantea* × *A. capillaris*, *Arctium minus* (Hill) Bernh., *Lupinus polyphyllos* Lindl., *Polygonum hydropiper* × *P. minus*, *P. hydropiper* × *P. persicaria*, *Robinia pseudoacacia* L.
Rare	**Segetal species (17):** *Amaranthus chlorostachys* Willd., *Anchusa arvensis* (L.) M. Bieb., *Anthemis arvensis* L., *Anthoxanthum aristatum* Boiss., *Arnoseris minima* (L.) Schweigg. & Körte, *Avena fatua* L., *Convolvulus arvensis* L., *Galinsoga ciliata* (Raf.) S. F. Blake, *Galium aparine* L., *Myosotis arvensis* (L.) Hill, *Papaver dubium* L., *Polygonum amphibium* L. f. *terrestre*, *Solanum nigrum* L. emend. Mill., *Trifolium arvense* L., *Veronica arvensis* L., *Vicia angustifolia* L., *Vicia villosa* Roth **Species of forests and shrub communities (14):** *Betula pendula* Roth, *Galeopsis pubescens* Besser, *Glechoma hederacea* L., *Gnaphalium sylvaticum* L., *Impatiens parviflora* DC., *Lapasana communis* L., *Linaria vulgaris* Cass., *Padus serotina* (Ehrh.) Borkh., *Pinus sylvestris* L., *Populus tremula* L., *Quercus robur* L., *Rubus idaeus* L., *Stellaria graminea* L., *Torilis japonica* (Houtt.) DC. **Species of moist habitats (7):** *Bidens frondosa* L., *B. tripartite* L., *Gnaphalium uliginosum* L., *Phalaris arundinacea* L., *Ranunculus repens* L., *Rorippa palustris* (L.) Besser, *Stachys palustris* L. **Meadow species (15):** *Cardaminopsis arenosa* (L.) Hayek, *Cerastium holosteoides* Fr. Emend. Hyl., *Dactylis glomerata* Horv., *Daucus carota* L., *Deschampsia caespitosa* (L.) P. Beauv., *Festuca rubra* L., *Holcus lanatus* L., *Leontodon autumnalis* L., *Medicago lupulina* L., *Phleum pretense* L., *Potentilla anserine* L., *Taraxacum officinale* Web., *Trifolium pratense* L., *Veronica chamaedrys* L., *Vicia cracca* L. **Ruderal species (2):** *Erigeron ramosus* (Walters) Britton, Sterns & Poggenb., *Solidago gigantea* Aiton **Species of treaded habitats (6):** *Lolium perenne* L., *Plantago lanceolata* L., *P. major* L., *Poa annua* L., *Polygonum minus* Huds., *Prunella vulgalis* Huds. **Species of dry grasslands (10):** *Carex hirta* L., *Euphorbia cyparissias* L., *Helichrysum arenarium* (L.) Moench, *Hypochoeris glabra* L., *H. radicata* L., *Jasione montana* L., *Oenothera biennis* L., *Pilosella officinarum* Vaill., *Rumex crispus* L., *Tanacetum vulgare* L. **Cultivated species (13):** *Avena strigosa* Schreb., *Brassica campestris* L., *B. napus* L., *B. rapa* L., *B. oleracea* L., *Fagopryron esculentum* Moench, *Helianthus annuus* L., *Lupinus angustifolius* L., *L. luteus* L., *Ornithopus sativus* Brot., *Phacelia tanacetifolia* Benth., *Pisum sativum* L., *Trifolium repens* L.
Infrequent	**Segetal species (13):** *Amaranthus retroflexus* L., *Apera spica-venti* (L.) P. Beauv., *Capsella bursa-pastoris* (L.) Medik., *Centaurea cyanus* L., *Digitaria ischaemum* (Schreb.) H. L. Mühl., *Equisetum arvense* L., *Erysimum cheiranthoides* L., *Geranium pusillum* Burm. fil. ex L., *Matricaria maritima* L. subsp. *inodora* (L.) Dostál, *Scleranthus annuus* L., *Spergula arvensis* L., *Stellaria media* (L.) Vill., *Viola arvensis* Murray

Table 1. continued (3)

Frequency class	Species
	Species of moist habitats (2): *Mentha arvensis* L., *Polygonum hydropiper* L. **Meadow species (2):** *Crepis capillaris* (L.) Wallr., *Juncus effusus* L. **Ruderal species (2):** *Melandrium album* (Mill.) Garcke, *Polygonum aviculare* L. **Species of dry grasslands (2):** *Calamagrostis epigejos* (L.) Roth, *Holcus mollis* L. **Cultivated species (2):** *Secale cereal* L., *Zea mays* L. Others (1): *Galeopsis bifida* Boenn.
Frequent	**Segetal species (8):** *Cirsium arvense* (L.) Scop., *Echinochloa crus-galli* (L.) P. Beauv., *Erodium cicutarium* (L.) L'Hér., *Fallopia convolvulus* (L.) Á. Löve, *Oxalis fontana* Bunge, *Polygonum persicaria* L., *Polygonum lapathifolium* L. subsp. *pallidum* (With.) Fr., *Setaria viridis* (L.) P. Beauv. **Meadow species (1):** *Achillea millefolium* L. **Ruderal species (2):** *Artemisia vulgaris* L., *Urtica dioica* L. **Species of dry grasslands (3):** *Agrostis capillaris* L., *Hypericum perforatum* L., *Rumex acetosella* L. **Cultivated species (2):** *Avena sativa* L., *Helianthus tuberosus* L.
Very frequent	**Segetal species (4):** *Agrostis gigantea* Roth, *Chenopodium album* L., *Elymus repens* (L.) Gould, *Galinsoga parviflora* Cav.
Common	**Segetal species (1):** *Setaria pumila* (Poir.) Roem. & Schult. **Ruderal species (1):** *Conyza canadensis* (L.) Cronquist

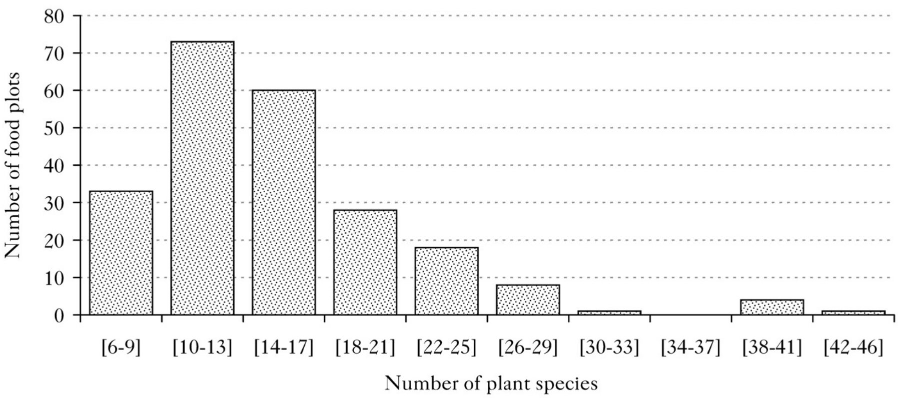

Fig. 1.
Distribution of species richness in the investigated food plots

were found in arable fields during extensive, long-term research in the Wielkopolska region (Latowski, 1998). Unlike in arable fields, where the cover of uncultivated species is very low, the total cover of this plant group in the food plots was quite high, on average 54%, ranging from 2% to 95%.

There were 67 segetal species (weeds) among the accompanying species, and 43 of them (13% of the total flora) were weeds typical of gardens and root crop fields. These species accounted for 30% of all recorded occurrences (Fig. 2A).

Many of segetal species are very rare or rare. Similar observations were made by Munoz *et al.* (2002), who assessed the rarity of field weeds in France. Only one segetal species, *Setaria pumila* (Poir.) Roem. & Schult, was classified as common in the studied plots.

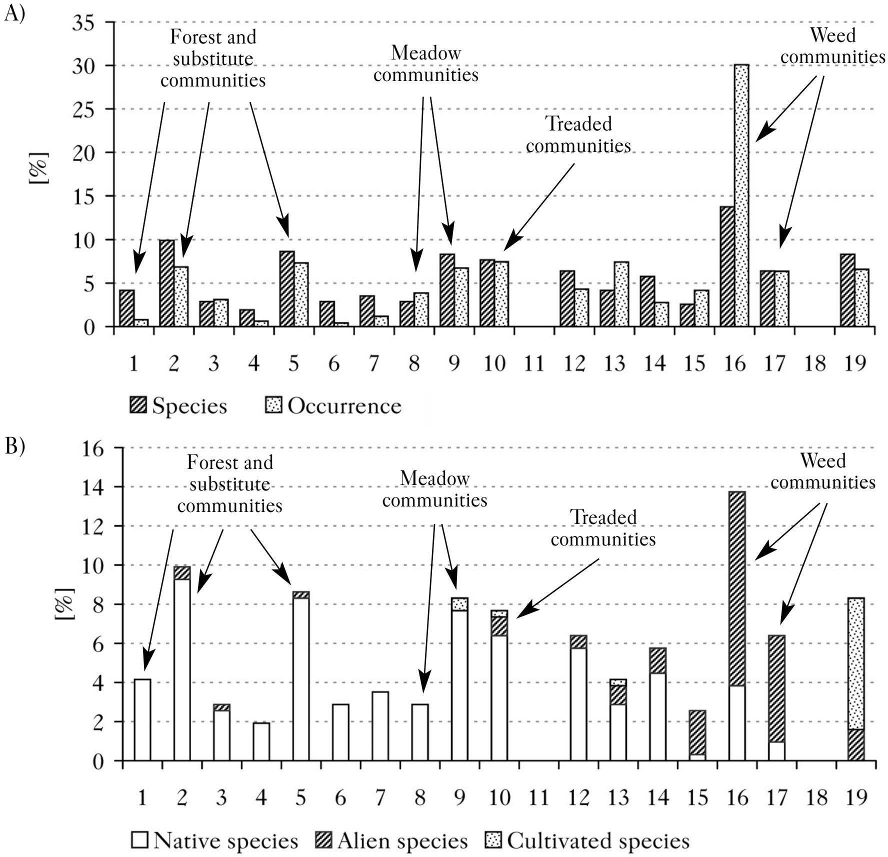

Fig. 2.

Participation of socio-ecological groups in the flora of food plots
A – share of species and their occurrences, B – share of species

Frequency classes of individual segetal species are generally similar in food plots and agricultural fields, with few exceptions. These include *Setaria pumila*, which is common in food plots and accompanies various cultivated plants, but is rare in Wielkopolska fields (Bojarszczuk and Podleśny, 2019). By contrast, some species that are rare or moderately frequent in food plots, are common in agricultural fields, *e.g. Anthemis arvensis* L., *Apera spica-venti* (L.) P. Beauv., *Galium aparine* L., and *Veronica persica* Poir. (Ługowska, 2014; Bojarszczuk and Podleśny, 2019).

Unlike in arable fields, in food plots it may be difficult to distinguish between cultivated and associated species (including segetal species) for several reasons. First of all, this is due to the use of mixtures of cultivated species, mentioned above. In extensive cultivation, the coverage of individual crop species included in the mixtures is sometimes so low that it may come close to the cover of some of the accompanying species. Then, using species that may be representatives of both distinguished groups may cause difficulties with classification. In this research, the most problematic species turned out to be *Setaria pumila*, which is a typical weed of agricultural fields. It matures and reproduces in large numbers on stubbles, young fallows, and old fields (Falkowski 1975; Suttie *et al.*, 2005). At the same time, this almost cosmopolitan species is one of the oldest useful plants (Nowiński 1970). Its grains are consumed (locally) in various regions of the world (Klmata *et al.*, 2000; Łuczaj 2011; Shah *et al.*, 2019). Currently, it is a rare ingredient of mixtures used for food plots (*e.g.* Kiepenkerl Biotop1). Due to the fact that its rough bristles are capable of penetrating the mucous membranes and causing massive injuries of the digestive tract of animals (Fava *et al.*, 2000; Puschner and Woods, 2003), it should be excluded from cultivation in food plots. Observations made in food plots indicate that currently this species is not sown (except for one plot), but its exceptionally high frequency of occurrence and large coverage suggests that it may be a remnant of former cultivation.

Biological structure. Life-forms in Raunkiaer's system and their variability are an expression of plant adaptation to survival in unfavourable periods, such as winter and droughts. The percentage share of species representing different life-forms is therefore closely related to climate diversity. The normal spectrum for Poland is as follows: hemicryptophytes > therophytes > geophytes > phanerophytes > chamaephytes (Kornaś and Medwecka-Kornaś, 2002). The spectrum of life-forms of the studied wildlife food plots (Fig. 3) differed from the normal spectrum. The most numerously represented groups were therophytes (T-1, T-2; 44% of species and 55% of occurrences), followed by hemicryptophytes (39% of species and 27% of occurrences). In this respect, the food plots resemble agricultural fields, although the dominance of annual plants over hemicryptophytes is even more evident in fields (Poggio *et al.*, 2013; Ługowska, 2014; Štefanić *et al.* 2019; Fanfarillo *et al.* 2020). The smaller disproportion between the shares of species from both discussed life-forms in food plots results from their specific use. Extensive farming and frequent introduction of perennial species to cultivation (mostly *Helianthus tuberosus*) favour the colonization of food plots by highly competitive, perennial species, and elimination of poorly competitive annuals. A similar loss of short-lived segetal species (Janicka *et al.*, 2021) and an increase in the share of perennial plants (Feledyn-Szewczyk *et al.*, 2019) were also observed on perennial plantations of energy crops. An interesting group are geophytes, which account for 7% of species and 13% of occurrences in food plots. The frequent presence and increased coverage of such geophytes as *Calamagrostis epigejos* (L.) Roth and *Elymus repens* (L.) Gould, for example, was associated with the extensive use of food plots. Megaphanerophytes were represented only by seedlings. Although the species diversity of this group was quite high (7%), the number of occurrences was small (2%) and the coverage was low (r, +). The presence of megaphanerophytes results from extensive management and is not a symptom of the initial phase of succession of woody vegetation. However, it shows that if agricultural activities in food plots were completely abandoned,

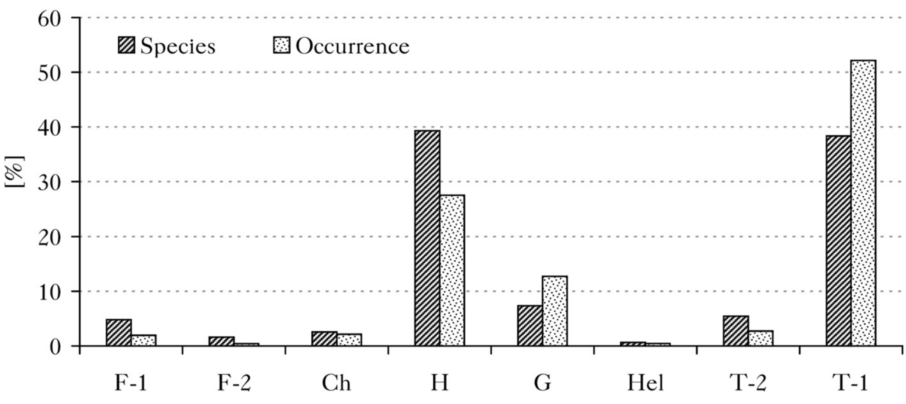

Fig. 3.

Participation of plant life-forms in the flora of food plots: share of species and their occurrences. Abbreviations – see 'Material and methods' the spontaneous restoration of forest ecosystems through secondary succession would be faster. Geographic-historical structure. The flora of food plots comprises various species, differing in terms of their origin and degree of naturalization. Out of the 313 recorded species, 66% were native. Among them the synanthropic apophytes clearly dominated, as they constituted 47% of the total flora (Fig. 4). The share of native species in agricultural areas ranges on average from ca. 60% in arable fields as well as in inter-field balks (Kutyna and Malinowska, 2011; Kutyna *et al*,. 2013; Ługowska *et al.*, 2014; Klarzyńska *et al.*, 2020) to ca. 75% in old fields (Kutyna and Malinowska, 2011), so the share of native species in food plots is in the middle of this range. A specific feature of food plots was the large number of native species typical of deciduous forests, mixed forests, and pine forests as well their substitute shrub and grassland communities (Fig. 2B). However, their frequency (Fig. 2A) and degree of cover were usually low. Among native species found in food plots, meadow plants and plants derived from treaded communities were quite numerous (Fig. 2A, B). Both groups of plants are also observed in agricultural fields (Ługowska, 2014). The presence of species typical of forest, shrub, and meadow communities in food plots indicates an immediate neighbourhood of a mosaic of ecosystems from which those species originated and reflects their influence on the flora of the studied plots. Some apophytes, *e.g. Euphorbia cyparissias* L. or *Corynephorus canescens* (L.) P. Beauv., were also present because acidic sites (unsuitable for agriculture) were used as food plots.

The largest group of alien plants were archaeophytes (15% of species and 21% of occurrences). Because of agrotechnical progress, especially the improved methods of purification of seed lots, many archaeophytes are now found in few localities, *e.g. Agrostemma githago* L. This decline is noticeable also in food plots, where this species was recorded in only one locality. The decline of some weed species is accompanied by expansion of others, including archaeophytes, *e.g. Capsella bursa-pastoris* (L.) Medik., *Myosotis arvensis* (L.) Hill, and *Matricaria maritima* L. subsp. *inodora* (L.) Dostál. These taxa are classified as naturalized but non-invasive in Poland (Tokarska-Guzik *et al.*, 2012).

Kenophytes constituted the second largest group of alien species (10% of species and 12% of occurrences). The most frequent kenophytes included *Conyza canadensis* (L.) Cronquist, *Galinsoga parviflora* Cav., and *Oxalis fontana* Bunge. It is noteworthy that *Anthoxanthum aristatum* Boiss. is

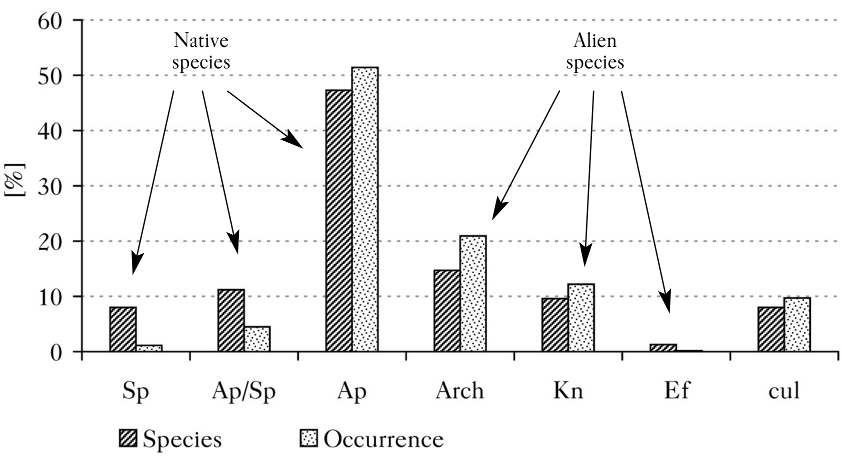

Fig. 4.

Participation of geographic-historical groups in the flora of food plots: share of species and their occurrences. Abbreviations – see 'Material and methods' relatively frequent. Its presence was first recorded in 1866 in agricultural fields in central Poland, and now it is a weed of invasiveness category I, *i.e.* the lowest (Tokarska-Guzik *et al.*, 2012). Attention should be paid also to *Oxalis dillenii* Jacq., a North American kenophyte, which is now rare but the number of its localities is gradually increasing in Poland (Zarzycki *et al.*, 2002).

Ephemerophytes were the least numerously represented geographic-historical group in food plots (1% of species and 0.1% of occurrences). The most interesting among them was witchgrass *Panicum capillare* L.. This species originating from North America is rare but has been unintentionally introduced in Poland many times (Jackowiak *et al.*, 2017).

ANTHROPOGENIC CHANGES OF FLORA. The analysis of anthropogenic changes of flora is of great cognitive importance. It enables evaluation of the studied areas in terms of flora naturalness (indices of naturalness, synanthropization, and anthropophytization), expansion of alien species (indices of kenophytization and floristic fluctuations), relative lability of the species composition of plant communities (indices of floristic fluctuations, kenophytization, and modernization) and relative stability of their species composition (indices of archaeophytization, naturalness, and stability).

The following indices were calculated for the flora of the food plots: N=7.99%; S_w=72.84%; S_p=84.02%; Ap_w=47.28%; Ap_p=58.46%; Aps_w=71.15%; Aps_p=87.98%; A_n=33.54%; A_r=14.69%; K_n=9.58%; M=39.47%; T_A=72.38%; T_C=90.73%; FL_A=3.8%; FL_C=1.27%.

The obtained results were primarily compared to floristic studies of cultivated agricultural fields as well as old fields (Kutyna and Malinowska, 2011), but also to research on forests (Kutyna and Malinowska, 2010) (Table 2). The values of most of the indices calculated for food plots fall between the values calculated for agricultural areas (fields and fallows) and forest habitats, but are closer to those for agricultural areas. The values of Ap_w and A_n were the most similar in food plots and cultivated fields, while those of N, S_w, Aps_w, Aps_p, A_r, and M for food plots were the most similar to those calculated for old fields. Very low floristic fluctuations (FL_A and FL_C) in

Table 2.
Comparison of anthropogenic changes in the flora of food plots, agricultural fields, and forests

Indices	Food plots	Farmlands*		Forests+	
		cultivated fields	old fields	coniferous habitats	forest habitats
N	8.0	2.9	4.5	30.8	31.8
S_w	72.8	91.3	83.5	35.9	38.6
S_p	84.0	97.0	95.4	69.2	68.2
Ap_w	47.3	53.4	58.7	25.6	27.3
Ap_p	58.5	59.3	70.6	59.0	56.8
Aps_w	71.2	85.9	78.1	28.6	30.8
Aps_p	88.0	95.3	93.9	65.7	64.1
A_n	33.5	37.7	24.8	10.3	11.4
A_r	14.7	30.8	16.0	0.0	0.0
K_n	9.6	4.6	5.2	7.7	6.8
M	39.5	13.1	24.5	100.0	100.0
T_A	72.4	93.8	85.9	75.0	60.0
T_C	90.7	97.6	96.5	97.4	95.5
FL_A	3.8	6.1	14.0	25.0	40.0
FL_C	1.3	2.3	3.4	2.6	4.5

Indices: see Material and methods
Sources: *Kutyna and Malinowska (2011), +Kutyna and Malinowska (2010)

food plots are associated with a very low share of transitional species. The low values of these indices and of index A_r can be attributed to the lower human interference in food plots. Extensive farming, irregular planting, and the introduction of perennial species into cultivation limit the occurrence of these two groups of alien species (diaphytes and archaeophytes) in favour of native species (including non-synanthropic and semi-synanthropic spontaneophytes), the occurrence of which is very limited in areas intensively used for agriculture.

The higher value of index M in food plots than in agricultural areas, means a greater share of kenophytes among permanently established alien species. The very high K_n index of the food plots reflects the large share of kenophytes (30 species) in the overall species richness. As 19 of them are invasive at the national level, we should consider food plots as potential footholds for the expansion of alien taxa to neighbouring ecosystems. Among the invasive species present in food plots there are taxa evidently coming from forests (*e.g.* woody species, *Impatiens parviflora* DC.) and those that prefer open agricultural landscape. In the latter group of species, particular attention should be paid to *Conyza canadensis*. Due to its common occurrence in our study, it can penetrate into forest ecosystems *e.g.* along forest roads or through clearings into degraded forest patches. This species has a wide ecological amplitude, as it can survive in a broad range of environmental conditions (Wang *et al.*, 2017a). Moreover, in its populations occurring in the warm temperate zone, a high reproductive allocation was observed (Wang *et al.*, 2017a), which could be modified under competitive conditions (Wang *et al.*, 2017b). As fecundity and high-efficiency multiple reproduction modes favour successful plant invasion, the spread of *Conyza canadensis* from food plots can be expected. This species was already observed at the forest-field borders, in clearings, small gaps inside a forest matrix (Popiela *et al.*, 2015; Marinšek and Kutnar, 2017) as well as in dried alder carr forests (Kopeć *et al.*, 2014) and riparian hardwood forests (Kowalska, 2020).

In food plots we found also several other very rare and rare invasive kenophytes that have the potential to spread into forest ecosystems. These are *Bidens frondosa* L., *Anthoxanthum aristatum*, *Epilobium ciliatum* Raf., *Erechtites hieracifolia* (L.) Raf. ex DC., and *Juncus tenuis* Willd.. *Bidens frondosa* is increasingly recorded in natural habitats; in the shore zones of water bodies (Popiela *et al.*, 2015) and in floodplain forest (Kopeć *et al.*, 2014). *Anthoxanthum aristatum* has already been found in psammophilous grasslands gradually overgrown by pine trees (Kirpluk and Bomanowska, 2015), at the forest-field borders, on sandy forest roads as well as in open pine, birch or pine-oak forests on former fields (Woziwoda, 2010). The three remaining invasive kenophytes are also recorded in forest ecosystems: in clear-cut areas, on forest edges, forest dividing lines, and along forest roads (*e.g. Epilobium ciliatum* – Matulevičiūtė, 2007; *Erechtites hieracifolia* – Górski *et al.*, 2003; Koczywąs *et al.*, 2012; *Juncus tenuis* – Myśliwy, 2008; Krzyżanowska *et al.*, 2018).

Four invasive species observed in food plots are archaeophytes: *Avena fatua* L., *Echinochloa crus-galli* (L.) P. Beauv., *Setaria pumila*, and *S. viridis* (L.) P. Beauv. In this group, both *Setaria* species have the highest expansion potential due to their frequent occurrence in food plots. *Setaria viridis* has already been found occasionally on gravel-sand roads in post-agricultural forests (Woziwoda, 2010) and showed a high invasive trend in different ecosystems in the forest-steppe zone of Ukraine (Pashkevych and Burda, 2017).

Out of the species included in the 'Regulation of the Council of Ministers on the list of invasive alien species posing a threat to the European Union and the list of invasive alien species posing a threat to Poland, remedial actions, and measures aimed at restoring the natural state of ecosystems' (2022), none occurred in food plots.

The studied food plots were poor in rare species and devoid of protected species. However, we recorded 2 species included in red lists for Poland – *Avena strigosa* (LC) and *Agrostemma githago* (NT).

Conclusions

The flora of the studied food plots is relatively rich. Despite its similarity to the flora of agricultural fields, it has many specific features, which result mainly from (1) extensive farming; (2) a large share in the cultivation of perennial Jerusalem artichoke, which affects the species composition of co-occurring plants by increasing the share of perennial native species; (3) contact of the food plots with forest communities; and (4) the establishment of many food plots on highly acidic sites.

There is a fairly large group of alien invasive species that can spread from food plots to nearby forest ecosystems, *e.g.*, along roads, forest dividing lines or through tree clearings into degraded forest patches: *Conyza canadensis*, *Anthoxanthum aristatum*, *Epilobium ciliatum*, *Erechtites hieracifolia*, *Juncus tenuis*, and *Setaria* species. It is recommended to monitor these species, and if they are found to be spreading, to eliminate them.

The food plots contain a relatively small group of threatened species. A necessary condition for their survival in their current locations is the continuation of extensive farming.

Authors' contributions

Research concept – A.C., R.N.; field work – A.C., W.S.; manuscript writing – R.N., A.C.; tables preparation – A.C.; data analysis and graphs preparation – R.N.

Conflicts of interest

The authors declare no conflict of interest.

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STRESZCZENIE

Czy flora poletek łowieckich przypomina florę pól uprawnych, czy też ma swoją specyfikę?

Poletka łowieckie to zwykle śródleśne obszary obsiane lub obsadzone roślinami stanowiącymi pokarm dla zwierzyny łownej. Jeden z typów poletek – poletka produkcyjne – ze względu na sposób gospodarowania może wykazywać szczególne podobieństwo do klasycznych pól uprawnych (agrocenoz). Podobnie jak w przypadku agrocenoz, na poletkach łowieckich pojawiają się rośliny towarzyszące uprawom. Ich znajomość pozwala oszacować bogactwo gatunkowe poletek oraz ich potencjalny wpływ na lokalne środowisko.

Poletka łowieckie nigdy nie były obiektem badań florystycznych. Niniejsza praca wypełnia tę lukę. Celem badań było ustalenie składu i struktury flory oraz identyfikacja podobieństw i różnic pomiędzy florą poletek i pól uprawnych. Badania przeprowadzono na 226 poletkach produkcyjnych zlokalizowanych w 37 nadleśnictwach w województwie wielkopolskim. Wielkość poletek wahała się od 4 do 600 arów. Na każdym poletku, na powierzchni 400 m^2, sporządzono spis roślin naczyniowych wraz z pokryciem (wg 7-stopniowej skali). W charakterystyce flory uwzględniono strukturę form życiowych, geograficzno-historyczną, socjologiczno-ekologiczną, analizę wskaźników antropogenicznych zmian flory i waloryzację. Wyniki porównano z danymi literaturowymi dotyczącymi agrocenoz.

Ogółem stwierdzono występowanie 313 gatunków roślin (tab. 1). Na poszczególnych poletkach występowało od 6 do 45 gatunków (ryc. 1). Duże zróżnicowanie liczby gatunków upodabnia poletka łowieckie do obszarów rolnych. O zróżnicowaniu liczebności gatunków mogą decydować zarówno czynniki naturalne, takie jak żyzność i wilgotność gleby, jak i czynniki agrotechniczne towarzyszące różnym typom upraw.

Na poletkach uprawiano łącznie 28 gatunków roślin. Na 16% zbadanych obszarów nie stwierdzono gatunków uprawnych. Z kolei mieszankę kilku gatunków odnotowano na 31% poletek. W odróżnieniu od pól uprawnych średnie pokrycie gatunków uprawnych było stosunkowo niskie i wynosiło 37%. Najczęściej uprawianą rośliną był słonecznik bulwiasty *Helianthus tuberosus*. Jest to antropofit zadomowiony, który choć nie rozprzestrzenia się generatywnie (nie zawiązuje nasion), tworzy liczne, drobne bulwy pędowe, więc może być trudny do eliminacji z uprawy. Gatunkiem rzadko uprawianym na poletkach jest owies szorstki *Avena strigosa* – zagrożony wyginięciem archeofit.

Stwierdzono obecność 285 gatunków towarzyszących uprawom. Jest to duża liczba w porównaniu z agrocenozami. Odmiennie niż na polach uprawnych, całkowite pokrycie tej grupy roślin na poletkach jest dość wysokie (średnio 54%). W tej grupie wystąpiło 67 gatunków segetalnych. Były to głównie chwasty typowe dla ogrodów i pól okopowych (ryc. 2A). Częstotliwość występowania poszczególnych gatunków chwastów na poletkach łowieckich i na polach uprawnych jest dość podobna, z nielicznymi wyjątkami (np. *Setaria pumila* występuje zdecydowanie częściej na poletkach, zaś *Anthemis arvensis*, *Apera spica-venti*, *Galium aparine* i *Veronica persica* są tam dużo rzadsze).

W przypadku poletek łowieckich rozróżnienie niektórych gatunków uprawnych od gatunków towarzyszących może być trudne. Problematycznym gatunkiem okazała się włośnica sina *Setaria pumila*. To częsty chwast upraw okopowych, jednocześnie bywa on składnikiem niektórych mieszanek przeznaczonych na poletka. Z uwagi na długie ości, powodujące uszkodzenia przewodu pokarmowego zwierząt, należy wykluczyć ten gatunek z uprawy, co ograniczy jego rozprzestrzenianie się.

Struktura form życiowych roślin cechuje się dużym udziałem roślin jednorocznych (ryc. 3). W odróżnieniu od agrocenoz na poletkach liczne są też hemikryptofity (35%), co jest pochodną mniej intensywnego zagospodarowywania tych terenów i wprowadzania do uprawy gatunków wieloletnich. W strukturze geograficzno-historycznej zaznacza się dominacja gatunków rodzimych, zwłaszcza apofitów (ryc. 4). W odróżnieniu od pól uprawnych duży udział wśród roślin rodzimych stanowią gatunki leśne (ryc. 2B).

Podczas gdy grunty rolne są zagospodarowywane głównie pod kątem produkcji roślinnej, gospodarowanie na poletkach powinno uwzględniać ich potencjalny wpływ na lokalne środowisko. Badania wykazały, że poletka charakteryzują się niższą synantropizacją mierzoną wskaźnikami antropogenicznych zmian flory (tab. 2). Większość gatunków obcych to nieekspansywne archeofity. Spośród 26 gatunków inwazyjnych taksonami, które mogą rozprzestrzeniać się do pobliskich ekosystemów leśnych, są *Conyza canadensis*, *Anthoxanthum aristatum*, *Epilobium ciliatum*, *Erechtites hieracifolia*, *Juncus tenuis*, *Setaria pumila* i *S. viridis*. Zaleca się monitorowanie tych gatunków, a w przypadku stwierdzenia ich rozprzestrzeniania się – eliminację. Na badanych poletkach występowały 2 zagrożone w skali kraju gatunki segetalne: *Agrostemma githago* i *Avena strigosa*. Gatunki te mają zdolność przetrwania w dynamicznych i zmieniających się środowiskach. Przy ekstensywnym zarządzaniu poletkami utrzymają się na tych terenach.