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Research Article

DISTRIBUTION OF *Ambrosia artemisiifolia* L. IN THE RIGHT-BANK FOREST-STEPPE OF UKRAINE AND ITS ADAPTIVE POTENTIAL

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Abstract: Invasions of alien species have become a global problem worldwide. Our paper presents the results of the study of the chorology of the invasive species *Ambrosia artemisiifolia* L. within the Right-Bank Forest-Steppe of Ukraine (RBFSU). We identified 13 new growth areas in the study area. These studies cover the observation and recording of the phenological behaviour of this species during 2020-2021. Although phenological observations are mainly carried out on cultivated plants, the data obtained as a result of the study is an important resource for preparing an invasive species control plan. Based on the indicators of temperature fluctuations, drought tolerance, light tolerance, relation to soil fertility, reproduction and shoot regeneration of *A. artemisiifolia*, a scoring method was proposed using the coefficient of complex adaptive potential (CCAP). However, our work is a pioneering study aimed at counteracting the spread of alien plants.

Özet: Yabancı türlerin istilası dünya çapında küresel bir sorun haline gelmiştir. Çalışmamızda, Ukrayna Sağ-Banka Orman-Bozkırında (RBFSU) istilacı *Ambrosia artemisiifolia* L. türünün korolojisi üzerine yapılan bir çalışmanın sonuçları sunulmaktadır. Yeni habitatlar tespit edilmiştir. Bu çalışmalar, 2020-2021 yılları arasında bu türün fenolojik davranışlarının gözlemlenmesini ve kaydedilmesini kapsamaktadır. Fenolojik gözlemler esas olarak kültür bitkileri üzerinde gerçekleştirilse de, çalışma sonucunda elde edilen veriler istilacı tür kontrol planı hazırlamak için önemli bir kaynaktır. *Ambrosia artemisiifolia'nın* sıcaklık dalgalanmaları, kuraklık toleransı, ışık toleransı, toprak verimliliği ile ilişkisi, üreme ve sürgün rejenerasyonu göstergelerine dayanarak, karmaşık adaptif potansiyel katsayısı (CCAP) kullanılarak bir puanlama yöntemi önerilmiştir. Bununla birlikte, çalışmamız yabancı bitkilerin yayılmasına karşı koymayı amaçlayan öncü bir çalışmadır.

Introduction

The ongoing decrease in the forest cover of Ukraine and the intense plough activities in forest-free areas eventually lead to the rapid spread of invasive plants, negatively affecting the growth of native species and causing occurrence of cases harming human health. *Ambrosia artemisiifolia* L. of the genus *Ambrosia* L. within the Asteraceae family is rapidly "capturing" the territory of the Right-Bank Forest-Steppe of Ukraine. The greatest threat related with this species is observed during the flowering of this plant during when its pollens, which causes an acute allergic disease called *autumn fever*, start to appear in the air (Pruntsev & Asmolov 2006).

The native land of *A. artemisiifolia* is North America (Pokotylo & Pospelov 2020). The species reached to the territory of Ukraine more than once. In 1914-1918 period, A. Kriker, a german colonist, grew it near Kudashivka Railway Station, currently the Dnipropetrovsk region (primary cell), as a medicinal plant, ignoring that the plant is a noxious weed in its homeland. It was brought to the southern regions from the Stavropol Territory, and got there in 1925 to Kyiv with clover seeds from the USA (Solonenko 2011). Subsequently, several secondary centres emerged - Kerch, Simferopol, Berdyansk, Luhansk, Kharkiv, Kyiv, Chernivtsi, Berehove (Transcarpathian region), where the species started invasion of other plants existing in adjacent areas (Bezruchenko & Chukorin 1956, Burda 1982, Protopopova 1991). Today, this species is distributed throughout the country in all administrative regions covering an area of 3.1 million ha, but mostly in the southern and eastern parts and in the northwest (Fisyunov *et al.* 1970, Maryushkina 2006, Besh *et al.* 2011, Palamarchuk 2012, Leiblein-Wild *et al.* 2014). Another source of ragweed expansion was recorded in 1946 when the first batches of wheat were shipped to the USSR from the United States. In the following years, with the decrease in the forest cover and as a result of intensive ploughing of areas free from forests, the rapid spread of this dangerous invasive plant was observed (Neilyk 2020).

A number of studies have been performed on *A. artemisiifolia* focusing mainly on the effective control strategies of the species. Onipko studied the effectiveness of biological control of *A. artemisifolia*. The study was carried out in the first two links of the grain-para-pasture crop rotation and was based on strengthening of competitiveness of field crops by selecting optimal seeding rates of their seeds, which was a prerequisite for phytocoenotic suppression of weeds in the crop due to the reduction of energy intensity of the lower tier of agrophytocenosis (Onipko 2016). Neilyk & Tsytsiura found out the biological features and adaptive potential of and control strategy against *A. artemisiifolia* (Neilyk & Tsytsyura 2020). Zavyalova *et al.* presented a comprehensive review of 42 alien species, including *A. artemisiifolia,* and their impact on the vegetation of Ukraine (Zavialova *et al.* 2021). Maryushkina found a decrease in the rate of progressive succession (using the example of the adventitious species *A. artemisiifolia*). She studied the phenomenon of heterocarpy in detail and developed method of phytocoenotic control in three variants, which led her to conclude that the late mowing of *A. artemisiifolia* is a simple, cheap and very effective remedy, which also prevents allergenic pollens from entering to the atmosphere and contributes to the improvement of the environment (Maryushkina 2006).

In the Right-Bank Forest-Steppe of Ukraine, Neilyk recorded *A. artemisiifolia* in 50 farms in the Vinnitsa region (Neilyk 2008). Chemerys & Konyakin assessed the current state of distribution and growth characteristics of *A. artemisiifolia* in the urban ecosystem of Cherkasy (Chemerys & Konyakin 2013). Bilyavskyi investigated the distribution of this species in the city of Bila Tserkva and in the coastal zone of the Ros River (Bilyavskyi 2011, 2021). Burda & Ignatyuk developed a methodology for a complex systematic study of the adaptive strategy of alien plant species in an urbanized environment, taking into account botanical (morphological description, taxonomic identification, field accounting, methods of comparative characteristics, study of reproductive capacity) and ecological (ecotopological analysis, research of life forms, analysis) features, population dynamics indicators, adaptive strategies and cartographic and statistical methods (Burda & Ignatyuk 2011).

Many studies emphasise the high degree of adaptability of alien species to changing environmental conditions. Species that have high adaptive potential and can survive in a wide range of changes in environmental conditions are called ecologically plastic, or eurybiotic (Anderson et al. 2019). Such species include *A. artemisiifolia*, which populates new habitats, adapts to large disturbances in ecosystem homeostasis and to changing environmental conditions.

In view of the above information, the development of methods for scaled assessment of the adaptive potential of *A. artemisiifolia* growing in the Right-Bank Forest-Steppe of Ukraine is quite relevant. Therefore, we aimed in the present study to determine the distribution of this species within the Right-Bank Forest-Steppe of Ukraine and its growth and development peculiarities in different environmental conditions. Based on the results, we are going to plan to develop a comprehensive scale of adaptive potential in the future.

Materials and Methods

In the structure of the physical-geographical zoning scheme of Ukraine, the Right-Bank Forest-Steppe of the country covers a significant part within the borders of Vinnitsa, the right bank of Cherkasy, the southern districts of Zhytomyr and Kyiv, the northern districts of Odesa, Mykolaiv and Kirovograd, and the eastern districts of Khmelnitsky Oblast (Denisyk & Kravtsova 2012).

The study is based on original expedition data from 2020-2021, supplemented by a critical analysis of literature, materials from the herbarium collections of the National Dendrological Park "Sofiyivka" of the National Academy of Sciences of Ukraine (NDP), Uman National University of Horticulture (UNUH) and Pavlo Tychyna Uman State Pedagogical University (USPU), as well as information from citizen science platforms (iNaturalist and UkrBin) (Bilyavskyi 2011, 2021, Chemerys & Konyakin S. 2013, Neilyk & Tsytsyura 2020).The herbarium materials of the map of currently known locations of *A. artemisiifolia* within the study area (Fig. 1) was produced by available tools at the website "Simplemappr" (Shorthouse 2010). Indicators of climatic conditions are given according to Weather & Climate (2020).

Stationary studies were conducted at the agrobiostation of the Uman State Pedagogical University named after Pavlo Tychyna. The indicators of the adaptive potential of *A. artemisiifolia* were determined in model locations of the Right-Bank Forest-Steppe of Ukraine. The ecotopes of the studied areas are roadsides, abandoned residential areas, wastelands, the port area, and the coastal zone. The method of visual observations of the state of the leaf apparatus was used to study drought resistance and resistance of dew to sharp temperature fluctuations during the growing season. The regeneration ability of the shoots was determined by deliberate damage to the crown during mowing.

The germination energy of seeds was determined by germination in Petri dishes using a Thermostatic drying cabinet TC-20 MICROmed with forced convection at a constant temperature of 20.0±2°C. Seed germination was determined by sowing the seeds into the soil to a depth of 2 cm.

The influence of soil fertility on the growth and development of *A. artemisiifolia* was studied under stationary conditions at the agrobiostation of Pavlo Tychyna Uman State Pedagogical University. The light intensity of *A. artemisiifolia* was determined in stationary conditions on the territory of the experimental plot of the Pavlo Tychyna Ukrainian State Pedagogical University Agricultural Biological Station, as it has all the conditions for research. The experiments were carried out using Luxometer CEM DT-8809A equipment. Due to the intensity of lighting, measurements were taken three times a day (early June, mid-July and late August). For this purpose, plots were formed where turf soil and sand (2:1), turf soil and humus (2:1) and turf soil and peat (2:1) were used as substrates. For the reliability of the research, the number of replications for each variant was three times. The experiment lasted during the growing season (from the beginning of sowing seeds to the end of the growing season).

To determine the adaptive potential of *A. artemisiifolia*, we propose to use a three-point scale, taking into account the following indicators (Table 1).

For the scale of assessing the adaptive potential of *A. artemisiifolia*, we suggest using the following formula for coefficient of comprehensive assessment of adaptation potential of invasive species (CCAAP):

$$CCAAP = TF + DR + LR + RSF + VR + SR + RS$$

If the resulting CCAAP value is in the range of 1 to 7, the adaptive capacity is considered low, 8 to 14 is considered medium, and high for values from 15 to 21.

Table 1. Three-point scale for determining adaptive capacity.

Indicators	Points		
	1	2	3
Temperature fluctuations (TF)	Unstable	Moderately stable	Stable
Drought resistance (DR)	Not drought resistant	Moderately drought-resistant	Drought-resistant
Light requirement (LR)	Light-requiring	Moderately light-requiring	Shade tolerant
Relation to soil fertility (RSF)	Related	Moderately related	Not related
Vegetative reproduction (VR)	Weak	Moderate	Good
Seed reproduction (SR)	Weak	Moderate	Good
Regeneration of the shoots (RS)	Weak	Moderate	High

Results

The climate of the Right-Bank Forest-Steppe of Ukraine is temperate continental. The average air temperature over the study period was 7.3°C, and the average rainfall was 535.1 mm. The monthly distribution of precipitation throughout the year is uneven and ranges from 12.00 to 90.00 mm. The winters are mild, with the coldest month being February with temperatures of -2.5 to +3.3°C. The total number of days with an average daily temperature below 0°C ranges from 92 to 122 days in cold winters, and from 57 to 87 in warm winters. The beginning of winter is considered to be the second and third decades of November, when the average daily temperature drops below 0°C. Soil freezing begins in the first decade of December. When the average daily temperature rises above 0°C, the spring season begins. The spring temperature regime varies widely. The period with an average daily temperature above +10°C is a period of intensive plant vegetation. The spring period during the study was characterised by the maximum amount of precipitation (May). A noticeable increase in temperature begins in April and lasts until July-August. The hottest month of the year is July with an average daily temperature of +22.0 to+23.7°C (Fig. 1).

According to the results of our research, more than 190 locations of *A. artemisiifolia* are known in the Right-Bank Forest-Steppe of Ukraine, thirteen of which were discovered for the first time (Supplemantary Material, Fig. 2, Table 2).

In order to carry out highly effective protection measures against this invasive plant, we determined the dynamics of the number of individuals. For this purpose, we selected four model plots located along the extreme borders of the Right-Bank Forest-Steppe of Ukraine, namely: No. 1 - near the railway line in Novoarkhangelsk, Golovanivskyi district, Kirovohrad region; No. 2 - near the railway stations, along the tracks, in Uman, Cherkasy region; No. 3 - Intermediate railway station of the Kozyatyn Directorate of the South-Western Railway (Ukraine), located on the stretch Kozyatyn I - Fastiv I between the stopping points Harliivka and Fastiv - Kozyatyn); No. 4 - in the urban settlement of Novoarkhangelsk (Fig. 3).

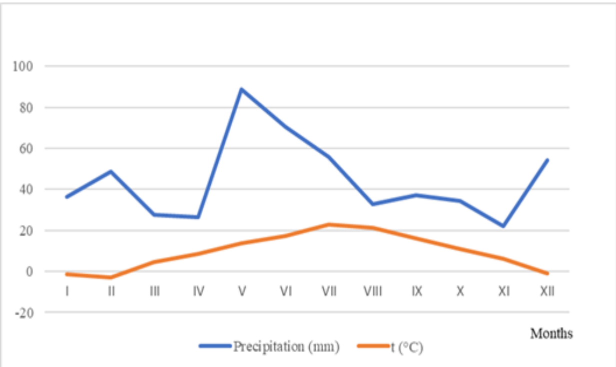

Fig. 1. Climatodiagram of the study area (2020-2021)

Table 2. New localities of *A. artemisiifolia* dicovered in this study.

No	Localities	Coordinates	Date	Leg.	Code
	Cherkasy region				
1.	Cherkas'kyi district, Cherkasy (intermediate railway station of the 1st class of the Shevchenko Directorate of the Odesa Railway on the partially electrified line Zolotonosh I — named after Taras Shevchenko),	49.469866, 32.012520	18.06.2021	Volodymyr Vitenko	SOF
2.	Cherkas'kyi district, the village of Moshny	49.527760, 31.733569	27.06.2020	Volodymyr Vitenko	SOF
3.	Cherkas'kyi district, Cherkasy, Mytnytsia	49.440777, 32.052904	12.06.2020	Volodymyr Vitenko	SOF
4.	Umansky district, (dead-end railway station of the 4th class of the Shevchenkivka Directorate of the Odesa Railway on the lightly loaded, non-electrified line Khrystinivka — Uman)	48.733807, 30.205273	03.06.2020	Volodymyr Vitenko	SOF
5.	Umansky district, the vicinity of the agrobiostation of Pavlo Tychyna Uman State Pedagogical University)	48.768309, 30.170079	17.07.2020	Volodymyr Vitenko	SOF
6.	Umansky district, the village of Polyanetske	48.746650, 30.199386	12.06.2022	Inna Didenko	SOF
7.	Umansky district, Khrystynivka city	48.814112, 29.951574	26.07.2023	Inna Didenko	SOF
	Khmelnytskyi region				
8.	Khmilnytskyi district, the city of Kalynivka (railway junction on the lines Kyiv — Odesa, Kyiv — Kamianets-Podilskyi, Berdychiv — Vinnytsia, Kozyatyn — Khmelnytskyi (Grechany), Kalynivka — Khmilnyk — Shepetivka)	49.455069, 28.478579	12.06.2020	Volodymyr Vitenko	SOF
	Kirovohrad region				
9.	Village Oleksandrivka, Kropyvnytskyi district (intermediate railway station of the Znam'yansk Directorate of the Odesa Railway on the Pomichna-Kolosivka line)	48.561005, 31.202496	29.06.2021	Volodymyr Vitenko	SOF
	Kyiv region				
10.	Bilotserkivskyi district, Tetiiv city, (Kozyatyn-Zhashkiv, Tetiiv and Slobidskyi Post railways)	49.689139, 30.070915	12.06.2020	Volodymyr Vitenko	SOF
11.	Kyiv City, (South-Western railway station, the main railway station of Kyiv)	50.439179, 30.486919	18.06.2020	Volodymyr Vitenko	SOF
12.	Intermediate railway station of the Kozyatyn Directorate of the South-Western Railway (Ukraine), located on the Kozyatyn I — Fastiv I section between the Harliivka stops, Fastiv — Kozyatyn railway line)	49.732034, 28.856388	23.06.2021	Volodymyr Vitenko	SOF
	Zhytomyr region				
13.	Berdychiv city, Berdychiv district (Berdychiv — Zhytomyr and Kozyatyn — Shepetivka highways)	49.915526, 28.591755	06.06.2021	Volodymyr Vitenko	SOF

SOF: Herbarium of the National Dendrological Park Sofiyivka of the National Academy of Sciences of Ukraine (Ukraine)

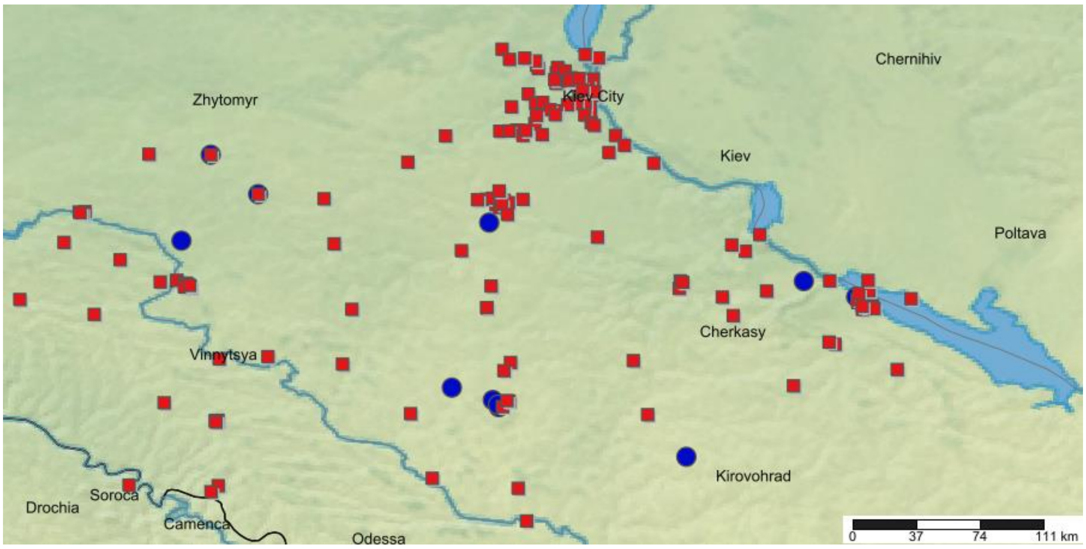

Fig. 2. Distribution of *Ambrosia artemisiifolia* within the Right-Bank Forest-Steppe of Ukraine (■ Currently known locations of the species, ● Locations we have identified).

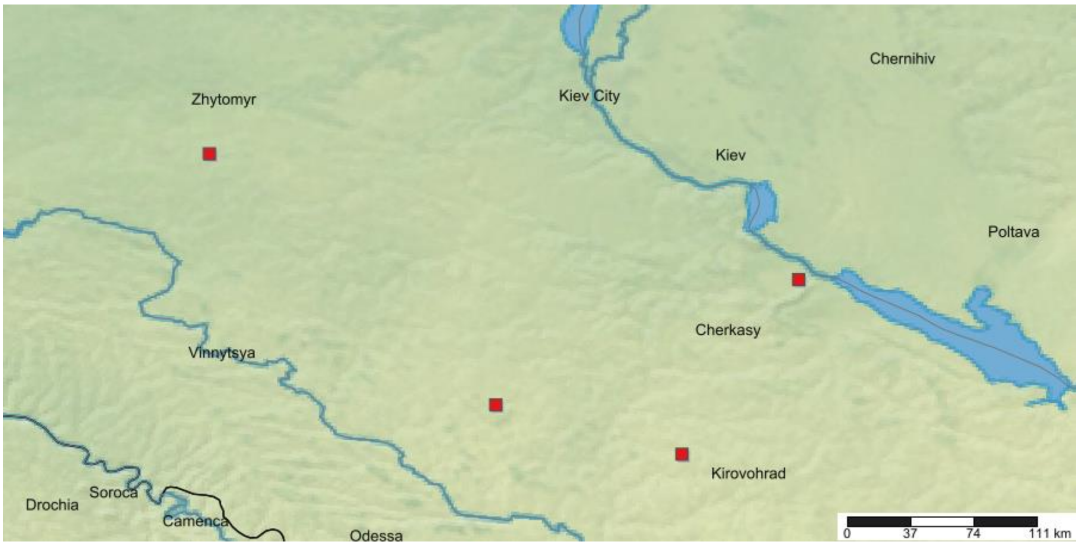

Fig. 3. Model plots for determining the dynamics of *A. artemisiifolia* abundance.

Each plot covered an area of 100 m². The results of a comparative analysis of the number of *A. artemisiifolia* plants in the study plots are shown in Fig. 4.

The analysis of the data presented in Fig. 4 shows a tendency to increase the number of *A. artemisiifolia* plants, which indicates the need for a control variant. In 2020, 20 plants grew in plot 1, and in 2021, the number increased to 35. The tendency to increase the number of plants from year to year is also observed in other plots: No. 2 - 8 plants per 15 plants; No. 3 - 3 to 20 plants; No. 4 - from 12 to 19 plants. In our opinion, this trend is due to a sharp change in climatic conditions, which are favourable for the intensive spread of this invasive plant (Fig. 3).

During the study of the adaptive potential of *A. artemisiifolia*, special attention was paid to the influence of the following indicators: temperature fluctuations during the growing season, drought resistance, soil fertility, light and reproductive traits.

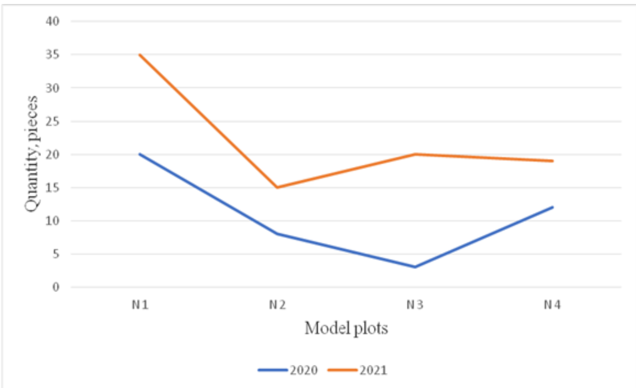

Fig. 4. Dynamics of *A. artemisiifolia* abundance in the studied areas.

In the conditions of the Right-Bank Forest-Steppe of Ukraine, *A. artemisiifolia* shows high plasticity in relation to sharp temperature fluctuations, which allows it to successfully complete the full development cycle and form viable seeds annually. Short-term spring and early autumn frosts on the soil surface (several hours of temperature drop to 2-3°C) did not significantly affect the ability of seeds to germinate. Despite significant temperature fluctuations in the spring and summer, there were no visible signs of deterioration in the plant's condition. The plant felt satisfactory at abnormally high air temperatures in summer: during the day it sometimes reached 38-40°C, and at night it dropped to 10-12°C. During the period of research from 2020 to 2021, fluctuations of up to 5-10 days were observed in the phase of seed germination, formation of the first pair of true leaves and formation of generative organs. Therefore, in relation to temperature fluctuations, *A. artemisiifolia* can be attributed to a resistant group, and in terms of its ability to withstand high temperatures, it can be classified as a highly drought-resistant plant.

A. artemisiifolia plants are also not picky about soil and air moisture. As can be seen from Fig. 4, the distribution of precipitation during the study period is not uniform. The maximum occurs in April and the minimum in November. In May - mid-June 2021, we observed prolonged waterlogging of the soil, which did not affect the growth and development of the root system and the plant as a whole.

The knowledge of the relationship of *A. artemisiifolia* plants to different soil types allows us to predict the intensity of the species' spread in the study area, as well as to confirm the results of the spread obtained from different sources of information. We studied the growth of plants on different substrates. The results are shown in Table 3.

Table 3. Growth rates of *A. artemisiifolia* on different soil substrates (2020-2021).

Substrate	Height (in cm) min.	med.	max.
1. Control (turf soil)	35.4	44.3	73.2
2. Turf soil + sand, 2:1	37.8	58.5	79.2
3. Turf soil + humus, 2:1	45.5	36.5	87.5
4. Turf soil + peat, 2:1 (pH peat 4.5-5.0)	38.2	60.0	81.8
HIP $_{0.95}$	1.8	2.4	3.2

HIP: least significant difference

The highest growth rates of *A. artemisiifolia* (87.5 cm) were obtained when using turf soil + humus in a 2:1 ratio, and the lowest ones were obtained in the control variant, where chernozem was used as a conventional substrate (plant height reached 73.2 cm), since turf soils were formed on the stationary study site. In general, it was noted that *A. artemisiifolia* can grow satisfactorily on different soils with different pH levels.

One of the factors that affect the rhythm of growth and development and the passage of all physiological processes is light. In order to determine the effect of light intensity on plants, we conducted stationary studies at the experimental site of the Pavlo Tychyna UDPU agrobiostation. Measurements of light intensity were carried out during the flowering period of *A. artemisiifolia*, on clear sunny days (three times a day at 8:30, 12:30 and 17:30 (Table 4)) using a luxmeter.

We found that the most intensive flowering occurred in the upper part of the crown (Table 3), where plants receive the maximum amount of light. Thus, ragweed belongs to the group of light-loving plants, but it can grow satisfactorily in moderate shade conditions. We also noted this in our field studies, as the plant likes to grow in sunny areas on both sides of roads, fields, and railway tracks.

Table 4. Illumination intensity of *A. artemisiifolia* on the territory of the experimental plot of the Pavlo Tychyna USPU agrobiostation (2020-2021).

Measurement area	Measurement time	Light, suites (in lux)	Flowering	Fruiting
- Lower part		8,300	+	+
- Middle part	8^{30}	13,500	+	+
- Top		22,500	+	+
- Lower part		23,400	+	+
- Middle part	12^{30}	37,500	+	+
Top		49,000	+	+
- Lover part		15,100	+	+
- Middle part	17^{30}	18,600	+	+
- Top		24,500	+	+

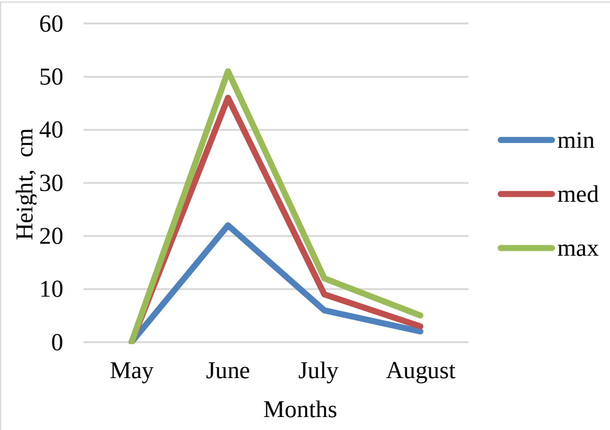

Fig. 5. Shoot growth dynamics of *A. artemisiifolia* during the growing season (average for 2020-2021).

Table 5. Germination energy and germination of *A. artemisiifolia* seeds under laboratory conditions (average for 2020-2021).

Seed fraction	Total number of seeds, pieces	Seed germination energy (%)		Seed germination (%)	
		±S	V	±S	V
Large (l)	300	55.6±1.55	3.2	65.4±0.62	1.51
Medium (m)	300	51.2±0.45	2.4	60.7±0.90	0.68
Small (s)	300	46.2±0.54	1.8	54.2±0.51	0.72
		D_l-D_m<0.05			
		D_m-D_s<0.05			

D - Differences at a reliable level

One of the main reasons for the rapid spread of the species under study in Ukraine is its biological characteristics, namely high seed productivity and high regeneration capacity.

In the areas of distribution, *A. artemisiifolia* plants reproduce well by seeds. In 2020-2021, we conducted research to determine the germination energy and soil germination of seeds (Table 5).

The table shows that all variants of seed fractions give high results in terms of both germination energy and germination rate. The difference at a significant level was observed only in the germination energy of individual plants between large and medium and large and small seeds ($P<0.05$). This fact can be explained by the fact that larger seeds swell more slowly during germination than smaller ones. In other variants of the experiment, the difference is quite insignificant and unreliable. Different indicators of germination energy and seed germination are explained by differences in weather conditions in different years (Fig. 1).

The formation of viable seeds of *A. artemisiifolia* depends on the dynamics of shoot growth and development, since seeds are formed at the tops of shoots. Measurements of shoot growth intensity of model individuals were carried out every 3-5 days from the beginning of formation to the complete cessation of growth in different experimental plots. The data obtained are shown in Fig. 5.

The greatest growth of *A. artemisiifolia* shoots was observed in May - mid-June, from 22 to 51 cm. A sharp decrease in growth was observed during August - from 2 to 5 cm (Fig. 5).

In order to reduce the intensity of the spread of *A. artemisiifolia* plants, we recommend (in the absence of preliminary control measures before flowering) mowing during the flowering period, namely 2-3 decades of August.

In our studies, we noted a high regeneration potential, which is manifested in the formation of shoots from renewal buds. We studied the regenerative ability of shoots experimentally (damaging shoots at different heights, from 20 to 40 cm) (Table 6).

If the shoots are damaged in June - July and early August, the plant has time to restore the lost organs and complete the generative phase (seeds can germinate even in the waxy ripeness phase). Therefore, we recommend mowing several times during the summer period.

The high regeneration potential of *A. artemisiifolia* is also manifested in the ability to form additional roots and successfully take root when the shoots are covered with soil. We also noted these phenomena during field studies, namely when mowing around roads and railways.

Table 6. Regeneration capacity of damaged shoots of *A. artemisiifolia* (2020-2021).

Month	Decade	Flowering period	Notes
June	1st decade	2-3-st decade of August	-
	2nd decade	3-st decade of August - beginning of September	-
	3rd decade	1-st decade of September	-
July	1st decade	1-2-st decade of September	-
	2nd decade	2-st decade of September	
	3rd decade	2-3-st decade of September	-
August	1st decade	1-st decade of October	Does not always have time to give seeds capable of germination

Table 7. Indicators of the adaptive potential of *A. artemisiifolia.*

No	Indicators	Points	Note
1	Temperature fluctuations	3	High plasticity to sudden changes in air temperature
2	Drought resistance	3	Can grow evenly in water-logging soil
3	Light-requiring	2	
4	Relation to soil fertility	3	
5	Vegetative reproduction	-	Vegetative reproduction is not detected
6	Seed reproduction	3	
7	Regeneration of shoots	3	A rapid recovery of lost shoots

Therefore, based on our own research, we propose to use a scoring method of evaluation using the coefficient of integral adaptive capacity (CCAP) (Table 4), which is a mathematical reflection of the adaptive potential of the plants under study.

Based on our own research, we propose to use a scoring method of assessment using the coefficient of integrated adaptive capacity (CCAP) (Table 7).

The obtained points (Table 4) for each individual factor were inserted into the formula for a complex assessment of the adaptive potential of *A. artemisiifolia* – CCAAP = 3 + 3 + 3 + 2 + 3 + 3 = 17 points. Based on the score, it can be concluded that in the conditions of the Right-Bank Forest-Steppe of Ukraine, this plant shows a high adaptive potential.

Discussion

Ambrosia artemisiifolia, which grows in different parts of Ukraine, was and is being studied by a number of scientists. The study of the bioecological features of plant growth and development makes it possible to predict the intensity of the spread of this plant in the study area and prevent this phenomenon. For example, Leiblin-Wilde *et al.* studied the frost resistance of *A. artemisiifolia* seedlings taken from different geographical locations. Germination, germination rate, seedling frost resistance and the width of the temperature niche for germination were significantly higher and wider, respectively, in European populations (Leiblin-Wilde *et al.* 2014). Guillemin *et al.* observed seed germination in the range of +3.6 to +5.0°C (Guillemin *et al.*). Brandes & Nitzsche indicate that the seeds of this invasive species can germinate even at temperatures of +40 - +45°C (Brandes & Nitzsche 2016). We agree with the conclusions of these researchers. After all, we have also noted the lability of plants of this species to weather conditions. A sharp drop in early spring temperatures did not affect seed germination, and abnormally high temperatures in summer did not affect the growth and development of plants in general.

Brandes & Nitzsche (2016), Friedman & Barrett (2011) state that *A. artemisiifolia* is undemanding to soil fertility, can grow satisfactorily on different soil types, and the most favourable for it are clay and sandy soils, which gives it an advantage over other plant species. We found that the highest growth rates of *A. artemisiifolia* (87.5 cm) were obtained on fertile soils (sod soil + humus in a ratio of 2:1), but in soil without humus addition, the plants reached 73.2 cm in height. Thus, our results confirm the findings of the researchers. In general, it was noted that *A. artemisiifolia* can grow satisfactorily on different soils with different levels of acidity. This is also noted by Sang *et al.* that successful germination of *A. artemisiifolia* seeds occurs in soil with an acidity of 4 to 12 (Sang *et al.* 2011).

For the first time, we propose to use a scale for assessing the adaptive potential of invasive species using *A. artemisiifolia* as an example, which is a mathematical reflection of the research results. It is based on the assessment of the impact of temperature fluctuations, drought tolerance, light sensitivity, vegetative and seed reproduction, and shoot regeneration. This scale allows us to objectively assess the intensity of species invasion. In the conditions of the Right-Bank Forest-Steppe of Ukraine, the adaptive potential of *A. artemisiifolia* is 17 points, which is high. This is confirmed by our finding of 13 new habitats in the study area.

Conclusion

Conclusions. As a result of our studies, it was found that *A. artemisiifolia* plants have a high adaptive potential in the conditions of the Right-Bank Forest-Steppe of Ukraine, which is 17 points according to the scale proposed by us. Based on the bioecological studies of *A. artemisiifolia*, we concluded that a number of effective measures (in particular, mowing during flowering) should be taken to prevent further spread of the species due to intensive seed reproduction, high regeneration capacity, high resistance to temperature fluctuations, drought tolerance, light tolerance and undemanding soil composition, acidity and fertility.

The study of the adaptive potential of *A. artemisiifolia* using the scale proposed by us is an example for determining and predicting the intensity of invasion of other herbaceous plants, which makes it possible to prevent this phenomenon.

Ethics Committee Approval: Since the article does not contain any studies with human or animal subject, its approval to the ethics committee was not required.

Data Sharing Statement: All data are available within the study and supplementary material.

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