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RESEARCH ARTICLE

Statistical characteristics and correlations of morphometric traits of *Asparagus officinalis* L. fruits in the M.M. Gryshko National Botanical Garden of the NAS of Ukraine

Victoria Gritsenko

M.M. Gryshko National Botanical Garden, National Academy of Sciences of Ukraine, Sadovo-Botanichna str. 1, 01014 Kyiv, Ukraine; gritsenkoviktoria@gmail.com

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Abstract

The current research was conducted in 2020–2023 on the botanical-geographical plot "Steppes of Ukraine" at the M.M. Gryshko National Botanical Garden of the NAS of Ukraine and was focused on ripe fruits of *Asparagus officinalis*. This study aimed to find out the main statistical characteristics of morphometric traits of *A. officinalis* fruits: fruit diameter, number of locules per fruit, number of seeds per fruit, number of seeds per locule, and to confirm or deny the hypothesis of positive pairwise correlations of the first three traits. Eighteen combinations of four morphometric traits were found in the *A. officinalis* fruits. For each morphometric feature of *A. officinalis* fruits, ten statistical characteristics were determined: arithmetic mean, median, mode, range of variation, oscillation coefficient, standard deviation, coefficient of variation, standard error of the mean, coefficient of skewness, and coefficient of kurtosis. The coefficient of variation showed that the number of seeds per fruit is the most variable of the studied morphometric traits of *A. officinalis* fruits, and the fruit diameter is the least variable. According to the comprehensive assessment of the coefficients of skewness and kurtosis, the distributions of the number of seeds per fruit and the diameter of the fruits are closest to the normal distribution. It was established that the correlations between pairs of such traits as fruit diameter and number of locules per fruit, fruit diameter and number of seeds per fruit, number of locules per fruit and number of seeds per fruit are positive, direct, and strong. Thus, considering the economic feasibility, it is more practical to collect *A. officinalis* fruits of a larger size to obtain a larger number of seeds. The results of this work are of interest for the morphology and biometrics of *A. officinalis* and its cultivation.

Keywords: *Asparagus officinalis*, fruit biometrics, variation series, alternative grouping

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Introduction

Asparagus officinalis L. (Asparagaceae) is a dioecious herbaceous perennial cryptophytic plant. Modern sources (GBIF, 2024; POWO, 2024), indicate the widespread distribution of A. *officinalis* in many regions and countries of the world, including in Ukraine. It is a native species of Ukrainian flora (POWO, 2024). Here, in its wild state, A. *officinalis* grows in natural

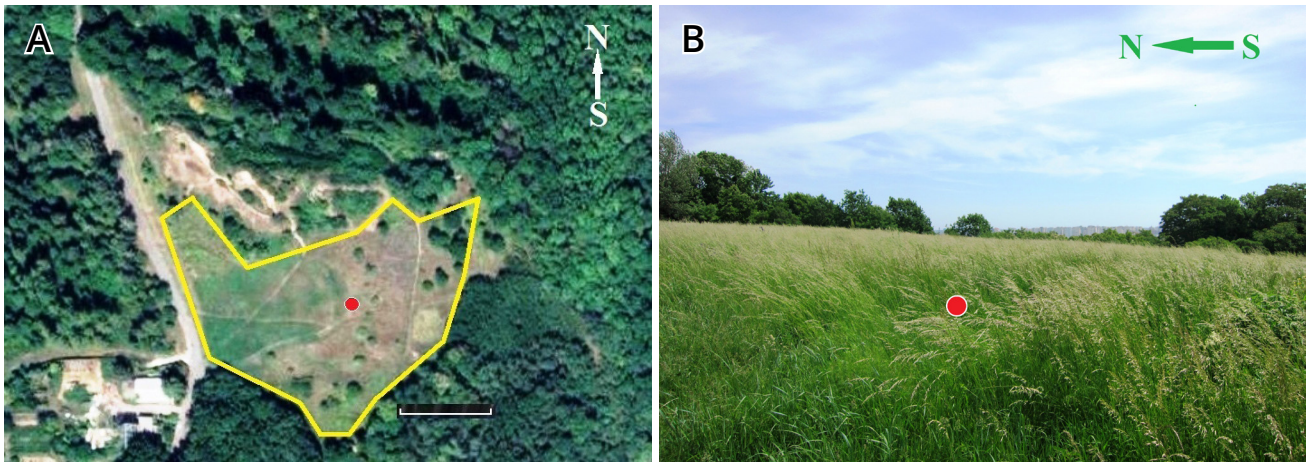

Figure 1. Geographical location of the study area: **A** – configuration and boundaries of the coenopopulation of *Asparagus officinalis* on the plot "Steppes of Ukraine" of the M.M. Gryshko National Botanical Garden of the NAS of Ukraine (source – Google Maps, 2024; the **yellow line** indicates the boundaries of the coenopopulation; the **red point** indicates the coordinates inside of the coenopopulation; scale – 50 m); **B** – a fragment of plant cover within *A. officinalis* coenopopulation (the **red point** corresponds to A).

phytocoenoses in steppes, meadows, forest edges, among bushes, and in other herbaceous communities of Ukraine.

Asparagus officinalis is one of the oldest vegetable crops known to humanity. Information on the cultivation and consumption of young shoots of A. *officinalis* and botanical illustrations of this species were given over 150 years ago (Schubert, 1870).

In the modern world, A. *officinalis* is widely cultivated, eaten, and used in medicine (Pegiou et al., 2019; Guo et al., 2020; Altunel, 2021; Özden et al., 2022; GBIF, 2024; POWO, 2024). It is characterized by many therapeutic and pharmacological qualities (Iqbal et al., 2017), particularly its antioxidant properties. The concentration of iron or selenium nanoparticles significantly increases the antioxidant activity of A. *officinalis* stems (Mohammadhassan et al., 2021).

In recent years, the following aspects have also been characterized. Guo et al. (2020) summarized the nutritional values, bioactive compounds, biological functions, and the food and non-food applications of A. *officinalis*. Moreno-Pinel et al. (2021) presented an overview of advances in cytogenetics and molecular markers linked to the sex of A. *officinalis*. Altunel (2021) conducted comprehensive studies of *Asparagus* species, including anatomical, morphological, habitat, and productive characteristics. Özden et al. (2022) revealed a wide range of variations in agro-morphological characteristics of A. *officinalis* like days to fruit ripening, edible spear length and diameter, fresh and dry weight, number of spears, male and female plant length, number and weight of fruits. They also stressed the need to collect A. *officinalis* seeds for cultivation and the feasibility of storing them in gene banks to protect genetic diversity (Özden et al., 2022).

Regarding morphology (Gritsenko et al., 2023), the fruit of A. *officinalis* is a berry, few-locules and few-seeds. The berry is juicy, spherical, smooth, and shiny. Ripe berries are red, and overripe berries are black (Sikura, 2014). Ripe berries contain sugars (up to 36.0%), capsanthin, physamine, alkaloids, malic and citric organic acids (Grodzinsky, 1989); quercetin, rutin (2.5% of dry weight), and hyperoside (Iqbal et al., 2017). Roots, shoots, leaves, flowers, and ripe berries contain vitamins (A, B, C, and E), inorganic compounds (Mg, P, Ca, Fe, and folic acid), essential oils, amino acids (asparagine, arginine, tyrosine), secondary metabolites – flavonoids, kaempferol, resin and tannins (Iqbal et al., 2017).

The morphometric traits of A. *officinalis* fruits have been characterized for many regions of the world (Bordzilovsky, 1950; Tutin et al., 1980; Takhtajan, 1985; Prokudin, 1987; Gleason & Cronquist, 1991; Tamanian, 2000; Nichols, 2004; Utech, 2008; Tropicos, 2009, 2011, 2013; McNeal, 2012; Sikura, 2014; Altunel,

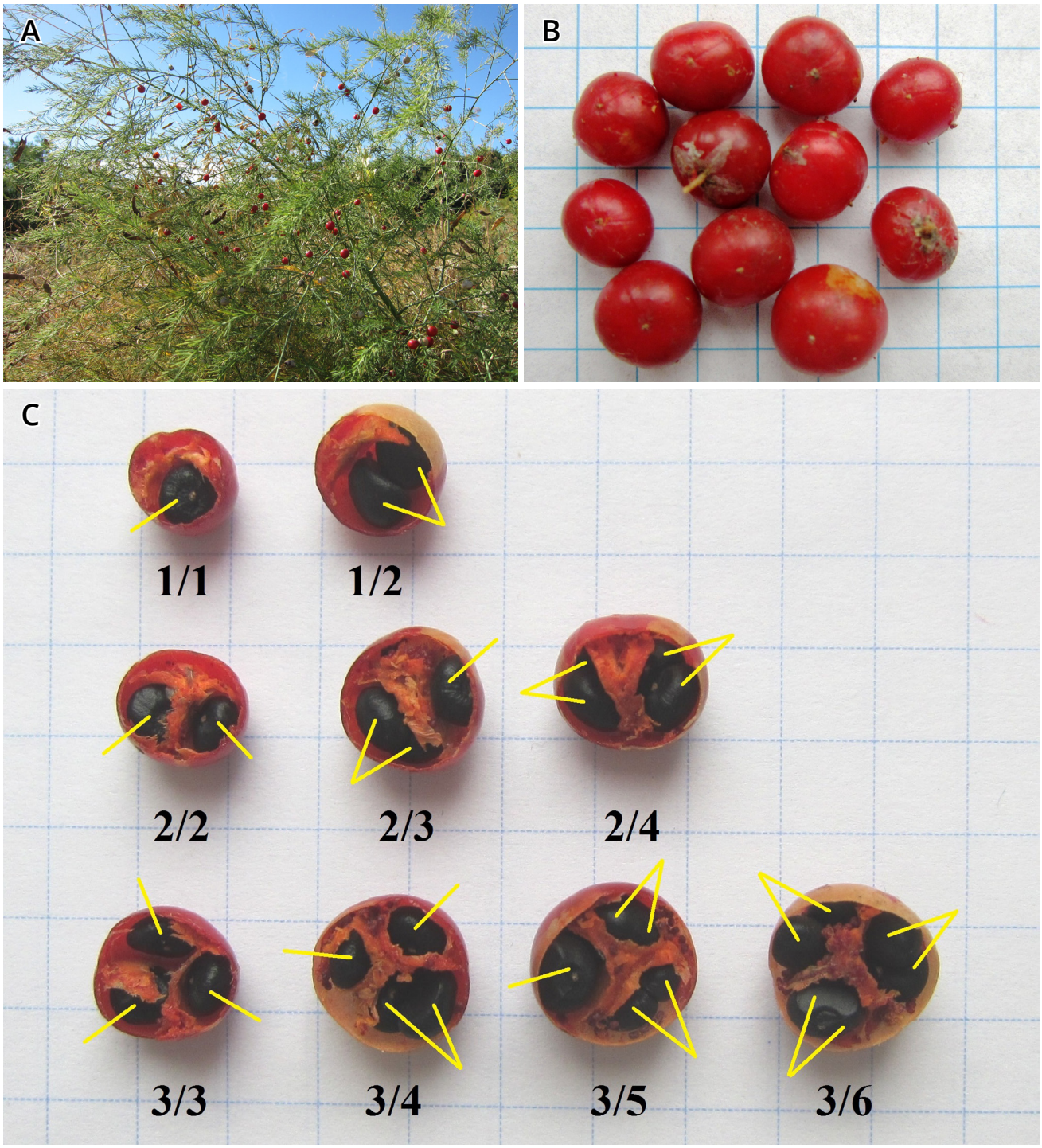

Figure 2. *Asparagus officinalis*: **A** – fruiting on the botanical-geographical plot "Steppes of Ukraine" of the NBG; **B** – ripe fruits; **C** – cross-sections of fruits (**numbers** indicate the number of locules/seeds per fruit; **yellow lines** indicate seeds). Scale: **B–C** – quadrate side is 5 mm.

2021; Native Plant Trust, 2024; WFO, 2024); such traits in different sources differ or are indicated without clear limits of traits.

In Ukraine, *A. officinalis* is applied in medicine (Grodzinsky, 1989), cultivated (Nechitaylo et al., 2005; Kutovenko et al., 2020), demonstrated and researched in botanical gardens and other botanical institutions as a medicinal and ornamental plant (Mashkovska, 2015). The morphology of fruits of *A. officinalis* from M.M. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine (hereinafter – NBG) was described (Gritsenko et al., 2023) but not analyzed statistically. It was assumed that the morphometric traits of *A. officinalis* fruits, such as fruit diameter,

number of locules per fruit, and number of seeds per fruit, should be positively correlated (Gritsenko et al., 2023).

A review of published sources revealed that statistical studies of the morphometric traits of A. *officinalis* fruits have not yet been conducted. Therefore, this study aims to statistically substantiate the obtained data on the morphometry and clarify the correlations of the morphometric traits of A. *officinalis* fruits. For practical use, it is worth discovering which fruits are better to collect to obtain more seeds. The established statistical characteristics can be used further for monitoring and/or comparisons.

Material and methods

The work has been conducted within the following research program of the Department of Natural Flora of the NBG 2020–2024 "Botanical-geographical principles of protection of *ex situ* floristic diversity and the formation of the introduction populations of plants". The research was conducted in 2020–2023 at the botanical-geographical plot "Steppes of Ukraine" of the NBG, Kyiv, Ukraine. *Asparagus officinalis* is one of the components of the artificially created meadow-steppe phytocoenosis in the plot "Steppes of Ukraine" of the NBG. This polygonal plot was established in the NBG in 1949 on an area of ca. 2.5 ha to demonstrate the *ex situ* floristic diversity of the Ukrainian Steppes. The primary material of A. *officinalis* was brought to the plot "Steppes of Ukraine" in 1952 from the natural steppe communities of Ukraine. For today, a stable coenopopulation of A. *officinalis* has formed. For over 70 years, a reasonably successful model of the meadow steppe of Ukraine was formed on the plot "Steppes of Ukraine"; a total of 347 species and subspecies were recorded in the flora of the plot "Steppes of Ukraine", including A. *officinalis* (Gritsenko & Shynder, 2022). The area configuration of the plot "Steppes of Ukraine" and angular landmarks along its perimeter were indicated (Gritsenko & Shynder, 2022). On the map, the boundaries of A. *officinalis* coenopopulation in the plot "Steppes of Ukraine" are shown (Fig. 1 A). The coenopopulation of A. *officinalis* in this plot is located in an open area with a flat relief and is surrounded by forest vegetation (Fig. 1 B). The coordinates inside of A. *officinalis* coenopopulation are: N 50.411958°, E 30.566045°.

Table 1. Designations of morphometric traits of *Asparagus officinalis* fruits and biometric terms.

Morphometric traits	
FD	Fruit diameter, mm
NLF	Number of locules per fruit
NSF	Number of seeds per fruit
NSL	Number of seeds per locule
Statistical characteristics	
As	Coefficient of skewness, asymmetry coefficient
Cv	Coefficient of variation
Ex	Coefficient of kurtosis
f	Absolute frequency of the trait
f, %	Relative frequency of the trait
$f_{x,y}$	Absolute frequency of trait pair
M	Arithmetic mean (sample mean)
m	Standard error of the mean
Me	Median
Mo	Mode
n	Sample size
p, q	Shares of the alternatives
r	Pearson's correlation coefficient
R	Range of variation
s	Standard deviation of the sample
s_p	Standard deviation of the shares of the alternatives
V_R	Oscillation coefficient
x, y	Numerical values of traits, variables
x_{min}, x_{max}	Minimum and maximum value, limits

At the plot "Steppes of Ukraine" of the NBG, mature and ripening A. *officinalis* fruits occur in September (Fig. 2 A, B). The following quantitative morphometric traits of A. *officinalis* fruits were determined: fruit diameter, number of locules per fruit, number of seeds per fruit, and number of seeds per locule (Fig. 2 C). The diameter of the fruits was measured using a caliper; the accuracy of the measurements was 1 mm. The number of locules per fruit was determined using a cross-section of the fruit (Fig. 2 C). The number of seeds per fruit and the number of

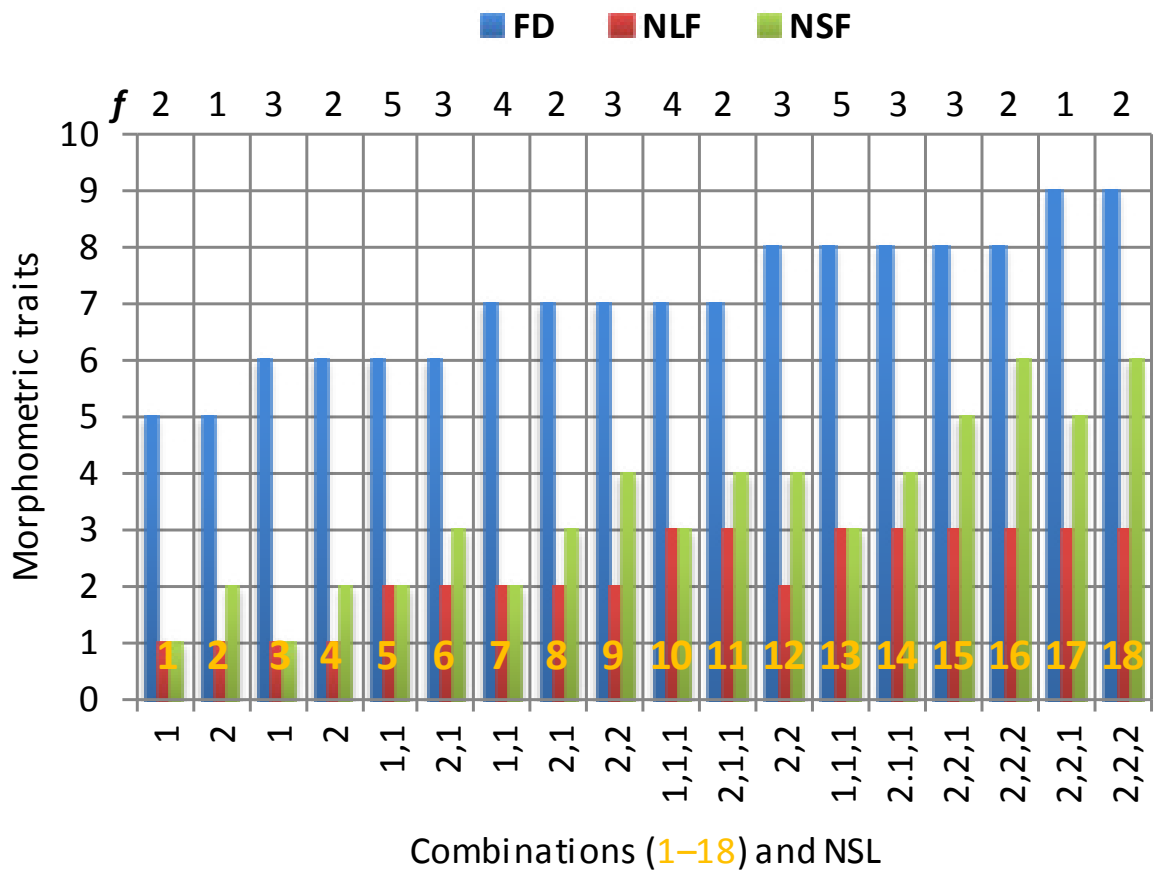

Figure 3. Combinations of morphometric traits in the *Asparagus officinalis* fruits. Along the abscissa axis, **numbers 1 to 18** indicate the combinations of morphometric traits; **1 and/or 2 (indicated vertically)** show the number of seeds in each locule for that particular combination. See abbreviations and units in Table 1.

seeds per locule were counted by breaking the fruit completely.

Sampling of A. *officinalis* fruits, grouping, and statistical processing of data was carried out using generally accepted concepts (Chaddock, 1925; Studfile, 2012; Kubay & Horbal, 2016; Illowsky & Dean, 2020; Dotmatics, 2024). Table 1 lists alphabetically the labels of morphometric traits and biometric terms, which are used below in the text, also in Tables 2–4 and Figs. 3–6.

The random (without repetitions) sampling included 50 ripe fruits of A. *officinalis*. Fruits were collected from different individuals at a distance of more than 3 m from each other. The results present eight combinations of the morphometric fruit traits (FD, NLF, NSF, and NSL). Indicators of each of the morphometric traits are grouped into variation series.

Calculation results in Table 2–3 and Fig. 6 are rounded and specified with an accuracy of 0.01 (original calculations were performed with an accuracy of 0.000001).

The taxonomic nomenclature is provided following POWO (2024).

Photos (Fig. 1 B; Fig. 2 A–C) were captured by the author using a Canon Power Shot SD 4000 IS digital ELPH camera.

Results and discussion

Data presentation

Eighteen combinations of four morphometric traits were found in the fruits of A. *officinalis* (Fig. 3). According to the set of traits in the sample of fruits (n = 50), the most common (f = 5) were: fruits with a diameter of 6 mm with two locules and two seeds per fruit; fruits with a diameter of 8 cm with three locules and three seeds per fruit. Often (f = 4) occurred: fruits with a diameter of 7 mm with two locules and two seeds per fruit; fruits 7 cm in diameter with three locules and three seeds per fruit. In all these cases, when f = 5 and 4, there was one seed in each locule.

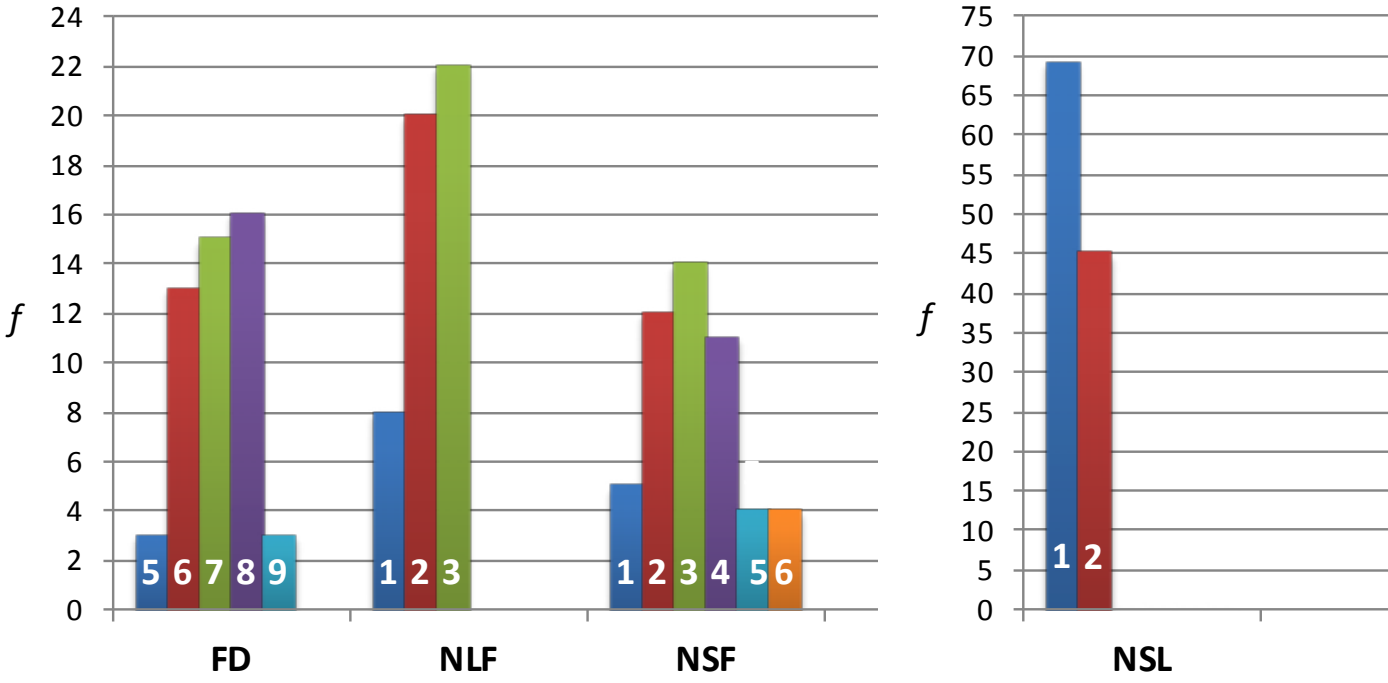

Figure 4. Variation series of morphometric traits of *Asparagus officinalis* fruits: **FD** and **NLF** – left-skewed distributions; **NSF** and **NSL** – right-skewed distributions. See abbreviations and units in Table 1.

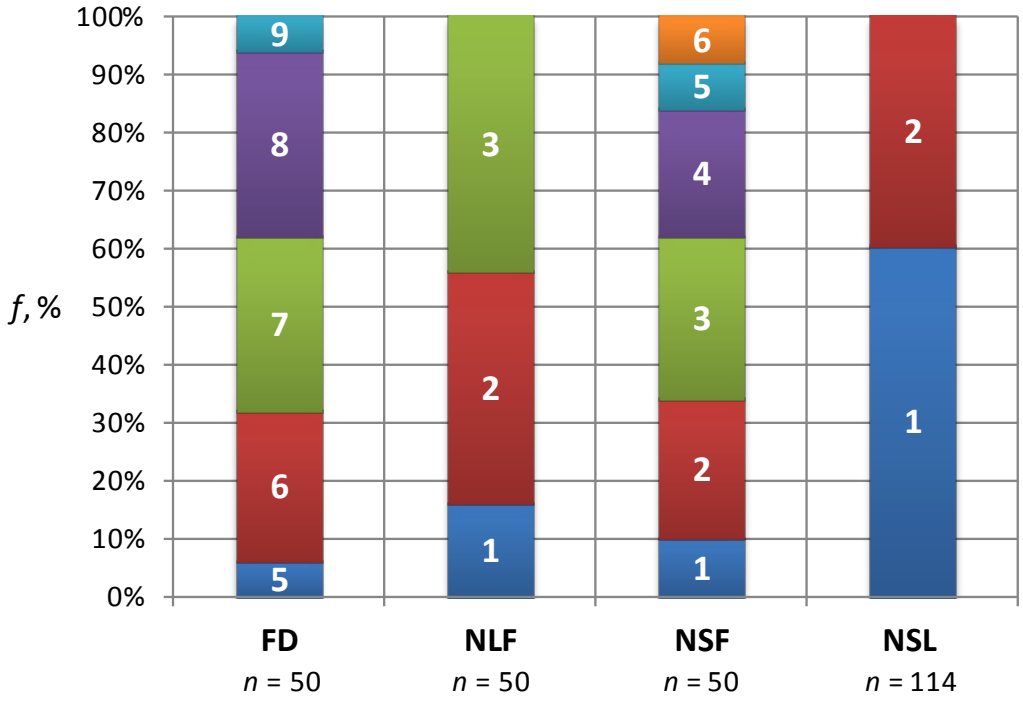

Figure 5. Relative frequencies of morphometric traits of *Asparagus officinalis* fruits. See abbreviations and units in Table 1.

Graphic representation of the variation series of morphometric traits of A. *officinalis* fruits gives a visualization of the variation of each of these traits (Fig. 4). Variation series represent quantitative morphometric traits of A. *officinalis* fruits (Fig. 4). NSL is an alternative trait (Figs. 2C, 3, 4). Absolute frequencies (*f*) show how often a particular variant occurs in the sample. The total sum of the absolute frequencies of each variation series is equal

Table 2. Principal statistical characteristics of *Asparagus officinalis* fruits. See abbreviations and units in Table 1.

Trait (n = 50)	Statistic characteristics									
	M	Me	Mo	R	V_R, %	s	Cv, %	±m	As	Ex
FD	7.06	7.00	8.00	4.00	56.66	1.04	14.71	0.15	-0.12	-0.70
NLF	2.28	2.00	3.00	2.00	87.72	0.73	32.00	0.10	-0.49	-0.95
NSF	3.18	3.00	3.00	5.00	157.23	1.38	43.41	0.20	0.39	-0.41

Table 3. Statistical characteristics at an alternative grouping of traits in the fruits of *Asparagus officinalis.* See abbreviations and units in Table 1.

Trait (n = 114)	Seeds per locule	Statistic characteristics												
		f	f, %	p, q	s_p	M	Me	Mo	R	V_R, %	Cv, %	±m	As	Ex
NSL	1	69	60.53	0.61	0.49	1.39	1.00	1.00	1.00	71.94	35.32	0.05	0.44	-1.84
	2	45	39.47	0.39										

to the sample size. Statistical totalities of morphometric traits of A. *officinalis* fruits are presented in the form of non-interval variation series; the frequencies refer directly to the ranked values of the traits, which acquire the position of individual classes of the variation series. According to the nature of the frequency distribution in the classes of each variation series, asymmetry of distributions is observed (Fig. 4).

Absolute frequencies of morphometric traits of A. *officinalis* fruits (Fig. 4) can be presented as a percentage of the total number, as relative frequencies; f,% are used to compare variation series that differ in volume (Fig. 5). The total sum of the relative frequencies of each variation series is equal to 100 % (Fig. 5).

Among tested A. *officinalis* fruits, the following features were most often represented: fruits with a diameter of 8 mm (f = 16; f,% = 32), 7 mm (f = 15; f,% = 30), and 6 mm (f = 13; f,% = 26); fruits with three (f = 22; f,% = 44) and two (f = 20; f,% = 40) locules; fruits with three (f = 14; f,% = 28), two (f = 12; f,% = 24) and four (f = 11; f,% = 22) seeds (Figs. 4 & 5). In 50 tested A. *officinalis* fruits, 114 locules, and 159 seeds were counted in total; each locule contained one or two seeds. One seed per locule occurred more often, and two seeds per locule – less frequently (Figs. 4 & 5).

Data analysis

The main statistical characteristics of fruit diameter (FD), number of locules per fruit (NLF), and number of seeds per fruit (NSF) of Asparagus officinalis

For the morphometric traits (FD, NLF and NSF) of A. *officinalis* fruits, the following basic statistical characteristics were determined: mean magnitudes (M, *Me*, *Mo*), indicators of variation (R, V_R, *s*, *Cv*), accuracy indicator (*m*) and distribution indicators (As, *Ex*).

Arithmetic means can be represented as decimals for the morphometric traits measured as whole numbers (e.g., NLF and NSF). The medians of the morphometric traits of A. *officinalis* fruits are smaller than the corresponding arithmetic means of these traits (Table 2). In a sample of 50 fruits, the following were most often found: fruits with a diameter of 8 mm; fruits with three locules; fruits with three seeds (Fig. 4; Table 2). Each of these distributions is unimodal (Fig. 4).

The range of variations in the morphometric traits of A. *officinalis* fruits is not large; R is largest for NSF and smallest for NLF (Table 2). The oscillation coefficient shows the degree of the range of variation relative to the M; V_R is the smallest for FD and the largest for the NSF. The standard deviation is used for the comparative assessment of mean magnitudes of the same name; s of A. *officinalis* FD, NLF and NSF are presented in Table 2 too.

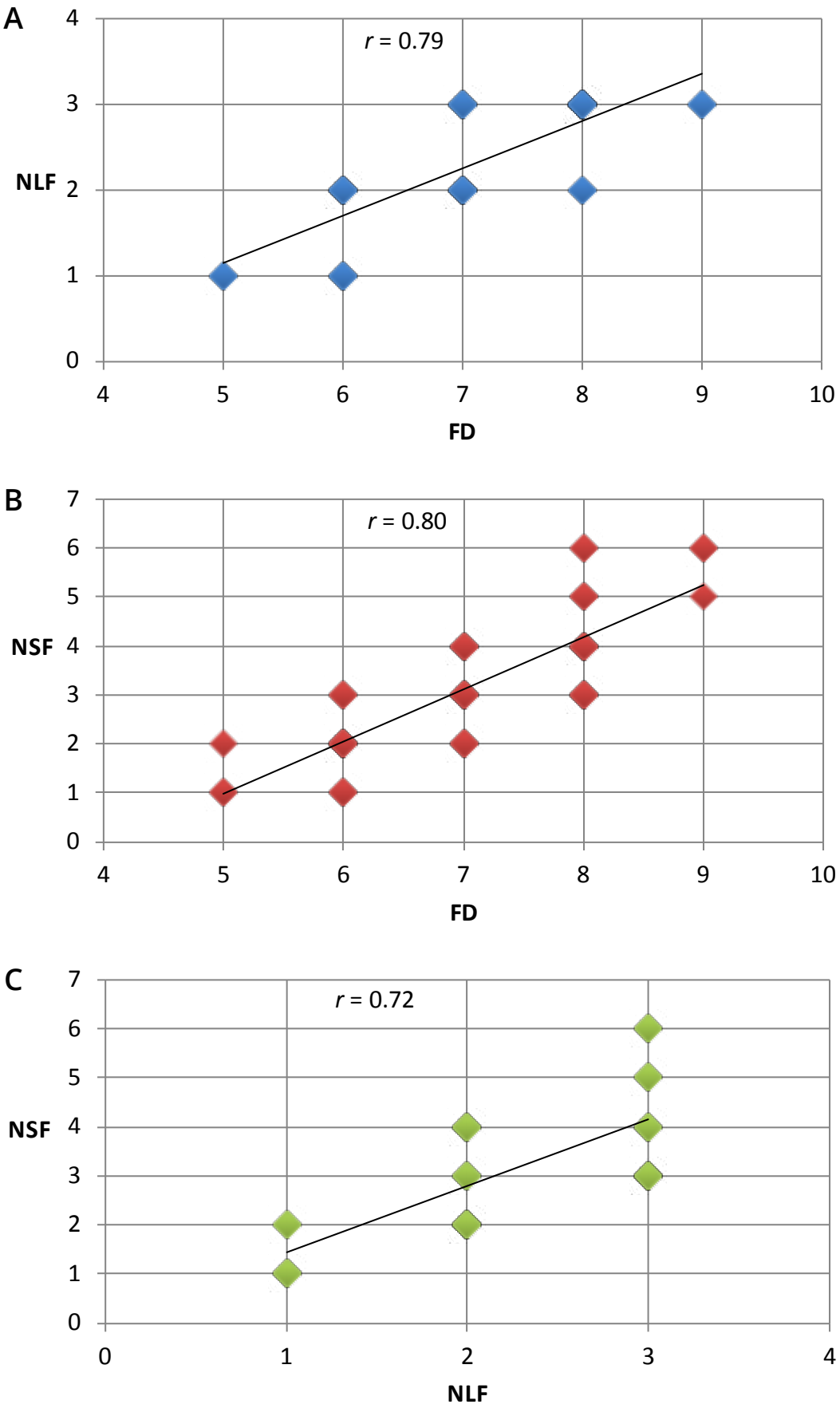

Figure 6. Correlations between pairs of morphometric traits of *Asparagus officinalis* fruits (n = 50). See abbreviations and units in Table 1. $f_{x,y}$ – absolute frequency of trait pair: **A** – $3_{5,1}$, $5_{6,1}$, $8_{6,2}$, $9_{7,2}$, $6_{7,3}$, $3_{8,2}$, $13_{8,3}$, $3_{9,3}$; **B** – $2_{5,1}$, $1_{5,2}$, $3_{6,1}$, $7_{6,2}$, $3_{6,3}$, $4_{7,2}$, $6_{7,3}$, $5_{7,4}$, $5_{8,3}$, $6_{8,4}$, $3_{8,5}$, $2_{8,6}$, $1_{9,5}$, $2_{9,6}$; **C** – $5_{1,1}$, $3_{1,2}$, $9_{2,2}$, $5_{2,3}$, $6_{2,4}$, $9_{3,3}$, $5_{3,4}$, $4_{3,5}$, $4_{3,6}$.

Table 4. Comparison of morphometric traits of *Asparagus officinalis* fruits. See abbreviations and units in Table 1.

Trait	Condition	Source
FD	7–8	Bordzilovsky (1950); Prokudin (1987); Tamanian (2000)
	6–10	Tutin et al. (1980); Utech (2008); Tropicos (2009, 2013); Native Plant Trust (2024)
	8	Gleason & Cronquist (1991)
	≤10	Nichols (2004)
	6–8	Tropicos (2011); McNeal (2012)
	≤6	Sikura(2014)
	5–9	Our data (2020–2023)
NLF	1–3	Our data (2020–2023)
	≥1	Native Plant Trust (2024)
NSF	(1–)2–4(–6)	Tutin et al. (1980)
	2–3	Tamanian (2000)
	1–6	Nichols (2004); Altunel (2021); our data (2020–2023)
	2–4	Utech (2008); Tropicos (2009, 2013)
	≥2	Native Plant Trust (2024)
NSL	1–2	Takhtajan (1985); our data (2020–2023)

Among sampled fruits, the coefficient of variation is the smallest for FD (Table 2). The variation of FD is interpreted as moderate. The coefficient of variation for NLF is 32.00%, which is interpreted as significant. The statistical totalities of FD and the NLF are considered homogeneous. The coefficient of variation is the largest (43.41%) for the NSF. Such a variation is significant. The NSF statistical totality is considered heterogeneous. The coefficient of variation made it possible to find out that the NSF is the most variable of the studied morphometric traits of A. *officinalis* fruits, and the FD is the least variable.

The standard error of the arithmetic mean indicates the accuracy with which the sample trait represents the general parameter. In a sample of 50 fruits of A. *officinalis*, *m* is the smallest for the arithmetic mean of NLF, so this sample characteristic is closest to the value of the general parameter (Table 2). In the same sample of fruits, *m* is the largest for the arithmetic mean of NSF, so this sample characteristic represents the general parameter less accurately.

The FD, NLF and NSF distributions are asymmetric one-peaked (Fig. 4). For the FD distribution (*M* 7.06 < *Mo* 8.00), the asymmetry is left-sided, negative (Fig. 4; Table 2). The NLF distribution is highly asymmetric: the highest frequency is located at the right end of the distribution (Fig. 4); for this distribution (*M* 2.28 < *Mo* 3.00) the asymmetry is left-sided, negative. The asymmetry of the NSF distribution (*M* 3.18 > *Mo* 3.00) is right-sided positive. There is a minor asymmetry for the FD distribution and moderate asymmetry for the NLF and NSF distributions (Table 2).

The kurtosis coefficients of the distributions of A. *officinalis* FD, NLF and NSF are negative (Table 2), proving that these distributions are smoothed compared to the normal distribution. The NSF distribution is characterized by moderately pronounced *Ex*, and the FD and NLF distributions are characterized by markedly pronounced *Ex* (Table 2).

According to the comprehensive assessment of *As* and *Ex* (Table 2), the NSF and FD distributions are closer to the normal distribution, and the NLF distribution is the most distant from the normal distribution (Fig. 4).

Distribution indicators and the other statistical indices given here can vary between

different samplings. In the future, our results can be used to compare data across various spatial and/or temporal scales or between different species of the genus *Asparagus* L.

Statistical characteristics for alternative grouping of the number of seeds per locule (NSL) With an alternative grouping of NSL, their statistical characteristics are both absolute (Fig. 4) and relative (Fig. 5) frequencies of alternatives opposed to each other (Table 3). The standard deviation of the shares of alternatives (s_p) is close to the maximum value. Since NSL is not only an alternative but also a quantitative trait, other statistical characteristics can be determined. Locules with one seed were the most common among the totality. The variation is significant; the NSL statistical totality is heterogeneous. The standard error of the mean is ±0.05, and the sample mean of the NSL is very close to the value of the general parameter.

The NSL distribution is highly asymmetric: the highest frequency is located at the left end of the distribution (Fig. 4); for this distribution (*M* 1.39 > *Mo* 1.00), the asymmetry is right-sided positive (Fig. 4; Table 3). There is moderate asymmetry for the NSL distribution (Table 3). A strongly pronounced negative kurtosis characterizes the NSL distribution. This indicates a smoothed NSL distribution compared to a normal distribution.

Correlation analysis
It was established that correlations between pairs of morphometric traits of *A. officinalis* fruits, such as FD and NLF, FD and NSF, and NLF and NSF are positive, direct, and strong (Fig. 6). For each of the correlation coefficients (Fig. 6 A–C), the *p*-value is <0.0001. Hence, this difference is highly statistically significant (Dotmatics, 2024). In the morphology of the fruits of *A. officinalis*, such regularities are statistically substantiated for the first time and represent a theoretical scientific novelty. In practice, to obtain a larger number of seeds, it is more appropriate to collect fruits of a larger size (Fig. 6 B).

Data comparison and application perspectives

The FD values of *A. officinalis* reported here generally correspond to previously published data (Table 4).

The NLF of *A. officinalis* is 1–3 (Figs. 2C, 3–5); these data specify and delineate the possible range of NLF (Table 4).

The obtained data on the NSF correspond to the data reported before (Tutin et al., 1980; Nichols, 2004; Altunel, 2021), which are given in part of the sources (Table 4). In the plot "Steppes of Ukraine" of the NBG, fruits of *A. officinalis* with 2–4 seeds are more common (Fig. 4–5); according to Table 4, this is typical for the European flora in general (Tutin et al., 1980).

The obtained data on the NSL and those given in other sources match (Table 4). Takhtajan (1985) indicated that in the *A. officinalis* fruits, two seeds per locule occur less often than one. Our study proved that the relative frequency of one seed per locule is 60.53%, and two seeds per locule is 39.47% (Fig. 5; Table 3).

In the future, it is worth analyzing samples of *A. officinalis* fruits from different parts of the world to conduct more detailed research.

Conclusions

Asparagus officinalis is a native species of the Ukrainian flora and, at the same time, is widely used all over the world as a food and medicinal plant. The current research was focused on the ripened *A. officinalis* fruits in an artificially created meadow-steppe culture phytocoenosis at the NBG (Kyiv, Ukraine).

Eighteen combinations of four morphometric traits: fruit diameter (FD), number of locules per fruit (NLF), number of seeds per fruit (NSF), and number of seeds per locule (NSL), were statistically processed in the *A. officinalis* fruits. In the variation series of these traits, the following occurred most often: fruits with a diameter of 8 mm; fruits with three locules; fruits with three seeds, and locules with one seed.

For each morphometric feature of *A. officinalis* fruits, ten statistical characteristics were determined: arithmetic mean, median, mode, range of variation, oscillation coefficient, standard deviation, coefficient of variation, standard error of the mean, coefficient of skewness, and coefficient of kurtosis. The coefficient of variation showed that the NSF is the most

variable of the studied morphometric traits of A. *officinalis* fruits, and the FD is the least variable. According to the comprehensive assessment of the coefficients of skewness and kurtosis, the NSF and FD distributions are closer to the normal distribution; the NLF and NSL distributions are the most distant from the normal distribution.

Using Pearson's correlation coefficient, it was established that the correlations between pairs of such traits as FD and NLF, FD and NSF, NLF and NSF are positive, direct, and strong. This is a new theoretical contribution to the morphology of A. *officinalis* fruits. As for practical application, considering the economic feasibility, it is more efficient to collect fruits of a larger size to obtain more seeds.

At the plot "Steppes of Ukraine" of the NBG, A. *officinalis* fruits are collected every fall. Extracted seeds are accumulated in the Seed Laboratory of the NBG to protect the gene pool, long-term storage and exchange with other botanical institutions of the world.

References

Altunel, T.A. (2021). Morphological and habitat characteristics of asparagus (*Asparagus officinalis* L.) and socio-economic structure of producers. *Turkish Journal of Agriculture-Food Science and Technology, 9*(6), 1092–1099. https://doi.org/10.24925/turjaf.v9i6.1092-1099.4269

Bordzilovsky, E.I. (1950). Family Liliyni – Liliaceae Hall. In M.I. Kotov (Ed.), *Flora of UkrSSR. Vol. 3* (pp. 61–266). Edition of the Academy of Sciences of the UkrSSR, Kyiv. (In Ukrainian)

Chaddock, R.E. (1925). *Principles and methods of statistics. 1st ed.* Houghton Miffin Company, the Riverside Press, Cambridge.

Dotmatics. (2024). GraphPad. https://www.graphpad.com/quickcalcs/pValue1/

GBIF. (2024). *Asparagus officinalis* L. https://www.gbif.org/ru/species/2768885

Gleason, H.A., & Cronquist, A. (1991). *Manual of vascular plants of northeastern United States and adjacent Canada. 2nd ed.* The New York Botanical Garden, Bronx, NY. https://sweetgum.nybg.org/science/world-flora/monographs-details/?irn=4208

Google Maps. (2024). https://www.google.com.ua/maps/@50.4122646,30.5646912,295m/data=!3m1!1e3?hl=ru

Gritsenko V.V., Vakulenko, T.B., & Kayutkina, T.M. (2023, February 20). Morphology of fruits and seeds of *Asparagus officinalis* L. (Asparagaceae) in the M.M. Gryshko National Botanical Garden of the NAS of Ukraine. In *PLANTA+. Science, practice and education: The proceedings of the Fourth Scientific and Practical Conference with International Participation, dedicated to the 20th anniversary of Pharmacognosy and Botany Department Bogomolets National Medical University. Vol. 1* (pp. 220–223). Kyiv. (In Ukrainian). https://www.researchgate.net/publication/368881507_Morfologia_plodiv_i_nasinna_Asparagus_officinalis_L_Asparagaceae_u_Nacionalnomu_botanicnomu_sadu_imeni_MM_Griska_NAN_Ukraini

Gritsenko, V.V., & Shynder, O.I. (2022). Flora of the botanical-geographical plot "Steppes of Ukraine" at the M.M. Gryshko National Botanical Garden of the NAS of Ukraine. *Plant Introduction, 95/96,* 96–129. https://doi.org/10.46341/PI2022020

Grodzinsky, A.M. (Ed.). (1989). *Medicinal plants: encyclopedic reference.* Head. ed. URE, Kyiv. (In Ukrainian)

Guo, Q., Wang, N., Liu, H., Li, Z., Lu, L., & Wang, C. (2020). The bioactive compounds and biological functions of *Asparagus officinalis* L. – a review. *Journal of Functional Foods, 65*, Article 103727. https://doi.org/10.1016/j.jff.2019.103727

Illowsky, B., & Dean, S. (2020). Statistics. OpenStax. https://openstax.org/details/books/statistics

Iqbal, M., Bibi, Y., Raja, N. I., Ejaz, M., Hussain, M., Yasmeen, F., Saira, H., & Imran, M. (2017). Review on therapeutic and pharmaceutically important medicinal plant *Asparagus officinalis* L. *Journal of Plant Biochemistry & Physiology, 5*(1), Article 1000180. https://doi.org/10.4172/2329-9029.1000180

Kubay, D., & Horbal, A. (2016). Basics of statistics and data analysis. In D. Kubay & A. Horbal (Eds.), *The open guide to open data. Ukrainian Center for Public Data.* (In Ukrainian). https://socialdata.org.ua/manual/manual4/

Kutovenko, V.B., Kostenko, N.P., Yermilov, A.S., & Kutovenko. V.O. (2020). Morphological–biometric assessment of asparagus hybrids (*Asparagus officinalis* L.) in the Steppe of Ukraine. *Plant and Soil Science, 11*(2), 67–73. (In Ukrainian). http://doi.org/10.31548/agr2020.02.067

Mashkovska, S.P. (Ed.). (2015). *Catalog of ornamental herbaceous plants of botanical gardens and arboretums of Ukraine: a reference guide.* Kyiv. (In Ukrainian). http://www.nbg.kiev.ua/upload/biblio/katalog.pdf

McNeal, D.W. (2012). *Asparagus officinalis* subsp. *officinalis*. In *Jepson Flora Project* (Eds.), The Jepson Herbarium. Jepson eFlora. University of California, Berkeley. https://ucjeps.berkeley.edu/eflora/eflora_display.php?tid=77139

Mohammadhassan, R., Ferdosi, A., Seifalian, A.M., Seifalian, M., & Malmir, S. (2021). Nanoelicitors application promote antioxidant capacity of *Asparagus officinalis* (*in vitro*). *Journal of Tropical Life Science, 11*(3), 259–265. https://doi.org/10.11594/jtls.11.03.01

Moreno-Pinel, R., Castro-López, P., Die-Ramón, J.V., & Gil-Ligero, J. (2021). Asparagus (*Asparagus officinalis* L.) breeding. In J.M. Al-Khayri, S.M. Jain, D.V. Johnson (Eds.), *Advances in plant breeding strategies: vegetable crops* (pp. 425–469). Springer, Cham. https://doi.org/10.1007/978-3-030-66961-4_12

Native Plant Trust. (2024). Go Botany (3.9). *Asparagus officinalis* – asparagus. https://gobotany.nativeplanttrust.org/species/asparagus/officinalis/

Nechitaylo, V.A., Badanina, V.A., & Gritsenko, V.V. (2005). The cultural plants of Ukraine. Kyiv. (In Ukrainian). https://www.researchgate.net/publication/337085456_The_cultural_plants_of_Ukraine

Nichols, M.A. (2004). *Asparagus officinalis* L. In G.J.H. Grubben & O.A. Denton (Eds.), *PROTA (Plant Resources of Tropical Africa)*. Wageningen, Netherlands. https://uses.plantnet-project.org/en/Asparagus_officinalis_(PROTA)

Özden, E., Şeyran, A., Koçak, M.Z., Kumlay, A.M, Tel, A.Z., & Alma, M.H. (2022). Determination of natural distribution areas and some agro-morphological characteristics with sexual dimorphism of wild asparagus (*Asparagus officinalis* L.) in Iğdır plain – Turkey. *Genetic Resources and Crop Evolution, 70*, 461–478. https://doi.org/10.1007/s10722-022-01440-4

Pegiou, E., Mumm, R., Acharya, P., de Vos, R.C.H., & Hall, R.D. (2019). Green and white asparagus (*Asparagus officinalis*): a source of developmental, chemical and urinary intrigue. *Metabolites, 10*(1), Article 17. https://doi.org/10.3390/metabo10010017

POWO. (2024). *Asparagus officinalis* L. Facilitated by the Royal Botanic Gardens, Kew. https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:531229-1

Prokudin, Y.N. (Ed.). (1987). *Key to higher plants of Ukraine.* Naukova Dumka, Kyiv. (In Russian)

Schubert, G.G. (1870). *Botanical atlas of Schubert. As an auxiliary addition to any training manual with a brief explanatory text in the translation of N.I. Raevsky.* F.A. Bitepage.

Sikura, Y.Y. (2014). *Morphological features of fruits and seeds of flowering plants of the world flora.* TIMPANI, Uzhhorod. (In Hungarian and Ukrainian). https://www.kmf.uz.ua/hun114/images/konyvek/Szikura_flora_teljes.pdf

Studfile. (2012). Daily statistics. University of Customs and Finance. (In Ukrainian). https://studfile.net/preview/5705743/

Takhtajan, A.L. (1985). *Comparative anatomy of seeds. Monocots. Vol. 1.* Nauka. (In Russian)

Tamanian, K.G. (2000). *Asparagus officinalis* L. In P.H. Raven & W. Zheng-Yi (Eds.), *Flora of China. Vol. 24* (p. 214). Science Press, Beijing, and Missouri Botanical Garden Press, St. Louis. http://www.efloras.org/florataxon.aspx?flora_id=2&taxon_id=200027573

Tropicos. (2009). *Asparagus officinalis* L. In *Flora de Nicaragua*. Missouri Botanical Garden. http://legacy.tropicos.org/Name/18403589?projectid=7&langid=66

Tropicos. (2011). *Asparagus officinalis* L. In *Flora of Pakistan*. Missouri Botanical Garden. http://legacy.tropicos.org/Name/18403589?projectid=32

Tropicos. (2013). *Asparagus officinalis* L. In *Manual de Plantas de Costa Rica*. Missouri Botanical Garden. http://legacy.tropicos.org/Name/18403589?projectid=66

Tutin, T.G., Heywood, H., Burges, N.A., Moore, D.M., Valentine, D.H., Walters, S.M., & Webb, D.A. (Eds.). (1980). *Flora Europaea. Vol. 5.* Cambridge University Press.

Utech, F.H. (2008). *Asparagus officinalis* L. In Flora of North America Editorial Committee (Eds.), *Flora of North America. Vol. 26* (p. 214). Missouri Botanical Garden, St. Louis, MO & Harvard University Herbaria, Cambridge, MA. http://www.efloras.org/florataxon.aspx?flora_id=1&taxon_id=200027573

WFO. (2024). *Asparagus officinalis* L. http://www.worldfloraonline.org/taxon/wfo-0000634022

Статистичні характеристики та кореляції морфометричних ознак плодів *Asparagus officinalis* L. у Національному ботанічному саду імені М.М. Гришка НАН України

Вікторія Гриценко

Національний ботанічний сад імені М. М. Гришка НАН України, вул. Садово-Ботанічна, 1, Київ, 01014, Україна; gritsenkoviktoria@gmail.com

Дослідження проводились у 2020–2023 рр. на ботаніко-географічній ділянці “Степи України” Національного ботанічного саду імені М.М. Гришка НАН України і були зосереджені на дозрілих плодах *Asparagus officinalis*. Метою цього дослідження було з’ясувати основні статистичні характеристики таких морфометричних ознак плодів A. officinalis, як діаметр плодів, кількість гнізд на плід, кількість насінин на плід та кількість насінин на гніздо. У плодах *A. officinalis* виявлено вісімнадцять комбінацій чотирьох морфометричних ознак. Для кожної морфометричної ознаки плодів *A. officinalis* з’ясовано по десять статистичних характеристик: середнє арифметичне, медіана, мода, розмах варіації, коефіцієнт осциляції, стандартне відхилення, коефіцієнт варіації, стандартна похибка середнього, коефіцієнт асиметрії та коефіцієнт ексцесу. Коефіцієнт варіації показав, що серед досліджуваних морфометричних ознак плодів *A. officinalis* найбільш варіабельною є кількість насінин на плід, а найменш варіабельний – діаметр плодів. Відповідно до комплексної оцінки коефіцієнтів асиметрії та ексцесу, найбільш близькими до нормального розподілу є розподіл кількості насінин на плід та розподіл діаметру плодів. Підтверджено гіпотезу про кореляції морфометричних ознак плодів *A. officinalis*. Встановлено, що кореляції між парами таких ознак, як діаметр плодів та кількість гнізд на плід, діаметр плодів та кількість насінин на плід, кількість гнізд на плід та кількість насінин на плід є позитивними, прямими та сильними. Таким чином, з огляду на економічну доцільність, для отримання більшої кількості насіння практичніше збирати плоди *A. officinalis* більшого розміру. Результати цієї роботи становлять інтерес для морфології та біометрії *A. officinalis* та його культивування.

Ключові слова: *Asparagus officinalis*, біометрія плодів, варіаційні ряди, альтернативне групування