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**MORPHOMETRIC ANALYSIS OF ZIZIPHUS JUJUBA MILL.  
FRUITS FROM THE KHOROL BOTANICAL GARDEN COLLECTION**

**Actuality.** *Ziziphus jujuba* Mill. is a subtropical deciduous plant whose fruits contain biologically active compounds with a wide range of pharmacological effects. Due to the ease of cultivation, its production is observed in 48 countries, reflecting its significant nutritional and economic value. The fresh fruits of *Z. jujuba* have a short shelf life; therefore, research is increasingly focused on their processing into functional products with extended storage potential. Moreover, the characterization of fruit morphological traits serves as a fundamental basis for numerous research programs, including breeding initiatives.

**Purpose of the study.** To determine the size and weight of fruits, stones, and seeds of *Z. jujuba* forms from the Khorol Botanical Garden collection.

**Materials and methods.** The study was conducted throughout 2024. The research material consisted of fruits collected from 48 *Z. jujuba* plants (25 fruits per plant) at the ripening stage. Measurements and morphometric analyses of the studied traits were carried out under laboratory conditions at the Khorol Botanical Garden on the day of fruit harvesting.

**Research results.** Five of the genotypes studied produce large fruits. These are forms 5-3-11, 6-3-18, 5-3-17, 6-3-25 and 6-3-17. Form 5-3-11 has the largest fruits, weighing an average of 19.3 g, followed by form 6-3-18 with an average fruit weight of 12.4 g. Forms 5-3-17, 6-3-25 and 6-3-17 have fruits weighing more than 10 g and significantly outperform all other forms with smaller fruits. The fruits of form 5-3-11, the largest-fruited form, significantly outperform all other forms in terms of linear dimensions, with an average length of 42.4 mm and an average diameter of 27.1 mm. While fruit weight, length and diameter are strongly correlated, not all large-fruited forms have outstanding linear dimensions. The forms 6-3-25 and 5-3-11, which bear large fruit, also have the longest pits at 28.5 mm and 24.1 mm respectively. These forms differ significantly in this respect and surpass all others. The shortest pits (11.3 mm) are found in form 6-3-14, which also has the smallest fruits. The spherical fruits of form 6-3-14 contain an almost spherical pit, whereas the pits of other *Z. jujuba* forms are elongated. Form 6-3-25 has the longest seeds and the highest form index (the ratio of seed length to width), at 3.3. Close behind are forms 6-3-20, 5-3-5 and 6-3-16, which have a shape index of 3.0–3.1. Forms 5-3-11 and 6-3-23 have the largest pit diameter (9.9–9.7 mm). These forms also have the heaviest stones at 0.68–0.62 g. The thickness of the fruit pulp ranges from 3.0 to 9.5 mm, with the largest thickness found in large-fruited forms. In form 6-3-8, the stone accounts for almost a third of the fruit's weight, at 30.6%. In large-fruited forms, the stone is small, giving them a high edible pulp content: Forms 5-3-11 (96.3%), 6-3-18 (96.1%), 5-3-17 (94.9%), 6-3-17 (94.8%) and 6-3-25 (94.1%) have the highest pulp content. However, the medium-sized form 6-3-19 has the highest pulp content (96.7%) and is therefore the leader. Another medium-sized variety, 6-3-20, has a pulp content that exceeds that of most large-fruited varieties (96.1%). The forms with the largest fruit weight also have the most seeds. Form 3-5-11 therefore has the highest seed weight (0.056 g), followed by forms 6-3-18 (0.051 g), 6-3-23 (0.047 g) and 6-3-9 (0.043 g), which differ significantly from each other.

**Conclusions.** Morphometric studies of 48 fruiting individuals of *Z. jujuba* were conducted for the first time in the forest-steppe zone of Ukraine. In terms of fruit weight, the individuals belonged to the following categories: large-fruited (five forms, weighing over 10 g); medium-fruited (15 forms, weighing 5–10 g); small-fruited (21 forms, weighing 3–5 g); and very small-fruited (seven forms, weighing less than 3 g). Form 5-3-11 was found to be the most promising in the collection due to its high average fruit weight (19.3 g) and pulp content (96.3%). The variability of all linear parameters of fruits, stones and seeds, including stone weight, is within the normal range (coefficient of variation (CV) up to 44%), while fruit and seed weight are characterised by a high CV (57.5% and 50.0%, respectively), indicating significant potential for breeding. For fresh and canned consumption, large-fruited forms with a fruit weight of over 10 g are recommended, as well as the medium-fruited Form 6-3-19, which despite its average size has the highest pulp content (96.7%). Large-fruited forms are particularly valuable for further breeding work as sources of large fruit size and high pulp content, while small- and medium-fruited forms are valuable as sources of rootstocks and high winter hardiness.

The research was carried out within the framework of the program for the registration of local accessions at the National Centre for Plant Genetic Resources of Ukraine.

**Key words:** *Ziziphus jujuba* Mill., introduction, breeding, Forest-steppe zone, Ukraine.

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## МОРФОМЕТРИЧНИЙ АНАЛІЗ ПЛОДІВ *ZIZIPHUS JUJUBA* MILL. КОЛЕКЦІЇ ХОРОЛЬСЬКОГО БОТАНІЧНОГО САДУ

**Актуальність.** *Ziziphus jujuba* Mill. – субтропічна листопадна рослина, плоди якої мають біологічно активні речовини із широким спектром фармакологічної дії. Завдяки легкості вирощування культури виробництво спостерігається у 48 країнах, що пов'язано з важливою харчовою та економічною цінністю. Свіжі плоди *Z. jujuba* мають короткий термін зберігання, тому поглиблюються дослідження щодо їх переробки на функціональні продукти тривалого зберігання, а важливість описів морфологічних ознак плодів є основою для багатьох дослідницьких програм, включно із селекційними.

**Мета дослідження** – встановлення розміру й маси плодів, кісточок і насінин форм *Z. jujuba* селекції Хорольського ботанічного саду.

**Матеріали та методи.** Досліджували стиглі плоди врожаю 2024 р. по 25 шт. кожної з 48 особин *Z. jujuba*, що становлять селекційний фонд Хорольського ботанічного саду (Полтавська обл., Лубенський р-н, м. Хорол). Морфометричний аналіз показників проводився в день заготівлі плодів.

**Результати дослідження.** П'ять досліджених генотипів мають великі плоди. Це 5-3-11, 6-3-18, 5-3-17, 6-3-25 і 6-3-17. Форма 5-3-11 має достовірно найбільші плоди масою 19,3 г. Їй поступається форма 6-3-18 (середня маса плодів – 12,4 г), яка достовірно перевершує інші форми. Форми 5-3-17, 6-3-25 і 6-3-17, які мають плоди більші за 10 г, достовірно перевершують усі інші форми з меншими плодами. Плоди найвеликопліднішої форми 5-3-11 достовірно перевершують всі інші форми за лінійними розмірами, маючи довжину 42,4 мм і діаметр 27,1 мм. Хоча ознаки маси, довжини й діаметра плодів сильно корелюють між собою, проте не всі великоплідні форми мають видатні лінійні показники.

Форми 6-3-25 і 5-3-11 з великими плодами мають і найдовші кісточки – 28,5 і 24,1 мм відповідно. Вони достовірно різняться за цим показником між собою і перевершують всі інші форми. Достовірно найкоротші кісточки у форми 6-3-14 (11,3 мм), яка має і достовірно найкоротші плоди. Кулясті плоди форми 6-3-14 містять і майже кулясту кісточку, тоді як у інших форм *Z. jujuba* кісточка видовжена. Форма 6-3-25 з найдовшими кісточками має і найбільший індекс форми (відношення довжини до ширини кісточки) – 3,3. Наближеними до неї є форми 6-3-20, 5-3-5, 6-3-16 з індексом форми 3,0–3,1. Форми 5-3-11 і 6-3-23 мають достовірно найбільший діаметр кісточок – 9,9–9,7 мм. Вони мають й найважчі кісточки – 0,68–0,62 г.

Товщина м'якуша плодів коливається від 3,0 до 9,5 мм, будучи найбільшою у великоплідних форм. У форми 6-3-8 частка кісточка становить майже третину маси плода – 30,6%. У великоплідних форм частка кісточка невелика, отже, вони мають високий вміст їстівного м'якуша: 5-3-11 (96,3%), 6-3-18 (96,1%), 5-3-17 (94,9%), 6-3-17 (94,8%), 6-3-25 (94,1%). Проте лідером є середньоплідна форма 6-3-19 з найвищим вмістом м'якуша (96,7%). Інша середньоплідна форма 6-3-20 також перевищує більшість великоплідних форм за вмістом м'якуша (96,1%).

Найбільші за вагою плодів форми мають і найбільше насіння. Так, форма 5-3-11 має достовірно найбільшу вагу насінини (0,056 г), за нею слідує форма 6-3-18 (0,051 г), 6-3-23 (0,047 г) і 6-3-9 (0,043 г), які достовірно різняться між собою.

**Висновки.** В умовах Лісостепу України вперше проведено морфометричні дослідження 48 плодоносних особин *Z. jujuba*. За масою плодів вони належать до великоплідних (5 форм, маса понад 10 г), середньоплідних (15 форм, маса 5–10 г), дрібноплідних (21 форма, маса 3–5 г) і дуже дрібноплідних (7 форм, маса менша за 3 г). Виявлено, що форма 5-3-11 є найперспективнішою серед колекції, оскільки має достовірно найбільшу середню масу плода (19,3 г) та найбільшу частку м'якуша (96,3%). Мінливість усіх лінійних параметрів плодів, кісточок та насінин, включно з масою кісточок, вкладається в межі норми ( $CV = 11,2$ – $28,2\%$ ), тоді як маса плодів і маса насінин характеризується високим коефіцієнтом варіювання (57,5 і 50,0% відповідно), що вказує на значний потенціал для селекції. Для вживання у свіжому та консервованому вигляді рекомендовані вели-

коплідні форми з масою плодів понад 10 г, а також середньоплідна форма 6-3-19, яка, попри середні розміри, має найвищий вміст м'якуша (96,7%). Особливо цінними для подальшої селекційної роботи є великоплідні форми (як джерела великоплідності та високого вмісту м'якуша), а також дрібно- та середньоплідні форми (як джерела підщеп і високої зимостійкості).

Дослідження проведено в рамках програми реєстрації місцевих зразків у Національному центрі генетичних ресурсів рослин України.

**Ключові слова:** *Ziziphus jujuba* Mill., плоди, морфометричні показники, інтродукція, селекція, Лісостепова зона, Україна.

**Introduction. Actuality.** *Ziziphus jujuba* Mill. (family *Rhamnaceae* Juss.) is a subtropical, deciduous, tree-like plant whose fruits are characterized by high nutritional value and contain biologically active compounds with a wide range of pharmacological effects. The species grows as a small tree or a spreading shrub. The fruit is a succulent pyrene of the most diverse shapes: ranging from spherical, oblong, elongated, ovoid, to pear-shaped forms, measuring up to 3–4 cm in length and up to 2.5 cm in diameter, with a thin, glossy skin. The pulp, depending on the cultivar or form, varies in texture – sometimes dry, mealy, and loose, while in other cases juicy and dense. The stone (endocarp) also varies in shape, from rounded to elongated.

The fruits of *Z. jujuba* differ from those of other fruit crops by their high concentration of dry matter and exceptional nutritional value. They are consumed fresh or preserved through drying and other culinary processing methods.

Modern literature sources indicate that China is one of the largest producers of *Z. jujuba* fruits in the world, with more than 40% of the global harvest cultivated in this country. According to Yang et al. (2021), its plantations cover an area of approximately 2 million hectares, serving as a primary source of income for about 20 million farmers, while more than 1 billion people across Asia use *Z. jujuba* in traditional medicine.

A growing interest in *Ziziphus jujuba* cultivation has been observed in Egypt, Iran, Saudi Arabia, Algeria, and Iraq, primarily due to the fruit's health-promoting properties and the ease of cultivation. In the United States, *Z. jujuba* is grown mainly in the southwestern, southern, and southeastern states. It is also cultivated in parts of Europe, particularly in Italy and the Balkans, according to Shahrajabian et al. (2020). As reported by Wu et al. (2025) and Ruan et al. (2024), *Z. jujuba* is now grown in more than 48 countries worldwide, a trend driven by its high nutritional, economic, and ecological value. The fruits of *Z. jujuba* have been used for thousands of years as a food source, dietary supplement, and natural flavoring due to their rich nutritional composition and beneficial bioactive compounds. An increasing body of evidence confirms the therapeutic benefits of *Z. jujuba*, including anticancer, anti-inflammatory, antioxidant, immunostimulatory, neuroprotective, hepatoprotective, and gastroprotective effects. These properties are primarily attributed to its key biologically active constituents (Lu et al., 2021; Movahed et al., 2024; Zhu et al., 2024).

Since fresh *Z. jujuba* fruits have a short shelf life, recent research has increasingly focused on developing functional processed products with extended storage stability, high consumer acceptability, and proven health benefits (Rashwan et al., 2020; Stan et al., 2021; Jia et al., 2025). Equally important are studies on the morphological structure of *Z. jujuba* fruits. In particular, Fukalova et al. (2023) reported significant variation in fruit size and shape, mainly attributed to cultivar differences. They also noted that these variations do not affect the degree of fruit sphericity, which is an important criterion for *Z. jujuba* fruit characterization. According to Khadivi et al. (2021, 2022), special attention is given to the description of morphological traits, including the dimensions of both fruit and seed, which serve as the foundation for numerous research initiatives, particularly in breeding programs.

In Ukraine, within the forest-steppe zone, the distribution of *Z. jujuba* is limited by climatic conditions and the insufficient availability of planting material. Therefore, one of the primary objectives for breeders is the development of large-fruited forms adapted to changing environmental conditions, that combine beneficial properties with the commercial qualities required by the modern market.

On the collection plots of the Khorol Botanical Garden, the introduced *Z. jujuba* plants and their breeding forms (small- and medium-fruited) endured temperature drops down to –28 to –30 °C during the period of deep winter dormancy without visible damage. In contrast, large-fruited breeding forms, when grown in open areas exposed to strong winds and without protective agronomic measures, showed partial dieback or significant injury. At the same time, protective agronomic practices for large-fruited *Z. jujuba* forms introduced through vegetative material transfer proved effective only for individuals of relatively small size. Therefore, the main objective of subsequent research was to obtain hybrid seeds of *Z. jujuba* under introduction conditions that could transmit genes controlling both winter hardiness and large fruit size to the progeny. In the course of the study, hybrid seeds were obtained to breed locally adapted large-fruited, winter-hardy forms through open pollination among parental components of the species. Crosses were performed between well-adapted, winter-hardy, medium-fruited local forms selected after several reproductive cycles and large-fruited cultivars

that, under the conditions of Ukraine's Forest-Steppe region, required mandatory protection from low temperatures in winter. According to Krasovsky (2020), genotypes such as the cultivars 'Tayangzao' and 'Vakhshskij' were used as sources of large-fruited traits in hybridization. In 2011, the hybrid seeds were sown in a nursery, and by 2014, the seedlings were transplanted to the collection plot "Garden of Subtropical Fruit Crops" at the Khorol Botanical Garden. At present, the collection comprises 50 *Z. jujuba* individuals, of which 48 are fruit-bearing.

Morphometric studies of the fruits of *Z. jujuba* breeding forms from the Khorol Botanical Garden collection are of particular relevance, as they constitute part of a comprehensive research effort aimed at registering local accessions in the National Center for Plant Genetic Resources of Ukraine, affiliated with the Institute of Plant Production named after V. Ya. Yuriev of the National Academy of Sciences of Ukraine.

**Purpose of the study** was to determine the size and weight of the fruits, stones, and seeds of *Z. jujuba* Mill. breeding forms developed at the Khorol Botanical Garden.

**Materials and methods.** *Plant material.* The experimental material consisted of fresh fruits from 48 collection forms of *Z. jujuba* bred at the Khorol Botanical Garden. The research was conducted in 2024. Fruit sampling (25 fruits per breeding form) was carried out during the period of weight ripening (from the second decade of September to the first decade of November), when the fruits reached the color, taste, and pulp consistency characteristic of each breeding form.

*Morphological measurements and weighing.* Measurements were performed under laboratory conditions at the Khorol Botanical Garden on the same day the fruits were harvested. Morphological studies included the following: length and diameter of fruit and stone; seed length, width, and thickness. These parameters were determined using an electronic digital caliper (model 300-I-0.01, IIIЦІ Shahe, China, 2021) in millimeters. The weight of fruits, stones, and seeds was measured using electronic scales (model FEH-300, 0.01 g precision, Ukraine, 2022; error  $\pm 0.01$  g). Fruit grouping and classification were performed according to the recommendations of Pasenkov et al. (1975).

*Statistical data processing.* Descriptive statistics were applied for data analysis, including the calculation of mean values (M), standard deviation (SD), and coefficient of variation (CV%). Statistical analyses were conducted in Microsoft Excel Office 2019 using analysis of variance (ANOVA). The significance of differences between means at a 95% confidence level ( $p \leq 0.05$ ) was determined using Fisher's Least Significant Difference (LSD) test.

**Results and Discussion.** The fruit of *Z. jujuba* is a single-stone drupe that usually contains one seed; however, in small-fruited breeding forms, two seeds were occasionally observed within a single stone. The shape of the fruit varies from round to ellipsoidal. The color of the skin of ripe fruits, depending on the breeding form, ranges from brownish-yellow to dark brown (Fig. 1).

Table 1 presents the morphometric and statistical parameters of fruits from the studied breeding forms of *Z. jujuba*.



**Fig. 1. Fruits of the *Z. jujuba* breeding forms from the Khorol Botanical Garden collection**

Note: The breeding forms are presented with continuous numbering.

Morphometric parameters of *Z. jujuba* fruits

Continuous Numbering	Breeding Form	Length, mm		Diameter, mm		Thickness, mm		Weight, g	
		lim	M±SD	lim	M±SD	lim	M±SD	lim	M±SD
1.	5-3-1	5-6	5.2±0.4	4-5	4.0±0.2	1-2	1.1±0.3	0.01-0.02	0.01±0.002
2.	5-3-2	7-9	7.4±0.8	5-6	5.1±0.3	2-3	2.2±0.4	0.02-0.03	0.02±0.004
3.	5-3-3	8-10	8.9±0.4	4-6	4.9±0.4	2-3	2.6±0.5	0.02-0.03	0.03±0.005
4.	5-3-4	6-9	7.0±0.8	4-5	4.2±0.4	1-2	1.2±0.4	0.02-0.03	0.02±0.004
5.	5-3-5	7-9	8.0±0.8	4-6	5.2±0.6	1-2	1.4±0.5	0.02-0.03	0.02±0.004
6.	5-3-6	7-9	7.8±0.9	5-6	5.3±0.5	1-2	1.3±0.5	0.01-0.02	0.01±0.005
7.	5-3-7	6-8	6.4±0.8	4-5	4.2±0.4	1-2	1.4±0.4	0.01-0.02	0.01±0.005
8.	5-3-8	6-8	6.9±0.8	5-7	5.6±0.9	1-2	1.3±0.5	0.02-0.03	0.02±0.005
9.	5-3-9	5-6	5.4±0.5	3-4	3.4±0.5	1-2	1.4±0.5	0.01-0.02	0.01±0.005
10.	5-3-10	5-7	6.0±0.6	3-4	3.3±0.5	1-2	1.3±0.5	0.01-0.02	0.01±0.005
11.	5-3-11	15-18	5.6±0.8	5-6	5.3±0.5	1-2	1.4±0.5	0.05-0.07	0.06±0.008
12.	5-3-12	5-7	5.7±0.8	4-6	5.3±0.6	1-2	1.4±0.5	0.01-0.02	0.01±0.005
13.	5-3-13	6-9	7.7±1.2	4-5	4.5±0.5	1-2	1.4±0.5	0.01-0.02	0.01±0.005
14.	5-3-14	5-7	6.3±0.8	4-5	4.6±0.5	1-2	1.6±0.5	0.01-0.02	0.02±0.005
15.	5-3-15	5-7	5.6±0.7	5-6	5.3±0.5	1-2	1.3±0.5	0.01-0.02	0.01±0.005
17.	5-3-17	7-8	7.2±0.4	4-6	5.1±0.5	1-2	1.2±0.4	0.02-0.03	0.02±0.004
18.	5-3-18	6-8	6.6±0.9	5-6	4.3±0.5	1-2	1.3±0.5	0.01-0.02	0.01±0.005
19.	5-3-19	5-6	5.5±0.5	4-5	4.5±0.5	1-2	1.5±0.5	0.01-0.02	0.01±0.005
20.	5-3-20	7-9	8.2±0.8	4-5	4.2±0.4	1-2	1.2±0.4	0.01-0.02	0.01±0.004
21.	5-3-21	6-9	7.8±0.9	5-6	5.2±0.4	1-2	1.2±0.4	0.01-0.02	0.01±0.004
22.	5-3-22	7-8	7.2±0.4	4-5	4.2±0.4	1-2	1.2±0.4	0.01-0.02	0.01±0.004
23.	5-3-23	8-10	8.2±0.5	4-5	4.9±0.3	1-2	1.6±0.6	0.01-0.02	0.02±0.005
24.	5-3-24	5-7	5.3±0.7	4-5	4.2±0.2	1-2	1.2±0.4	0.03-0.04	0.03±0.004
25.	5-3-25	7-10	8.3±1.0	4-6	5.2±0.5	1-2	1.2±0.4	0.02-0.03	0.02±0.004
27.	6-3-2	8-10	8.4±0.7	5-6	5.1±0.3	2-3	2.1±0.3	0.01-0.02	0.01±0.003
28.	6-3-3	6-7	6.3±0.5	5-6	5.7±0.5	1-2	1.6±0.5	0.01-0.02	0.02±0.005
29.	6-3-4	11-12	11.2±0.4	5-7	5.4±0.8	1-2	1.2±0.4	0.01-0.02	0.01±0.004
30.	6-3-5	6-7	6.2±0.4	5-5	5.3±0.5	1-2	1.3±0.5	0.01-0.02	0.01±0.005
31.	6-3-6	7-10	8.3±1.2	5-6	5.4±0.5	1-2	1.4±0.5	0.03-0.04	0.03±0.004
32.	6-3-7	5-6	5.2±0.4	4-5	4.2±0.4	1-2	1.2±0.4	0.02-0.03	0.02±0.004
33.	6-3-8	5-7	6.1±0.6	4-5	4.2±0.4	1-2	1.2±0.4	0.01-0.02	0.01±0.003
34.	6-3-9	6-8	7.2±0.6	4-6	5.2±0.6	1-2	1.3±0.5	0.04-0.05	0.04±0.005
35.	6-3-10	6-8	7.1±0.7	5-6	5.2±0.4	1-2	1.2±0.4	0.02-0.03	0.02±0.004
36.	6-3-11	5-7	6.2±0.8	4-5	4.5±0.5	1-2	1.5±0.5	0.02-0.03	0.02±0.005
37.	6-3-12	9-11	9.2±0.5	5-6	5.3±0.5	1-2	1.3±0.5	0.02-0.03	0.02±0.005
38.	6-3-13	7-8	7.2±0.4	5-7	5.9±0.7	1-2	1.2±0.4	0.03-0.04	0.03±0.004
39.	6-3-14	5-6	5.5±0.5	5-6	5.4±0.5	1-2	1.4±0.5	0.01-0.02	0.01±0.005
40.	6-3-15	5-7	6.4±0.7	4-5	4.5±0.5	1-2	1.5±0.5	0.01-0.02	0.01±0.005
41.	6-3-16	8-10	9.6±0.7	5-6	5.6±0.5	1-2	1.6±0.5	0.03-0.04	0.04±0.005
42.	6-3-17	7-10	7.9±1.2	4-5	4.3±0.5	1-2	1.3±0.5	0.03-0.04	0.03±0.005
43.	6-3-18	7-9	7.3±0.7	5-7	5.8±0.6	2-3	1.1±0.3	0.05-0.06	0.05±0.003
44.	6-3-19	7-10	8.9±0.7	4-5	4.1±0.3	1-2	1.1±0.3	0.02-0.03	0.02±0.003
45.	6-3-20	8-11	9.5±1.1	5-6	5.3±0.5	1-2	1.2±0.4	0.03-0.04	0.03±0.003
46.	6-3-21	5-7	6.3±0.5	5-6	5.6±0.5	1-2	1.6±0.5	0.02-0.03	0.04±0.005
47.	6-3-22	6-9	7.3±1.2	4-6	4.9±0.8	2-3	2.2±0.4	0.02-0.03	0.02±0.004
48.	6-3-23	5-7	5.7±0.5	4-5	4.7±0.5	1-2	1.7±0.5	0.04-0.05	0.05±0.005
49.	6-3-24	8-10	8.6±0.8	4-6	5.5±0.6	1-2	1.5±0.5	0.02-0.03	0.03±0.005
50.	6-3-25	9-12	10.5±1.0	5-7	6.6±0.6	1-2	1.7±0.5	0.03-0.04	0.04±0.005
LSD <sub>005</sub>			0.41		0.28		0.25		0.003

Note: lim – range; M±SD – mean ± standard deviation; LSD – Least Significant Difference.

According to Sinko (1975), the fruits of *Z. jujuba* are classified as large – with a weight exceeding 10 g, medium – 5–10 g, small – 3–5 g, and very small – less than 3 g.

Five of the studied genotypes have large fruits. They are 5-3-11, 6-3-18, 5-3-17, 6-3-25, and 6-3-17. The breeding form 5-3-11 has the statistically largest fruits, with the weight of 19.3 g. It was followed by form 6-3-18 (average fruit weight 12.4 g), which significantly exceeds the other forms. The forms 5-3-17, 6-3-25, and 6-3-17, whose fruits weighed more than 10 g, also significantly surpass all other forms with smaller fruits. Fifteen breeding forms are identified as medium-fruited: 6-3-20, 6-3-12, 6-3-16, 6-3-4, 5-3-15, 6-3-6, 5-3-2, 6-3-22, 5-3-25, 6-3-23, 5-3-13, 6-3-19, 5-3-24, 5-3-14, and 5-3-3. Twenty-one forms are classified as small-fruited: 5-3-9, 5-3-23, 5-3-22, 6-3-24, 5-3-5, 6-3-5, 6-3-21, 6-3-10, 5-3-18, 6-3-11, 6-3-2, 6-3-15, 5-3-21, 5-3-8, 6-3-13, 6-3-3, 5-3-19, 5-3-4, 5-3-10, 5-3-6, and 5-3-1. Seven breeding forms are categorized as very small-fruited: 5-3-12, 6-3-9, 6-3-7, 5-3-7, 5-3-20, 6-3-14, 6-3-8. There is no clear boundary between the last three groups. For example, the medium-fruited form 5-3-3 (5.1 g) does not differ significantly in fruit weight from the small-fruited form 5-3-9 (4.8 g). Similarly, the small-fruited form 5-3-1 (3.0 g) shows no significant difference compared to the very small-fruited forms 5-3-12 and 6-3-9, with average fruit weight of 2.9 g and 2.7 g, respectively.

The fruits of the largest-fruited form, 5-3-11, significantly exceed all other forms in their linear dimensions, measuring 42.4 mm in length and 27.1 mm in diameter. The fruits of form 6-3-25 rank second in length

(37.7 mm), significantly surpassing the other forms in this parameter. However, by fruit diameter, they belong to the same group as forms 6-3-6, 6-3-20, and 5-3-23, while being slightly inferior to forms 6-3-18 (26.0 mm) and 5-3-17 (24.8 mm), which hold the second and third positions, respectively.

In terms of fruit length, following forms 5-3-11 and 6-3-25 is a group consisting of forms 6-3-6, 6-3-12, 6-3-18, and 6-3-20, which do not differ significantly from each other but are all superior to the remaining forms.

Although fruit weight, length, and diameter are strongly correlated traits, not all large-fruited forms display outstanding linear dimensions. For example, form 5-3-17 ranked only tenth in fruit length, while form 6-3-17 ranked ninth in fruit diameter.

The range of variation in fruit traits is as follows: total and mean fruit length – 11–48 mm (13–42 mm); total and mean diameter – 10–31 mm (11–27 mm); total and mean fruit weight – 0.7–23.4 g (0.8–18.3 g). Variation within 5–44% is considered normal for plants, while 45–63% indicates high variability (Mezhenskyj, 2017). In the studied *Z. jujuba* forms, fruit length and diameter vary within the normal range – 21.4% and 17.4%, respectively. The coefficient of variation for fruit weight (57.5%) indicates substantial variability.

The stones of the examined plants are round in cross-section, with terminal tapering of varying sharpness and a distinctly sculptured surface (Fig. 2).

Table 2 presents the morphometric parameters of the fruit stones.

Forms 6-3-25 and 5-3-11, which produce large fruits, also have the longest stones – 28.5 mm and 24.1 mm,



Fig. 2. Stones of fruits from the *Z. jujuba* breeding forms of the Khorol Botanical Garden collection

Note: continuous numbering of the studied forms is provided.

Table 2

Morphometric parameters of fruit stones of *Z. jujuba* breeding forms from the Khorol Botanical Garden

Continuous Numbering	Breeding Form	Length, mm		Diameter, mm		Weight, g	
		lim	M±SD	lim	M±SD	lim	M±SD
1	5-3-1	12-14	12.1±0.4	7-8	7.0±0.2	0.2-0.3	0.26±0.03
2	5-3-2	17-19	17.2±0.5	8-9	8.2±0.4	0.4-0.5	0.45±0.04
3	5-3-3	20-23	21.1±0.5	7-9	7.9±0.4	0.4-0.5	0.46±0.03
4	5-3-4	15-18	16.0±0.8	7-8	7.2±0.4	0.3-0.4	0.36±0.03
5	5-3-5	21-24	22.2±1.2	7-8	7.4±0.5	0.3-0.4	0.36±0.05
6	5-3-6	16-19	17.3±1.4	7-8	7.3±0.5	0.2-0.3	0.27±0.03
7	5-3-7	14-17	14.4±0.9	6-7	7.2±0.4	0.3-0.4	0.35±0.03
8	5-3-8	15-17	15.9±0.8	8-9	8.2±0.4	0.3-0.4	0.36±0.04
9	5-3-9	16-18	16.6±0.8	7-8	7.4±0.5	0.3-0.4	0.36±0.02
10	5-3-10	19-22	20.2±0.9	7-8	7.3±0.5	0.3-0.4	0.35±0.03
11	5-3-11	23-28	24.1±1.6	9-12	9.9±1.2	0.6-0.9	0.68±0.08
12	5-3-12	14-16	14.7±0.8	7-8	7.4±0.5	0.2-0.3	0.26±0.04
13	5-3-13	18-21	19.7±1.2	7-8	7.5±0.5	0.3-0.4	0.36±0.04
14	5-3-14	12-14	13.3±0.8	8-9	8.6±0.5	0.3-0.4	0.36±0.03
15	5-3-15	15-18	15.8±1.1	8-9	8.3±0.5	0.4-0.5	0.44±0.02
17	5-3-17	17-20	17.8±1.1	9-10	9.2±0.4	0.5-0.6	0.54±0.03
18	5-3-18	14-17	15.0±1.4	7-8	7.3±0.5	0.2-0.3	0.27±0.04
19	5-3-19	12-14	13.0±1.0	7-8	7.5±0.5	0.2-0.3	0.25±0.02
20	5-3-20	14-16	15.1±0.8	6-7	6.2±0.4	0.1-0.2	0.17±0.03
21	5-3-21	18-20	19.0±0.7	9-10	9.2±0.4	0.5-0.6	0.58±0.03
22	5-3-22	14-17	15.0±0.9	6-7	6.2±0.4	0.3-0.4	0.35±0.02
23	5-3-23	17-20	18.1±0.7	7-8	7.9±0.3	0.3-0.4	0.36±0.03
24	5-3-24	20-23	20.8±1.0	8-10	8.3±0.7	0.5-0.7	0.56±0.07
25	5-3-25	15-18	16.3±1.0	8-9	8.2±0.4	0.4-0.5	0.48±0.02
27	6-3-2	13-16	13.8±1.1	7-9	8.1±0.4	0.3-0.4	0.36±0.03
28	6-3-3	14-17	15.3±1.1	7-8	7.7±0.5	0.3-0.4	0.37±0.03
29	6-3-4	18-21	19.1±1.0	7-9	7.4±0.8	0.3-0.5	0.42±0.07
30	6-3-5	18-20	18.8±0.7	8-9	8.3±0.5	0.4-0.6	0.50±0.04
31	6-3-6	18-21	19.3±1.2	7-8	7.4±0.5	0.4-0.5	0.44±0.04
32	6-3-7	13-15	13.6±0.9	8-9	8.2±0.4	0.3-0.4	0.35±0.03
33	6-3-8	14-15	14.2±0.4	6-7	6.2±0.4	0.2-0.3	0.25±0.02
34	6-3-9	18-20	19.2±0.6	8-10	9.2±0.6	0.5-0.6	0.56±0.03
35	6-3-10	15-16	15.3±0.5	7-8	7.2±0.4	0.2-0.3	0.26±0.04
36	6-3-11	14-16	15.2±0.8	8-10	9.3±0.8	0.3-0.4	0.37±0.02
37	6-3-12	22-25	22.9±1.0	8-9	8.3±0.5	0.4-0.6	0.49±0.04
38	6-3-13	14-16	14.9±0.7	7-9	7.9±0.7	0.4-0.5	0.46±0.03
39	6-3-14	10-12	11.3±0.8	7-8	7.4±0.5	0.2-0.3	0.26±0.02
40	6-3-15	14-15	14.5±0.5	8-9	8.5±0.5	0.3-0.4	0.37±0.02
41	6-3-16	19-20	19.6±0.5	6-7	6.6±0.5	0.2-0.3	0.26±0.02
42	6-3-17	20-23	20.9±1.2	8-9	8.3±0.5	0.5-0.6	0.54±0.04
43	6-3-18	18-21	19.0±1.0	8-10	8.8±0.6	0.4-0.6	0.48±0.05
44	6-3-19	15-18	17.0±0.6	7-8	7.1±0.3	0.4-0.5	0.47±0.01
45	6-3-20	17-21	19.4±1.3	6-7	6.3±0.5	0.3-0.4	0.35±0.02
46	6-3-21	13-15	14.3±0.5	7-8	7.6±0.5	0.3-0.4	0.33±0.03
47	6-3-22	17-20	18.3±1.2	7-9	7.8±0.8	0.4-0.5	0.46±0.03
48	6-3-23	18-20	18.8±0.5	9-10	9.7±0.5	0.5-0.6	0.56±0.02
49	6-3-24	17-20	18.3±1.1	8-9	8.5±0.5	0.4-0.6	0.50±0.50
50	6-3-25	27-30	28.5±1.0	8-9	8.7±0.5	0.5-0.7	0.62±0.62
<i>LSD</i> <sub>0.05</sub>			0.52		0.29		0.02

Note: lim – range; M±SD – mean ± standard deviation; LSD – Least Significant Difference.

respectively. These two forms differ significantly from each other in this parameter and exceed all others. The third position by stone length (22.9 mm) belongs to form 6-3-12, which bears medium-sized fruits. It is followed by form 5-3-5 with a stone length of 21.1 mm, which is significantly shorter than that of form 6-3-12 but longer than in the subsequent forms. Interestingly, 5-3-5 is not among the leading forms in either fruit length or fruit weight. The shortest stones were recorded in form 6-3-14 (11.3 mm), which also has the smallest fruits. The spherical fruits of 6-3-14 contain nearly round stones, while stones of other *Z. jujuba* forms are elongated.

Form 6-3-25, with the longest stones, also has the highest shape index (length-to-width ratio) – 3.3. Close values were observed in forms 6-3-20, 5-3-5, and 6-3-16, with indices ranging from 3.0 to 3.1.

Forms 5-3-11 and 6-3-23 have significantly larger stone diameters – 9.9 mm and 9.7 mm, respectively – followed by a group of forms (6-3-11, 5-3-21, 5-3-17, 6-3-9) with diameters of 9.3–9.2 mm. These two forms, 5-3-11 and 6-3-23, with the largest linear dimensions of stones, also have the heaviest stones, weighing 0.68–0.62 g, which significantly exceeds the next group (0.56–0.48 g) that includes forms 5-3-21, 5-3-24, 6-3-23, 6-3-9, 5-3-17, 6-3-17, 6-3-24, 6-3-5, 6-3-12, and 6-3-18. The group of forms: 5-3-6, 6-3-16, 5-3-1, 6-3-10, 5-3-12, 6-3-14, 5-3-19, 6-3-8, and 5-3-20 has the lightest stones, weighing only 0.27–0.17 g.

The pulp thickness of the fruits ranges from 3.0 to 9.5 mm, being greatest in large-fruited forms. An impor-

tant quality indicator is the seed-to-pulp ratio as a percentage of total fruit weight. The poorest value was observed in form 6-3-8, where the stone accounts for almost one-third of the fruit's weight (30.6%). In large-fruited forms, the stone proportion is small, resulting in a high content of edible pulp: 5-3-11 (96.3%), 6-3-18 (96.1%), 5-3-17 (94.9%), 6-3-17 (94.8%), and 6-3-25 (94.1%). However, the highest pulp content was recorded in the medium-fruited form 6-3-19 (96.7%). Another medium-fruited form, 6-3-20, also exceeds most large-fruited forms in pulp percentage (96.1%).

All stone parameters show coefficients of variation within normal limits: length – 19.2%, diameter – 11.2%, and weight – 28.2%.

The seeds of the studied breeding forms are ellipsoid, often laterally compressed, with some having a pointed apex (Fig. 3).

The characteristics of the seeds are presented in Table 3.

Seed variability falls within the normal range: the coefficient of variation for length is 19.9%, for width – 13.5%, and for thickness – 21.8%. However, seed weight shows high variability – 50.0%

Larger seeds generally have better germination potential, as they contain a greater reserve of nutrients. The form 6-3-4 has significantly the longest seeds (11.2 mm), followed by form 6-3-25, whose seeds (10.5 mm) are significantly longer than those of the next forms. Form 6-3-25 has significantly the widest seeds (6.6 mm). The greatest thickness was recorded in



Fig. 3. Seeds of fruits from the *Z. jujuba* breeding forms of the Khorol Botanical Garden collection. October 9, 2024

Note: continuous numbering of the studied forms is provided.

Table 3

Morphometric parameters of *Z. jujuba* seeds from the breeding forms of the Khorol Botanical Garden

Continuous Numbering	Breeding Form	Length, mm		Diameter, mm		Thickness, mm		Weight, g	
		lim	M±SD	lim	M±SD	lim	M±SD	lim	M±SD
1	5-3-1	5-6	5.2±0.4	4-5	4.0±0.2	1-2	1.1±0.3	0.01-0.02	0.01±0.002
2	5-3-2	7-9	7.4±0.8	5-6	5.1±0.3	2-3	2.2±0.4	0.02-0.03	0.02±0.004
3	5-3-3	8-10	8.9±0.4	4-6	4.9±0.4	2-3	2.6±0.5	0.02-0.03	0.03±0.005
4	5-3-4	6-9	7.0±0.8	4-5	4.2±0.4	1-2	1.2±0.4	0.02-0.03	0.02±0.004
5	5-3-5	7-9	8.0±0.8	4-6	5.2±0.6	1-2	1.4±0.5	0.02-0.03	0.02±0.004
6	5-3-6	7-9	7.8±0.9	5-6	5.3±0.5	1-2	1.3±0.5	0.01-0.02	0.01±0.005
7	5-3-7	6-8	6.4±0.8	4-5	4.2±0.4	1-2	1.4±0.4	0.01-0.02	0.01±0.005
8	5-3-8	6-8	6.9±0.8	5-7	5.6±0.9	1-2	1.3±0.5	0.02-0.03	0.02±0.005
9	5-3-9	5-6	5.4±0.5	3-4	3.4±0.5	1-2	1.4±0.5	0.01-0.02	0.01±0.005
10	5-3-10	5-7	6.0±0.6	3-4	3.3±0.5	1-2	1.3±0.5	0.01-0.02	0.01±0.005
11	5-3-11	15-18	5.6±0.8	5-6	5.3±0.5	1-2	1.4±0.5	0.05-0.07	0.06±0.008
12	5-3-12	5-7	5.7±0.8	4-6	5.3±0.6	1-2	1.4±0.5	0.01-0.02	0.01±0.005
13	5-3-13	6-9	7.7±1.2	4-5	4.5±0.5	1-2	1.4±0.5	0.01-0.02	0.01±0.005
14	5-3-14	5-7	6.3±0.8	4-5	4.6±0.5	1-2	1.6±0.5	0.01-0.02	0.02±0.005
15	5-3-15	5-7	5.6±0.7	5-6	5.3±0.5	1-2	1.3±0.5	0.01-0.02	0.01±0.005
17	5-3-17	7-8	7.2±0.4	4-6	5.1±0.5	1-2	1.2±0.4	0.02-0.03	0.02±0.004
18	5-3-18	6-8	6.6±0.9	5-6	4.3±0.5	1-2	1.3±0.5	0.01-0.02	0.01±0.005
19	5-3-19	5-6	5.5±0.5	4-5	4.5±0.5	1-2	1.5±0.5	0.01-0.02	0.01±0.005
20	5-3-20	7-9	8.2±0.8	4-5	4.2±0.4	1-2	1.2±0.4	0.01-0.02	0.01±0.004
21	5-3-21	6-9	7.8±0.9	5-6	5.2±0.4	1-2	1.2±0.4	0.01-0.02	0.01±0.004
22	5-3-22	7-8	7.2±0.4	4-5	4.2±0.4	1-2	1.2±0.4	0.01-0.02	0.01±0.004
23	5-3-23	8-10	8.2±0.5	4-5	4.9±0.3	1-2	1.6±0.6	0.01-0.02	0.02±0.005
24	5-3-24	5-7	5.3±0.7	4-5	4.2±0.2	1-2	1.2±0.4	0.03-0.04	0.03±0.004
25	5-3-25	7-10	8.3±1.0	4-6	5.2±0.5	1-2	1.2±0.4	0.02-0.03	0.02±0.004
27	6-3-2	8-10	8.4±0.7	5-6	5.1±0.3	2-3	2.1±0.3	0.01-0.02	0.01±0.003
28	6-3-3	6-7	6.3±0.5	5-6	5.7±0.5	1-2	1.6±0.5	0.01-0.02	0.02±0.005
29	6-3-4	11-12	11.2±0.4	5-7	5.4±0.8	1-2	1.2±0.4	0.01-0.02	0.01±0.004
30	6-3-5	6-7	6.2±0.4	5-5	5.3±0.5	1-2	1.3±0.5	0.01-0.02	0.01±0.005
31	6-3-6	7-10	8.3±1.2	5-6	5.4±0.5	1-2	1.4±0.5	0.03-0.04	0.03±0.004
32	6-3-7	5-6	5.2±0.4	4-5	4.2±0.4	1-2	1.2±0.4	0.02-0.03	0.02±0.004
33	6-3-8	5-7	6.1±0.6	4-5	4.2±0.4	1-2	1.2±0.4	0.01-0.02	0.01±0.003
34	6-3-9	6-8	7.2±0.6	4-6	5.2±0.6	1-2	1.3±0.5	0.04-0.05	0.04±0.005
35	6-3-10	6-8	7.1±0.7	5-6	5.2±0.4	1-2	1.2±0.4	0.02-0.03	0.02±0.004
36	6-3-11	5-7	6.2±0.8	4-5	4.5±0.5	1-2	1.5±0.5	0.02-0.03	0.02±0.005
37	6-3-12	9-11	9.2±0.5	5-6	5.3±0.5	1-2	1.3±0.5	0.02-0.03	0.02±0.005
38	6-3-13	7-8	7.2±0.4	5-7	5.9±0.7	1-2	1.2±0.4	0.03-0.04	0.03±0.004
39	6-3-14	5-6	5.5±0.5	5-6	5.4±0.5	1-2	1.4±0.5	0.01-0.02	0.01±0.005
40	6-3-15	5-7	6.4±0.7	4-5	4.5±0.5	1-2	1.5±0.5	0.01-0.02	0.01±0.005
41	6-3-16	8-10	9.6±0.7	5-6	5.6±0.5	1-2	1.6±0.5	0.03-0.04	0.04±0.005
42	6-3-17	7-10	7.9±1.2	4-5	4.3±0.5	1-2	1.3±0.5	0.03-0.04	0.03±0.005
43	6-3-18	7-9	7.3±0.7	5-7	5.8±0.6	2-3	1.1±0.3	0.05-0.06	0.05±0.003
44	6-3-19	7-10	8.9±0.7	4-5	4.1±0.3	1-2	1.1±0.3	0.02-0.03	0.02±0.003
45	6-3-20	8-11	9.5±1.1	5-6	5.3±0.5	1-2	1.2±0.4	0.03-0.04	0.03±0.003
46	6-3-21	5-7	6.3±0.5	5-6	5.6±0.5	1-2	1.6±0.5	0.02-0.03	0.04±0.005
47	6-3-22	6-9	7.3±1.2	4-6	4.9±0.8	2-3	2.2±0.4	0.02-0.03	0.02±0.004
48	6-3-23	5-7	5.7±0.5	4-5	4.7±0.5	1-2	1.7±0.5	0.04-0.05	0.05±0.005
49	6-3-24	8-10	8.6±0.8	4-6	5.5±0.6	1-2	1.5±0.5	0.02-0.03	0.03±0.005
50	6-3-25	9-12	10.5±1.0	5-7	6.6±0.6	1-2	1.7±0.5	0.03-0.04	0.04±0.005
LSD <sub>005</sub>			0.41		0.28		0.25		0.003

Note: lim – range; M ± SD – mean ± standard deviation; LSD – Least Significant Difference.

seeds of form 5-3-3 (2.6 mm), followed by the group of forms 6-3-22, 5-3-2, and 6-3-2, with seed thickness ranging from 2.2 to 2.1 mm. The largest in fruit weight forms also have the largest seeds. Thus, form 5-3-11 has a significantly higher seed weight (0.056 g), followed by forms 6-3-18 (0.051 g), 6-3-23 (0.047 g), and 6-3-9 (0.043 g), which differ significantly from each other.

**Conclusions.** Under the conditions of the Forest-Steppe zone of Ukraine, morphometric studies of 48 fruit-bearing specimens of *Z. jujuba* were conducted for the first time.

Based on fruit weight, the studied forms were classified as large-fruited (5 forms, fruit weight over 10 g), medium-fruited (15 forms, 5–10 g), small-fruited (21 forms, 3–5 g), and very small-fruited (7 forms, less than 3 g). It was found that form 5-3-11 is the most promising among the collection, as it has the highest average fruit weight (19.3 g) and the greatest pulp proportion (96.3%).

**The variability of all linear parameters of fruits, stones, and seeds – including stone weight – falls within the normal range (CV = 11.2–28.2%), while fruit weight and seed weight show high coefficients of variation (57.5% and 50.0%, respectively), indicating substantial potential for further breeding.**

Large-fruited forms with fruit weight above 10 g, as well as the medium-fruited form 6-3-19 – which, despite its moderate size, has the highest pulp content (96.7%) – are recommended for fresh consumption and processing.

Particularly valuable for future breeding work are the large-fruited forms (as sources of fruit size and high pulp content) and the small- and medium-fruited forms (as sources of rootstocks and high winter hardiness).

The study was carried out within the framework of the program for registering local accessions at the National Center for Plant Genetic Resources of Ukraine.

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**Krasovskiy V.** – research idea, construction of the algorithm of the article, search for information, drafting of the text, correction of the article, conclusions, photo fixation, implementation of the practical part, morphometric measurements;

**Mezhenskyj V.** – statistical research, search for information, drafting of the text, correction of the article;

**Mezhenska L.** – searching for information, drafting of the text, correction of the article;

**Cherniak T.** – search for information, design of the article, implementation of the practical part, morphometric measurements;

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