

UDC 581.4:582.681.41:631.529

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To cite this article: Krasovskyi V., Yehorkina S., Cherniak T., Diachenko-Bohun M., Antonets O. (2024). Morfobiologichni osoblyvosti *Passiflora incarnata* L. za introduktsii v Livoberezhnomu Lisostepu Ukrainy [Morphobiological characteristics of *Passiflora incarnata* L. after its introduction into the Left Bank Forest Steppe of Ukraine]. *Fitoterapiia. Chasopys – Phytotherapy. Journal*, 4, 110–118, doi: <https://doi.org/10.32782/2522-9680-2024-4-110>

MORPHOBIOLOGICAL CHARACTERISTICS OF *PASSIFLORA INCARNATA* L. AFTER ITS INTRODUCTION INTO THE LEFT BANK FOREST STEPPE OF UKRAINE

Actuality. *Passiflora incarnata* L. is a valuable medicinal fruit plant, it is included in the official list in Ukraine because it is used in modern medicine for the preparation of medicines, the inner edible part of the fruit is used in food. Due to its subtropical origin, the species is included in the collection of subtropical plants of the Khorolskyi Botanical Garden as an introducer. An actual issue is testing of *P. incarnata* in the introduction points of the Left Bank Forest Steppe of Ukraine as a fruit plant.

The purpose of the work is search and mobilization of the source material of *P. incarnata*, development of plants for introduction in the conditions of the Left Bank Forest Steppe of Ukraine (introduction point is Khorolskyi Botanical Garden), clarification of morphobiological features and identification of promising samples among them for further selection programs regarding the use of the species as a fruit plant.

Research materials and methods. The object of research was morphobiological features of plants. *P. incarnata* plants growing on the territory of the Khorolskyi Botanical Garden and in the nursery outside its territory were the subject of the research. The research period was 2022–2024. Research methods were botanical and geographical, gradual acclimatization, free-pollination seed sowing, observation under the conditions of introduction, morphometric measurements, photofixation, description.

Research results and their discussion. *P. incarnata* was propagated by sowing seeds that germinated on the 7th day, the first sprouts appeared on the 10th day, mass sprouts appeared on the 17th day. At the stage of three leaves, the plants were dived. Before planting in the soil in the second or third decade of May, the plants had one stem and 5–7 leaves. In the open ground during the growing season, further growth of the vegetative mass of plants took place, namely the development of leaves, elongation and branching of stems, appearance of buds, flowering, fruit formation, ripening of fruits, and death of the above-ground part of plants.

Due to the sufficient temperature regime of the Left Bank Forest-Steppe of Ukraine and precipitation in the form of rain, the vegetative phase of the life cycle of *P. incarnata* was characterized by appearance of strong stems and a large number of green leaves, which is important for photosynthesis, beginning and development of the reproductive phase and transition of plants to a state of rest.

In the process of morphobiological research on plant development, growth of vegetative mass, and fruit quality, 5 samples were selected in 2023 from among 55, in 2024 from among 10 plants whose rhizomes were wintered in the open ground, 7 samples were selected. The berry-like fruits of the selected samples were oval-shaped with a thick dense shell, greenish-yellow outside. Each seed was encased in an edible, jelly-like, juicy aril. According to the results of the assessment of quality indicators, the pulp of the fruits of the selected samples changed from slightly acidic to acidic and had a pleasant specific aroma, characteristic only of the genus *Passiflora*.

Conclusion. Under the conditions of introduction, based on the results of research of the morphobiological features of *P. incarnata* species during 2023-2024, 12 samples were selected, the fruits of which had the largest linear dimensions and mass among those studied. They acquired sufficient ripeness so that their juicy part was suitable for use in food. Selected specimens can be distributed among gardeners as a fruit plant.

Key words: *Passiflora incarnata*, Khorolskyi botanical garden, open ground, cultivation.

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Бібліографічний опис статті: Красовський В., Єгоркіна С., Черняк Т., Дяченко-Богун М., Антонєць О. (2024). Морфобіологічні особливості *Passiflora incarnata* L. за інтродукції у Лівобережному Лісостепу України. *Фітотерапія. Часопис*, 4, 110–118, doi: <https://doi.org/10.32782/2522-9680-2024-4-110>

МОРФОБІОЛОГІЧНІ ОСОБЛИВОСТІ *PASSIFLORA INCARNATA* L. ЗА ІНТРОДУКЦІЇ У ЛІВОБЕРЕЖНОМУ ЛІСОСТЕПУ УКРАЇНИ

Актуальність. *Passiflora incarnata* L. – цінна лікарська плодова рослина, в Україні включена до офіційальних, адже застосовується в сучасній медицині для приготування ліків, внутрішню їстівну частину плодів використовують у харчуванні. Зважаючи на субтропічне походження, вид залучено до колекційного фонду субтропічних рослин Хорольського ботанічного саду як інтродуцент. Актуальним питанням є випробування *P. incarnata* в інтродукційних пунктах Лівобережного Лісостепу України як плодової рослини.

Мета дослідження. Пошук та мобілізація вихідного матеріалу *P. incarnata*, освоєння рослин за інтродукції в умовах Лівобережного Лісостепу України (пункт інтродукції – Хорольський ботанічний сад), з'ясування морфобіологічних особливостей та виявлення серед них перспективних зразків для подальших селекційних програм щодо використання виду як плодової рослини.

Матеріал і методи. Об'єкт дослідження – морфобіологічні особливості рослин. Предметом дослідження були рослини *P. incarnata*, які зростають на території Хорольського ботанічного саду та у розсаднику за межами його території. Період досліджень – 2022–2024 рр. Методи дослідження – ботаніко-географічний, ступеневої акліматизації, висіву насіння вільного запліднення, спостереження в умовах інтродукції, морфометричних вимірювань, фотофіксації, опису.

Результати дослідження. Розмножували *P. incarnata* посівом насіння, яке проростало на сьому добу, перші сходи з'явилися на 10-ту, масові – на 17-ту добу. На стадії трьох листків рослини пікірували. До висадки в ґрунт у другій-третьій декаді

травня рослини мали одне стебло і 5–7 листків. У відкритому ґрунті впродовж вегетаційного періоду відбувалося подальше наростання вегетативної маси рослин, а саме: розвиток листків, подовження і розгалуження стебел, поява пуп'янків, цвітіння, утворення плодів, досягання плодів та відмирання надземної частини рослин.

Завдяки достатньому температурному режиму Лівобережного Лісостепу України та опадам у вигляді дощу вегетативна фаза життєвого циклу *P. incarnata* характеризувалася появою міцних стебел і великої кількості зеленого листя, що важливо для фотосинтезу, початку та розвитку репродуктивної фази та переходу рослин у стан спокою.

У процесі морфобіологічних досліджень за розвитком рослин, наростанням вегетативної маси та якістю плодів у 2023 р. з-поміж 55 відібрано 5 зразків, у 2024 р. з-поміж 10 рослин, кореневища яких зимували у відкритому ґрунті, відібрано 7 зразків. Ягодоподібні плоди відібраних зразків були овальної форми, з товстою щільною оболонкою, зеленувато-жовті зовні. Кожна насінина була обгорнена їстівним желеподібним соковитим арилусом. За результатами оцінки якісних показників м'якуш плодів відібраних зразків змінювався від слабокислого до кислого і мав приємний специфічний аромат, притаманний лише роду *Passiflora*.

Висновок. В умовах інтродукції за результатами досліджень морфобіологічних особливостей виду *P. incarnata* впродовж 2023–2024 рр. відібрано 12 зразків, плоди яких мали більші лінійні розміри та масу серед досліджених. Вони набували достатньої стиглості, щоб їхня соковита частина була придатна для використання у харчуванні. Відібрані зразки можуть бути поширені серед садівників як плодова рослина.

Ключові слова: *Passiflora incarnata*, Хорольський ботанічний сад, відкритий ґрунт, культивування.

Introduction. Actuality. The introduction of plants is an important factor in the ecological optimization of phytocenoses and enrichment of plant resources in general (Rakhmetov, 2017a, pp. 8–24; Klymenko et al., 2012, 34–293). Adaptation of a plant in the process of introduction is an adjustment that manifests itself in a complex manner and serves as the basis for the survival of the species in new conditions of existence. According to the modern definition, the introduction of plants is a complex of methods and techniques for growing plants of natural and cultural flora, which contribute to adaptation processes in areas located outside their geographical, ecological and cultigenic areas (Mezhenskyiet al., 2015, pp. 118–124). The task of introducers is to identify potentially valuable objects for transfer to new geographical areas because in nature there is a significant variety of polycarpic fruit plants, including subtropical ones, which have valuable economic qualities and morphobiological features that distinguish them from other plants and on which their successful introduction can be based.

To enrich the species diversity, the valuable medicinal fruit plant *Passiflora incarnata* L. from the family *Passifloraceae* Juss. was added to the collection fund of subtropical plants of the Khorolskyi Botanical Garden (Krasovskiy et al., 2021, pp. 188–191; Mezhenskyi et al., 2014, pp. 74–76), which is studied as an introduction.

P. incarnata is native to South America, Australia, and Southeast Asia (Janda et al., 2020a, p. 19), has documented therapeutic properties, and has been used medicinally for centuries (Zanardi et al., 2023a, p. 12), it is sufficient studied from a pharmacological point of view (Da Fonseca, et al., 2020a, p. 18). In recent years, research on the species *P. incarnata* has also focused mainly on phytochemistry and pharmacological aspects (Janda et al., 2020b, p. 19; Da Fonseca, et al., 2020b, p. 18; Zanardi et al., 2023b, p. 12; Patel et al., 2009a, pp. 175–181; Michael et al., 2022, pp. 287–292), side effects (Miroddi et al., 2013, pp. 791–801) of preparations from *P. incarnata*, used in the food

industry with high potential use as dietary supplements (Nikolova et al., 2024a, p. 20). The decorative qualities of the plant (Boboc (Oros) et al., 2017, pp. 77–81) and its bioecological and morphological features are rarely studied (Goyal et al., 2019, pp. 1211–1216; Ozarowski et al., 2022, p. 3).

In Ukraine, *P. incarnata* occupies an important place among medicinal plants and belongs to official plants (State Pharmacopoeia of Ukraine, 2023, p. 338). Among the medicinal products obtained from *P. incarnata* raw materials, the pharmaceutical market of Ukraine includes such medicines as Kvait stress relief, Tsefaneiro, Niureksan, Spaskuprel, Novo-pasyt, Sedistres, Bioson, Belisa (State Register of Medicinal Products of Ukraine, 2024).

The inner part of the fruit is used in food (Da Fonseca et al., 2020c, p. 18) and people appreciate it for its unique taste (Stafne, 2022, pp. 919–924). The fruits have a high content of potassium, calcium, magnesium, vitamin C and carotenoids. In addition, the fruits are rich in polyphenols, flavonoids (apigenin and chrysin), amino acids. As for sugars, fruits contain glucose, fructose and sucrose, as for organic acids they contain citric and malic acids (Nikolova et al., 2024b, p. 20). *P. incarnata* contains alkaloids: harmin, harmol, harmalin, harmalol and harman (Da Fonseca et al., 2020d, p. 18)

P. incarnata is a perennial herbaceous liana with large, mostly lilac flowers. The above-ground part of the plant dies off annually, and in the spring it grows from dormant regeneration buds, which are stored on a well-developed rhizome. Such a feature of the species should be considered as an adaptation potential to the unfavorable climatic conditions of the Left Bank Forest Steppe of Ukraine upon introduction because this is what ensures the survival of the species at low winter temperatures.

Since the introduction of new economically valuable species and their reproduction serve as the basis for the preservation and enrichment of phytodiversity, testing of *P. incarnata* in the introduction points of the Left Bank Forest Steppe of Ukraine as a new medicinal and fruit plant is an urgent issue.

The purpose of the work is search and mobilization of the source material of *P. incarnata*, development of plants for introduction in the conditions of the Left Bank Forest Steppe of Ukraine (introduction point is Khorolskyi Botanical Garden), clarification of morphobiological features and identification of promising samples among them for further selection programs regarding the use of the species as a fruit plant.

Research materials and methods. The object of research was morphobiological features of *P. incarnata* plants. The research period was 2022–2024.

The work consisted of the following stages: selection of source material for introduction; mobilization of introductory material; mastering of introductory material in new natural and climatic conditions; selection of the most promising samples according to morphobiological indicators.

In the course of the work, the following introductory, acclimatization, and morphobiological research methods were applied: botanical-geographical, gradual acclimatization, sowing of free-pollinated seeds, observation under the conditions of introduction, morphometric measurements, photofixation, description (Rakhmetov, 2017b, pp. 8–24).

The botanical-geographical method was based on finding the northern limit of the artificial range of *P. incarnata*. In the process of expeditionary search, such an area was discovered in Bukovyna. Therefore, for the introduction of the species in 2022, the source material was collected in Chernivtsi from Dmytro Frunza, a private breeder of this species, by harvesting ripe fruits, extracting seeds from them (fig. 1) and storing them in a dry state until sowing. The species belonging to the obtained material was identified by scientists of the Khorolskyi Botanical Garden based on morphological features and it corresponds to the description of the species (Patel et al., 2009b, pp. 175–181).



Fig. 1. Obtained seeds of *P. incarnata*, 2022.

Using the gradual acclimatization method, which consisted in the gradual transfer of plants from one geographical area to another by sowing seeds, the range of growth of *P. incarnata* was extended from south to north, where the geographical extent was about 170 km.

To grow seedlings and obtain new specimens of the species, the method of mass sowing of free-pollinated seeds was used directly under the conditions of introduction.

Research results and their discussion. *P. incarnata* seeds soaked in warm water for 2 days were sown into a substrate of chernozem and river sand (1:1) to a depth of 3–4 mm. To obtain seedlings, high humidity is necessary, therefore, to create greenhouse conditions, the containers were covered with a transparent polyethylene film and kept under bright diffused light in laboratory conditions at a temperature in the range of 20–25 °C. The seeds germinated on the 7th day (fig. 2), the first sprouts appeared on the 10th day, and mass ones appeared on the 17th day. At the stage of three leaves, when the plants had a height of about 5 cm and a tap root of the same length (fig. 3), they were dived. Before planting in open ground in the second or third decade of May, the plants had one stem and 5–7 leaves (fig. 4).

In the open ground during the growing season, there was a further increase in the vegetative mass of plants, namely development of leaves, elongation and branching of stems, appearance of buds, flowering, fruit formation, ripening of fruits, and death of the above-ground part of plants. Thanks to the sufficient temperature regime and precipitation in the form of rain (data from the Lubensk weather station in 2023, the sum of average daily air temperatures: above + 5 °C – 2419.7; above + 10 °C – 1436.0; precipitation by month, mm: V – 25,3; VI – 37,5; VII – 89,1; VIII – 32,7; IX – 50,5; X – 100,7; XI – 113,4) the vegetative phase of the life cycle of *P. incarnata* was characterized by the appearance of strong stems and a large number of green leaves (fig. 5), which is important for photosynthesis, beginning and development of the reproductive phase and transition of plants to a state of rest. Therefore, it can be stated that during the growing season, the climatic conditions of the Left Bank Forest Steppe of Ukraine ensure the passage of a full cycle of seasonal development of *P. incarnata*. Describing the individual organs of the introducer, it is worth noting that the stems of the plants were smooth, rounded, vine-like with a maximum length of 2.6 m, woody at the base, clinging to the support with tendrils that developed in the axils of the leaves and twisted into a spiral.

The leaves were simple, alternating, placed on the shoot at a distance of 5–10 cm from each other, deeply three-parted with a finely serrated edge, leathery. The

leaf plate was dark on top, bare light green on the bottom, the length varied within 10–18 cm, the width varied within 11–21 cm. Its side lobes were oblong-ovate, thin and sharp-serrate towards the top, the middle part was elongated-ovate, on the ends were slightly pulled back. The petiole of the leaf was 3–6 cm long, rounded below, grooved above, closer to the base of the plate with two flat brown glands. The stipules fell early, very small, dentated, with rounded, shiny green glands at the ends of the jagg (fig. 6).



Fig. 2. Germinated seeds, 2023



Fig. 3. Seedling of *P. incarnata* before diving, 2023



Fig. 4. *P. incarnata* seedlings before planting in open ground, 2023

The plant was entomophilous and cross-pollinated, in the conditions of introduction, the flowers were most often pollinated *Apis mellifera sossimai*, *A. mellifera mellifera*, rarely representatives of the genus *Bombus* Latreille. The first buds appeared in the third decade of July, the plants bloomed from the first decade of August to September. The flowers were regular, bisexual, with a double perianth, 6–8 cm in diameter. There were 5 fused sepals and petals. Pedicels were 5–13 cm long, with small bracts. Sepals were broad-lanceolate, long 2.7–3 cm, 0.8–1 cm wide, green below, pale purple above, leathery, with spiny outgrowths at the top. The

petals were of the same shape as the sepals, delicate, pale purple, with one middle vein. Between the petals and stamens there was a crown consisting of several circles of numerous thread-like outgrowths 2.5–3 cm long. In the center of the flower head there was a long column that carried stamens and pistils. There were 5 stamens with thick dorsoventrally flattened filaments 0.9–1 cm long, to which sac-like anthers were attached by means of an extremely mobile ligament. The ovary was upper, single-nested, pubescent, with three carpels, with three club-like columns ending in large pillow-like receptacles, weakly bipartite at the apex (fig. 7).



Fig. 5. Vegetative growth of *P. incarnata*, 2023



Fig. 6. Leaves of *P. incarnata*, 2023



Fig. 7. Flower of *P. incarnata*, 2023

The berry-like fruits were oval in shape with a thick dense shell, 5.1–8 cm long and 5.0–6.5 cm wide, greenish-yellow, with three nests of black seeds. Each seed was enveloped by an aril with a membranous sac-like sheath. The seed was 0.7–0.8 cm long and 0.38–0.4 cm wide, flat, ovoid, black, with a mesh-cellular surface. The first fruits ripened in the second decade of October,

acquiring a light green color with a yellow tint (fig. 8). Under the conditions of introduction, one annual plant formed up to 7 fruits per season. For their maturation, 5 fruits were left on each plant, which formed first and had intensive development.

In the process of morphobiological research on the development of plants, the growth of vegetative mass and the quality of fruits (they had an early ripening period of fruits, their largest linear dimensions, weight, a significant number of seeds), 5 samples were selected from among 55, the fruits of which are shown in fig. 9, and their morphometric indicators are given in Table. 1.



Fig. 8. Fruiting of *P. incarnata*, 2023

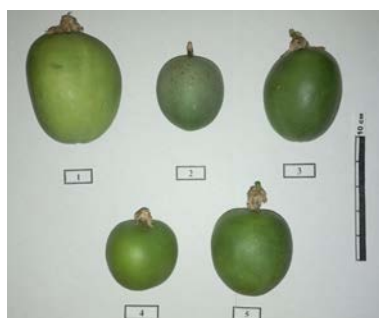


Fig. 9. Fruits of selected samples of *P. incarnata*, 2023

At the end of the growing season, 45 of the 55 studied samples were transferred to the basement for the winter period as annual rhizomes (one of which is shown in fig. 10), the other 10 samples wintered in the open

ground. As an agrotechnical method of protecting them from freezing, insulating material was used in the form of foam plates measuring 100x50x3 cm - one for each plant. In the spring of 2024, the plants that overwintered in the open ground started vegetation in the third decade of April - the first decade of May. Planted rhizomes from the basement into the soil vegetated in the second-third decade of May and slowly increased the vegetative mass.



Fig. 10. Rhizome of the annual plant of *P. incarnata* before planting in the soil in 2024

7 samples were selected from among 10 plants that overwintered in open ground with insulation of the rhizomes, the general appearance of the fruits of which is shown in fig. 11, and their cross-sectional view in fig. 12. Morphometric indicators are given in table 2.



Fig. 11. Fruits of selected samples of *P. incarnata*, 2024

Table 1

Morphometric indicators of the fruits of the selected samples, 2023

Sample No	Dimensions		Weight of the fruit, g	Seed weight, g	The number of seeds in the fruit, pcs.
	Length, cm	Width, cm			
1-23	8.0±0.11	6.5±0.071	55.5±1.72	0.3	63±3.74
2-23	6.8±0.089	5.5±0.105	27.6±0.51	0.4	66±2.83
3-23	5.5±0.10	5.0±0.071	17.8±0.20	0.6	56±3.29
4-23	5.1±0.032	5.1±0.045	21.5±0.5	0.4	32±1.41
5-23	6.3±0.089	6.2±0.114	47.6±1.91	0.5	81±3.49

Morphometric indicators of the fruits of the selected samples, 2024

Sample	Dimensions		Weight of the fruit, g	Weight of seeds (10 pcs.), g	The number of seeds in the fruit, pcs.
	Length, cm	Width, cm			
1-24	5.8±0.071	6.1±0.221	27.0±1.58	0.29	70±3.16
2-24	6.1±0.045	5.4±0.063	31.9±0.84	0.24	99±0.7
3-24	6.4±0.114	5.3±0.092	36.5±1.25	0.35	48±7.58
4-24	5.8±0.212	5.2±0.127	24.9±1.27	0.26	74±1.41
5-24	5.6±0.118	4.5±0.058	23.7±0.406	0.27	62±1.35
6-24	4.7±0.114	4.9±0.12	20.8±0.465	0.26	53±1.52
7-24	5.2±0.089	4.8±0.103	20.6±0.51	0.27	48±2.28



Fig. 12. Fruits of selected samples of *P. incarnata*, half cut fruits, 2024

According to the data of the Lubensk weather station, the absolute minimum air temperature recorded during the winter of 2023-2024 was on January 8 with a mark of minus 13.9 °C. Over the last decade, the lowest

temperature was recorded on January 30, 2014, minus 22.8 °C. When planning agrotechnical measures for plant protection, the amplitude of fluctuations in minus air temperatures is taken into account.

According to the results of the assessment of quality indicators, the pulp of the selected samples changed from slightly acidic to acidic. Also, the fruits of these samples were distinguished by a very pleasant specific aroma, characteristic only of the *Passiflora* genus. The pulp was consumed fresh, added to ice cream and drinking water as a flavoring.

Conclusions

Under the conditions of introduction, based on the results of research into the morphobiological features of the *P. incarnata* species during 2023-2024, 12 samples were selected, the fruits of which had the largest linear dimensions and mass among those studied. They acquired sufficient ripeness so that their juicy part was suitable for use in food. Selected specimens can be distributed among gardeners as a fruit plant.

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Стаття надійшла до редакції 25.06.2024.

Стаття прийнята до друку 24.10.2024.

The authors declare no conflict of interest.

Contribution of the authors:

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Yehorkina S.O. – implementation of the practical part of research, photo fixation, morphometric measurements;

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