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DISTRIBUTION AND BIOLOGICAL FEATURES OF *PAEONIA ANOMALA* (PAEONIACEAE) ONTOGENESIS IN KAZAKHSTAN

The article presents data on the distribution and biological features of the ontogenetic states of *Paeonia anomala* L. on the territory of Kazakhstan. The distribution of the species was established according to field research, observations, literature and materials of herbarium collections: MW, NUR and AA. The age of the plants was determined by the annual layers on the rhizomes of *P. anomala*. According to the data obtained, the main distribution area of *P. anomala* in Kazakhstan is located within the East Kazakhstan region, in the Katon-Karagai, Kurchum, Shemonaikha, Ulan and Zyryanovsky administrative districts. It is much less common in the Zhambyl and Almaty regions, the south-western border of the general distribution area of the species passes in these regions. Our studies have not confirmed the growth of *P. anomala* on the territory of the Kokchetav upland of the Kazakh small-grassland. The results of the research made it possible to establish in the ontogenesis of *P. anomala* L. 9 age-related conditions: latent state, seedlings, juvenile, immature, virginal, young generative, mature generative, old generative and senile. Life span of *P. anomala* in East Kazakhstan is 55–70 years old, sometimes more. In populations confined to the Subalpine belt and sparse forest cenoses, age spectra with an absolute maximum of the age cycle are characteristic.

Key words: *Paeonia anomala*, population, ontogenetic structure, age composition.

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¹Қазақстан Республикасы экология және табиғи ресурстар министрлігі орман шаруашылығы
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Қазақстандағы *Paeonia anomala* (Рaeониaceae) онтогенезінің таралуы және биологиялық ерекшеліктері

Мақалада Қазақстан аумағында *Paeonia anomala* L. өсімдігінің таралуы, онтогенетикалық жағдайлары мен биологиялық ерекшеліктер туралы деректер келтірілген. Түрдің таралу аймағы далалық зерттеулер, бақылаулар, әдебиеттер мен MW, NUR, AA гербарий коллекцияларының материалдары негізінде белгіленді. Өсімдіктердің жасы *P. anomala* тамырсабақтарындағы біржылдық қабаттармен анықталды. Алынған мәліметтерге сәйкес, Қазақстандағы *P. anomala* өсімдігінің негізгі таралуы аймағы Шығыс Қазақстан облысы, Катонқарағай, Күршім, Шемонаиха, Ұлан және Зырян әкімшілік аудандарында орналасқан. Түр Жамбыл және Алматы облыстарында әлдеқайда сирек кездеседі, бұл аймақтарда түрдің жалпы таралу аймағының оңтүстік-батыс шекарасы өтеді. Біздің зерттеулеріміз Қазақтың ұсақ шоқыларының Көкшетау тауының аумағында *P. Anomala* өскетіндігін растамады. Зерттеу нәтижелері *P. anomala* L. онтогенезінде 9: латенттік (жасырын), өскін, ювенильдік, имматурлық, виргинильдік, жас генеративтік, жетілген генеративтік, қартайған генеративтік, сенильдік тіршілік күйлерін анықтауға мүмкіндік берді.

Шығыс Қазақстандағы *P. anomala* өсімдігінің тіршілік ету ұзақтығы 55-70 жыл, кейде одан да көп. Субальпілік белдеумен және сирек орман ценоздарымен шектелген популяциялар жас циклінің абсолютті максимумымен жас спектрлерімен сипатталады.

Түйін сөздер: *Paemonia anomala*, популяция, онтогенетикалық құрылымы, жастық құрамы.

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Распространение и биологические особенности онтогенеза *Paemonia Anomala* (Paeoniaceae) в Казахстане

В статье приводятся данные по распространению и биологическим особенностям онтогенетических состояний *Paemonia anomala* L. на территории Казахстана. Распространение вида установлено по данным полевых исследований, наблюдений, литературы и материалам гербарных коллекций: MW, NUR и AA. Возраст растений определяли по годичным слоям на корневищах *P. anomala*. Согласно полученным данным, основной ареал распространения *P. anomala* в Казахстане находится в пределах Восточно-Казахстанской области, в Катон-Карагайском, Курчумской, Шемонаихинском, Уланском и Зыряновском административных районах. Значительно реже вид встречается в Жамбылской и Алматинской областей, в этих регионах проходит юго-западная граница общего ареала распространения вида. Наши исследования не подтвердили произрастание *P. anomala* на территории Кокчетавской возвышенности Казахского мелкосопочника. Результаты исследований позволили установить в онтогенезе *P. anomala* L. 9 возрастных состояний: латентное состояние, проростки, ювенильные, имматурные, виргинильные, молодые генеративные, зрелые генеративные, старые генеративные и сенильные. Продолжительность жизни *P. anomala* в Восточном Казахстане составляет 55–70 лет, иногда и более. В популяциях, приуроченных к субальпийскому поясу и по разреженным лесным ценозам характерны возрастные спектры с абсолютным максимумом возрастного цикла.

Ключевые слова: *Paemonia anomala*, популяция, онтогенетическая структура, возрастной состав.

Introduction

Paemonia anomala L. is a mesophyte, widespread in the northern hemisphere, from the European part of Russia to Mongolia and China. It's one of the most valuable medicinal and ornamental plants of the flora of Kazakhstan. Its roots and grass are used for the manufacture of many phytopreparations with sedative, analgesic, tonic, antitumor, antiviral, immunomodulatory, antioxidant effects [1-3]. The species is included in the Red Book of Kazakhstan (2014) (IV category of protection) [4]. The main limiting factors of the rarity of the species in Kazakhstan are the collection of flowers for bouquets, logging, grazing and harvesting of peony roots as medicinal raw materials. In order to preserve the species, it is necessary to develop effective methods of vegetative and seed propagation and plantation cultivation of the species in culture, and to strengthen protection measures in places where peony grows. Prohibit the harvesting of peony rhizomes and flowers [5-6].

Paemonia anomala is a herbaceous perennial 40-80 cm high, roots spindle thickened from the stem itself. The stems are bare, with scaled lower and twice palmed upper leaves, with shares deeply triple or peristo-dissected into lancetic elongated lobes of the second order. The flowers are purple, 8-15 cm in diameter, the petals are silky, the seeds are black. In Kazakhstan, it is found in the following floristic areas: 4. Se-myp. Bor., 5. Kokchet., 6. Kassp. (Zavol-region), 12. Zais., 22. Altay, 23. Tarb., 24. Jung. Alat., 25. Zail. Alat., 25a. Ketm. Ters. Alat. 27. Kirg. Alat., 29. Zap. TS [7]. The species grows in dark-coniferous, mixed forests, on the steep forest and shrub slopes of the northern exposition, overgrown kurumas, bottoms of interorne lairs, river valleys, on high-grass meadows and forest lowlands. The species blooms in May-June, bears fruit in July-August [8].

Paemonia anomala is known throughout the world as one of the most valuable plants due to its ornamental and medicinal properties. The roots of *Paemonia anomala* contain various beneficial

chemical compounds, including: paeoniflorin [9], glycoiridoid (paeoniflorin, albiflorin, etc.), glucosides [10-11], ellagic acid, phenols, tannins, flavonoids, saponins [12], peonovycinoside (methyl salicylate 6'- α -L-arabino-pyranosyl- β -D-glucopyranoside), β -sitosterol, gallic acid, methyl ester [13]. Peony roots are used to treat many therapeutic conditions, including: kidney disease, bleeding disorders, indigestion, nocturnal enuresis, bleeding, exhaustion and respiratory diseases [14], gynecological diseases, and bladder inflammation [15-16]. Has antitumor, antiviral, cardiovascular, immunomodulatory [10, 17-19], antioxidant [20-21] action.

There are quite a lot of publications in the literature on the study of the phytochemical composition, medicinal properties of *Paeonia anomala*. However, the biological features of the species and its distribution in Kazakhstan remain insufficiently studied. Therefore, the purpose of this work is to study the biological features of the ontogenetic states and the spread of the dodging peony in Kazakhstan.

This research is a continuation and addition to the study of *Paeonia anomala* in Kazakhstan, which began in 2019 [6]. Previously, a comprehensive analysis of the current state of *Paeonia anomala* populations in Eastern Kazakhstan and an assessment of its genetic biodiversity, as well as floristic, anatomical-morphological and ecological-phylogenetic characteristics of habitats were carried out.

Materials and methods

Research was carried out from 2019 to 2023 in the East Kazakhstan region, on the Ivanov Ridge, in the valley of the Bolshaya Poperechka River, in the Seriy Lug tract. Populations of *Paeonia anomala* in the Seriy Lug tract are less susceptible to anthropogenic impact and are represented by all age conditions. This was the reason for choosing this site to study the ontogeny of *Paeonia anomala*. The ontogenetic state characterizes the biology of the development of a species in different age states, ranging from seedlings to the senile state.

The distribution of *Paeonia anomala* on the territory of Kazakhstan was determined on the basis of field studies, literature and materials from herbarium collections of Moscow State University (MW), Astana Botanical Garden (NUR), Institute of Botany and Phytointroduction (AA). In addition, the observation data on the sites was taken into account (<https://www.inaturalist.org/>, [\[plantarium.ru/\]\(https://www.plantarium.ru/\)\). The distribution map of *P. anomala* in Kazakhstan was made in ArcMap \[22\].](https://www.</p>
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Studies of the age-related conditions of *P. anomala* were carried out according to the methodology proposed by Rabotnov (1964) and Smirnova (1976) [23-24]. The following classification of age groups was used in the description: seedlings (p), juvenile (j), immature (im), virginal (v), young generative (g_1), mature generative (g_2), old generative (g_3), aging individuals (ai).

The age of individuals was determined by annual layers on the rhizomes of *P. anomala*. In any community, as a rule, all species are represented by numerous individuals of different ages, from seedlings to old plants. The accuracy of age determination increases with an increase in the number of studied individuals. We have determined the age of 80 individuals from different populations.

Results and discussion

According to the results of the conducted studies, it was found that the main distribution area of *Paeonia anomala* in Kazakhstan is located within the East Kazakhstan region, in the Katon-Karagai, Kurchum, Ulan and Zyryanovsky administrative districts (Figure 1). The species is much less common in the Zhambyl and Almaty regions, in these regions the south-western border of the general distribution area of the species passes. In the old literary sources Gorchakovsky (1987) [25] there is an indication *P. anomala* is located on the Kokchetav upland of the Kazakh melkosopchnik, however, more modern reports (Kupriyanov, 2020) [26] do not confirm this location. Our special expeditions also did not confirm the location of *P. anomala* in the Kazakh upland. The places of growth of this species on the territory of Kazakhstan in the following floristic areas have been identified: 22. Altai, 23a. Saur, 24. Jung. Alat., 27. Kirg. Alat.

The main data on the study of the distribution of the species were herbarium materials (39 locations) and observations (9 locations), a small number of locations were identified from literary sources (2 locations), which indicates a weak study of the distribution of the species in Kazakhstan.

ALTAI. East Kazakhstan Region: Sarymsakty ridge: Katon-Karagay district, lower north slope of Sarimsakty Range between Chingistai and Enbek (Km 85/29) montane meadows with scattered *Larix sibirica*, H=1100-1000 m. (49°09'09"N, 085°59'07"E), 02 AUG 1995, Solomon (MO20323); Katon-Karagai district, mixed grass meadow steppe, northern slopes of

Sarymsak Mountain, 26 JUN 1936, Elenevsky s.n. (MW0063897); near Katon-Karagai, northern slope, shrubby thickets, 1400 m above sea level, 17 JUN 1936, Elenevsky s.n. (MW0063898); at the foot of the Katon-Karagai Mountains, north slope 1.5 km from Katon-Karagai to the south, 26 JUN 1936, Skobelev s.n. (MW0063899); Katon-Karagai district, 1.5 km from the village of Altaisky, thickets of shrubs on the slope of the north-eastern exposure, 1100 m above sea level, 5 AUG 1932, Voronov s.n. (MW0063902); south-eastern slope, valley of the Tekeli river, forest 1600 m above sea level, 2 AUG 1985, Bialieva s.n. (AA); **Narymsky ridge**: vicinity of the village of Cherdoyak, aspen-birch forests, flood meadows, 14 JUN 1986, Bidullaeva s.n. (AA); Terekty gorge, north-eastern rocky slope. 1250 – 1750 m above sea level, 4 AUG 1987, Bidullaeva s.n. (AA); Orta - Terekty gorge, on the floodplain of the river Orta-Terekty, 5 AUG 1987, Bidullaeva s.n. (AA); **Southern Altai ridge**: Chindagatui: the upper reaches of the 1st camp, south-west. slope in the coniferous forest, 1820 m., 28 JUL 1986, Ivashenko s.n. (AA); **Tarbagatai ridge**: vicinity of the Archaty outpost, left bank of the Bukhtarma river, birch-coniferous forest, 1250 m above sea level, 23 JUL 1987, Ivashenko s.n. (AA); southern slope of the mountain, Kara-Kaba depression, 1000 – 2100 m above sea level, 2 JUL 1987, Ivashenko s.n. (AA); **Kalbinsky ridge**: Sibinsky lakes, closer to Sadyrkol Lake, (49°27'14.9"N 82°34'50.6"E), 10 MAY 2021, O. Blazhko <https://www.inaturalist.org/photos/127988857>; vicinity of the village of Kasym Kaysenova (Molodezhnoe) (49°51'28"N, 82°34'30"E), 1 MAY 2021, Serfus <https://www.inaturalist.org/photos/124654983>; Sibinsky Lakes, 29 JUN 1975, Klyuykov (MW0063901); eastern part of the Kalbinsky ridge, 10 km southeast of Asubulak village (49°31'38"N, 83°05'16"E) V.D., 1196 m above sea level (Kubentaev et al., 2019); **Southern Altai ridge**: 3 km east of the Pronikha river, steppe 1300-1400 m. above sea level, 27 JUL 1987, Ivatshenko s.n. (AA); **Kurchumsky ridge**: Markakol, left bank of the river Tikhushki, lower course, meadows in the forest belt 1800-1700 m above sea level (48°47'31"N, 85°59'57"E), 7 JUL 1987, Ivashenko s.n. (AA); **Azutau ridge**: mountain slopes along the road NE of Alexejevka (48°29'05" N, E85°52'33"E), 13 JUN 1993, Karis (S08-13633); territory of the Markakolsky Reserve, forest edge (48°47'00"N, 86°01'40.0"E), 3 AUG 2008 (Glazunova, 2008); **Ivanovsky ridge**: Glubokovsky district, the vicinity of the village of Tarkhanka, southern slope of the hill (50°06'35.3"N 82°58'00.1"E), 25 APR 2017 (Rib, 2007a); Ridder

city, the vicinity of the Maloulba reservoir, edge of fir forest 50°11'56.0"N 83°48'36.6"E 30 JUL 2008 (Rib, 2017b); Ivanovsky belok (50°19'36.9"N 83°53'38.2"E), 18 JUL 2020, O. Blazhko <https://www.inaturalist.org/photos/86541775>; Riddersky district, ridge to the west of Krestovaya, 1 JUL 1937, Kuznetsov s.n. (AA); northwest of Ridder, on the mountain slope opposite the Kalmyk Key, among the tall grass, 26 JUL 1947, Poljakov s.n. (AA); Ridder district, Ivanovsky belok to the west of Krestovaya Mountain, 1 JUL 1937, Kubanskaya s.n. (AA); Ridder, log. of the Khorizovka River 26 JUN 1936 Kubanskaja s.n. (AA); **Ulbinsky ridge**: near the village of Gorno - Ulbinki, in fir forests, 23 JUL 1960 Roldugin s.n. (AA); **Lininsky ridge**: West Altai Reserve; the vicinity of the Linisky pass, 1600 m above sea level, mixed forest 30 JUN 2019 (Kolbintzev, 2019a); **Listvyaga ridge**: Rakhmanov spring, the right bank of Lake Rakhmanovskoye, 1760 m above sea level, edge of the dark coniferous forest 24 JUN 2019 (Kolbintzev, 2019b); **Saur ridge**: Kendyrlyk river, upper. Maychat river 20 JUL 1967 Stepanova s.n. (AA); Akzhal Mountain, Ak-Kalke river gorge, 19 JUN 1967, Stepanova s.n. (AA); DZUNGARIAN ALATAU: Almaty region: **Dzungarian Alatau ridge**: valley of the Karagaily river, along meadow slopes, 18 MAY 1959 Goloskokov s.n. (AA); Sarkandsky district, 112 km from the village of Shilinash in the station Zhasyl-kol, 07 JUL1991, Bajmuhamedova s.n. (AA); ZAILIYSKY ALATAU: north-eastern slopes of the foothills. 1975 Filatov s.n. (AA); KYRGYZ RANGE: Dzhambul region: hr. Kyrgyz: Karaarcha Gorge, the middle part of the gorge of the northern slope, 29 MAY 1984, Nelina s.n. (AA); northern gorges of the Kainda site, damp slopes, among birches, 31 MAY 1961, Gamajuniva s.n. (AA); Central Asia: mountains near Merke (42°46'34"N 73°13'40"E), 23 APR 1895, Chaffanjon (MNH P00200491).

The ontogenetic states of *P. anomala* were studied on the Ivanov Ridge, in the valley of the Bolshaya Poperechka River, in the Seriy Lug tract. The species in the surveyed territory reproduces mainly by seed, but in some places vegetative reproduction is noted due to the division of rhizomes.

The results of the research allowed us to establish 9 age-related states in the ontogenesis of *P. anomala* (latent state, seedlings, juvenile, immature, virginal, young generative, mature generative, old generative and senile) (Fig. 1). The life expectancy of *P. anomala* is 55-70 years, sometimes more. The duration of the life cycle depends on the ecology of the habitat. In populations confined

to the Subalpine belt and sparse forest cenoses, age spectra with an absolute maximum of the age cycle are characteristic. Populations in thickened forest and shrubby habitats on the southern slopes

are in unfavorable environmental conditions for the species and are characterized by a minimum age cycle. Below is a description of all age-related conditions of *P. anomala*.

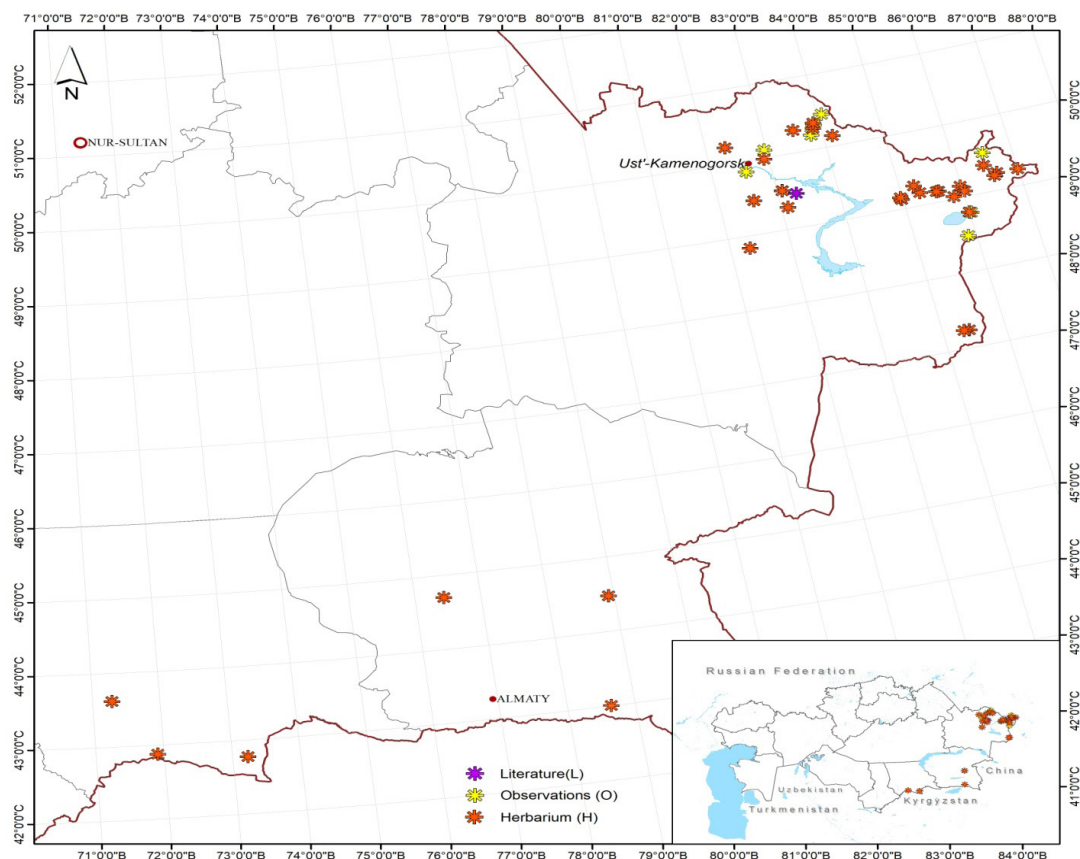


Figure 1 – Scheme map of the distribution of the *P. anomala* in East Kazakhstan
(Scheme map was obtained by ArcGIS)

1. *Latent state* (primary dormancy period) This period is represented by dormant seeds. Freshly harvested seeds are characterized by deep physiological rest. The seeds are large, rounded, and have a relatively large embryo. The shape of the seeds is ovoid, sometimes barrel-shaped, with dents in the lateral part. The surface of the seeds is bare, smooth. The color of the seeds is burgundy-black. Seed length: 7.06 ± 0.17 mm, width: 5.58 ± 0.36 mm, thickness: 3.99 ± 0.19 mm. The weight of 1000 pieces of seeds is 83.9 ± 1.36 g. Their germination requires variable temperature and prolonged stratification. Freshly harvested seeds germinate during the year by 75%. Seeds after a year of storage germinate in two years by 50%.

2. *Sprouts*. Seed germination is underground, usually at the end of May – at the beginning of

June. Cotyledons are crumpled, enclosed in a peel, pale green or with a faint pinkish tinge, elliptical in shape. Cotyledon plate length: 7.56 ± 0.09 mm, width: 6.25 ± 0.04 mm. The hypocotyl is short 5.28 ± 0.12 mm, the main root has a length of 2.85 ± 0.02 cm, with two or three lateral branches. The condition of the seedling lasts for two to three months.

3. *Juvenile* (Fig. 2 (j)). In July-August of the first growing season, individuals enter the juvenile phase. In this state, they exist for two or three growing seasons. This condition is characterized by one shortened shoot with 3-4 scaly leaves at the base and one triple leaf on a petiole about 6.25 ± 0.04 cm long. The leaves have whole or incised lobes at the top. The length of the leaf blade: 5.35 ± 0.06 cm, width: 8.59 ± 0.12 cm. Their underground part is characterized by the presence of a significantly

thickened main root (0.4 ± 0.06 cm) with a length of 14.5 ± 0.21 cm.

4. *Immature*. (Fig. 2 (im)). Individuals enter the immature state from the age of two to 3 years. They are characterized by a single shoot 9.6 ± 0.14 cm long, with 2-3 dissected leaves. The size of the leaf blade in diameter is 12.9 ± 0.24 cm. In the underground parts of these plants there is a sympodially growing rhizome and the main root is preserved, which deepens into the ground up to 22.6 ± 1.95 cm. The rhizome has 1-2 rarely 3 branches.

5. *Virginal* (Fig. 2 (v)). The species enters the virginal state in nature at the age of 3-4 years and is in this state up to 8-10 years. Individuals are characterized by the presence of one or two leafy shoots 44.65 ± 3.95 cm long with three or four double-triple assimilating leaves. The length of the leaf blade segment is 16.32 ± 1.87 cm, width – 19.8 ± 1.36 cm, petiole length – 7.1 ± 0.06 cm. There are 4-6 scaly leaves at the base of the renewal shoot. The underground organ is represented by a short, slightly branched, thickened (1.32 ± 0.06 cm) rhizome with small fusiform adventitious roots.

6. *Young generative* (Fig. 2(g1)). In this state, plants have a short rhizome, on which 1-2 sometimes up to three shoots with a terminal flower and one or two vegetative shoots are formed. The plant enters the young generative state at the age of 8-10 years and remains in this state until 20-22 years. The generative shoot is elongated, leafy has $6.25 \pm$

1.21 pcs of assimilating leaves. The main root is preserved, but it gradually merges with numerous subordinate roots. The roots thicken strongly, acquiring a fusiform shape.

7. *Middle-aged generative* (Fig. 2 (g2)). In this state, plants from 20-22 to 40 years old are marked. These are large tall (117.6 ± 2.94 cm) plants forming a loose bush consisting of 3-5 generative and 1-2 vegetative shoots. Leaves on long petioles, triple-dissected with lanceolate segments 24.4 ± 0.63 cm long, 31.9 ± 0.58 cm wide. The flowers are large 11.3 ± 1.94 cm in diameter, single, pink-red. The rhizome is large, repeatedly branched, with a large number of renewal buds.

8. *The old generative ones* (Fig. 2 (g3)). In old generative individuals, the rhizome is largely destroyed, the number of generative shoots decreases. Individuals in this condition have been recorded at the age of 40-55 years. The main root is missing. Appendage fusiform-thickened roots are well developed.

9. *Senile individuals* (Fig. 2 (ai)). Senile individuals were recorded at the age of 55-70 years. They are isolated articles with a small number of renewal buds, do not have generative shoots. Vegetative shoots are poorly developed, stunted, among several or numerous. The underground part is severely destroyed, the number of renewal buds is noticeably reduced.

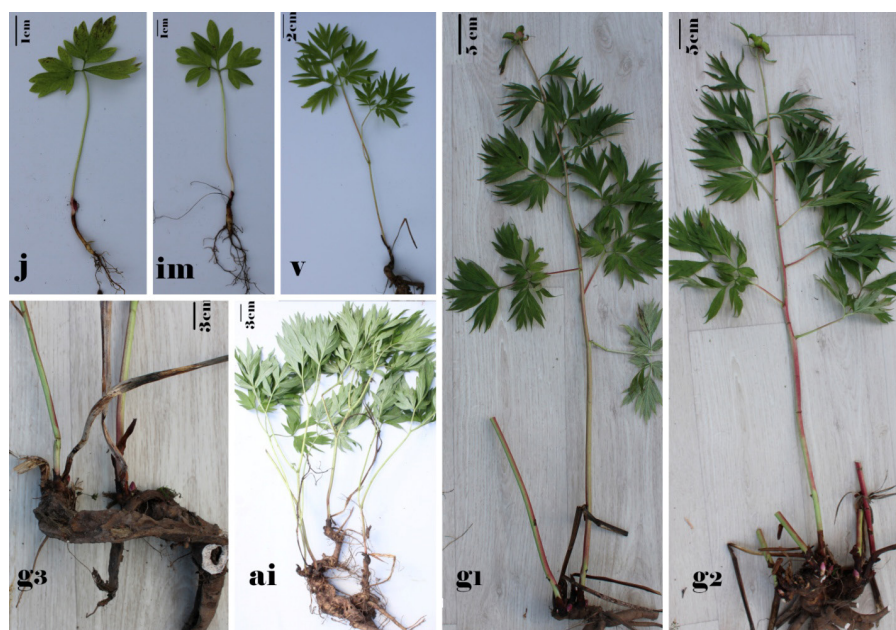


Figure 2 – Ontogenetic state *P. anomala*: j – juvenile; im – immature, v – virginile, g1 – young generative, g₂ – mature generative; g₃ – old generative; ai – ageing individuals (photo by S. Kubentayev).

Conclusion

It has been established that the main distribution area of *Paeonia anomala* in Kazakhstan is located within the East Kazakhstan region, in the Katon-Karagai, Kurchum, Ulan and Zyryanovsky administrative districts. The species is much less common in the Zhambyl and Almaty regions, in these regions the south-western border of the general distribution area of the species passes. Our studies have not confirmed the growth of *P. anomala* on the territory of the Kokchetav upland of the Kazakh small-grassland. The results of the research made it possible to establish in the ontogenesis of *P. anomala* L. 9 age-related conditions: latent state, seedlings, juvenile, immature, virginal, young generative, mature generative, old generative and senile. The life expectancy of *P. anomala* in Eastern Kazakhstan is 55-70 years, sometimes more, depends on the habitat ecology. In populations confined to the Subalpine belt and sparse forest cenoses, age

spectra with an absolute maximum of the age cycle are characteristic. Populations in thickened forest and shrubby habitats on the southern slopes are in unfavorable environmental conditions for the species and are characterized by a minimum age cycle.

It is necessary to continue further research to identify new locations of the species, control and monitor the state of populations, as well as to study the number of species in order to develop and improve measures aimed at ensuring the safety and reproduction of the dodging peony.

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