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Biomorphological analysis and developmental features of two short-lived plants: Stachys annua (L.) L. and Clinopodium acinos (L.) Kuntze

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Abstract. To clarify life form, ontogeny and features shoot formation of individuals *Stachys annua* and *Clinopodium acinos* were studied. It was found that the duration ontogeny of species is determined by rate of development shoot of an individual. It was found that both species bloom in the first year, however, individuals of *S. annua*, having reached their maximum growth, completely die off at the end of the first growing season. Accelerated development of *S. annua* individuals leads to the formation of powerful synflorescence and inhibition development unrealized buds of basal part shoot. In contrast to *S. annua*, ontogeny of *C. acinos* individuals is long (5–6 years). The slowed down development rate of the *C. acinos* shoot leads formation of a weak generative sphere and development of innovation zone consisting of 1–2 metameres with functionally developed naked buds. The performed biomorphological analysis allows us to classify *S. annua* as typical annual monocarpic, *C. acinos* as oligocarpic, belonging to the *sensu lato* short-lived plants group.

The comparative ecological and morphological method in the plant studies allows us to establish their life form, which serves as the basis for solving various problems in botany and ecology. In contrast to perennial plants, species united in the group of short-lived plants are less studied and arouse certain interest related to their development, structure, and evolution [1]. The structural and morphological analysis of the biomorph, including the assessment of the vegetative–generative sphere and the peculiarities of shoot formation, which determine the multiplicity of fruiting in short-lived plants, makes it possible for researchers to reasonably classify them in the appropriate group. Our work is aimed at studying two short-lived plants of *Stachys annua* (L.) L. and *Clinopodium acinos* (L.) Kuntze species, which, according to different literature data, have a controversial biomorphological portrait. The our study specifies the belonging of the these species to the group of short-lived plants *sensu stricto* and *sensu lato*.

S. annua, *C. acinos* are herbaceous species from *Lamiaceae* family. These are Eurasian species with similar range: Europe, Mediterranean, Asia Minor, Caucasus, North America (invasive). In Russia, species are found in European part, in Western Siberia and in Far East

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as invasive species [2–5]. Both species belong to the weed-steppe coenotic group confined to steppe biotopes [6, 7]. *S. annua* is more often a part of segetal vegetation agrophytocenoses, *C. acinos* is more related to synatropic plants [6, 8, 9]. In the floral reports, *C. acinos* is defined as a one-, or two-year-old species, *S. annua* is an annual species [2–5]. There are indications that these species can bloom for several years in number of works [10–13]. The aim of the work is to find out features of development and morphological signs that determine duration of ontogeny and multiplicity of flowering *S. annua* and *C. acinos*.

Material was collected in Altai Territory on fallow in Charysh district near Ust-Belaya village (*S. annua*) and on an overgrown deposit near Krasnoshchekovo village (*C. acinos*). *S. annua* grows along edge of fallow, on side of country road as part weed vegetation (*Setaria viridis* (L.) P. Beauv., *Elymus repens* (L.) Gould, *Erodium cicutarium* (L.) L'Hér., *Cirsium arvense* (L.) Scop. and etc.). *C. acinos* is part of settled plant community in an abandoned field. The community is in state of demutation succession. Total projective grass cover is 60%: grasses – 30%, forbs – 30–40%. Grasses are represented by *Elymus repens* (L.) Gould, *Calamagrostis epigejos* (L.) Roth, *Phleum pratense* L., *Bromus inermis* Leyss., *Stipa sibirica* (L.) Lam. The forbs contain *Salvia dumetorum* Andrz. ex Besser, *Trifolium lupinaster* L., *Galium verum* L., *Melilotus officinalis* (L.) Lam., *Medicago falcata* L., *Bupleurum multinerve* DC. The individual development was studied using the concept of a discrete course of ontogeny [14]. To compare the development of these species, 20–25 flowering plants were measured. Obtained values of biomorphological parameters were processed statistically in the Excel software package. The significance of differences in the individual parameters from different habitats was determined using the Student's t-test [15]. All values are significantly different at the 5% significance level.

S. annua and *C. acinos* are tap-root plants with an elongated shoot. *S. annua* is a single-shoot plants, two shoots rarely develop with early death apical bud of main shoot. The primary shoot is elongated, branching up to the third order. Shoots of all orders end with an inflorescence. The floral unit is thyrsus from dichazia. The aboveground part of *C. acinos* is represented by one or more elongated shoots branched up to second order. Lateral shoots are often rosette, if elongated, then noticeably shorter than main shoot. The elongated main and lateral shoots end in an open thyrsus. The ontogeny of *S. annua* and *C. acinos* belongs to the A-type, which is characterized by absence postgenerative period [16]. Reproduction occurs only by seed. The ontogeny of these species differs only in their duration [12, 13]. In the first year, *S. annua* individuals reach generative state and maximum development, and they completely die off at the end growing season. Individual of *C. acinos* blooms in the first year life (g_1), but reaches its maximum development (g_2) in subsequent years. The *C. acinos* ontogeny lasts 5–6 years. It is known that the emergence of new shoots is possible only in presence viable buds that form in the basal part of shoot. Therefore, it is necessary to study development of axillary buds on plant shoots during ontogeny (Figure 1).

Ontogenesis of *S. annua* is characterized by high growth rates, especially during the transition to flowering. A juvenile plant (j) develops a shoot of 2 short metameres (with cotyledons and first pair of true leaves). Shoot growth up to 2–3 cm occurs due to elongation of the 3–4th metameres (im). At this moment, naked buds appear in the axils of all leaves, they consist of one pair of primordia. Differentiation of leaf primordia in them increases from bottom to top with the same bud capacity; cotyledon buds least developed. A shoot of 5–8 metameres has an ambiparous apical bud. On shoot axillary buds increase their capacity to two metameres, except for buds in lower part – in cotyledon axils and first pair of true leaves. Active sylliptic branching shoot is observed simultaneously with appearance the first flowers in apex main shoot (at the 6–9th metameres). From 3rd to 8th metameres, lateral shoots of second order (paracladia) begin to form, the largest on 5–6th

metameres. Then there is a simultaneous growth of shoots all orders, later shoots third order are formed.

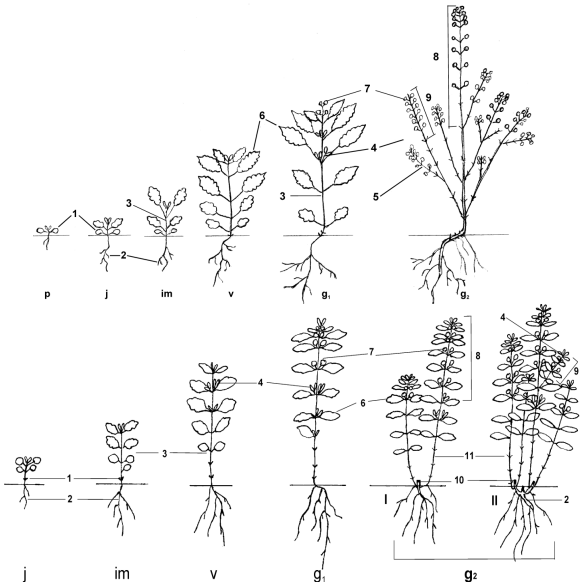

Fig. 1. Ontogenesis of *Stachys annua* (top) and *Clinopodium acinos* individuals (bottom).

Legend: 1 – cotyledon leaves; 2 – main root; 3 – primary shoot; 4 – sylleptic shoot II order; 5 – sylleptic shoot III order; 6 – adult leaf; 7 – dichasium; 8 – thyrsus 1st order; 9 – thyrsus 2nd order; 10 – dead shoot; 11 – proleptic shoot (renewal); I – an individual second year life; II – perennial individual; $p - g_2$ – ontogenetic states.

The shoot length first order increases to 20–60 cm, diameter of its base – from 0.1 to 0.3 cm. Shoots of the second order are inferior to the main shoot in length, but they can also be 50 cm in length. Shoots of the III order are shorter and do not exceed 11 cm. The inflorescence is formed on shoots of all orders. The aboveground part of adult *S. annua* plant is synflorescence. The most developed thyrsus (10–13 pairs of dichasias) is formed on the main shoot (I order). Inflorescences on the tops of shoots of the II order (up to 11 pairs) are comparable to it, on shoots of the III order the thyrses are noticeably shorter (up to 7 pairs of dihazia). The hypocotyl increases to 0.3–0.4 cm in diameter. The main root is 10–15 cm long and branches up to the third order. Its growth leads to the immersion of the shoot base into the substrate to a depth of up to 2 cm (3–4 lower metameres).

An individual of *S. annua* develops a powerful shoot as a result of active branching of the aboveground part in the first year of life. The average value of the shoot mass is 2 g (varying in the range of 0.17–6.1 g). Almost all its axillary buds involve in formation of generative part of the plant. Only the buds of the cotyledons and the 1st lower short metamer do not function; they remain small and poorly differentiated (1–2 pairs of primordia). The buds of cotyledons in a flowering plant often destroy. They can start growing when the apical part main shoot is damaged only in the pregenerative period. Then 1–2 replacement shoots develop. As a result, there are no developed viable buds at base of *S. annua* shoot at end growing season, and emergence of new shoots is impossible next year. The features of shoot formation revealed by us do not confirm possibility of existence two-year-old individuals of *S. annua*, noted in agrocenoses of Northwestern Caucasus [11]. Shoot necrosis affecting the cotyledon node and main root leads to death entire individual at the end growing season.

The first stages of ontogenesis of *C. acinos* proceed in the same way as in *S. annua*, but there are slight differences in length and number of shoot metameres (Fig. 1). The shoot of juvenile plant consists only of 2–3 elongated metameres. Shoots of pregenerative individuals have a greater number of metameres in comparison with individuals of *S. annua* (im – 4–7 metameres, v – 7–12 metameres), which also determines the length of the primary shoot (respectively: 1.8–5.5 cm and 3.5–6 cm). Buds with a capacity of 1–2 primordia pairs are laid in axils of leaves in an immature state. Lateral sylleptic shoots begin to grow below flowering main thyrsus. In the first year, the primary shoot has an average length of 10 (5–18) cm and the diameter of its base varies from 0.05 to 0.1 cm, this is significantly less than the parameters of the *S. annua* shoot. Most of the individuals branch forming 1–4 pairs of second-order shoots, but they remain rosette. The generative part of the plant is represented only by the main shoot thyrsus, which consists on average of 4 (2–8) pairs of dichasias. The axillary buds of the lower 3–5 shoot metamers do not participate in branching. Underground part of individual: hypocotyl has a diameter of 0.1 cm, main root branched up to the third order, elongates to 16 cm. The average mass of the primary shoot of *C. acinos* is 0.05 (from 0.01 to 0.13) g. Unrealized axillary buds are preserved in the basal part of the shoot, of which the most important are the cotyledon buds. Their capacity increases to 3–4 primordia pairs after the death of the primary shoot in autumn. One or two renewal shoots are formed from these buds the following spring. The average length of the shoot is 17 (9–27) cm, its thyrsus consists on average of 7 (2–12) dichasias pairs. The size of the renewal shoots is higher than the size of the primary shoot. Renewal shoots branch up to second order (1–4 pairs of lateral shoots), some them reach a length of 3–8 cm and develop an apical inflorescence. The average value of mass renewal shoot increases and has 0.14 g (from 0.03 to 0.43). The sizes of new shoots remain within the same limits in subsequent years. Weakly branching 2 (1)–6 (up to 11) generative shoots of n+1 orders form a bush. The length of the shoots is up to 27 cm, the diameter of their base is 0.1 cm. A perennial sympodial system (caudex) with a length of 1–1.5 (up to 3.5) cm from several (4–5) basal parts of shoots of different years with long branching adventitious roots develops in underground part of plant. The main root gradually dies off from the distal end feeding of individual is carried out mainly by adventitious roots. Individuals older than 6 years were not found. This is due to death of the main root.

An analysis of developmental features of *S. annua* and *C. acinos* showed that both species bloom in the first year. Powerful individuals of *S. annua* completely die off at the end of the first growing season, unlike individuals of *C. acinos*, whose ontogenesis lasts up to 6 years. Consequently, *S. annua* manifests itself as a typical annual monocarpic through accelerated growth. There is a skip of the virginal state in the pregenerative period. The laying of generative organs begins in the apical bud of the shoot immediately after its regrowth (im). The main part of plastic substances goes to the formation of a powerful synflorescence during the shoot growth. Therefore, the buds that are not involved in the branching of the shoot remain underdeveloped or are destroyed. This excludes the possibility of resuming the individual for the next year. *C. acinos* belongs to the group of oligocarpics according to the number of flowering years in its ontogenesis. In the first year, the individual passes all the pregenerative ontogenetic states (j–v) and blooms. The primary shoot develops a small synflorescence. The shoot mass is small. The renewal zone is formed in the lower part of the shoot, it is represented by open cotyledon buds, from which renewal shoots develop next year. Renewal shoots also have an average growth rate and mature open buds are laid in their basal part. They persist until the next spring and new shoots of the n+1 order grow out of them. Thus, the explosive growth generative shoot of *S. annua* suppresses all other processes of formation namely the development of renewal buds. This determines the one-year development individual cycle and monocarpity plant. The average shoot growth rates of the *C. acinos* lead to the formation of a smaller

generative sphere, and the simultaneous development of a renewal zone from open buds of 1–2 lower metamers. Ontogeny of an individuals and its flowering can last 3–6 years, so plant is an oligocarpic. The data obtained by us coincide with results of introduction *C. acinos* in Main Botanical Garden of Almaty (Kazakhstan). The species ontogenesis here lasts 3–6 years, and the aboveground mass of one plant ranges from 4.8–64.1 g [10]. It is known that introduction of wild species is characterized by reduction in their ontogeny. Therefore it can be argued that of *C. acinos* does not belong to the group of short-lived plants in narrow sense (monocarpic one-, and two-year-old). The inclusion by many botanists of *C. acinos* in the group of juveniles (*sensu stricto*) is probably due fact that the species can develop like *S. annua* (forming a powerful shoot) in habitats with disturbed natural vegetation cover. However data on high aboveground mass of 3–6 year-old generative of *C. acinos* individuals in the introduction do not agree with this assumption [10]. More research is needed to clarify this issue.

Thus in our work, the following was found out. *S. annua* is annual monocarpic, with early formation powerful generative sphere, which excludes development of renewal zone. *C. acinos* is an oligocarpic with low growth rates of shoots, the formation of a renewal zone on the shoots ensures the duration of its ontogenesis. The species can be attributed to the short-lived plants group, understood in a broad sense, when it includes not only one-and two-year-old monocarpics (*sensu stricto*), but also oligocarpics that live no more than 15 years (*sensu lato*) [17]. The work was carried out with the project of the State Assignment of Central Siberian Botanical Garden of the Siberian Branch of the Russian Academy of Sciences № AAAA–A21–121011290026–9.

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