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Resource potential of amaranth and possibilities of its cultivation in the conditions of the south of Western Siberia

Amaranth, with more than 60 species, was introduced to Europe in the 16th century and is currently gaining popularity due to its high content of protein, vitamins and antioxidants. Its importance has increased in recent decades, both globally and in the conditions of Siberia, where it has become an object of selective breeding. The article provides a brief historical sketch on the study and breeding of new amaranth varieties in the south of Western Siberia. In addition, the biological features of amaranth (*Amaranthus* L.) and its importance as a valuable food and fodder crop are considered. The analysis of breeding traits allowed us to identify the most promising samples for successful cultivation in the south of Western Siberia: amaranth panicle (PC-318 and PC-391) and dark amaranth (PC-42). They are characterized by the shortest growing season and have greater resistance to adverse factors. The results of the study show that amaranth can become an important crop for Western Siberia, providing high yield and adaptability in difficult climatic conditions.

Keywords: squalene, growing season length, *Amaranthus cruentus* L., *Amaranthus hypohondriacus* L., *Amaranthus caudatus* L., *Amaranthus tricolor* L., introducer, ontogenesis stages.

Introduction

Amaranth (*Amaranthus* L.) is a genus of plants in the Amaranth family (Amaranthaceae Juss.) with more than 60 species. The greatest diversity of forms, species and varieties is represented on the territory of South America and Mexico, which is its homeland. Northern India and China are considered to be the second center of form formation. Amaranth was introduced to Europe only in the 16th century by the Spaniards for ornamental purposes and only two centuries later it was cultivated for seeds and animal feed.

Amaranth is of great importance in the food industry and fodder production. Plants contain a large amount of protein, balanced and unique in amino acid composition, valuable oils, pectin. Daily consumption of 100 g of amaranth seeds provides the human body with essential amino acids for 140 % of the adequate daily intake. It is important to note the presence of antioxidants in the seeds and green mass: carotenoids, amaranthine, squalene and vitamins B_2, C. The ascorbic acid content in different varieties of amaranth can be up to 50 mg/100 g [1–4]. In fodder production, amaranth is valued for its high potassium content and a large amount of easily digestible plant protein (1.0-1.5 tons/ha) [5]. The most valuable species in economic terms are: amaranth panicle (*Amaranthus cruentus* L.), amaranth sad (*A. hypohondriacus* L.), amaranth *caudate (A. caudatus* L.), and amaranth *tricolor (A. tricolor* L.).

In Russia, fodder species of amaranth became known in the 30s of the XX century, when Nikolai Ivanovich Vavilov brought seeds from an expedition to South America. He actively advocated for the wider use of amaranth in agriculture because of the large number of advantages of this crop. Even in difficult climatic conditions, high yields were noted because the C-4 type of photosynthesis provides amaranth with rapid growth and drought resistance [6, 7]. The resumption of amaranth research as a valuable food, fodder and ornamental crop occurred only at the end of the XX century and is currently being actively pursued [8]. Due to the difficult weather and climatic conditions of Siberia, the assortment of fodder crops in the region was rather scarce. To solve this problem, comprehensive research on the evaluation of non-traditional crops and selection of promising introducers was launched. Since the mid-1980s, active study of agrobiological features of the "forgotten" high-protein crop in Siberia began using seed samples transferred from VIR (Federal Research Center All-Russian Institute of Plant Genetic Resources named after N.I. Vavilov). Thus, at the workshop "Results of research and applied work with amaranth for 1987-1988", the staff of Altai State University Marina Mikhailovna Yablokova, Raisa Nikolaevna Afonina and Elena Vasilievna Repetunova presented a report on the successful experience of growing amaranth in the conditions of the Altai Territory [9].

In the conditions of the Tomsk and Novosibirsk regions, scientists under the leadership of Valentina Pavlovna Rykova also identified promising early maturing samples of the collection, which in the zone of risky agriculture give high yields [10, 11].

A little later, in 1995, the Federal Research Center IRCIG SB RAS together with the Omsk Agrarian Scientific Center registered the first in Siberia broad-plastic and early maturing amaranth variety "Cherginsky" [12].

Since the early 2000s, Svetlana Ivanovna Mikhailova, Tatiana Petrovna Astafurova, and Anastasia Anatolievna Burenina have been actively studying amaranth biology at Tomsk State University [13–17]. In 2006, the State Register of Breeding Achievements Allowed for Use in the Russian Federation included the variety "Yantar" developed by the Federal Altai Scientific Center for Agrobiotechnology and FIC ICIG SB RAS. The variety has a short vegetation period (106 days) and has a special value in fodder production. It significantly surpasses oilseed radish, rape, peas and beans in terms of yield of fodder mass and quality of plant raw material [18, 19].

In 2019, scientists of the Kuzbass State Agricultural Academy showed interest in grain forms of amaranth and optimized the technology of their cultivation in the conditions of the West Siberian forest-steppe in the Kemerovo region. In particular, the dependence of the quality of green mass and grain yield on the biological characteristics of the variety and such an agrotechnical technique as row spacing width was determined [20]. Currently, the staff of the Siberian Botanical Garden of TSU is implementing a project on cultivation of agricultural plants on carbonaceous farms in the sub-taiga zone of Western Siberia and, in addition to the range of traditional crops, offers amaranth as a promising introducer [21]. Thus, the interest in amaranth as a highly productive agricultural crop with a valuable protein composition has been growing rapidly in recent years.

The purpose of this work was the primary evaluation of a number of breeding and significant traits of plants of the amaranth genus to identify the most promising species and varieties for cultivation in the south of Western Siberia.

Experimental

The objects of the study were 7 amaranth cultivars of different origins: 1) *Amaranthus cruentus* L. — PK-318 (Russia), PK-391 (Brazil); 2) Amaranth hybrid (*A. hybridus* L. convar *erythrost*.) — PK-96 (Germany); 3) Amaranth caudatus (*A. caudatus* L.) — PK-146 (Germany), PK-150 (Greece); 4) Amaranth *tricolor* (*A. tricolor* L.) — PK-168 (Nepal); 5) Dark amaranth (*A. hypochondriacus* L.) — PK-429 (Mexico).

Seed material was obtained from the world collection of plant genetic resources of All-Russian Institute of Plant Industry named after N. Vavilov, St. Petersburg. To perform the experimental part of the work we used "Methodology of tests for distinctiveness, uniformity and stability of amaranth Federal State Center "State sort committee" (2007).

Pre-sowing tillage was carried out in spring using a gasoline cultivator Huter GMC-6.5. Sowing was carried out on June 3. Seed sowing rate was 0.5 kg/ha, sowing density was 20 plants/m^2. Repetition of the experiment was fourfold, experimental plot area was 1 m^2. Sowing was carried out manually in a wide-row method. Seeds were mixed with washed coarse sand. Later, we additionally thinned the seedlings and regularly loosened the soil during the growing season to break the soil crust and kill weeds. Starting from the emergence of seedlings, phenological phases were noted and morphological parameters were measured. Seeds were harvested and threshed manually.

Results and Discussion

In the vegetation period of amaranth there are 5 phenological phases: sprouting, growth, bottoming, flowering and fruiting. On average, the totality of all development periods is 110–140 days and varies depending on the variety and species. Seeds begin to germinate when the soil warms up to +10...+12°C, but the seedlings are extremely unstable to any frost. Therefore, sowing amaranth in the south of Western Siberia should be carried out when the threat of return frosts has finally passed — in the last decade of May or early June. Sprouts appear on the 6th-7th day and their development in the first three weeks is extremely slow due to a small supply of nutrients because of the size of the seeds. However, due to a special type of photosynthesis, the plants begin to grow rapidly after the start of the growth phase and the formation of green phytomass. The budding phase lasts 1-2 weeks on average, energy is redistributed to the formation of inflorescences — panicles, and growth in height is somewhat slower. Then, flower blossoming and seed ripening take place [22].

Amaranth plants have a fairly high seed production coefficient, but not every variety has seeds that reach physiological maturity before the onset of frost and cold weather. Therefore, breeding selection of this crop is aimed at developing early-ripening, cold- and drought-resistant varieties with high yield values. Among the species and varieties studied, Russian (PK-318, "Frant") and Brazilian (PK-391) amaranth varieties, as well as dark amaranth from Mexico (PK-429) showed excellent performance. The vegetation period for representatives of these species was 95–100 days, with the first seeds beginning to form on the 60–65th day (Fig.). Hybrid amaranth (PK-96, Germany) should be considered later maturing. In this species, the budding phase occurred on 93–95 days from seedlings, and the first seeds on single specimens matured on 105–110 days. *Amaranthus caudatus* (PK-146, Germany) had a similar growing season, but was twice affected by harmful insects and mold fungi. Tricolor amaranth (PC-168, Nepal) and Greek tail amaranth (PC-150) did not have time to form seeds before the first frosts and finished the vegetation at the budding and flowering stage. These species have too long vegetation period and their cultivation in local conditions is inexpedient.

Figure. Amaranth panicle (PK-318, Russia) during growth and flowering phases

In addition to the growing season, an important economic and valuable feature of amaranth is the low stature of plants. Private farms do not have special harvesting machines and use combines like KSK-100, KPKU-75, etc. For morphological description of the studied species we used the materials of "Methods of testing for distinctiveness, homogeneity and stability of amaranth" of Federal state center "State sort committee" (2007). The obtained data are presented in Table.

Table

Morphological traits of the studied amaranth breeding samples

PC-	Species name	Average plant height in the middle of vegetation, cm	Average plant height at the end of vegetation, cm	Presence of side shoots	Stem thickness at the end of vegetation, cm	Coloration of leaf lamina, presence of "spot"	Inflorescence coloration
318	*Amaranthus cruentus* L.	110	190	-	1,9	red, no.	red
96	*Amaranthus hybridus* L.convar *erythrost*.	136	223	-	2,2	green, V-shaped "spot" in the center	red
146	*Amaranthus caudatus* L.	126	190	-	1,9	green, no	green
150	*Amaranthus caudatus* L.	106,5	160	+	2,5	green, no	green
168	*Amaranthus tricolor* L.	57,5	100	-	1,2	green, egg-shaped "spot" in the center	red
391	*Amaranthus cruentus* L.	71	119	-	1,2	green, no	green
429	*Amaranthus hypochondriacus* L.	76,5	146	-	1	green, no	green with red spots
Statistical characteristics*							
ẋ		97.6	161.1				
σ		29.7	43.3				
Cv		30.4	26.9				
SDx		11.2	16.4				
Note. *ẋ — mean, σ — standard deviation, CV — coefficient of variation, %, SDx — standard error of the experiment							

According to the results of the experiment of the first year, hybrid amaranth plants (PK-96, Germany) were the tallest — up to 223 cm. The average height of amaranth panicle PK-318 (Russia) at the time of harvesting was 190 cm, dark amaranth PK-429 (Brazil) — 146 cm. The lowest of the listed varieties was the height of Mexican amaranth panicle PC-391 (Mexico) — 119 cm.

All the studied samples with a vegetation period suitable for local conditions can be proposed for cultivation not only as food and fodder plants, but also for ornamental purposes. In addition, the leaves of the red-colored amaranth variety (PK-318, Russia) can be used to produce fermented tea, which is of great importance in functional nutrition [23].

Conclusion

Thus, at the primary stage of study of a number of samples from the amaranth collection of "All-Russian Institute of Plant Industry named after N. Vavilov" the most promising species, varieties and breeding samples for cultivation in climatic conditions of the south of Western Siberia were identified: amaranth panicle (PK-318, "Frant", Russia; PK-391, Brazil), dark amaranth (PK-429, Mexico).

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Амаранттың ресурстық әлеуеті және оны Батыс Сібірдің оңтүстігінде өсіру мүмкіндігі

Алпыстан астам түрі бар амарант Еуропаға XVI ғасырда енгізілген және қазіргі уақытта ақуыздың, витаминдердің және антиоксиданттардың көп болуына байланысты танымал болып келеді. Оның маңызы соңғы онжылдықтарда әлемдік масштабта да, Сібірде де өсті, онда ол селекциялық іріктеу объектісіне айналды. Мақалада Батыс Сібірдің оңтүстігінде амаранттың жаңа сорттарын зерттеу және өсіру туралы қысқаша тарихи очерк берілген. Сонымен қатар, амаранттың биологиялық ерекшеліктері (*Amaranthus* L.) және оның құнды азық-түлік және жем-шөп дақылдары ретіндегі маңызы қарастырылған. Селекциялық белгілерді талдау Батыс Сібірдің оңтүстігінде табысты өсіру үшін ең перспективалы үлгілерді анықтауға мүмкіндік берді: шашақты амарант (ПК-318 және ПК-391) және күңгірт амарант (ПК-42). Олар ең қысқа вегетациялық кезеңмен сипатталады және қолайсыз факторларға үлкен төзімділікке ие. Зерттеу нәтижелері амаранттың Батыс Сібір үшін маңызды ауыл шаруашылығы дақылына айналуы мүмкін екенін көрсетті, ол жоғары өнімділік пен күрделі климаттық жағдайларда бейімделуді қамтамасыз етеді.

Кілт сөздер: сквален, вегетациялық кезеңнің ұзақтығы, *Amaranthus cruentus* L., *Amaranthus hypohondriacus* L., *Amaranthus caudatus* L., *Amaranthus tricolor* L., жерсіндірілген түр, онтогенез кезеңдері.

К.С. Панченко, М.М. Силантьева, Д.В. Соколова

Ресурсный потенциал амаранта и возможности его выращивания в условиях юга Западной Сибири

Амарант, насчитывающий более 60 видов, завезен в Европу в XVI веке и в настоящее время набирает популярность благодаря высокому содержанию белка, витаминов и антиоксидантов. Его значение возросло в последние десятилетия, как в мировом масштабе, так и в условиях Сибири, где он стал объектом селекционного отбора. В статье приведен краткий исторический очерк по изучению и выведению новых сортов амаранта на юге Западной Сибири. Кроме того, рассмотрены биологические особенности амаранта (*Amaranthus* L.) и его значимость как ценной пищевой и кормовой культуры. Анализ селекционных признаков позволил выделить наиболее перспективные образцы для успешного возделывания в условиях юга Западной Сибири: амарант метельчатый (ПК–318 и ПК–391) и амарант темный (ПК–42). Они характеризуются наиболее коротким вегетационным периодом и обладают большей устойчивостью к неблагоприятным факторам. Результаты исследования показывают, что амарант может стать важной сельскохозяйственной культурой для Западной Сибири, обеспечивая высокую урожайность и адаптивность в сложных климатических условиях.

Ключевые слова: сквален, длина вегетационного периода, *Amaranthus cruentus* L., *Amaranthus hypohondriacus* L., *Amaranthus caudatus* L., *Amaranthus tricolor* L., интродуцент, стадии онтогенеза.

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