UDC 582.4 : 582.662 + 581.9 + 581.522.6 + 581.527

QUINOA AS A PROMISING PSEUDOCEREAL CROP FOR UKRAINE

S. L. Mosyakin, V. V. Schwartau

[1] *M. G. Kholodny Institute of Botany, National Academy of Sciences of Ukraine*
2, Tereshchenkivska Str., Kyiv, Ukraine, 01601
[2] *Institute of Plant Physiology and Genetics, National Academy of Sciences of Ukraine*
31/17, Vasylkivska Str., Kyiv, Ukraine, 03022

e-mail: S_Mosyakin@hotmail.com; VictorSchwartau@gmail.com

Received on February 09, 2015

The article provides an assessment of perspectives of quinoa (*Chenopodium quinoa* L.) cultivation in Ukraine, based on international experience and original field tests, with the aim of ensuring further development and diversification of crop production in Ukraine and expanding modern crop rotation systems. The data on the taxonomic position of quinoa and its relationships with other species of the genus *Chenopodium* and the history of species domestication are provided. Quinoa is a crop of high nutritional value and can be used in gluten-free diets, which are important components of human ration. The results of test cultivation of quinoa in 2013–2014 under conditions of the experimental agricultural farm of the Institute of Plant Physiology and Genetics, National Academy of Sciences of Ukraine, located in Vasylkiv District (*rayon*) of Kyiv Region (*oblast*), are provided. It is concluded that quinoa is a promising crop for domestic grain producers. The introduction of quinoa into crop rotation systems can improve ecological conditions of agroecosystems and promote restoration of soil fertility in the country without diminishing the revenues of farmers.

Key words: *Chenopodium quinoa*, quinoa, biology, taxonomy, domestication, agricultural technologies.

INTRODUCTION

The Big Three cereals – wheat, rice and corn – are justly considered to be the main cereal crops and feeders of humanity. According to FAO (http://www.fao.org), cereals account for about 58 % of the annual crop areas and provide humans with over 50 % of food calories. By 2050, the share of the three mentioned crops together is expected to amount up to 80 % of the increase in cereal consumption [1, 2]. However, it is acknowledged that along with the increase in the cultivation of the main crops there is a need for diversification in cultivation and consumption of other crops, including those currently of lesser significance (so-called *minor crops*), but which were in the past, and still are, components of traditional agricultural systems [2–5]. These crops may be better adjusted to the conditions of specific geographic regions of the Globe, where the cultivation of the main crops is complicated, risky, or economically or ecologically unreasonable.

Except for the vegetation season of 2014, during the recent five years Ukraine witnessed numerous long-term drought periods, which sharply decreased crop yield of spiked cereals, technical and other crops. Each year the fields of the Steppe zone of Ukraine suffer from droughts of varied intensity. Rapid changes in the structure of Ukrainian agriculture caused by the formation of agroholdings (agricultural holding companies and corporations) and the decline of animal farming resulted in reduced crop rotations with the cultivation of only immediately profitable and cost-efficient crops with high nutrient removal from soils. This, in turn, resulted in considerable worsening of phytosanitary conditions of agroecosystems and segetal plant communities, the increase in weed infestation levels and growing threats of emergence of pesticide-resistant pathogens, pests, and weeds, as well as the decline of soil fertility. A considerable share of winter wheat fields is occupied by cultivars and hybrids of foreign selection, which often become frostbitten in vast areas. Among staple cereals registered in Ukraine, spring wheat does not match the main domestic crop – winter wheat – in the yield level and qualitative indices, while other crops (peas, for instance) also require the application of great amounts of pesticides.

It is important to amend crop rotations in Ukraine with highly cost-efficient spring crops with low level of nutrient removal, which are resistant to high temperatures and droughts and tolerant to the application of agricultural chemicals. Therefore, so-called pseudocereals nowadays appear to be quite promising food and technical crops. Pseudocereals are defined as non-grass crops that can be used in much the same way as true cereals (grass cereals). It means that their seeds ("grain") are used similarly to cereal grain, e.g., pseudocereal seeds can be ground into flour, grits, etc. Typical pseudocereals include buckwheat (*Fagopyrum esculentum* Moench, family *Polygonaceae*), grain amaranths (several domesticated species of the genus *Amaranthus* L., family *Amaranthaceae*), as well as quinoa (*Chenopodium quinoa* L.) and some other species of the genus *Chenopodium* L. (family *Chenopodiaceae*).

Quinoa, an ancient crop that emerged approximately 7,000 years BP (before present) in the mountain regions of the central part of the Andes in South America, currently enjoys the period of its revival and renewed popularity. It is caused by unique food (nutrient) characteristics of this species, its easiness of cultivation, environmental resistance and tolerance, and a great number of available and diverse cultivars [2, 3, 5, 6]. This crop was even used as an experimental object in the NASA space program [7]. Therefore, the United Nations General Assembly and FAO declared 2013 as the International Year of Quinoa (http://www.fao.org/quinoa-2013/en/).

As for nutritional properties of quinoa, its protein content in "grain" varies from 13.81 to 21.9 %, depending on a cultivar. Quinoa is one of a few edible plants containing all essential amino acids and most closely corresponding to human food standards approved by FAO. The balance of essential amino acids in quinoa protein considerably exceeds the indices of amino acid content in wheat grain, barley, and soybean, approaching in that respect the parameters of milk protein. Quinoa also has significantly higher calcium, magnesium, iron and zinc contents as compared to those values in wheat, corn, rice, barley, oats, rye, and triticale, among others. It is important that quinoa is suitable for gluten-free diet [5].

The taxonomic position of quinoa and its relationships to other species of *Chenopodium*

According to modern views, the family *Chenopodiaceae* Vent. belongs to the order *Caryophyllales* Juss. ex Bercht. & J. Presl of the unranked group of eudicot, or true dicotyledonous angiosperms [8, 9]. According to our variant of the system of flowering plants [9], the taxonomic position of *Chenopodiaceae* is viewed as follows: division *Magnoliophyta* Cronquist, Takht. & W. Zimmerm. ex Reveal (angiosperms, or flowering plants), class *Rosopsida* Batsch (= *Dicotyledonae*, eudicots), subclass *Caryophyllidae* Takht., order *Caryophyllales* Juss. ex Bercht. & J. Presl., and suborder *Chenopodiineae* J. Presl.

In all three published variants of the APG system, the family *Chenopodiaceae* [8, 10, 11] was merged with the family *Amaranthaceae*, the latter name having nomenclatural priority and thus being used for the combined family. However, it is difficult to agree with this decision, especially considering available taxonomic and nomenclatural evidence [9, 12]. More detailed justification of the need to preserve the independence of the family *Chenopodiaceae* will be published in another article (Mosyakin, in print).

Within the family, the genus *Chenopodium* belongs to subfamily *Chenopodioideae* Burnett, tribe *Chenopodieae* Dumort. It has been suggested to synonymize the latter with tribe *Atripliceae* Duby [13], but it seems to be not the best option (Mosyakin, in print).

The modern system of *Chenopodium sensu lato* and other genera previously included into this aggregate is based on the system of Aellen, a Swiss botanist [14–16]; that system was later improved and updated by Scott [17], further on – by one of the authors of this article [18–21], in particular, in collaboration with the US botanist Clemants [22, 23]. Mosyakin and Clemants [22, 23], among other taxonomic and nomenclatural proposals, first justified the phylogenetic isolation of so-called glandular chenopods (aromatic species with glandular trichomes) from typical representatives of *Chenopodium sensu stricto* (in the strict sense) and transferred these species to a re-circumscribed genus *Dysphania* R. Br., providing necessary nomenclatural combinations. This taxonomic decision was initially accepted in our floristic and taxonomic treatments for the *Flora of North America North of Mexico* and the *Flora of China* [24, 25], later confirmed by molecular phylogenetic data [13, 26–28], and currently it is almost universally accepted.

In addition, modern molecular phylogenetic studies justified further segregation of several additional genera from *Chenopodium sensu lato* (in the wide sense) [13, 28, 29]. However, these radical changes do not affect the group that includes quinoa and other pseudocereals of the genus, since they all remain in *Chenopodium* in the strict sense.

According to modern taxonomic views [30, 31], quinoa belongs to sect. *Chenopodium* (the typical section, containing the nomenclatural type of the genus), which includes most species of the genus further segregated into several subsections. Subsection *Favosa* (Aellen) Mosyakin & Clemants (= *Chenopodium* series *Favosa* Aellen) includes species geographically ranging from South America (*C. quinoa* Willd., *C. hircinum* Schrad. etc.) to North America (a group of species related to *C. berlandieri* Moq.) and Eastern and South Asia (*C. ficifolium* Sm. *sensu lato*). The latter species (the lectotype of subsect. *Favosa*) was widely naturalized in other regions outside its initial natural range, due to which it was sometimes erroneously considered a species of Mediterranean origin. The phylogenetic integrity of the newly outlined subsect. *Favosa* was conclusively supported by modern molecular and phylogenetic evidence [13, 28] and comparative anatomic and carpological data [32].

Issues of taxonomy and evolution of several species of *Chenopodium*, in particular, American cultivated races of quinoa (*C. quinoa*), huazontle (*C. nuttalliae* Safford), and their wild relatives (*C. hircinum* etc.) and probable ancestors were considered in some substantial, as of that time, publications by Wilson and his colleagues [35−42]. Even at that time, these integral studies involved the methods of traditional taxonomy, palaeoethnobotany (archaeobotany), biochemistry, and biosystematics.

Recently the nomenclatural type (lectotype) of the species has been selected for *C. quinoa* [43]; this herbarium specimen (the reference sample of the species) is deposited at the Willdenow Herbarium of the Botanical Garden and Museum in Berlin (Botanischer Garten und Botanisches Museum Berlin-Dahlem).

History and peculiarities of domestication of quinoa and some other unique crops of America

The issues of history and peculiarities of domestication of quinoa and some other unique crops of America has already been considered in detail by one of the authors of this article [44]; subsequent discussion in the present article is partially based on that earlier publication.

In pre-Columbian times (i.e. prior to the beginning of colonization by the Europeans) ancient inhabitants of America managed to domesticate quite a wide range of local wild plants; however, these crops considerably differed taxonomically from the domesticated plants of Eurasia. The unique feature of the ancient American domestication experience is the use of exclusively local resources, especially under very limited contacts even between American geographical and cultural centers of domestication. Several main centers of plant domestication and origin of agriculture, with their peculiar sets of crops, are distinguished in the Americas (North, Central, and South) (see reviews for further information [45–53]).

The following centers of plant domestication are usually distinguished, with some variants, in the Americas:

▪ Mesoamerican upland and Mesoamerican lowland centers (remarkable domesticates are corn *Zea mays* L., grain amaranth *Amaranthus cruentus* L. = *A. paniculatus* L., species of such genera as beans *Phaseolus*, squash and pumpkin *Cucurbita*, paprika *Capsicum* etc.);

▪ Andean center (potato *Solanum tuberosum* L. s.l. (some taxa), ulluco *Ullucus tuberosus* Caldas, oca *Oxalis tuberosa* Molina; quinoa *Chenopodium quinoa* Willd., qañiwa *C. pallidicaule* Aellen, foxtail amaranth *Amaranthus caudatus* L. etc.);

▪ Arizonian-Sonoran center (formed under the influence of the Mesoamerican upland center; also includes specific cereals at early stages of domestication, in particular, barnyard millet from the *Echinochloa muricata* (P. Beauv.) Fern. group, species of millet *Panicum* s.l., barley *Hordeum* s.l., bromegrass *Bromus* s.l. etc.);

▪ Eastern North American, also known as Alabaman-Illinoian, center (*Chenopodium berlandieri* Moq. – *C. nuttallii* aggr., species of genera *Helianthus*, *Cyclachaena*, *Ambrosia*, *Polygonum* s.l., *Phalaris* etc.);

▪ Peruvian coastal center (mainly adoption of crops from the Andes);

▪Amazonian, also known as Amazonian-Orinocan or Brazilian-Paraguayan, center (manioc *Manihot esculenta* Crantz, sweet potato *Ipomoea batatas* (L.) Lam., and some other crops).

As we can see, the absolute majority of domesticates of American origin, especially those used at the stage of early agriculture, are remarkable for their ruderal (explerent) life strategy; by their ecological and phytosociological features they are somewhat similar to weeds or plants of marginal habitats [44].

Species of families *Chenopodiaceae* and *Amaranthaceae* occupy a prominent place among the cultivated native plants of America [6, 35, 36, 39–42, 49, 52–59]. The independent domestication of ruderal species of *Chenopodiaceae* and *Amaranthaceae* in America can be viewed as a unique domestication experiment. The documented role of these domesticated plants in America was much more important than the role of crops of these families in the Old World. With the exception of beet (*Beta vulgaris* L.) and spinach (*Spinacia oleracea* L.) that originated in the Mediterranean region [60, 61], chenopod crops did not have significant distribution in the Old World, mainly being used there from time to time as leaf crops (salad plants) or as substitutes of normal and wholesome food in famine years (so-called famine food).

The ethnobotanical data on the use of wild representatives of *Chenopodiaceae* and *Amaranthaceae* by native peoples of North and South America are present in many publications (see above), and similar data on North America were critically analyzed and summarized in a thorough monograph by Moerman [63]. Fresh green parts of many representatives of *Chenopodiaceae* (species of genera *Atriplex* and *Chenopodium*) were used as green (salad) vegetables or potherbs. The seeds of many wild species of *Chenopodiaceae* served as substitutes of cereals: grit or flour were made of them; they were soaked, ground, boiled and prepared as porridge, bread substitute, and pemmican-type dry mixtures. In particular, Moerman [63] described the use of fruits and seeds of at least 9 species of *Atriplex* (orache), 10 species of *Chenopodium*, species of *Cycloloma* Moq. (winged pigweed), *Corispermum* L. (bugseed) etc. as food products, but the real number of species actually used must have been much higher, as ethnobotanists often did not indicate the precise species-level identification of plants, reporting only the genus or another supraspecific group.

Archaeological and palaeoethnobotanical data (see references above) indicate wide use of seeds of several species of *Chenopodium*, which may be considered true domesticates, in North and South America: *C. quinoa* (quinoa, the Andes), *C. pallidicaule* (qañiwa or qañawa, the Andes), *C. nuttaliae* Safford (= *C. berlandieri* subsp. *nuttalliae* (Safford) H.D. Wilson & C.B. Heiser; huazontle, Mexico), *C. berlandieri* (central and southwestern part of South America), *C. bushianum* Aellen (= *C. berlandieri* subsp. *bushianum* (Aellen) Cronq., North American Atlantic region), *C. bushianum* subsp. *jonesianum* B.D. Smith (the subspecies considered already extinct), and some others. Among the mentioned species and races, only quinoa still maintains its economic importance, while remaining species have been either forgotten (for instance, domesticated North American large-seeded races of the *C. berlandieri* group), or are preserved only locally, as relict crops.

The majority of domesticated species and subspecies of *Chenopodium* demonstrate some morphological and physiological changes likely caused by domestication: disruption of the normal mechanism of spontaneous dissemination (however, seeds are easily shed while being thrashed), lost (or at least decreased) dormant period in seeds; the sizes of seeds increase considerably; the pericarp is easily isolated from the testa (seed coat), the testa itself becomes thinner, due to which the “seeds” acquire shades of white, yellow or reddish color.

As we can see, practically all cultivated species of *Chenopodium* were domesticated independently in various regions of America. In particular, the fact of independent origin of Andean cultivars of *C. quinoa* and Mexican cultivars of *C. nuttaliae* [42] has been proven without doubt. Despite numerous studies, the origin of quinoa is still a matter of dispute. This species is likely to have originated from one of the local Andean tetraploid wild species belonging to subsect. *Favosa.* At present the researchers [64, 65] are inclined to think that tetraploid American species of *Chenopodium* from subsect. *Favosa* (including the cultivated ones) are allopolyploids that originated from ancient hybridization events between the local American and probably some Asian (or Eurasian) species. In particular, it is believed that one diploid ($2n$ = 18) ancestor of species of the tetraploid ($2n$ = 36) American complex (*C. berlandieri*, *C. hircinum*, etc.) could be the North American species *C. standleyanum* Aellen. Eurasian species *C. album* L. or *C. ficifolium* were suggested for the role of the second probable diploid ancestor. In our opinion, typical *C. album*, being hexaploid ($2n$ = 54), cannot be considered as a potential parental species of a tetraploid taxon. Therefore, diploid *C. ficifolium* is best suited for the role of such an ancestral species. The species *C. standleyanum* was placed by us [24, 30] in a separate subsection *Standleyana* Mosyakin & Clemants, which is extremely interesting in terms of its phytogeography, since it links North American and East Asian taxa. This subsection also includes East Asian *C. bryoniifolium* Bunge (= *C. koraiense* Nakai s. str.), *C. gracilispicum* H.W. Kung (*C. koraiense* auct. p.p.), *C. atripliciforme*

Murr s. str. (*C. badachschanicum* auct., non Tzvelev), North American *C. standleyanum* (*C. boscianum* auct. non Moq.), and probably also *C. missouriense* Aellen emend. F. Dvořák. Thus, there is an evident "East Asian trace" in the origin of American tetraploid species of subsect. *Favosa* (including *C. berlandieri*, *C. hircinum*, and *C. quinoa*).

As currently generally estimated, quinoa emerged about 7,000 years BP, but there are some indications to an older age of this crop. The archaeobotanical remains of the fruits similar to those of quinoa in the northern part of Peru on the western slopes of the Andes are dated by the Las Pircas period (9,800–7,800 years B.P.); however, it is possible that these earliest finds indicate the pre-domestication use of plants from natural habitats by tribes of hunters-gatherers rather than complete domestication [43].

Contrary to the older Andean complex, the so-called "Eastern complex" of crops was formed in North America in the eastern and central parts of the present-day USA about 5,000 years ago, i.e. much later than the time of quinoa domestication in South America. Besides the races of the *C. berlandieri – C. bushianum* group, this complex also included *Ambrosia trifida* L. (giant ragweed), *Helianthus annuus* L. s.l. (sunflowers) and local species of genera *Cyclachaena* (marsh-elder) and *Amaranthus*. Considerable domestication-caused morphological changes in the seeds of cultivated species of *Chenopodium* are reliably traced in the archaeological records of this region for the period of 3,500–2,000 years B.P. During that period, forms with large (about 2 mm in diameter) seeds and thinner testa (10–15 µm as compared to 40–78 µm in wild species) appeared, which may testify to the emergence of true domesticated cultivars. The cultivation of local *Chenopodium* domesticates (as well as many other species) in North America gradually ceased starting with the 2nd–3rd centuries C.E. due to the adaptation of more productive Mesoamerican (Central American) crops, in particular, corn, several species of beans, squash and pumpkin [53]. However, the ancient tradition of cultivation of South American species of *Chenopodium* (especially quinoa) continued and still continues until now.

Quinoa has many native landraces and other cultivars adapted to extremely diverse natural and climatic conditions of South America. In particular, the following groups of cultivars, landraces, and forms are distinguished [6]: (1) Altiplano (northern Andean highlands), (2) Salares (southern highlands), (3) Inter Andean Valleys, (4) arid zones (in particular, western highlands), plants of (5) high altitudes and cool climate, (6) coastal regions, (7) jungle and tropical zones, and (8) high rainfall and humidity zones. Such a considerable diversity of cultivars and forms opens excellent prospects for the search for cultivars best pre-adapted to the conditions of different physiographic and climatic zones of Ukraine.

Peculiarities of quinoa cultivation

The culture of quinoa is new for domestic producers in Ukraine. Under the conditions of southern Polissia and northern Forest-Steppe zones of Ukraine – at the experimental agricultural farm of the Institute of Plant Physiology and Genetics, NAS of Ukraine (Vasylkiv District, Kyiv Region) – quinoa was sown in well prepared leveled soil in early May in 2013–2014 at stable positive temperatures (8−10 °C) and sufficient humidity of soil. The row planting was made 1–2 cm deep with the row spacing of 30 cm. The seeds were kindly provided by Dr. Jamal B. Rakhmetov (M.M. Gryshko National Botanical Garden, NAS of Ukraine). Late terms of sowing allow using non-selective herbicides based on N-(phosphonomethyl)glycine (Glyphosate), in spring and relieving the fields from wheatgrass, *Elytrigia repens* (L.) Desv. ex Nevski (*Agropyrum repens* L.), sow-thistle species (*Sonchus* spp.), and other weeds. Being the predecessor, quinoa allows decreasing the weed infestation of the field with thermophylic grass species (in particular, foxtail species, *Setaria* spp. *etc*.) on condition of introducing graminicides of the classes of aryloxyphenoxypropionic acid, cyclohexanediones *etc*. A considerable drawback is a high level of infestation of quinoa fields with common goosefoot (*Chenopodium album* L., a species very widespread in Ukraine) and other related species of the genus, as well as species of the genus *Atriplex* L. (orache). However, if quinoa is used as a predecessor of winter wheat or corn, on the fields of which the use of herbicides to control *Chenopodium album* is efficient, high levels of weed biomass accumulation may be considered as application of green manure.

Quinoa responds very well to soil enrichment with nitrogen [66]. To cultivate the organic crop, quinoa should be sown after the application of organic fertilizers, green manure, nitrogen-fixing grain legumes, or either nitrogen-fixing species of plants should be used as green manure.

Quinoa demonstrates good response to the foliar application of macro- and microelements. However, the damage of quinoa leaves with agrochemicals may be observed as early as after the introduction of 1–3 % working solutions of fertilizers. Foliar biofortification of quinoa yield is efficient using fertilizers containing nutrition elements and amino acids (Megafol, Megafol Protein, Isabion).

Due to the fact that quinoa seeds have high content of proteins and amino acids, it was demonstrated that it may condition the increase in selenium accumulation in the yield in the forms of selenomethionine, selenate (Se(VI)), and in non-protein compounds. On condition of the application of barium selenate and barium selenite during the vegetation period, quinoa seeds accumulate organic selenium [67].

Quinoa is a known photoperiod-responsive crop. For instance, cultivars from Ecuador need at least 15 days with short illumination period for 10 h to transfer to the flowering phase. The duration of the vegetation period may vary in different years, being from 108 to 148 days [68].

Quinoa is uniquely adapted to the cultivation in different agroecological regions; it grows at relative humidity from 40 to 88 % and can endure the temperatures from −4 °C to +38 °C. This crop uses water with high efficiency and forms the yield even at 100–200 mm of rainfall during the vegetation season [5]. However, the physiological mechanisms of stress resistance of this crop are studied insufficiently [69].

In the vegetation season of 2014 with high amount of rainfall, the fields of quinoa in Kyiv Region were slightly infested with downy mildew (*Peronospora farinosa*) and sugarbeet root aphid (*Pemphigus fuscicornis*). No infestation with these pathogen and pest should be expected under dry conditions of the vegetation season.

In 2014, the yield of quinoa was 1.05 t/ha, thus making the cultivation of this crop highly cost-efficient. According to many authors, the yield may be as high as 2.5 t/ha [70].

Therefore, quinoa is a promising crop for domestic grain producers. The introduction of quinoa into crop rotation systems can improve ecological conditions of agrophytosystems and promote the restoration of soil fertility in the country without diminishing the revenues of farmers and grain producers. The issues still to be solved in promoting quinoa cultivation in Ukraine are the identification of crop genotypes optimal for the regions in the Steppe, Forest-Steppe, and Polissia zones, the control of dicotyledonous species of weeds in the fields, and some aspects of introducing the mechanical aids into crop production.

Кіноа – перспективна для України «зернова» культура

С. Л. Мосякін [1], В. В. Швартау [2]

e-mail: S_Mosyakin@hotmail.com;
e-mail: VictorSchwartau@gmail.com

[1] Інститут ботаніки ім. М. Г. Холодного НАН України
Вул. Терещенківська, 4, Київ, Україна, 01004
[2] Інститут фізіології рослин і генетики НАН України
Вул. Васильківська, 31/17, Київ, Україна, 03022

Для забезпечення зростання й диверсифікації рослинництва України і розширення сучасних сівозмін на основі узагальнення світового досвіду та проведених польових експериментів досліджено можливість вирощування в країні кіноа (*Chenopodium quinoa* L.). Наведено дані з систематичного положення кіноа та спорідненості культури з іншими видами роду *Chenopodium*, з історії доместикації виду. Кіноа має високу харчову цінність, її можна використовувати у безглютенових дієтах, що є важливим компонентом раціону людини. Представлено результати вирощування кіноа у 2013–2014 рр. за умов дослідного сільськогосподарського виробництва Інституту фізіології рослин і генетики НАН України (Васильківський район Київської області). Таким чином, культура кіноа є перспективною для вітчизняних зерновиробників. Введення кіноа до сівозмін може покращити екологічний стан агрофітоценозів та сприяти відновленню родючості ґрунтів країни без зниження прибутків аґраріїв.

Ключові слова: *Chenopodium quinoa*, кіноа, біологія, систематика, доместикація, технології вирощування.

Киноа – перспективная для Украины «зерновая» культура

С. Л. Мосякин [1], В. В. Швартау [2]

e-mail: S_Mosyakin@hotmail.com;
e-mail: VictorSchwartau@gmail.com

[1] Институт ботаники им. Н. Г. Холодного НАН Украины
Ул. Терещенковская, 4, Киев, Украина, 01004
[2] Институт физиологии растений и генетики НАН Украины
Ул. Васильковская, 31/17, Киев, Украина, 03022

Для обеспечения роста и диверсификации растениеводства Украины, а также расширения современных севооборотов на основе обобщения мирового опыта и проведенных полевых экспериментов исследована возможность выращивания в стране киноа (*Chenopodium quinoa* L.). Приведены данные по систематическому положению киноа и родстве культуры с другими вида-

ми рода *Chenopodium*, по истории доместикации вида. Киноа имеет высокую пищевую ценность, ее можно использовать в безглютеновых диетах, что является важным компонентом рациона человека. Представлены результаты выращивания киноа в 2013–2014 гг. в условиях опытного сельскохозяйственного производства Института физиологии растений и генетики НАН Украины (Васильковский район Киевской области). Таким образом, культура киноа является перспективной для отечественных зернопроизводителей. Введение киноа в севообороты может улучшить экологическое состояние агрофитоценозов и способствовать восстановлению плодородия почв страны без снижения прибылей аграриев.

Ключевые слова: *Chenopodium quinoa*, киноа, биология, систематика, доместикация, технологии выращивания.

REFERENCES

1. *Rosegrant M, Ringler C, Sinha A, Huang J, Ahammad H, Zhu T, Msangi S, Sulser T, Batka M*. Exploring alternative futures for agricultural knowledge, science and technology (AKST). *ACIAR Project Report ADP/2004/045*. Canberra, ACIAR.2009;84 p.
2. *Food* Outlook: Biannual report on global food markets. June 2013. Rome, FAO.2013;132 p.
3. *Neglected* crops: 1492 from a different perspective. Eds J. E. Hernandes Bermejo, J. Leon. *FAO Plant Production and Protection Series, no. 26*. Rome, FAO.1994; xxii + 341 p.
4. *Descriptores* para quinua (*Chenopodium quinoa* Willd.) y sus parientes silvestres. Roma, Bioversity International. 2013; vi + 52 p.
5. *Quinoa*: An ancient crop to contribute to world food security. FAO, Regional Office for Latin America and the Caribbean. 2011; vi + 55 p.
6. *Bazile D, Fuentes F, Mujica A*. Historical perspectives and domestication. Ch. 2. *Quinoa: botany, production and uses*. Eds A. Bhargava, S. Srivastava. Wallingford, CABI.2013;16–35.
7. *Schlick G, Bubenheim DL*. Quinoa: candidate crop for NASA's Controlled Ecological Life Support Systems. *Progress in new crops*. Ed. J. Janick. Arlington, ASHS Press.1996;632–40.
8. *The Angiosperm Phylogeny Group*. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. *Bot J Linnean Soc*. 2009; **161**(2):105–21.
9. *Mosyakin SL*. Families and orders of angiosperms of the flora of Ukraine: a pragmatic classification and placement in the phylogenetic system. *Ukr Bot Zh*.2013;**70**(3):289–307.
10. *The Angiosperm Phylogeny Group*. An ordinal classification for the families of flowering plants. *Ann Missouri Bot Gard*.1998;**85**(4):531–53.
11. *The Angiosperm Phylogeny Group II*. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG II. *Bot J Linnean Soc*.2003;**131**(4):399–436.
12. *Takhtajan A*. Flowering plants. 2nd ed. Berlin, Springer. 2009; xlvi + 871 p.
13. *Fuentes-Bazan S, Uotila P, Borsch T.* A novel phylogeny-based generic classification for *Chenopodium* sensu lato, and a tribal rearrangement of *Chenopodioideae* (*Chenopodiaceae*). *Willdenowia*.2012;**42**:5–24.
14. *Aellen P. Chenopodium amaranticolor* Coste et Reynier, *Ch. purpurascens* Jacquin, *Ch. giganteum* Don, *Ch. Quinoa* Willd., *Ch. Moquinianum* Aellen und *Ch. Reynieri* Ludwig et Aellen. Eine nomenklatorischen und systematischen Studie. *Ber. Schweiz. Bot. Ges*.1929;**38**:5–23.
15. *Aellen P, Just T.* Key and synopsis of the American species of the genus *Chenopodium* L. *Amer Midl Nat*. 1943;**30**(1):47–76.
16. *Aellen P. Chenopodiaceae*. G. Hegi. *Illustrierte Flora von Mitteleuropa*. Berlin & Hamburg: Paul Parey. 1960–1961; Band 3, Teil 2 (Lief. 2–4):533–762.
17. *Scott AJ.* A review of the classification of *Chenopodium* L. and related genera (*Chenopodiaceae*). *Bot Jahrb Syst*. 1978;**100**:205–20.
18. *Mosyakin SL* An outline of a system for *Chenopodium* L. (species of Europe, North and Central Asia). *Ukr Bot Zh*. 1993; **50**(5):71–7.
19. *Mosyakin SL, Chenopodium L* Flora Europae Orientalis. St. Petersburg, Mir i Semya-95.1996;Vol. 9:27–44.
20. *Mosyakin SL* The system and phytogeography of *Chenopodium* subgen. *Blitum* (L.) I. Hiitonen (*Chenopodiaceae*). *Ukr Bot Zh*.2002;**59**(6):696–701.
21. *Mosyakin SL* The system and phytogeography of *Chenopodium* subgen. *Chenopodium* (*Chenopodiaceae*). *Ukr Bot Zh*.2003;**60**(1):26–32.
22. *Mosyakin SL, Clemants SE.* New nomenclatural combinations in *Dysphania* R. Br. (*Chenopodiaceae*): taxa occurring in North America. *Ukr Bot Zh*.2002;**59**(4):380–85.
23. *Mosyakin SL, Clemants SE.* Further transfers of glandular-pubescent species from *Chenopodium* subg. *Ambrosia* to *Dysphania* (*Chenopodiaceae*). *J Bot Res Inst Texas*.2008;**2**(1):425–31.
24. *Clemants SE, Mosyakin SL. Dysphania* R. Brown; *Chenopodium* Linnaeus. *Flora of North America north of Mexico*. Ed. by FNA Editorial Committee. New York, Oxford Univ. Press.2003;Vol. 4:267–99.
25. *Zhu Gelin, Mosyakin SL, Clemants SE. Chenopodiaceae*. *Flora of China*. Eds Wu Zhengyi, P. H. Raven. Beijing, Science Press & St. Louis, Missouri Botanical Garden Press.2003;Vol. 5:351–414.
26. *Kadereit G, Borsch T, Weising K, Freitag H.* Phylogeny of *Amaranthaceae* and *Chenopodiaceae* and the evolution of C_4-photosynthesis. *Int J Plant Sci*.2003;**164**(6):959–986.
27. *Kadereit G, Gotzek D, Jacobs S, Freitag H.* Origin and age of Australian *Chenopodiaceae*. *Org Divers Evol*. 2005;**5**(1):59–80.
28. *Fuentes-Bazan S, Mansion G, Borsch T.* Towards a species level tree of the globally diverse genus *Che-*

nopodium (*Chenopodiaceae*). *Mol Phylogenet Evol*. 2012;**62**(1):359–74.

29. *Mosyakin SL.* New nomenclatural combinations in *Blitum*, *Oxybasis*, *Chenopodiastrum*, and *Lipandra (Chenopodiaceae*). *Phytoneuron*.2013;**2013-56**:1–8.
30. *Mosyakin SL, Clemants SE.* New infrageneric taxa and combination in *Chenopodium* L. (*Chenopodiaceae*). *Novon*. 996; **6**(4):398–403.
31. *Mosyakin SL. Teloxys* Moq., *Dysphania* R. Br., *Blitum* L., *Chenopodium* L. *Conspectus Florae Europae Orientalis*. Eds N. N. Tzvelev, D. V. Geltman. St Petersburg, Moscow, KMK Scientific Press.2012;Vol. 1:276–86.
32. *Sukhorukov AP, Zhang M.* Fruit and seed anatomy of *Chenopodium* and related genera (*Chenopodioideae*, *Chenopodiaceae/Amaranthaceae*): Implications for evolution and taxonomy. *PLoS One*.2013;**8**(4):e61906.
33. *Crawford DJ, Wilson HD.* Allozyme variation in several closely related diploid species of *Chenopodium* in the Western United States. *Amer J Bot*. 1979;**66**(3):237–44.
34. *Wilson HD.* Artificial hybridization among species of *Chenopodium* sect. *Chenopodium. Syst Bot*.1980;**5**(3): 253–63.
35. *Wilson HD.* Genetic variation among South American populations of tetraploid *Chenopodium* sect. *Chenopodium* subsect. *Cellulata. Syst Bot*.1981;**6**(4):380–98.
36. *Wilson HD.* Domesticated *Chenopodium* of the Ozark Bluff dwellers. *Econ Bot*.1981;**35**(2):233–9.
37. *Wilson HD. Chenopodium quinoa* Willd.: variation and relationships in southern South America. *Natl Geogr Soc Res Reports*.1985;**19**:711–21.
38. *Wilson HD.* Allozyme variation and morphological relationships of *Chenopodium hircinum* (s.l.). *Syst Bot*. 1988;**13**(2):215–28.
39. *Wilson HD.* Quinoa biosystematics I: Domesticated populations. *Econ Bot*. 1988;**42**(4):461–77.
40. *Wilson HD.* Quinoa biosystematics II: Free-living populations. *Econ Bot*. 1988;**42**(4):478–94.
41. *Wilson HD.* Quinoa and relatives (*Chenopodium* sect. *Chenopodium* subsect. *Cellulata*). *Econ Bot*.1990; **44**(3):92–110.
42. *Wilson HD, Heiser CB.* The origin and evolutionary relationships of “huazontle” (*Chenopodium nuttaliae* Safford), domesticated chenopod of Mexico. *Amer J Bot*. 1979;**66**(2):198–206.
43. *Lack HW, Fuentes S.* The discovery, naming and typification of *Chenopodium quinoa* (*Chenopodiaceae*). *Willdenowia*.2013;**43**(1):143–9.
44. *Mosyakin SL.* Life strategies of wild relatives of crop plants as prerequisites of their domestication. *Botany and mycology: Modern horizons. In memory of Academician A. M. Grodzinsky (1926–1988.* Kyiv, Akademperiodyka. 2007;150–68.
45. *Vavilov NI.* Centers of origin of crops. Leningrad, All-Union Inst. of Applied Botany and New Crops.1926;248 p.
46. *Baschilov VA*. Appearance of crop plants in the oldest agricultural centers of America. *Latin America*. 1980;(5):92–101.
47. *Bashilov VA.* Periodisation and tempos of the historical process of the Neolithic Revolution in the Middle East and in the New World. *Ancient civilizations of the Orient*. Tashkent, FAN Publ.1986;61–6.
48. *Schnirelman VA.* Ideas of N. I. Vavilov and modern data on formation of early centers of food production. *Vavilov's heritage in modern biology*. Moscow, Nauka. 1989;299–317.
49. *Prehistoric* food production in North America. Ed. R. I. Ford. Ann Arbor, Univ. Michigan Press.1985;411 p.
50. *Diamond J.* Guns, germs and steel. A short history of everybody for the last 13,000 years. London, Vintage. 1998;480 p.
51. *Diamond J.* Evolution, consequences and future of plant and animal domestication. *Nature*.2002;**418**(6898): 700–7.
52. *Smith BD. Chenopodium* as a prehistoric domesticate in eastern North America: Evidence from Russell Cave, Alabama. *Science*.1984;**226**(4671):165–7.
53. *Smith BD.* Eastern North America as an independent center of plant domestication. *Proc Natl Acad Sci U S A*. 2006;**103**(33):12223–8.
54. *Hunziker AT.* Estudios sobre *Amaranthus*. I. Los especies alimenticias de *Amaranthus* y *Chenopodium* cultivadas por los indios de América. *Revista Argent. Agron*. 1943;**10**:297–354.
55. *Hunziker AT.* Los pseudocereales de la agricultura indígena de América. (Mus. Bot. Córdoba; Publ. Misc. No. 3.) Buenos Aires, ACME Agency.1952;104 p.
56. *Sauer JD.* The grain amaranths: a survey of their history and classification. *Ann Missouri Bot Gard*. 1950;**37**(4):561–632.
57. *Sauer JD.* The grain amaranths and their relatives: a revised taxonomic and geographic survey. *Ann Missouri Bot Gard*.1967; **54**(2):103–37.
58. *Sauer CO.* Agricultural origin and dispersal. Cambridge, MTI Press.1969;143 p.
59. *Mosyakin SL, Robertson KR. Amaranthus* Linnaeus (*Amaranthaceae*). *Flora of North America north of Mexico*. Ed. by FNA Editorial Committee. New York, Oxford Univ. Press.2003;Vol. 4:410–35.
60. *Ford-Lloyd BV, Williams JT.* A revision of *Beta* section *Vulgares* (*Chenopodiaceae*), with new light on the origin of cultivated beets. *Bot J Linnean Soc*.1975;**71**(2):89–102.
61. *de Bock TSM.* The genus *Beta*: domestication, taxonomy and interspecific hybridization for plant breeding. *Acta Hort*. 1986;**182**:335–43.
62. *van Dijk H, Desplanque B.* European *Beta*: Crops and their wild and weedy relatives. *Plant evolution in manmade habitats*. *Proc. VII Int. IOPB Symp*. (Amsterdam, The Netherlands; August 10–15, 1998). Amsterdam, Univ. Amsterdam Press.1999;257–70.

63. *Moerman DE.* Native American ethnobotany. Portland, Oregon, Timber Press. 1998;927 p.

64. *Jellen EN, Kolano BA, Sederberg MC, Bonifacio A, Maughan PJ.* Chenopodium. *Wild crop relatives: genomic and breeding resources*. Ed. C. Kole. Berlin, Springer. 2011;35–61.

65. *Jellen EN, Maughan PJ, Fuentes F, Kolano BA*. Capitulo 1.1: Botánica, filogenia y evolución. *Estado del arte de la quinua en el mundo en 2013*. Eds D. Bazile et al. Santiago de Chile, FAO y CIRAD (Montpellier, Francia). 2014;12–25.

66. *Thanapornpoonpong S.* Effect of nitrogen fertilizer on nitrogen assimilation and seed quality of amaranth (*Amaranthus* spp.) and quinoa (*Chenopodium quinoa* Willd.). *Doctoral Dissertation submitted for the degree of Doctor of Agricultural Sciences of the Faculty of Agricultural Sciences Georg-August-University of Gottingen*. Gottingen. 2004;79 p.

67. *Kitaguchi T, Ogra Y, Iwashita Y, Suzuki KT.* Speciation of selenium in selenium-enriched seeds, buckwheat (*Fagopyrum esculentum* Moench) and quinoa (*Chenopodium quinoa* Willdenow). *Eur Food Res Technol*. 2008;**227**(5):1455–60.

68. *Jacobsen SE.* The worldwide potential for quinoa (*Chenopodium quinoa* Willd.). *Food Rev Int*. 2003;**19(**1−2):167–77.

69. *Tapia ME.* Cultivos andinos subexplotados y su aporte a la alimentación [Underexploited Andean crops and their nutritional contribution]. 2nd ed. Santiago (Chile), FAO. 1997;273 p.

70. *Jacobsen SE.* Adaptation of quinoa (*Chenopodium quinoa*) to Northern European agriculture: studies on developmental pattern. *Euphytica*.1997;**96**(1):41–8.