Morphological characteristics of garlic (*Allium sativum* L.) genetic resources collection – Information

H. Stavělíková

Department of Vegetables and Special Crops, Crop Research Institute, Prague-Ruzyně, Olomouc, Czech Republic

ABSTRACT: Maintenance of garlic (*Allium sativum* L.) genetic resources has had a long tradition in the Czech Republic. The collection was founded in 1951 and its current holder is the Crop Research Institute, Department of Vegetables and Special Crops in Olomouc. The collection consists of 613 genotypes. The oldest genotype was acquired in 1954. The collection has been evaluated according to the Descriptor list for *Allium* spp. (IPGRI 2001). 17 characters of the Descriptor list were supplemented with 5 additional characters. The photos of all garlic genotypes were taken. The genotypes were divided into the three main morphological groups according to the ability to produce the scape: the first group with the scape (bolting) – 300 genotypes, the second part without the scape (non-bolting garlic) 205 genotypes and the third part presents semi-bolting garlic – 108 genotypes. The last morphological type has bulbils in the different parts of the pseudostem.

Keywords: garlic; morphological characteristic; genetic resources; scape

The garlic (*Allium sativum* L.) belongs to the genus *Allium*. The taxonomic position of *Allium* and related genera had been a matter of controversy for long (Fritsch, Friesen 2002). The following hierarchy was adopted (Takhtajan 1997):

1. Class – *Liliopsida,* 2. Subclass – *Liliidae,* 3. Superorder – *Liliianae,* 4. Order – *Amaryllidales,* 5. Family – *Alliaceae,* 6. Subfamily – *Allioideae,* 7. Tribe – *Allieae,* 8. Genus – *Allium.*

The estimations accept about 750 species in the genus *Allium* (Stearn 1992). Thus, the sum of all species numbers given exceeds 800, which is possibly somewhat too high, but a number of about 780 *Allium* species currently seems a realistic estimation (Friesen et al. 2006). This large number of species was divided into 6 subgenera and 56 sections (Hanelt et al. 1992). The most recent classification proposal is based primarily on sequences of the internal transcribed spacer region of nuclear ribosomal DNA, grouping about 780 species to 15 subgenera and 56 sections (Friesen et al. 2006).

The genus *Allium* is widely distributed over the warm-temperate and temperate zones of northern hemisphere and it occurs in boreal zone. One or two species occur even in the subartic belt, e.g. *A. schoenoprasum* L. A few *Allium* species are scattered in mountains or highlands within the subtropics and tropics areas, e.g. in Sri Lanka, Ethiopia and Central America (Hanelt 1990; Fritsch, Friesen 2002). Only one species from the southern hemisphere (South Africa), *A. dregeanum* Kth., was described, but its status is doubtful and it may have been brought from Europe by early settlers (De Wilde-Duyfjes 1976). A region of especially high species diversity stretches from the Mediterranean basin to Central Asia and Pakistan. The second, less pronounced centre of species diversity occurs in the western part of North America (Fritsch, Friesen 2002).

Some *Allium* species, e.g., garlic, shallot and most ornamentals, are propagated vegetatively from axillary bulbs, bulblets on stolons, division of rhizomes, and topsets (Kamenetsky, Rabinowitch 2006). Maintaining of vegetatively propagated crops in the genebank requires more efforts than generatively propagated crops. Cryopreservation is the most efficient technique for these crops (Keller et al. 2007); it is a modern and effective method for plant germ-

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Table 1. Harvest area and production of garlic (FAO 2008)

	2003	2004	2005	2006
Harvest area of garlic (ha)				
Africa	34,998	34,728	37,312	37,486
America	68,774	60,946	60,734	59,570
Asia	906,496	932,314.80	952,298	956,382
Europe	123,393	116,220	114,040	112,035
Oceania	280	280	285	285
World	1,133,941	1,144,488	1,164,669.10	1,165,758.40
China	632,350	637,250	647,250	657,250
Production of garlic (t)				
Africa	378,398	383,607	361,106	366,539
America	740,259	667,221	613,313	596,410
Asia	11,717,807	12,444,235	12,924,667	13,395,831
Europe	759,830	808,141	816,982	823,340
Oceania	1,680	1,660	1,740	1,480
World	13,597,974	14,304,864	14,717,808	15,183,600
China	10,080,948	10,596,559	11,084,194	11,587,000

plasm storage. The plant material is stored straight in liquid nitrogen in the temperature of –196°C or in the vapour of liquid nitrogen in the temperature of –150°C. During storage in ultra low temperature the cell life activity is reduced to stop all physiological processes in stored material. Successful material transfer from the cultivation to liquid nitrogen and back without strong damage of the material is important precondition for using this method (Faltus et al. 2005). The important crops (garlic, potato, apple, pear, cherry, strawberry and hop) are cryopreserved in the Czech Cryobank by modified vitrification methods (Zámečník et al. 2007).

The genus *Allium* is economically important because it includes several important vegetable crops – onion, garlic etc., as well as many ornamental species. The garlic is the second most important *Allium* species. It is grown worldwide as an important spice and medicinal plant. The bulb, composed of few to many cloves, is the main economic organ. The fresh leaves, pseudostems and bulbils (topsets) are also consumed (Fritsch, Friesen 2002). Like onion, garlic has been used by humans for a very long time. The first mentions about the garlic are 6,000 years old; Sumerians, Egyptians or Jews used it. The parts of garlic plants were found also in Southern Moravia. They come from 2000 B.C. (Lužný, Vaško 1982).

Since ancient times, garlic, onion and related species have been widely used in many parts of the word as vegetables, as well as in traditional folk medicine. Garlic and onion have been the most intensively investigated. Garlic showed lipid-lowering effects, antiplatelet activity and antiatherosclerotic activities. The cardiovascular effects of garlic are among the best investigated of all medicinal plants species (Keusgen 2002). Louis Pasteur was the first to describe the antibacterial effect of onion and garlic juices. Garlic exhibits a broad antibiotic spectrum against both gram-positive and gram-negative bacteria. *Helicobacter pylori* (*H. pylori*) is a bacterium implicated in the etiology of stomach cancer and ulcers. The incidence of stomach cancer is lower in populations with high intake of *Allium* vegetables.

It was demonstrated *in vitro* that *H. pylori* is susceptible to garlic extract at a fairly moderate con-

Table 2. Production, harvest area and import of garlic in the Czech Republic

	2003	2004	2005	2006
Harvest area (ha)	381	333	328	337
Production (t)	957	1,927	1,712	2,079
Import (t)	7,762	8,251	7,042	6,928

Table 3. Structure of garlic collection according to the origin of accessions

Country of origin	Number of accessions
Former Soviet Union	149
Czech Republic	127
Bulgaria	59
Poland	42
Slovakia	38
Austria	26
Spain	26
Romania	26
Hungary	22
Portugal	22
Other	76
Total	613

centration. Even some antibiotic-resistant *H. pylori* strains are susceptible to garlic (Sivam 2001).

Garlic, Japanese bunching onion, leek and onion are most important edible *Allium* crops. World production of garlic (*Allium sativum* L.) occupies the second position after onions (*Allium cepa* L.) among the *Allium* species (Fritsch, Friesen 2002). Garlic is grown in many the countries today; China, India and Republic of Korea are its principal producers (Table 1). Russian Federation, Ukraine and Spain are then the biggest producers of garlic in Europe (FAO 2008).

In the Czech Republic the import of garlic is several times greater than its home production (Table 2) (Buchtová 2006, 2007).

MATERIAL AND METHODS

Maintenance of garlic (*Allium sativum* L.) genetic resources has had a long tradition in the Czech Republic. The collection was founded in 1951 in the Research Institute of Vegetable Growing and Breeding in Olomouc (RIVGB in Olomouc). Now the holder of this collection is the Crop Research Institute, Department of Vegetables and Special Crops in Olomouc. The collection has 613 genotypes (Fig. 1) at present. The oldest genotype was acquired in 1954.

The actual collection comprises material from all over the world (Table 3). Passport data of collection are available on-line on the web application EVIGEZ (Catalogue Plant Genetic Resources in the Czech Republic), http://genbank.vurv.cz/genetic/resources/. The passport information is included also in the ECPGR European Allium Database available at the URL: http://www2.warwick.ac.uk/fac/sci/hri/about/staff/dastley/gbrhrigru/ecpallium/.

Fig. 1. Field collection of garlic

The *Allium* collection held at the CRI Olomouc is the official International collection of vegetatively propagated *Allium* sp. for long – day type. The important parts of the collection are represented by garlic landraces from different parts of the Czech Republic, by Czech cultivars and wild species as well as by primitive forms of garlic originating from Central Asia and Siberia.

Garlic was grown in the field conditions in Olomouc-Holice (49°37'N, 17°17'E, 209 m a.s.l.). Mean air temperature is 8.7°C and mean precipitation is 570 mm (CHMI 2007).

The trial plots have loam sand to loam soil horizon and the soil type is alluvial and gley soil.

Garlic was transplanted in field in the autumn time, namely in the mid October. It was stained by combination of effectual substance iprodian 255 g/l (Rowral Flo), chlorinepyrifos-methyl 400 g/l (Reldan 40 EC) and carbendazin 500 g/kg (Bavistin WG) for 20 min. The harvest time was the end of June and beginning of July. The weed control was done during

Fig. 2. The bulb structure

Fig. 3. Different types of bulbils

all vegetative period. The insecticide chlorinepyrifos – methyl 400 g/l (Reldan 40 EC) and diazion 10% (Basudin 10G) were used as the protection of the pests. The harvested plants were dried in the special room with good air circulation. After 6–8 weeks the rest of leaves and roots were cut and garlic was prepared for planting.

Since 2002, whole collection has been described according to the Descriptor list for *Allium* spp. (IPGRI 2001). The Descriptor has 17 characters: Foliage – colour and attitude, leaf – cross section, shaft – length, bulb – shape of mature garlic, outer skin colour of compound bulb, skin colour of the clove, number of cloves per compound bulb, structure type, shape of the compound bulb in horizontal section and weight of cloves, ability to flower, ability to produce scape, number of bulbils (topset), bulbils weight, general fertility and flower number in umbel. 17 characters from Descriptor were supplemented with 5 characters – plant vigour, leaf – diameter and attitude after winter, shaft diameter and number of branches in umbel. The characters were rated on a scale from 1 to 9, where 1 means the lowest and 9 means the highest expression of the character. The description of all genotypes was done within a three-year period. The character 'ability to produce the scape' was monitored in the long term.

We took photos of all garlic accessions – sideways/sidelong look, top point of view, horizontal cross section. The shape of the compound bulb and bulb structure type are seen on them (Fig. 2). Individual garlic cloves and bulbils were photographed as well (Fig. 3).

RESULTS

The collection of garlic comprises 613 genotypes. The collection was divided into three main morphological groups according to the ability to produce scape: the first group presents 300 genotypes with the scape (bolting garlic), the second comprises 205 genotypes without scape (non-bolting garlic), and the third part presents semi-bolting garlic – 108 genotypes. The last morphological type has bulbils in the different parts of the pseudostem (Fig. 4).

Twenty-five genotypes from the second (non-bolting garlic) and five genotypes from the third group (semi-bolting garlic) are able to produce scape under special conditions.

All genotypes were divided according to the different expression of the character. Most genotypes (350) had medium plant habitus and 507 genotypes had green color of foliage. The prostrate foliage attitude was described at 57 genotypes, 469 genotypes had erect foliage in the spring, compared to 368 genotypes (gt) in summer. The flat leaf – cross section was observed at 468 genotypes. 302 genotypes had the width of leaf in a range from 15 mm to 21 mm. The most genotypes (516) had the length of shaft from 18 cm to 27 cm and 273 genotypes had intermediate (8 mm–10 mm) diameter of shaft. Many genotypes (344) had broadly ovate shape of mature garlic bulb and 477 genotypes had cream colour of compound bulb. Only three genotypes had one clove, whereas 334 genotypes had number of coves in the interval from 5 to 10. 209 genotypes had bulb structure with regular multi-fan groups, which is a characteristic type for non-bolting garlic. The weight of clove was low at 334 genotypes. Two landraces (Villaviiosa 1, Bozanes 1) from Spain and


Fig. 4. Semi-bolting garlic

one landrace from Portugal had the ability to flower, however, these flowers were sterile. 330 genotypes had ability to produce scape, while 180 genotypes did not produce scape and 103 genotypes produced scapes but never develop heads. 176 genotypes had more than 30 bulbils in one head (umbel). The weight of 100 bulbils was lower than 10 g at 167 genotypes. Two branches of the umbel were reported at 32 genotypes, three branches at 3 genotypes.

CONCLUSION

The first step of description of garlic collection genetics resources comprised of morphological characterization in association with passport data. On this basis, it is possible to choose the genotypes for further evaluation – dry matter content, content of sulphur, suitability for new and effective method of the germplasm storage – cryopreservation, and selection set of "core collection". The first steps of evaluation were done. The collection was included into the project *Optimization of Recovery Methods and in vitro Propagation for Purpose of Long-time Preservation by Cryoconservation of National Garlic Genotypes* (National Agency of Agricultural Research QH71228) and to the 050 AGRI GEN RES 870/2004 acronym EURALLIVEG Contract No. AGRI-2006-0395 *Vegetative Allium, Europe's Core Collection, Safe & Sound*. The main aim is the establishment of European Core Collection of vegetative alliums, including garlic molecular characterization, cryopreservation and virus elimination, and molecular characterization of shallot.

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Morfologický popis kolekce genetických zdrojů česneku kuchyňského (*Allium sativum* L.) – Informace

ABSTRAKT: Uchovávání genetických zdrojů česneku (*Allium sativum* L.) má v České republice dlouhou tradici. Kolekce byla založena v roce 1951 a nyní je udržována Výzkumným ústavem rostlinné výroby, v.v.i., Oddělením zelenin a speciálních plodin v Olomouci. Kolekce zahrnuje 613 genotypů. Nejstarší genotyp byl získán v roce 1954. Kolekce je popisována podle Klasifikátoru pro *Allium* spp. (IPGRI 2001). K 17 morfologickým znakům z klasifikátoru bylo přidáno dalších pět. Byly vyfotografovány všechny genotypy. Genotypy byly rozděleny do tří základních morfologických skupin podle schopnosti vytvářet květní stvoly: první skupina 300 genotypů vytváří květní stvoly, druhá skupina 205 genotypů nevytváří květní stvoly, třetí skupina 108 genotypů tvoří ne zcela vyvinutý květní stvol a má pacibulky v různých částech pseudostonku.

Klíčová slova: česnek; morfologický popis; genetické zdroje; květní stvol

Corresponding author:

Ing. Helena Stavělíková, Ph.D., Výzkumný ústav rostlinné výroby, v. v. i., Praha-Ruzyně, Oddělení zelenin a speciálních plodin, Šlechtitelů 11, 783 71 Olomouc, Česká republika
tel.: + 420 585 209 965, fax: + 420 585 209 969, e-mail: stavelikova@genobanka.cz