



Genetic Improvement of Field Pea (*Pisum sativum* L.) in Bulgaria

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Summary: Field pea attained greater importance as a cultivated plant in Bulgaria at the beginning of the 20th century. Until 1964, only breeding for forage was in use, with developed winter varieties №5 and Pleven 2. Recently, field pea achieved the greatest increase (283.3%) in the sown areas, since the variety structure was updated annually. There are 10 registered varieties in total, with 7 spring and 3 winter ones. The composition of the Bulgarian *Pisum* collections is highly variable, with accessions of diverse status. The greatest efficiency is obtained in a combination of bulk method in the early generations and certain features of pedigree, single seed method, with possible modifications and inclusion of the mutational variability.

Key words: accession, collections, field pea, grain legumes, improvement, *Pisum sativum*

Introduction

Field pea (*Pisum sativum* L.) is one of the most important grain legumes in the world. Its grain is a major source of plant-based dietary protein for animals. Pea is a legume native to South-West Asia and was one of the first cultivated crops. World production of field pea is $5,389 \times 10^6$ ha with the most important producing countries being Canada, China, India and the Russian Federation, all representing almost 70% of the total crop area (FAOSTAT 2006). It is consumed as green vegetables (whole pods or immature seed) in Asian countries and as dry seed in Europe, Australia, America and Mediterranean regions. It ranks third in the world production amongst the food legumes (Ghafoor & Arshad 2008).

Field pea can provide protein-rich feed and improve the sustainability of organic systems. The share of agricultural land that is under organic agriculture approaches 4% in EU and 7% or more in Scandinavian countries, Italy, Austria and Greece, and it may reach 25% in EU by 2030 (Annicchiarico & Filippi 2007).

The nutritional value of dry pea seed is similar to other grain legumes and contains 18-30% protein, 35-50% starch and 4-7% fiber. Pea protein is deficient in sulfur-containing amino acids, but contains relatively high levels of lysine, making

it a good dietary complement to cereals. Anti-nutritional factors, although present in pea, are relatively minor and do not adversely affect crop use (McPhee 2003).

History

Pea attained greater importance as a cultivated plant in Bulgaria at the beginning of the 20th century. It is supposed that the first true pea varieties were first introduced in Western Europe. In Bulgaria, there are no accurate data for the introduction of pea as a crop. After the establishment of first agricultural schools, pea was grown as a garden plant in southern Bulgaria and as a forage crop in northern Bulgaria (Kalaydzhieva 1980). In Bulgaria in 1939, pea was cultivated at 1,000 ha, with introductions from Romania, while in 1965 it took 49,800 ha including both introduced and Bulgarian varieties. During the years that followed, the areas under pea were small despite the increase of the needs for pea as a protein-rich feed. Until 1964, only breeding for forage was in use. The winter varieties №5 and Pleven 2 were developed during this period, but without wide distribution due to a short generative coefficient. After 1964, the hybridization was introduced in pea breeding, with winter varieties such as Pleven 10. Afterwards, experimental mutagenesis followed (Sachanski 1988).

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The winter forage pea varieties are suitable for arid regions. The utilization of winter forage pea in the conditions with a high water deficit results in higher and more stable aboveground biomass and protein yields, enhancement of the ratio between symbiotic and fertilizer nitrogen in organic farming and the possibilities for more economic use of the agricultural land (Filipov 1997, Filipov 1998).

Today

The productivity of pea varieties depends to a great extent on climatic conditions and individual characteristics of a variety. The soil-climatic conditions in Bulgaria enable pea to be grown as a cover crop in the spring, summer or autumn. Because of its numerous uses and diverse soil-climatic conditions, there are several breeding directions: both winter and spring varieties for both forage and grain production (Kuzmova 2002a; Kuzmova 2002b).

In Bulgaria, pea is most frequently used in feeding ruminant and monogastric animals, and is regarded as a possible alternative to soybean meal. Among leguminous crops, pea covers the greatest area and has higher yields ($4,100 \text{ kg ha}^{-1}$) in comparison to soybean ($2,860 \text{ kg ha}^{-1}$), common bean (590 kg ha^{-1}) and lentil (370 kg ha^{-1}). Mainly white-flowered spring varieties are grown with low content of anti-nutritional factors. Its contribution to the biological nitrogen content in the system of organic farming is obvious and expected to increase (Mihov et al. 2002, Mehandzhiev et al. 2006, Krachunov et al. 2007).

During the last decade in Bulgaria and Europe, a broad set of spring pea is cultivated for grain, offering a good choice for the Bulgarian farmers. During season 2003-2004, 5,000 ha were sown for grain production in animal feeding. The low yields during this period ($1,700 \text{ kg ha}^{-1}$) indicate that the used varieties did not have great potential, while the new varieties were not sufficiently grown.

Table 1. Composition of the Bulgarian grain legume collections in the Institute of Plant Genetic Resources Institute (IPGRI) in Sadovo

Tabela 1. Sastav bugarskih zbirki zrnenih mahunarki u Institutu za biljne genetičke resurse u Sadovu

Genus Rod	Total Ukupno	Long-term conservation Dugoročno čuvanje	Middle-term conservation Srednjeročno čuvanje	Working <i>ex situ</i> collection Radna <i>ex situ</i> zbirka
<i>Pisum</i>	2510	610	900	1000
<i>Lupinus</i>	284	70	204	10
<i>Lathyrus</i>	410	270	100	40
<i>Phaseolus</i>	2066	777	1151	138
<i>Cicer</i>	294	234	56	4
<i>Lens</i>	716	385	237	94
<i>Vicia</i> sp.	1808	1150	534	124

Table 2. Bulgarian official catalogue of field pea varieties in 2009

Tabela 2. Zvanična lista sorti stočnog graška Bugarske 2009.

Denomination of the variety Naziv sorte	Year of registration Godina priznavanja
Amitie	2004
Bohatyr	1995
Drujba	2006
Kristal	2004
Picardi	2004
Pleven 4	2008
Yunak	1989
№11	1999
Vesela 23 E	2003
Mir	2000

At the present moment, most areas are sown with Pleven 4, registered in 1985, that does not satisfy the increasing requirements of the producers any more. This variety easily lodges and sometimes the grain losses are too great. At the end of the 70s and at the beginning of the 80s, varieties from East Europe were introduced, such as Yunak, Yubileen and Dukat. Relatively recent Dutch varieties, such as Solara, Baccara, Mira and Alex are grown at a limited area (Angelova 2005).

The aim of pea breeding is to develop new intensive varieties with increased productivity, better ecological plasticity, improved resistance to biotic and abiotic factors, and desirable biochemical and technological qualities. The new varieties are characterized with high production potential and stable yields. In 2004, the variety Kristal, which has 36.9% higher yield than the former standard Pleven 4, was introduced as another official standard (Mihov et al 2005).

In the National Seed Genebank of Bulgaria in Sadovo, each year about 60 characters of its forage pea accessions are analyzed in accordance with the FAO descriptors. Breeding for grain yield prefers spring, early-maturing, white-flowering, short-vining and light-coloured seeds, while breeding for forage yields prefers winter varieties with purple flowers, longer stems, dark seeds and normal leaves (Angelova 1995).

The grain legume crops are good preceding crops because of the biological nitrogen fixation by the soil bacterium *Rhizobium leguminosarum*, which has the capability of fixing atmospheric nitrogen into plant-accessible forms and reduces the need to apply artificial nitrogen fertilizers. However, until 2006 grain legumes were grown on a small area because of the limited needs of animal husbandry, with common bean at 3,676 ha, lentil at 1,918 ha, vegetable pea at 1,086 ha, dry pea at 570 ha, chickpea at 519 ha, soybean at 89 ha and faba bean at 12 ha, making 7,872 ha in total. Despite this, the Institute of Plant Genetic Resources in Sadovo maintained a large grain legume collection (Tab. 1). During the last years, dry pea achieved the greatest increase (283.3%) in the sown areas in 2007 in comparison to 2006, since the variety structure was updated annually (Tab. 2). There are 10 registered varieties in total, with 7 spring and 3 winter ones, namely №11, Vesela – 23 E and Mir. All of them are of Bulgarian origin and over 90% of them were included into the List A of the Official Variety List of Bulgaria after 2000 (Stancheva 2007, MZH 2008, Bulgarian Official Catalogue of Varieties of Agriculture and Vegetable Plant Species 2009).

The average grain yields in Bulgaria in the last years were low and varied between 1,220 kg ha⁻¹ and 1,860 kg ha⁻¹. The lasting climatic changes require that the new varieties have good adaptability. The development of the variety Kerpo improves the variety structure of spring pea in Bulgaria and provides a good choice to producers and farmers (Kertikova et al. 2009).

The expansion of the areas under pea and the use of various variety groups by farmers are possible only with an efficient and well-organized grain production. Such cultivars are included in both European and Bulgarian Lists (Angelova 2005).

The problem for the effectiveness of breeding is heavily present with many different aspects. It is related with a broad inclusion and a rational use of various genetic selection materials, with shortening the deadlines for developing new varieties and increasing the efficiency of the selection in hybrid progenies (Mihov et al. 2006).

So far, research has been done regarding the diverse issues related to pea genetics and breeding in Bulgaria. A rich collection is included and a great genetic diversity is developed. An intensive breeding program of common bean and pea has been carried out recently in several centers in Bulgaria, such as Sadovo, Pleven and General Toshevo. All breeding directions are fully developed and new technologies are used. Breeding is mainly targeted towards earliness, winter hardness and drought resistance. The specific climate conditions and climate changes call for the development of early maturing varieties in all grain legumes. Only early and moderately early cultivars in Bulgaria can express their full yield potential. The composition of the Bulgarian *Pisum* collections is highly variable (Tab. 3). They include landraces, old cultivars, local populations, all newly developed and cultivated varieties, breeding lines, various forms, wild relatives, etc. Predominant in these pea collections are the accessions with the status of breeding material (Angelova & Stoilova 1998, Angelova 2000, Mihov et al. 2002, Angelova 2008).

Selection for productivity is most time-consuming in the process of the pea genetic improvement. Most valuable genotypes for this purpose are those that form two pods at one node. In relation to the global warming, it is demanded that the newly developed cultivars have shorter growing season and avoid the high temperatures in mid June and thus overcome the high temperature stress. The small-seeded varieties, as well as those with wax coating, have more prominent drought resistance and may be successfully used

Table 3. The classification of the pea collections in the Institute of Plant Genetic Resources (IPGR) in Sadovo and the Research Institute of Forage Crops (RIFC) in Pleven

Tabela 3. Klasifikacija zbirki graška u Institutu za biljne genetičke resurse u Sadovu i Naučnom institutu za krmno bilje u Plevnu

IPGRI		
Winter hardiness Ozimost 80 – 100%	Low sensitivity Niska osetljivost 70 – 80%	High sensitivity Visoka osetljivost 60 – 70%
187 samples <i>Pisum arvense</i>	350 samples <i>Pisum sativum</i>	278 samples <i>Pisum sativum hortense</i>
Old local varieties, populations, forms, typical fodder varieties and breeding lines used for production of green mass	Newly created local and introduced varieties, breeding lines of dry pea	Green pea varieties, breeding lines, afila forms, fasciated forms
RIFC		
116 samples <i>Pisum arvense</i>	49 samples <i>Pisum sativum</i>	1 sample <i>Pisum sativum</i> var. <i>triver</i> 5 samples <i>Pisum sativum</i> var. <i>hiemale</i> 1 sample <i>Pisum sativum</i> var. <i>melanocarpum</i>
Newly introduced typical fodder varieties, afila forms	Newly introduced typical fodder varieties, afila forms	Fodder populations and forms

as donors of this trait in hybridization. The resistance to insects and pests is a very difficult breeding task due to the limited resources of the knowledge about the genetic control of this resistance and a lack of highly tolerant forms to the main pests. By means of hybridization and the repeated individual selection tolerant forms are being developed with damages by pea weevil (*Bruchus pisorum* L.) from 2% to 7%. The lines with a partial parchment of pods and a decreased susceptibility to pod dehiscence and seed shattering have also been developed (Mihov et al. 2003).

Perspectives

The necessary genetic improvement and its use in the development of new genotypes is related to different climatic conditions by using the most appropriate methods of the selection in mutant populations. Hybridization is one of the main methods of combining different characters and quality parameters of parental varieties. However, the method of inter-variety hybridization is closely linked to many difficulties due to a low level of crossing success and a high labour input. The greatest efficiency is obtained in a combination of bulk method in the early generations and

certain features of pedigree single seed method, with possible modifications and inclusion of the mutational variability (Mihov 1988, Kalapchieva 2002).

Mutation breeding has been used worldwide for the improvement of grain legumes through an increased genetic variation and the development of novel alleles. Several pea cultivars resulting from mutagenesis have been released with improvements including increased yield, lodging resistance (afila leaf type), larger seed, increased protein content and modified maturity.

Induced biochemical mutations can change the content of amino acids by the stimulation of expression of certain genes and thus affect the biosynthesis of various products. Mutant forms with increased content of protein (28.74% to 32.59%) have been developed. The contribution of experimental mutagenesis to the pea genetic improvement is reflected in the fact that there are new line-donors with high productiveness and earliness (15-20 days before the standard), resistance to the economically important diseases (*Ascochyta pisi* and *Erysiphe pisi*) and improved standing ability. They can be used in the conventional breeding for the development of varieties with good ecological stability and desirable quality characters (Mihov et al. 2003).

In order to increase the efficiency of breeding process in forage pea it is needed to have a good knowledge on the combining ability of varieties used. Without it, it would be impossible to permanently upgrade and improve the available genetic variability (Koeva et al. 2002, Mehandzhiev et al. 2006).

Conclusions

Field pea continues to be an important crop worldwide both for food and feed and as a rotational crop with other cultures. The pea breeding programs are based on yield and yield components. Pea grain yield is a quantitative trait which is affected by many genetic and environmental factors. The availability of the genetic diversity of the *Pisum* germplasm provides breeders with ability to overcome many production constraints. The advanced genetic study and understanding of the pea crop and its genetics as a whole will open the opportunities for its improvement.

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Genetičko unapređenje stočnog graška (*Pisum sativum*) u Bugarskoj

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Izvod: Grašak je postao značajan usev u Bugarskoj početkom 20. veka. Do 1964. postojalo je jedino oplemenjivanje za krmu, sa stvorenim ozimim sortama №5 i Plevén 2. Tokom poslednjih godina, proteinski grašak je ostvario najveće povećanje setvenih površina (283,3%) pošto se sortiment osavremenjuje svake godine. Ukupno je priznato 10 sorti stočnog graška, od čega 7 jarih i 3 ozime. Sastav bugarskih zbirki graška je veoma raznovrstan, sa genotipovima različitog statusa. Najveća efikasnost oplemenjivanja ostvarena je kombinacijom metoda u smeši tokom ranih generacija i izvesnih odlika pedigre metoda, sa mogućim modifikacijama i uključivanjem mutantne varijabilnosti.

Ključne reči: genotip, grašak, kolekcija, *Pisum sativum*, poboljšanje, zrnene mahunarke