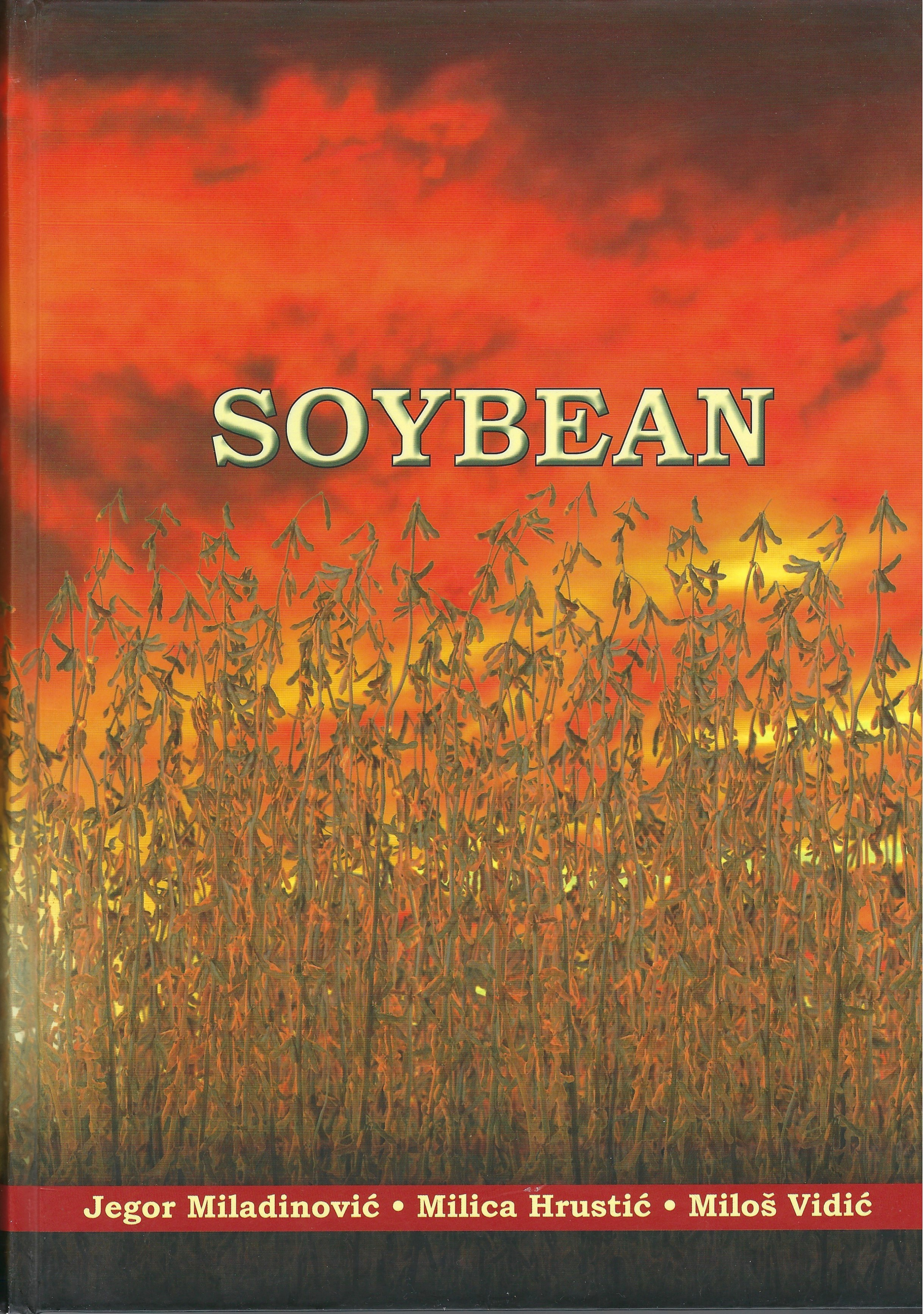
SOYBEAN



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SOYBEAN

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SOYBEAN

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FOREWORD

This is a translated edition of the book titled "Soja" published in Serbian language in 2008, which displayed the accumulated knowledge on fundamental and applied soybean research, as well as soybean breeding efforts at Institute of Field and Vegetable Crops in Novi Sad, Serbia.

Global importance of soybean is continually growing, with soybean planted areas reaching almost 99 million ha in 2009 and production of soybean grain exceeding 222 million tons. According to these indicators, soybean is the most important industrial plant worldwide, both as a basic source of protein nutrients for cattle, poultry and fish and as the most important source of plant oil.

Simultaneously with increased interest in growing this plant species, scientific research on soybean has also been enhanced, especially regarding fundamental research. For the most part, this book deals with achievements of Serbian researchers. Chapters dealing with soybean morphology and its requirements during growth and development have been updated and revised. Content of chapters dealing with production technology, seed production and importance, as well as chapters giving an overview of diseases and pests affecting soybean is somewhat characteristic for Serbian climate and soil. Therefore, the authors would particularly recommend to foreign readership the chapters dealing with quantitative and qualitative genetics of soybean prepared for this edition by leading experts and professors from University of North Carolina and University of Iowa. Outline of the most recent achievements in the field of soybean breeding has also been prepared by scientists from the USA, where such research is most developed.

Chapter dealing with soybean importance and origin gives a chronological survey of soybean breeding results at Institute of Field and Vegetable Crops. The previous decade was outstandingly dynamic and successful in this area, witnessed by impressive results. The number of soybean varieties developed at Institute of Field and Vegetable Crops released in Serbia has doubled, while there was a ten-fold increase in the number of varieties released abroad - from four varieties released in 2000 to 49 released so far.

Hence we believe that this edition will be useful to everyone involved in soybean production, especially to students and scientists conducting research on soybean.

Authors would like to thank all who have participated in preparation of this book in any way, and especially to reviewers whose efforts and pieces of advice largely contributed to the form and content of this book.

Special gratitude is extended to the Ministry of Science and Technological Development of the Republic of Serbia for financially aiding the printing of this book.

In Novi Sad, in February 2011.

Authors.

IMPORTANCE, ORIGIN AND EXPANSION OF SOYBEAN

Milica Hrustić, Jegor Miladinović

IMPORTANCE OF SOYBEAN

What is the first thing that comes to mind at the mention of the word soybean? An average Chinese person would probably think of all the different dishes and beverages that have been sustaining their and their ancestors' lives for countless generations. An average crop farmer would think of the profit the plant could generate and the beneficial effects soybean imparts on soil it has been grown on. A livestock farmer would associate the word with soybean meal, an essential component of quality animal feed. A nutritionist would immediately think of the essential amino acids found in soybean protein, while an industrialist's attention would be focused on all the processed products that can be made from the plant. The owner of a trucking company might calculate the price of transporting large quantities of soybean beans and processed products, and a merchant would contemplate how much profit buying and selling all those goods might bring. The soybean plant has many varied uses and its importance is multifaceted.

Soybean's importance comes first and foremost from the chemical composition of its grain, which is about 40% protein and around 20% oil. This adds up to soybean having over 60% of different nutrients that can be used for various purposes. Because soybeans can be used whole or can be processed to obtain oil or protein, the plant is used widely and extensively not only in the food sector but in various other industries as well. In more recent times, it has been gaining increasing importance in international commerce too. Soybean meal is an indispensable source of protein in the nutrition of livestock, poultry and fish. Although soybean is an important protein source for the ever-growing human population, soybean protein is still not used as much as it should be in the human diet. There are several reasons for this. In the developed world, there is an abundance of traditional protein sources (meat, milk, eggs) and soybean is used primarily in special diets and in Asian cuisine. The developing countries, on the other hand, are deficient in high-protein foods but do not have the industrial capabilities needed to process soybean for human consumption.

Soybeans are also a major source of vegetable oil and are used to produce one third of all such oil in the world. Thus far, soybean oil has been primarily used in the food industry for purposes such as cooking and preparation of ready-to-eat meals, mayonnaise, margarine, and so on. There is, however, a growing trend towards using the crop for various other industrial purposes, such as the manufacture of soaps, detergents, paints and varnishes. One of the most common products based on soybean oil is newspaper printing ink, which has an advantage over the traditionally used ink in that it does not rub off. Soybean oil is used increasingly as the carrier of the active ingredient in pesticides, where it reduces the amount water needed for the aerial application of the chemical. One important component of soybean oil is lecithin, which is used in the manufacture of baking and confectionery products as well as in medicine and the textile and chemical industries. Soybean production and processing are constantly on the rise, and because soybean-producing and soybean-consuming regions do not fully overlap, the importance of the crop is increasing both in the processing industry and international commerce and transport.

We must not forget the role of soybean in field crop production either. Being a legume, soybean has the ability to fix atmospheric nitrogen and provide itself with sufficient amounts of readily available nitrogen, thus reducing the need for nitrogen fertilizer application. This makes this plant a very good fit for crop rotations.

HISTORY AND SPREAD OF SOYBEAN

Birthplace of soybean

The earliest history of soybean has been lost in the mists of time. According to ancient Chinese texts, soybean had been grown and highly valued as food for centuries before the first written records appeared. The first written mention of the crop is found in the book Materia Medica by the Chinese Emperor Shennong, dating back to 2838 BCE (Morse et al., 1949). As per ancient Chinese literature, soybean's original name was "shu". This word appears in the Book of Songs (Shi Jing), one of the five classics of Chinese literature, which covers the period from the 11th century to the year 771 BCE (end of the Zhou dynasty). Among the writings of the Shang dynasty (16th to 11th century BCE) a character has been found that has been identified as the original form of the word "shu". Having been in cultivation for several thousand years, soybean, along with rice, wheat, barley, and millet, has been one of the five sacred crops essential to the survival of the Chinese civilization (Gutschy, 1950; Morse, 1950).

For a great many years, soybean did not spread much beyond its native land of northeastern China, which is regarded as the primary place of the plant's genetic origin. By the start of the Common Era, soybean had likely reached central and southern China and the Korean Peninsula. The crop expanded into Japan between 200 BCE and the 3rd century CE (Caldwell, 1973), and the first written records of it in the country date back to the 7th century CE. Between the start of the Common Era and the 15th and 16th centuries, soybean was introduced to Indonesia, the Philippines, Vietnam, Thailand, Malaysia, Burma, Nepal, and northern India. There, different landraces of the crop developed, so this part of the world is considered the secondary point of soybean origin (Hymowitz, 1988).

Global expansion of soybean

Soybean first appeared in the botanical and home gardens of Europe and America only as late as in the 18th century, when the development of marine traffic enabled better communication between distant parts of the world. People of Europe first learned of soybean from the German botanist Engelbert Kaempfer, who visited Japan in 1691-1692 and later wrote a book entitled "Amoenitatum exoticarum politico-physico-medicarum". The book was published in 1712 and included a detailed description of the soybean plant as well as recipes for preparing various soybean-based dishes and beverages (Gutschy, 1950; Hymowitz, 1988). Soybean descriptions subsequently appeared in several other books, the first of which was "Musaeum Zeylanicum" by Paulus Herman (1726). In his 1737 book "Hortus Califfortianus", Charles Linne mentions soybean under the name Phaseolus max., while another book by the same author, a 1753 title called "Species Plantarum", refers to soybean as Dolichos soja. Konrad Moench gave soybean the name of Soja hispida and Maksimovič (1873) that of Glycine hispida.

The written record shows that in the 18th century soybean was grown in Europe only in a handful of botanical and house gardens. Hymowitz (1988) argues that the practice of soybean growing in Holland predates the year 1737, basing his conclusion on a description of plants grown in a garden in Hartekamp that was published by Linne in that year. Soybean seeds sent back to France by missionaries stationed in China were planted at Jardin des Plantes in Paris in 1739. Soybean was grown in the Royal Botanic Gardens at Kew, England in 1790 and in the Dubrovnik area in 1804. The cultivation of soybean in all these and similar cases was motivated either by sheer curiosity or by the desire to determine the plant's taxonomic affiliation, as the crop's uses were still unknown to Europeans.

In Yugoslavia, according to Hymowitz (1988), soybean was cooked after the harvest and then mixed with cereals and fed to poultry in order to increase the production of eggs.

Soybean expansion and popularization in Europe began with the Austrian botanist Friedrich Haberlandt, who in an 1875 book titled "Die Sojabohne" reported detailed results on the study of about 20 soybean varieties from several European countries. Although the results of these trials were promising, it would still take quite a while (except for some parts of Romania, Czechoslovakia, and Austria) before soybean would become a major crop on the European continent.

Due to the absence of adequate cultural practice and a lack of knowledge of the plant's great usefulness, soybean accounted for only a small fraction of the overall agricultural output in 19th century Europe. The failure of the cotton crop in the U.S. in 1908 resulted in a shortage of vegetable oil in England, so soybean was imported into the country from Japan. The oil obtained by crushing the imported soybeans received a great reception and was an outstanding success. Importation of soybean into Europe continued in the subsequent years, and some time later major-scale soybean-growing operations were established in several European countries, most notably Romania, Bulgaria, Czechoslovakia, Austria, Yugoslavia, and Hungary (Gutschy, 1950; Morse, 1949).

During the 18th century, soybeans were grown from time to time on some US farms as well. Henry Jonge is regarded as the first grower of soybean in America. He began cultivating the crop in 1765 using plants he had received from Samuel Bowen in London via China. From 1766 onwards Jonge grew and processed soybean regularly on his estate in Georgia and he even patented some of the processed products made from the plant. After his death in 1777, however, this work was discontinued. Another attempt at growing soybean in what was soon to become the United States occurred in 1770 in the garden of the Philadelphia botanist John Burton. Soybean was probably grown in various locations in the US during the first half of the 19th century as well, but there are no surviving records of this, as the reports were printed in local papers or were presented at local meetings. In the mid-19th century, soybean was tested on a large number of farms across the U.S. and was considered a new crop species. It was accepted by many farmers, who used it as animal feed, hay or silage, either on its own or in combination with other crops.

The scientific approach in evaluating soybean genotypes began to be used in the late 19th century with the introduction of agricultural experiment stations. As early as the start of the 20th century, a great effort was made to collect as many soybean genotypes as possible, which were then studied extensively. Up until that time, only a small number of varieties of the crop had been grown, and they were mostly used for silage. It was only in the 1940s that the portion of the soybean crop harvested for grain reached the one half mark, with 4,000,000 ha being the total area planted. The use of soybean as a source of vegetable oil in Europe between 1900 and 1910 resulted in an increased interest in soybean utilization in the U.S. (Smith and Huyser, 1987). According to Howell (1982), the increase in US soybean acreage was precipitated by the simultaneous emergence of several factors. Perhaps the most important among these was the mechanization of agriculture, which reduced the need for draft animals and vacated millions of hectares of land that had up to that point been used to produce animal feed. Also, synthetic fibers replaced cotton, which had previously occupied large areas. Another important influence was a large population growth, which brought about significant food shortages. The confluence of these factors created a favorable climate for a plant such as soybean, which had a good balance of oil and protein and was known to have been used in China at the time for obtaining oil and flour. The plant had thus been able to meet all the production and market requirements and had found its place in agricultural, processing and food industries.

SOYBEAN PRODUCTION WORLDWIDE

In the early 1900s soybean was a little-known plant that was grown in only a handful of countries, but by the end of the 20th century it had developed into a leading field crop on the global scale. In the mid-20th century, soybean was grown internationally on about 15 million hectares but had not yet become a major crop in many countries. It was only in the 1950s that a sharp increase occurred in global soybean acreage. In recent years, the crop has been grown on nearly 100 million hectares annually. Aside from the staple cereal grains such as wheat, rice and maize, this is the largest total area sown to any field crop on a global scale. In the mid-1970s, the total annual production of soybean in the world ranged from 50 to 60 million tons. In the next two decades, the global annual output of the crop doubled to over 120 million tons, and in 2009 more than 222 million tons were produced. These increases are not only due to the increased acreage but came as a result of increased yield per unit area as well. Nowadays, soybean is grown in most countries to a greater or lesser extent, but in recent years about 90% of the world's production have been concentrated in only several countries.

For the past few decades, the US has been the world leader in producing, processing and trading in soybean and its processed products. Up until the 1940s, soybeans were grown in the US primarily for the purposes of silage. It was at some point during that decade that half of the annual US crop was for the first time harvested for the beans. After that, areas sown to the crop kept increasing until the 1980s, when they reached 28 million hectares, which is the level they have been at ever since, with some minor fluctuations. For quite some time, the average yields were at around 2 t/ha, and then between 1980 and 2000 they increased to 2.3-2.5 t/ha. In the last couple of years, the yields have again increased significantly, averaging 2.8 t/ha in 2004, 2.9 t/ha in 2005, and 3.0 t/ha in 2006. The total soybean production in the US varies from 80 to 90 million tons per year, which accounts for one third of the world's total output.

Brazil and Argentina do not have a long tradition of soybean growing, but it has not taken long for both these countries to become major soybean producers. Soybean growing began in Brazil in the 1960s and the acreage was initially negligible. The areas planted to soybean rose sharply in the 70s and began to exceed 10 million hectares in the 80s. In the last ten years or so, the country's soybean acreage has doubled and is now exceeding 20 million hectares. The average yields vary a lot, as does the overall production, but in recent years Brazil is producing over 50 million tones of soybean grain, which is almost a quarter of all the soybean produced in the world. Argentina has increased its soybean acreage from several hundred thousand hectares in the 1970s to its present output of more than 16 million hectares and growing. The 40 million tons of soybean grain produced in Argentina every year make this country one of the top soybean growers in the world (Table 1.1).

In the early 20th century, China was the only country that cultivated soybean on areas measured in millions of hectares. The annual hectarage averaged four to five million before 1950 and seven to nine million afterwards, the only notable exception being the year 1955, when the plant was sown on around 12 million hectares. In the last three years, China has grown between nine and ten million hectares of soybean per annum. The average yields have been low – they hovered around 1 t/ha until the 1980s and then began to increase slowly until they reached their present-day levels of 1.6-1.8 t/ha. Over the same period, the annual production of the crop increased as well. For a long time, China produced between seven and nine million tons of soybean a year, with a record 11 million tons in 1938 (Ma, 1982). Since the mid-1980s, Chinese soybean production has been increasing slowly but steadily – in 2005, for instance, 17 million tons of the grain were produced. Before the 1950s, the country accounted for about 50% of global soybean production, but this percentage has decreased since. In the last decade, China has contributed less than 10% to total soybean production in the world. India, the only other major grower of the crop on the Asian continent, cultivates soybean on 6-7 million hectares, with an average yield of around 1 t/ha.

Contribution of Europe to world soybean production ranges from 1 to 2% and the plant is important in only some countries of the continent (this will be discussed in more detail a little later in the chapter).

Baker (1970) argues that soybean has never become popular in Africa, but many African countries have introduced soybean as a commercial crop since the 1970s and now have their own programs aimed at increasing the acreage sown to the plant. In 2008, for example, soybean was grown in Africa on more than one million hectares. There are, however, a number of factors hampering soybean growing on the African continent. These include insufficient knowledge of the growing technologies, a lack of an adequate selection of cultivars and inoculants, lack of processing facilities, and loss of seed germinability during storage (Jackai et al., 1984). The largest producers of soybean on the continent are Nigeria, Zimbabwe, Egypt and Zambia.

World soybean production has been increasing year after year and the crop has spread to almost every part of the globe. Overall, the crop is grown the most on the American continent, followed by Asia, while in Europe, Africa and Australia the volume of soybean production is considerably smaller (Table 1.1).

Table 1.1

Area harvested, yield and production quantity of soybean in the world from 2004 to 2009

	2004			2005			2006			2007			2008			2009		
	000 ha	t/ha	000 t	000 ha	t/ha	000 t	000 ha	t/ha	000 t	000 ha	t/ha	000 t	000 ha	t/ha	000 t	000 ha	t/ha	000 t
WORLD	91,189	2.2	206,461	91,418	2.3	214,347	92,988	2.4	221,501	90,199	2.4	220,532	96,870	2.4	230,952	98,827	2.2	222,269
N. America	31,107	2.8	88,060	30,037	2.8	86,997	30,280	3.0	91,202	27,131	2.8	75,556	31,401	2.7	83,871	32,288	2.9	94,921
USA	29,930	2.8	85,012	28,879	2.9	83,998	28,983	3.0	87,670	25,960	2.8	72,860	30,206	2.7	80,535	30,907	2.9	91,417
Canada	1,177	2.5	3,048	1,158	2.5	2,998	1,225	2.9	3,533	1,171	2.3	2,695	1,195	2.8	3,335	1,382	2.5	3,504
S. America	38,967	2.2	87,104	40,137	2.4	96,874	40,595	2.4	98,884	40,393	2.8	113,747	41,812	2.8	115,505	42,771	2.2	94,561
Brazil	21,538	2.3	49,793	22,895	2.3	52,700	22,006	2.4	52,356	20,565	2.8	57,857	21,271	2.8	59,916	21,760	2.6	56,961
Argentina	14,320	2.1	31,500	14,037	2.7	38,300	15,097	2.7	40,467	15,981	2.9	47,482	16,380	2.8	46,232	16,768	1.8	30,993
Paraguay	1,870	1.9	3,583	1,935	1.8	3,513	2,200	1.7	3,800	2,429	2.4	5,856	2,645	2.6	6,808	2,570	1.5	3,855
Asia	18,445	1.4	27,481	18,323	1.4	26,546	18,633	1.4	26,334	19,479	1.4	27,183	20,600	1.3	27,218	20,362	1.3	27,596
China	9,700	1.8	17,600	9,500	1.8	17,400	9,100	1.7	15,500	8,900	1.5	13,800	9,127	1.7	15,545	8,800	1.6	14,500
India	6,900	1.0	7,500	6,900	0.9	6,600	7,710	1.0	8,270	8,880	1.2	10,968	9,600	0.9	9,045	9,600	1.0	10,217
Europe	1,396	1.7	2,480	1,636	1.5	2,531	2,305	1.5	3,607	1,893	1.4	2,630	1,702	1.6	2,743	1,963	1.7	3,353
Africa	1,133	0.9	1,080	1,150	0.9	1,133	1,221	1.1	1,417	1,210	1.0	1,253	1,241	1.1	1,381	1,316	1.2	9,512
Oceania	33	2.2	74	26	2.1	56	24	2.3	55	13	2.4	32	17,5	2.0	35	42	1.9	80

Source: FAOSTAT, FAO Statistic Division 2010, http://faostat.fao.org/

SOYBEAN PRODUCTION IN EUROPE

The first attempts at growing soybean in Europe were recorded in Holland, France, and England, and, later, in Austria and Germany as well. To this day, however, the crop has never managed to take root and spread to major areas in any of these countries with the exception of France. Up until the 1980s, soybean was grown in Europe mostly in Romania, Bulgaria, Hungary and Yugoslavia and the total acreage was less than 500,000 ha. A major expansion of the crop on the continent began in 1985, primarily in Italy and France, and the acreage reached one million hectares in 1990. With minor fluctuations, the soybean acreage in Europe remained at this level until the last few years, when soybean areas began to increase in Russia and Ukraine (in 2005, for instance, the European area in soybean totaled 1.6 million hectares) (Table 1.2).

Table 1.2

Area harvested (000 ha) and yield (t/ha) of soybean in Europe from 1996 to 2009

	Europe		France		Italy		Romania		Serbia		Croatia		Russia		Ukraine	
Year	000 ha	t/ha	000 ha	t/ha	000 ha	t/ha	000 ha	t/ha	000 ha	t/ha	000 ha	t/ha	000 ha	t/ha	000 ha	t/ha
1996	1,039	1.6	86	2.6	223	3.6	80	1.4	72	2.1	16	2.1	485	0.5	16	0.9
1997	923	2.3	98	2.7	301	3.8	63	1.9	61	2.5	16	2.4	317	0.8	14	1.2
1998	1,214	2.0	111	2.5	351	3.5	147	1.3	82	2.0	34	2.2	377	0.7	31	1.1
1999	1,137	2.0	98	2.6	246	3.5	99	1.8	108	2.9	46	2.5	404	0.8	42	1.0
2000	1,105	1.7	77	2.5	252	3.5	117	0.5	141	1.3	47	1.3	337	1.0	60	1.0
2001	1,039	2.0	120	2.5	234	3.8	44	1.6	87	2.5	41	2.2	371	0.9	73	1.0
2002	977	2.0	74	2.7	152	3.7	69	2.0	100	2.5	47	2.7	362	1.1	98	1.2
2003	1,219	1.5	80	1.8	152	2.5	122	1.8	131	1.8	49	1.6	399	0.9	189	1.2
2004	1,396	1.7	58	2.5	150	3.4	120	2.4	117	2.7	37	2.1	555	0.9	256	1.4
2005	1,636	1.5	57	2.4	152	3.6	136	1.8	130	2.8	50	2.2	690	0.8	310	1.0
2006	2,305	1.5	45	2.7	177	3.1	177	1.9	156	2.7	62	2.8	810	1.0	725	1.2
2007	1,893	1.4	37	2.7	132	3.3	109	1.2	147	2.0	46	1.9	709	0.9	583	1.2
2008	1,702	1.6	22	2.9	108	3.2	46	1.9	144	2.4	36	3.0	712	1.0	538	1.5
2009	1,936	1.7	43	2.5	134	3.5	48	1.7	144	2.4	44	2.6	794	1.2	622	1.6

Source: FAOSTAT, FAO Statistic Division 2010, http://faostat.fao.org/

The case of Italy and its soybean industry is especially interesting. Till the year 1980, according to official statistics, not a single hectare of soybean was planted in the country. In 1981, the first 3,000 ha were sown and the yields were high (3 t/ha). The area in soybean continued to increase until the late 1990s, when it exceeded 350,000 hectares, after which it dropped to about 150,000 ha, despite the fact that the yields were high and stable (over 3.5 t/ha). The decrease in soybean acreage had been caused by reduced soybean subsidies on the part of the European Union, which translated into reduced profit margins for the growers in spite of their record yields on a worldwide scale. A similar thing has happened in France, where the soybean acreage has dropped from 100,000 to about 40,000 ha in recent years.

European soybean production is thus moving east, to countries of the former Soviet Union. In the former USSR, soybean was grown since ancient times in the Asian part of the country as well as in the southern portion of the European part of Russia and in North Caucasus. Following the Second World War, the acreage fluctuated between 200,000 and 400,000 ha, then increased, and then settled finally at around 800,000 ha in the decade preceding the breakup of the Soviet Union. As of 1992, separate data is available for soybean acreage in each of the post-Soviet states. The single largest producer is Russia with 500,000-800,000 ha and an average yield of around 1 t/ha.

In the last 10 years, soybean areas in Ukraine have increased sharply, from several tens of thousands of hectares a decade ago to over 700,000 ha in 2006. Still, just like in Russia, the average yield is low, and in past few years it is slightly over 1 t/ha.

Apart from the former USSR, Romania is the only country in Europe which planted more than 100,000 ha of soybean back in 1939. In the post WWII period, there was a growing trend towards increased soybean growing, and from 1979 on the acreage started to exceed 300,000 ha. From 1991 onwards, the area planted to the crop dropped below 100,000 ha, but in the last few years, as European soybean production began to move to the east of the continent, the country's soybean acreage has slowly begun to rise again. Although Romania has a long tradition of soybean growing, the yields are not high – about 1.5 t/ha.

During the 1984-1993 period, the former Yugoslavia contributed 0.12 and 6.67% to the global and European soybean production, respectively (Božidarević and Vlahović, 1995). After the breakup of Yugoslavia and a period of reduced soybean production, the acreage in the crop increased again in both Serbia and Croatia thanks to the favorable growing conditions in the regions of Vojvodina and Mačva in the former and Slavonija and Baranja in the latter former republic. Serbian acreage in soybean has surpassed 100,000 ha in each of the past few years and the yields have averaged about 2.2 t/ha.

SOYBEAN PRODUCTION IN THE FORMER YUGOSLAVIA AND SERBIA

Soybean has been present in Yugoslav and Serbian field crops production since the start of the 20th century, but the area sown to the crop has varied a lot. In an article entitled "Soybean Production and Its Potentials in Serbia Proper", Bošković (1966) reported that soybean had been introduced to the region 50-60 years prior to that time and noted that the local growers' had a relatively poor knowledge of the value of soybean and its products, which was the reason why the plant could not become a major crop in the country.

An extensive effort to promote soybean growing in the former Yugoslavia was made by Stjepan Čmelik in 1921 in the town of Virovitica (Heneberg, 1966). Further evidence that soybean was not an unknown plant in the country in the early decades of the 20th century can be found in the "Lexicon of Goods in Commerce and Economy", written by Milutin Urbani and published in Zagreb in 1925. The lexicon states: "Soybeans are the seeds of the plant Dolichos soja or Soja (Glycine) hispida; the beans are like those of the round bean and are brown or black. Soybean is cultivated in Japan (Daidsu), China, and East Ind., and some is grown in Germany and even in our country as well. Soybean is used to prepare dishes like Shoyu, Miso Yuba, Tofu (in Japan and China) and bean cheese (Bohnen Käs, Natto). Different kinds of soybean are grown in Germany to be used as a surrogate for coffee or for forage, etc." According to Gutschy (1950), the first larger-scale campaign to promote soybean growing in the country was conducted in 1934 by the oil crushing plant in Zagreb. The campaign did not produce the expected results due to a lack of proper organization, but it did have some positive effects in that soybean growing took root on some farms and became a regular practice.

The official records on soybean growing date back to 1934. Between 1934 and 1939, soybean was grown on 600-3,500 ha in the then Yugoslavia and the yields averaged 0.93-1.26 t./ha (Table 1.3). According to foreign sources (Gutschy, 1950), soybean was cultivated in Yugoslavia on 12,000 ha in 1940 and 17,000 ha in 1941, with the yield averaging about 1.2 t/ha. Such relatively large areas were the result of a large demand for soybean in Germany.

Table 1.3

Production quantity of soybean in Yugoslavia from 1934 to 1939

Year	Acreage (ha)	Production (t)	Yield (t/ha)
1934	600	708	1.18
1935	1,060	986	0.93
1936	644	599	0.93
1937	1,160	1,462	1.26
1938	3,520	3,802	1.08
1939	3,240	2,819	0.87

In the post-WWII statistical records, soybean appears again in 1947 (Table 1.4). In 1949, according to the record, the plant was grown on 15,500 ha, but the areas decreased sharply in the ensuing couple of years, reaching 1,296 ha in 1954. In the 1960s, another attempt was made to try to popularize soybean growing in Yugoslavia. In the year 1960, 20.800 ha of the crop were sown, which was up until that time the largest area planted to this species in the country. This was followed by another decline, and in 1970 the areas dropped to as little as 3,770 ha. For the most part, these large variations concerned the public sector. The private sector's contribution to total soybean production varied from 11 to 70%, but in absolute terms the soybean acreage planted by private-owned enterprises remained more or less constant, ranging from 2,500 to 3,500 ha (Popović, 1966). The largest areas in the private sector were cultivated in Serbia proper and Bosnia and Herzegovina. According to Bošković (1966), the reasons for the lack of soybean expansion in the public sector lay in the low yields, economic policies that were not conducive to the advancement of soybean production, and a lack of processing capacities necessary to obtain profitable, high-quality soybean products. Generally speaking, the acreage in soybean remained small for a number of reasons, including a lack of soybean-growing tradition, i.e. insufficient knowledge of soybean production and uses; not enough economic incentive to grow the plant; and uncertainty with regard to the placement of the crop on the market. Soybean areas in Yugoslavia began to increase markedly in 1975, when a broad public campaign was launched to introduce soybean growing to Yugoslav agriculture on a larger scale. The sowing action plan designed in those years would have probably ended up as another unsuccessful attempt at large-scale soybean growing in the country, had it not been for the fact that it was accompanied by a complementary plan for industrial soybean processing too. The largest annual soybean areas – around 100,000 ha on average – were planted between 1981 and 1990, and the average production output was nearly 200,000 t per year.

Table 1.4

Acreage and yield of soybean in Vojvodina and SFRY from 1947 to 1990

	Vojvodina		SFRY	
Year	Acreage (ha)	Yield (t/ha)	Acreage (ha)	Yield (t/ha)
1947	-	-	1,605	0.64
1948	-	-	5,126	0.65
1949	1,758	0.60	15,507	0.62
1950	1,738	0.31	13,138	0.31
1951	855	0.54	7,044	0.61
1952	41	0.37	1,968	0.56
1953	160	1.09	1,536	0.96
1954	274	0.71	1,296	1.01
1955	258	1.15	2,784	1.21
1956	890	1.00	2,340	0.85
1957	1,620	1.21	6,090	1.32
1958	3,210	0.98	8,140	0.86
1959	4,850	1.72	10,100	1.66
1960	9,680	1.26	20,800	1.25
1961	7,530	0.80	12,800	0.77
1962	476	1.13	7,620	1.04
1963	250	0.90	5,370	1.30
1964	129	1.89	5,720	1.67
1965	124	0.79	8,040	1.19
1966	980	1.54	6,330	1.71
1967	160	1.33	6,740	1.32
1968	207	1.28	4,550	0.65
1969	71	1.01	4,326	1.27
1970	119	1.17	3,770	1.30
1971	244	1.10	4,848	0.87
1972	62	1.99	3,553	1.61
1973	491	1.19	9,449	1.35
1974	1,251	1.76	8,678	1.58
1975	7,944	2.22	14,475	2.07
1976	22,268	1.61	31,293	1.54
1977	23,344	2.16	31,967	2.09
1978	25,913	1.95	34,237	1.84
1979	31,084	2.23	34,358	2.15
1980	13,575	2.08	17,289	1.97
1981	38,296	2.03	47,756	1.94
1982	63,217	2.67	77,391	2.56
1983	82,574	1.94	107,220	1.96
1984	82,722	1.98	114,380	2.00
1985	69,489	1.67	101,233	1.73
1986	62,035	2.33	95,645	2.35
1987	63,537	2.34	105,030	2.26
1988	67,300	1.61	110,214	1.63

1989	50,094	2.30	87,893	2.38
1990	51,258	1.52	93,275	1.68

Source: 1947-1965 period - Popović (1966)

Source: 1966-1990 period – Statistical Yearbook of the S.F.R. Yugoslavia

From the year 1991 on, the soybean acreage in the Federal Republic of Yugoslavia and Serbia has been increasing steadily and in 2006 reached a record 156,680 ha (Table 1.5). During this period, the average soybean yields were around 2.2 t/ha, which is on a par with the average global yields of the crop. The yield of 3.15 t/ha from 2010 shows that not only are there favorable natural conditions for soybean growing in the country, but also that the domestic growers have managed to familiarize themselves with the growing technologies used in soybean cultivation. Despite the fact that an occasional dry year may still cause significant losses resulting in yields well below the long-term average (1992, 1993, 2000) and a reduced soybean acreage in the following year, it is safe to say that soybean has become a major crop in the country and that the areas sown to it will in all likelihood continue to increase in the years to come.

Table 1.5

Acreage and yield of soybean in Vojvodina and Serbia from 1991 to 2010

	Vojvodina		Serbia	
Year	Area (ha)	Yield (t/ha)	Area (ha)	Yield (t/ha)
1991	38,333	2.69	43,530	2.65
1992	58,738	1.31	67,797	1.32
1993	49,463	1.38	55,843	1.38
1994	43,568	1.67	49,621	1.68
1995	46,047	2.08	52,123	2.06
1996	65,496	2.11	72,757	2.10
1997	55,326	2.52	61,014	2.50
1998	75,503	1.97	82,409	1.94
1999	100,712	2.75	108,163	2.72
2000	133,868	1.22	141,559	1.20
2001	80,936	2.39	87,382	2.37
2002	93,044	2.47	100,047	2.44
2003	123,639	1.71	131,403	1.72
2004	109,687	2.72	117,270	2.71
2005	123,054	2.83	130,936	2.81
2006	146,291	2.77	156,680	2.74
2007	136,623	2.10	146,988	2.07
2008	132,762	2.46	143,684	2.44
2009	133,514	2.41	144,386	2.42
2010			155.150	3.15

Source: Statistical Office of the Republic of Serbia http://webrzs.stat.gov.rs/axd/en/index.php

SOYBEAN IN VOJVODINA

Soybean was known in Vojvodina as early as the early 19th century, as evidenced by the reports submitted to the High Command by the Šajkaš battalion, which are cited in the book "History of the town of Šajkaš" by Avram Đukić (1975). One of the book's chapters, "Agriculture in the Šajkaš Area", reports as follows: "In the year 1817, two lots of Persian soybean were sown for trial purposes and produced a seed yield of five pounds and 25 lots. Two years later, the plant was sown again, and on a much larger acreage at that, and the yield was 368 pounds and eight lots. Due to a severe drought, the planting done the following year (1820) using the previous year's crop yielded only eight pounds and four lots of bean. This poor yield performance notwithstanding, the Persian soybean has been shown to produce less ample flour yields than domestic soybeans. A decision was thus made to abandon any further attempts at promoting intensive cultivation of this plant and to leave it to the discretion of the frontiersmen themselves whether to grow the crop or not". This report shows that by 1817 soybean had already become a domestic plant in Vojvodina. As indicated by the report, however, soybean growing was apparently discontinued in the province soon thereafter, as the crop disappeared from the written records for a long while. The plant emerges again in the region only in the 1930s, when it was noted that Yugoslavia had very favorable conditions for soybean growing, especially in the regions of Srem, Posavina, Podunavlje, Mačva and Metohija (Gutschy, 1950).

Vojvodina was the main soybean-producing region in the former Yugoslavia and is also, and even more so, the main soybean-growing area in today's Serbia, where the only soybean production outside the province exists in the region of Mačva in the northwest of Serbia proper (around 10,000 hectares). From the end of the Second World War until 1974, the areas in soybean in Vojvodina varied from several tens to several thousands of hectares, and the yields were around 1 t/ha until the 1970s. After 1975, the acreage began to increase markedly, until more than 82,000 ha of soybean were planted in each 1983 and 1984. After that, the soybean areas started to decrease and then stabilized at around 50,000 ha in the 1990s. In the last ten years or so, the acreage in the crop has been on a steady rise in the province and has reached a maximum of over 120,000 hectares in both 2000 and 2003.

Serbia's soybean output has thus far been unable to meet the domestic demand for this crop. The country's soybean production could be increased not only by increasing the area sown to the crop but also by increasing yield per unit area. This would require higher-yielding varieties, better cultural practices, and more complete protection from weeds. Another way to improve yield levels would be to use double cropping to obtain two harvests per year. This option has not been sufficiently explored in Serbia as of yet.

SOYBEAN PROGRAM OF THE INSTITUTE OF FIELD AND VEGETABLE CROPS IN NOVI SAD

Successful crop production and management of problems associated with crop growing cannot be carried out without the support of good and versatile research work. In the early days of soybean growing in Yugoslavia, the small and highly variable acreage sown to this plant and the uncertain outlook for the crop on the market did not provide enough incentive for a large number of researchers to devote their time and effort to the issues of soybean production. Nevertheless, there were some scientists who did carry out work on identifying and trying to resolve problems occurring in the cultivation of soybean. Nearly all agricultural research centers in the country assembled collections of foreign and domesticated varieties of the crop and studied their agronomic traits. This was first done at agricultural institutes, and then, starting in 1952, at agricultural stations as well. The Institute of Field and Vegetable Crops in Novi Sad is the oldest research institution in Vojvodina, founded in 1938 to serve as an agricultural, trial and control station. After the Second World War, the Institute began collecting material from various industrial crops in order to study and improve it. This included plant species such as sunflower, hemp, soybean, flax, castor bean and others (Stojković, 1963). By 1954, work on soybean selection had been done by Dr Lazar Stojković, Dr Relja Savić and Dr Dušan Dimitrijević, and in 1954 Dr Bogdan Belić began working on soybean breeding as well.

In the mid-1970s, an action plan on soybean was prepared that was the most comprehensive such plan in Yugoslavia up until that point. It included plans for the introduction of soybean into commercial production as well as a plan for the construction of processing facilities for the crop. This created a market for the placement of the plant and gave the growers the assurance that their product would be purchased after the harvest, thus fulfilling the second major precondition for the spread of soybean in Yugoslav agriculture.

As there were no domestic varieties of soybean available in the country at the time, foreign cultivars had to be imported (Hrustić et al., 1998a). The imported varieties were the best of their time (mostly US ones) and were chosen based on their suitability for the domestic growing conditions. Most were from Maturity Group I (Hodgson, Rampage, Chippewa, Traverse and Hark), because it was established that this particular group was best suited for the growing conditions in Yugoslavia. Of cultivars from Maturity Group II, Corsoy, Amsoy and Wells were imported. The early varieties Swift and Evans (Maturity Group 0) and the very early ones Clay and Morsoy (Maturity Group 00) were also introduced. At the same time these varieties were being introduced to commercial production, they were also tested in a series of large-plot trials set up across the province of Vojvodina. These trials had a double purpose. The first one was to investigate the adaptability and stability of the cultivars being introduced in the domestic growing conditions and to match them with the regions most suitable for their cultivation. The second goal was to popularize soybean as a crop and to allow as many growers as possible to become familiar with the plant. Extension efforts on the advancement and popularization of soybean growing continued after this period as well.

The results of the large-plot trials showed that the adaptability and yield stability of some of the varieties tested was unsatisfactory in Yugoslav conditions and that there was a lot of variability in yield among the different locations and years. This resulted in a reduced number of introduced varieties and only the best continued to be grown commercially. These were the cultivars Evans, Hodgson, Hark, Amsoy, and Corsoy, which were grown in the country for many years.

However, because intensive production cannot be based on introduced varieties developed for completely different growing conditions, it became necessary to develop a set of high-yielding domestic varieties.

Genetic resources

Because soybean is almost exclusively a self-pollinated plant with a very small percentage of cross-pollination, the starting variability is obtained by crossing different genotypes. Choosing genotypes to be used in the crosses as parents is not an easy task, especially in the case of soybean, whose genetic base is very narrow. Modern-day US varieties, which make up more than 80% of the crop's current genetic basis, originate from only ten or so genotypes introduced from China at the start of the 20th century. Modern breeding of soybean began in the U.S. in the 1920s, and the newly developed cultivars spread from there to South America, Europe, India, and even China, the place of the crop's origin. Around the world, these new cultivars then went through the processes of introduction, hybridization and selection.

It is, therefore, not an easy task for a soybean breeder to pick their starting material for selection from a large number of genotypes with a similar genetic background, because only crosses among genetically divergent genotypes result in transgressive segregation for various traits, including those that are economically important. For this reason, germplasm collections are an essential resource in the development, advancement and improvement of soybean cultivars. Soybean breeding at the Institute of Field and Vegetable Crops in Novi Sad was started by using a rich collection of soybean genotypes that had been assembled over time by Prof. Bogdan Belić from various parts of the world. Over the years, the collection has been expanded and organized and today represents the largest assemblage of soybean germplasm in this part of Europe (Vasić et al., 2007).

The Institute's soybean collection is made up of more than 800 cultivars and lines originating from America, Asia, and Europe. Most of the genotypes belong to Maturity Groups 0 and I, but the collection includes genotypes ranging from MG 000 to MG V.

The genetic backgrounds of Novi Sad soybean cultivars consist primarily of American genotypes from the northern germplasm collection. Gizlice et al. (1994) studied the pedigrees of 256 North American varieties developed between 1947 and 1988 and found that 80% of the genetic base of American soybean cultivars originate from only 13 genotypes. It is important to note that the authors of the study analyzed complete pedigrees of the cultivars (not just the parental components) and arrived at a set of 35 ancestral genotypes, whose contribution to the genetic background of American soybean cultivars exceeds 95%. Since some of the most widely used US cultivars (Hodgson, Evans, S1347) are also the parental components of the most widely spread Novi Sad varieties (Afrodita, Balkan, Vojvođanka), and given the fact that the coefficient of parentage between the varieties Hodgson and Corsoy is 0.566 and that between Evans and Corsoy 0.484 (Allen and Bhardwaj, 1987), it is apparent that the list of ancestral genotypes of NS soybean cultivars is much shorter. An analysis was made of the parental components of the NS varieties of soybean (without conducting detailed pedigree analysis and identifying all ancestral genotypes) and 60 different genotypes were found. Eighteen of those 60 accounted for 70% of the genetic makeup of the cultivars, while the remaining 42 were represented with less than 1% each (Table 1.6). The greatest contributors to NS soybean germplasm are the varieties Hodgson, Evans, S-1346, and Corsoy, while a certain smaller proportion originates from European varieties, most notably ISz10, Fiskeby and Four.

Table 1.6

Parental components of NS soybean cultivars and their percentage contribution to the NS germplasm of the crop

No.	Parent	Origin	Percentage	Cumulative perc.
1.	Hodgson	USA	13.85	13.85
2.	Evans	USA	10.96	24.81
3.	S1346	USA	10.00	34.80
4.	Fiskeby	SWE	4.04	38.84
5.	ISz 10	HUN	3.84	42.69
6.	Corsoy	USA	3.46	46.14
7.	Afrodita	YUG	2.88	49.03
8.	Vojvođanka	YUG	2.50	51.52
9.	Balkan	YUG	2.50	54.02
10.	L-16	YUG	2.31	56.33
11.	Krajina	YUG	2.30	58.63
12.	Gema	USA	1.73	60.36
13.	Wells	USA	1.54	61.90
14.	Weber	USA	1.54	63.44
15.	Resnik	USA	1.54	64.98
16.	NS-L-MM	YUG	1.54	66.52
17.	Hawkeye 66	USA	1.54	68.05
18.	Gadir	FRA	1.54	69.59

Methods and directions of breeding

Modern-day soybean breeding involving hybridization began in the 1920s in the U.S. and China and over 3,500 soybean cultivars have been developed globally since (Carter et al., 2004). Soybean breeding and selection is a continual process by which yield levels are increased and resistance to abiotic and biotic stresses is improved. Improved cultural practice and increasing yield potential and atmospheric CO2 concentration have been the contributing factors to an increase in soybean yield levels and soybean growing productivity. Specht et al. (1999) reported an annual yield increase 23 kg in the U.S.

Each cycle of breeding begins with the selection of parental pairs to be used for obtaining new genetic variability. Choosing parental pairs is the first crucial moment in breeding, because it determines the success of the future selection process. Generally, elite parental lines of different origin have the greatest chance of producing superior progeny (Burton, 1997; Miladinović et al., 1999). The choice of pairs to be used in crosses depends on many factors – the traits one is trying to improve, the relative importance of other traits in relation to yield, the origin of the lines being used, and the resources the breeder has available to them. The most commonly used method of choosing the parents is evaluation of varieties and genotypes per se. This is also the most economical method, because the data from small- and large-plot trials are readily available to the breeder. St. Martin et al. (1996) have also developed a test cross method for identifying potential parents in soybean. Test crosses have proven more useful in identifying parents than the method that uses heterosis for the same purpose (Lewers et al., 1998). Another method that has proven very useful in predicting superior combinations is the BLUP (best linear unbiased prediction) one. Although this technique has often been used in animal breeding in the past, its use in plant breeding is of more recent date (Panter and Allen, 1995). An increasing number of researchers are turning their attention to molecular markers, so techniques based on these markers can also be used in the selection of parental components (Helms et al., 1997; Manjarrez-Sandoval et al., 1997; Kiasha et al., 1997).

Once hybridization is performed and genetic variability is obtained, the potentially superior progeny must be turned into homozygous lines.

The choice of the selection method depends on the goal of the breeding program as well as on other important factors, such as the variability one has at their disposal, the availability of agricultural machinery and greenhouses, the number of personnel and their level of training, and so on. Soybean breeding makes use of methods that are used in the selection of other self-pollinated crop species as well. These include: pedigree selection, single seed descent, the bulk method, the early generation testing procedure, and backcrossing. With the discovery of genetic male sterility, recurrent selection has become another useful tool for developing new soybean varieties (Hrustić et al., 1997; Wilcox, 1998).

The backcross method is most often used in cases when a certain trait, such as resistance to a disease, needs to be incorporated into a good standard variety that is widely grown commercially in order for said variety to be able to maintain its share on the market. The goal, therefore, is not to develop a new cultivar but to improve an already existing one that is of good quality (Borojević, 1992).

Similar is the case with early generation testing. This method is used when a cultivar containing a particular trait needs to be developed fast. Testing is conducted as early as the F2 generation and a large number of potentially good genotypes are discarded early (Cooper, 1990).

The bulk method is the most economical way of obtaining homozygous lines after hybridization. This technique is also known as the bulk population method and was first introduced by Nilson Ehle in Sweden in the early 20th century. The theoretical development of the method was first carried out by Harlan and Martini (1938) in their work on barley. The method involves obtaining the next generation by planting a large number of seeds, harvesting the plants in bulk, and planting a sample of the seed the following year. The advantage of this approach is that it enables a larger number of crosses to be grown without the need for a lot of labor, observation, and selection. As the hybrid mixture of the populations contains different genotypes with differing levels of productivity and different interaction with the environment, natural selection occurs, which may result in a loss of valuable genotypes. Still, the theoretical basis of this method relies on the proposition that an increase of yield occurs in the process of selection, because natural selection favors high-yielding genotypes (Suneson, 1956). To make bulk selection more effective, the hybrid generations are grown in bulk only up to the F4 generation instead of up to F6, and this is the major characteristic of the method. Individual selection of the best plants begins in the F4 generation and is followed by the selection of new lines in the later generations by the pedigree method. This is considered a modified and improved version of the bulk method. Two major disadvantages of this type of selection are the loss of genetic variability in each subsequent generation due to the use of an inadequate sample and the possibility that natural selection occurring in the population may take an undesirable turn (Empig and Fehr, 1971).

The pedigree method of soybean selection consists in growing progenies of crosses through generations of self-pollination by growing rows of progenies of plants selected in each generation based on their phenotypic traits, with the pedigree of each line being maintained in the subsequent generations. This was the predominant method of soybean breeding in the U.S. up until the mid-1960s and was effective in developing varieties with an increased grain yield and resistance to lodging. It was also used in the early days of soybean breeding at the Institute of Field and Vegetable Crops. The method is useful for evaluating progenies of crosses between phenotypically different parents, since it makes it possible to identify and discard a large number of undesirable progenies in the early generations, leaving a high frequency of superior lines for final selection in the later generations. Unlike bulk selection, the pedigree method reduces competition among different genotypes to a minimum and makes it irrelevant for the success of the selection process. The greatest disadvantage of the method is that it is labor-intensive and requires a lot of manpower. It involves individual selection of the plants, their threshing, planting, and marking, and the recording of a large amount of data, all for the purpose of maintaining the pedigree of the lines in successive generations. This makes the method highly unsuitable for handling a larger number of crosses. In addition, pedigree selection involves constant selection of a certain number of heterozygotes that would have become homozygous in the later generations even without the breeder's intervention.

The single seed descent method was proposed by Brim (1966) and the procedure has been the predominant method of soybean selection in the U.S. since. Single seed descent makes it possible to produce three generations of self-pollination in a single year using winter nurseries or greenhouses, thus accelerating the development of homozygous lines for the testing of yield in replicated trials. The method is used in the soybean program of the Institute of Field and Vegetable Crops in Novi Sad as well. However, due to the unavailability of a winter nursery and a lack of sufficient greenhouse space that would accommodate all of the breeding materials, the Institute has had to adapt the method to make it suitable for such conditions and is making use of only those aspects that involve the reduction of space and labor while at the same time maintaining a satisfactory level of variability up to the F5 generation (Miladinović, 1999).

The single seed descent method is usually not applied until a certain level of homozygosity is reached in the F4 or F5 generation. Selection in the earlier generations can still be done, but on a smaller scale, i.e. it is performed in the sense that pods are not taken from plants that are diseased or lodged or prone to pod splitting and so on.

Single seed descent requires that only the most basic data be taken down, such as the designation of the cross and what generation it is in. Also, minimal space is required to grow successive generations of individual plants when compared to the rows of progenies characteristic of pedigree selection. Another advantage of the single seed descent method is the presence of full variability in each generation. With no selection in the early generations, the amount of variability present among the F5 plants is similar to that found in the F2 generation. Finally, the number of recessive homozygotes increases in successive generations – with the postponement of selection for a recessive trait until the F5 generation, nearly 47% of the plants will be homozygous for such a trait (Wilcox, 1998).

Perhaps the biggest disadvantage of single seed descent consists in the irreversible loss of identity of superior plants from the earlier generations. Besides that, a superior plant observed in the F2 generation will be represented by no more than a single plant in the subsequent generations, making it impossible to select a larger number of lines from superior plants. Moreover, plants that would otherwise be discarded will remain in the population up until the F5 generation.

Each method, therefore, has its advantages and drawbacks. The challenge is for the breeder to choose and make use of the most effective method for the achievement of their breeding goals. Comparisons among the different selection procedures (Miladinović, 1999; Miladinović et al., 2000) have shown that the modified version of the single seed descent method that is in use in soybean breeding at the Novi Sad Institute is more effective than the other methods. The best evidence of this is the success of the Institute's soybean program.

Beginnings of soybean breeding at the Institute

During the campaign for the spread of soybean growing in the country in the 1970s, a soybean team was formed at the Institute of Field and Vegetable Crops in Novi Sad. The team was headed by Prof. Dr Bogdan Belić and was composed of plant breeders, cultural practice specialists, phytopathologists and seedsmen. The team's primary goal was to develop the first high-yielding domestic soybean varieties that will be suited to the local growing conditions, thus creating the conditions for the establishment of stable production and the replacement of foreign cultivars on the domestic market. The concept of the program was to develop varieties with different growth periods (Maturity Groups 0, I and II) that could be grown in all the different soil and climatic conditions of the country. Later on, the program's goals were expanded to include the development of cultivars with very short growth periods (MGs 00 and 000) that would enable soybean to be used in double cropping or grown as a stubble crop. Another objective was to develop soybean varieties suitable not only for intensive farming but also for extensive agriculture conditions that involved soils having unfavorable composition or an inadequate nutrient supply, areas in which proper tillage was not possible, and so on. The new varieties also had to be resistant to lodging, pod splitting, and major diseases.

Soybean breeding is a complex and difficult task that takes a long time. It takes six years for a genotype to progress from the initial cross to a line that can be considered pure. Another three years are needed for preliminary and comparative trials. Then, even if no multi-site or large-plot trials are carried out, three more years are needed for the official variety trials. Therefore, it takes a minimum of 12 years for a soybean variety to be developed. Of course, testing can also be done in the early phase of breeding and it is still perfectly possible for an insufficiently tested variety to be put through the official trials and even outperform the standard variety, especially if the standard is an introduced cultivar. In the first 12 years of the Institute's soybean program, seven new varieties were developed based on the existing material and new crosses (Table 1.7). Three of those, NS-6, NS-9 and NS-10, have found commercial success.

Table 1.7

NS soybean varieties released between 1975 and 1987

No.	Variety	Maturity Group	Year of release
1	NS Kasna	III	1979
2	NS – 11	II	1980
3	NS – 6	0	1982
4	NS – 9	I	1983
5	NS – 10	I	1985
6	Hy – 12	00	1986
7	NS – 13	I	1987

Soybean breeding for productivity and other traits

The first soybean cultivars of the NS Institute that had gone through an entire breeding cycle were released in 1988 (Table 1.8).

Table 1.8

NS soybean varieties released between 1988 and 1992

No.	Variety	Maturity Group	Year of release
8	NS – 16	I	1988
9	NS – 17	I	1988
10	NS – 18	I	1988
11	NS – 20	II	1988
12	NS – 21	II	1988
13	NS – 102	I	1989
14	NS – 104	I	1989
15	NS – 105	I	1989
16	NS – 201	II	1989
17	NS – 202	II	1989
18	Dunav	0	1990
19	Kolubara	0	1990
20	Bačka	0	1992
21	Banat	0	1992
22	Sremica	0	1992

Two of the five cultivars registered that year (NS-16 from MG I and NS-21 from MG II) began to be grown commercially on a wide scale. In the four years that followed, a number of varieties, mostly early ones, were released. The best among them, Kolubara and Bačka, spread across the fields of Serbia, gradually replacing the foreign, introduced varieties.

In parallel with soybean breeding, the Institute also worked on all the other problems connected with soybean production. Since soybean was for the most part an unknown crop to Serbian growers, soybean growing technology became the subject of many studies by the Institute's research staff (Belić, 1966; Belić and Molnar, 1977; Hrustić, 1983; Jocić and Sarić, 1984; Relić, 1996; Miladinović et al., 1998; Tatić et al., 2006). The results of this research were immediately transferred to actual agricultural practice, and this undoubtedly contributed to the increase of soybean yields in the country.

Studies dealing with mineral nutrition and nitrogen fixation have shown that soybean growing does not require mineral fertilizer incorporation, provided nodule bacteria are present in the soil. No such bacteria are found in Serbian soils, however, so soybean seeds need to be inoculated before being planted, and this is done using a preparation called Nitragin. Nitragin is a biofertilizer composed of an optimally balanced mixture of the most productive strains of nitrogen-fixing bacteria identified by research conducted at the Institute of Field and Vegetable Crops (Mrkovački et al., 1989; 1992; Milić, 1990; Milić et al., 1991; Marinković et al., 2004).

Many studies have also been conducted to determine the optimum irrigation rates and timing for soybean (Bošnjak, 1978; 1987; Vučić et al., 1981; Pejić, 1993; Dragović, 1994; Miladinović et al., 1997a). Their results have shown that grain fill is the most critical stage of soybean growing and a time when the plant's water requirements are at their highest. These studies have also shown that soybean can be grown as a second or stubble crop in irrigated conditions.

Research in the field of soybean phytopathology has also been of great importance (Jasnić and Vidić, 1981; 1985; 1986; Vidić, 1982; 1987; Jasnić, 1984; Vidić and Jasnić, 1998; Vidić et al., 1998). These studies have consisted in determining the racial composition of pathogens and identification of sources of resistance to the most economically important soybean pathogens in the country, such as Peronospora manshurica (downy mildew), Pseudomona syringae pv. glycinea (bacterial spot), Diaporthe phaseolorum var. caulivora (stem canker), Sclerotinia sclerotiorum (Sclerotinia stem rot) and Macrophomina phaseolina (charcoal rot). Work on breeding for resistance to diseases performed in the Institute's soybean program involves the incorporation of genes for resistance to the dominant races of the above pathogens into commercial soybean cultivars.

All the above research efforts have significantly helped the NS soybean program and have enabled it to focus on the development of varieties best suited for the growing conditions in the country.

The years 1993 and 1994 can be regarded as the golden years of NS soybean breeding, because in those two years alone 12 new NS cultivars of soybean were released that have completely replaced foreign cultivars on the domestic market thanks to their superior characteristics, most notably their high potential for yield.

Table 1.9

NS varieties released in 1993 and 1994

No..	Variety	Maturity Group	Year of release
23	Krajina	00	1993
24	Panonka	0	1993
25	Mačvanka	II	1993
26	Tamiš	II	1993
27	Jelica	00	1994
28	Afrodita	0	1994
29	Ravnica	I	1994
30	Balkan	I	1994
31	Vojvođanka	II	1994
32	Nizija	II	1994
33	Simonida SP	II	1994
34	Šumadija	II	1994

The 12 cultivars included the very early varieties Krajina and Jelica, which are suitable for planting as a second or stubble crop. Krajina is also the standard variety in the national variety trials. There is also a large interest in these two cultivars in the European countries that lie at more northerly latitudes, in which the two varieties can be grown as a full-season crop. Jelica has been released in Russia and Krajina in Russia as well as Hungary.

Together with the cultivar Bačka, which had been registered a little earlier, the varieties Panonka and Afrodita were the mainstays of the early-maturing cultivar range in the country for several years after their release. Afrodita is the standard for Maturity Group 0 in the national variety trials and has also been released in the European Union.

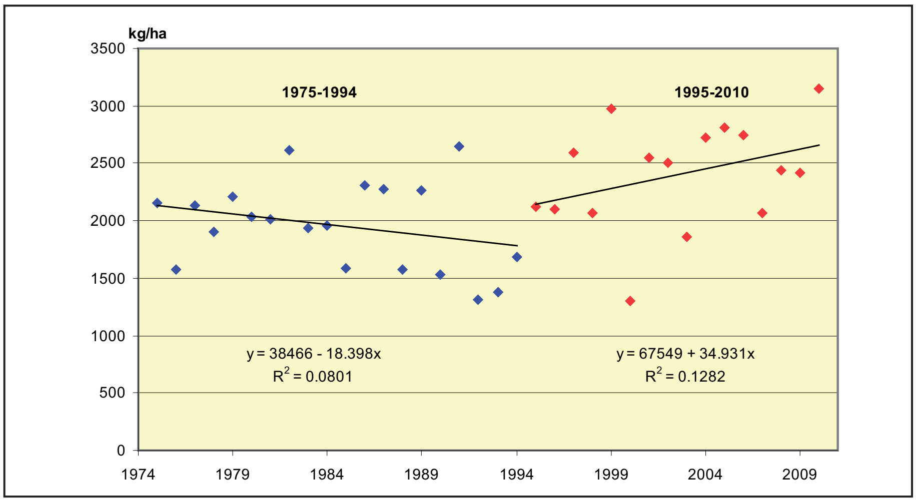
The cultivars Balkan and Ravnica are the most widely grown soybean varieties in the country, because they are medium-maturing and are thus ideal for the growing conditions in Serbia. Thanks to its adaptability and ability to produce satisfactory yields even in unfavorable years and locations, Balkan is still the most sought-after NS variety of soybean on the domestic market and has been released in Romania and Bulgaria as well.

The late-maturing cultivar Vojvođanka managed to supplant from the domestic market the introduced variety Corsoy, which was the last remaining foreign introduction on the Serbian soybean market. Thanks to its extremely high yield, Vojvođanka is one of the most widely grown NS cultivars of soybean. Like Afrodita, it is a registered variety in the European Union.

The year 1995 was the first year in which no foreign cultivars of soybean were grown in the country, and the period between 1995 and 2007 saw an increase of an average soybean yield in Serbia of 44 kg/ha per year (Fig. 1.1). By comparison, from 1975, when foreign cultivars of the crop were first introduced to Serbia, until 1994, the year in which they were fully supplanted by the domestic varieties, the yields decreased by an average of 18 kg/ha per annum, which is a very strong argument in favor of continuing to develop and replenish the domestic stock of soybean germplasm.

Figure 1.1

Soybean yield trends during the 1975-1994 and 1995-2010 periods in Serbia



In each of the first few years following 1995, several new NS cultivars of soybean were released (Table 1.10), but these were either never grown commercially or were sooner or later withdrawn from the market. This was not because they were not good - these were outstanding varieties – but because they did not outperform the already existing cultivars by a significant margin, and the Institute is not in the habit of replacing its cultivar range just for the sake of doing so. The cultivars Danica, Vera, Srbobranka and Indijana, all released during this time, were grown commercially for a while, but their growing was then discontinued, mostly because they were somewhat less adaptable to different growing conditions.

Table 1.10

NS varieties released between 1995 and 1998

No.	Variety	Maturity Group	Year of release
35	Danica	000	1995
36	Pobeda	0	1995

37	Biserka	0	1995
38	Maja	0	1995
39	Košava	II	1995
40	Avala	II	1995
41	Ranka	00	1996
42	Belka	0	1996
43	Vera	I	1996
44	NS – Nada	II	1996
45	Srbobranka	I	1997
46	Indijana	II	1997
47	Gordana	II	1997
48	Jelena	II	1998

Soybean breeding for special traits

Soybean selection at the Institute of Field and Vegetable Crops has so far focused the most on the increase of yield (Miladinović et al., 1997b; 2000; Miladinović, 1999) and its stability and on developing varieties adaptable to different growing conditions (Hrustić et al. 2003; 2004; Miladinović et al., 2003; 2006). However, the Institute's soybean program also makes sure to take into account the preferences of its customers and the processing industry and to adapt to the demands of the market. This is reflected most notably in our work on increasing the protein content of our cultivars by conducting studies in field (Miladinović et al., 1996b; 2001; 2004) and laboratory conditions.

We also do research on nitrogen metabolism in soybean (Miladinović et al., 1996a; Malenčić et al., 2005; Kereši et al., 2007), increasing the quality of soybean oil (Miladinović et al., 1996c; Hrustić et al., 1998b), and studying the antioxidative properties of soybean (Malenčić et al., 2007; 2008). In addition to this, the discerning market of the West has a preference for a good balance between the oil and protein contents in order to use soybean for manufacturing products for human nutrition as well as for certain levels of amino acids containing sulfur, a balance between the levels of oligosaccharides and polysaccharides for the purposes of fish food production (Vucelić-Radović et al., 2005; Hollung et al., 2005), and improved nutritional and medicinal properties of soybean (Cvejić et al., 2009).

The first soybean varieties with increased protein levels developed and commercialized in Serbia were Novosađanka and Proteinka. Another standout in this regard is the NS cultivar, which is capable of having a grain protein content of up to 44% (Table 1.11).

Table 1.11

NS varieties released from 2000 to 2011

No.	Variety	Maturity Group	Year of release
49	Bojana	0	2000
50	Novosađanka	I	2000
51	Milana	III	2000
52	Nađa	0	2001
53	Proteinka	0	2001
54	Tisa	I	2001
55	Morava	III	2001
56	Sanja	0	2002
57	Lasta	0	2002
58	Venera	I	2002
59	Posavka	I	2002
60	Ivana	III	2002
61	Fortuna	00	2003
62	Lara	0	2003
63	Valjevka	0	2003
64	Ana	I	2003
65	Melodija	I	2003
66	Branislava	I	2003
67	Meli	00	2004
68	Bečejka	0	2004
69	Tara	0	2004
70	Zvezda	I	2004
71	Glorija	I	2004
72	Tea	I	2004
73	Sava	I	2004
74	Šapčanka	I	2004
75	Drina	I	2004
76	Mima	II	2004
77	Bistrica	II	2004
78	Alisa	0	2005
79	Iva	0	2005
80	Rita	0	2005
81	Duga	II	2005
82	Senka	II	2005
83	Gracia	000	2006
84	Galina	0	2006
85	Vesna	II	2006
86	Julija	00	2007
87	Diva	I	2007
88	Prima	00	2008
89	Merkur	00	2008
90	Marta	II	2008
91	Idila	II	2008
92	Rubin	II	2008

93	Neda	0	2009
94	Victoria	I	2009
95	Iskra	I	2009
96	Trijumf	II	2009
97	Favorit	000	2010
98	Emina	00	2010
99	Frajla	00	2010
100	Tajfun	00	2010
101	Zlata	I	2010
102	Aleksandra	I	2010
103	Kinđa	I	2010
104	NS Alfa	00	2011
105	NS Virtus	00	2011
106	NS Zenit	0	2011
107	NS Maximus	0	2011

An increased protein content is of particular importance for the purposes of processing, so these cultivars have a variety of special uses in the processing industry. Besides their increased protein levels, these varieties also have a high genetic potential for yield, resistance to lodging, and a high degree of field resistance to the economically important diseases, so the acreage on which they are grown can be expected to increase more and more with time. This projection is further supported by the fact that both Proteinka and Novosađanka have been released in Croatia and Romania, Proteinka is also registered in Ukraine, while Novosađanka has been registered in Hungary and Italy as well. Soybean breeding for an increased grain protein content is a complex and difficult task. High-protein varieties of soybean must also be good performers with respect to the other agronomic ally important traits, most importantly yield, which makes their selection difficult, since high protein content and yield are negatively correlated. It is even more difficult to develop varieties with a protein content of over 45% and a yield performance on a par with that of the commercially grown varieties.

Soybean storage proteins are divided into three large groups based on the sedimentation constant. The dominant fractions are glycinin (11S fraction) and conglycinin (9S fraction), while the 2S fraction contains protease inhibitors. Some breeding programs have it as their goal to reduce the activity of protease inhibitors in the bean in order to save the energy needed to thermally deactivate these inhibitors during the processing. The Institute has no such program. There are two main reasons for that. Firstly, protease inhibitors have a favorable amino acid composition, most importantly they are rich in amino acids containing sulfur. The other protein fractions of soybean (methionine, cystine) are deficient in such acids, so the reduction of this fraction would have a detrimental effect on the favorable amino acid composition of the soybean bean (Pešić, 2003). Secondly, cultivars with reduced inhibitor activity have a decreased total protein content of the seed. Testing of isogenic lines for the Kunitz trypsin inhibitor has shown a significant reduction of the total protein content of the soybean grain, with the oil content remaining unchanged (Vollmann et al., 2002).

The total fatty acid content and composition are another essential component of soybean breeding for a modified chemical composition of the grain. The dominant fatty acid fraction comprises linoleic acid (18:2) with about 55% contribution and oleic acid (18:1) with about 20%. Linolenic (18:3, approx. 8%), palmitic (16:0, approx. 10%) and stearic (18:0, approx. 4%) are also present. The general trend in breeding for fatty acid composition is to reduce the levels of polyunsaturated fatty acids and increase the oleic acid content. Reducing the levels of polyunsaturated fatty acids increases the oxidative stability of soybean oil and also reduces the need for the catalytic hydrogenation of polyunsaturated lipids during the processing of soybean oil. The use of soybean cultivars with an altered fatty acid composition is not only advantageous from the technological point of view but is also beneficial health-wise. Oleic acid is known to be the most desirable fatty acid from the point of view of human nutrition, so the increase of oleic acid levels has a positive effect on the quality of products obtained from high-oleic cultivars. Another benefit comes from the fact that the catalytic hydrogenation of polyunsaturated fatty acids produces not only cis isomers but also trans isomers, which have a proven negative effect on human health.

Among the currently grown NS cultivars of soybean, the variety Venera has an especially high oil content of the grain and another high-oil cultivar, Mima, will also begin to be grown on a large-scale soon. This cultivar takes a little longer to reach maturity than the variety Vojvođanka and hence has to be planted sooner. Although Venera performs the best yield-wise in optimal growing conditions, it also produces stable yields in unfavorable, droughty conditions, which is not typical of a genotype with a long growth period. Venera has been released in Serbia as well as Romania and Bulgaria.

The cultivar Lasta, released in 2002, has a well-balanced fatty acid composition of the oil and a very high oleic acid content. It is not grown commercially at present, because the Serbian market has no special need for high-quality soybean oil as of yet.

Carbohydrates are not abundant in soybean grains but can be a limiting factor in the nutrition of certain animals. The amount of stachyose and raffinose in soybean beans and products limits the digestibility and usability of soybean oil and protein in nonruminants. Soybean breeding for grain carbohydrate composition is aimed at reducing the levels of stachyose and raffinose and increasing the sucrose content of soybean grain. Breeding programs on this are still in the early stages, so it is too early to talk about their results.

For certain uses, the ratio between oil and protein in the soybean beans is important as well. This is the case with soybean milk, for example, because this ratio is of importance for obtaining of a high-quality final product when such milk is manufactured.

In the last few years, the NS soybean program has produced a number of high-yielding cultivars, which are expected to become market leaders in the next several years. These include Tajfun and Merkur from MG 00, Valjevka and Galina from MG 0, Sava and Victoria from MG I, and Venera and Rubin from MG II.

NS soybean cultivars abroad

The registration and release of a cultivar are the end results of the selection process and are therefore an important indicator of a breeding program's success. The release of a cultivar on a foreign market is of special importance, because it is an indication of a wider recognition and a sign that one's work has transcended local boundaries. The NS soybean program has thus far released 49 cultivars abroad (Table 1.12).

Table 1.12

NS soybean varieties released abroad

Country	Variety	Year of release
Hungary	Davodi 2016 Anita 66 Bacskun Alisa Meli	1993 1994 2002 2003 2004
Ukraine	Bojana Proteinka Ravnica Lara Sedmica Ina Tavria Poema Poltava Irina Galina Larisa Fortuna	2005 2005 2005 2005 2005 2008 2008 2009 2009 2009 2009 2011 2011
Italy	Avila Condor Neoplanta Po Fortezza Tea	1996 1996 2005 2005 2007 2007
Romania	Proteinka Balkan Venera Neoplanta	2002 2003 2005 2005
Bulgaria	Avila Balkan Zora Venera	2001 2001 2005 2005
Croatia	Proteinka Neoplanta Alisa NS Ana Galina Tea Julija Merkur	2006 2006 2007 2007 2008 2008 2009 2009

Russian Federatio	Jelica Volga Irina Duga Tavria	2001 2001 2009 2009 2009
Moldova	Tihana Meli Alisa Galina	2010 2010 2010 2010

The Institute has 13 of its soybean cultivars released in Ukraine, eight in Croatia, six in Italy, five each in Hungary and Russia, and four each in Romania, Bulgaria, and Moldova. In 2005 alone, 11 new cultivars were registered abroad. As many as 43 of the total 49 releases occurred after the year 2001, which shows that the registration of NS soybean varieties on foreign markets is of fairly recent date and that NS germplasm of this crop can still be expected to make a major impact on the international market in the years to come

SUMMARY

Despite the centuries of traditional growing in its region of origin, the Far East, it was only in the forties that soybean transformed from a minor crop serving as ensiled feed into a major crop and globally important source of food. For several decades, the United States with about 30,000,000 hectares have been the leading country in soybean production, processing, and trade. In last few decades, Brazil and Argentina, with the acreages of about twenty and fifteen million hectares, respectively, became important soybean producers on the global scale. Attempts to grown soybean have been made in a number of countries. Most countries in the world are presently growing soybean but on a limited acreage.

The soybean was introduced in our country in the 19th century but it remained a minor crop until three decades ago. The global trend of increasing the soybean acreage has been felt in our country too. Aglthough the acreage fluctuated in dependence of yields achieved and economic incentives offered, the soybean should nevertheless be considered a major field crop. The largest soybean acreage is located in the Vojvodina Province. As a result of an intensive research work, the introduced foreign varieties have been replaced by domestic ones and a number of problems in the field of cultural practices has been solved. The presently grown soybean varieties have been developed in our agroecological conditions and the cultural practices have been modified to fit the pravailing climatic and soil factors.

REFERENCES

Allen, F.L. and Bhardwaj, H.L. (1987): Genetic relationships and selected pedigree diagrams of North American soybean cultivar. The University of Tennessee, Agricultural experimental station, Knoxville, Tennessee.

Baker, H.G. (1970): Plants and Civilization, Wadsworth Publishing Company, Inc. California.

Belić, B. (1966): Uticaj vremena setve na dužinu vegetacije i prinos soje. Arhiv za polj. nauke, vol. 19, No. 66: 3 – 14.

Belić, B. and Molnar, I. (1977): Najznačajnije agromere za postizanje visokih prinosa soje i izbor sorti za pojedine rejone Vojvodine. Zbornik radova savetovanja o unapređenju proizvodnje soje u Vojvodini. Novi Sad, 1 – 15.

Borojević, S. (1992): Principi i metode oplemenjivanja bilja. Naučna knjiga, Beograd.

Božidarević D., Vlahović, B. (1995): Osnovna obeležja međunarodnog i domaćeg tržišta soje, Savremena poljoprivreda, vol. 43, br. 3: 101-113.

Bošković, M. (1966): Stanje i mogućnosti proizvodnje soje u užoj Srbiji, Soja; proizvodnja, prerada, potrošnja, Zagreb. 103-112.

Bošnjak, Đ. (1978): Uticaj zalivnog režima na fenološke pojave i morfološke karakteristike sorti soje različite dužine vegetacije i njihov odnos prema prinosu. Zbornik za prirodne nauke Matice srpske, 56: 79-93.

Bošnjak, Đ. (1987): Potrebe za vodom i zalivni režim soje. Nauka u proizvodnji, Osijek, 15: 47-56.

Brim, C.A. (1966): A modified pedigree method of selection in soybeans. Crop Sci. 6:220.

Burton, J.W. (1997): Soybean (Glycine max (L.) Merr.). Field Crops Res. 53:171-186.

Caldwell, B.E. (1973): Soybeans: Improvement, production and uses. Agron. Monogr. 16, ASA, Madison WI.

Carter, T., Nelson, R., Sneller, C., Cui., Z. (2004): Genetic Diversity in Soybean. In Boerma, H., Specht, J. (Ed): Soybeans: Improvement, production and use, Third edition, American society of agronomy, Madison, Wisconsy, USA, 303-450.

Cooper, R.L. (1990): Modified early generation testing procedure for yield selection in soybean. Crop Sci. 30: 417 – 419.

Cvejić, J., Malenčić, Đ., Tepavčević, V., Poša, M., Miladinović, J. (2009): Determination of Phytoestrogen Composition in Soybean Cultivars in Serbia. Natural Product Communication, Vol.4, No. 8, 1069-1074

Dragović, S. (1994): Uticaj suše u različitim fenofazama razvića na prinos soje i efekat navodnjavanja. Zbornik radova Instituta za ratarstvo i povrtarstvo, Novi Sad, 22: 143-152.

Empig, L.T. and Fehr, W.R. (1971): Evaluation of methods for generation advance in bulk hybrid soybean populations. Crop Sci. 11: 51 – 54.

Gizlice, Z., Carter, J., Burton, J. (1994): Genetic base for North American public soybean cultivars released between 1947 and 1988. Crop Sci. 34:1143-1151.

Gutschy, Lj. (1950): Soja i njezino značenje u narodnom gospodarstvu, poljoprivredi i prehrani, Tehnička knjiga, Zagreb.

Harlan, H.V. and Martini, M.L. (1938): The effect of selection in mixture of barley varieties. Jour. Agr. Res. 57: 189 – 199.

Helms, T., Orf, J., Valland, G., McClean, P. (1997): Genetic variance, coefficient of parentage and genetic distance of six soybean population. Theor. Appl. Genet. 94:20-26.

Heneberg R. (1966): Razvoj i stanje selekcije soje kod nas, Soja; proizvodnja, prerada, potrošnja, Zagreb, 216-220.

Hollung, K., Overland, M., Hrustic, M., Sekulic, P., Miladinovic, J., Martens, H., Narum, B., Sahlstrom, S., Sorensen, M., Storebakken, T., Skrede, A. (2005): Evaluation of Nonstarch Polysaccharides and Oligosaccharide Content of Different Soybean Varieties (Glycine max) by Near-Infrared Spectroscopy and Proteomics. J. Agric. Food Chem.; 53(23); 9112-9121.

Howell, R.W. (1982): Historical Development of the United States Soybean Industry, Proceedings of the First China / USA Soybean Symposium and Working Group Meeting. Illinois. 11-15.

Hrustić M. (1983): Uticaj gustine sklopa na komponente prinosa soje. Savremena poljoprivreda, Vol. 31, br. 12, 1-2, 41-52.

Hrustić M., M. Milošević, J. Miladinović. (1997): Efikasnost i stabilnost muske sterilnosti u oplemenjivanju soje. Selekcija i semenarstvo vol. 3, 3 - 4: 54 – 59.

Hrustić M., Jocković, Đ., Vidić, M. (1998a): Oplemenjivanje soje u Institutu za ratarstvo i povrtarstvo. *In* Hrustić M., Vidić, M., Jocković, Đ. (ured.) : Soja. Institut za ratarstvo i povrtarstvo, Novi Sad i Sojaprotein, Bečej. 135 – 153.

Hrustić, M., Vidić, M., Miladinović, J., Tatić, M. (1998b): Uticaj ekoloških faktora na sadržaj proteina i ulja u zrnu soje. Zbornik radova 39. Savetovanje proizvodnja i prerada uljarica. Budva. 41 – 46.

Hrustić, M., Vidić, M., Miladinović, J. (2003): Nove sorte soje. Selekcija i semenarstvo IX, 1 - 4: 27 – 31.

Hrustić, M., Vidić, M., Miladinović, J. (2004): Soja i stres. Zbornik radova Naučnog Instituta za ratarstvo i povrtarstvo, Vol. 40: 217 – 226.

Hymowitz, T. (1988): Soybeans: The Success Story, Proceedings of the First National Symposium. New Crops: Research, Development, Economics Indianapolis, Indiana, 159-163.

Jackai, L.E.N., Dashiell, K.E., Shannon, D.A. and Root, W.R. (1984): Soybean production and utilization in Sub-Saharan Africa, World Soybean Research Conference III, Ames, Iowa, 1193-1202.

Jasnić, S. (1984): Ascochita sojaecola Abram - Nov parazit soje u Jugoslaviji. Zaštita bilja, 35 (3) 169: 217-233.

Jasnić, S., Vidić, M. (1981): Crna pegavost stabla nova bolest soje u Jugoslaviji. Glasnik zaštite bilja 2: 44-46.

Jasnić, S., Vidić, M. (1985): Occurence of soybean diseases in Yugoslavia. Eurosoya, No. 3, 43-46.

Jasnić, S., Vidić, M. (1986): Rhizoctonia solani Kühn parazit soje u Jugoslaviji, Zaštita bilja 176: 143-151.

Jocić, B. and Sarić, M. (1984): proučavanje efekta azotnih, fosfornih i kalijumovih đubriva kod različitih sorata soje. Savremena poljoprivreda, vol. 32, br. 11 – 12: 525 – 533.

Kereši, S.T., Malenčić, Đ.R., Popović, M.T., Kraljević-Balalić, M., Miladinović, J.A., Ilić, A.D. (2007): Nitrogen metabolism enzymes, soluble protein and free proline content in soybean genotypes and their F1 hybrids. Proceedings for Natural Sciences, Matica Srpska 115, 21-26.

Kiasha, T., Sneller, C. and Diers, B. (1997): Relationships between genetic distance among parents and genetic variance in populations of soybean, Crop. Sci. 37:1317-1325.

Lewers, K.S., St.Martin, S.L., Hedges, B.R. and Palmer, R.G. (1998): Testcross evaluation of soybean germplasm. Crop.Sci. 38:1143-1149.

Ma, R.H. (1982): Historical Development of Soybean Production in China, Proceedings of the First China/USA Soybean Sumposium and Working Group Meeting, Illinois.

Malenčić, Đ., Popović, M., Prvulović, D., Miladinović, J. (2005): Protein enrichment of soybean as affected by different nitrogen metabolism enzymes. Proceedings of the 8th International Symposium »Interdisciplinary Regional Research Hungary-Romania-Serbia and Montenegro«, Szeged. 14-18.

Malenčić, Đ., Popović, M., Miladinović, J. (2007): Phenolic content and antioxidant properties of soybean (Glycine max (L.) Merr.) seeds. Molecules, 12, 576-581.

Malenčić, Đ., Maksimović, Z., Popović, M., Miladinović, J. (2008): Polyphenol contents and antioxidant activity of soybean seed extracts. Bioresource Technol. 99 (14), 6688-6691.

Manjarrez-Sandoval, P., Carter, T., Webb, D. and Burton, J. (1997): RFLP genetic similarity estimates and coefficient of parentage as genetic variance predictors for soybean yield. Crop. Sci. 37: 698-703.

Marinković, J., V. Milić, N. Mrkovački, S. Milić, V. Đukić, J. Miladinović (2004): Effect of inoculation of different soybean genotypes on symbiotic effectivenes and microbiologica activity in the soil. European society for new methods in agricultural research ESNA XXXIV annual meeting Novi Sad Serbia and Montenegro 29 August-2 September 2004, Proceedings, 169-172.

Miladinović, J., Malenčić, Đ., Hrustić M., Gašić O., Verešbaranji, I. (1996a): Analysis of activity of nitrogen metabolism enzymes on grain yield and content of soluble proteins in soybean. Eurosoya, 10: 51 – 56.

Miladinović, J., Hrustić M., Vidić, M., Tatić, M. (1996b): Path coefficient analysis of the effect of yield, oil content and the duration of vegetative and reproductive period on seed protein content in soybean, Eurosoya, 10: 26 – 33.

Miladinović, J., Hrustić, M., Vidić, M., Tatić, M. (1996c): Path koeficijent analiza međuzavisnosti prinosa, sadržaja proteina i dužine trajanja vegetativnog i reproduktivnog perioda na sadržaj ulja u zrnu soje. Zbornik radova 37. Savetovanje proizvodnja i prerada uljarica. Budva. 233 – 241.

Miladinović, J., Hrustić, M. and Tatić, M. (1997a): Međuzavisnost prinosa i hemijskog sastava zrna soje u uslovima navodnjavanja i suvog ratarenja. Selekcija i semenarstvo vol. 4 (3 - 4): 109 – 113.

Miladinović, J., Vidić, M. and Tatić, M. (1997b): Interakcija genotip x spoljašnja sredina i genotipske i fenotipske korelacije prinosa zrna i žetvenog indeksa soje. Selekcija i semenarstvo vol. 3 (3 - 4): 60 – 65.

Miladinović, J., Hrustić, M., Vidić, M., Tatić, M. (1998): Soja: optimalni i mogući rokovi setve. Zbornik radova Instituta za ratarstvo i povrtarstvo, 30: 289 – 297.

Miladinović, J. (1999): Genetska dobit kao pokazatelj efikasnosti tri različita metoda selekcije soje (Glycine max (L.) Merr.) Doktorska disertacija, Univerzitet u Novom Sadu, Poljoprivredni fakultet.

Miladinović, J., Hrustić, M., Verešbaranji, I. (1999): Morphological and Biochemical Linkage of Some Soybean Varieties. World Soybean Research Conference VI, Proceedings, Chicago, USA. 521.

Miladinović, J., Hrustić M., Vidić, M., Tatić, M., Žarković J. (2000): Oplemenjivanje soje: Efikasnost klasičnih metoda selekcije u oplemenjivanju na prinos. Zbornik izvoda III JUSEM, Zlatibor. 18.

Miladinović, J., Hrustić, M., Vidić, M., Tatić, M., Burton, J. (2001): Pravci selekcije soje kod nas i u SAD. Zbornik radova 35. Seminara agronoma, Institut za ratarstvo i povrtarstvo, Vol. 35: 351 – 358.

Miladinović, J., Hrustić, M., Vidić, M., Balešević – Tubić, S., Tatić, M. (2003): Adaptabilnost i stabilnost novih genotipova soje. Selekcija i semenarstvo IX, 1 - 4: 51 – 55.

Miladinović, J., Hrustić, M., Vidić, M., Tatić, M., Balešević – Tubić, S. (2004): Međuzavisnost prinosa, sadržaja ulja i dužine trajanja vegetacionog perioda na sadržaj proteina u zrnu novih sorti soje. Zbornik radova Naučnog Instituta za ratarstvo i povrtarstvo, Vol. 40: 227 – 234.

Miladinović, J., Kurosaki, H., Burton, J.W., Hrustic, M, Miladinovic, D. (2006): The adaptability of shortseason soybean genotypes to varying longitudinal regions. Eur. J. Agron. 25: 243-249.

Milić V. (1990): Odnos između sadržaja materija rastenja i efektivnosti u Bradyrhizobium japonicum. Doktorska disertacija, Poljoprivredni fakultet, Novi Sad.

Milić V., Sarić Z., N. Mrkovački, Verešbaranji, I. (1991): Bradyrhizobium japonicum capacity to synthesize growth regulators affecting nodulation and nitrogen uptake by soybean. Mikrobiologija, Vol. 28, No 2: 145-152.

Morse, W.J., Cartter, J.L., Williams, L.F. (1949): Soybeans: culture and varieties, U. S. Government Printing Office.

Morse, W.J. (1950): History of soybean production. In Markley K.S. (ed.). Soybeans and soybean products. I. Interscience Publishers Inc., New York, 3-59.

Mrkovački N., Sarić Z. and Milić V. (1989): Dinamika nodulacije i aktivnosti fiksacije sojeva R. japonicum u toku vegetacije nekih sorata soje. Mikrobiologija Vol. 26, No 2: 123-133.

Mrkovački N., Sarić Z., Sarić, M.R., Milić V. (1992): Symbiotic effectivenes of some soybean genotypes, Mikrobiologija, Vol. 29, No 1: 1-16.

Panter, D.M. and Allen, F.L. (1995): Using best linear unbiased prediction to enhance breeding for yield in soybean. I. Choosing parents. Crop Sci. 35:397-405.

Pejić, B. (1993): Analiza vodnog bilansa i vlažnosti zemljišta kao osnove zalivnog režima soje. Magistarski rad, Poljoprivredni fakultet, Novi Sad.

Pešić, M. (2003): Uticaj proteinske molekularne strukture genotipova na tehnološke i funkcionalne osobine soje. Magistarski rad, Poljoprivredni fakultet, Zemun.

Popović, B. (1966): Kretanje proizvodnje u SFRJ, Soja; proizvodnja, prerada, potrošnja, Zagreb, 93-102.

Relić, S. (1996): Variranje komponenata prinosa u zavisnosti od genotipova i gustine sklopa i njihov uticaj na prinos soje. Doktorska disertacija, Poljoprivredni fakultet, Novi Sad.

Smith, K.J. and Huyser, W. (1987): World distribution and significance of soybean. In: Wilcox, J.R. (ed). Soybeans: improvement, production and uses. Agron. Monogr. 16, ASA, CSSA and SSSA, Madison, WI, Sec. Ed., 1-22.

Specht, J.E., Hume, D.J. and Kumundin, S.V. (1999): Soybean yield potetial – A genetic and physiological perspective. Crop Sci. 39:1560-1570.

St.Martin, S.K., Lewers, K.S., Palmer, R.G. and Hedges, R.B. (1996): A testcross procedure for selecting exotic strains to improve pure-line cultivars in predominantly self-fertilizing species. Theor.Appl.Genet. 92:78-82.

Stojković, L. (1963): Oplemenjivanje bilja, semenarstvo i agrotehnika. Zbornik radova Instituta za poljoprivredna istraživanja. 29-48.

Suneson, C.R. (1956): An evolutionary plant breeding method. Agron. J. 48: 188 – 191.

Tatić, M., Miladinović, J., Kostić, M., Đukić, V. (2006): Uticaj primenjene tehnologije proizvodnje na prinos semena soje u 2005. godini. Zbornik radova Naučnog Instituta za ratarstvo i povrtarstvo, Vol. 42: 361 – 368.

Vasić, M., Mihajlović, V., Jovićević, D., Hrustić, M., Miladinović, J., Ćupina, B., Katić, S., Vasiljević, S., Mikić, A., Đorđević, V., Milić, D. (2007): Legume genetic resources and their utilisation in the Institute of field and vegetable crops, Novi Sad, Serbia. Abstract. 1st GL-TTP Workshop, Targeting Science to Real Needs, Paris, France, 23-25 april 2007.

Vidić, M. (1982): Sclerotinia sclerotiorum (Lib.) de Bary parazit soje u Vojvodini. Magistarski rad, Univerzitet u Novom Sadu, Poljoprivredni fakultet Novi Sad.

Vidić, M. (1987): Epidemiologija Diaporthe phaseolorum (Cke et Ell.) Sacc. var. caulivora Athow et Caldwell prouzrokovača crne pegavosti stabla soje. Doktorska disertacija. Poljoprivredni fakultet, Novi Sad.

Vidić, M. and Jasnić, S. (1998): Bolesti soje. *In* Hrustić, M., Vidić, M., Jocković, Đ. (Ured.): Soja. Institut za ratarstvo i povrtarstvo, Novi Sad i Sojaprotein, Bečej. 277-338.

Vidić, M., Jasnić, S., Jocković, Đ. (1998): Occurrence of Phomopsis longicolla Hobbs on Soybean in Yugoslavia. Acta Phytopathologica et Entomologica Hungarica 33 (3-4), pp. 313-321.

Vollmann, J., Schausberger, H., Bistrich, H. and Lelley, T. (2002): The presence or absence of the soybean Kunitz trypsin inhibitor as a quantitative trait locus for seed protein content. Plant Breeding 121, 272—274.

Vucelić-Radović B., M. Barać, S.Stanojević, M. Pešić, M. Hrustić, J. Miladinović, Lj. Prijić, M. Srebrić (2005). Biološki vredni proteini domaćih sorti soje u proizvodnji riblje hrane. II International Conference ”Fishery”, Belgrade. Conference Proceedings, 268-274.

Vučić, N., Dragović, S., Bošnjak, Đ. (1981): Zalivni režim soje u klimatskim uslovima Vojvodine, Vodoprivreda, 13, 72: 311-314.

Wilcox, J.R. (1998): Metodi oplemenjivanja soje. *In* Hrustić, M., Vidić, M., Jocković, Đ. (Ured.): Soja. CTP Astrodesign, Beograd, 123 – 134.

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