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RUNNER BEAN (*Phaseolus coccineus* L.) – BIOLOGY AND USE

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Abstract. Runner bean (*Phaseolus coccineus* L.) is, after common bean (*Phaseolus vulgaris* L.), the second most important species, both around the world and in Poland. However, as compared to common bean, runner bean was not so well recognized, which is indicated by reports from literature. Among the most important values of this bean species are large and very large seeds (the weight of one thousand seeds: 900–3000 g), which, with respect to their nutritional value rival common bean seeds. There are forms of it that differ in plant growth type, morphological features of flowers, pods and seeds, as well as in the manner of use – green pods and for dry seeds. On the basis of world literature, results of the author's own studies, as well as the studies conducted in Poland by her collaborators and other authors, the issues of development biology, agrotechnical and environmental requirements, flowering and pollination of this allogamous species were presented, as well as yielding, sensitivity to herbicides, effect of pathogenic factors upon generative organs, as well as chemical composition of runner bean seeds and pericarp (*Phaseoli pericarpium*).

Key words: runner bean, cultivars, flowering, pollinating insects, yield, use, dry seeds, harvest

INTRODUCTION

The seeds of leguminous plants, including bean, have high (more than 20%) contents of protein with high biological value, carbohydrates – including fibre, mineral salts – potassium, phosphorus, magnesium and calcium, as well as vitamins from group B. Bean plants constitute the basic source of protein in nutrition in many regions of the world. They are applied as components for preparing various dishes and used in processing industry– freezing, canning, manufacturing protein isolates. For health reasons, it is now commonly recommended to increase the participation of plant products (in. a. leguminous) in human nutrition, with simultaneous limitation of animal protein and fat

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consumption [Kosson et al. 1988, Łabuda et al. 1988, Graham and Ranalli 1997, Lampart-Szczapa 1997, Łabuda and Papliński 2005, Makri and Doxastakis 2006, 2007].

Bean seeds also contain non-nutritional substances, favorably affecting our health. These include in. a. fibre, oligosaccharides, phenolic compounds – phenolic acids and flavonoids, as well as inositol phosphates. These substances are present in common bean and runner bean seeds, and their contents are differentiated, depending on parts of the seeds (cotyledons, seed coat) and their colour. Concentrations of phenolic compounds with antioxidant properties are generally higher in the seeds of both common bean and runner bean with coloured seed coat [Kosson 1988, Troszyńska et al. 2000, Drużyńska 2002, Drużyńska and Klepacka 2004, Łabuda and Papliński 2007].

In Poland runner bean is used exclusively for dry seeds. As early as in the period between the 1st and 2nd World Wars a cultivar of runner bean called Piękny Jaś was known in the markets. Its seeds, attractive because of their size (1500–3000 g), as well as taste values, nowadays are also looked for by consumers. The runner bean cultivar Piękny Jaś has the longest vegetation period (145–160 days) from among all the bean cultivars grown in Poland. In numerous studies conducted throughout the recent thirty years the issues of improving and simplifying the cultivation of this precious cultivar have been undertaken. A great interest in research works dealing with runner bean contributed to getting acquainted with the biology and most important use features of local semi-runner cultivars of this species, commonly grown in South Eastern and Southern Poland. An enormous progress was also marked in studies and works on growing runner bean. The works of breeders were concentrated mainly on obtaining dwarf, large-seeded forms of this species that could fully replace the Piękny Jaś cultivar. Breeding and entering into the Register of Cultivars in Poland, in the year 1991 of the first cultivar of dwarf runner bean – Eureka, and then Blanka, and in the subsequent years – of the semi-runner cultivars: Felicja, Nata, Karo, Kontra, Westa and in the year 2006 – Riposta was an important achievement of Polish breeders. The weight of 1000 seeds of these cultivars equals 900–1500 g, and the plants do not require any supports in cultivation. Since the beginning of 1990s the approved runner bean seeds have found themselves in the seeding material turnover.

ORIGIN AND DISTRIBUTION OF BEAN IN CULTIVATION

Growing and using bean seeds have been known for several thousand years. The most important from among all the species of *Phaseolus* in the world is common bean (*Phaseolus vulgaris* L.), which is represented in cultivation by more than fourteen thousand cultivars. Common bean comes from Central and Southern America. It is mostly grown in America, but also in Europe, Asia and Africa. Runner bean (*Phaseolus coccineus* L. syn. *Phaseolus multiflorus* Willd.) is a slightly less significant cultivable plant, both around the world and in Poland. However, runner bean is the second species in the world, besides common bean, popularly grown mostly in America and Europe. Runner bean comes from Mexico, and until today there have been the most crops of it on the uplands of Southern Mexico. There are also wild forms of this species, as weeds in the crops of corn. Runner bean is frequently grown coordinately with corn. It can also

constitute a good fodder as an admixture to souring [Asch and Hart 2004, Makri and Doxastakis 2006, Contreas-Govea et al. 2009].

The grown forms of runner bean are differentiated as to the type of plant growth (dwarf, semi-runner, runner), morphological features of flowers, pods and seeds, as well as the manner of use [Bowring 1970, George 1985, Quagliotti and Marletto 1987, Łabuda 1987]. The plants of most runner bean cultivars are characterized with strong growth (up to 4 m), as well as large and very large seeds (weight of a thousand seeds: 900–3000 g) and they require supports in cultivation.

In Great Britain, Holland and Germany especially popular cultivars are green pod crops of the runner beans with 20–40 cm long pods, with very long flowering period, large red or white flowers, as well as yielding until late autumn (Photo 1). In large-scale production bamboo poles are commonly used for supporting the plants.

Photo. 1. Red flowers and green pods of runner bean (cultivar: Enorma)
Fot. 1. Czerwone kwiaty i strąki fasoli wielokwiatowej szparagowej odmiany Enorma

Runner bean is also used for dry seeds. It is most important in growing for seeds in Austria, in the states of former Yugoslavia, Northern Spain, cooler, mountainous regions of Greece, north-western part of Italy and in Poland, where it is used exclusively for dry seeds, which are white [Łabuda 1987, 1995, Quagliotti and Marletto 1987, Santalla et al. 2004].

In Poland common bean is mainly grown. Several dozens of cultivars belonging to this species are used (green pods – french bean and for dry seeds). Common bean is a plant of substantial economic importance, the cultivation surface has recently amounted to more than 20 thousand ha (for dry seeds) and about 10 thousand ha of french bean cultivars, whereas runner bean was for many years represented by only one runner cultivar – Piękny Jaś, and local semi-runner bean cultivars, commonly grown in South-Eastern and Southern Poland, and in the region of Lublin – near Chełm and Zamość (Photo 2).

Photo. 2. Habits of local cultivars of semi-runner bean plants
Fot. 2. Pokrój roślin miejscowych odmian fasoli wielokwiatowej biczykowej

Photo. 3. Pods of local semi-runner bean cultivars
Fot. 3. Strąki miejscowych odmian biczykowych fasoli wielokwiatowej

The plants of local cultivars of semi-runner bean do not need supports in crops and have large seeds (weight of one thousand seeds: 900–1100 g), smaller than the seeds of Piękny Jaś cultivar, but larger than the seeds of all common bean cultivars (Photo 3 and Photo 4).

Photo 4. Seeds of local semi-runner bean cultivars
Fot. 4. Nasiona miejscowych odmian biczykowych fasoli wielokwiatowej

Studies conducted in Poland since the early 1980s on runner bean included more important issues of the biology of growth, yielding and quality of runner bean seeds of Piękny Jaś cultivar, as well as of local semi-runner bean cultivars [Łabuda 1987, 1988, Łabuda and Kossowski 1988, Lipiński et al. 1988, Lipiński and Skąpski 1988, Borowy 1989, Lipiński and Mieloch 1990, Łabuda and Pięta 1991, Łabuda 1993, 1995, Borowy 1996, 1999, Łabuda and Pięta 1999, Łabuda et al. 1999].

BIOLOGY OF RUNNER BEAN

Runner bean is a perennial plant and in a warmer climate the thickened, fleshy roots hibernate, which are also used in human nutrition (after cooking). In the moderate climatic zone it is grown as an annual plant, and the thickened roots in creative growing serve only for vegetative reproduction. They keep well in humid substratum, in the temperature of 5°C [Kooistra 1968]. The runner bean plants have indeterminate type of growth, very long vegetation period, they bloom and set pots until the first autumn freezes.

The cultivars of runner bean species are characterized by large and very large seeds, whether they are for green pods cultivars (Photo 5), or those used for dry seeds [Bowring 1970]. The asparagus cultivars of runner bean, which the author described many years ago, in. a. Enorma, Scarlet Emperor and Desiree are now widely spread in European cultivation.

Photo 5. Seeds of runner bean for green pods cultivar Enorma
Fot. 5. Nasiona tyczkowej odmiany szparagowej fasoli wielokwiatowej Enorma

Study results [Witek and Witek 1988] show that species crossing of runner and common bean makes it possible to obtain valuable recombinants, joining the dwarf habit of common bean plants with the size of runner bean seeds. The authors report that there is no natural changeability of the very large seed feature in *Ph. vulgaris*. In natural conditions of field growing the phenomenon of overcrossing between those species may also occur [Rutger and Beckham 1970].

The runner bean plants reveal greater tolerance to cold than the common bean plants [Hardwick 1972]. In the studies conducted in England, on green pods cultivars of runner bean the author demonstrated that the seedlings of the plants of this bean species at early sowings in April were 15 days earlier, as compared to the seedlings of common bean plants. It was also demonstrated that there were differences between species and cultivars in the pace of seedlings and weight of seedlings after emergence. Runner bean was an object of seeking forms resistant to low temperatures [Holubowicz and Dickson, 1989, Hołubowicz and Khan 1989].

The reports from world's literature reveal that in the studies on runner bean a lot of attention was devoted to the biology of flowering and pod setting , as well as to the role of insects in pollination [Free 1966, Blackwall 1969, 1971, Williams and Free 1975, Webster et al. 1980, Quagliotti and Marletto 1987].

Runner bean, in contrast to common bean, is an allogamous plant, and thus the presence of pollinating insects conditions pod setting early yielding and the yielding quantity, which is extremely important, both in the case of growing for green pod cultivars and those used for dry seeds. In growing the green pod cultivars achieving high early yield affect the profitability of cultivation [Blackwall 1969]. Runner bean is pollinated first of all by honeybees (*Apis mellifera* L.) and bumblebees (*Bombus* spp.), especially

long-tongued ones: red bumblebee (*Bombus agrorum* F.) and garden bumblebee (*Bombus hortorum* L.). Intense bumblebee fly round was demonstrated over the runner bean plantation at the beginning of flowering, whereas honeybees were usually observed later. The activity of insects was changeable and related to the weather conditions (temperature, precipitation) in the bean blooming period, time of the day, attractiveness of cultivation – abundance of pollen and nectar, as well as the distance of plantation for pollinators and closeness of other cultivations in plant blooming period at the same time.

The studies conducted in our country [Anasiewicz 1994] reveal that honeybee is the only species of runner bean pollinator of economic importance. The runner bean plants (isolated), with no access of insects, despite abundant flowering, did not set pods. The presence of bumblebee (*Bombus terrertris* L.) was undesirable on a runner bean plantation because of flower destruction and lower efficiency of bees in pollinating. Similar study results were presented in the paper by Quagliotti and Marletto [1987].

The studies conducted in Poland also reveal that runner bean is a melliferous plant, whose magnificent flowers (up to 25 pieces in an inflorescence), secrete abundant amounts of nectar and the flowering period (48–107 days) prolonging to the period of the post-harvest gap in the summer bee pollen and honeydew is very beneficial for bees [Jabłoński 1988, Wróblewska 1991, Wróblewska and Warakomska 1994, Jabłoński and Kołtowski 1999]. The beginning of plant flowering fell onto the third decade of June and the end – depending on cultivar – in the middle of August or up to the harvest – Piękny Jaś runner bean [Łabuda 1988, 2003, Wróblewska 1994]. It was also demonstrated that semi-climbing forms of runner bean were distinguished by honey yield, which was about 50% smaller, as compared to the Piękny Jaś cultivar of runner bean. Wróblewska and Warakomska [1994] demonstrated the beekeeping value of nectaring and pollen yield of runner bean. In honey that was regarded by a beekeeper as bean honey 23% participation of bean pollen was determined. The analysis also confirmed that bees had flown over runner bean to collect the nectar. The authors also demonstrated that in the conditions of free flying over, the plants produced on average 22.1–35.5% full pods in relation to the number of flowers, whereas the isolated ones produced only 0–0.9%. Łabuda [2003] demonstrated that the participation of pods with reference to the number of flowers in a field grown runner bean cluster varied from 14.0 to 40.6%, depending on cultivar (Photo. 6).

The magnificent runner bean flowers, most often red-colored, are also used as food – additionally they decorate salads, soups, appetizers, desserts and drinks. As Kelley et al. [2003] report, they maintain very good quality after storage in the temperatures from 0 to 10°C in polyethylene bags for the period of seven days.

In the studies of runner bean yielding the effects of weather course, organic fertilization and irrigation were taken into account [Blackwall 1969]. The subject of research conducted in Great Britain was runner bean cultivars for green pods. It was revealed that the runner bean plants were the most sensitive to water deficiency in the period of first green flower buds, and irrigation in this period caused the increase of pod yield from a plant by 8–64% , depending on cultivation season. Fertilizing with organic manure caused the increase of the number of flowers by ca. 21%, as well as of the number of marketable pods on a plant and of their weight. Besides, the plants covered from wind gave a bigger pod yield by 20 to 50%, as compared to unshielded plants.

Photo 6. Flowering and pod setting in a runner bean cultivar
Fot. 6. Kwitnienie i zawiązywanie strąków u tyczkowej odmiany fasoli wielokwiatowej

The Piękny Jaś runner bean cultivar grown in Poland was distinguished by a significant variability of total seed yield, ranging from 0.93 to 4.70 t·ha^{-1}, depending on total precipitation during vegetation period (May–September), which were, respectively: 240.5 and 320.2 mm, whereas the weight of a 1000 seeds was 1943 g , at the optimum water supply to plants and 1480 g at insufficient water supply [Łabuda and Papliński 2003].

Runner bean, contrary to common bean, is characterized by hypogeal germination. Studies [Borowy 1988, 1989, Borowy et al. 1988; Borowy 1996] reveal that runner bean plants are more sensitive to the recommended herbicides, as compared to common bean. EPTC, commonly used for fighting weeds in common bean, turned out to be too phytotoxic for the runner bean plants. The big difference that was found in sensitivity to EPTC between runner and common bean results from different seed germination manner of these species. Young sprouts of runner bean were much more harmed by this herbicide than the sprouts of common bean.

In the studies with runner bean, the aspect of pre-harvest pod maturity, i.e. the length of local semi-runner cultivar plants vegetation period turned out to be extremely important and significant [Łabuda and Pięta 1991, Łabuda 1995]. For it was demonstrated that the marketable yield of seeds was on similar levels, irrespectively of the length of plant vegetation period (120–158 days) and it was from 2.4 to 2.6 t·ha^{-1}. The quantity of seed yield also depended on the genetic properties of examined cultivars, which was confirmed by studies on the dry matter accumulation in plant vegetation period [Łabuda 1993]. The optimum semi-runner bean harvest period for drying up in natural conditions in the field was the time when there were about 50% mature pods on a plant, which was after about 130 days after sowing. Delaying harvest after the second decade of September and decrease of marketable yield of seeds in this period was caused first of all by the increased effect of pathogenic factors upon the seeds. The sowing value of seeds re-

vealed the highest parameters at previous harvests, up to the middle of September, whereas the total protein contents in seeds coming from pods of varied maturity was on the similar level and equaled more than 21% d. m. [Łabuda 1995].

As [Kosson 1988, Kosson et al. 1988] report, the seeds of local semi-runner bean cultivars were distinguished by total protein contents lower by about 2% as compared to the seeds of Piękny Jaś cultivar, whereas no differences were found in the amino acid composition of protein. The protein of examined semi-runner and runner bean cultivars was characterized by high contents of asparagin and glutamine acids, as well as exogenic acids: lysine and leucine, and the lowest contents of metionine.

The studies [Łabuda and Papliński 2005] on the comparison of total nitrogen contents in the seeds of nineteen bean cultivars demonstrated that it varied depending on study years, as well as species and variety features. The total nitrogen contents in the seeds of new runner bean cultivars ranged from 3.32 to 3.78% d. m, and in common bean – from 3.31 to 3.97% d. m.

In the studies on growing Piękny Jaś runner bean the application of Reglone and Ethrel was taken into consideration, to hasten the maturing and drying up of pods and seeds, as well as different terms of undercutting and plant heading and training methods of plant [Borkowski 1976; Lipiński 1988; Łabuda et al. 1999; Łabuda and Papliński 1999, 2000a, 2000 b, 2001a; Papliński and Łabuda 2003]. The application of Ethrel and Reglone for defoliation and desiccation of plants influenced a slight increase of the yield, but it simultaneously caused the decrease of 1000 seeds' weight. The effectiveness of these preparations, as well as bean yielding was strongly determined by weather conditions.

Different terms of undercutting and heading of Piękny Jaś runner bean plants and drying them up naturally on construction in the field, constitute an important problem in pro-ecological plant growing. With this harvest method, when no chemical means are applied for drying up, there is a possibility of not only obtaining high yield of good quality seeds, but also of bean pericarp *Phaseoli pericarpium*, which can be used as raw material in herbal an pharmaceutical industries [Łabuda and Papliński 2001b].

The studies [Łabuda et al., 2001, Łabuda and Papliński 2004, Papliński 2005, 2007] reveal that runner bean pericarp, similarly to the pericarp of common bean, contains precious biologically active substances – phenoloacids, the levels of which, converted into coffeic acid, exceeds the values given in FP V vol. 5 (1999), according to which the contents should not be lower than 0.1 mg/g raw material. The common bean pericarp is a pharmacopeal material and a component of many herbal mixtures: Betagran, Betasol, Diabetosan, Diabetovit, Diabetomix, Herbosan, Urosan, Nefrol, Urosept, used in treating urinary tract diseases. It also has anti-diabetic effect.

In the studies with runner bean a lot of attention was devoted to the issue of sowing material healthiness. For the seeds are the sources of primary plant infection, and the disease of flowers and young pod genmmae also significantly contributes to yield decrease and lowering of seed quality [Pięta and Łabuda 1990, 1992a, 1992b, 1993, 1994a, 1994b, Pastucha 2003]. Besides, runner bean growing is aimed at seeds designed for consumption or processing, so obtaining seeds of best possible biological properties is the most important task in cultivation technology. Sowing healthy seeds determines normal development of plants and good yielding. Runner bean seedlings from normally

Photo 7. A plant of the first dwarf cultivar of runner bean
Fot. 7. Roślina pierwszej karłowej odmiany fasoli wielokwiatowej

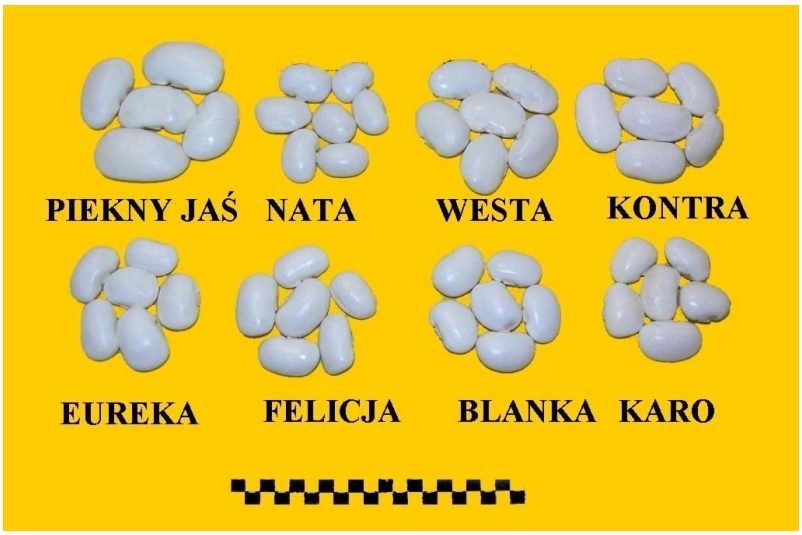

Photo 8. Seeds of some runner bean cultivars
Fot. 8. Nasiona niektórych odmian fasoli wielokwiatowej

coloured seeds were 12 to 20 cm high, whereas the plants grown from mottled seeds were half as tall. The most important role in affecting seedling roots and stem bases was played by fungi: *Rhizoctonia solani* and *Fusarium culmorum*, as well as *Fusarium oxysporum*. Łacicowa and Pięta [1992] report that good results in protecting runner bean

plants from pathogenic fungi affecting roots were obtained with seed treatment with biopreparations with *Trichoderma* spp. and *Gliocladium* spp. The study results [Łabuda and Pięta 1999] demonstrated that presowing bean seeds inoculation with *Rhizobium leguminosarum* bv. *phaseoli* bacteria inhibited the growth of pathogenic fungi and affected the increase of the number of root nodule on a common bean plant on average by 22.7% and on a runner bean plant – by 44.4%. The cultivar characterized by a significant increase of root nodule number was also distinguished by the greatest seed yield increase.

Plant growing has recently been aimed at limiting the application of chemical preparations, mainly because of the danger of contaminating the environment and field crops. This tendency also concerns leguminous plants. More and more often biopreparations based on organic compounds are applied, antagonistic fungi and bacteria are also introduced into the environment in order to protect it from diseases [Pięta et al. 2004, 2005, Pastucha 2008, Pięta and Pastucha 2008, Pięta and Pastucha 2009]. Applying biological fungi control has improved seedlings, healthiness and yielding of leguminous plants.

In the last twenty years enormous progress has been marked in the studies and growing works on runner bean. The increasing demand for large seeds contributed to it. The works of the breeders mainly focused on obtaining dwarf, large-seeded forms of this species, which would fully replace the Piękny Jaś cultivar. The effect of these works was breeding and entering in the year 1991 into the Register of Cultivars in Poland of the first dwarf cultivar of runner bean – Eureka (Photo 7), and then Blanka, as well of semi-climbing cultivars – Felicja, Nata, Karo, Kontra, Westa in the subsequent years, and Riposta in the year 2006 – weight of 1000 seeds of these cultivars equals 900–1500 g, (Photo 8), and the plants do not require supports in cultivation [Witek 1990, Witek and Witek 1988, 1990, Żebrowska and Gawroński 1991, Łabuda and Wojciechowska 1992, Łabuda and Kossowski 2001, Hołubowicz et al. 2004, Łabuda and Witek 2004, Łabuda et al. 2004].

To sum up, it has to be emphasized that as a result of widely conducted research works on runner bean in the years 1980–2009, the scholars elaborated on the issues of growth and development biology, flowering, pollination, growing methods, healthiness of generative organs, yielding, sensitivity to herbicides, chemical composition of seeds, as well as their use in food industry. Besides, one can get acquainted with scholarly works on plant physiology and biochemistry, where the subject of research is runner bean (*Phasolus coccineus* L.) [Skórzyńska-Poliot et al. 1998, Ngai and Ng 2004, Maksymiec et al. 2005, Szymańska and Kruk 2008, Chen et al. 2009].

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FASOLA WIELOKWIATOWA (*Phaseolus coccineus* L.) – BIOLOGIA I UŻYTKOWANIE

Streszczenie. Fasola wielokwiatowa (*Phaseolus coccineus* L.) jest drugim po fasoli zwykłej (*Phaseolus vulgaris* L.) gatunkiem o największym znaczeniu, zarówno na świecie, jak i w Polsce. Jednak gatunek ten został w mniejszym zakresie poznany w porównaniu z fasolą zwykłą, na co wskazują doniesienia piśmiennictwa. Jednym z największych walorów tego gatunku fasoli są duże i bardzo duże nasiona (masa tysiąca nasion 900–3000 g), które pod względem wartości odżywczej dorównują nasionom fasoli zwykłej. W uprawie znajdują się formy, które różnią się pod względem typu wzrostu roślin, cech morfologicznych kwiatów, strąków i nasion oraz sposobu użytkowania – szparagowe i na suche nasiona. Opierając się na piśmiennictwie światowym, wynikach badań własnych i współpracowników oraz innych autorów przeprowadzonych w Polsce przedstawiono zagadnienia biologii rozwoju, wymagań agrotechniczno-środowiskowych, kwitnienia i zapylania tego obcopylnego gatunku, plonowania, wrażliwości na herbicydy, porażenia organów generatywnych przez czynniki patogeniczne oraz składu chemicznego nasion i owocni (*Phaseoli pericarpium*) fasoli wielokwiatowej.

Słowa kluczowe: fasola wielokwiatowa, odmiany, kwitnienie, owady zapylające, plonowanie, użytkowanie, suche nasiona, zbiór

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