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AGROBIOLOGICAL AND TECHNOLOGICAL CHARACTERIZATION OF *PHASEOLUS COCCINEUS* L.

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Abstract

Phaseolus coccineus L. (runner bean) belongs to the Fabaceae family and is the second most important species of the Phaseolus genus, after the common bean (Phaseolus vulgaris L.), which is often confused. The species is cultivated especially for seeds (mature or immature) and some cultivars are grown for pods. The runner bean is grown as an annual plant in pure crop or intercropping, being appreciated, to a lesser extent, also for its ornamental value. In Romania it is cultivated in small areas, especially in family gardens, using local populations without using a standard technology, but rather one that is adaptable to environmental conditions. The study focuses on aspects such as morpho-physiological, ecological, and phenological features, and different cultivation technologies, but also on genetic features and potential breeding methods.

Key words*: runner bean, crop systems, Fabaceae.*

INTRODUCTION

P. coccineus is a perennial species originating from the mountainous, humid tropical areas of Mesoamerica. In its native area, it can live up to ten years, but outside this area, it behaves as an annual plant because its aerial parts cannot tolerate frost (Rodiño et al., 2007).

ORIGIN AND DISTRIBUTION AREA

The best-known species of the genus *Phaseolus*, both in terms of area and geographical distribution, is the common bean (*Phaseolus vulgaris* L.). Next to this, but cultivated in smaller areas is the broad bean (*Phaseolus coccineus* L.). Both species are native to America, more precisely from northern South America, Central America (Guatemala and Honduras), and southern North America (Mexico) (Salinas, 1988).

The two species were brought to Europe after the discovery of the American continent by Columbus (1402). Here they underwent a process of adaptation to lower temperatures (Spataro et al., 2011; Rodriguez et al., 2013).

It seems that these two species were cultivated in the Neolithic, about 10-12 thousand years ago, when in fact the first great agrarian revolution was recorded. Evidence in support of what has been presented has been brought by various scientific works dedicated to this subject, such as those of authors such as Salinas (1988) and Philips (1993), Kaplan and MacNeish (1960), Kaplan (1965), Flannery (1973) or Smart (1976). Traces of the great bean, cultivated in Mexico, have been found in archaeological sites at Telmacan, Puebla, Rio Zaze, and Durango, dated to between 2200 and 1300 BC (Popa, 2010; Vargas et al., 2012).

However, bio-geographic research, which uses the cpSSR and nonSSR techniques, suggests multiple evolutionary processes of the species in Mesoamerica as well (Angioi et al., 2009; Spataro et al., 2011; Rodriguez et al., 2013).

It is important to remember, for the explanation of some ecological peculiarities of the broad bean species, as it results from the works of the authors mentioned above, that the broad bean was formed in the mountainous regions of Mexico, delimited by the states of Puebla, Oaxaca, and Chiapas.

The species *P. coccineus* is represented in culture, especially in regions close to the area of origin, by two subspecies, *coccineus* and *darwinianus* (Salinas, 1988) opines that the subspecies *darwinianus* would be an ancestral hybrid between *P. vulgaris* and *P. coccineus*, i.e. it would be a kind of "bridge species" between them.
Salinas opinion that *P. coccineus darwinianus* is the said hybrid may be true given the extremely varied environmental conditions during the periods of thousands or hundreds of thousands of years of coevolution of the two species.
In Romania, this species once arrived, probably, with the common bean, with which it was and still is confused (Popa, 2010). The first information about this species appears in Alexandru Borza's "Ethnobotanical Dictionary" (1968) and the monographic book "Fasolea" by Olaru (1982). A distinct report with many details about the biology, ecology, mode of cultivation, and use of the crop was that made by Munteanu (1985) and entitled "*Phaseolus coccineus* L. - a vegetable species that deserves more attention", using the appropriate literature appearing in outside of Romania.

THE IMPORTANCE OF CULTURE

Food importance

Worldwide, different consumer preferences are known. Thus, in the USA and Western Europe, the broad bean is known especially for its large, wide pods (similar to the pods known for the common bean), of a raw green colour (Santalla et al, 2004). In Latin America, but also some European countries, such as those in South-Eastern Europe, the broad bean is known mainly for its mature or immature seeds, which are large, oblong, slightly flattened, white or coloured (Munteanu, 1985; Stan et al., 2003; Tay et al., 2008).
In general, this type of bean is known as a luxury food product and is valued at much higher prices than common beans (Kay, 1979)
From specialized research, it can be concluded that 60% of a pod can be consumed due to its nutritional value as well as its nutritional, catalytic, and mineralizing complex (Table 1).

Table 1. Content of seeds and pods in broad bean (Munteanu, 2005)

The composition	Pod (edible part)	Immature seeds (green	Mature seeds (dry)
Water	58,3	34,2	12,0
Protein (%)	7,4	2,6	20,0
Carbohydrates (%)	29,8	47,9	63,0
Fats (%)	1,0	0,3	1,5
Fibre (%)	1,91	12,2	5,0
Ash (%)	1,63	2,8	3,5
Calcium mg/100 g	50,0	60,6	120,0
Phosphorus mg/ 100 g	160,0	276,6	-
Iron mg/100 g	2,6	4,1	10,0
Thiamine mg/100 g	0,34	0,54	0,3
Riboflavin mg/100 g	0,19	0,14	0,1
Niacin mg/100 g	-	2,3	2,0
Ascorbic acid mg/100 g	27,0	0,2	-
Carotene mg/100 g	0,057	0,324	-

In Central America, the tuberized (fleshy) roots, rich in starch, are also used in food, after they have been boiled and the boiling liquid removed (Munteanu, 1985). Another method of preparation consists of drying the roots for a week, then portioning them and boiling them for 6-8 hours. Sometimes, the boiled roots are eaten as such (Salinas, 1988). In Oaxaca and Chiapas, the raw roots are used to regulate digestion, and in Guatemala, the water in which the roots have been boiled is used as a remedy against malaria (Salinas, 1988).
In Mexico, the young leaves and shoots, as well as the inflorescences, are boiled and then fried, eaten as such, after seasoning them with garlic and onion, or as side dishes.

Ornamental importance

In the countries of Germany, the USA, etc., the use of broad beans for ornamental purposes can be observed, but the plants being exposed to high temperatures, although they bloom profusely, do not bind pods because the atmospheric moisture requirement is not covered.
This species is decorative due to the diversified colouring of the flowers (from intense red to white or even bicolor) which are arranged on a raceme up to 60 cm long that stands out from the abundant foliage, especially in the climbing forms (Schwember et al., 2017).

Due to the diversified colour of the flowers, the broad bean attracts various insects such as butterflies, bees but also birds (hummingbirds) (Teliban, 2015).
The broad bean is cultivated as an ornamental plant in Romania, and is known as a "flower bean" (Popa, 2010).

Agrotechnical importance
The large bean, due to its positive characteristics, is of very high agrotechnical interest. This lends itself very well to growing between rows of plants (corn) but also cabbage, carrot, lettuce, etc. (Munteanu et al., 2007).
As a precursor plant, the bean is essential because it contributes high amounts of biological nitrogen in crop rotations due to its ability to symbiosis with nitrogen-fixing bacteria belonging to the genus *Rhizobium*, which use nitrogen from the atmospheric air (78%), and which transforms into ammoniacal nitrogen (NH_4) (Ciofu et al., 2003; Stan et al., 2003).
Due to the lower temperature requirements for germination and plant growth, *P. coccineus* L., can grow in cooler environmental conditions than those required by *P. vulgaris* L. making it important for the Great Britain (Rodiño et al, 2007). Due to its tolerance to low temperatures, it has become an important crop in the northern part of Europe and in the mountainous areas of southern Europe where it is grown from spring to summer. It is also cultivated in the upper regions of Africa and Asia.
The broad bean can be grown in various places and cropping systems: as an annual plant (monoculture or intercropping), as a perennial plant, interspersed with trees in the orchard, or cultivated on fences, lines, and hedgerows (Hernandez et al., 1979), of mention is that in greenhouses and solariums, it is cultivated only to obtain green pods (Teliban et al., 2014).

Economic importance
From the point of view of the economy, broad beans are preferred by hypermarkets, markets and other areas of trade due to the fibre and protein intake as well as the special taste. Although it has a higher price compared to the common bean, it is marketed very easily (Teliban, 2015). For this reason, broad beans have attracted the attention of both researchers and producers.
To ensure the profitability of broad bean crops, it is very important to apply the appropriate cultivation technology of the species and ensure favourable growing conditions (Teliban et al., 2015).

Risk factors
The main risks associated with the cultivation of this plant are mostly related to environmental conditions (Popa, 2010). Below are some of these factors: temperatures below 5 ºC stop plant development (Rodiño et al., 2007), and temperatures below 0ºC destroy plants; temperatures above 25ºC can prevent formation; placing the culture in areas with periods with temperatures between 0 and 5ºC during the 120-130 days of vegetation; drought can delay seed germination, lead to uneven germination and/or the appearance of a large number of voids in the crop; prolonged drought during flowering can lead to abundant flower drop or lack of fertilization, leading to the formation of small pods and seeds of poor quality; heavy rainfall during harvest can be a real calamity because it can cause disease in the pods, leading to quality deterioration and quantitative reduction of the harvest (Popa et al., 2020).

BOTANICAL AND BIOLOGICAL PARTICULARITIES

Phaseolus coccineus has a tuberous taproot, rich in starch, with nodules and vegetative buds in the neck area. The emergence of broad beans is hypogeic (Giurcă, 2009). The 2-7 m stem is tall, vigorous, and slightly twisted. The buds from which the stem branches grow and develop are formed in the axils of the leaves at the base, and the flower buds are formed in the upper part (Popa, 2010). The leaves are trifoliate, with oval leaflets, acuminate to the tip and round at the base. The inflorescence is zygomorphic, hermaphrodite, multifloral raceme longer than the leaves, 25-60 cm, with red, white, pink, bicolour flowers and allogamous pollination, rarely autogamous. Cross-pollination is specific to climbing beans and occurs before the flower opens. Considering that flowering extends over a longer period, allogamy is favoured (Hamburdă and Munteanu, 2016). The fruit is linear oblong to oblong. The seeds are very large, 20-25 mm long, 13-14 mm wide and 8 mm thick. They have different colours: white, black, beige, and purple (Teliban, 2015). The weight of 1000 grains is between 1000 and 3000 g (Labuda, 2010).

RELATIONS WITH ENVIRONMENTAL FACTORS

Relations with temperature

The broad bean is a species adapted to the humid tropical conditions found in the high plateaus. Compared to common beans, it is more tolerant of low temperatures. Germination occurs starting from temperatures of 8-12ºC, and the optimum temperature for growth and development is 16-18ºC (Popa, 2010). Usually, temperatures above 25ºC inhibit the formation of pods, and temperatures below 5ºC adversely affect the plants, possibly even leading to their destruction by frost. Thus, to ensure optimal growing conditions, the vegetation period without the risk of frost should be 130-150 days (Salinas, 1988; Popa, 2010).

Relations with water

Water is a crucial factor for growing broad beans, and for this reason, it is mainly grown in temperate areas of Europe where irrigation is possible. The critical periods when water availability becomes crucial are during germination, flowering and pod formation. Even a short period of drought at these stages can result in the dropping of buds, flowers, and newly formed pods (Popa, 2010). On the other hand, excessive moisture at these times can be harmful, causing excessive vegetative growth, affecting the grain, and increasing susceptibility to diseases, especially anthracnose.

During the flowering period, lack of water can shorten this phase and reduce the number of flowers and pods per plant. During grain formation, insufficient water can lead to grain size reduction (Kay, 1979).

Broad beans are not very resistant to soil drought and atmospheric drought during the flowering and fruiting stages. These conditions can cause a significant decrease in flower formation and production. To ensure an optimal bean crop during the flowering and pod formation stages, it is critical to have well-irrigated soil and a moist and warm environment (Kay, 1979).

Relations with the soil

In growing broad beans, the soil plays an essential role. Among legumes, broad beans are known for their high soil requirements. To obtain quality production, it is necessary to cultivate on deep, well-drained soils with a light or medium texture and a pH between 6.5 and 7.4 (Popa, 2010).

Beans get some of their nitrogen needs from nitrogen-fixing bacteria found in the nodules on their roots. However, to ensure the healthy growth of the plant, it is important to supplement the nutrients in the soil, especially in the first stages of vegetation. Thus, less fertile soils must be enriched with chemical and organic fertilizers (in quantities of 40-80 tons/ha) (Stan et al., 2003).

Relations with nutrients

The growth and development of bean plants is strongly influenced by the availability of nutrients. Their lack can have significant effects on the plant. For example, the lack of nitrogen in the soil can cause the yellowing of leaves in young plants, a phenomenon accentuated in cold weather conditions (Olaru, 1982).

In the case of a lack of phosphorus in the soil, the growth and development of young plants can be significantly delayed, and the leaves can acquire a pale colour, later turning yellow and even red (Olaru, 1982).

A lack of potassium can cause chlorosis, characterized by yellowing of the leaves. The absence of calcium in the soil can lead to problems such as the curling of young bean leaves and the deformation of their edges.

Micronutrients such as zinc, boron, manganese, and molybdenum have a positive impact on the growth and development of beans. For example, a lack of boron in the soil can slow growth and reduce production, while a lack of manganese can cause severe chlorosis and leaf necrosis (Olaru, 1982).

Molybdenum in the soil has multiple beneficial effects, including the accumulation of calcium and phosphorus in leaves and roots, as well as active nitrogen fixation, an activity carried out by nitrogen-fixing bacteria. Lack of

molybdenum can lead to small plant sizes and reduced production (Olaru, 1982).
Studies in the specialized literature highlight the ability of rhizobacteria to solubilize organic and inorganic phosphates in the soil and to produce indoleacetic acid. Seed inoculation with bacteria from the rhizosphere of bean plants, such as strains S4 and S7, can increase photosynthesis, transpiration, water use efficiency, leaf chlorophyll content, and yield (Ștefan et al., 2013a; 2013b).

GROWING TECHNOLOGY

The choice and preparation of the land

The choice and preparation of the land are carried out similarly to the common bean crop. Romanian specialized literature does not provide a standard methodology in this way.
The culture is located on flat or sloping land, with a uniform slope, with deep, well-worked, well-drained, loamy soil, from light to medium in texture. In Europe, the crop is practiced only under irrigation conditions (Kay, 1979).
Heavy, wet, and cold soils, as well as those that form a crust, are unsuitable, since, in such conditions, the beans sprout hard and unevenly (Olaru, 1982).
In principle, any of the vegetable species are accepted as precursor plants, except those from the same botanical family (Stan and Stan, 2010). Sometimes, monoculture can be practiced, if the disease attack was not strong or if too large a reserve of pathogens did not form in the soil (Stan, 2005).
Basic fertilization is differentiated, depending on the fertilization system of the preceding plant, as well as the nature of the type of soil on which the crop is placed. A quantity of 60-80 t/ha of well-decomposed manure, 400-600 kg/ha of superphosphate, and 200-300 kg/ha of potassium salt is administered. On soils with high fertility, no manure is applied, and the doses of chemical fertilizers are reduced by half (Davidescu and Davidescu, 1992).
When manure is applied, it must be well decomposed, and in this case, facial fertilizers are quantitatively reduced (Kay, 1979).
Basic ploughing is performed immediately after fertilizing, at a depth of 28-30 cm, with PP-3x30 M; the land is left in the furrow until spring (Stan et al., 2003).
In early spring, the land is worked through 1-2 passes with the harrow with adjustable tines, to keep the soil loose and destroy any weeds that appear, as well as for levelling the basic ploughing (Dumitrescu et al., 1998).
Starter fertilization follows harrowing and is done with 100-150 kg/ha of ammonium nitrogen (Dumitrescu et al., 1998). An insecticide can also be applied to prevent the attack of the *Delia platura* pest, but also herbicide to control weeds (Stan et al., 2003).

Crop establishing

The establishment of the crop must be carried out 10-14 days after weeding. Culture is usually done by direct sowing, but also by seedling.
The establishment period begins with the achievement of a temperature above the threshold of 10-12ºC, which corresponds, in the southern areas of the country, to the period of April 15-20, and in the more northern areas, to the period of May 10-20. The establishment of the spring crop can continue, staggered, until the end of May (Popa and Munteanu, 2009).
The establishment scheme is variable, the technical element that differentiates the crop establishment scheme is the palisade method. If the palisade is made on canes, the culture is established in nests of 4-6 plants, arranged in parallel rows 80-100 cm apart; the distance between the nests in a row is 50-60 cm. In this way, a density of 17-25 thousand nests/ha or 70-150 thousand plants/ha is achieved (Stan et al., 2003).
If the plant stringing is carried out on the trellis, the same density and, partially, the establishment scheme are respected. Usually, the trellis consists of a row of 200 cm high posts, arranged at a distance of 8-10 m between them; a 2-3 mm thick galvanized wire is attached to the top end of the poles (Popa et al., 2020). A row of nests of 3-5 seeds each, at a distance of 40-80 cm, is placed on one side and the other of the trellis; the distance between the nests is 40-60 cm. In this way, the densities that can be achieved vary between 18 and 36 thousand nests/ha (Stan et al., 2003; Hamburda et al., 2014).

The sowing rate is 70-80 kg/ha, depending on the density and the mass of a thousand grains. The sowing depth is 3-4 cm; emergence occurs more easily when sowing is done in nests (Popa et al., 2020).

Care work

Care work does not differ much from climbing garden beans, but a standard technology is not known. In the households of the population, as a rule, the same works are applied to the corn culture, with which it is most often associated. Here, as a distinct work, we can distinguish the palisade, which is made on long arches (over 2 m), which ensures good exposure to light (the palisades can also be made on different types of trellises). In some countries, bamboo stems are used, which are resistant and very cheap. After digging into the soil, the arachnids are caught in pairs at the level of the trellis wire with raffia or twine (Munteanu et al., 2007).

For the success of the culture, pinching and sausage are practiced. Pinching is mandatory work, which ensures a good branching of the stems and a remarkable increase in the harvest. The pinching is done by breaking the tops of the stems, when they reach 60-80 cm, then at 100-120 cm, and after they have reached the level of the trellis wire. Sausage is recommended to stop the growth of the stem and to speed up the ripening of the formed pods (Ciofu et al., 2003).

During the growing period, a good distribution of rainfall is required, because broad bean is very sensitive to drought and requires a relatively high humidity at seed setting. In England, the crop is often irrigated from the green bud stage, normally from June to August (Kay, 1979).

Combating diseases has some peculiarities, due to the phenomenon of "disease escape", determined by the fickle behaviour of plants (Ruşti and Munteanu, 2008). Pest control is based on their biology and ecology.

Due to its allogamy, the runner bean requires the presence of pollinating insects such as bees (*Apis mellifera* L.) and bumblebees (*Bombus* spp.), which significantly influence both early pod formation and overall yield, which is of paramount importance for varieties grown for both green pods and dry seeds (Łabuda, 2010).

Harvesting

The experiments at the Bacau Vegetable Research Station, in the period 1980-1986, allowed an evaluation of the production that varied between 1000-2500 kg/ha of dry beans. The culture was carried out in its field, as a monoculture, on a specially arranged land with a palisade system, used for the culture of climbing garden beans (Munteanu et al., 1985).

The pods will be harvested every five days or even more often. The pods should be harvested when they are almost full length, usually 20-30 cm, and before they form threads. It is very important to continue harvesting all the pods as soon as they reach the technical time of ripening; otherwise, the plants will slow down their flowering. In the vast majority of gardens, the plants will then continue to produce flowers and pods until the vegetation is stopped by the first frost (Brink and Belay, 2006).

Cultivation systems in the field and tunnels

Worldwide, broad beans are grown almost exclusively in the field, in row or palisade cropping systems, as well as in succession or double cropping. In Mexico, for example, four cultivation systems are used, namely: as an annual plant, as a perennial plant, interspersed with orchard trees, and cultivated on fences, hedgerows, etc. In Grand Britain, systems with climbing plants or bush plants are very popular; the latter system is mainly used in areas with strong winds. In other Western European countries (the Netherlands, Belgium, France, Spain), the culture system with climbing varieties in monoculture, similar to the common climbing bean, is mostly used.

In Romania, most often, broad beans are grown in association or interspersed with corn, supported on canes, but also in their cultivation system next to fences (Haburda and Munteanu, 2016).

Greenhouses practices is mainly used to obtain pods, especially in countries such as the Netherlands and Belgium. A variety that lends itself to this cultivation system is the Desiree variety (Teliban, 2015).

Intensive (conventional) and sustainable (unconventional) cultivation systems

Sustainable farming systems are already known worldwide, as well as in our country.

These systems have been imposed by the fact that they represent a viable alternative to the current intensive or industrial agriculture systems (Stan et al., 2003).

Broad bean lends itself very well to both cultivation systems. Lately, with the promotion of non-conventional (organic/biological) cultivation, the broad bean, as well as the climbing common bean, has become a preferred species for organic cultivation, because, for this cultivation system, plants with a high ecological plasticity are recommended, with a certain rusticity towards environmental factors, with genetic resistance (especially horizontal) to pathogenic and harmful agents, etc. The specialized literature confirms what was presented above (Munteanu et al., 2007).

Ways of growing broad beans

Ways of growing broad beans vary according to region, traditions and available technical resources.

In UK, both seed cultivation and tuberous root planting are practiced. The preferred seeds are those obtained from disease-free early or mid-season crops (Kay, 1979).

Systems with climbing plants or bush plants are also encountered. In areas with strong winds, bush plants are preferred, but they are more exposed to diseases and require more attention. Another form is to support plants with canes from bamboo stems or wire, allowing them to climb naturally (Wood, 1979).

In other European countries such as the Netherlands, Belgium, France and Spain, the cultivation system with climbing varieties in monoculture, similar to that of the common bean, is used more. In Central America, broad beans are associated with corn or grown in a household system, in pots, where 10-15 plants can grow.

In Romania, broad beans are grown in all agricultural areas, in small areas, and family households. It is often grown in association with other crops or alone, supported on trellises or next to fences. The culture is established by direct sowing and germination is hypogeic (Munteanu et al., 2007; Łabuda, 2010).

Optimizing planting schemes and densities is essential for achieving efficient production, taking into account the specific environmental conditions in each area (Munteanu, 2005; Hamburda et al., 2016).

BREEDING AND SEED PRODUCTION

The species *P. coccineus* L. belongs to the group of allogamous species, a fact determined, first of all, by the genetic mechanisms that govern fertilization and which are specified as the genetic mechanisms specific to gametophytic incompatibility (Munteanu, 2005).

The runner bean, within the context of genetic improvement for the common bean, presents a significant range of variability across various traits, as noted in studies by Salinas (1988), and Singh (2001). This species offers valuable agronomic features and resistance to diseases, such as resistance to lodging due to sturdy stem bases, tolerance to cold conditions, extended epicotyls and racemes, the presence of a tuberous root system enabling perennial growth cycles (Santalla et al., 2004), potentially high pod counts per inflorescence, and resilience against pathogens like *Sclerotinia sclerotiorum* (Gilmore et al., 2002), *Ascochyta blight* (Schmit and Baudoin, 1992), and root rots caused by *Pythium* or *Fusarium* (Dickson and Boettger, 1977), among others.

As theoretical and practical support for the establishment of a conservation scheme for runner bean, can be considered knowledge of the biology and genetics of the species, the biological and genetic basis for breeding and conservation selection, and, respectively, the model of the selection scheme for annual autogamous plants, including that of the climbing common bean (Popa et al., 2020).

CONCLUSIONS

Following the research carried out both in Romania and abroad and summarized in the review, regarding the botanical and biological peculiarities, the high ecological plasticity, the important biochemical and agro-productivity characteristics, the adaptability to the different schemes and cultivation methods. At the same time, it’s also sensitivity to atmospheric drought, as well as the species' allogamy, we consider it opportune to carry out for the first time in Romania a runner bean breeding program, to create genotypes with specificity for pods or grains, superior from quality and quantity point of view, adapted to current climate change and with high economic efficiency.

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