# chapter seven

# Legumes

The family *Fabaceae* — commonly known as grain legume species like beans (*Phaseolus* sp.), mung bean, cowpea (*Vigna* sp.), soya bean (*Glycine* sp.), groundnut (*Arachis* sp.), chickpea (*Cicer* sp.), fenugreek (*Trigonella* sp.), and so forth [1] and forage legumes like clovers (*Trifolium* sp.), *Lathyrus* sp., *Vicia* sp., alfalfa (*Medicago* sp.), sarradella (*Ornithopus* sp.), sainfoin (*Onobrychis* sp.), trefoils (*Lotus* sp.), and so forth [2] comprises some 700 genera and 18,000 species [2]. Most of them are adapted to tropical or arid growth conditions [3] and do not include plants of economic interests in temperate and continental regions. However, many species of clovers and other forage legumes — and also some genotypes of grain legumes, like beans, broad beans, peas, lens, soya beans, and chickpeas — are well adapted to temperate and sometimes continental climates.

Legumes are beneficial in crop rotation under organic farming systems. Since the beginning of agriculture, legume crops have been irreplaceable crops for their natural nitrogen fixation abilities. Legumes fix atmospheric nitrogen in a symbiotic association with bacteria of the genus *Rhizobium*, which attaches to the roots and forms nodules. Active nodules can fix up to 600 kg of nitrogen $ha^{-1}$, but a more normal amount is 200 to 250 kg of fixed nitrogen $ha^{-1}$ by forage legumes, and 80 to 150 kg nitrogen of fixed $ha^{-1}$ by grain legumes. For example, in the climbing bean, up to 84% of nitrogen may be derived from fixation [4]. In soils not infected by symbiotic bacteria, the bacteria need to be applied to the seed at sowing. However, absence of bacteria is expected in the low pH soil; in the absence, the host should be planted in crop rotation over many years.

Legumes are frequently used as organic manure, due to their positive effects on soil structure and nutrient availability. Legumes may be also mixed or intercropped by other crops. Important benefits in organic farming of mixed or intercropping cereals with legumes are as follows: efficient competition of cereals with weeds, improved soil structure, reduced loss of plant nutrients, less damage of plants to pathogens and insects [5], and more available nitrogen due to nitrogen fixation. Due to the high content of proteins in the dried grain, grain legumes can be the most important source of



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proteins for animal feed, because animal proteins are identified as a source of mad cow disease caused by Bovine Spongiform Encephalopathy (BSE). Corn/bean or maize/soybean intercropping may help fix a deficiency of proteins in the silage [6], as well as increased nitrogen digestibility for ruminants compared to corn silage [7].

Legumes play an important role in human nutrition since they are rich sources of protein, calories, certain minerals, and vitamins [8]. According to Iqbal et al. [9], crude protein is provided in the following amounts: lentil 26.1%, green pea 24.9%, chickpea 24.0%, groundnut 26% [10], vigna-cowpea 19–24% [11] to 24.7% [9], and soya bean 24 to 55% [11]. A legume enhances the protein content of cereal-based diets and may improve their nutritional status. Cereal proteins are deficient in certain essential amino acids, particularly lysine [12]. On the other hand, legumes have been reported to contain adequate amounts of lysine, but are deficient in S-containing amino acids (methionine, cystine, and cysteine) [13]. Amjad Iqbal et al. [9] conclude that legumes like chickpeas, lentils, cowpeas, and green peas are rich in lysine, leucine, and arginine and can fulfill the essential amino acid requirement of the human diet, except for S-containing amino acids and tryptophan. In order to compensate for the deficiency of certain essential amino acids in legume protein, they must be supplemented with other vegetables, dairy products, or meat.

The high value of proteins and rich amount of essential amino acids in its seeds rank grain legumes among the top sources of human nutrition throughout the world. Legume proteins can help people avoid a serious nutritional problem, called protein calorie malnutrition, especially among children in developing countries. In this book, however, only grain legumes that are more or less suitable for growth in temperate climates and their modest applications to organic farming practice will be covered.

## 7.1 Chickpea

### 7.1.1 Introduction

The chickpea, also called garbanzo, bengal gram, or egyptian pea (*Cicer arietinum* L., syn.: *C. edessanum* Stapf., *C. grossum* Salisb., *C. sativum* Schkuhr) is the third most widely spread grain legume in the world, after beans and soya beans. The chickpea is produced in the Asian part of Turkey and India; other important producers include France and Spain [14]. The lack of organic chickpea on the world market is evident, and it is mainly certificated by the company Organic India. It is frequently used in vegetarian dishes.

Chickpea seeds need a longer time for cooking than bean and lens. The seeds contain 13 to 32% of proteins, which are similar to animal proteins. The percentage of eight essential amino acids (especially arginine, lysine, threonine, valine, and phenylalanine) is especially important; the seeds contain 1.5 to 5% of cellulose and 2 to 5% of ash. The percentage of oil is relatively high (2.7%) in comparison to other legumes; only the grains of soybeans are

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higher. The chickpea seed is rich with essential phosphorus compounds, provitamin A, and vitamin $B_1$ [14].

Intensified secretions of the pancreas may be attributed to consumption of the chickpea, and it is also a known diuretic due to the content of asparagic acid in its seeds.

### 7.1.2 Botany

Chickpea is a member of genus *Cicer* L. and family *Fabaceae* (*Leguminosae*). Genus *Cicer* is one of 27 species — 22 perennial and 5 annual [15]; only thechickpea (*Cicer arietinum* L.; arietum-men ram head) is cultivated. There are four subspecies: *Cicer arietinum* L. ssp. *orientale* Pop., *Cicer arietinum* L. ssp. *asiaticum* Pop., *Cicer arietinum* L.ssp. *euroasiaticum* Pop. Ans., and *Cicer arietinum* L. ssp. *mediterraneum* Pop. All are divided into numerous genotypes.

Chickpea is an annual crop, with tuff and roots that extend approximately 1 mm deep. The roots, which form numerous nodules, can be affected by nitrogen-symbiotic bacteria from the genus *Rhizobium*. The plant may be erect, with numerous branches, and the lower part of the stem lignifies at full maturity. The pilose stems grow to lengths of 0.2 to 0.5 m, sometimes as much as 1.0 m. The first two leaves on the stem are scale-like, and further leaves are pinnate with 9 to 17 leaflets and a midrib terminating with a leaflet. The leaflets are about 8 to 18 mm long and 3 to 10 mm wide, and the complete leaves reach about 5 cm in length. The leaflets are elliptical, ovate, or obovate, with serrated margins. The flowers may be white, red-blue, or pink, and quite small (about 1 cm, sometimes to 2.2 cm). Individual flower clusters are auxiliary. The flowers are hermaphroditic, usually solitary, and born on peduncles 2 to 4 cm in length. The number of flowers per plant varies from 40 to 100, depending on climatic conditions, cultivar, and cultivation practice. The fruits are swollen and oblong pods (Figure 7.1). The pods of light colored seeds are straw yellow; the pods of dark colored seeds are ash violet. The pods grow between 1.5 and 3.0 cm long, contain only one or two seeds, and may be sterile at times. Seeds vary in shape from angular to round, and from smooth to very wrinkled; seed color may be white, yellow, orange, red-brown, or black. Comparing 1000-seed weight, the chickpea is separated into three groups: below 200 g, between 200 and 300 g, and above 300 g.

### 7.1.3 Climatic conditions, growth, and development

Chickpea needs a sum of average temperatures between 1800 and 2000°C. This annual crop is partly tolerant to cool temperatures; it can be grown in all regions where the climatic conditions are suitable for vine growth. Compared to other grain legumes, it is the most cool-weather-tolerant crop, except for the pea. The minimum temperature for germination is 2 to 3°C, but the optimum is between 20 to 25°C [15]. Germination under cold conditions

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*Figure 7.1* Chickpea plant with fruit.

often results in the decay of germinating seeds. Young plants can tolerate temperatures as low as –16°C after emergence.

Chilling (< 15°C) during the reproductive phase of the chickpea leads to the loss of flowers and pods, infertile pods, smaller seeds, reduced seed yields [16], and negative effects on the functions of reproductive structures [17]. In cold-stressed plants, seed number per 100 pods, seed weight per plant, average seed weight, and average seed size decreased by 35, 43, 41, and 24%, respectively. Seed reserves of starch, protein, and fat decreased by 34, 33, and 43% respectively, while total soluble sugars increased twofold. The accumulation of proteins such as globulins and albumins was inhibited to a greater extent than that of prolamins and glutelins. Most of the amino acids decreased as a result of stress, while some — such as proline and glutamic acid — increased significantly [16].

The young plants are also tolerant to drought; the chickpea transpiration coefficient is lower than most other crops. In the case of high relative humidity, the plants lose flower buds. However, full irrigation in a cool to temperate, sub-humid climate from emergence to physiological maturity always gives the highest seed yield (> 4.7 t/ha), and there is no indication of a critical period of sensitivity to water stress [18].

The bud formation starts in long-day circumstances. The duration of the growth period is between 70 and 100 days, depending on daylight, humidity, and temperature. In the case of high temperatures, the growth period is shorter. The plants grow very slowly for the first 14 days; after that, growth and development speed up. The stems are thin, characteristic of xerophytes plants (small plants with small masses of leaves; the plant is pilose). The flowering stage lasts about 20 days, and the seeds are mature about 40 days afterward. Chickpea flowers are mainly self-pollinated. The pollen and pistil matured 1 to 4 days before the flower is open. Only under

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extreme drought periods may the 3 to 5% of flower be cross-pollinated. All of the pods mature in each period. The senescence is intensive, causing the leaves to fall away from the plant, but the pods remain strongly attached to the stems. At the stage of over-maturity, the pods fall away, but they do not lose the seeds. The pods breaks after one week, and many grains may be lost during harvesting.

## *7.1.4 Cultivation practice*

The chickpea is a very appropriate crop for organic production. It does not need a special previous crop in crop rotation, but there are legumes that should not follow other legumes. The best previous crops are potato and sunflower. Chickpea grown in monoculture results in lower yielding; it is a smart choice for a previous crop when the nitrogen needs of following crops are a bit higher.

Chickpea is the crop of calcareous and marly soils, grows well in sandy soils, and tolerates salt soils better than most other crops. Acid and heavy soils, conversely, are not suitable for chickpea production. Slightly acid soils must be calcificated at the soil tillage in autumn, a year before the chickpea is sown. The most common soil tillage for chickpea is the same as for other spring crops.

Cultivars are known from Hungary (Pax, Kompolti bordo), Greece (Euros, Gravia, and Thiva), Spain (Candil, Castud, and Tizon), and Canada (Oxley), and there are 12 more cultivars from Maroko and 9 from Australia.

With a yield of 2000 kg grain $ha^{-1}$, the uptake of nutrients amounts to 100 kg of nitrogen, 22 kg of phosphorus, 45 kg of potassium, and 33 kg of calcium $ha^{-1}$. Despite the possibility of nitrogen fixation, nitrogen must be available at the young stages. Fertilization with composted stable manure or other organic fertilizers with at least 30 to 40 kg nitrogen $ha^{-1}$ is recommended. Top dressing is also necessary if a lack of available nitrogen is noted in the soil and the plants are without nodules inoculated by *Rhizobium*; 20 nodules per plant are required for symbiotic fixation of nitrogen to be considered effective enough. The phosphorus and potassium fertilizers must be added according to the deficits in the soil by allowed fertilizers. In the case of sandy soils, the fertilization with stable manure from 15 to 30 t $ha^{-1}$ may affect resources of available nutrients, especially available nitrogen from the potential mineralization process.

Inoculation of biofertilizers (vesicular arbuscular mycorrhiza and phosphate-solubilizing bacteria) significantly increased yield attributes of pods/plants and seeds/plants and yield of chickpea. Among biofertilizers, dual inoculation of vesicular arbuscular mycorrhiza and phosphate-solubilizing bacteria markedly enhanced these yield attributes and yield compared with vesicular arbuscular mycorrhiza or phosphate-solubilizing bacteria alone [19]. Rudresh et al. [20] also report that the effect of a combined inoculation of *Rhizobium*, a phosphate-solubilizing *Bacillus megaterium* sub sp. *phospaticum* strain-PB and a biocontrol fungus *Trichoderma* spp. increased

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germination, nutrient uptake, plant height, number of branches, nodulation, pea yield, and total biomass of chickpea compared to either individual inoculations or an uninoculated control. Vesicular arbuscular mycorrhizal infectivity was also improved significantly with combined inoculants and farmyard manure compared to sole application of farm yard manure [21].

The deficiency of molybdenum may reduce the percentage of proteins and yielding [22]. According to Nautiyal et al. [23], both deficiency and excess of molybdenum deteriorated the quality of seeds by increasing the content of phenols, cysteine, and albumin and decreasing that of methionine, lysine, legumin, and vicilin protein fractions, apart from reducing the seed weight.

The old seed is not suggested for sowing because the seeds lose germination very fast. The seeds must be healthy, with high 1000-seed weight. If the chickpea is grown for the first time in the field, the seeds need to be inoculated with symbiotic bacteria. Organic seeds can decay in unsuitable climatic conditions; the plants can slowly emerge at 4 to 6°C. Therefore, it is possible to sow on a relative early sowing date, but sufficient soil moisture can increase the seed decay. For orientation, chickpea sowing data can be about 2 weeks before the usual date for sowing corn.

Chickpea can be sown in interrow spacing from 40 to 45 cm or even 50 cm, when interrow hoeing or other accepted weeding for organic farming is used. In case of narrow inter-row spacing of 15 to 20 cm or 30 to 35 cm, mechanized hoeing is not possible and not acceptable for organic farming in large farms. The suggested plant population is 35 to 40 germinated seeds $m^{-2}$ at wide interrow spacing and 50 to 60 viable seeds $m^{-2}$ at narrow interrow spacing; the sowing rate is 70 to 100 kg seeds $ha^{-1}$ for wide interrow spacing and 100 to 150 kg seeds $ha^{-1}$ at narrow interrow spacing where 1000-grain mass is between 200 and 250 g. For higher 1000-grain mass, the seeding rate must also be higher.

Crust soils must be hoed carefully, without damaging the plants. After emergence, the plants need to be hoed twice: first when the plants are 10 cm high, and second at the stage of flower buds. In organic farming, weeding with a harrow comb is suggested, and the best effect can be achieved at midday, when the plant turgor is lower.

Chickpea must be kept weed-free between the five-leaf and full-flowering stages (24–48 days after crop emergence) and from the four-leaf to beginning-of-flowering stages (17–49 days after crop emergence) at the two sites, respectively, in order to prevent > 10% seed yield loss. At both sites, reduction in seed yield, because of the increased weed interference period, is accompanied by simultaneous reduction in plant dry weight, number of branches, pods per plant, and 100-seed weight [24, 25].

In hot climates, soil solarization is a preplanting technique used to control weeds and soil-borne pathogens consisting of mulching the soil surface with polyethylene sheets. On the basis of beneficial effects (improved grain yield, increased nitrogen availability in soil, nitrogen accumulation in plants, and improved plant growth), soil solarization — which avoids site contamination and is suited to organic farming — should be a good opportunity in

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Mediterranean areas where the level and stability of grain yields are low and the infestation of parasitic weed *Orobanche crenata* is high [26].

The maturity of the crop is uniform in 3 to 5 days. Because the plants mature very quickly, the rapidly approaching harvest time is more or less a surprise. The pods fall off the plant, especially in rainy periods and at the stage of over-maturity, and the combine must be adapted. By manual harvesting, the plants have to be cut and not pulled, in order to preserve the symbiotic bacteria in the soil. The pods can be shelled like beans.

### 7.1.5 Some remarks on the nutritional value of chickpea and other grain legumes

With 24% crude proteins in the chickpea seeds, the essential amino acid composition of chickpea is as follows: arginine 8.3%, histidine 3.0%, isoleucine 4.8%, leucine 8.7%, lysine 7.2%, methionine 1.1%, phenylalanine 5.5%, threonine 3.1%, trypthophane 3.1%, and valine 4.6% [27]. However, ordinary cooking resulted in the improvement of protein and starch digestibility of the food legumes by 86.0–93.3% and 84.0–90.4%. The reduction in the levels of nutrients is also significant, along with an improvement in protein and starch digestibility, respectively [28], and content of saponins, which was observed after cooking food legumes. Despite the high content of amino acids in the seeds, cooking decreased contents like lysine, histidine, and arginine. In addition, protein solubility and vitamin content decreased with increased cooking time. Chickpea should be cooked in an autoclave at 121°C for no longer than 1 hour to minimize losses in vitamins and amino acids [29].

## 7.2 Groundnut

### 7.2.1 Introduction

Groundnut, also known as peanut or goober (*Arachis hypogaea* L., syn.: *A. africana* Lour., *A. americana* Tenore, *Arachnida hypogaea* Moench) is a subtropical crop, mainly grown from the equator to 40° of geographical longitude. It is cultivated in 107 countries; annual production in 2001 was 35.09 million tonnes from 25.54 million hectares [30]. The groundnut crop is cultivated in 27 Asian countries, accounting for 67% of global production and 58% of global area. The two major producers in Asia are India, with 8.2 million hectares (55.9% of Asia), and China, with 4.6 million hectares (31.6% of Asia). Average productivity in Asia (1.6 t $ha^{1}$) is higher than the world average (1.37 t $ha^{1}$). Groundnut is an important worldwide source of food, protein, fat, minerals, and vitamins in the diets of rural populations, especially children. It is the most important major crop in all of India. Of its total production, 12% is for seeds, 8% for edible purposes, 70% for extraction of oils, and 10% for export; hence, it is considered an economically important crop [31]. Within Europe, it is grown in Spain, Italy, and other Mediterranean regions. Groundnut also experienced some efficient growth periods in temperate

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climates, as in Vojvodina, but its production strongly depends on climatic conditions. Thus, in temperate regions, production may be limited. An average yielding varies but may reach 860 kg $ha^{-1}$ in Asia, 743 kg $ha^{-1}$ in Africa, 1230 kg $ha^{-1}$ in South America, 2200 kg $ha^{-1}$ in Europe, and 2560 kg $ha^{-1}$ in the U.S. [32]. The biology, processing, and utilization of groundnut are extensively described [33] and investigated, but a great lack of research and description of organic farming methods exists for this crop.

### 7.2.2 Climate, growth, and development

As a subtropical plant, groundnut needs an average sum of 3000°C for its vegetation period. It emerges at a temperature between (12)14 and 15°C; for flowering, a temperature above 20°C is required. The optimal temperature is a middle temperature, around 23.5°C, and active assimilation takes place within the range of 10.5 to 28.5°C. Plants flower after 30 and sometimes more than 40 days. Leaves are easily destroyed by frost; groundnut grows and develops most successfully at warm temperatures. It demands water but can survive short periods of drought, and late autumn rainfall causes seed emergence in soil. The growing stage takes from 90 to 150 days, and sometimes longer.

### 7.2.3 Morphology

The groundnut plant is similar to low bans, though the leaves resemble clover leaves (but evenly divided) (Figure 7.1). Loose roots are placed in spiral rows around lateral roots. Roots are branched and usually have some bacteria nodules. Long-trailing stems growing 40 to 80 cm, with opposite leaves similar to broad bean leaves, sprout from every direction. Leaves are hairy on the bottom and flowers are joined in inflorescence growing from nodes. The calyx is intensely yellow; pistil ovary is placed at the bottom flower part near the node. The ovary continues into a long style, reaching through hypanthium, and ends with stigma. After successful fertilization, an elongated peg carpophore bearing ovules is formed; it bends to the ground and penetrates the soil. At a depth of 6 to 10 cm, it forms a pod containing two or more seeds resembling hazelnuts. Each pod grows to a length of 10 cm. The 1000-seed weight is 200 to 250 g, and the hectoliter weight is 70 to 80 kg $hl^{-1}$ [32; Ivanicič, personal communication].

### 7.2.4 Genotypes

The *Arachis* genus consists of 70 species, among which only groundnut (*Arachis hypogaea*) is suitable for production.

The groundnut (*Arachis hypogaea*) core collection for Asia consists of 504 accessions, 274 of whice belong to subspecies *fastigiata* (var. *fastigiata* and *vulgaris*) and 230 to subspecies *hypogaea* (var. *hypogaea*). The *hypogaea* group takes longer to flower, has more primary branches, longer primary and

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cotyledonary branches, more nodes on cotyledonary branches, more total pods, mature pods, and pegs per plant, longer and wider pods, and heavier seeds than the *fastigiata* group [34*].

Old cultivars appropriate for production in the Slovenian Primorska region are panski beli, Amarelo, and Valencija. In Hungary, the cultivars Makó (Kecskemet) and Kiszombori (Szeged) have been registered since 1986 and in Greece, the tetraploids Lakonia 4x and Seraiki.

Cultivars of the Virginia type, with alternate branching seeds, have a longer dormancy stage. There is little or no expressed seed dormancy in the subsequent branching of Spanish Valencia.

In the U.S., the number of registered groundnut cultivars has increased over the years (Virginia 81 from 1982; NC 6, NC 7, and NC-VII from Raleigh, North Carolina, 1998). In addition to cultivars from Oklahoma, Florida and Virginia, the number of cultivars from Asia (Icrisat), Indija, and Ghana (Sinkazei) also increased. The register of OECD also includes cultivars from Argentina (Florman and Manfredi) and North America (Selie). The cultivar Dixie Giant in the U.S. is the major germplasm source in all pedigrees of runner market-type groundnuts, while Small White Spanish-1 cultivar exists in 90% or more pedigrees. These two lines contributed nearly 50% of the germplasm of runner cultivars [35].

### 7.2.5 Cultivation practice

Structured, airy, and humus soils are suitable for groundnut. Unstructured soil easy that easily forms crust is unsuitable. It will grow in acid and basic soil but favors pH 6.5. In crop rotation, groundnut is sown after cereals, and It is sufficient for the previous crop to leave behind light soil as long as enough calcium is available. Without enough calcium, plants develop slowly, form poor flowers, and have lower yield that is more affected by disease.

The optimal sowing date is similar to that for corn. The seeds can be sown in heaps with few seeds together or at interrow spacing of 50 to 60 cm or 70 to 80 cm. For sowing, 60 to 90 kg seed ha$^{-1}$ are required to reach 250,000 plants ha$^{-1}$, and the sowing depth should be 5 cm. The groundnut can be also intercropped [36–38]. The maximum recorded monetary advantage was for the groundnut corn intercropping system in the semiarid tropics of India. There was a 20% reduction in nodule mass in intercropped groundnuts in association with corn. Yield advantage in terms of Land Equivalent Ratio (LER) was greatest (1.68) in the groundnut/corn association [39].

Healthy organic fertilizers are recommended in autumn with calculated incorporation of 80 to 100 kg $K_20$ ha$^{-1}$ and 80-100 kg $P_2O_5$ ha$^{-1}$. Before sowing, nitrogen needs amount to about 30 kg N ha$^{-1}$ if the symbiotic processes will start actively. Rao and Shaktawat [40] reported that application of farm-yard manure 10 tones ha$^{-1}$ and poultry manure 5 tones ha$^{-1}$ under rainfed

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condition increased pod yield of groundnut by a mean of 14.0 and 11.3%, owing to farmyard manure and poultry manure application, respectively, over the control (1620 kg $ha^{-1}$). *Bradyrhizobium* inoculation and mycorrhiza (*Glomus* spp.) statistically increased yield, 1000-seed weight, hydration coefficient, and content of P, K, Na, Cu, and Mg. Use of bacteria and mycorrhiza is cheap and simple in organic farming and it influences development as well as height and quality of yield [41].

Right after emergence, when plants have grown two pairs of leaves, hoeing should be done for the first time; this procedure should be repeated two to three times in 14-day intervals. With first hoeing, the plants are thinned to just two to three plants if sowing was done in heaps. Regular shedding should be performed in order to enable the plant to form a high quantity of pods. Irrigation and top dressing are usually implemented at the beginning of fthe lowering stage and during pod formation. Plant protection is not simple, because the groundnut is threatened by many diseases and pests; however, the crop was not threatened by them in the nontraditional groundnut-growing regions of Vojvodina and Serbia in 1995. The following year, production was threatened by unfavorable climatic conditions.

Groundnut is mature when leaves turn yellow and grains in pods color. At this stage, the plants need to be plowed or pulled. The plants should be left on the ground to dry for a couple of days; later, they will be placed on drying equipment or hayracks. Pods are torn off of dry plants and cleaned in special separation machines. Expected yield in organic farming varies between 1500 and 3500 kg seeds $ha^{-1}$ and can be lower and higher, depending on genotype adaptability and numerous growth factors.

### *7.2.6 Nutritional value and use*

Groundnut is first of all an oil crop, because its seeds contain 45 to 50% of quality oil. After pressing, the seed cakes maintain about 45 to 60% of crude proteins; the seeds contain about 26% of crude proteins. Approximately 100 g of shelled crude seeds contain more than 2093 J of energy, 4 to 13 g of water, 21.0 to 36.4 g of protein, 35.8 to 54.2 of fat, 6.0 to 24.9 g of carbohydrates, 1.2 to 4.3 g of fiber, 1.8 to 3.1 g of ash, 49 mg of Ca, 409 mg of P, 3.8 mg of Fe, 15 μg β-carotene equivalent, 0.79 mg of thiamin, 0.14 mg of riboflavin, 15.5 mg of niacin, and 1 mg ascorbic acid [42*].

Raw or roasted seeds sold as "kikiriki" are popular in temperate regions. In Asia and the U.S., the groundnut is used in many ways. It is used for oil, margarine, and peanut butter production; it is also canned, fried, added to cakes and breads, soups, cold cream, pharmaceutical products, ointments, emulsions for insect protection, and fuel in diesel motors.

Groundnut is consumed in boiled or roasted form, and also as a groundnut cake ("kulikuli"). The dry roasted groundnut snack is, at present, the most widely consumed form. It can be consumed alone or combined with

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dry roasted corn (popcorn), "gari," coconut, bread, or plantains. The traditional method of preparing dry roasted groundnut first involves sorting out the physically damaged and moldy kernels of raw groundnuts, followed by soaking them in water for about 20 minutes, salting with sodium chloride to taste, and then roasting by stirring the kernels in hot sand placed in an earthenware pot on an open fire. Upon cooling, roasted groundnuts are separated from the sand by a metal sieve [43]. Not much has been left in writing about groundnuts in folk medicine. It was thought to possess aphrodisiac, haemostatic, and protective hemophilic elements, along with other effects.

### 7.2.7 Dangerous aflatoxins

The seeds are susceptible to attack by a number of fungal diseases (the most well known is *Aspergilus flavus*). Closely related secondary fungal metabolites are aflatoxins, which are very powerful hepatocarcinogens, and naturally occurring mixtures of aflatoxins have been classified as the most dangerous human carcinogens [44]. Aflatoxins are a group of highly oxygenated heterocyclic compounds with closely related structure of $B_1$, $B_2$, $G_1$, and $G_2$. Aflatoxin synergizes with other agents, such as hepatitis B, in the causation of liver cancer [45]; it has been linked with the high incidence of liver cancer in Africa [46]. The $LD_{50}$ for aflatoxin-sensitive organisms is 1 mg aflatoxin per $kg^{-1}$ body weight. Carcinogenic effects are present with the use of 15 g aflatoxin $kg^{-1}$ food. The $B_1$ form of aflatoxin shows hematocarcinogenic effects [32]. In Nigeria, aflatoxin $B_1$ was found in 64.2% of samples. Aflatoxins $B_2$, $G_1$, and $G_2$ were detected in 26.4%, 11.3%, and 2.8% of the samples, respectively, in the contaminated samples [43]. Producers and consumers of conventionally and organically grown groundnuts must be aware of these potential hazards.

## 7.3 Soybean: small attention to the important crop

### 7.3.1 Introduction into utilization

Production of soybean, also called soya bean, and soy (*Glycine max* [L.] Merr., syn.: *G. hispida* [Moench] Maxim., *Soja max* Piper) grew in China over 5000 years ago and spread through Asia quite early. Its production began in Europe during the nineteenth century. Soybean is produced in the highest quantities in the U.S., Asia (mostly China), Europe, and Africa. It is one of the most extensively described and researched plants; therefore, we would like to pay special attention to its organic production and importance. The use of organic soybean products is increasing, but more research regarding the organic farming of soy still needs to be conducted.

Soy is one of the most important plants for protein production in the world; its seed contains 24 to 55% protein. It is also an important oilseed, with 17 to 24% oil content. Its fat consists mostly of polyunsaturated fatty

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acids (5 to 10% linoleic and 43 to 57% linolenic). The carbohydrates content is quite low (2.7 to 12%); carbohydrates are comprised of 5.2% galactose, 5.4% pentose, 3.6% saccharose, 1.3% raffinose, 0.8% invert sugar, 0.4% starch, 2.8% cellulose, and approximately 0.4% dextrins. Ash content is between 3.7 and 5.9% [47]. Soy a semidrying oil with an iodine value between 85 and 130 and is mostly used raw for its protein content. Additionally, soy oils or foods taste like fish after frying due to their thermal treatment. The soybean comprises an important part of animal nutrition. Soy cakes that remain after oil pressing, flour, and groats can be used as high-quality protein feed. Soy as a protein source has been gaining importance in organic farming, organic breeding, and anywhere that animal proteins (the cause of mad cow disease) or genetically manipulated plants have to be replaced with less controversial proteins grown according to organic farming guidelines. Whole plants provide quality feed for silage, most often prepared in combination with corn, resulting in a favorable starch-protein ratio. Whole soy plant contains approximately 15.1% protein, 45.5% nonnitrogen extract, and 11.1% mineral substances.

People use the seeds as a main food or side dish in the human diet, and also in flour, soy milk, cheese, and butter. Soy is an important raw material in food processing (bread, pasta, margarine, grease) and the chemical processing industry (plastic material, glue, insulation material, rubber, soap, oil colors). Besides its protein and oil, the high vitamin content of soy is also important; it contains substantial amounts of the provitamins A, $B_1$, $B_2$, C, D, E, and K. As a legume, it requires between 120 and 300 kg of nitrogen $ha^{-1}$ in soil. The nutritional and biological values of soy used as food have been stressed lately, especially for people who consume little or no animal proteins. The biological protein value in soy seeds is much higher than other proteins in the human and animal diet (Table 7.1); 0.6 to 0.8 g $kg^{-1}$ of soy protein equal 0.4 g of egg protein.

Soy combined with cereals can cover most essential amino acid requirements in a vegetarian diet, satisfying the demands for cystine and methionine, (present in low amounts in soy) and lysine (present in low amounts in cereals). The amount of methionine present in meat cannot be replaced this way, however. Despite the high biological value of soy proteins, their digestibility is worse than other proteins due to the presence of two substances that hinder the digestion of proteins, trypsin inhibitor and hemagglutine. Cooking for long periods of time improves the digestibility of soy proteins but decreases their biological value. Studies have shown that children who consume unbalanced vegetarian diets without the benefit of industrially synthesized additives in soy products do not develop as well as children who consume meat and milk. Soy consumption reduces absorption elements, such as iron and zinc. Some people simply cannot tolerate soy for medical reasons.

Nutritionists and doctors attribute more positive effects to semisaturated soy fats, favorable amino acid rations, and other grain substances. These

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***Table 7.1*** Amino Acids in Soyabean Comparing Some Important Products [2]

| Amino Acid | Soyabean | Wheat | Beef | Milk | Eggs |
|---|---|---|---|---|---|
| | | Kg/16 kg | Nitrogen | | |
| Arginine | 7.0 | 3.6 | 5.3–5.5 | 3.7 | 5.7 |
| Cysteine | 1.2 | 4.0 | 1.4 | 0.8 | 2.3 |
| Phenylanaline | 5.3 | 4.9 | 3.8–4.5 | 5.0 | 5.1 |
| Histidine | 2.5 | 1.3 | 3.7–3.9 | 3.2 | 2.3 |
| Izoleucine | 6.3 | – | 5.2 | 5.6 | 6.8 |
| Leucine | – | 9.3 | 8.1–8.7 | 9.8 | 9.2 |
| Lizyne | 6.6 | 2.5 | 9.2–9.4 | 7.9 | 7.4 |
| Methionine | 1.2 | 0.7 | 4.1–4.5 | 2.7 | 3.0 |
| Threonine | 4.0 | 2.5 | 4.8 | 5.1 | 4.1 |
| Thrypthopane | 1.1 | 1.2 | – | – | 1.0 |
| Valine | 6.7 | 2.9 | 4.8–5.5 | 6.1 | 6.9 |

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help to prevent cancer, lower blood cholesterol, lower serum fat concentration-triglycerides in blood, and lower blood sugar in diabetics [48].

### *7.3.2 Genotypes*

The ancestor of *Glycine max* (L.) Merr. was thought to be *Soja ussuriensis* Rgl. et Mack (*Glycine soja* Sieb. et Zucc.). According to geographical and climatic characteristics, *Glycine max* L. Merr. is grouped into six ssp. (*gracilis*, *indica*, *chinensis*, *corejensis*, *manchurica*, *slavonica*) with extensive morphological differentiations.

Cultivars are distinguished according to determinate and indeterminate growth, seed color, purpose of production (oil, protein), disease resistance, pests, drought, moisture, and length of growing stage, which lasts from 90 to 160 days. Numerous cultivars are divided into the categories early, medium early, and late. Very early cultivars (marked as 00) are more suitable for temperate conditions than cultivars (marked as 0). Both groups of cultivars are also marked with numbers from I to VI; groups III and IV occur too late for temperate climates. The cultivar needs to ripen before frost.

### *7.3.3 Morphology*

Soy roots are well branched and. develop to plowing depth, for the most part. Although they can sometimes be found at a depth of 1.5 m 30 to 40 days after emergence, they will develop tuber-like formations due to infections from nitrogen bacteria (*Bradyrhizobium japonicum*). The number of tube-like formations varies (up to 90) and depends on the presence of bacteria.

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Young plant stems are green with various color shades, up to light violet. The stem reaches a height between 0.2 and 1.0 m (with late cultivars and in favorable conditions, they may grow as tall as 2 m) and has 12 (15) internodes that grow between 3 and 13 cm in length. Between internodes there are nodes where plants sprout leaves and side shoots. The stem is branched and between 2 and 15 side shoots generally form. The first side shoots appear at a height between 1 and 20 cm and emerge from plumule nodes; thisoccurs mostly with early cultivars. The angle of side shoot growth varies from 50 to 70°, and branching depends on cultivar characteristics and growing conditions. Plants with high density branch only a little or not at all, and they are taller than lower-density plants. Plants growing in isolation develop a bush-like form.

Leaves are trifoliate with the exception of the first pair, which only grows one leaflet on the petiole. The petiole of the middle leaflet is the longest. Leaflets have different shapes (cordate, ovate, lanceolate) with pointed bracts; leaflet length is between 6 and 12 cm and width is between 3 and 9 cm.

The inflorescence of soy is *racemus*, forming 2 to 5 groups of flower (up to 20). Inflorescences are formed by composite leaves toward the top of the stem, reaching 3 to 15 cm above ground. Flowers can be short and tight or long and loose inflorescences. Flowers consist of five sepals, three petals, 10 anthers, and a pistil. Filaments of nine anthers are grown together, and the 10th anther (the upper one) is free. Determinate and indeterminate soy types are distinguished by inflorescence growth [47].

The flower petals may be white, pale violet, or pale yellow. Flowers open in the morning; the flowering stage depends on the earliness or lateness of the cultivar and can take between 15 and 80 days. Flowers have all of the characteristics of legumes and are 99.6% self-pollinated. Under normal production conditions, 20% of flowers fall off, but with temperatures under 10°C, high temperatures, or a lack of moisture, more than 90% of flowers can fall off.

Pods are 3 to 5 cm long with one 5 seeds and 2 to 3 seeds in most cases (Figure 7.2), and between 10 and 300 seeds can be expected per plant. Before maturing, green pods turn from light to dark yellow. The average plant grows 25 to 35 pods, but this number varies considerably. The opening of pods at full maturity is a varietal characteristic.

The seed consists of seed coat or testa (7 to 8% of joint seed weight) and embryo. The embryo consists of two cotyledons, plumula (embryonic shoot), and radicle (embryonic root). Testa is light yellow, brown, green, black, or a combination of colors. Cotyledons represent 90% of seed weight and are yellow or greenish. The part that connects a seed to a pod is called a funicle, which is a bit darker than a seed. Seeds are round or ovate; from the side, they are usually flattened with expressed funicle and grow to between 5.7 and 14 mm long. Absolute seed weight is 100 to 300 (40 to 450) g, and hectoliter weight is 85 kg $hl^{-1}$.

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*Figure 7.2* Pods of soya bean.

### 7.3.4 Susceptibility to climate circumstances

Soy requires similar growth circumstances as corn and thrives where the sum of active temperatures in the growing stage amounts to at least 1700°C. Soy germinates at 8 to 10°C and emerges at 10 to 12°C. The optimal flowering temperature is 25 to 28°C (minimal is 17 to 18°C), pod formation temperature is 21 to 23°C (minimal is 13 to 14°C), and maturity temperature is 8 to 9°C. Soy normally matures at 16°C, butsome believe that the optimal maturing temperature ranges between 19 and 20°C.

Young emerged plants can survive spring frosts to –2.5°C without great damage; in early autumn, the crop is resistant to a temperature of –3°C. With temperatures that exceed 33°C and a lack of moisture in the flowering period, over 90% of flowers can fall off. Soy requires a great deal of moisture up to the flowering stage and afterward; during flowering, rain and excessive irrigation negatively influence pollination. Soy transpiration coefficients vary between 500 and 600 (390 to 750). In temperate conditions, precipitation is not a limiting production factor but distribution is. The most important factor is relative air moisture, which should be between 78 and 80%. Soy is a short-day plant. If produced in long-day circumstances, green weight growth increases and plants flower and mature later.

### 7.3.5 Cultivation according to organic guidelines

Soy cannot be grown as a monoculture. Suitable precrops are stable, manure-fertilized arable crops, stubble cereals, and oilseeds. Sunflowers are not included in alternative production crop rotation. Soy is a recommended precrop for most crops, though it is more difficult to optimize nitrogen

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fertilization with stubble crops because approximately 40 to 75 kg N ha$^{-1}$ remains in the soil with nodules or bacterial tubers. Soy is most successfully produced in fertile, light, deep, and slightly moist neutral soil; swampy soil is inappropriate, as are clay and sandy soils. Soy demands structured soil with a regulated water-air regime. In Slovenia, the most appropriate soil type is deep sandy-clay brown soil. Salty and acid soils are not recommended for soy; it grows well with a pH between 6.6 and 7.2.

Basic and precrop soil cultivation is the same as for early crops. Plowing should be done in autumn to the plowing depth. Roughly evening the soil also makes it easier to prepare the field with the presowing machine and an even sowing layer.

#### *7.3.5.1 Fertilization*

Between 1000 and 3500 kg seed ha$^{-1}$ can be expected. Nutrient uptake with 100 kg of seed included aboveground mass vary between 7.2 and 10.8 kg of nitrogen, 1.1 and 4.0 kg of phosphorus, and 3.0 and 6.2 kg of potassium. These amounts can be used to calculate the total of nutrients according to soil composition. Soy can also take 50 to 75% of nitrogen from the air through nitrogen bacteria, though this requires a suitable inoculation with relevant symbiotic nitrogen bacteria (*Bradyrhizobium japonicum*). Phosphorus and potassium fertilizers are plowed individually in autumn (one-third to one-half in spring) or in combination with 20 to 30 tons of stable ha$^{-1}$; during the first growth stages, the plants need available nitrogen in the soil (approximately one-third, from calculated needs). Animal manures and plant composts are more recommendable for fertilization and top dressing. For top dressing before the flowering stage, fertilizers for organic production can be used for plants not forming tubers. Because soy can use nutrients that are not easily accessible, yield is high even with poor fertilization but it leaves soil poor, which negatively influences the following yield.

Bacterial inoculation of seed is done with special preparations (nitragin, radicin, azotofiksin, and so forth) of the chosen soy-symbiotic bacteria. Seed is inoculated by mixing it with pulpy preparation directly before sowing. Infected moist seeds are protected from direct sun heat at sowing.

The sowing date is the same as for corn, or it follows immediately if corn is sown early. Late sowings in spring are also successful, but only with early cultivars. Stubble-crop sowing after early potatoes and barley is successful only with suitable irrigation. The sowing rate is between 80 and 130 kg seed ha$^{-1}$.

Sowing can be performed to depths of 3 to 5 cm with a corn-sowing machine. For home production, however, sowing may be done in heaps. If there is a danger of drought rolling should be performed immediately after sowing. Crusty soil is crushed before emergence; later on, crust is removed only between rows.

Weeds are removed with interrow hoeing, which preserves soil structure. Cultivation should take place to a depth of 10 cm when the first trifoliate

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leaf appears, and another shallow hoeing follows after 14 days. Later, hoeing is done when necessary until rows are joined.

Weed suppression can be avoided by sowing in weed-free soil. The use of herbicides in classical production is limited to rows, due to ecological damage. Hoeing should be done between rows. Irrigation takes place during the critical development stages before flowering, and also during pod formation and grain assimilation. Approximately 30 to 40 mm of water are used in one ration, and sprinkled if possible. As with other field crops, attention must be paid to soil pests (wireworms, chafer grubs, weevils, cutworms) and spider mites.

The soybean can be affected by some plant diseases. Mildews can be suppressed by somewhat effective sprays, while other diseases are closely connected to inappropriate crop rotation (e.g., white rot or *Sclerotinia sclerotiorum* appears in sunflower crop rotation, and root and stem rots appear with other crops).

### *7.3.6 Harvesting*

Maturing is initiated by late drying of leaves, stems, and pods. The plant part becomes harder, the seed colors according to variety, and stems and pods turn brown. When 95% of pods obtain the significant color, approximately 10 days without rain are required to enable combining; seed can contain only 15% moisture. At the stage of over-maturity, the amount of losses from pods can exceed 35%. Therefore, we begin combining somewhat early, during uneven crop maturity, when pods are not yet completely ripe. Harvesting combines are adjusted by increasing the number of scythe movements, reducing the number of turns at the combine outlet, building a rubber curtain at the elevator entrance, adjusting the height of the reel, and surrounding it with sponge. All of these procedures result in yield loss. However, soy may be dried from small fields in heaves. Storage seed should be dried to contain less than 13% moisture and is stored in the same way as cereals.

## *7.4 Vigna: a few words about a widely spread genus*

Vigna is a genus from the family *Fabaceae*, which have been described in the past as an Asian group of beans from genus *Phaseolus*. Vigna originated in Asia and Africa, but during the last two decades the interest in breeding and production programs has increased throughout the world, especially in the U.S. Important producers include China, India, Japan, Korea, Niger, Mexico, Cuba, Indonesia, Malaysia, New Zealand, and Australia. The crop requires tropical growth conditions and only a few species are suitable for production in temperate climates.

The *Vigna* sp. is one of the 12 most important grain legumes in the world, and its seeds contain between 19 and 24% proteins, depending on genotype. Some species, like *Vigna radiata* and *Vigna angularis*, are utilized for the

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production of edible sprouts; around 1 kg of seeds has the potential to produce 0.8 kg of sprouts. So-called "azuki" beans (azuki bean = adzuki = adsuki) are important for production, as well. The name, directly translated from Chinese, means "small bean." Azuki belongs to the Asian subgenus *Ceratotropis*, which includes 17 species, 7 of which are species cultivated with wild ancestors. Due to numerous morphological differences, systematists first submitted the Azukia species to the genus *Dolichos*, which was later reclassified into *Vigna*. Many synonyms appearing in folk and expert nomenclature cause problems and misunderstandings, because there is no clear overview of various systematics. The synonyms for important cultivated *Vigna* species or Adzuki beans, mungo, and others without spontaneously grown species are worth reviewing (Table 7.2).

The group of mungo beans (*Vigna radiata*, *V. mungo*, and *V. aconitifolia*) grown mainly in India features epigeal germination, with the visible primary leaf of the seedling. Azuki beans (like *V. angularis* and *V. umbel latta* from East Asia) feature hypogeal germination, when the first dicotyledonous leaves stay underground and the epicotyl part (the prolonged small stem with the first leaf) looks similar to the pea [49].

Identification for some *Vigna* species [49–53] is as follows:

- *Vigna unguiculata*: includes three ssp. *cylindrica* (7 to 12 cm long pods), ssp. *sesquipedalis* (30 to 90 cm long pods), and ssp. *unguiculata* (10 to 30 cm long pods). This plant is closely related to azuki and mungo beans: azuki beans grow 0.6 to 3 m high, while mungo beans are lower (0.3 to 0.9 m).
- *Vigna aconitifolia*: leaflets deeply lobed with 3 to 5 narrow lobes, pods glabrous, and stipules small to lanceolate.
- *Vigna mungo*: leaflets entire or very occasionally with 2 to 3 shallow broad lobes; plant and pods have hairy dull seeds and a short petiole on the primary leaf of the seedlings.
- *Vigna radiate*: leaflets like *V. mungo*, pods point sideways or down, covered with short hairs, seeds nearly or quite globular, brown to black, and hilum not concave.
- *Vigna angularis*: plants and pods glabrous or nearly so, seed smooth to shiny, a long petiole on primary leaf of the seedlings, pods constricted between seeds, and hilum not concave.
- *Vigna umbellata*: like *V. angularis*, but pods not constricted between seeds and hilum concave.

The inflorescence structure is similar to that of legumes. Seed color is not a reliable indicator for distinguishing species because it can vary with new varieties from chestnut brown, blue-black, black, green, ash grey, brown, grass green, and white to combination of colors; in production, red seeds prevail.

Yield varies from 300 to 3500 kg seed ha$^{-1}$ depending on species, varieties, and climate. Besides its economical function, production of this legume

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**Table 7.2** Cultivated (C) and Cultivated-Wild (CW) Vigna Species [1–3]

| Actual Nomenclature/ Morphology | C, CW, 2n (group) | Synonyms | Common Name |
|---|---|---|---|
| *Vigna aconitifolia* (Jacq.) Maréchal | KD, 22 mungo | *Phaseolus aconitifolius* Jacq.; *P. palmatus* Forsk.; *Dolichos dissectus* Lam. | moth bean, mat bean |
| *Vigna angularis* (Wild.) Ohwi in Ohashi | CW, 22 azuki | *Phaseolus angularis* (Willd.) Wight; *Dolichos angularis* Willd.; *Azukia angularis* (Willd.) Ohwi | Azuki bean |
| *Vigna angularis* var. *angularis* | C, 22 | | |
| *Vigna glabrescens* M. M. & S. | CW, 44 | *Phaseolus glaber* Roxb.; *P. glabrescens* Steudel; *Vigna reflexopilosa* Hayata; *V. mungo* var. *glabra* (Roxb.) Baker; *V. radiata* var. *glabra* (Roxb.) Verdc. | tetraploid vigna |
| *Vigna mungo* (L.) Hepper | CW, 22 mungo | *Phaseolus mungo* L.; *P. Viridissimus* Ten.; *Azukia mungo* (L.) Masamune | blackgram, black mapte, kalai mash, mungo, urd, |
| *Vigna mungo* var. *mungo* | C, 22 mungo | *Phaseolus mungo* L. | urid, woolly, pyrol |
| *Vigna radiate* (L.) Wilczek | CW, 22 mungo | *Phaseolus radiatus* L.; *P. mungo sensu* F. B. I. non L.; *P. radiatus* var. *typicus* Matsum; *P. aureus* Roxb.; *Azukia radiata* (L.) Ohwi; *Rudua aurea* (Roxb.) Maekawa; *Vigna aureas* (Roxb.) Hepper; *V. mungo* Hepper, non (L.) | chickasaw pea, bundo, goldengram, greengram, moong, mung, mungbean |
| *Vigna radiate* var. *radiate* | C, 22 mungo | *Phaseolus radiatus* L.; *P. aureus* Roxb.; *Azukia radiata* (L.) Ohwi; *Rudua aurea* (Roxb.) Maekawa | mungo, Oregon pea, Yae-nari |
| *Vigna umbellata* (Thunb.) Ohwi & Ohashi | CW, 22 azuki | *Dolichos umbellatus* Thunb., *Phaseolus pubescens* Blume; *P. calcaratus* Roxb. *P. chrysanthus* Savi; *P. torosus* Roxb.; *P. ricciardianus* Tenora; *Vigna calcarata* (Roxb.) Kurz; *Azukia umbellata* (Thunb.) Ohwi | rice bean, climbing mountain bean |
| *Vigna umbellata* var. *umbellate* | C azuki | *Phaseolus calcaratus* var. *major* Prain; *P. calcaratus* var. *rumbaiya* Prain | Jerusalem pea, Mambi bean, red bean, oriental bean, Pegin bean, tzuruazuki, kanime |

*(continued)*

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*Table 7.2* Cultivated (C) and Cultivated-Wild (CW) Vigna Species [1–3] (Continued)

| Actual Nomenclature/ Morphology | C, CW, 2n (group) | Synonyms | Common Name |
|---|---|---|---|
| *Vigna unguiculata* (L.) Walp. ssp. *cylindrica* (L.) Vedrc. | C biflora | *Dolichos biflorus* L.; *Dolichos catiang* L.; *D. catiang* Burm.; *Phaseolus cylindricus* L.; *Vigna catjang* (Burm. f.) Walp.; *V. cylindrica* (L.) Skeels | catjang, sow-pea, Catjangbohne-nem |
| *Vigna unguiculata* (L.) Walp. ssp. *sesquipedalis* (L.) Vedrc. | C unguiculata | *Dolichos sesquipedalis* L.; *Vigna sesquipedalis* (L.) Fruwirth; *V. sinensis* ssp. *sesquipedalis* (L.) Van Eselt | yard-long bean, pea bean, asparagus bean |
| *Vigna unguiculata* (L.) Walp. ssp. *unguiculata* | C unguiculata | *Dolichos sinensis* L.; *D. unguiculatus* L.; *Phaseolus unguiculatus* (L.) Piper; *Vigna sinensis* (L.) Savi & Hassk. | southern pea, cowpea, black-eyed pea, crowder pea |
| *Vigna subterranea* (L.) Vedrc. | C | *Glycine subterranea* L.; *Voandzeia subterranea* (L.) Thouars & DC. | bambarra groundnut, grund-bea, Congo goober, hog peanut |

provides the possibility of symbiotic nitrogen fixation with relevant strains from the genus *Bradyrhizobium*; provision with mycorrhiza from the genus *Glomus* in also possible. Nitrogen fixation amounted to between 1 and 99 kg N $ha^{-1}$ in tests.

Organic production from nonbean-growing regions is not well developed, but some Web sites feature organically grown products from the genus *Vigna*. For the species *V. unguiculata* ssp., similar growing conditions as the common bean (*P. vulgaris*) may be utilized. This species prefers nighttime temperatures of 18°C and daytime temperatures between 20 and 25°C; these temperatures are utilized for some species of vigna produced in greenhouses in the Netherlands. Two seeds of $m^{-2}$ are used for high plants, the same as for the climbing or runner bean; for bush types, same rules are applied as for the bush bean. Weed control is more critical for vigna than for many other dry, edible grain legumes, because the thermophilic vigna has a slow growth rate in the spring. Weeds can be controlled with cultivation after the second true leaf has developed on the seedlings, normally after about 3 weeks.

Growth conditions for vigna are closely related to the growth conditions of the soybean or bush bean. Azuki beans grow successfully in 30 to 36°C and can survive extreme drought.

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