Monograph - Agriculture

Phaseolus vulgaris L(Common Bean)

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Colegio Bolívar

2019-2020

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1 Introduction

Phaseolus vulgaris is a crop with global importance. It is the most important food legume for direct consumption in the world (Jones, 1999), being the most consumed dry seed crop globally, with a great market potential and nutritional value (Wortmann, 2006). It representing the main source of protein for people in several parts of the world (Rivera et al., 2018), providing as much as 15% of the total daily calories and 36% of total daily protein in many parts of Africa and the America (Li & Olsen, 2016), also contributing greatly to diet with starch, fiber, vitamins, and minerals (Rivera et al., 2018), along with folic acid, dietary fibre and complex carbohydrates. Its consumption is high because of its benefit of being a relatively inexpensive food (Jones, 1999). The common bean has one of the highest levels of variation in growth habit, seed characteristics, maturity, and adaptation, allowing it to be cultivated in many crop systems and very environmentally diverse regions like Latin America, Africa, the Middle East, China, Europe, the United States, and Canada (Jones, 1999). It has many uses that will be discussed later on, but one of its most important characteristics would be that dry seeds can be stored for long periods of time (Li & Olsen, 2016). Annual global production is presently approximately 26.5 million tons, and most of its production is used for human consumption (Rivera et al., 2018).

2 Ecology of *Phaseolus vulgaris*

2.1. Origin and taxonomy

Phaseolus vulgaris, also known as the common bean, is native to the New World, most likely Central Mexico, and Guatemala. They were taken to Europe by the Spanish and to Africa and other parts of the world by the Portuguese. Now, they are widely cultivated in the tropics, subtropics and temperate regions, and roughly 30% of world production is in Latin America (Duke, 1983). The bean was domesticated in the ancient Andeans about eight thousand years ago and it is known to be one of the most important legume crops and vegetable protein sources for humanity (the Native Plant Trust, n.d.), providing as much as 15% of total daily calories and 36% of total daily protein in parts of Africa and America (Schmutz et al., 2014, as cited in Li & Olsen, 2016).

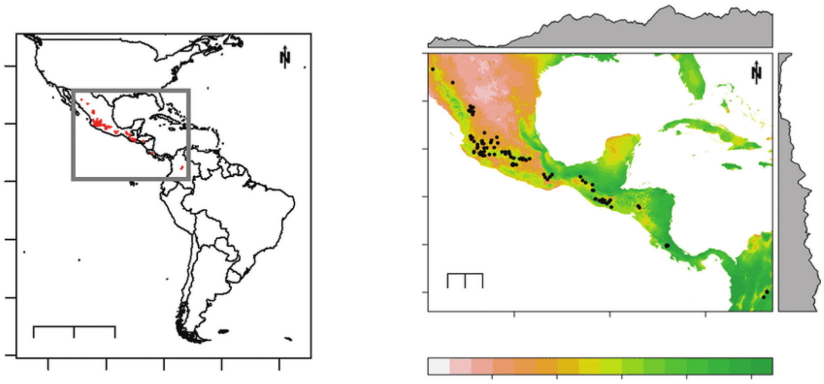


Figure 1. Location of origin of wild *Phaseolus vulgaris* retrieved from (Berny Mier y Teran et al., 2018).

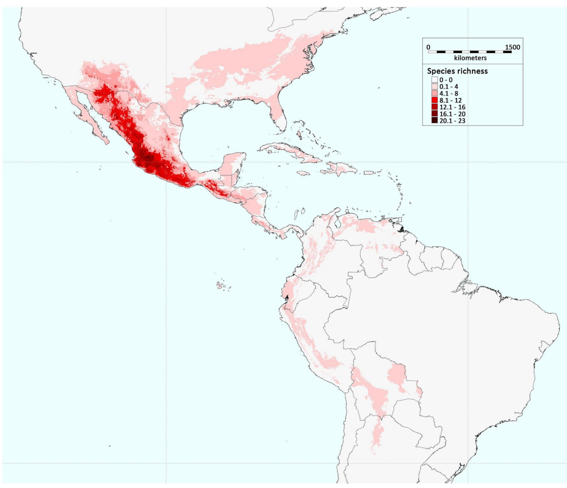


Figure 2. Geographic distribution of *Phaseolus* species richness in America. (Ramírez-Villegas et al., 2010, cited in Bitocchi et al., 2017).

2.2. Species (taxonomy and affinity)

The scientific name of common bean is *Phaseolus vulgaris* L. and it is a member of the legume family.

Kingdom	Plantae
Phylum	Tracheophyta
Class	Magnoliopsida
Order	Fabales
Family	Fabaceae
Genus	*Phaseolus L.*
Species	*Phaseolus vulgaris L.*

The genus *Phaseolus* includes approximately 80 cultivated and wild species, *Phaseolus vulgaris* being the most widely cultivated species (Purseglove, 1968; Freytag and Debouck, 2002; Bailey, 1975; Porch et al., 2013, cited in OECD, 2015). The 80 species are shown in Appendix I.

Their most closely related species are displayed in the table below:

Table 1: Species closely related to *Phaseolus vulgaris*

Species	Geographic location
P. acutifolius	Mexico, southwestern United States
P. albescens	Western Mexico
P. coccineus	Guatemala, Honduras, Mexico
P. costaricensis	Eastern Costa Rica, western Panama
P. dumosus	Western Guatemala, Mexico
P. parvifolius	Southwestern United States, Guatemala, Pacific coast of Mexico and Central America
P. persistentus	Guatemala

Sources: Porch et al. (2013); Bellucci et al. (2014), cited in OECD,2015.

Along with *Phaseolus vulgaris,* there are other four cultivated species: *P. dumosus, P. coccineus, P. acutifolius, and P. lunatus* (Bellucci et al., 2014; Lioi and Piergiovanni, 2013, cited in OECD, 2015).

The Fabaceae family, which *Phaseolus vulgaris* belongs to species displaying a wide variety of forms: trees, shrubs, and herbs. Most of them have five-petaled flowers with a distinctive butterfly-like shape. The fruit of Fabaceae species is the legume, which is a single-carpel pod of various shapes and sizes that bear seeds (Wortmann, 2006, cited in OECD, 2015).

Figure 3: *Flowers of P.vulgaris. Left: ("Fabaceae | Biology 343," n.d.) Right: (Bresson, n.d.).*

Figure 4: *Pods of P.vulgaris — Left: (Coleby-Williams, 2013) / Right: (Yuste-Lisbona et al., 2014).*

2.2.1. Characteristics

Table 2: Characteristics of *P. vulgaris* (adapted from the Native Plant Trust, n.d.).

Habitat	Terrestrial Anthropogenic (man-made or disturbed habitats), meadows and fields

Flower petal color	blue to purple pink to red white
Leaf type	the leaves are compound (made up of two or more discrete leaflets
Leaf arrangement	alternate: there is one leaf per node along the stem
Leaf blade edges	the edge of the leaf blade is entire (has no teeth or lobes)
Flower symmetry	there is only one way to evenly divide the flower (the flower is bilaterally symmetrical)
Number of sepals, petals or tepals	there are five petals, sepals, or tepals in the flower there are four petals, sepals, or tepals in the flower
Stamen number	10
Fruit type (general)	the fruit is dry but does not split open when ripe
Fruit length	80–200 mm

2.3. Fossil Records

For *Phaseolus vulgaris,* there are no fossil or pollen records that can indicate when or where the plant originated. However, research has shown that the Mesoamerican species *P. coccineus, P. coccineus* (in Mexico), *P. costaricensis* (in central-eastern Costa Rica and western Panama), *P. dumosus* (in western Guatemala), and *P. albescens* (in western Mexico), are the closest relatives to *P. vulgaris* indicating its Mesoamerican origin (Freytag and Debouck 1996, Delgado-Salinas et al. 1999, cited in Chacón S., Pickersgill, Debouck, & Arias, 2007). Another study suggests that, based on the gene coding for phaseolin (the main seed storage protein), the ancestors of the Mesoamerican and southern Andean *P. vulgaris* populations are likely to be from the Andes of Ecuador-northern Peru in South America

(Kami et al. 1995, cited in Chacón S., Pickersgill, Debouck, & Arias, 2007). It has also been suggested from sequences of the a-amylase inhibitor gene, that *P. vulgaris* diverged from P. *coccineus* and *P. dumosus* about 2 million years ago (Gepts et al. 1999, cited in Chacón S., Pickersgill, Debouck, & Arias, 2007). If these calculations of divergence from nucleotide sequences are correct, it would mean that the wild common bean has migrated from its place of origin, most likely from either Mesoamerica or South America, to other regions after the closure of the Isthmus of Panama. The plant originated after the land bridge formed (Chacón S., Pickersgill, Debouck, & Arias, 2007).

2.4 Present Distribution

P. vulgaris was introduced to the Old World by the Spaniards and the Portuguese, and it is now a major food crop in many areas of the Americas, Europe, Africa and Asia (Heuzé et al., 2015). The current distribution of this species has a large geographical area from northern Mexico to northwestern Argentina. In general two ecogeographical locations are Mesoamerica and the Andes. These two gene pools have partial reproductive isolation in both wild and domesticated materials, preventing members of different species from producing offspring or even making them sterile. We can find the *P.vulgaris* in Peru and Ecuador, Colombia, Central America, Mexico, Bolivia and as mentioned before Argentina (Bitocchi et al., 2012).

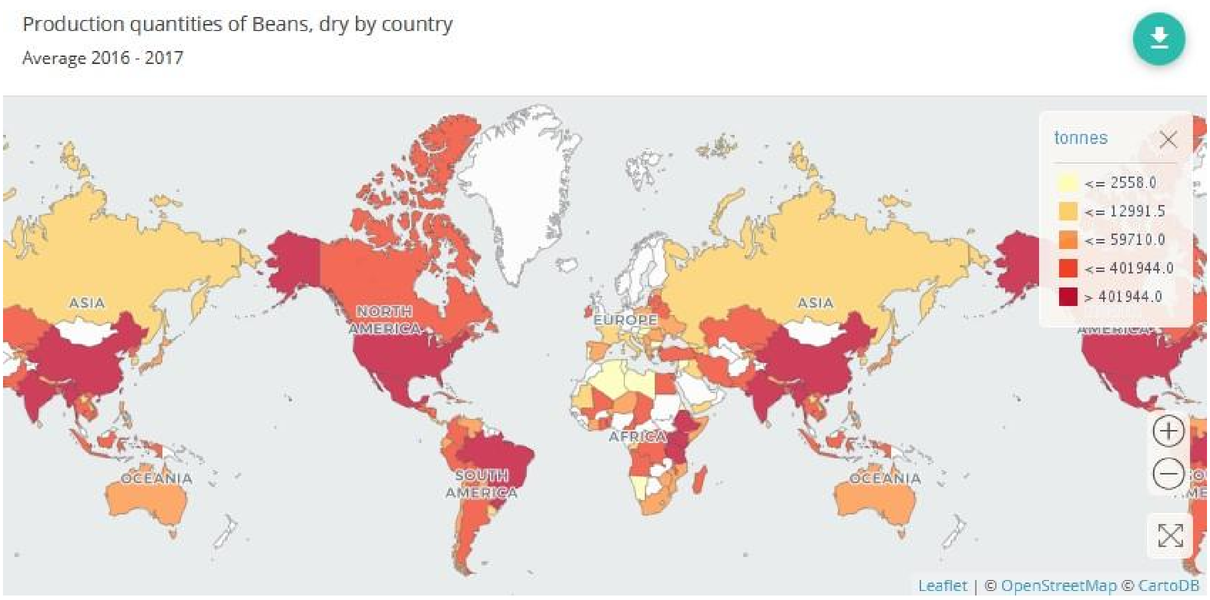


Figure 5: Total world production of dry beans by country in tonnes - 2016-17. (FAO, 2020)

2.5 Elevation and Climate

A farmer's ability to plant one or two crops is essentially determined on rainfall patterns. The quantity of crops that can be planted depends on the amount of rainy seasons the location has, two plantings per year if it's a tropical region and only one if it's a place with temperate climate. The climate where the *P. vulgaris* originated is subtropical to temperate, where the wet and dry seasons are defined, yet the bean prefers regions that have a moderate rainfall rather than excessive rain or dryness (Beebe et al., 2014, cited in OECD, 2015). *P.vulgaris* is intolerant to very low temperatures, therefore, also elevation above 3000 meters, but they can grow as annuals in temperate climates and annuals or perennials in tropical climates (Purseglove, 1968; Gentry, 1969, cited in OECD, 2015). Also, low temperatures delay pod production leading empty pods, and excessive temperatures cause flowers to fall off (Liebenberg, 2009, cited in OECD, 2015).

2.6 Soil and Geology

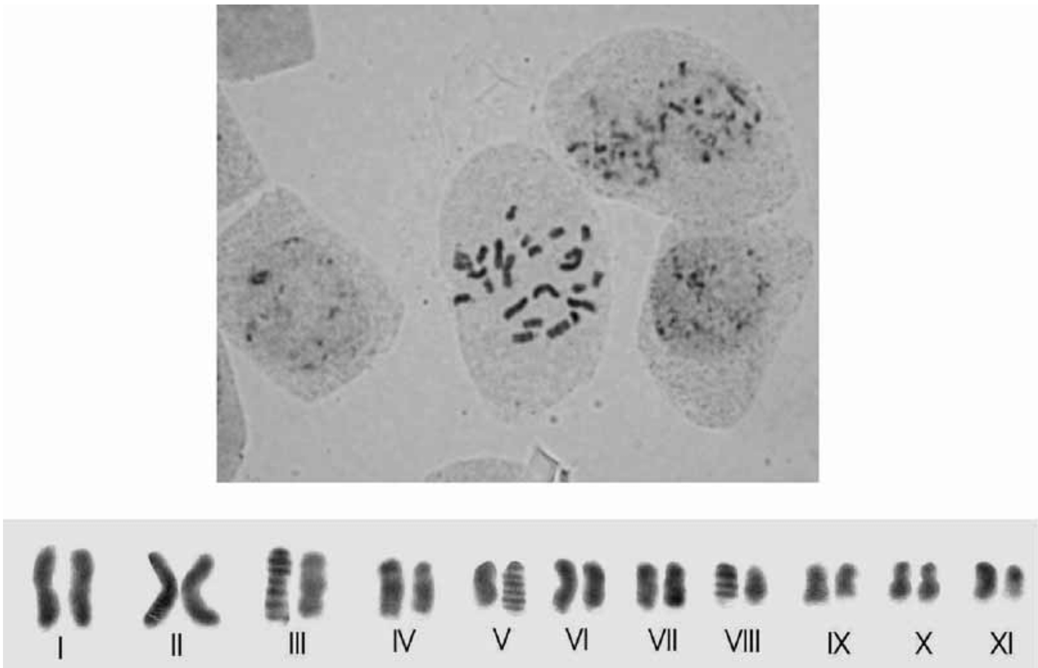
Beans are typically planted in monoculture (Singh and Schwartz, 2010; Wortmann, 2006, as cited in OECD, 2015) because the varieties consumed as a vegetable can produce pods in two months (Purseglove, 1968; Broughton et al., 2003, as cited in OECD, 2015). They are mostly planted on level land but if there are heavy soils or the water table is high, beans could be planted on hills or ridges (Wortmann, 2006, as cited in OECD, 2015). The common bean has a variable effectiveness of nitrogen fixation, so during the soil preparation phase the soil can be supplemented with fertilisers if needed (Liebenberg, 2009, as cited in OECD, 2015). The soil temperature needs to be minimum at 12°C for the seeds to be able to germinate, and the optimum temperature ranging from 22-30°C, and the flowering can begin four to six weeks after planting depending on the bean variety (Wortmann, 2006, as cited in OECD, 2015). Also, P. vulgaris prefers sandy clay or sandy loam soils with moderate acidity, with a pH 5.8-6.5 with balanced fertility (Liebenberg, 2009).

3 Biology

3.1 Chromosome Complement

3.1.1 Chromosome number & data

The chromosome number is 2n=22 for all Phaseolus cultivars. All chromosomes were found to be morphologically uniform, without satellites (CIMPEANU et al., 2005), which means that the ends of the chromosomes aren't separated from the rest of the chromosome by a secondary constriction *(Ferguson-Smith, 2013)*, and without submetacentrics, which means that the chromosomes don't have a centromere that causes one arm to be shorter than the other (CIMPEANU et al., 2005).



3.2 Life Cycles & Phenology

P. vulgaris is a warm-season, annual, and highly polymorphic plant, which means it can have many genetic variations leading to several different forms or types of individuals in a single species. It does better under subtropical and temperate conditions and even though it can be found in tropical areas, it does not do well under very wet conditions because of fungal disease and flower drop (Heuzé et al., 2015). The common bean can grow from a sea level up to an altitude of 2200-3000 m where the average temperatures range between 15°C and 23°C, annual rainfall is between 300 and 4300 mm, but the optimum would be between 500 and 1500 mm. *P. vulgaris* in higher temperatures (35°C) but can delay seed production, and it has slight frost tolerance but growth stops below 10°C because frost harms the stages of growth, and dry weather during the maturing stage benefits seed preservation. The duration of its life cycle ranges from 60-90 days for determinate types and 250-300 days for indeterminate climbing types (Heuzé et al., 2015).

Figure 7: *P. vulgaris* plant life cycle (*How Do Seeds Sprout?*, n.d.).

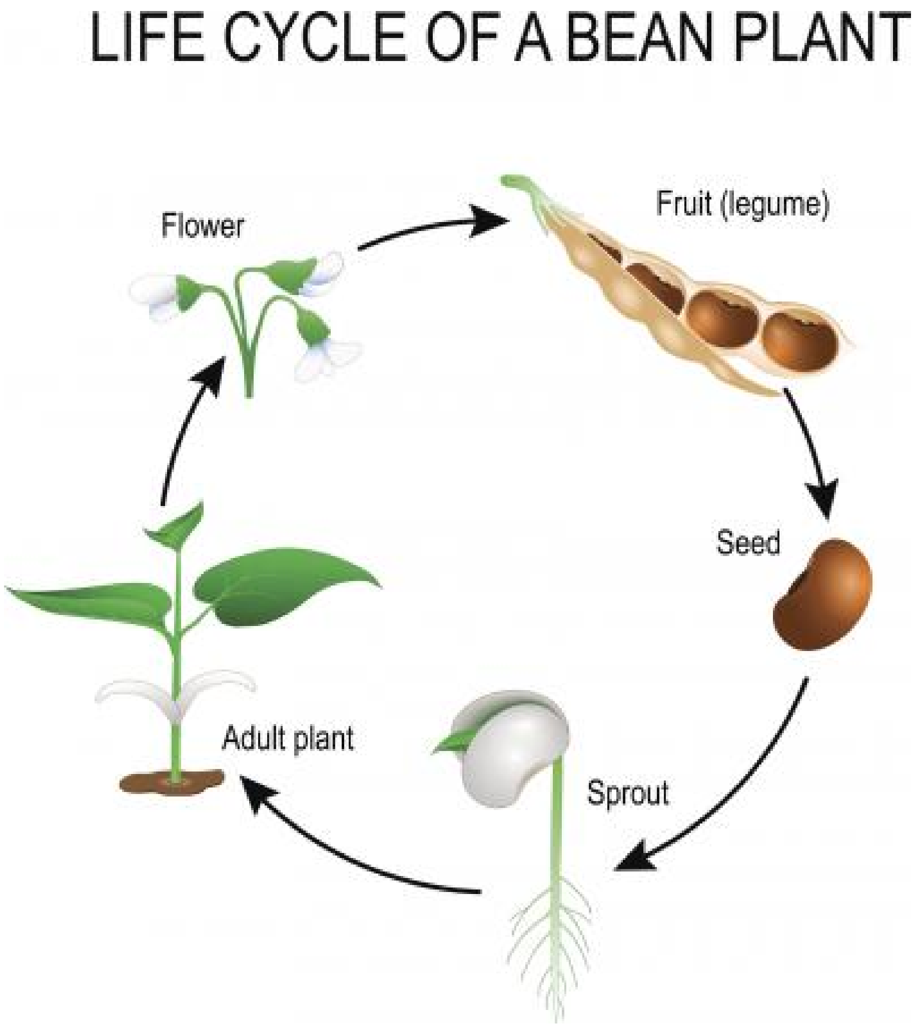


Figure 8: Life cycle of a bean plant (Andy Martin Gardening Instructor, 2006).

3.2.1 Bean Seed Stage

Inside each pod, beans produce a variety of seeds and as they mature, the pods dry up and splits open letting the seeds fall to the ground. Their color varies depending on the cultivar (Purseglove, 1968; Wortmann, 2006) along with their size (Wortmann, 2006). During the cultivation process, the gardener removes the seeds before this happens in order to consume or plant them. As displayed in Figure 9 below, bean seeds have two parts which develop into the first leaves of the plant, called cotyledons. They contain food source for the plant in development, and can also use that food source until they are able to reach the nutrients in the soil (Martin, 2006).

The seed pods are narrow, approximately 8-20 cm x 1-2 cm, and can have up to 12 seeds per pod, even though most varieties have 4-6 seeds (Purseglove, 1968; Wortmann, 2006).

Seed maturity varies widely, and can take from 50 to more than 250 days dependending on the cultivar, their photoperiod, which is the period of time during the day during when the plant receives illumination, and the environmental conditions (*Common bean (Phaseolus vulgaris)*, 2015).

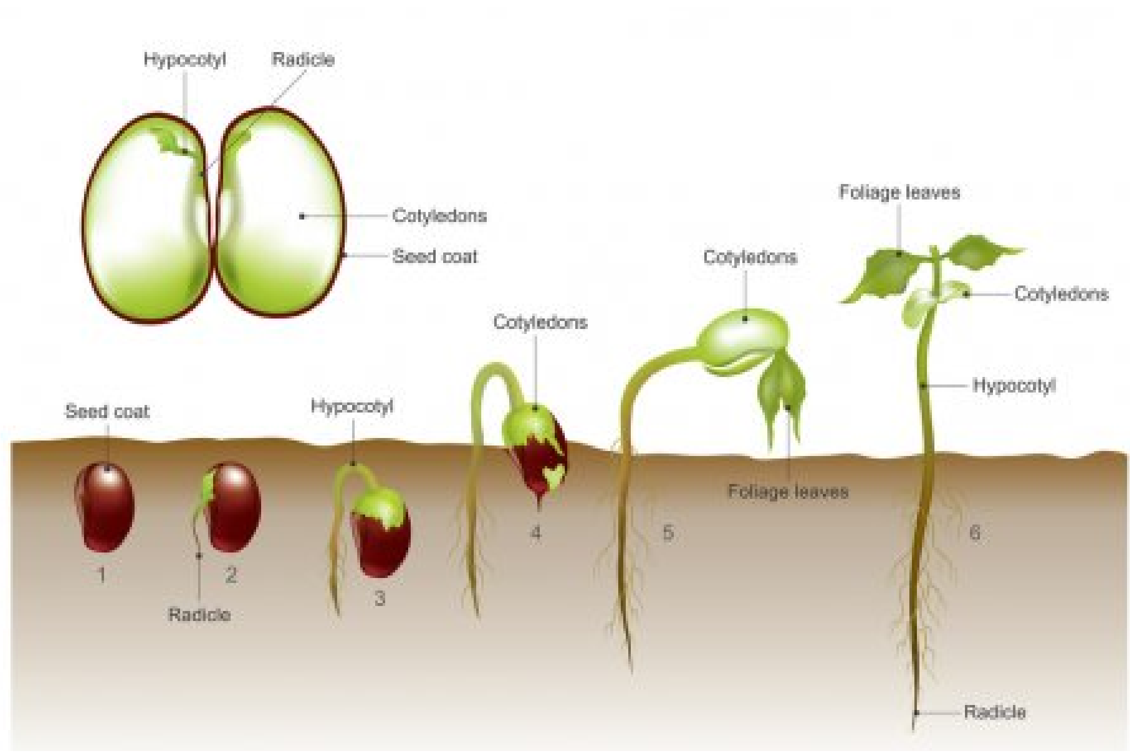


Figure 9: Common bean (*Phaseolus vulgaris*) life cycle (*Vectores de stock de Seed coat, ilustraciones de Seed coat sin royalties | Depositphotos®*, n.d.).

3.2.2. Germination Stage and Root Growth

Beans germinate when water opens the casing around the embryo, and then the embryonic root (radicle) will emerge. Warmth speeds up the process since it will allow the water to crack through or dissolve the seed coat faster. More roots will slowly unfurl from the seed reach out for moisture and nutrients in the soil. It is essential, like for other plants, that the soil is rich in nutrients, therefore, if planting beans, the soil should be amended and continually replenished with nutrients (Martin, 2006).

The seed is composed by seed coat, the outer covering the of seed which protects the internal parts, the seed leaves or cotyledons, which absorb the food from the parent plant and store it for the embryo, and the embryo, which gives rise to the plumule and radical ("Seeds," 2018).

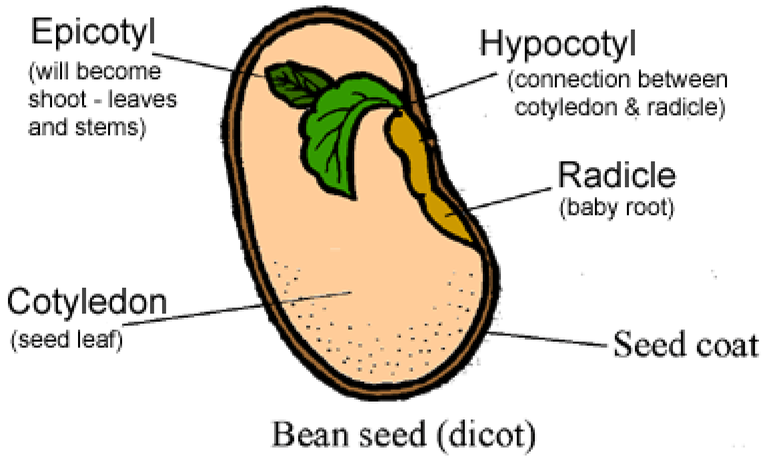


Figure 10: Bean seed parts ("Seeds," 2018).

3.2.3. Leaf Growth

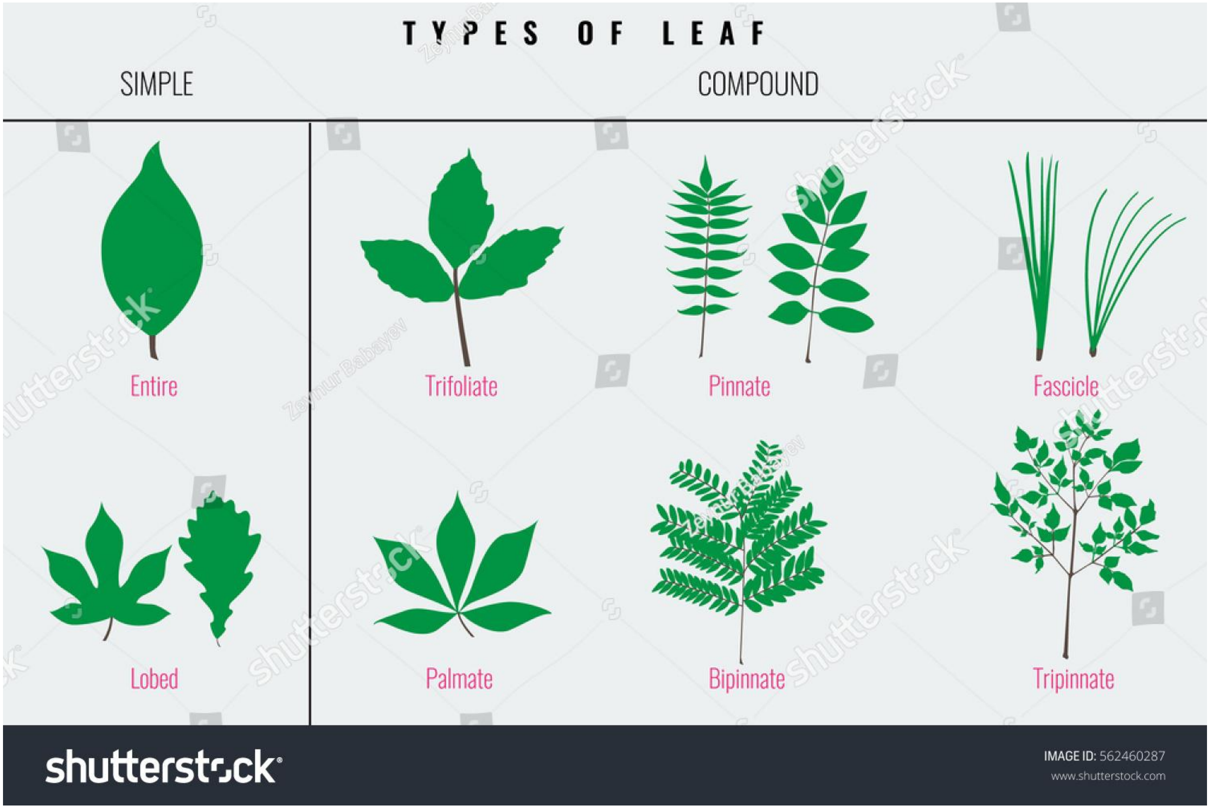
After the seed germinates, the roots descend, and the seed has enough nutrients, the bean plant starts to grow out a single stem. Two little leaves, the dicotyledons, which don't look like a typical bean plant because they are round, emerge above the ground, unlike other plants, and serve the purpose of helping the plant grow quickly and strong. They also provide photosynthesis for the seedling and drop off when the mature leaves sprout. The stem, hypocotyl, sets the plant firmly. The new leaves emerge when the entire plant is formed (Martin, 2006).

The leaves are *trifoliate*, with hairy, broad bases and pointed tips (generally), and alternate on the stems. They are approximately 8-15 cm x 5-10 cm, with small stipules (Purseglove, 1968; Wortmann, 2006).

Figure 11: *P. vulgaris* trifoliolate leaves (*Phaseolus vulgaris*, n.d.).

Trifoliate: Having three leaf like structures. See image below.

Figure 12: Types of leaf (Babayev, n.d.).



3.2.4. Flowering Cycle

The last stage is flowering. The flowering stage depends of the type of bean, generally within six to eight weeks of germination. Flowers are the reproductive part of the plant. They start reproducing as soon as they can and when they are pollinated or fertilized, seed pods develop. When these mature and dry, as said before, the seed pods are picked by gardeners or they dry out and let the seeds fall to repeat the cycle (Martin, 2006). Depending on the cultivar, flowers are white, pink, or violet, and they sprout as axillary buds or racemes. Bisexual flowers are keeled and they terminate in a coil. (Purseglove, 1968; Bailey, 1975; Wortmann, 2006).

Figure 13: *P. vulgaris* flowers, left (*Phaseolus vulgaris*, n.d.), right, ("Phenotypic characterization of common bean (Phaseolus vulgaris L.) accessions conserved at the Genetic Resources and Biotechnology Institute – JBES," 2018).

Figure 14: Bean pods (*Phaseolus vulgaris*, n.d.).

3.3. Propagation

Phaseolus vulgaris is most commonly propagated by seed, by pre-soaking the seeds in warm water for 12 hours and waiting for them to germinate (about 10 days) to then plant them (2). An alternative to seed propagation would be vegetative propagation by cutting the stem (*Common bean (Phaseolus vulgaris)*, 2015). This is done by placing the stem cutting in fresh water until they have fully rooted. The roots should be about 1-2 inches or more to be placed in the soil (Kefeli & Blum, 2010).

3.3.1 Pollination and Dispersal

Phaseolus vulgaris is primarily a self-pollinating species, but bumble, carpenter and honey bees could also be potential carriers of bean pollen (*Common bean (Phaseolus vulgaris)*, 2015), and there isn't much information about its longevity (Andersson and de Vincente, 2010). Bees and other insect species could be responsible for some of the outcrossing observed between bean varieties grown in close proximity. Outcrossing rates are dependent on the bean genotype, the environmental conditions, and synchrony of flowering (*Common bean (Phaseolus vulgaris)*, 2015). Birds are known to consume immature seeds while still in the developing pods, but don't disperse mature seeds probably due to their toxicity (Debouck et al., 1993).

4 Management

4.1 Planting

Phaseolus vulgaris seeds can be planted by broadcasting, which is scattering seeds mechanically or by hand over a relatively large area, or by row planting, which is planting seeds in straight lines next to each other (Wortmann, 2006). They grow the best in sunny areas where the soil is warm and well-drained (*How to Grow Beans (Phaseolus Vulgaris)*, 2017).

Figure 15: Seeds planted by broadcasting.

Top: mechanically (Seeding Equipment | SS30B Broadcast Spreaders | John Deere US, n.d.). Bottom: manually (Jaishankar, 2010).

Figure 16: Row planting (*Photo D869_28_116, from Dissolve*, n.d.).

The minimum soil temperature needs to be 12°C for the seeds to germinate, but the ideal temperature is between 22-30ºC. Beans are mostly cultivated in flat surfaces but can be sown on hills or ridges where the soil is heavy or the groundwater table is high. The sowing rates of sole cropping ranges from 150,000–400,000 seeds per hectare and with intercropping sowing rates decrease depending on the crops. Beans are planted in monocultures typically for vegetable use, since the varieties used for this produce pods fast (about two months) and farmers usually do rotations with other crops. The seeds—regardless of the use—are sown 3 to 6 seeds per hole, 3–4 cm deep—7 cm if the soil surface is dry and not prone to crusting or heavy—in rows 100–120 cm apart with 40–50 cm spacing within the row (Wortmann, 2006). Widely spaced rows facilitate cultivation but closely space ones yield larger plants, more pods and produce, but this also depends on environmental factors and increases the risk of spreading diseases. Planting densities vary widely, even within types, and bush-type varieties are planted at higher densities than pole-type varieties. Still, increasing the density increases the yields for the most part. If the beans are to be consumed as vegetable, green beans are harvested 2-4 weeks after flowering, and dry beans when the pods have turned yellow and the seeds have matured. Seeds mature when their moisture content is about 50% and they are harvested when they dry down to 15-16%. If they dry too much pods may open spontaneously and drop seeds on the ground or cause split seeds (*Common Bean (Phaseolus Vulgaris)*, 2015).

Figure 17: Mature pods (Willis, 2018).

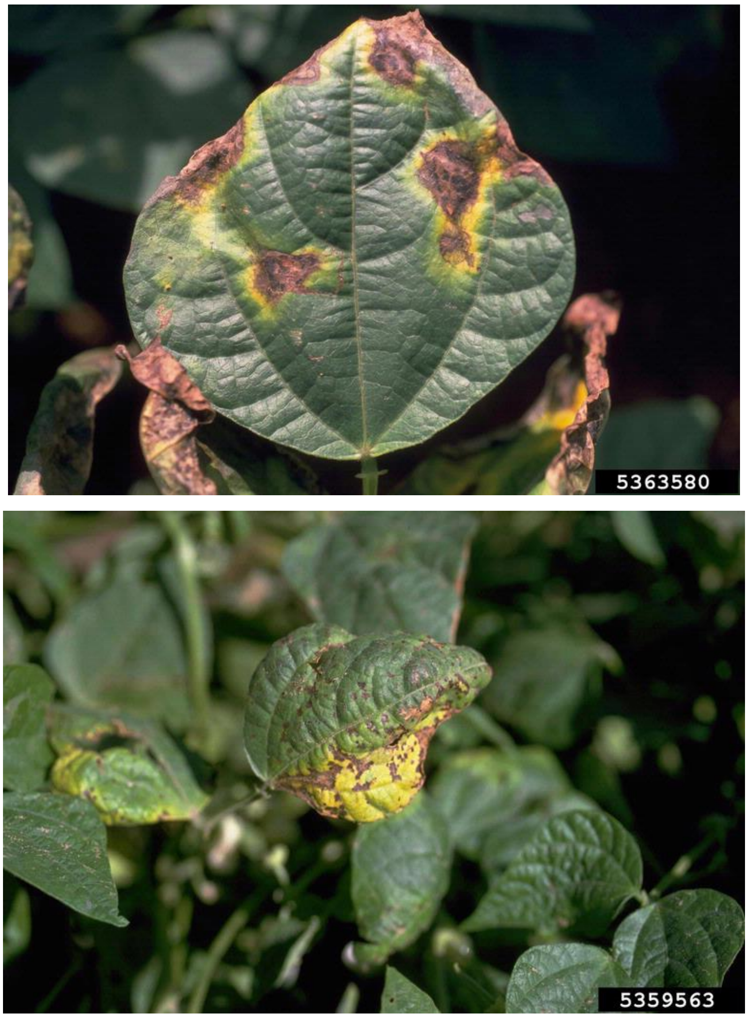
4.2 Management and Pest Disease and Control

Certain varieties have greater competition with weeds. Weed control is essential in the early establishment of the crop because they may cause overgrowth (*Common Bean (Phaseolus Vulgaris)*, 2015), and for a profitable and sustainable production because, being weak to weeds, P. vulgaris gets infested heavily by a wide variety of them causing significant yield and quality loss, therefore, reduced market value. Weeds can be managed with either herbicides or hand weeding (Tana et al., 2015). Manually weeding should be done carefully to avoid damaging the collar of the plant, which is likely to happen (Wortmann, 2006). Using herbicides to manage weeds is more effective because it takes less time, labour, and it suppresses weeds more successfully, however, overusing them can cause pollution, soil and water contamination, threats to the farmer's health, as well as the weeds developing resistance to it (Tana et al., 2015). Another thing to keep in mind is that phosphorus deficient soil is a major constraint to common bean production, and if this is the case, the soil should be fertilized (*Common Bean (Phaseolus Vulgaris)*, 2015).

Phaseolus vulgaris is very susceptible to many pests and diseases, which vary with geographic location, and they can cause significant or total yield loss. Some of the insect pests that attack these crops are wide range of arthropods like aphids, beetles, caterpillars, leafhoppers, whiteflies, mites and thrips, and maggots (*Common Bean (Phaseolus Vulgaris)*, 2015). These affect especially at the early growth stages. Rodents can cause post-harvest damage but, since uncooked dry beans are toxic to mammals, this is less of a problem. The common bean can also be affected by seed-borne fungal diseases like the *Phaeoisariopsis griseola* and the *Colletotrichum lindemuthianum,* bacterial diseases like the *Xanthomonas campestris* pv. *phaseoli* and the *Pseudomonas savastanoi* pv. *phaseolicola,* and the common mosaic virus (BCMV), among other diseases. Check out the Appendix II to see the full list of pests and diseases that can affect *P. vulgaris* (*Common Bean (Phaseolus Vulgaris)*, 2015). To control pests and diseases, sowing disease-free seed can be useful to control seedborne diseases (but disease-free seeds are scarce), crop rotation, intercropping, sowing of resistant or tolerant cultivars, and using insecticide (Wortmann, 2006). Also, since some diseases can remain in the soil for several years, cultivating beans in different areas of your garden each year is recommended, along with avoiding working on your cultivars when the foliage is wet to prevent spreading fungal and bacterial diseases among plants. Many of these pests and diseases can be treated with pesticides and fungicides, which many smallholder farmers don't usually use. To get rid of beetles and bugs, pick them off and toss them into a jar of soapy water (*How to Grow Beans (Phaseolus Vulgaris)*, 2017).

Figure 18: Leaves affected by pests (lharinck, 2019).

Figure 19: Leaves affected by diseases (*Bean | Diseases and Pests, Description, Uses, Propagation*, n.d.).



5 Markets and Uses

5.1. Markets

From market data (FAOSTAT, 2017) it is evident that Colombia is a net importer of beans, that is it consumes more beans than it produces (Table 3).

Table 3: Colombia's import and export values for 2017, by tonnage and US$.
Chart adapted from FAOSTAT (http://www.fao.org/faostat/en/#data/QC). Data may include aggregated official, semi official, estimated or calculated data.

Colombian (import/exports)	Value (US$ 1000)	Tonnage (Tonnes)
Imports	**17086**	**17370**
Exports	**1139**	**584**

Data from FAOSTAT (2017) (Tables 4 and 5) show that although all continents export and import beans, it is Africa and South America that are net exporters with Europe and north America as net importers. Asia is by far the largest exporter and importer of beans in total terms. The import and export values of beans per continent are shown in Table 4 and 5 respectively.

Table 4: World import values by continent for 2017, by tonnage and US$ 1000.
Chart adapted from FAOSTAT (http://www.fao.org/faostat/en/#data/QC). Data may include aggregated official, semi official, estimated or calculated data.

Area	Tonnage (Tonnes)	Value (US 1000)
World	3,477,751	3,328,052
Africa	502,314	320,039
Northern America	255,931	285,591
South America	251,720	215,884
Asia	1,512,897	1,475,433
Europe	582,892	668,595

Table 5: World export values by continent for 2017, by tonnage and US$ 1000.
Chart adapted from FAOSTAT (http://www.fao.org/faostat/en/#data/QC). Data may include aggregated official, semi official, estimated or calculated data.

Area	Tonnage (Tonnes)	Value (US 1000)
World	3,891,736	3,431,260
Africa	744,686	405,819
Northern America	823,117	736,491
South America	513,080	431,265
Asia	1,362,513	1,370,095
Europe	180,470	217,475

5.2 Uses

5.2.1 Edible Uses

Green pods are commonly used as a vegetable. These immature seeds can be boiled or steamed to be eaten. Also, mature seeds can be dried and, if stored properly, they will last pretty much indefinitely. You can eat them boiled, baked, pureed, ground into a powder, among others. Though, they must be pre soaked in water for about 12 hours and cooked thoroughly before being eaten. Beans are a great source of protein and provide a very rich flavor as an additive when powdered. The common bean has also been roasted and used as a coffee substitute, and another edible part of the plant are the leaves which can be used as a potherb and as a salad (Plants for a future, 2020).

Figure 20: Colombian beans (Àngels, 2017).

5.2.2 Medicinal Uses

There is limited scientific evidence to support all of the *P. vulgaris'* medicinal uses. Green pods are mildly diuretic (Plants for a future, 2020), meaning it can cause increased passing of urine, which can help people with high blood pressure, heart failure, swollen tissues, and kidney disease (Ware et al., 2017). Also, because beans are a fiber-rich food, they can help keep blood sugar levels stable for longer and are considered a diabetes superfood (Roland, 2020). Beans can be used to treat ulcers externally by grounding them into a flour, and consumed for treating cancer of the blood. Beans have been boiled with garlic to cured intractable coughs. Another thing to note is that the roots have narcotic properties. The whole plant is used for homeopathic treatments of rheumatism, arthritis, and urinary tract disorders (Plants for a future, 2020).

5.2.3 Other Uses

Other uses of the common bean can be as fungicide, because the plant contains phaseolin, as a source of biomass and nitrogen fixer, to revive woollen fabrics by using water used to cook the beans, and to extract brown dye (Plants for a future, 2020).

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Appendix I

Phaseolus vulgaris: cultivated and wild species
Acutifolii, Bracteati, Brevilegumeni, Chiapasana, Coccinei, Coriacei, Digitati, Falcati, Minhelersia, Paniculati subsects. Volubili and Lignosi, Pedicellati, Phaseoli, Revoluti, Rugosi and Xanthotricha. The new taxa are: P. acinaciformis, P. albiflorus, P. albinervus, P. albiviolaceus, P. altimontanus, P. carteri, P. campanulatus, P. coccineus subsp. coccineus vars. argenteus, condensatus, lineatibracteolatus, parvibracteolatus, pubescens, semperhracteolatus, splendens, tridentatus, and zongolicensis, P. coccineus subsp. striatus vars. guatemalensis, minuticicatricatus, pringlei, purpurascens, rigidicaulis, and timilpanensis, P. dasycarpus, P. esquincensis, P. gladiolatus, P. leptostachyus vars. lobatifolius, nanus, and pinnatifolius fs. purpureus andalbus, P. longiplacentifer, P. maculatifolius, P. magnilobatus, P. nodosus, P. parvifolius, P. persistentus, P. polymorphus var. albus, P. pyramidalis, P. reticulatus, P. rotundatus, P. scrobiculatifolius, P. teulensis, and P. trifidus. The new combinations are: P. coccineus subsp. coccineus var. griseus, P. coccineus subsp. coccineus var. strigillosus, P. coccineus subsp. striatus var. striatus, P. leptostachyus var. intonsus, P. maculatus subsp. ritensis, P. polystachyus subsp. sinuatus, and P. polystachyus subsp. smilacifolius.

Appendix II

Table 4.A1.1. **Arthropod pests of common bean**

Scientific and common name	Types of damage	Control methods	Resistant species
Storage pests			
Zabrotes subfasciatus Mexican bean weevil	Damage to mature seed in storage	Mixing seeds with ash, sand or lime; refrigerated storage; coating with edible oil; fumigation	*P. vulgaris*
Acanthoscelides obtectus Bean weevil, bean beetle	Damage to mature seed in storage	Mixing seeds with ash, sand or lime; refrigerated storage; coating with edible oil; fumigation	*P. vulgaris*
Seedling-attacking pests			
Delia pratura Seedcorn maggot	Larvae feed on bean seeds or seedlings	Cultural practices (shallow planting in warm, moist soil) seed	*P. vulgaris*
Elasmopalpus lignosellus Lesser cornstalk borer	Larvae enter the stem just below soil surface and tunnel upwards	Heavy irrigation and proper land preparation and weed control	No good resistance
Agrotis ipsilon, Spodoptera spp. Cutworms	Larvae cut stems of young seedlings. Older plants can be damaged by stem girdling.	Proper land preparation and weed control	No good resistance
Teratopactus nodicollis	Larvae cause damage at germination, emergence and during early vegetative growth. When larvae feed on the radicle and hypocotyl, the seedlings die before emergence.	Cultural practices (proper land preparation, weed control, increasing planting rate)	No good resistance
Ophiomyia phaseoli, O. specerella Bean fly, bean stem maggot	Feed on stem at seedling stage	Seed and seedling treatments with systemic insecticides	*P. vulgaris, P. coccineus*
Leaf-feeding pests			
Diabrotica spp., *Cerotoma* spp. Chrysomelids	Larvae damage roots and roots nodules, adults feed on foliage and are vectors of important viral diseases	Yellow traps; neem oil as antifeedant agent	No good resistance

Table 4.A1.1. **Arthropod pests of common bean** (*continued*)

Scientific and common name	Types of damage	Control methods	Resistant species
Liriomyza spp. Leafminers	Larvae damage leaves by making serpentine tunnels while feeding on leaf palisade tissues	The insect is usually controlled by natural enemies	No good resistance
Omiodes indicate Webworm	Larvae weave leaves together and feed on the parenchyma	The insect is usually controlled by natural enemies	No good resistance
Urbanus proteus Bean leafroller	Larvae fold the leaf margin and feed within the fold	Chemical control is seldom required	No good resistance
Chrysodeixis (=Pseudoplusia) includes Soybean looper	Larvae feed on underside of the leaves, avoiding the veins of the leaves, leaving a transparent appearance on parts of the leaf	*Bacillus thuringiensis* sprays, *Trichogramma* releases	No good resistance
Helicoverpa armigera	Larvae feed on leaves and pods	*Bacillus thuringiensis* and *Baculovirus* sprays, *Trichogramma* releases	No good resistance
Epilachna varivesta Mexican bean beetle	Adults and larvae feed on leaves. Stems and pods can also be damaged when populations are high.		*P. vulgaris*
Ootheca spp. Foliage beetles	Feed on leaves during pre-flowering period; virus vector	Crop rotation, intercropping, resistant cultivars	No good resistance
Epinotia aporema			No good resistance
Piercing and sucking pests			
Empoasca spp. Leafhoppers	Desiccation and necrosis of leaves; transmission of viral diseases	Intercropping with corn; *Zoophthora* spp. epizootics	*P. vulgaris*
Aphis fabae, A. craccivora Aphids	Sucks plant sap from leaves and stems at seedling stage and from pods; virus vector	Crop rotation, intercropping, resistant cultivars	*P. vulgaris*
Thrips palmi, T. tabaci, Frankliniella occidentalis, F. schultzei, Caliothrips brasiliensis, Megalurothrips sjostedti Thrips	Damage to leaves and growing tips	Crop rotation, intercropping resistant cultivars	*P. vulgaris*
Bemisia tabaci, Trialeurodes vaporariorum Whitefly	Adults and nymphs suck sap from leaves; main damage as virus vector	Crop rotation, intercropping, resistant cultivars	*P. vulgaris*
Polyphagotarsonemus latus, Tetranhychus urticae Mites	Suck sap from the lower surfaces of leaves	Insecticide sprays for egg and nymph control	No good resistance
Pod-attacking pests			
Apion godmani Bean pod weevil	Damage to immature pods and seeds	Bean-corn associations	*P. vulgaris*
Maruca vitrata, Spodoptera spp., *Etiella zinchenella* Pod borer	Larvae feed on developing seeds and expel frass into pod	*Bacillus thuringiensis* sprays	No good resistance
Clavigralla spp. Spiny bug	Suck sap from green pods, causing premature drying	Insecticide sprays	No good resistance
Neomegalotomus simplex	Adults and nymphs suck sap from green pods	Insecticide sprays	No good resistance
Nezara viridula, Euschistus heros, Piezodorus guildini, Thyanta perditor, Edessa meditabunda, Chinavia spp. Stink bugs	Suck sap from developing pods, thereby shriveling pods and seeds. Cause loss of yield and reduce germination of surviving seeds.	Insecticide sprays	No good resistance

Sources: Porch et al. (2013); Purseglove (1968); Miklas et al. (2006); Sanchez-Arroyo (2014); Wortmann (2006); FAO (1999); Cardona (1989); Karel and Autrique (1989); Quintela (2009).

Diseases

The main fungal diseases affecting common bean are listed in Table 4.A1.2, bacterial diseases in Table 4.A1.3 and viral diseases in Table 4.A1.4.

Table 4.A1.2. **Fungal diseases of common bean**

Name	Disease symptoms	Control methods	Resistant species
Thanatephorus cucumeris Web blight	Brownish, irregular lesions on pods; under humid conditions, mycelia will cover pods	Application of fungicides, planting disease-free seed	*P. vulgaris*
Colletotrichum lindemuthianum Anthracnose	Dark brown to black lesions affecting stems, pods and lower surfaces of leaves	Plant disease-free seed, application of fungicides, crop rotation	*P. vulgaris*, *P. coccineus*, *P. dumosus*
Sclerotinia sclerotiorum White mold	Destruction of the tissue, followed by superficial growth of white mycelia, under humid conditions. Seed-transmitted disease.	Application of chemical or biological pesticides, wide-row spacing, use of upright cultivars	*P. vulgaris*, *P. coccineus*, *P. dumosus*, *P. costaricensis*
Phoma exigua var. *diversispora*, *P. exigua* var. *exigua* Ascochyta blight	Red-brown lesions on leaves, stems, pods. Can cause rapid plant death.	Plant resistant varieties, plant clean seed, long crop rotations	*P. coccineus*, *P. dumosus*
Fusarium solani Fusarium root rot	Reddish-brown lesions on stems, lengthwise cracks that may extend down the main taproot, which decays	Good soil drainage, long crop rotations	No good resistance
Fusarium oxysporum Fusarium wilt	Yellowing and wilting of lower leaves, stunting	Plant resistant varieties	*P. vulgaris*
Rhizoctonia solani Rhizoctonia root rot	Damping off, oval, reddish-brown lesions on the hypocotyl, cankers on older stems	Fungicidal seed treatments, crop rotation	No good resistance
Uromyces phaseoli, *U. appendiculatus* Bean rust	Dry yellow to reddish spore masses on lower leaf surfaces and pods	Plant resistant varieties, fungicide applications	*P. vulgaris*
Phaeoisariopsis griseola Angular leaf spot	Grey to brown leaf lesions becoming necrotic; lesions may appear on stems and pods; pod lesions are oval and reddish-brown	Planting disease-free seed, fungicides, sanitation practices	*P. vulgaris*, *P. dumosus*, *P. coccineus*

Sources: Singh and Schwartz (2010); Schwartz and Singh (2013); Purseglove (1968); Kelly et al. (2003); Porch et al. (2013); Schmit and Baudoin (1992); Miklas et al. (2006).

Table 4.A1.3. **Bacterial diseases of common bean**

Name	Disease symptoms	Control methods	Resistant species
Xanthomonas campestris pv. *phaseoli* or *Xanthomonas axonopodis* pv. *Phaseoli* Common bean blight	Necrotic lesions on leaves, pods and seeds; seed-transmitted disease	Planting of disease-free seed, removal of disease reservoir plants in the field and the application of copper-based bactericides	*P. vulgaris*, *P. acutifolius*, *P. coccineus*
Pseudomonas syringae pv. *phaseolicola* or *Pseudomonas savastonoi* pv. *Phaseolicola* Halo blight	Brown necrotic spots surrounded by a light green halo, appearing on both leaves and stems. Infections can be systemic, and seeds may carry the disease.	Planting of disease-free seed, removal of disease reservoir plants in the field and the application of copper-based bactericides	*P. vulgaris*
Pseudomonas syringae pv. *Syringae* Bacterial brown spot	Brown lesions on both leaves and pods; seed-transmitted disease	Planting of disease-free seed, removal of disease reservoir plants in the field and the application of copper-based bactericides	*P. coccineus*

Sources: Liebenberg (2009); Singh and Schwartz (2010); Kelly et al. (2003); Porch et al. (2013).

Table 4.A1.4. **Viral diseases of common bean**

Name	Disease symptoms	Control methods	Resistant species
Bean common mosaic virus Potyvirus	Mosaic mottling of the leaves; vectored by aphids; seed-transmitted disease	Planting virus-free seed and using pesticides to control aphid populations	*P. vulgaris*
Bean golden mosaic virus Geminivirus	Yellow-green mosaic on leaves, stunted growth and distorted pods. Significant losses, as high as 100%.Vectored by whitefly (*Bemisia tabaci*).	Insecticide applications to control the vector	*P. vulgaris* (low level), *P. coccineus*
Bean common mosaic necrosis virus Potyvirus	Light green to yellow mosaic pattern on leaves, with puckering and rolling of the leaves	Plant resistant varieties; virus-free seed	*P. vulgaris*
Beet curly top virus Curtovirus	Strong down-cupping and puckering of leaves. Leaves are thickened and brittle and turn dark green. Plants are dwarfed. Vectored by leafhoppers.	Plant resistant varieties, virus-free seed; insecticide sprays to control leafhopper vectors	*P. vulgaris*
Bean yellow mosaic virus Potyvirus	Bright yellow to green mosaic pattern on leaves, cupping and wrinkling of leaves. Vectored by aphids.	Plant resistant varieties, virus-free seed, insecticide sprays to control aphid vectors	*P. vulgaris*

Sources: Singh et al. (2009); Singh and Schwartz (2010); Miklas et al. (2006); Bonfim et al. (2007); Aragão et al. (2013); Faria et al. (2014).