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REVIEW ARTICLE

ORIGIN, DOMESTICATION, TAXONOMY, BOTANICAL DESCRIPTION, GENETICS AND CYTOGENETICS, GENETC DIVERSITY AND BREEDING OF BEANS (*Phaseolus vulgaris* L.)

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ABSTRACT

Phaseolus spp. beans are valued grain legumes or pulse crops of worldwide importance in terms of human and animal consumption. Common bean (*Phaseolus vulgaris* L.) is the most important *Phaseolus* spp. worldwide, while the runner bean (*Phaseolus coccineus* L.) is the third, right after lima bean (*Phaseolus lunatus* L.). *P. vulgaris* beans come in an enormous variety of shapes, sizes, and colors, from pinto to pink to black to white. Despite this diversity, wild and domestic beans belong to the same species, as do all of the colorful varieties ("landraces") of beans. The main difference between wild and cultivated beans is, well, domestic beans are less exciting. There is a significant increase in seed weight, and the seed pods are less likely to shatter than wild forms: but the primary change is a decrease in the variability of grain size, seed coat thickness and water intake during cooking. Domestic plants are also annuals rather than perennials, a selected trait for reliability. Despite their colorful variety, the domestic bean is much more predictable. Common Names for Common bean are bean, French bean, haricot bean, salad bean, snap bean, string bean, kidney bean, runner bean, scarlet runner bean, multiflora bean, butter bean, garden bean, green bean, bush bean, navy bean, pole bean, flageolet bean, Anasazi beans, black beans, northern beans, pinto beans, Cannellini beans, scarlet bean, Judión or Spanish bean. Some varieties of the common bean are grown only for the dry seeds, some only for the edible immature pods, and others for the seeds, either immature or mature. Varieties differ greatly in size, shape, colour, and fibrousness or tenderness of the immature pods. In general, varieties grown for dry mature seeds produce pods that are too fibrous to be eaten at any state of development. The Mesoamerican region is considered the center of origin and diversification of beans (*Phaseolus spp*), cultivated and wild. Two main gene pools, Mesoamerican and Andean associated with these two geographical areas, have been described in wild and cultivated common beans. Genetic diversity or variation between different populations belonging to the same genus resulted from the evolution of crops through the history, in response to different environments and husbandry practices (Fowler, 2008). Genetic diversity of runner bean has been less extensively investigated. The largest set of European landraces, more than 300, was evaluated by cpSSRs and a smaller set was studied also for phenotypic traits. Green beans are classified by growth habit into two major groups, "bush" (or "dwarf") beans and "pole" (or "climbing") beans. All beans are ecologically beneficial as they form a symbiotic relationship between nodules on their roots and nitrogen fixing bacteria called rhizobia. This bacteria adds much needed nitrogen back into soil profiles. Beans also form another symbiotic relationship in their roots with mycorrhizal fungi. The mycorrhizal fungi gain carbon from the host plant and in turn they increase the root surface area allowing for better uptake of water and nutrients, especially slow moving phosphorus. Recently the role of bean in human diet is being focused not only in its protein content but in the functional properties also and some authors have reported that its consumption could contribute to reduce risk of obesity, diabetes, cardiovascular diseases and colon, prostate and breast cancer. These health benefits could be due to the fiber content in the grain but also to antoxidant compounds as the phenolic ones. In this review article on Origin, Domestication, Taxonomy, Botanical Description, Genetics and Cytogenetics, Genetic Diversity, Breeding, Uses, Nutritional Value and Health Benefits of beans are discussed.

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INTRODUCTION

Phaseolus spp. beans are valued grain legumes or pulse crops of worldwide importance in terms of human and animal consumption (Aquino-Bolaños *et al.,* 2016). Common bean (*Phaseolus vulgaris* L.) is the most important *Phaseolus* spp. worldwide, while the runner bean (*Phaseolus coccineus* L.) is the third, right after lima bean (*Phaseolus lunatus* L.) (Santalla *et al.,* 2004). *P. vulgaris* beans come in an enormous variety of shapes, sizes, and colors, from pinto to pink to black to white. Despite this diversity, wild and domestic beans belong to the same species, as do all of the colorful varieties ("landraces") of beans. The main difference between wild and cultivated beans is, well, domestic beans are less exciting. There is a significant increase in seed weight, and the seed pods are less likely to shatter than wild forms: but the primary change is a decrease in the variability of grain size, seed coat thickness and water intake during cooking. Domestic plants are also annuals rather than perennials, a selected trait for reliability. Despite their colorful variety, the domestic bean is much more predictable (Kris, 2020). Green beans are young, unripe fruits of various cultivars of the common bean (*Phaseolus vulgaris*), although immature or young pods of the runner bean (Phaseolus coccineus), yardlong bean (Vigna unguiculata subsp. sesquipedalis), and hyacinth bean (Lablab purpureus) are used in a similar way. Green beans are distinguished from the many other varieties of beans in that green beans are harvested and consumed with their enclosing pods before the bean seeds inside have fully matured (Wikipedia, 2023c).

Most of the kinds of beans commonly eaten today are part of the genus *Phaseolus*, which originated in the Americas. The first European to encounter them was Christopher Columbus, while exploring what may have been the Bahamas, and saw them growing in fields. Five kinds of *Phaseolus* beans were domesticated by pre-Columbian peoples: common beans (*P. vulgaris*) grown from Chile to the northern part of what is now the United States; and lima and sieva beans (*P. lunatus*); as well as the less widely distributed teparies (*P. acutifolius*), scarlet runner beans (P. coccineus), and polyanthus beans (Wikipedia, 2023f). A bean is the seed of several plants in the family Fabaceae, which are used as vegetables for human or animal food. They can be cooked in many different ways, including boiling, frying, and baking, and are used in many traditional dishes throughout the world (Wikipedia, 2023f). Beans with various pod colors (green, purple, red, or streaked) are collectively known as snap beans, while green beans are exclusively green. Shapes range from thin "fillet" types to wide "romano" types and more common types in between. Green beans may have a purple rather than green pod, which changes to green when cooked. Yellow-podded green beans are also known as wax beans. Wax bean cultivars are commonly of the bush or dwarf form (Wikipedia, 2023c). The three commonly known types of green beans are string or snap beans, which may be round or have a flat pod; stringless or French beans, which lack a tough, fibrous string running along the length of the pod; and runner beans, which belong to a separate species, *Phaseolus coccineus*. Green beans may have a purple rather than green pod, which changes to green when cooked. Wax beans are *P. vulgaris* beans that have a yellow or white pod. Wax bean cultivars are commonly grown; the plants are often of the bush or dwarf form (Wikipedia, 2023e). As the name implies, snap beans break easily when the pod is bent, giving off a distinct audible snap sound. The pods of snap beans (green, yellow and purple) are harvested when they are rapidly growing, fleshy, tender (not tough and stringy), and bright in color, and the seeds are small and underdeveloped (8 to 10 days after flowering) (Wikipedia, 2023e; NCEG, 2023).

Shell, shelled, or shelling beans are beans removed from their pods before being cooked or dried. Common beans can be used as shell beans, but the term also refers to other species of beans whose pods are not typically eaten, such as lima beans, soybeans, peas, and fava beans. Fresh shell beans are nutritionally similar to dry beans but are prepared more like vegetables, often steamed, fried, or made into soups (Wikipedia, 2023e). The *nuña* is an Andean subspecies, *P. v.* subsp. *nunas* (formerly *P. vulgaris* Nuñas group), with round, multicolored seeds that resemble pigeon eggs. When cooked on high heat, the bean explodes, exposing the inner part in the manner of popcorn and other puffed grains (Wikipedia, 2023e; NCEG, 2023). Runner bean (*Phaseolus coccineus* L.) is a climbing perennial leguminous plant for human consumption, broadly distributed in Spain. It occupies the third position in the economic ranking among the different *Phaseolus* species. It is grown both as a food plant and an ornamental plant (Santalla *et al*., 2004: Wikipedia, 2023).

Common Names for Common bean are bean, French bean, haricot bean, salad bean, snap bean, string bean, kidney bean, runner bean, scarlet runner bean, multiflora bean, butter bean, garden bean, green bean, bush bean, navy bean, pole bean, flageolet bean, anasazi beans, black beans, northern beans, pinto beans, cannellini beans, Scarlet bean, Judión or Spanish bean (Santalla *et al*., 2004; Heuzé *et al*., 2015; OECD, 2016: Britannica, 2023). The kidney bean is a variety of the common bean (*Phaseolus vulgaris*) named for its resemblance to a human kidney (Wikipedia, 2023b). Kidney bean refers to a specific type that is definitely kidney-shaped and is red, dark red, or white. Some varieties of the common bean are grown only for the dry seeds, some only for the edible immature pods, and others for the seeds, either immature or mature (Britannica, 2023). Varieties differ greatly in size, shape, colour, and fibrousness or tenderness of the immature pods. In general, varieties grown for dry mature seeds produce pods that are too fibrous to be eaten at any state of development (Britanica, 2023). Green beans are known by many common names, including French beans (French: haricot vert), string beans (although most modern varieties are "stringless"), and snap beans or simply "snaps." The common bean has a long history of cultivation. All wild members of the species have a climbing habit, but many cultivars are classified either as *bush beans* or *climbing beans*, depending on their style of growth. Best-known cultivar groups include the kidney bean, the navy bean, the pinto bean, and the wax bean. The other major types of commercially grown beans are the runner bean (*Phaseolus coccineus*) (Wikipedia, 2023e). The pinto bean (/ˈpɪntoʊ/) is a variety of common bean (*Phaseolus vulgaris*). In Spanish they are called *frijoles pintos*, literally "painted bean". It is the most popular bean by crop production in Northern Mexico and the Southwestern United States. common bean, (*Phaseolus vulgaris*), any of a variety of legumes (family Fabaceae) widely cultivated for their edible seeds and seedpods (Britannica, 2023). There are different classifications of kidney beans. Red kidney bean (also known as: common kidney bean, rajma in India, surkh (red) lobia in Pakistan). 1) Light speckled kidney bean (and long shape light speckled kidney bean). 2) Red speckled kidney bean (and long shape light speckled kidney bean). And 3) White kidney bean (also known as cannellini in Italy, lobia in India, or safaid (white) lobia in Pakistan) (Wikipedia, 2023b).

The Mesoamerican region is considered the center of origin and diversification of beans (*Phaseolus spp*), cultivated and wild (Hernández *et al.,* 2013). Two main gene pools, Mesoamerican and Andean associated with these two geographical areas, have been described in wild and cultivated common beans. As a result of the domestication process, a great number of varieties showing differences in morpho-agronomical quantitative traits including seed size, seed quality, and plant growing period, were obtained, and this variation has been extensively used in breeding programs or diversity studies (Pérez-Vega *et al.,* 2010). Large or medium seed morphology characteristic was reported for Andean and mostly small seeds for Mesoamerican group genotypes (Singh *et al.,* 1991). Purple seed colour was found to be exclusively Andean, while pink, brown, and black predominantly Mesoamerican pool origin. Cream, yellow, and red seed colours were found in both gene pool groups. Andean beans having a tendency for higher iron seed concentration and lower seed zinc concentration than Mesoamerican and putative hybrids between gene pools (Blair *et al*., 2010). Cultivated common and runner beans were domesticated independently within two centres of diversity, giving rise to two gene pools, i.e., Mesoamerican and Andean (González *et al*., 2009). Genetic diversity or variation between different populations belonging to the same genus resulted from the evolution of crops through the history, in response to different environments and husbandry practices (Fowler, 2008). Genetic diversity of runner bean has been less extensively investigated. The largest set of European landraces, more than 300, was evaluated by cpSSRs and a smaller set was studied also for phenotypic traits (Rodriguez *et al.,* 2013).

Green beans are classified by growth habit into two major groups, "bush" (or "dwarf") beans and "pole" (or "climbing") beans. Bush beans are short plants, growing to not more than 61 cm in height, often without requiring supports. They generally reach maturity and produce all of their fruit in a relatively short period, then cease to produce. Owing to this concentrated production and ease of mechanized harvesting, bush-type beans are those most often grown on commercial farms. Bush green beans are usually cultivars of the common bean (*Phaseolus vulgaris*). Pole beans have a climbing habit and produce a twisting vine, which must be supported by "poles," trellises, or other means. Pole beans may be common beans (*Phaseolus vulgaris*), runner beans (*Phaseolus coccineus*) or yardlong beans (*Vigna unguiculata* subsp. *sesquipedalis*). Half-runner beans have both bush and pole characteristics, and are sometimes classified separately from bush and pole varieties. Their runners can be about 1- 3 m. long **(Fig.1)** (Wikipedia, 2023c). Common beans can present four growth habits: type I determined (bush type), type II indeterminate (bush type), type III indeterminate prostrate and type IV indeterminate climber. Those of determined growth can reach heights between 30cm and 90cm, while those of indeterminate habit reach heights from 50cm to 3m (Rosas, 2003).

Fig. 1: Bush type plant | **Pole type plants**

The bean has a primary root and many secondary roots with nodules developed from an association with the nitrogen-fixing bacterium Rhizobium. Like other legumes, *P. vulgaris* associates with *Rhizobium* bacteria in the soil, which form root nodules (OECD, 2016). All beans are ecologically beneficial as they form a symbiotic relationship between nodules on their roots and nitrogen fixing bacteria called rhizobia. This bacteria adds much needed nitrogen back into soil profiles. Beans also form another symbiotic relationship in their roots with mycorrhizal fungi. The mycorrhizal fungi gain carbon from the host plant and in turn they increase the root surface area allowing for better uptake of water and nutrients, especially slow moving phosphorus **(Fig. 2)** (NCEG, 2023). *Phaseolus vulgaris*, the common bean, is a herbaceous annual plant grown worldwide for its edible dry seeds or green, unripe pods. Its leaf is also occasionally used as a vegetable and the straw as fodder. Its botanical classification, along with other *Phaseolus* species, is as a member of the legume family Fabaceae. Like most members of this family, common beans acquire the nitrogen they require through an association with rhizobia, which are nitrogen-fixing bacteria (Wikipedia, 2023e).

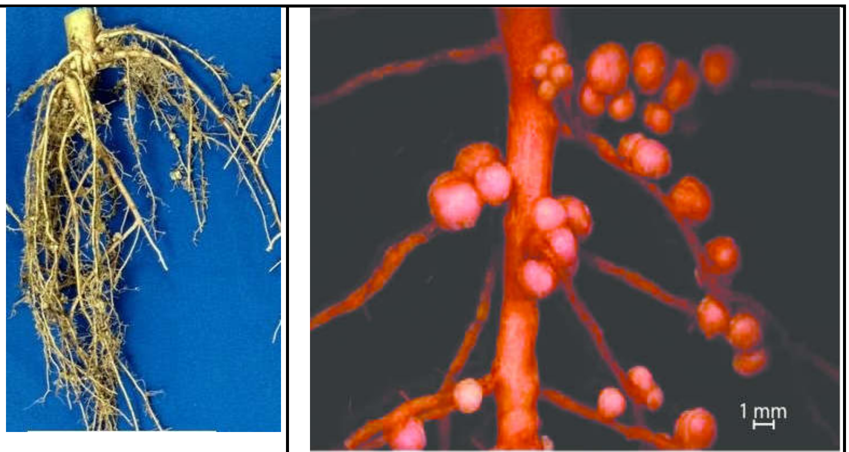

Fig. 2. *Rhizobium* nodules on the roots of common bean

Beans are produced and consumed mainly as a dry food legume, due to the high protein content of the grain, but the use of the fresh pod (snap bean) is common in many countries. Common bean is highly preferred in many parts of Africa and Latin America (where it can be the most important source of dietary protein), as well as in traditional diets of the Middle East and the Mediterranean region. This legume is part of the healthy diet of the Mediterranean basin and gaining importance in the USA where consumption has been increasing due to greater interest in "ethnic" and healthy foods (De Ron *et al*., 2016). Recently the role of bean in human diet is being focused not only in its protein content but in the functional properties also and some authors have reported that its consumption could contribute to reduce risk of obesity, diabetes, cardiovascular diseases and colon, prostate and breast cancer. These health benefits could be due to the fiber content in the grain but also to antoxidant compounds as the phenolic ones (De Ron *et al.,* 2016). The countries producing substantial dry beans are Brazil, Mexico, Argentina, Chile, Central America and Latin America. In India, green pod as well as dry seed consumption is conspicuous, but figures on area and production are not available. In India, it is primarily grown in Jammu and Kashmir, Himachal Pradesh and hills of Uttaranchal. Production is spreading in plains in Maharashtra, Gujarat, Bihar, Jharkhand and Karnataka (Vidhi, 2023). In this review article on Origin, Domestication, Taxonomy, Botanical Description, Genetics and Cytogenetics, Genetic Diversity, Breeding, Uses, Nutritional Value and Health Benefits of beans are discussed.

ORIGIN AND DOMESTICATION

Phaseolus vulgaris originated in Latin America where its wild progenitor has a wide distribution ranging from northern Mexico to northwestern Argentina (De Ron and Santalla, 2013). ***Phaseolus vulgaris*** originated from Central and South America, where it was cultivated as early as 6000 BC in Peru and 5000 BC in Mexico. It was introduced to the Old World by the Spaniards and the Portuguese. It is now widespread and cultivated as a major food crop in many tropical, subtropical and temperate areas of the Americas, Europe, Africa and Asia (Heuzé *et al.,* 2015). Wild common bean populations were first documented in Guatemala in 1947, and they occur from northern Mexico to northern Argentina. However, the distribution is not continuous through that region, due to climatic variations unfavourable to the species, that is, regions with excessive rainfall or elevations below700 metres or above 3 000 metres. Habitat destruction throughout the species' range has accelerated the interest in identifying and preserving ancestral varieties (OECD, 2016). Although 200 years ago it was believed that common bean originated in Asia, a large body of evidence indicates that *P. vulgaris* originated in the New World. Archaeological records indicate that the species originated and was first domesticated as early as 5 000 B.C., although there is evidence for a more recent origin in Mesoamerica. Multi-locus sequence data have indicated that the domestication of common bean was initiated 8 000 years ago (OECD, 2016). The results of seed characterization indicate the origin (Andean, Mesoamerican, putative hybrids between gene pools) and domestication pathways of common and runner beans. To date, this is the first study reporting the morphological characteristics and comparisons of whole common bean and runner bean germplasm conserved in one of the Central European collections. The results obtained in this study are serving as the useful information on genetic diversity of common bean and runner bean accessions at the Slovene gene bank, which could be used for development of new bean varieties for studied seed characteristics. Non-destructive screening test based on the seed characterization of large bean germplasm is shown to be an informative, non-invasive, and suitable tool for distinction of bean accessions according to the gene pool origin (Sinkovič *et al*., 2019).

Common bean is the principal grain legume of North-India including Jammu and Kashmir and Ladhak. Owing to its high protein content, abundance of various micronutrients and essential amino acids and low cost, it is sometimes referred to as poor man's meat. It is a very diverse crop and presents a rich reservoir of genetic resource to be explored. In the present study, we collected 102 common bean genotypes from different north western Himalayan regions of Jammu and Kashmir and Ladakh. This germplasm was then systematically purified and then characterised using SSRs. In order to examine the genetic diversity, various parameters were considered. The PIC values for the SSR loci ranged from 0.738 to 0.966 with an average of 0.899. The gene diversity between common bean genotypes ranged from 0.751 to 0.967. The major allele frequency ranged from 0.076 to 0.469 and the expected heterozygosity ranged from 0 to 0.135. Further, model based STRUCTURE analysis generated three subpopulations that correspond to distance based groups. Furthermore, the PCR assay for phaseolin locus led to the characterization of 81 genotypes into Meso-American and Andean types. Out of 81 genotypes, 40 possessed "S" type phaseolin and 41 possess "T" type phaseolin. The results of this study revealed the origin of common bean landraces grown in the north western regions of Jammu & Kashmir and Ladakh, India (Bashir *et al*., 2020).

Domestication of common bean occurred independently in two major centres, resulting in two major gene pools Middle American and Andean, that vary on yield and other physiological traits (Kwak and Gepts, 2009). Four gene pools of the wild bean were detected by amplified fragment length polymorphism analysis (Tohme et al., 1996) that evolved in succession (Smith and Rao, 2021). Beans are known to have originated as early as 800 years ago in Mesoamerica. The *Phaseolus vulgaris* plant has been cultivated for hundreds of years in the nations of Mexico, Peru. European settlers subsequently introduced them to many other countries like the U.K. USA, India, Thailand, Australia and this lead to the growth of many different varieties of beans. French beans are one popular variety with edible pods and as many as 150 varieties are presently harvested across the globe (Wellness, 2021). Runner beans were grown as food plants in North America and Europe from the 1600s, and also as ornamentals for their attractive flowers. This species originated from the mountains of Central America. It was most likely cultivated in the highlands of Mexico and Guatemala around 2000 BC (Wikipedia, 2023). The green bean (*Phaseolus vulgaris*) originated in Central and South America, where there is evidence that it has been cultivated in Mexico and Peru for thousands of years (Wikipedia, 2023c). The wild *P. vulgaris* is native to the Americas. It was originally believed that it had been domesticated separately in Mesoamerica and in the southern Andes region, giving the domesticated bean two gene pools. However, recent genetic analyses show that it was domesticated in Mesoamerica first, and traveled south, probably along with squash and maize. The three Mesoamerican crops constitute the "Three Sisters" central to indigenous North American agriculture (Wikipedia, 2023e). The common bean arrived in Europe as part of the Columbian exchange. In 1528, the pope, Giulio de' Medici, received some white beans, which thrived. Five years later, he gave a bag of beans as a present to his niece, Catherine, on her wedding to Prince Henri of France, along with the county of the Lauragais, whose county town is Castelnaudary, now synonymous with the white bean dish of cassoulet (Wikipedia, 2023e)

Some scientists have proposed Mesoamerica as a possible origin for the common bean. Scientists disagree over whether the common bean was a product of one or multiple domestication events. Over time two diverse gene pools emerged: the Andean gene pool from Southern Peru to Northwest Argentina and the Mesoamerican gene pool between Mexico and Colombia **(Fig. 3)** (Wikipedia, 2023e).

Fig. 3: **Areas of common bean domestication.**

1 - Mesoamerican area. 2 - Andine area

Large-seeded varieties of the domesticated bean have been found in the highlands of Peru, dating to 2300 BC, and spreading to the coastal regions by around 500 BC. Small-seeded varieties were found in sites in Mexico, dating to 300 BC, which then spread north and east of the Mississippi River by 1000 AD (Wikipedia, 2023e)

Beans are one of the longest-cultivated plants in history. The oldest-known domesticated beans in the Americas were found in Guitarrero Cave, an archaeological site in Peru, and dated to around the second millennium BCE. However, genetic analyses of the common bean *Phaseolus* show that it originated in Mesoamerica, and subsequently spread southward (Wikipedia, 2023f). The common bean originated in the new world, principally Central and South America. Systematists concerned with the origin of the common bean have disagreed or have been inconsistent in what name should be applied to the closest wild relatives of the domesticated *Phaseolus vulgaris* L. *Phaseolus aborigineus* Burk, *P. aborigineus* var. *hundorensis* Burk, *P. vulgaris* forma *aborigineus* Burk, *P. vulgaris* ssp. *aborigineus* Burk are names which have been applied. In Phaseolus, there are five cultivated species, each with its own ancestor, and about 50 rue wild species. The cultivated species are *P. vulgaris* (common bean/French bean), *P. lunatus* (lima bean), P. coccineus (runner bean), *P. polyanthus* (the year bean) and *P. acutifolius* (tepary bean). During the process of domestication in common bean, several morphological changes have occurred. The cultivated French bean is an erect growing plant with determinate branching, whereas the wild type is indeterminate and profusely branched. The cultivated types have smaller number of nodes on the main axis, while the wild forms have more nodes. The internode length 5 relatively shorter in the cultivated types. The changes under domestication are typically loss of seed dormancy and pod dehiscence mechanism, a change from perennial to the annual life form and a great change in seed size correlated with modified shoot architecture. Stems tend to be thicker, leaves larger, branches fewer, the number of nodes may be reduced and inter-node length is shortened. This process culminates in evolution of self-supporting plants well adapted to mono-crop husbandry systems. This has also led to appearance of a vast variety of seed sizes, shapes and colour and selection for photoperiod insensitivity (Vidhi, 2023).

Centers of Domestication: Scholarly research indicates that beans were domesticated in two places: the Andes mountains of Peru, and the Lerma-Santiago basin of Mexico. The wild common bean grows today in the Andes and Guatemala: two separate large gene pools of the wild types have been identified, based on the variation in the type of phaseolin (seed protein) in the seed. DNA marker diversity, mitochondrial DNA variation and amplified fragment length polymorphism, and short sequence repeats marker data (Kris, 2020). The Middle American gene pool extends from Mexico through Central America and into Venezuela; the Andean gene pool is found from southern Peru to northwestern Argentina. The two gene pools diverged some 11,000 years ago. In general, Mesoamerican seeds are small (under 25 grams per 100 seeds) or medium (25-40 gm/100 seeds), with one type of phaseolin, the major seed storage protein of the common bean. The Andean form has much larger seeds (greater than 40 gm/100 seed weight), with a different type phaseolin (Kris, 2020). Recognized landraces in Mesoamerica include Jalisco in coastal Mexico near Jalisco state; Durango in the central Mexican highlands, which includes pinto, great northern, small red and pink beans; and Mesoamerican, in lowland tropical Central American, which includes black, navy and small white. Andean cultivars include Peruvian, in the Andean highlands of Peru; Chilean in northern Chile and Argentina: and Nueva Granada in Colombia. Andean beans include the commercial forms of dark and light red kidney, white kidney, and cranberry beans (Kris, 2020).

Origins in Mesoamerica: In 2012, work by a group of geneticists led by Roberto Papa was published in the *Proceedings of the National Academy of Sciences* (Bitocchi *et al*. 2012), making an argument for a Mesoamerican origin of all beans. Papa and colleagues examined the nucleotide diversity for five different genes found in all forms—wild and domesticated, and including examples from the Andes, Mesoamerica and an intermediary location between Peru and Ecuador—and looked at the geographic distribution of the genes (Kris, 2020). This study suggests that the wild form spread from Mesoamerica, into Ecuador and Columbia and then into the Andes, where a severe bottleneck reduced the gene diversity, at some time before domestication. Domestication later took place in the Andes and in Mesoamerica, independently. The importance of the original location of beans is due to the wild adaptability of the original plant. which allowed it to move into a wide variety of climatic regimes, from the lowland tropics of Mesoamerica into the Andean highlands (Kris, 2020).

Dating the Domestication: While the exact date of domestication for beans has not yet been determined, wild landraces have been discovered in archaeological sites dated to 10,000 years ago in Argentina and 7,000 years ago in Mexico. In Mesoamerica, the earliest cultivation of domestic common beans occurred before ~2500 in the Tehuacan valley (at Coxcatlan), 1300 BP in Tamaulipas (at (Romero's and Valenzuela's Caves near Ocampo), 2100 BP in the Oaxaca valley (at Guila Naquitz). Starch grains from Phaseolus were recovered from human teeth from Las Pircas phase sites in Andean Peru dated between ~6970-8210 RCYBP (about 7800-9600 calendar years before the present) (Kris, 2020).

Evolution of gene pools in common bean: Mesoamerica has been suggested to be the center from which common bean originated, ultimately forming the distinct modern wild Andean and Mesoamerican gene pools. To investigate the differentiation of these wild populations, we performed pooled resequencing of 30 individuals each from Mesoamerican and Andean wild populations (Ohbayashi *et al.*, 2019) **(Fig. 4).**

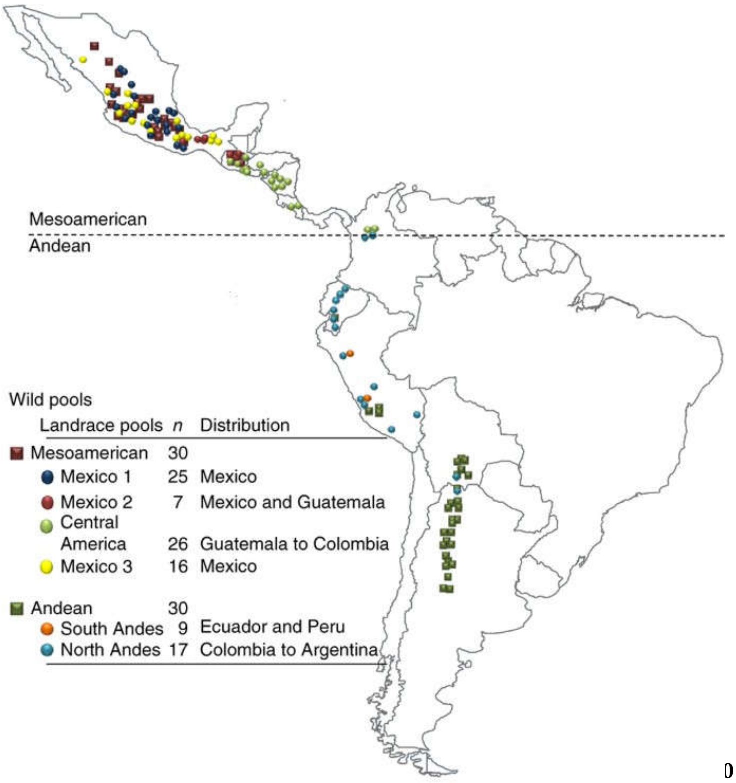

Figure 4. Geographic distribution of sampled genotypes.

Demographic inference for the wild Andean gene pool suggested that it was derived from the wild Mesoamerican population with a founding population of only a few thousand individuals (Ohbayashi *et al.,* 2019) (Fig. 5).

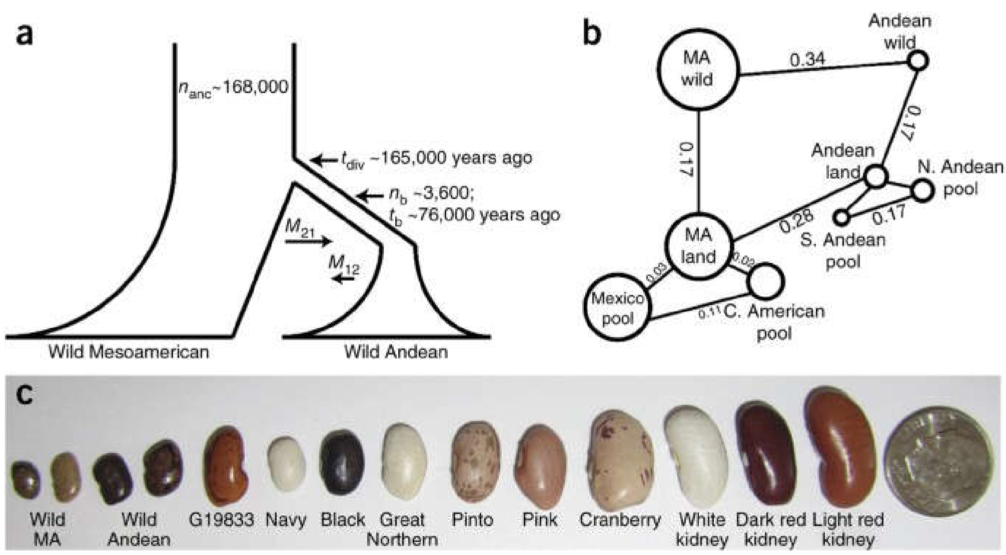

Figure 5. Evolution and domestication of common bean

(a) Divergence of the wild Mesoamerican and Andean common bean pools. The wild Andean gene pool diverged from the wild Mesoamerican gene pool ~165,000 years ago, with a small founding population and a strong bottleneck that lasted ~76,000 years. The bottleneck was followed by an exponential growth phase extending to the present day. Asymmetric gene flow between the two pools had a key role in maintaining genetic diversity, especially in the Andean population, with average migration rates M_{21} = 0.135 (wild Mesoamerican to wild Andean) and M_{12} = 0.087 (wild Andean to wild Mesoamerican). This scenario conforms to the Mesoamerican origin model of the common bean, with an Andean bottleneck that predated domestication. (n_{anc}, size of ancestral population; t_{div}, start of bottleneck; n_b, size of bottleneck population; t_b, length of bottleneck)

(**b**) Population genomic analysis based on SNP data from the resequencing of DNA pools for common bean. The size of the circle for each pool is proportional to the π value for the pool. For a reference, π = 0.0061 for the wild Mesoamerican (MA) pool. F_{ST} statistics, representing the differentiation of any two pools, are noted on the lines (not proportional) connecting pools. Data are average statistics across all 10-kb/2-kb sliding/discarding windows with <50% called bases. Land, landrace; N, north; S, south; C, central.
(**c**) Variation in seed size in common bean. The seeds of wild Mesoamerican and Andean beans (two each) are smaller than the seeds corresponding to the reference genotype (G19833) and the multiple market classes of common beans grown in the United States (navy to light red kidney).

TAXONOMY

Common bean belongs to the Familia**:** Fabaceae , Subfamily**:** Faboideae, Tribe**:** Phaseoleae , Genus**:** Phaseolus, Species: *Phaseolus vulgaris* L. (Fernández *et al*., 1984; Sitte *et al*., 2004; OECD, 2016; Wikimedia, 2019; Wikipedia, 2022d**).** The generic name *Phaseolus* was introduced by Linnaeus in 1753, from the Latin *phaseolus*, a diminutive of *phasēlus*, in turn borrowed from Greek 'cowpea', of unknown origin. The Latin word *phaseolus* is often incorrectly glossed as 'kidney bean', a New World crop (Wikipedia, 2022d). *Phaseolus* (bean, wild bean) is a genus of herbaceous to woody annual and perennial vines in the family Fabaceae containing about 70 plant species, all native to the Americas, primarily Mesoamerica. It is one of the most economically important legume genera. Five of the species have been domesticated since pre-Columbian times for their beans: P. *acutifolius* (tepary bean), P. coccineus (runner bean), P. dumosus (year bean), P. lunatus (lima bean), and P. vulgaris (common bean).[4][5] Most prominent among these is the common bean, *P. vulgaris*, which today is cultivated worldwide in tropical, semitropical, and temperate climates (Wikipedia, 2022d). It is an annual herbaceous plant, and depending on the growth habit, it can reach heights up to two meters (Fernández *et al*., 1984). Within the genus *Phaseolus* there are different groups or natural gene pools (Gepts and Debouck, 1991). The primary gene pool of the common bean includes the wild populations and the cultivated varieties of the species, which can intersect each other and recombine without any genetic barrier. The secondary gene pool includes the runner bean and the year bean. The crossing between common bean and the species of the secondary gene pool is easily done without embryo rescue, although using runner bean as female parent requires usually in vitro embryo rescue techniques (Bannerot, 1979). The tertiary gene pool includes the tepary bean and the crosses with common bean require techniques "in vitro. Lima bean belongs to the quaternary gene pool, and no successful crosses between the two species have been reported. The common bean *Phaseolus vulgaris* is a member of that immense family of plants, the Leguminosae (Fabaceae) which comprises about 600 genera and about 13 000 species. The genus *Phaseolus* includes 150–200 species of plants many of which are cultivated as food or garden ornamentals. The specific name *Phaseolus vulgaris* refers to hundreds of varieties and cultivars of the common bean which has been in cultivation for thousands of years. Thus the name *Phaseolus vulgaris* refers equally to the kidney bean, navy bean, French bean, haricot bean, pinto bean, field beans, China bean, frijol, marrow bean, snap bean, black bean or white bean (Nwokolo, 1996). Until now, over 400 species have been described in the genus *Phaseolus* (Freytag and Debouck, 2002) of which five have been domesticated and are being currently cultivated: *Phaseolus vulgaris* L. (common bean), *P. lunatus* L. (lima bean), P. coccineus L. (runner or scarlet bean), *P. acutfolius* A. Gray (tepary bean), and *P. polyanthus* Greenman (year bean). These species have genetic and phenotypic differences, particularly the reproductive system, which could be self-pollinated or outcrossed based. Beans usually refers to legumes of the genus Phaseolus, family Fabaceae or Leguminosae, subfamily Papilionoideae, tribe Phaseoleae, and subtribe Phaseolinae. The reviews of many herbaria and field collections of germplasm have shown that a large quantity of variability exists in the genus *Phaseolus*. In 2002, Freytag and Debouck estimated that perhaps over 400 Phaseolus species were described since the eighteenth century. Linnaeus defined 11 species of this genus, but some of them were later reclassified into other genus as Vigna**.** Phaseolus species display a wide range of variability in many morphological and physiological traits. Biological cycle may be annual or perennial, growth habit range from dwarf or bush to climbing, reproductive system varies from selfing to outcrossing, and the different species and varieties are able to grow in very different environments: cool or warm, dry or wet (De Ron and Santalla, 2013). The genus contains five domesticated species: P. vulgaris L. (common bean), Phaseolus lunatus L. (lima bean), Phaseolus **coccineus** L. (runner or scarlet bean), Phaseolus acutifolius A. Gray (tepary bean), and Phaseolus polyanthus Greenman (year bean), with distinct adaptations and reproductive systems: mesic and temperate, predominantly self-pollinated; warm and humid, predominantly self-pollinated; hot and dry, cleistogamous; cool and humid, outcrossing; and cool and humid, outcrossing, respectively**.** Phaseolus lunatus is phylogenetically more distant from the other domesticated species, which are sibling species and constitute a syngameon (De Ron and Santalla, 2013).

The genus *Phaseolus* is large, including approximately 80 cultivated and wild species,but *P. vulgaris* is the most widely cultivated species. The most closely related species to *P. vulgaris* are *P. albescens*, P. coccineus, *P costaricensis*, *P. dumosus*, *P. parvifolius* and *P. persistentus.* In addition to *P. vulgaris*, four other *Phaseolus* species are cultivated: *P. dumosus* (year bean), P. coccineus (scarlet runner), *P. acutifolius* (tepary bean) and *P. lunatus* (lima bean) (OECD, 2016). Previous classifications placed a number of other well-known legume species in this genus, but they were subsequently reassigned to the genus Vigna, sometimes necessitating a change of species name. The modern understanding of *Phaseolus* indicates a genus endemic only to the New World (Wikipedia, 2022d).

Species have been organized into eight groups based on phylogenetic clades (Wikipedia, 2022d):

Filiformis group

- Phaseolus angustissimus A. Gray
- Phaseolus filiformis—slimjim bean
- Phaseolus carterae

Leptostachyus group

- Phaseolus leptostachyus
- Phaseolus macvaughii
- Phaseolus micranthus

Lunatus group

- Phaseolus augusti
- Phaseolus bolivianus
- Phaseolus lunatus—lima bean, butter bean
- Phaseolus pachyrrhizoides
- Phaseolus viridis
- Phaseolus mollis

Pauciflorus group

- Phaseolus pauciflorus
- Phaseolus parvulus
- Phaseolus perplexus
- Phaseolus pluriflorus
- Phaseolus tenellus

Pedicellatus group

- Phaseolus altimontanus
- Phaseolus dasycarpus
- Phaseolus esperanzae
- Phaseolus grayanus
- Phaseolus laxiflorus
- Phaseolus neglectus
- Phaseolus pedicellatus
- Phaseolus texensis

Polystachios group

- Phaseolus albinervus
- Phaseolus jaliscanus
- Phaseolus juquilensis
- Phaseolus maculatus—spotted bean
- Phaseolus marechalii
- Phaseolus polystachios
- Phaseolus reticulatus
- Phaseolus ritensis
- Phaseolus smilacifolius

Tuerckheimii group

- Phaseolus chiapasanus
- Phaseolus gladiolatus
- Phaseolus hintonii
- Phaseolus oligospermus
- Phaseolus tuerckheimii
- Phaseolus xanthrotrichus
- Phaseolus zimapanensis

Vulgaris group

- Phaseolus acutifolius—tepary bean
- Phaseolus albescens
- Phaseolus coccineus—runner bean
- Phaseolus costaricensis
- Phaseolus dumosus—year bean
- Phaseolus parvifolius
- Phaseolus persistentus

- *Phaseolus vulgaris*—common bean, French bean, black bean, kidney bean, pinto bean, green bean

Uncategorized

- Phaseolus amblyosepalus
- Phaseolus anisotrichos
- Phaseolus brevicalyx
- Phaseolus chacoensis
- Phaseolus cibellii
- Phaseolus galactoides
- Phaseolus glabellus
- Phaseolus leucanthus
- Phaseolus macrolepis
- Phaseolus massaiensis
- Phaseolus microcarpus
- Phaseolus nelsonii
- Phaseolus oaxacanus
- Phaseolus plagiocylix
- Phaseolus polymorphus
- Phaseolus sonorensis
- Phaseolus vulcanicus

Synonyms of *Phaseolus vulgaris* L. (Heuzé *et al*., 2015).

1. Phaseolus aborigineus Burkart,
2. Phaseolus compressus DC.,
3. Phaseolus compressus var. carneus G. Martens,
4. Phaseolus compressus var. cervinus G. Martens,
5. Phaseolus compressus var. ferrugineus G. Martens,
6. Phaseolus ellipticus var. albus G. Martens,
7. Phaseolus ellipticus var. aureolus G. Martens,
8. Phaseolus ellipticus var. helvolus Savi,
9. Phaseolus ellipticus var. mesomelos Haberle,
10. Phaseolus ellipticus var. pictus Caval.,
11. Phaseolus ellipticus var. spadiceus G. Martens,
12. Phaseolus gonospermus var. oryzoides G. Martens,
13. Phaseolus gonospermus var. variegatus Savi,
14. Phaseolus nanus L.,
15. Phaseolus oblongus var. albus G. Martens,
16. Phaseolus oblongus var. spadiceus Savi,
17. Phaseolus oblongus var. zebrinus G. Martens,
18. Phaseolus sphaericus var. atropurpureus G. Martens,
19. Phaseolus sphaericus var. minor G. Martens,
20. *Phaseolus vulgaris* var. albus Haberle,
21. *Phaseolus vulgaris* var. mexicanus Freytag, nom. inval.,
22. *Phaseolus vulgaris* var. nanus G. Martens,
23. *Phaseolus vulgaris* var. niger G. Martens,
24. *Phaseolus vulgaris* var. ochraceus Savi,
25. *Phaseolus vulgaris* var. variegatus DC.,
26. Phaseolus zebra var. carneus G. Martens,
27. Phaseolus zebra var. purpurascens G. Martens.

Synonyms of *Phaseolus vulgaris* L. (Wikipedia, 2023e)

1) *Phaseolus aborigineus* Burkart
2) *Phaseolus communis* Pritz.
3) *Phaseolus compressus* DC.
4) *Phaseolus esculentus* Salisb.
5) *Phaseolus nanus* L.

Gene pools

The Genus Phaseolus includes common bean *(P. vulgaris)* and four other cultivated species: the scarlet runner bean (P. coccineus, known for its red/scarlet flower); year-bean (*P. dumosus*, aka *P. polyanthus*, name changed in 1995); tepary bean (P. *acutifolius*); and lima bean (P. lunatus). These species have similar origins in the Americas, the tepary bean is found in northwest Mexico and southern Arizona, scarlet runner and year-beans are found in southern Mexico and the highlands of Guatemala and the lima bean mirrors the common bean in that it has two centres of origin: one in the Andean region and the other in Middle America (Smith and Rao, 2021). There are over 50 species of wild beans in existence. The wild bean originated across a wide geographic area in the tropics and subtropics of Latin America from north central Mexico to northwest

Argentina and is found in forest clearings with well-defined wet and dry seasons (Toro *et al*., 1990). The wild bean evolved patterns of growth and development that assure survival with important implications for genetic improvement (Beebe *et al*., 2008). Significant changes have occurred with domestication and further agronomic selection (Smartt, 1990). These include: (i) loss of seed dormancy; (ii) changed growth habit (from climbing or half-runner to bush); (iii) photoperiod insensitivity; (iv) reduction in fibre and selection of the green bean type of pod from the original dehiscent pod; (v) greatly increased seed size (from 20 to 50 mg in wild material to > 200 mg in cultivated material); and (vi) white seeds that are preferred by the canning industry (Smith and Rao, 2021). Species that can be crossed with P. vulgaris represent an important genetic resource for crop improvement and cover the secondary gene pool *(P. dumosus* and *P. coccineus,* wild P. *costaricensis* and P. *albescens*) and tertiary gene pool *(P. acutifolius* and *P. parvifolius). P. lunatus* is the fifth domesticated species within the genus. It is classified into a quaternary gene pool in relation **to** P. vulgaris and cannot be crossed with common bean (Smith and Rao, 2021).

Races of French Bean (Singh, 1991; Vidhi, 2023**)**

Middle American Races

***Mesoamerica*:** This race includes small-seeded (< 25 g/100 seed) landraces of all seed colours and growth habits. The group is often characterised by an ovate, cordate or hastate terminal leaflet of trifoliate leaves and large, broad cordate or lanceolate bracteoles. Inflorescences are multinoded. Pods are 8-15 cm long, slender, fibrous or parchmented and easy to thresh. This race is distributed throughout the tropical low lands and intermediate altitudes of Mexico, Central America, Colombia, Venezuela and Brazil.

***Durango*:** These are predominantly of indeterminate, prostrate growth habit III, which is characterized by relatively small to medium ovate or cordate leaflets, thin stems and branches, short internodes, and fruiting commencing from and concentrated in basal nodes. These landraces often possess small ovate bracteoles with a pointed tip. The pods are medium sized (5-8 cm), flattened with 4-5 flattened rhombohedric seeds of medium size (25-40 g/100 seeds). This race is distributed in semiarid central and northern highlands of Mexico and Southwestern USA.

***Jalisco*:** This race is often characterized by indeterminate growth habit IV. Plant height can be over 3 m in its natural habitat. The terminal leaflet of trifoliolate leaves is hastate, ovate, or rhombohedric and sometimes relatively large. Stems and branches are weak and have medium-sized or long internodes. Most germplasm from this race possesses medium-sized, cordate, ovate, or lanceolate bracteoles. Fruiting is distributed either along the entire length of the plant or mostly in its upper part. Pods are 8-15 cm long and have five to eight medium-sized seeds, whose shape is round, oval, or slightly elongated and cylindrical or kidney-shaped. Their natural habitat is the humid highlands of central Mexico and Guatemala, where maximum diversity is found.

South American Races

***Nueva Granada*:** Germplasm is mostly of growth habits I, II, and III with medium (25-40 g/100 seeds) and large seeds (< 40 g/100 seeds) of often kidney or cylindrical shapes which vary greatly in colour. Leaves are often large with hastate, ovate, or rhombohedric central trifoliolate leaflets and long, dense, straight hairs. Stem internodes are intermediate to long. Bracteoles are small or medium, and ovate, lanceolate, or triangular. Dry pods are fibrous, hard, medium to long (10-20 cm), and leathery, and possess four to six seeds. The pod beak often originates between the placental and ventral sutures. This race is distributed mostly at intermediate altitudes (< 2000 m) of the northern Andes in Colombia, Ecuador, and Peru, but it is also found in Argentina, Belize, Bolivia, Brazil, Chile, Panama, and some Caribbean countries, including the Dominican Republic, Haiti, and Cuba.

Chile: Landraces are predominantly of indeterminate growth habit III. These are characterised by relatively small or medium hastate, rhombohedric, or ovate leaves; short internodes; small or medium, and narrowly triangular, spatulate, or ovate bracteoles; light pinkish or white flower; medium-sized (5-8 cm) pods, often with reduced fibre content; and round to oval seeds (three to five per pod). Morphologically, these landraces largely resemble germplasm from race Durango, except that seeds of race Chile are round or oval, and fruiting is more sparse. In some of the landraces (e.g., ‘Coscorron’ (G 4474) and ‘Frutilla’ (G 5852), pods exhibit an attractive anthocyanin striping, and in many countries these are harvested for green seeds (green shelled or “granados”) before physiological maturity. This race is distributed in relatively drier regions at lower altitudes in the southern Andes (southern Peru, Bolivia, Chile, and Argentina).

Peru: Key morphological characteristics of germplasm belonging to this race are the large hastate or lanceolate leaves (often basal) and long and weak internodes with either indeterminate or determinate type IV climbing growth habit. In its natural habitat, it is always grown in association with maize and other crops. Pods are often long (10-20 cm) and leathery. Fruiting is distributed either along the entire stem length or only in the upper part of the plants. Seeds are large and often round or oval but can also be elongated. This group is highly photoperiod sensitive and is adapted to moderately wet and cool temperatures often requiring more than 250 days to maturity. The race is distributed from the northern Colombian highlands (>2000 m) to Argentina.

BOTANICAL DESCRIPTION

Common bean presents ten phonological phases during its development, divided into 5 vegetative and 5 reproductive stages: germination (V0); emergence (V1), when the cotyledons appear at ground level; primary leaves (V2), when cotyledons leaf unfold; first trifoliate leaf (V3), when the leaf is entirely unfolded and with the leaflets located in a plane; third trifoliate leaf (V4); flower bud or pre-flowering (R5), when the formation of the first flower bud begins in varieties of determined habit, and when a flower cluster forms in varieties of indeterminate habit; flowering (R6),in the first flowers-in those of a determined habit, flowering begins in the last node of the stem and branches and, in those of indeterminate habit, flowering begins in the lower part of the stem or branches; pod formation (R7), when the first pod appears but the corolla is still visible; pod filling (R8), when the first pods begin to fill up and the active growth of seeds begins; and maturity (R9), when discoloration and drying of the first pods begin, and the seeds are acquiring the shape, solidity and colour typical of the variety. In the determinate varieties, the vegetative development of the main stem stops before flowering, while in the indeterminate it generally ends in stage R8, which is when defoliation also begins (Fernández *et al.,* 1984).

The leaves are trifoliate. The flowers have a tubular calyx of five sepals, a papilionoid corolla of unequally sized petals, ten stamens, and a receptive stigma. The flower color can be white, lilac, purple, or bicolored. The fruits are legumes, also called pods, and the seeds have two cotyledons. The seeds inside the pods are rich in protein (Clavijo, 1980). The common bean (*Phaseolus vulgaris* L.) is a major grain legume consumed worldwide for its edible seeds and pods. It is a highly polymorphic warm-season, herbaceous annual. There are 2 plant types: erect herbaceous bushes, up to 20-60 cm high; and twining, climbing vines up to 2-5 m long. It has a taproot with many adventitious roots. The stems of bushy types are rather slender, pubescent and many-branched. In twinning types, the stems are prostrate for most of their length and rise toward the end. The leaves, borne on long green petioles, are green or purple in colour and trifoliate. Leaflets are 6-15 cm long and 3-11 cm broad. The inflorescences are axillary or terminal, 15-35 cm long racemes. The flowers are arranged in pairs or solitary along the rachis, white to purple and typically papillonaceous. Once pollinated, each flower gives rise to one pod. Pods are slender, green, yellow, black or purple in colour, sometimes striped. They can be cylindrical or flat, straight or curved, 1-1.5 cm wide and up to 20 cm in length. The pods may contain 4 to 12 seeds. The seeds are 0.5-2 cm long, kidney-shaped and highly variable in colour depending on the variety: white, red, green, tan, purple, gray or black (Heuzé *et al*., 2015). *P. vulgaris* belongs to the Fabaceae family, which comprises species displaying a wide variety of forms: trees, shrubs and herbs, including many with a climbing growth habit. Most species bear five-petaled flowers with a distinctive papilionaceous or butterfly-like shape. The flowers have a single large upright petal, flanked by two horizontal "wing" petals, and subtended by two petals at the bottom of the flower, partially or completely joined to form a boat-like "keel." Flowers typically have ten stamens, nine of which may form a tube surrounding the ovary and one that is separate from the others and positioned above the ovary, although there are variant stamen configurations in some species. The fruit of Fabaceae species is the legume –a single-carpelled pod of various shapes and sizes, bearing from one to many seeds. In many species the pod splits, either along one or both edges, known as the placental and central sutures, to release the seeds. *P. vulgaris* shares many of the features characterising the family, but two features distinguish the entire *Phaseolus* genus from the rest of the family: the keel of the flower terminates in a coil, having from one to two turns and uncinate hairs are present on both vegetative and reproductive structures of the plant. The wild ancestor of *P. vulgaris* has been referred to as the same species; as a variety of domesticated common bean, *P. vulgaris* var. *mexicanus;* as a separate species, *P. arborigineus* ; and as a subspecies, *P. vulgaris* subsp. *arborigineus* (OECD, 2016). Cultivated *P. vulgaris* has a taproot-based root system with lateral roots typically located within the top 15 cm of soil. The roots are colonised by *Rhizobium* bacteria, resulting in irregular root nodules. The stems are typically hairy, with the length and density of the hairs dependent on the cultivar. However, short, hooked hairs (uncinate hairs) are always present on the younger portions of the stems. The hairs have a role in both disease and insect resistance. There is evidence that the hairs interrupt the production of fungal spores, thereby reducing secondary inoculum (*e.g.* bean rust, *Uromyces appendiculatus*) and can physically wound insects (such as leafhoppers, *Empoasca fabae*), resulting in reduced predation. When the climate is sufficiently warm to allow a semi-perennial growth habit, the stems of wild *P. vulgaris* can grow to a diameter of 1.5 cm and may develop a corky outer layer. The leaves are trifoliolate and alternate on the stems. The leaflets are entire and somewhat hairy, 8-15 cm x 5-10 cm, with small stipules. Leaflet shape differs among the cultivars, but leaflets generally have broad bases and pointed tips. Flowers are borne on axillary or terminal racemes, in colours of white, pink or violet, depending on the cultivar. The bisexual flowers are keeled, and the keel terminates in a coil, with one to two turns. The seed pods are narrow, 8-20 cm x 1-2 cm, with up to 12 seeds per pod, but most varieties have 4-6 seeds. Seeds are produced in a wide variety of colours, depending on the cultivar, and the seeds vary considerably in size,with a range of 150-900 g per 1 000 seeds (OECD, 2016).

The *Phaseolus vulgaris* plant thrives in warm, moist soils in tropical and temperate regions, being native to Mexico and Peru, but grown worldwide in many other countries. This annual herbaceous plant grows up to 18 inches in height, with broad, green leaves, white flowers and long, green fruits. These unripe fruits are harvested after gauging their succulent taste and consumed before the white seeds in them can mature fully. French beans or green beans have a green outer skin, with a slightly fleshy interior with tiny white seeds, with or without strings on the outside depending on the local variety. They have a crispy texture and a subtly sweet taste which makes them a wonderful addition to a host of dishes like salads, soups, curries, dals and casseroles (Wellness, 2021). The common bean is a highly variable species with a long history. Bush varieties form erect bushes 20–60 cm tall, while pole or running varieties form vines 2–3 m long. All varieties bear alternate, green or purple leaves, which are divided into three oval, smooth-edged leaflets, each 6–15 cm long and 3–11 cm wide. The white, pink, or purple flowers are about 1 cm long, and they give way to pods 8–20 cm long and 1–1.5 cm wide. These may be green, yellow, black, or purple, each containing 4–6 beans. The beans/seeds are smooth, plump, kidney-shaped, up to 1.5 cm long, range widely in color and are often mottled in two or more colors. Raw or undercooked beans/seeds contain a toxic protein called phytohaemagglutinin (Wikipedia, 2023e). The common bean is an annual herbaceous plant that features compound leaves with three leaflets. Most varieties grow either as an erect bush or as a climbing plant. When the climbing type is grown for its immature pods, such as for green beans, artificial supports are necessary to facilitate harvesting. Varieties differ greatly in size, shape, colour, and fibrousness or tenderness of the immature pods. In general, varieties grown for dry mature seeds produce pods that are too fibrous to be eaten at any state of development. Most edible-podded beans produce relatively low yields of mature seeds, or seeds that are of low eating quality. Seed colours range from white through green, yellow, tan, pink, red, brown, and purple to black in solid colours and countless contrasting patterns **(Fig. 6)** (Britannica, 2023).

Description of Runner bean (*Phaseolus coccinius*): Most varieties have red flowers and multicolored seeds (though some have white flowers and white seeds), and they are often grown as ornamental plants. The vine can grow to 3 m (9 ft) or more in length. It differs from the common bean *(P. vulgaris)* in several respects: the cotyledons stay in the ground during germination, and the plant is a perennial vine with tuberous roots (though it is frequently treated as an annual in colder climates). The knife-shaped pods are normally green; however, there are very rare varieties bred by amateurs that have very unusual purple pods **(Fig. 7)** (Wikipedia, 2023).

Wild *Phaseolus vulgaris:* Wild *P. vulgaris* differs from the cultivated types in several characteristics. The plants are typically indeterminate climbers with shorter main stems than the cultivated varieties. Main stem branches are more numerous, but with fewer nodes. A twining growth habit helps the plant to better compete for sunlight with forest vegetation than a shrubby determinate habit. Flowers, seed pods and seeds of the wild species are more numerous; pods and seeds are smaller; and the pods have adehiscence slit near the pedicel and are explosively dehiscent. The wild species has a much longer flowering period than cultivated varieties (OECD, 2016).

Floral biology and Pollination *:* Flowers of wild *Phaseolus vulgaris* are generally purple, pink or white. The floral structure of P. vulgaris contributes to the high rate of self-pollination: anther dehiscence and stigma receptivity occur at the same time, before the flower is fully open, and the anthers and stigma are positioned near one another at the time of anther dehiscence and stigma receptivity. Bracts on the rachis of the inflorescences are persistent, and the size and shape of the bracteoles are distinguishing characteristics of bean cultivars (OECD, 2016). The pollen grains of common bean have a diameter of approximately 30 micrometres.They are spherical to triangular and tricolporate in shape, with a reticulate exine. Little is known about the longevity of bean pollen. Common bean is regarded primarily as a self-pollinating species, due to floral morphology. However bumble bees, carpenter bees and honeybees have been identified as potential pollen carriers between cultivated bean plants. These species, as well as other insects such as thrips, are responsible for the low frequencies of outcrossing observed between bean varieties grown in close proximity. Published reports indicate that the outcrossing frequency approaches zero when bean plants are separated by three to ten metres, but outcrossing rates are dependent on both the bean genotype and the environmental conditions. Intervarietal cross-pollination would also depend on synchrony of flowering (OECD, 2016).

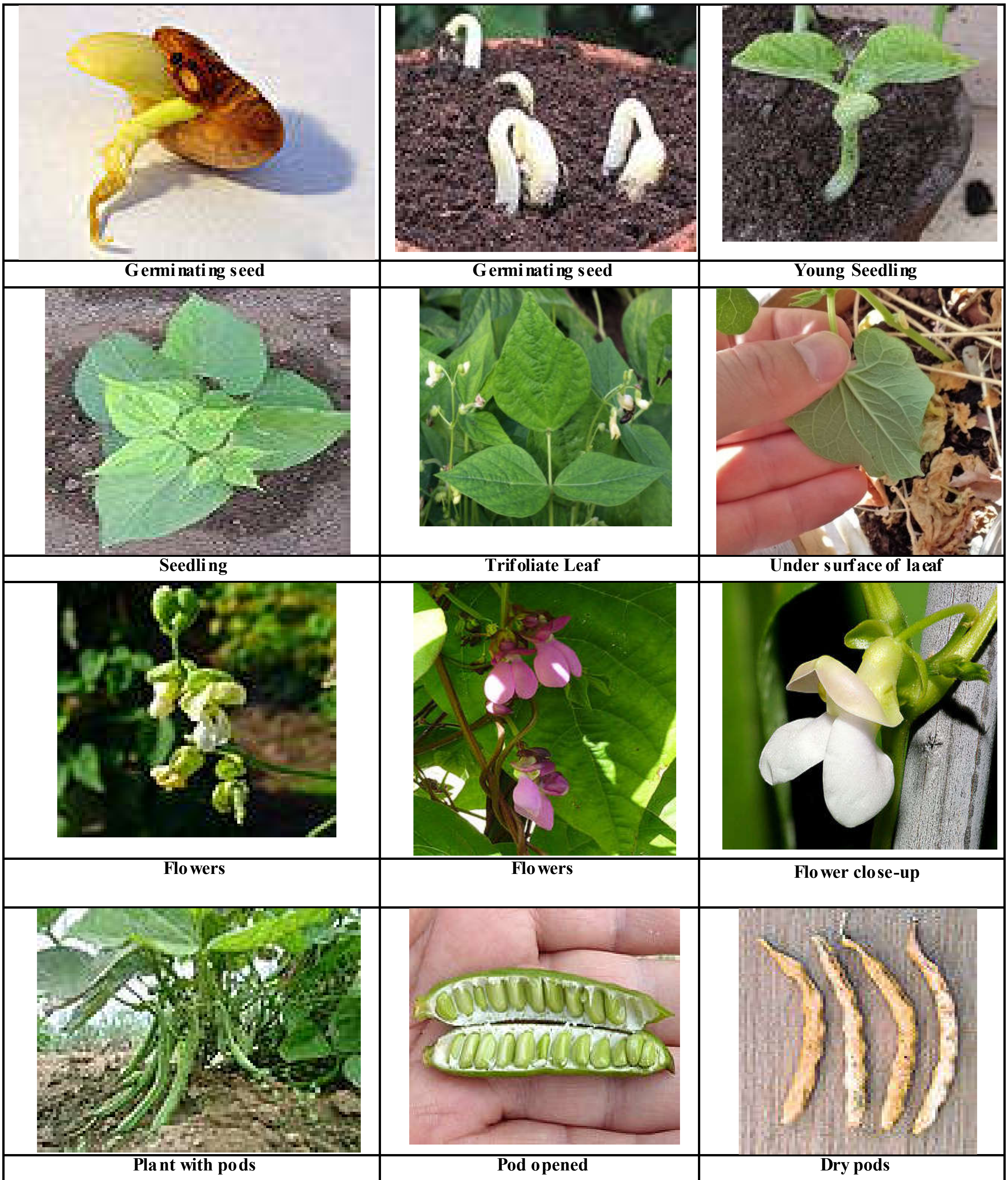

Fig. 6: Botanical Description of Common bean *Phaseolus vulgaris* L.

Climbing plants

Climbing plants

Red flowers

Red flower

Knife-shaped pods

Different colored pods

Seeds

Seeds

Seeds

Seeds

Fig. 7 : Botanical Description of Runner bean- Phaseolus coccineus

GENETIC DIVERSITY

There is variability for plant type *viz.,* Bush and climbing plants/ determinate and indeterminate plants; variability for pod type *viz.* 1) Green bean, 2) Wax bean (Yellow pods), 3) Romano/Italian/Flat podden bean and 4) Round podded bean; variability for pod color (Fig. 8) *viz.,* 1) Green, 2) Yellow (wax), 3) Purple, 4) Multi coloured and 5) Dark green (Blue Lake type) pod colors; variability for string on the pod *viz.,* String bean and Stringless beans; variability for seed shape (Fig. 9 & 10) *viz.,* 1) Round, 2) Round to elliptic, 3) Elliptic and 4) Kidney-shaped seeds; variability for seed color (Fig. 9 & 10) *viz.,* 1) Black, 2) White, 3) Green, 4) Grey, 5) Yellow, 6) Buff, 7) Red and 8) Violet colored seeds; Snap Beans viz., 1) Home garden types (Cover a wide range of pod sizes, shapes, colours, flavours, determinate bush to indeterminate types), 2) Fresh market types (Grown close to market, cover a wide range of types), 3) Shipper types (Appear fresh-looking after several days in transit), and 4) Processing/freezing types (Fresh market types with light to medium green colour, *e.g.,* Tender crop); and variability for use viz., Horticultural beans/ Vegetable bean and Green shell or fresh grain beans/Dry beans **(**Vidhi, 2023**).**

	
Green	Pink
	
Red	Purple

Fig. 8. Variability for pod color

		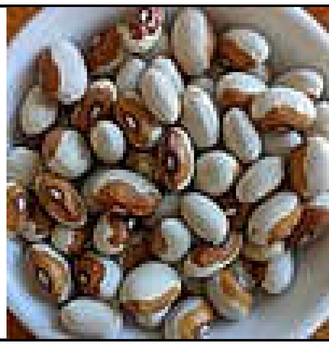
		
		

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Fig. 9: Variability for seed color, shape and size

Fig. 10: Genetic Diversity in dry common beans

Cultivated common bean were developed from wild common bean, and domestication has introduced several agronomically useful traits: indeterminate and bush types; increased leaf, pod and seed size; and suppression of pod dehiscence and seed dormancy. Vast diversity of seed size, shape and colour has also resulted from domestication (Singh *et al*., 1991; Broughton *et al*., 2003). Crop earliness has been enhanced by selecting for photoperiod insensitivity. Domestication of the common bean has also resulted in a significant reduction in genetic diversity, compared to the species in the wild (OECD, 2016). Sinkovič *et al*. (2019) described for the first time large-scale morphological seed characterization of the common and runner bean collection germplasm conserved in the Slovenian gene bank. The germplasm evaluated has a wide range of morphological variability based on fourteen seed characteristics. The study encompassed 953 accessions of common bean and 47 accessions of runner bean. Seeds of each accession were evaluated for quantitative characteristics: (Seed length) L (range 7.3–27.2 mm); (Seed thickness) T (range 4.2–11.0 mm); (Seed width) W (range 0.3–16.5 mm); L/W (range 0.4–2.6 mm); W/T (range 0.6–2.2 mm); and 100 for common (range 19.3–98.4 mm) or 10 for runner (range 7.6–26.7 mm) bean seed weight. Furthermore, seeds were evaluated using qualitative characteristics: seed colour (50.3% of common beans and 76.6% of runner beans were colour mixture), number of seed colours (49.7% of common beans had one colour and 76.6% of runner beans two colours per seeds), primary/main seed colour (31.5% of common beans were brown and 25.5% of runner beans black), predominant secondary seed colour (14.6% of common beans had red colour and 34.0% of runner beans brown colour), distribution of secondary seed colour (41.8% of common beans and 74.5% of runner beans had secondary colour distributed on the entire seed), seed veining (62.5% of common beans and 80.9% of runner beans had weak seed veining), seed shape (33.1% of common beans had oval/circular to elliptic and 53.2% of runner beans cuboid/elliptic seed shape), and seed colour and coat pattern (11.5% of common beans had large and one-colour brown seeds; 25.5% of runner beans had bicolour constant mottled seeds) (Sinkovič *et al*., 2019).

In Slovenia, the majority of the bean production is based on local populations and varieties grown by small-scale farmers in low input production systems. Populations are well adapted to the specific growing conditions and microclimate agroenvironments and show a great seed morphological diversity. The aim of the present study was to evaluate the common bean and runner bean germplasm collections from Slovene gene bank using seed characteristics and to establish clusters of the most distinct genetic resources, based on morphological seed evaluation (Sinkovič *et al.,* 2019). Based on quantitative measurements, the common bean accessions were classified according to the L into three groups, i.e., small, medium and large. The first group included accessions with small seeds and the L < 10.0 mm (18 accessions or 2%); the second group accessions with medium seeds measuring from 10.0 to 15.0 mm (734 accessions or 77%); and the third group accessions with large seeds and L > 15.0 mm (201 accessions or 21%) (Fig. 11) (Sinkovič *et al.,* 2019).

Fig. 11: Common bean accessions (*Phaseolus vulgaris* L.) groups distribution according to seed length: (First Row) small, (Second Row) medium, and (Third Row) large

Based on quantitative measurements, the common bean accessions were classified according to the 100 seed weight into three groups, i.e., low-weight, medium-weight and high-weight. Low-weight seeds group included common bean accessions with 100 seed weight < 35.0 g (112 accessions or 12%); the medium-weight seeds group accessions with 100 seed weight measuring from 35.0 to 75.0 g (801 accessions or 84%); and the high-weight seeds group accessions with 100 seed weight > 75.0 g (40 accessions or 4%) (Fig. 12) (Sinkovič *et al.*, 2019).

Fig. 12 : Common bean accessions (*Phaseolus vulgaris* L.) groups distribution according to 100 seed weight: (First Row) low-weight, (Second Row) medium-weight, and (Third Row) high-weight.

Based on the quantitative measurements, the accessions of runner bean were classified according to the L into three groups, i.e., small, medium and large. The first group included runner bean accessions with small seeds and the L < 20.0 mm (20 accessions or 43%); the second group accessions with medium seeds measuring from 20.0 to 25.0 mm (23 accessions or 49%); and the third group accessions with large seeds and L > 25.0 mm (4 accessions or 8%) (Fig. 13) (Sinkovič *et al*., 2019).

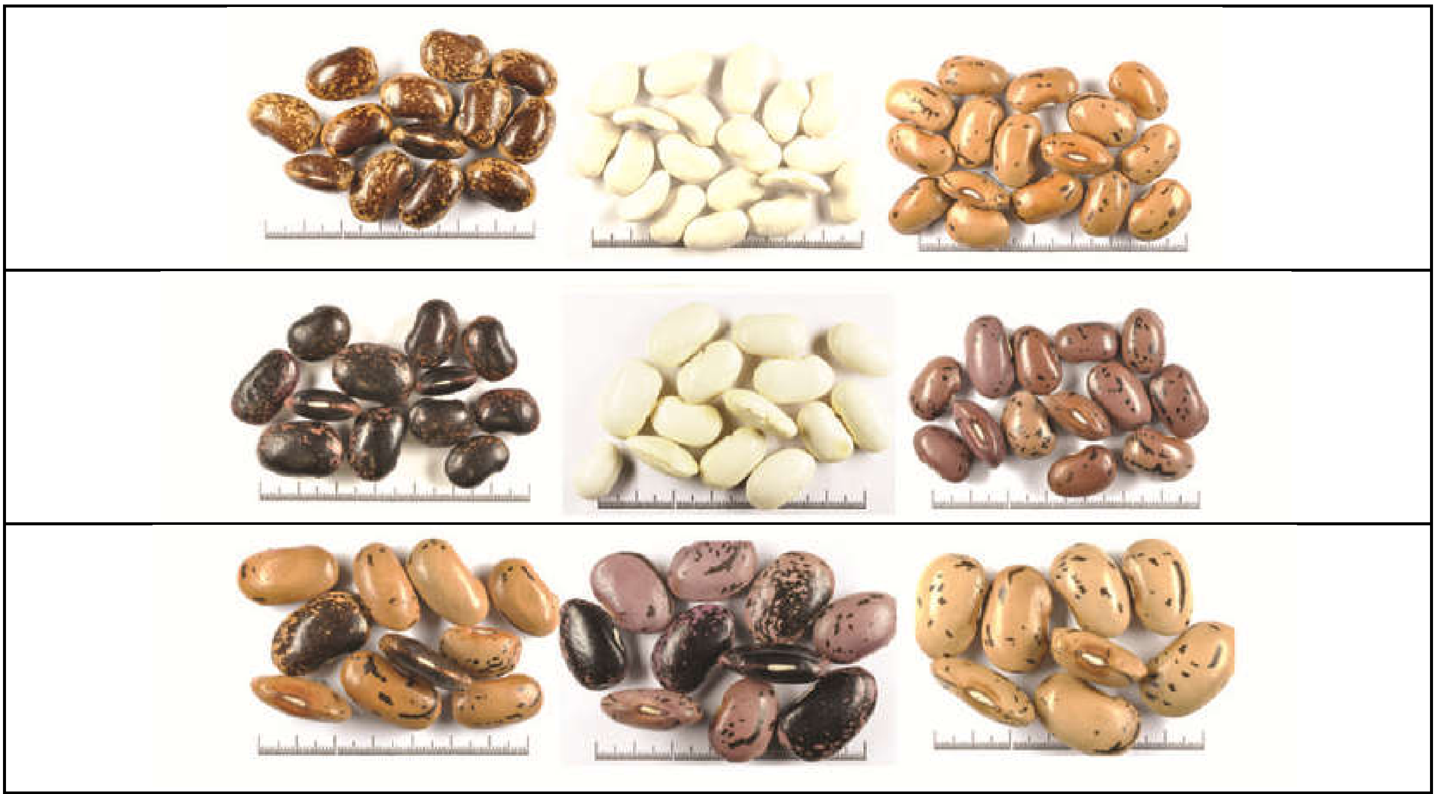

Fig. 13 : Runner bean accessions (*Phaseolus coccineus* L.) groups distribution according to seed length: (First Row) small, (Second Row) medium, and (Third Row) large

Based on the quantitative measurements, the accessions of runner bean were classified according to the 10 seed weight into three groups, i.e., low-weight, medium-weight and high-weight. Low-weight seeds group included common bean accessions with 10 seed weight < 10.0 g (4 accessions or 9%); the medium-weight seeds group accessions with 10 seed weight measuring from 10.0 to 20.0 g (41 accessions or 87%); and the high-weight seeds group accessions with 10 seed weight > 20.0 g (2 accessions or 4%) (Fig. 14) (Sinkovič *et al*., 2019).

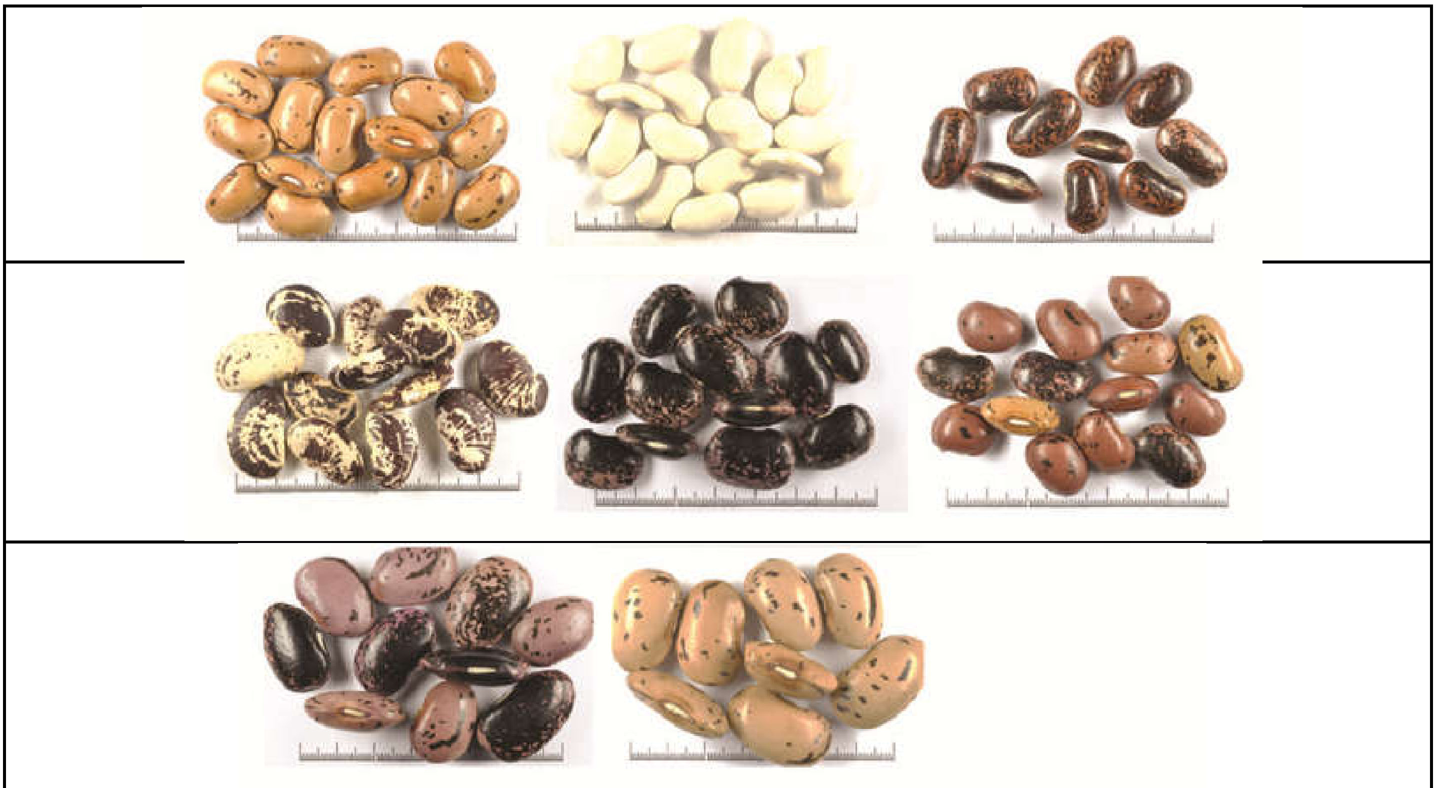

Fig. 14: Runner bean accessions (*Phaseolus coccineus* L.) groups distribution according to 10 seed weight: (First Row) low-weight, (Second Row) medium-weight, and (Third Row) high-weight.

The aim of this study was to determine the variability and genetic advancement of common bean varieties. Randomized Completed Block Design was used to evaluate 15 varieties at Koga and Chefa in 2013. Cluster, principal, and biplot analysis including genetic parameter estimation were done following analysis of variance. Most of the traits have a high phenotypic and genotypic coefficient of variation, heritability, and genetic advance, and selection was effective in the breeding program. The breeding program has brought about 0.27 tonnes of seed yield increment or an annual rate of genetic progress of 0.0077 t ha^{-1} (0.37% ha^{-1} $year^{-1}$). However, the breeding program should reconsider the breeding procedure as there are some varieties released in the same year with similar genetic potential (Kefelegn *et al.,* 2020). The objective of this study was to examine the genetic diversity present among 297 common bean genotypes using 2554 SNPs and 12 insects and seed-related traits. The phenotyping was done under laboratory condition while the genotyping was conducted by using the Illumina SNP BeadChip. High phenotypic diversity among traits were recorded, ranging from 0.87 to 0.96, with a mean of 0.92. Principal component and discriminant analyses identified four PCs and three discriminant functions, which explained 82% and 100% of the total phenotypic variations among genotypes, respectively. Polymorphic Information Content ranged from 0.21 to 0.38, with a mean of 0.34. The mean gene diversity among genotypes ranged from 0.24 to 0.50, with a mean of 0.44. Genetic distance ranged from 0.19 to 0.82, with a mean of 0.62, while the phenotypic distance ranged from 0.00 to 1.00, with a mean of 0.64 were observed aamong genotypes. The analysis of molecular variance revealed highly significant differences ($p<0.001$) among and within individuals and among populations. Both the SNP and the phenotypic markers grouped the 297 genotypes into two major distinct clusters and three sub-clusters. This information is useful for identification and development of common bean germplasm with economically valuable traits and the conservation and utilization of genotypes (Tigist *et al.*, 2020).

Mesera *et al*. (2022) conducted study on one hundred common bean landraces at the Jimma Agricultural Research Center, Melko, with the objective of assessing genetic variability and association of traits in common bean landraces collected from different parts of Ethiopia. The experiment was laid out in a simple lattice design with two replications. Analysis of variance showed significant differences among genotypes for all traits. This highly significant difference indicates the existence of large variability among genotypes. High phenotypic coefficients of variation and genotypic coefficients of variation were obtained for plant height (19.43, 11.73), pod length (11.27, 10.69), and 100-seed weight (15.42, 12.74). High heritability in the broad sense was found for days to 50% flowering (66.98), days to 90% maturity (87.43), pod length (90.03), pod width (78.23), harvest index (98.67), and 100-seed weight (68.31). High genetic advance as a percentage of mean with high heritability was obtained for pod length, pod width, harvest index, and hundred seed weight. Grain yield had a positive and significant association with pod length (rp = 0.153, rg = 0.282) and 100-seed weight (rp = 0.294, rg = 0.492). Hundred seed weight exerted the highest positive direct effect (0.294) on grain yield at genotypic level. The D^2 classified landraces into 7 clusters and one solitary, which makes them moderately divergent. The highest inter-cluster distance was observed between clusters VII and IV. The first five principal components with eigenvalues greater than one altogether explained about 79.56% of the total variation. In conclusion, the top high-yielding landraces, namely, P#1247, P#1092, P#1077, P#861, P#990, P#763, P#58, and P#857, should be included in the next breeding program. 100-seed weight had the highest direct effect and a positive significant association with grain yield. Thus, it should be considered as the selection criteria for further common bean yield improvement (Mesera *et al*., 2022). A study was conducted for evaluation of biological diversity of common bean landraces from Azad Kashmir and Northern areas of Pakistan using morpho-physiological and molecular markers. Thirty-five common bean ecotypes along with one check variety were collected from different altitudes of Azad Kashmir and Northern Pakistan and screened for biological diversity. Morphological characterization revealed high genetic diversity in parameters including stem anthocyanin, growth type, days to flowering, pods/plant and 100 seeds weight. Genomic characterization using SSR markers, for allelic diversity evaluation among germplasm, also provided diverse profile with 83.3% polymorphism in banding pattern. The bulk of gene pool diversity evaluated within bean landraces may help to initiate breeding program for common bean improvement (Jannat *et al.,* 2022).

GENETICS AND CYOTOGENETICS

Both cultivated and wild forms of the species are diploid (2n = 22), and the two forms hybridise readily. Crosses between the Middle American and Andean gene pools are easily accomplished, although differences in flowering time can make crossing difficult. It has been noted that divergences between the two gene pools may make recovery of progeny more difficult than with crosses within the two pools, and occasionally crosses result in dwarfism or lethality. This hybrid weakness is thought to be due to semi-dominant alleles of two "dosage-dependent lethal" (DI) genes. Depending on the heterozygosity of these two genes, hybrids between the two gene pools may exhibit complete lethality, lethality at high temperatures or only sublethal symptoms (OECD, 2016).

Qualitative Genetics of French Beans (Vidhi, 2023)**:** An exhaustive list of about 150 genes of Phaseolus has been compiled by Yarnell (1965). A few important genes from that list as summarised by Ram and Singh (1994) are given in **Table 1.**

Table 1: Some important genes of *Phaseolus vulgaris*

Gene symbols	Phenotype
Are	Resistance to anthracnose
Da	Straight pod
dw 1 dw 2	Duplicate gene causing dwarf plant
Ext	Interspecific gene for external stigma in *Phaseolus coccineus*
Fa	Basic gene for pod membrane
Fin (fin^+)	Indeterminate vs 'fin' determinate plant growth
gas	Causes both male and female sterility
in	Determinate growth = (fin)
itor	With *ram* triple branched inflorescence
L	Long vs l short internodes
mo	Conditions resistance to bean virus
neu^+	Short day flowering response
ri	Confers resistance to bean virus 1
St	Stringy pods
T	Twining habit vs t non-twining
te	Pod short (5– 8 cm) and narrow
To	Cell wall fibre
tri	Produces three cotyledons
Uni	Unifoliate leaves

There are atleast 8 genes controlling seed colour and one P is basic to coloured seeds so that all white seeded forms are homozygous recessive pp and breed true. Black seed is epistatic to all other colours. French-bean (*Phaseolus vulgaris* L.) is an important legume crop to be used as green pod vegetable (known by various names as snap bean, string bean, garden bean, fresh bean) or dry seeds (known as dry bean). The dry seed type varieties are called as 'Rajmash' in India. Snap bean seed can also be used in dry state like the dry bean types. In that case, pinto, kidney, pink, small red, etc., terms are also used (Vidhi, 2023).

Cytogenetics: Both cultivated and wild forms of the species are diploid (2n= 2x = 22), and the two forms hybridise readily (TSP, 2023; *Wikipedia, 2023*).

BREEDING

Germplasm: Large germplasm collections of domesticated and wild forms are located at Centro Internacional de Agricultura Tropical, Cali, Colombia; United States Department of Agriculture (USDA), Pullman, Washington, USA; Vavilov Research Institute, St. Petersburg, Russia; Leinbiz-Institut für pflanzengenetik und kulturpflanzenforschung (IPK), Gatersleben, Germany; Centro Nacional de Recursos Fitogenéticos - Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (CRF-INIA), Alcalá de Henares, Spain; and Misión Biológica de Galicia - Consejo Superior de Investigaciones Científicas (MBG-CSIC), Pontevedra, Spain. The reference collection of Phaseolinae is located at the National Botanical Garden, Meise, Belgium (De Ron and Santalla, 2013). The common bean (*Phaseolus vulgaris* L.) is the most important grain legume for direct human consumption on a global scale. Current bean germplasm collections show a wide variation of phenotypes, although genetic erosion is gradually affecting this species as in many countries local traditional varieties are being replaced by elite cultivars. This crop has spread to every continent over the past few centuries, which has resulted in a complex genetic structure of bean germplasm outside its areas of origin and domestication (South and Central America). Some evidence indicates that this germplasm is more complex than previously thought and contains additional, as yet unexplored, diversity. This is especially the case in southern Europe, particularly in the Iberian Peninsula, where it was introduced in the early sixteenth century and has been documented as a secondary focus of domesticaton of the species (De Ron *et al.*, 2016).

International Centre for Tropical Agriculture (CIAT), Cali, Colombia has the mandate for global germplasm collection and conservation of Phaseolus beans. The status of bean collections held at the CIAT Genetic Resources Unit, Colombia is given in Table 2 (Vidhi, 2023).

Table 2. Bean germplasm collections at CIAT.

Species Introduced	Number of accessions
Phaseolus vulgaris	31,619
P. vulgaris wild ancestors	364
P. lunatus	2,563
P. lunatus wild ancestors	63
P. coccineus ssp. *coccineus*	792
P. coccineus ssp. *polyanthus*	415
P. coccineus wild ancestors	67
P. acutifolius	134
P. acutifolius wild ancestors	50
Wild non-cultivated	
P. anisotrichus, *P. filiformis*	
P. galactoides, *P. microcarpus*	
P. metcalfei, *P. pedicellatus*	
P. polystachius, *P. parvulus*	
P. ritensis, *P. wrightii*	
P. pachyrrhizoides	87
Total	**36,154**

CIAT, Cali, Colombia has mandate to conserve over 30,000 accessions of domesticated and wild beans, as well as newer collections made in collaboration with International Board for Plant Genetic Resources (IBPGR) now International Plant Genetic Resources Institute (IPGRI). The IPGRI database contains passport data of over 30000 accessions representing the Phaseolus collections maintained in European gene-banks (www(dot)gene bank(dot)at/phaseolus) (Vidhi, 2023).

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These accessions are maintained under two types of storage: 1) Short-medium term storage at 5° C-working collections. And 2) Long term storage sealed in laminated bags at 5-8% seed moisture and stored at -20° C.
In India, French-bean germplasms are conserved at NBPGR-Regional Station, Bhowali Uttarakhand and Regional Station, Shimla (Vidhi, 2023).

Breeding Goals of French Beans

1) High pod yield, 2) Non-stringy, long pods, flat or round in shape, 3) Early pod harvesting, 4) Bush/pole plant type, 5) High number of green pods/plant, 6) High number of pod clusters/plant, 7) High number of primary, branches/plant, 8) Free from inter-locular space and 9) Abiotic stress tolerance (high and low temperature, drought, salinity, soil nutrient deficiency, N.fixation, resistance to diseases and pests) (Vidhi, 2023).

Breeding for Yield

Strategies employed by dry bean breeders to improve yield include early generation testing, ideotype breeding, selection for physiological efficiency, and selection based on genotypic performance and combining ability across gene pools of *Phaseolus vulgaris*. Ideotype breeding has been successfully deployed to improve yield in navy, pinto and great northern seed types. The ideotype method is based on an ideal plant architecture to which breeders target their selection. Breeding for physiological efficiency is important in combining increased biomass, high growth rates and efficient partitioning. Genotypic performance and combining ability are also critical for yield improvement, since crosses between gene pools can exhibit negative combining ability and problems with lethality, whereas interracial crosses within the same gene pool exhibit the greatest potential. Breeders must work within specific constraints for growth habit, maturity, seed quality and disease resistance. A three-tiered pyramidal breeding strategy is proposed to facilitate yield improvement in dry bean. Breeding of elite, agronomically acceptable germplasm within the same market class is restricted to the apex of the pyramid. The intermediate level has fewer constraints and greater access to diverse germplasm. Interracial crosses within the same gene pool are utilized to exploit genetic differences within adapted material. Extracting genetic diversity from un-adapted sources, including wild germplasm and other *Phaseolus* species, is conducted at the base of the pyramid. The objective of this breeding strategy is the movement of improved germplasm towards the apex, using different breeding procedures to optimize improvement at each tier of the breeding pyramid **(Fig.15)** (MSU, 2023).

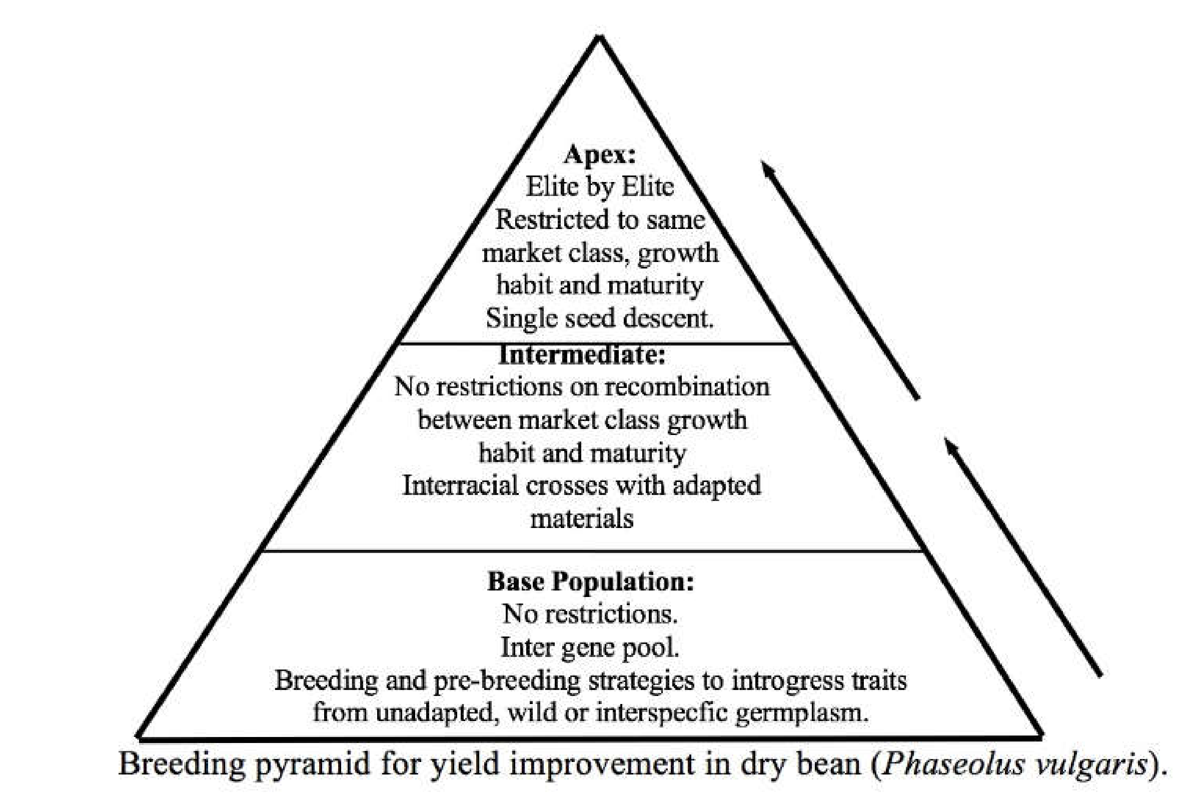

Fig. 15: Breeding pyramid

Breeding Procedures of French Beans: French bean is an autogamous crop and breeding procedures applicable to such crops are generally applicable to this. Pedigree selection is effective for such characters as height, maturity and disease resistance. However, single plant selection for yield in early generations has not been encouraging. In this situation, the use of bulk-breeding is often suggested. Results often suggest that bulk-breeding does not lead to the elimination of high yielding genotypes. Therefore, bulk- breeding would appear to be a better use of resources, when selecting for seed yield. The populations are bulk-bred until F_5 and then individual plant progenies are evaluated in replicated yield trials. A procedure of gamete selection followed at CIAT, Cali, Colombia is given **Fig. 16**. Gamete selection is a selection based on F_1 derived families that come from crosses that are multiple-parent, heterogeneous and heterogametic. In bean breeding, the contributions of Anderson, Frazier Parker, Pierce, Zaumeyer, Silbernagel, Shree Pal Singh and Gepts deserve special mention and appreciation (Vidhi, 2023).

Hybridisation and Introgression

Natural crosses between common bean and other *Phaseolus* species are inhibited by a variety of incompatibility mechanisms, such as incomplete chromosome pairing, sterility of F_1 hybrids and embryo abortion. Other barriers, such as photoperiod sensitivity and flowering time, have also been noted as limiting opportunitiesfor interspecific crossing without human intervention. However, wild-collected plants representing hybrids of *P. vulgaris* x P. coccineus have been reported. Experimental crosses have been attempted between *P. vulgaris* and several closely related species, such as P. coccineus, *P. dumosus*, *P. costaricensis*, *P. acutifolius*, *P. parvifolius*, *P. filiformis* and *P. angustissimus*, to take advantage of disease and insect resistance and abiotic stress tolerance traits that these species possess. However due to partial incompatibility, viable offspring from such crosses may require embryo rescue, and hybrids frequently exhibit dwarfism and partial or complete sterility. Using *P. vulgaris* as the female parent may reduce the need for embryo rescue. Data indicate that under the right environmental conditions, cultivated *P. vulgaris* plants can pollinate nearby wild *P. vulgaris* plants, resulting in fertile hybrids and the potential for domestication traits to introgress into wild populations. Manual crosses between cultivated bean varieties and wild *P. vulgaris* are easilymade, resulting in viable, fertile F_1 offspring(OECD, 2016).

Population development
Development of single, double, and multiple crosses, using plant-to-plant, pairwise pollinations between females and males at Palmira
↓
Developing F_1–derived F_2($F_{1.2}$ families)
Space-planting the final F_1 crosses (BZ 9780, G X 9792) at Palmira
↓
Harvesting each F_1 plant separately
↓
Selecting promising families
Evaluating $F_{1.2}$ for ALS and CBB at Quilichao
↓
Evaluating $F_{1.3}$ for ANT at Popayan and LHP at Palmira
Selecting $F_{1.3}$ segregating for ALS, ANT, CBB, and LHP resistance
Selecting for carioca-type seeds
↓
Evaluating $F_{1.4}$ for BGM under greenhouse conditions at Palmira, and for ANT at Popayan
↓
Selecting $F_{1.4}$ segregating for ALS, ANT, BGM, CBB and LHP
↓

Line development and seed increase
Space-planting $F_{1.5}$ at Palmira
↓
Harvesting separately each upright plant possessing carioca-type seeds
↓
Growing plant-to-progeny rows of $F_{5.6}$ at Popayan under ANT pressure
↓
Bulk-harvesting lines uniform for ANT resistance, flower colour, growth habit, maturity, and seed type
↓
Seed increase of $F_{5.7}$ at Quilichao and $F_{5.8}$ at Palmira
↓
Evaluating $F_{5.9}$ lines
Separate nurseries for BCM, BGM, ALS, ANT, CBB and LHP
↓
Selecting lines possessing BCM, ANT, and CBB resistance
↓
Replicated yield trial in seven environments

Fig. 16. Population development, evaluation and selection procedure used to breed for multiple resistance in common bean

Varieties of French Beans: Many well-known bean cultivars and varieties belong to this species, and the list below is in no way exhaustive. Both bush and running (pole) cultivars/varieties exist. The colors and shapes of pods and seeds vary over a wide range (Wikipedia, 2023e). The following varieties of French beans **are listed by** Vidhi (2023**):**

Bush Types

Contender: This is an introduction from USA. Plants are bush type and dwarf. Flowers are pink. Pods are round, green, about 15 cm long, non-stringy, meaty and slightly curved. Seeds are light brown. First green pod picking can be had in 50 – 55 days after sowing. It is susceptible to bean common mosaic virus. Green pod yield potential is about 80 q/ha. It has been recommended by IARI, New Delhi and is very old variety.

Pusa Parvati: This variety has been developed as a mutant at IARI Regional Research Station, Katrain from irradiation of a yellow podded line EC 1906. The plants are bush type, early, taking about 50 days for first green pod picking. Pods are long (15 – 18 cm), straight, flattish round, string-less and green in colour. Green pod yield potential is 80 q/ha. It is susceptible to viral diseases.

VL Boni 1: This variety has been developed as a selection from germplasm at Vivekanand Parvatiya Krishi Anusandhanshala, Almora. Plants are dwarf (40 cm). It was identified for release by 1985 vegetable workshop for the northern hilly regions. Flowers are white and purple tinged. The pods are medium long (12 cm), round, fleshy, non-stringy with pale green colour. Pods are ready for harvesting in about 55 says. It can be planted in the hills from March to July. It is susceptible to viral diseases. The yield of green pods is about 80 q/ha.

Arkal Komal: It is an Australian introduction by IIHR, Bangalore, accessioned as IIHR 60. It was identified by 1987 vegetable workshop for northern hills, semi-arid Lava plateau, central highlands and humid to semi-arid western Ghats and Karnataka plateau. Plants are erect and bushy. Pods are straight, flat, tender, green and suitable for transport. First green pod picking takes 65-70 days. The green pod yield potential is about 100 q/ha.

Pant Anupama: This was obtained through selection in germplasm lines maintained at GBPUAT, Pantnagar. The line was evaluated as UPF 191 in the coordinated trials. The plants are dwarf with dark green foliage. It is a prolific bearer with smooth, tender, non-stringy, medium long, round, straight, translucent, and green pods concentrated at mid-height. The pods are below the canopy and thus, remain protected from sun light. The pods are so tender and fibreless that these could be eaten as such as salad also. The seeds are dark brown. It was released by the U.P. state variety release committee in 1983 followed by its notification in 1984 by the central variety release committee. It was formally identified by the vegetable workshop in 1987. First picking is done in 55-65 days. The yield potential is 90 q/ha. It is moderately resistant to bean common mosaic virus and resistant to rust.

Pant Bean 2 (UPF 626): This variety was developed at GBPUAT, Pantnagar through pedigree method of breeding from a cross of Turkish Brown x Contender. It was released by the U.P. state variety release committee in 1995 and was notified by the central variety release committee in 1996. The plants are bush type and sturdy. The pods are flattish round, straight and non-stringy at edible stage. The seeds are brown with mottling and are bold. Thus, this variety is dual purpose i.e. vegetable type as well as dry seed type (Rajmash). First green pod picking is done in about 60 days after sowing. The yield potential is 90 q/ha, green pods. It is moderately resistant to bean common mosaic virus and resistant to rust.

Arka Suvidha: Bush type, high yielding, multiple disease resistant variety developed by IIHR, Bangalore has been registered by PPV FR and A, GOI.

Pole Types:

Kentucky Wonder: It is an introduction from USA. The plants are tall, pole type and have creeping/viny habit. Green pods are ready for harvesting in 60 – 65 days. There are 4 – 5 pods/cluster. Pods are long (20 cm), flattish, meaty, string-less. Seeds are light brown. Green pod yield potential is 100-125 q/ha.

Canadian Wonder: This is a white seeded cultivar. Plants are climbing type and need staking. Pods are straight, round, non-stringy, fleshy, green, about 10-12 cm long. Pods are in clusters of 4-5 pods. The variety is high yielding and widely adapted

USES

Immature pods are eaten fresh and can be easily preserved by freezing, canning or dehydrating. Mature pods and seeds are dried. Beans are eaten boiled, baked, fried, or ground into flour. Crop residues, such as dried pods and stems (straw) and processing by-products (discarded pods, pod extremities), can be used as fodder (Heuzé et al., 2015). As common food in many countries, green beans are sold fresh, canned, and frozen. They can be eaten raw or steamed, boiled, stir-fried, or baked. They are commonly cooked in other dishes, such as soups, stews, and casseroles. Green beans can be pickled, similarly to cucumbers. A dish with green beans common throughout the northern US, particularly at Thanksgiving, is green bean casserole, a dish of green beans, cream of mushroom soup, and French-fried onions (Wikipedia, 2023c).

The pinto bean is most often eaten whole (sometimes in broth), or mashed and then refried. Either way, it is a common filling for burritos, tostadas, or tacos in Mexican cuisine, also as a side or as part of an entrée served with a side tortilla or sopaipilla in New Mexican cuisine. There are a number of different varieties of pinto bean, notably some originating from Northern Spain, where an annual fair is dedicated to the bean (Wikipedia, 2023**a**). The dried pinto bean is the bean commonly used reconstituted or canned in many dishes, especially refried beans. It is popular in chili con carne, although kidney beans, black beans, and many others may be used in other locales. Pinto beans are often found in Brazilian cuisine. Legumes, mainly the common bean, are a staple food everywhere in the country, cultivated since 3000 BC, along with starch-rich foods, such as rice, manioc, pasta, and other wheat-based products, polenta and other corn-based products, potatoes and yams. Pinto beans are also a very important ingredient in Spanish cuisine and Mexican cuisine. In Spanish cuisine pinto beans are mostly used in a dish named after them. In the Southern United States, pinto beans were once a staple, especially during the winter months. Some organizations and churches in rural areas still sponsor "pinto bean suppers" for social gatherings and fund raisers (Wikipedia, 2023a).

Dry beans will keep indefinitely if stored in a cool, dry place, but as time passes, their nutritive value and flavor degrade, and cooking times lengthen. Dried beans are almost always cooked by boiling, often after being soaked in water for several hours. While the soaking is not strictly necessary, it shortens cooking time and results in more evenly textured beans. In addition, soaking beans removes 5 to 10% of the gas-producing sugars that can cause flatulence for some people. The methods include simple overnight soaking and the power soak method, in which beans are boiled for three minutes and then set aside for 2–4 hours. Before cooking, the soaking water is drained off and discarded. Dry common beans take longer to cook than most pulses: cooking times vary from one to four hours but are substantially reduced with pressure cooking (Wikipedia, 2023e). The seeds of the plant can be used fresh or as dried beans. The pods are eaten whole while young and not yet fibrous. The starchy roots of this perennial are eaten in Mesoamerica. In Greece, cultivars of the runner bean with white blossom and white beans are known as *fasolia gigantes* . The pods can be identified by their big size and the rougher surface (Wikipedia, 2023). .In Mexico, Central America, and South America, the traditional spice used with beans is *epazote*, which is also said to aid digestion. In East Asia, a type of seaweed, *kombu*, is added to beans as they cook for the same purpose. Salt, sugar, and acidic foods such as tomatoes may harden uncooked beans, resulting in seasoned beans at the expense of slightly longer cooking times. Dry beans may also be bought cooked and canned as refried beans, or whole with water, salt, and sometimes sugar (Wikipedia, 2023e).

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NUTRITIONAL VALUE

Common beans are an important source of proteins, minerals (iron and zinc) and vitamins for many human populations (Heuzé et al., 2015). *Phaseolus* beans contain trypsin inhibitors (many of them also inhibit chymotrypsin), amylase inhibitors, lipoxygenases, and several other minor protein components. Most of these proteins are a part of albumins. Trypsin and chymotrypsin inhibitors in *Phaseolus* beans typically account for up to 10% of the total proteins and are generally rich in sulfur amino acids. The MWs of these inhibitors range from 2000 to 23 000. Most Phaseolus beans lack Kunitz-type (inhibitors with 170–200 amino acids with MW of ~ 20 000) trypsin inhibitors. Amylase inhibitors in dry beans have been characterized from only a few cultivars and therefore not yet extensively studied. The MW of kidney bean amylase inhibitor (a glycoprotein) has been shown to be 50 000. Appropriate moist-heat treatment (such as cooking or autoclaving) can inactivate both the protease and amylase inhibitors (Sathe, 2016).

Low on calories and with negligible fats, ample dietary fibres, French beans are a blessing for weight loss and can be eaten in moderate portions daily to efficiently shed extra kilos and avert obesity. They contain profuse amounts of vitamin K, besides calcium, magnesium, phosphorous which supply strong bones, fortified joints and lower the risk of fractures, arthritis, osteoporosis. These long green vegetables are also packed with crucial minerals of iron, zinc, potassium, copper, for improved blood circulation, enhanced heart health and antioxidant potential to avert chronic diseases of diabetes, cardiovascular disease (CVD), cancer, dementia etc. (Wellness, 2021). The Nutritional Value Per 100 g serving of raw green beans or raw french beans, as mentioned by the United States Department Of Agriculture (USDA) Food Central Database, is as follows (Wellness, 2021): Energy 31 kcal; Carbohydrates 6.97 g; Dietary fibre 2.7 g; Fat 0.22 g; Protein 1.83 g; Vitamin A 35 μg; Thiamine (Vitamin B1) 0.082 mg; Riboflavin (Vitamin B2) 0.104 mg; Niacin (Vitamin B3) 0.734 mg; Pantothenic acid (Vitamin B5) 0.225 mg; Vitamin

B6 0.141 mg; Folate (Vitamin B9) 33 µg; Vitamin C 12.2 mg; Vitamin K 14.4 µg; Calcium 37 mg; Iron 1.03 mg; Magnesium 25 mg; Manganese 0.216 mg; Phosphorus 38 mg; Potassium 211 mg; Zinc 0.24 mg and Copper 0.13 mg. Moreover, French Beans house a treasure trove of phytonutrients that display tremendous antioxidant, anti-inflammatory, antimicrobial, anti-cancer and anti-ageing traits to boost overall wellness. The myriad bioactive compounds in French beans include flavonoids, polyphenols, catechin, epicatechin, epigallocatechin, quercetin, kaempferol and myricetin. These verdant vegetables also possess ample proteins with a spectrum of essential amino acids - tryptophan, methionine, phenylalanine, histidine, isoleucine, leucine, lysine, threonine and valine, thereby making them an excellent plant-based source of proteins to incorporate in the daily diet (Wellness, 2021).

Kidney beans, cooked by boiling, are 67% water, 23% carbohydrates, 9% protein, and contain negligible fat (table). In a 100-gram reference amount, cooked kidney beans provide 532 kJ (127 kcal) of food energy, and are a rich source (20% or more of the Daily Value, DV) of protein, folate (33% DV), iron (22% DV), and phosphorus (20% DV), with moderate amounts (10–19% DV) of thiamine, copper, magnesium, and zinc (11–14% DV) (Wikipedia, 2023b). Raw green beans are 90% water, 7% carbohydrates, 2% protein, and contain negligible fat (table). In a 100-gram (3.5-ounce) reference amount, raw green beans supply 31 calories and are a moderate source (range 10–19% of the Daily Value) of vitamin C, vitamin K, vitamin B_6, and manganese, while other micronutrients are in low supply (table) (Wikipedia, 2023c). Compared to dry beans, green and wax beans provide less starch and protein and more vitamin A and vitamin C. Green beans and wax beans are often steamed, boiled, stir-fried, or baked in casseroles (Wikipedia, 2023e). The following Tables (4 7) give Nutritional Value of 1) Green beans, raw; 2) Beans, snap, green, raw; 3) Beans, white, mature seeds, cooked, boiled, without salt; and 4) Beans, pinto, mature seeds, cooked, boiled, without salt **(Tables 3-6).**

Table 3. Green beans, raw

Nutritional value per 100 g (3.5 oz)	
Energy	31 kcal (130 kJ)
Carbohydrates	6.97 g
Sugars	3.26 g
Dietary fiber	2.7 g
Fat	0.22 g
Protein	1.83 g
Vitamins	Quantity %DV†
Thiamine (B1)	7% 0.082 mg
Riboflavin (B2)	9% 0.104 mg
Niacin (B3)	5% 0.734 mg
Vitamin B6	11% 0.141 mg
Folate (B9)	8% 33 µg
Vitamin C	15% 12.2 mg
Minerals	Quantity %DV†
Calcium	4% 37 mg
Iron	8% 1.03 mg
Magnesium	7% 25 mg
Phosphorus	5% 38 mg
Potassium	4% 211 mg
Sodium	0% 6 mg
Zinc	3% 0.24 mg
Other constituents	Quantity
Water	90.3 g

Table 4: Beans, snap, green, raw

Nutritional value per 100 g (3.5 oz)	
Energy	152 kJ (36 kcal)
Carbohydrates	6.97 g
Sugars	3.26 g
Dietary fiber	2.7 g
Fat	0.22 g
Protein	1.3 g
Vitamins	Quantity %DV†
Vitamin A equiv. beta-Carotene lutein zeaxanthin	4% 35 µg 4% 379 µg 640 µg
Thiamine (B1)	7% 0.082 mg
Riboflavin (B2)	9% 0.104 mg
Niacin (B3)	5% 0.734 mg
Pantothenic acid (B5)	5% 0.225 mg
Vitamin B6	11% 0.141 mg
Folate (B9)	8% 33 µg
Vitamin C	15% 12.2 mg
Vitamin E	3% 0.41 mg
Vitamin K	41% 43 µg
Minerals	Quantity %DV†
Calcium	4% 37 mg
Copper	3% 0.069 mg
Iron	8% 1.03 mg
Magnesium	7% 25 mg
Manganese	10% 0.216 mg
Phosphorus	5% 38 mg
Potassium	4% 211 mg
Selenium	1% 0.6 µg
Sodium	0% ,6 mg
Zinc	3% 0.24 mg
Other constituents	Quantity
Water	90.3 g
Lycopene	0 µg
Fluoride	19 µg
Choline	15.3 mg
Starch	0.88 g

Table 5. Beans, white, mature seeds, cooked, boiled, without salt

Nutritional value per 100 g (3.5 oz)	
Energy	581 kJ (139 kcal)
Carbohydrates	25.1 g
Sugars	0.34 g
Dietary fiber	6.3 g
Fat	0.35 g
Protein	9.73 g
Vitamins	**Quantity %DV†**
Vitamin A equiv. beta-Carotene lutein zeaxanthin	0% 0 μg 0% 0 μg 0 μg
Thiamine (B1)	10% 0.118 mg
Riboflavin (B2)	4% 0.046 mg
Niacin (B3)	1% 0.14 mg
Pantothenic acid (B5)	5% 0.229 mg
Vitamin B6	7% 0.093 mg
Folate (B9)	20% 81 μg
Vitamin C	0% 0 mg
Vitamin E	6% 0.94 mg
Vitamin K	3% 3.5 μg
Minerals	**Quantity %DV†**
Calcium	9% 90 mg
Copper	14% 0.287 mg
Iron	28% 3.7 mg
Magnesium	18% 63 mg
Manganese	30% 0.636 mg
Phosphorus	16% 113 mg
Potassium	12% 561 mg
Selenium	2% 1.3 μg
Sodium	0% 6 mg
Zinc	15% 1.38 mg
Other constituents	**Quantity**
Water	63.1 g
Lycopene	0 μg
Fluoride	0 μg
Choline	35.1 mg

Table 6: Beans, pinto, mature seeds, cooked, boiled, without salt

Nutritional value per 100 g	
Energy	598 kJ (143 kcal)
Carbohydrates	26.22
Sugars	0.34
Dietary fiber	9.0
Fat	0.65
Saturated	0.109
Monounsaturated	0.106
Polyunsaturated	0.188
Protein	9.01
Vitamins	Quantity %DV†
Vitamin A equiv.	0% 0 μg
Vitamin A	0 IU
Thiamine (B1)	17% 0.193 mg
Riboflavin (B2)	5% 0.062 mg
Niacin (B3)	2% 0.318 mg
Vitamin B6	18% 0.229 mg
Folate (B9)	43% 172 μg
Vitamin C	1% 0.8 mg
Vitamin D	0% 0 μg
Vitamin D	0% 0 IU
Vitamin E	6% 0.94 mg
Vitamin K	3% 3.5 μg
Minerals	Quantity %DV†
Calcium	5% 46 mg
Iron	16% 2.09 mg
Magnesium	14% 50 mg
Manganese	22% 0.453 mg
Phosphorus	21% 147 mg
Potassium	9% 436 mg
Zinc	10% 0.98 mg
Other constituents	Quantity
Water	62.95 g

The nutritional content varies during the maturation stages of the plant. For example, green beans are rich in vitamins, like vitamin C, vitamin K, vitamin B_6, whereas dry beans are rich in minerals and folate (see the nutritional tables) (Wikipedia, 2023e). Raw green beans are 90% water, 7% carbohydrates, 2% protein, and contain negligble fat (table). In a 100 grams (3.5 oz) reference serving, raw green beans supply 31 calories of food energy, and are a moderate source (10-19% of the Daily Value, DV) of vitamin C (15% DV) and vitamin B6 (11% DV), with no other micronutrients in significant content (table) (Wikipedia, 2023f).

Antinutrients: Many types of bean like kidney bean contain significant amounts of antinutrients that inhibit some enzyme processes in the body. Phytic acid and phytates, present in grains, nuts, seeds and beans, interfere with bone growth and interrupt vitamin D metabolism. Pioneering work on the effect of phytic acid was done by Edward Mellanby from 1939 (Wikipedia, 2023f).

Toxicity: The toxic compound phytohaemagglutinin, a lectin, is present in many common bean varieties but is especially concentrated in red kidney beans. White kidney beans contain about a third as many toxins as the red variety; broad beans (*Vicia faba*) contain 5 to 10% as much as red kidney beans. Phytohaemagglutinin can be deactivated by cooking beans for ten minutes at boiling point (100 °C, 212 °F). Insufficient cooking, such as in a slow cooker at 80 °C/ 176 °F, is insufficient to deactivate all toxins. To safely cook the beans, the U.S Food and Drug Administration recommends boiling for 30 minutes to ensure they reach a sufficient temperature for long enough to destroy the toxin completely. For dry beans, the FDA also recommends an initial soak of at least 5 hours in water which should then be discarded.[11] Outbreaks of poisoning have been associated with cooking kidney beans in slow cookers. The primary symptoms of phytohaemagglutinin poisoning are nausea, vomiting, and diarrhea. Onset is from one to three hours after consumption of improperly prepared beans, and symptoms typically resolve within a few hours. Consumption of as few as four or five raw, soaked kidney beans can cause symptoms. Canned red kidney beans are safe to use immediately, as they have already been cooked. Beans are high in purines, which are metabolized to uric acid. Uric acid is not a toxin but may promote the development or exacerbation of gout. However, more recent research has questioned this association, finding that moderate intake of purine-rich foods is not associated with an increased risk of gout (Wikipedia, 2023e).

HEALTH BENEFITS

1. Lowers cholesterol: The high content of complex carbohydrates and dietary fibre in kidney beans lowers cholesterol levels in the blood. The presence of soluble dietary fibre forms a gel like substance in the stomach, which surrounds the cholesterol and prevents its reabsorption into the body.

2. Good for diabetics: Rajma is a healthy option for diabetics because of its low glycemic index, which keeps body's sugar content balanced. It also reduces the risk of developing diabetes.

3. Improves memory: Kidney beans are rich in Vitamin B1, which contributes greatly to healthy cognitive functions. Sufficient levels of Vitamin B1 help in synthesising acetylcholine (an important neurotransmitter), which ensures proper functioning of the brain and boosts concentration and memory. It is also beneficial in slowing the progress of Alzheimer's and dementia.

4. Boosts energy: Manganese in the kidney beans is very important in conducting metabolism, which is basically breaking down of nutrients to produce energy for the body.

5. Anti-oxidative properties: Manganese in kidney beans also aids body's antioxidant defences to make sure that the harmful free radicals in the body are properly and efficiently destroyed**.** Hence kidney beans fall under the category of antioxidant rich foods.

6. Powerhouse of proteins: Kidney beans have high protein content. So much so that it can serve as a great substitute for meat for vegetarians. When consumed with rice or whole wheat pasta, it provides a boost of protein to the body without the added calories of meat or heavy dairy products.

7. Natural detoxifier: A lot of foods these days are loaded with preservatives, which contain sulphites. High sulphite content is known to be toxic to the body. The molybdenum present in kidney beans helps in detoxifying the body off sulphites. It is also beneficial for people with sulphite allergies because the symptoms of the allergies rapidly decrease after regular consumption of kidney beans.

8. Prevents hypertension: Kidney beans being a good source of potassium, magnesium, soluble fibre and protein help reduce hypertension. Together these elements help in maintaining normal blood pressure. The potassium and magnesium expand the arteries and vessels and ensure smooth blood flow.

9. Helps in weight loss: The large amount of dietary fibre in kidney beans keeps one full for longer. Also, low fat content makes it a wholesome low calorie meal.

10. Relieves constipation: The insoluble dietary fibres add bulk to your stool, which ensures a smooth bowel movement and helps in relieving constipation..

11. Boosts immunity: The antioxidants in kidney bean strengthen the immune system by getting rid of the free radicals and protecting the cells of our body

12. Has anti-ageing properties: Antioxidants in the kidney beans get rid of the free radicals and slow down ageing of cells. They also help in reducing wrinkles, healing acne and nourishing hair and nails.

13. Cleanses stomach: When kidney beans are consumed in the right quantities they can also help with cleansing the digestive tract, ensuring removal of toxins from the body and lowering the risk of colon cancer.

14. Improves heart health: High quantity of magnesium in kidney beans acts on the cholesterol and helps the body fight diseases associated with the heart like stroke, vascular diseases, coagulation of the arteries, heart attack, etc. and maintain a strong heart.

15. Strengthens the bones: The manganese and calcium present in the kidney beans make the bones stronger and help in preventing osteoporosis. The folate in kidney beans helps in maintaining bone and joint health, which reduces the risk of bone diseases and fractures.

16. Helps reduce migraine: The magnesium present in kidney beans helps in preventing the awful migraine headaches and also stabilises blood pressure.

17. Helps in tissue repair: Vitamin B6 helps in tissue growth and repair of the skin and hair. It also helps in preventing any sort of degeneration of the eye. It even helps in stopping hair fall.

18. Helps reduce cataracts: Vitamin B3 has been seen to reduce and in some cases cure cataracts. The high quantity of vitamin B3 in kidney beans will pretty much ensure the same.

19. Helps relieve rheumatoid arthritis: The high copper content in kidney beans reduces inflammation in the body in the case of arthritis. Copper also ensures flexibility of the ligaments and joints.

20. Helps relieve asthma: The magnesium present in kidney beans has a bronchodilatory effect and ensures smooth air passage in and out of the lungs. Studies have shown that low magnesium levels can lead to asthma.

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