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OVERVIEW OF RESEARCH AND DEVELOPMENT IN BEANS (*PHASEOLUS SP.*) : A REVIEW

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ABSTRACT

Beans (*Phaseolus sp.*) have been widely cultivated and extensively domesticated throughout world over a long period of time. The demand for beans and peas is generally rising, because of their high nutrional value, production capacity, sustainability, flexibility, and environmental friendliness due to which major producing countries are engaging in international trade. The large-scale cultivation of these crops has been made easier by significant advancements in production techniques, which have resulted in increases in cultivable area and yield. Many current research initiatives focus on tackling the main issues surrounding the production of beans in both developed and developing countries across the globe. These efforts are primarily focused on increasing the production and improving the quality of the produce, which will be accomplished through plant breeding and efficient agronomic practices. Furthermore, a deliberate effort is made to use these crops as a source for nutraceutical and medicinal products. This paper delves into the possibilities and production barriers surrounding beans with a specific focus on lima bean, Yardlong bean, Snap bean, Faba bean. It covers aspects such as nutritional benefits, agronomic practices, genetic wealth, varietal performance, pests and diseases as well as advancements in breeding techniques.

Keyword : Beans, Genetic resource, Legume vegetables, Nutritional profile, Production constraints, Research and development for beans.

Introduction

Beans (*Phaseolus sp.*) are among the most adaptable non-cereal food crops globally, known for their diverse benefits. They belong to the large-seeded legume group within the Fabaceae family, which is also known as Leguminosae or simply the bean, pea, or legume family. This family is significant in agriculture and includes shrubs, trees, and herbaceous plants, both annual and perennial, identified by their compound, stipulate leaves and leguminous fruit. With approximately 20,000 species across 765 genera, Fabaceae is widespread and ranks third among terrestrial plant families by species count.

Beans are vital sources of plant-based protein, carbohydrates, vitamins, minerals, and various antioxidants and health-enhancing compounds. When consumed as vegetables, beans have higher water content and lower protein levels compared to their dry pulse form. Fresh vegetable beans are also more appealing in taste due to their higher soluble carbohydrate content and lower starch levels. Additionally, these vegetable beans are rich in health-promoting substances like carotenoids, phenolics, chlorophyll, vitamins A and C, and are low in fat, which are typically found in fresh plant matter (Bhattacharya, Malleshi 2012) Many bean species also play a crucial role in soil enrichment by acting as green manure, thanks to their symbiotic relationship with rhizobia bacteria that enable nitrogen fixation (Ntatsi *et al.*, 2018).

While some antinutritional factors, such as lectins, phytic acid, saponins, and oligosaccharides from the raffinose family, along with vicin and convicin from faba beans, may be present, their levels are generally lower in fresh vegetables than in dry pulses. These factors typically do not significantly limit the consumption of legume vegetables. Breeding efforts hold promise in reducing antinutritional factors, enhancing health-promoting compounds, and improving the flavor of legume vegetables. However, despite the rising interest in beans, their cultivation and utilization still face challenges. Thus, it is crucial to explore and consolidate advanced agronomic practices, such as optimizing planting density, refining irrigation techniques, and managing nutrients, while also considering sustainable agricultural methods that focus on eco-friendliness, resource efficiency, and biodiversity conservation. This approach can provide a comprehensive framework for the latest research and development in bean cultivation.

This review covers essential aspects such as the nutritional value, genetic improvement, production and management, seed systems, genetics and genomics, plant genetic resources, as well as pest and disease management for lima beans, faba beans, and yard-long beans.

Area and Production

In 2020, the global area under common bean cultivation was estimated by FAOSTAT to be 34.80 million hectares, with a production value of 27.54 million tons. The main producers of common beans among the major bean-producing regions were China, India, Burma, Brazil, the United States of America, and Africa. The common bean, also called rajmash, is grown primarily as a Kharif crop in India according to a traditional production system that involves intercropping with maize or potatoes in the Himalayan foothills and rotating with vegetables.

In india main factors that determine a bean cultivar's value are its yield, maturity period, and market demand. Grain cost, bean color, hulling simplicity, nutritional content, and bean taste are the most crucial attributes. Brazil (2.8M tonnes), India (6.9M tonnes), and Myanmar (3.9M tonnes) were the top three countries in the world's dry bean consumption in 2018—representing 36 percent of the total.84 million tons of dry grains globally in 2017, placing them fourth among cool-season food legumes. However, given that most faba beans are cultivated and consumed in food chains, this figure likely greatly underestimates the species' nutritional and social significance. used for vegetable purposes locally by farmers in many Mediterranean nations, South America, China, and India. (ICAR-IIPR) (Fig 1,2 and 3)

On a land area of 1.99 lakh hectares, the world produces 1.87 million tonnes of yard-long beans (FAOSTAT, 2018). It is widely grown throughout Southeast Asia, including Pakistan, Malaysia, Indonesia, Thailand and Philippines as well as, India, China and Southern China (Benchasri *et al.* 2011). The crop is cultivated on a small-scale in-home garden throughout the West Indies, the Mediterranean region, and the Southern United States. It is extensively found in semi-arid and subtropical regions. Since this crop is mostly grown as an intercrop, a part of mixed cropping, or on homesteads, it is difficult to estimate the annual area and production under it in India. But according to (Toppo *et al.* 2019)India's yard-long bean area is only 0.18–0.20.lakh/ha. It is grown in the Andaman and Nicobar Islands, Goa, Kerala, Tamil Nadu, and the tribal regions of northeastern India. (Table. 1)

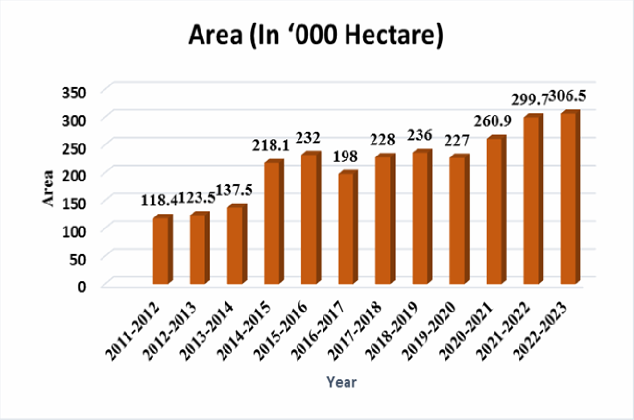

Fig. 1 : Area (In ‘000 Hectare) under cultivation of beans in India

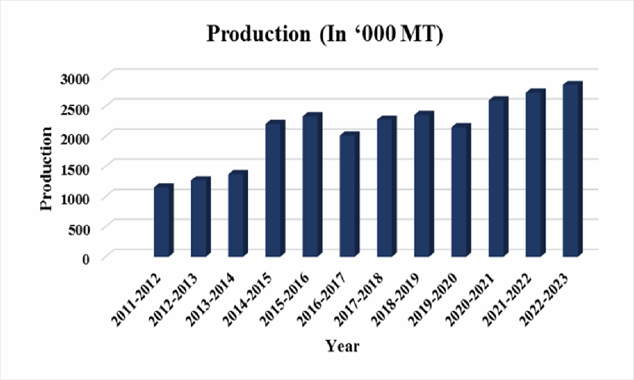

Fig. 2 : Productivity (In MT/Hectare) of beans in India

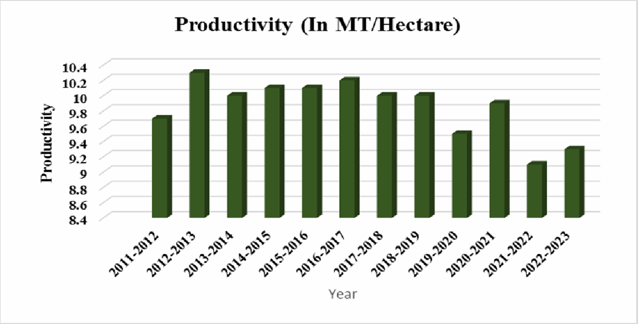

Fig. 3 : Production (IN '000 MT) of beans in India

Table 1 : Area, Production and Yield of Beans (Green) in India

(2011–2012 to 2022–2023 – 3rd Advance Estimation)

Year	Area (In '000 Hectare)	Production (In '000 MT)	Productivity (In MT/ Hectare)
2011-2012	118.4	1151.4	9.7
2012-2013	123.5	1268.9	10.3
2013-2014	137.5	1370.2	10.0
2014-2015	218.1	2203.9	10.1
2015-2016	232.0	2334.0	10.1
2016-2017	198.0	2012.0	10.2
2017-2018	228.0	2277.0	10.0
2018-2019	236.0	2356.0	10.0
2019-2020	227.0	2150.0	9.5
2020-2021	260.9	2594.7	9.9
2021-2022	299.7	2725.9	9.1
2022-2023	306.5	2854.0	9.3

Source: Ministry of Agriculture and Farmers Welfare, Govt. of India. (ON3422) & Past Issues.

Nutritional profile

Faba bean

Field beans, or *Vicia faba* L. are one of the earliest crops to be cultivated. It is claimed to have come from Central or West Asia. For rural communities with small land holdings, the faba bean is especially significant for food, nutrition, financial stability, and livelihood opportunities. Faba bean seeds are indeed a valuable source of essential amino acids, containing high levels of lysine, leucine, and arginine, with concentrations reaching up to 67 g kg-1 dry matter. They also contain a high concentration of calories (320 kcal/100 g dry weight), digestible proteins (250 g protein/kg seed), minerals and vitamins (Crépon *et al.*, 2010). Parkinson's disease patients are administered L-3,4-dihydroxyphenylalanine (L-DOPA), a precursor to the neurotransmitter catecholamine (Brauckmann, Latté 2010).

Snap bean

French bean (*Phaseolus vulgaris* L.) is an important warm-season vegetable crop that provides essential vitamins, minerals, fibre and protein. The basic composition of snap bean in 100g of seed weight are Carbohydrates 6.6g, Glucose 0.4g, Fructose 0.5g, Sucrose 0.5g, Sodium 3.1mg, Potassium 146.9 mg. (Table.2)

Table 2 : Seed composition of lima bean per 100 g seed weight

Basic Composition		Amino Acids		Macrominerals		Microminerals	
Carbohydrate (g)	20.88-45	Glutamic acid (mg)	3330	Calcium (mg)	17- 147.4	Copper (mg)	0.84-1.3
Protein (g)	7.8-20.6	Alanine (mg)	1210	Magnesium (mg)	43-216	Iron (mg)	2.39-6.8
Starch (mg)	43	Glycine (mg)	1280	Phosphorus (mg)	111-366	Manganese (mg)	0.516-2.6
Sugars (mg)	1.99-2.9	Lysine (mg)	1470	Potassium (mg)	508-1750	Selenium (mg)	0.0012
Basic composition of yardlong bean (100 g of Edible Pod)				Basic composition of snap bean			
Moisture	Carbohydrates	6.6g	72.0mg	Carbohydrates		6.6g	
Energy	Glucose	0.4g	59mg	Fibre		25.2g	
Carbohydrates	Fructose	0.5g	2.5mg	Fructose		0.5g	
Digestible protein	Sucrose	0.2g	564mg	Sucrose		0.2g	
thiamine	Sodium	3.1mg	0.09mg	Glucose		0.4g	
Vitamin C	Potassium	146.9mg	3.26-3.67mg	Sodium		3.1mg	
Mn	0.29-0.33mg	Co	0.03-0.06mg	Potassium		146.9mg	

https://www.eatthismuch.com/food/nutrition/snap-beans,2349

Lima Bean

The lima bean (*Phaseolus lunatus* L.) (Fig. 4 and 5) sometimes referred to as the sugar bean, Java bean, sieva bean, Madagascar bean, sugar bean or butter bean is a tropical plant that is indigenous to South America. It is a legume with nitrogen-fixing capabilities. In addition, it sheds a lot of leaves, which helps restore the richness of the land (da Costa Neto *et al.*, 2017). In India, butter beans are cultivated in Tamil Nadu (Kodaikanal and Nilgiris), Maharashtra, Pune, and Karnataka (Chikmangalur). Lima beans are renowned for their rich mineral content, high protein content and low sugar levels all of which combine to enhance their nutritional value. Per 100 grams of seed weight, lima beans exhibit the following composition in the (Table 2). (Souci *et al*., 2008) (Salau 2010).

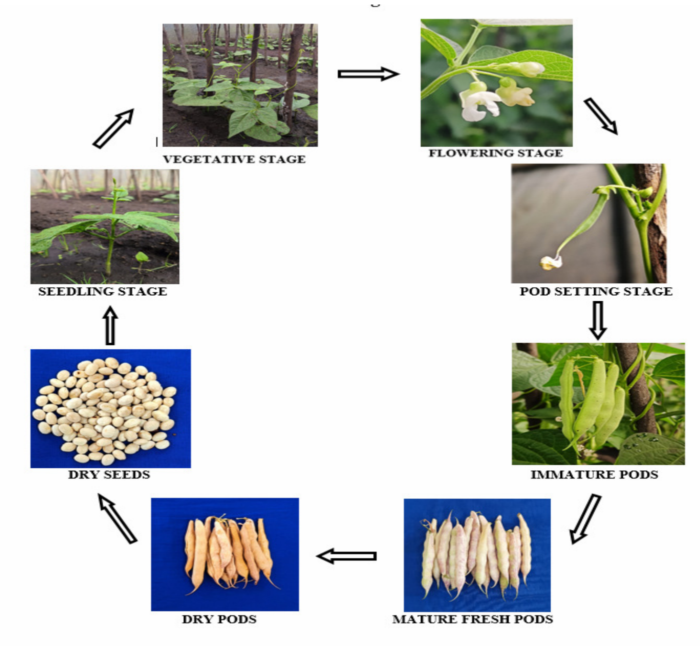

Fig. 4 : Different stage of Butter beans

Fig. 5 : Vegetative and flowering stages of butter beans

Yardlong Bean

Vegetable legumes are of great importance in Asia's tropics and subtropics include yardlong beans. Botanically known as *V. unguiculata* sub sp. *sesquipedalis* (L.) Verdc., they are thought to have evolved from vegetable varieties of *V.unguiculata* L. in South-East Asia, where they were chosen and cultivated for their long, tender pods. They are rich in vitamins A and C. According to the United State Department of Agriculture (USDA, 2005) basic composition of edible pod weighing 100 grams are following Table 2 (Ano, Ubochi 2008)

Genetic Resources

Lima Bean

The International Center for Tropical Agriculture (CIAT) collection in Cali (Colombia) has over 3000 germplasm accessions collected from all over the world, with seeds primarily from West Africa (primarily Ghana and Nigeria), Philippines, Central and East Africa, Madagascar, Burma, Myanmar, South and Central America and India (Dohle 2017), Wild and weed varieties constitute approximately 3% to 5% of the whole collection. According to International Plant Genetic Resources Institute (IPGRI), other large collections of lima bean exist in the Philippiness (National Plant Genetic Resources Laboratory, University of the Philippines, Laguna, 780 entries), Costa Rica (Universidad de Costa Rica, San Pedro de Montes de Oca, 400 entries), Brazil, the United States (Regional Plant Introduction Station, Washington, 1060 entries) and Indonesia (Research and Development Centre for Biology, Bogor, 3850 entries IPGRI has designated the Belgian National Botanical Garden in Meise as the primary conservatory for wild.

Snap Bean

More than 260,000 accessions of various *Phaseolus* species have been gathered and are kept in more than 245 gene banks across multiple nations (FAO). 2010), which included roughly 2,900 accessions at NBPGR in New Delhi. *Phaseolus* species conservation and global germplasm collection are under the purview of CIAT, Cali, Colombia. With over 36,000 *Phaseolus* materials, representing 44 taxa from 110 countries, the Germplasm Bank of CIAT is home to the largest and most varied collection in the world. The Neotropics (Mexico, Peru, Colombia, and Guatemala) are home to the majority of these collections' primary centers of origin. ICAR-IIVR, Varanasi, Uttar Pradesh, also maintains 214 accessions of different *Phaseolus* species (*P. vulgaris,)* including both bush and pole forms; there are nine *P. lunatus,* two *P. coccineus*, and one *P. acutifolius*. The genetic base of commercial cultivars of green bean market classes, especially snap bean, is narrow despite their wide diversity (Kelly 2002).

Faba Bean

32% of the global Faba bean collection is held by International Center for Agricultural Research in the Dry Areas (ICARDA), which has the largest collection in the world. Reported by (Redden 2018), this global collection conserves materials from 71 countries, a significant portion of which are unique germplasm, Of these germplasm, 10320 are part of the global collection, which is held in trust for the entire world community. Over 3000 accessions of wild *Vicia* species are among the approximately 6000 accessions of different *Vicias* species that are part of the ICARDA collection.

Yard Long Bean

Delhi maintains 129 accessions in long-term storage kept at 218°C to 220°C, whereas its regional station in Thrissur, Kerala, stores 108 accessions in medium-term storage kept at 5°C to 7°C for conservation and subsequent supply and consumption purposes, respectively. Other ICAR agricultural research institutes including Indian Institute of Horticultural Research (IIHR) in Bengaluru, IIVR in Varanasi and IIPR in Kanpur is maintained for the purpose of breeding and developing varieties that are well-suited to various agro-climatic conditions. The Asian Vegetable Research and Development Center, now called as World Vegetable Center, in Taiwan, oversees a collection of 478 yard-long bean accessions distributed across the globe. (Ng 2012) (Fig. 6 and 7)

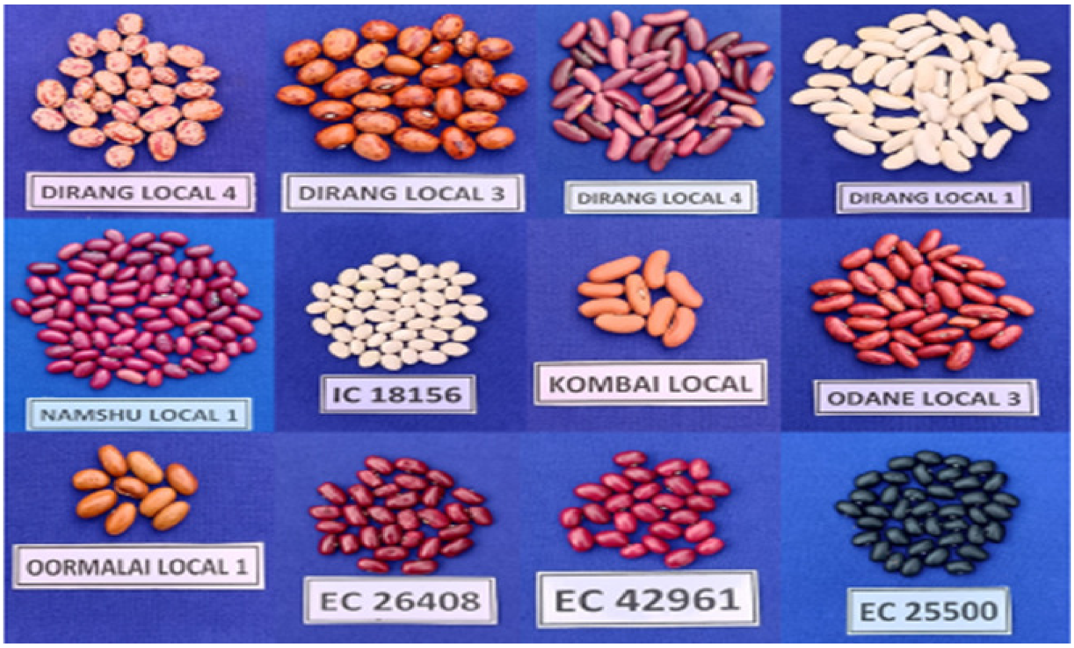

Fig. 6 : Variability for seed colour and different bean accessions

A

B

Fig. 7: **(A)**Variability in yard-long bean germplasm **(B)** Flower variability in yard-long bean Germplasm

Land Races

Yard-long bean is a vegetable crop valued in Southeast Asia for its high genetic variety. Kerala is endowed with a high number of landraces of this crop *viz.,* Chuvappukuruthola, Kanjikuzhipayar, Kurutholapayar, Vallipayar, Karimanippayar, Pathinettumaniyan, Chuvannachatta, Kottayam Payar, Kuttipayar, Vellapayar, Neelappayar Thattappayar, Vithapayar, Kokkirithenagani, Pullipayar, and Padapayar. The landraces names are completely based on their development habits, quantity of seeds per pod, seed coat colour pod colour, pod length and so on. IC 622601 was identified from Velanthavalam village in Palakkad district, Kerala, due to its distinctive violet striations on the surface of its pods and its desirable cooking characteristics. Another collection from Kerala, IC626172, is characterized by purplish rose pods. It was found to be distinct due to its low fiber content, making it easy to slice. Current survey and collection trips in the northeastern Indian states of Mizoram, Nagaland and Arunachal Pradesh have potentially resulted in the acquisition of 46 yard-long bean collections exhibiting various characteristics of pod.

Genetic Diversity

Faba bean - Utilizing genomic selection and a novel molecular approach to increase accuracy and selection intensity. Developing targeted and suitable crosses for the traits will increase the population's genetic variability and lowering the breeding cycle by using a speedy breeding strategy.

Snap bean - Bean classifications are primarily determined by market classes and agronomic characteristics. (Voysest, Dessert 1991) and (Santalla *et al.* 2002). Great variation is found among dry bean market classes, with differences in seed shape (elongate, round and kidney), seed size (which varies from small-medium to large size), seed color (classified into nine groups: black, white, cream, purple, red, brown, yellow, pink and other = green/ gray etc.), seed pattern or striation (bi-color, mottled and striped) as well as in pod shape, size, and color, growth habit, and phenological traits (Singh 2001). In common bean cultivars, seed size can range from small (less than 25 grams per 100 seeds) to large (more than 40 grams per 100 seeds). Seed shape in common beans can vary from round to oblong to kidney-shaped, often exhibiting diverse combinations of color patterns (Voysest, Dessert 1991). Common bean seeds also exhibit variation in surface texture, ranging from shiny (brilliant) to opaque to intermediate.

Common bean genotypes can also be classified based on their growth habit, with some being determinate bush types and others having an indeterminate climbing growth habit. The growth habit classification for beans divides them into four groups: Type I (determinate bush), Type II (indeterminate bush), Type III (indeterminate semi-climber), and Type IV (indeterminate climber) (Singh 1991). Beans are sometimes classified by their origin into major gene pools: the Andean and Mesoamerican gene pools (Beebe *et al.* 2013). In many developing countries, priorities for bean breeding may differ from those in developed countries. For instance, there might be a greater emphasis on reducing cooking time and improving the mineral composition of beans. Additionally, biotic stress challenges like web blight and nematodes could be more pressing concerns in specific locations. On a global scale, various root rot diseases are a significant problem that affects bean cultivation worldwide. See references in "Breeding Objectives for Common Bean" section for discussion of relative priorities.

Agronomical Method

Agronomic manipulations include climate, sowing, variety choice, water supply, cultures rotation, disease, pest and weed management, and harvest.

Climate

Beans are generally classified as long day, short day and day neutral plants. Most French bean varieties are day-neutral, meaning they are not significantly affected by day length and can flower and produce pods under a wide range of day lengths. However, some semi-pole varieties are classified as short-day types, which means they require shorter day lengths to initiate flowering and pod development. Beans are cool weather crop and grow well at a temperature range of 15 to 25°C. They are highly sensitive to frost, high temperature and high rainfall. Beans are grown as a winter crop in plains while it can be grown round the year except winter in hills. In hot and rainy weather, French bean plants can experience blossom or young pod shedding. It does well in the places between 1000-2000 m above sea level.

Selection of Variety

The lima bean comes in a wide variety of types and shapes. Market gardeners and home gardeners greatly value the vine varieties, still known as indeterminate type (vine) varieties or Pole Bean, which is not appropriate for commercial production. Bushy varieties are necessary for mechanical harvesting, so varieties created for commercial production have a fixed growth habit (Table 3).

Table 3 : Improved varieties of beans

<table>
<tr><td colspan="3">Improved varieties of lima bean</td></tr>
<tr><td>Pole Type</td><td>Semi Pole Type</td><td>Bush Type</td></tr>
<tr><td>KKL 1</td><td rowspan="2">Hopi</td><td>Handerson Bush</td></tr>
<tr><td>Karolina Butter</td><td>Burpee Bush</td></tr>
<tr><td>Challenger</td><td rowspan="2">Wilbur</td><td>Baby Potato</td></tr>
<tr><td>Florida butter</td><td>Baby Fodhook</td></tr>
<tr><td colspan="3">Improved varieties of snap bean</td></tr>
<tr><td>Bush Type</td><td colspan="2">Pole Type</td></tr>
<tr><td>Contender</td><td colspan="2">Pusa Himlata</td></tr>
<tr><td>Pusa Parvati</td><td colspan="2">Ooty 1</td></tr>
<tr><td>Arka Komal</td><td colspan="2">Ooty 2</td></tr>
<tr><td>Arka Suvidha</td><td colspan="2">TKD 1</td></tr>
<tr><td>Arka bold</td><td colspan="2">YED 1</td></tr>
<tr><td>Arka Anoop</td><td colspan="2">SVM 1</td></tr>
<tr><td colspan="3">Improved varieties of faba bean</td></tr>
<tr><td>Long pod type</td><td colspan="2">Windsor type</td></tr>
<tr><td>Aquqdule Claudin</td><td colspan="2">Giant Four Seeded Green Windsor</td></tr>
<tr><td>Imperial White Long Pod</td><td colspan="2">Imperial White Windsor</td></tr>
<tr><td>Green Long Pod</td><td colspan="2" rowspan="2">Imperial Green Windsor</td></tr>
<tr><td>Red Epicure</td></tr>
<tr><td colspan="3">Improved varieties of yardlong bean</td></tr>
<tr><td>Arka Mangala</td><td colspan="2">Red Noodle Bean</td></tr>
<tr><td>Asparagus Beans</td><td colspan="2">Yu Long Noodle Kin Beans</td></tr>
<tr><td>White Seeded Beans</td><td colspan="2">Oriental Yard Long Bean</td></tr>
</table>

Nutrient management

The beans give good response to organic manure and therefore it should be applied at least 20-25 tons/ha to obtain better initiation of growth and better soil moisture condition (Table.4). In addition to this apply, half dose of nitrogen and full dose of P and K fertilizer at the time of sowing. Apply the remaining half doses of nitrogen (N) fertilizer at the time of earthing up, typically after the 3rd week of sowing. Beans show poor response to nitrogen. The poor response to nitrogen may be due to the inherent capacity of legume to fix almospherin nitrogen. Phosphorus applications enhance the nodulation in beans. Foliar application of various micro- nutrient produce higher quality and increase yield. Application of zink and magnesium produced higher quality and high yield. Recommended doses of NPK in different beans are (Singh 2018)

Brady rhizobium elkani, *Rhizobium etli*, *R. phaseoli* (Araujo *et al.*, 2015), and *Meso rhizobium (Santos et al. 2011)* are the bacteria that can form symbiosis with lima beans. The strain chosen affects how the lima bean reacts to rhizobial inoculation. According to (da Costa Neto *et al.* 2017), lima bean nodules nodulated with *Brady rhizobium* exhibited greater values of nitrogen flow, total chlorophyll, and nodule parameters compared to plants inoculated with *rhizobium*. A few months prior to sowing, apply 3–5 t/acres of animal or poultry manure as an organic amendment (Temegne *et al.* 2021).

Table 4 : Nutrient management for different beans cultivation

Crop	Nitrogen kg/ha	Phosphorus kg/ha	Potash kg/ha
Snap bean	50	75	75
Lima bean	40	50	50
Faba bean	20	50	40
Yardlong bean	75	60	30

(Singh 2018)

Pollination

Vegetables and faba beans require the pollination of wild pollinators like leafcutter bees, longhorn bees, bumblebees (*Bombus hortorum, B lapidarius., B. pascuorum*), mason bees, carpenter bees, hoverflies and digger bees (*Anthophora plumipes)*(Gharzeddin *et al.*, 2019). By attracting these wild pollinators, farmers can significantly boost yield (Aouar-Sadli *et al.*, 2008) (Nayak *et al.*, 2015); (Andersson *et al.*, 2014); (Bishop *et al.*, 2016) claim that pollinators can even mitigate the negative effects of heat stress.

Crop Rotation

Tomato, cotton, safflower, maize, wheat, alfalfa, rice, cucurbits, sunflower, and orchard crops, can all be grown in rotation with lima beans. Crop rotation every three years helps reduce the spread of most harmful microorganisms that infect lima beans. To have a proper crop rotation lima beans shouldn't be grown in subsequent years. It is strongly recommended to wait two to three years between bean crops. Dried lima beans produce better in a brief rotation when planted after grasses (Temegne *et al.*, 2021).

In addition to being interplanted with vegetables and sugarcane, faba beans are a valuable rotation and mixed crop that improve soil fertility and support the sustainable production of cereal crops, primarily wheat. Many studies have shown that it is possible to achieve significant reductions in the amount of nitrogen fertilizer needed to maximize the yield of subsequent crops, with savings of up to 100–200 kg N/ha. According to faba bean rotation (López-Bellido *et al.*, 1998; Wani *et al.*, 1991). In comparison to chickpea and lentil, which fix 57 and 63 kg/ha of nitrogen respectively, faba beans in West Asia are estimated to fix 154 kg of nitrogen per hectare (Kg shoot N per ha) (Jensen *et al.*, 2010). Crops such as vegetables, tubers, and cereals are grown alongside faba beans in China. Such systems provide a quality food harvest after non leguminous crops and improve soil fertility on farms (Zong, 2002)

It is an essential part of kitchen gardens and homestead cultivation in South India. In addition, In Kerala, common beans are cultivated in various cropping systems. They are grown as the main crop in some areas, as an intercrop among tapioca plants, as a marginal crop in rice fields, and as a ground cover in coconut gardens. The soil type, irrigation facilities, variety used, and growing conditions all affect the seed rate (Rana, 2015), A suitable seed rate for yard long beans is 20–25 kg/ha for bush types and 4–5 kg/ha for trailing types (KAU, 2011).

Maturity Standards and Yield

The various maturity standards like seed size, distribution of pods, percent seed and dry matter content according to sieve size are found to be reliable maturity standards (Table 5).

Table 5 : Yield of different beans

Crop	Yield (t/ha)
Snap bean	8-10
Faba bean	5-10
Lima bean	3-5
Yardlong bean	7-10

(Singh 2018)

Production Constraints

Foliar and soil-borne diseases have an impact on the productivity and production of beans and peas in many different countries. The effects of these illnesses differ depending on the location. Growers employ a variety of disease management techniques, such as fungicides, resistant cultivars, cultural practices, and combining two or more approaches.

Pest and Disease

The main factors reducing yard-long bean yield are pests and diseases. According to reports, insect pests cause a yield loss of between 12% and 30% in yard-long beans (Hossain *et al.* 1992). Legume crops, such as beans, are subject to various challenges in the cultivation process. These include the scarcity of high-yielding varieties, biotic and abiotic stresses, poor seed germination, insufficient or delayed rainfall, pest and disease attacks, low market value, inferior need and insufficient outreach services (Edeh, Igberi 2012). Yard-long bean cultivation can occasionally encounter issues due to photosensitivity. (Meena *et al.* 2016) conducted a study which found that the main limitation identified by Kerala's yard-long bean varieties was the absence of a suitable high-yielding variety. One effective way to bridge the gap between the level of adoption and the release of technology is to have farmers demonstrate recently released varieties in their fields. Diseases and pests are the main factors reducing yard-long bean yields. According to (Hossain *et al.* 1992), insect pests cause a yield loss of between 12% and 30% in yard-long beans. Pod borer (Maruca vitrata) is a significant pest of cowpea that results in a 20%–88% reduction in yield, according to (Singh 1990). larvae of According to (Singh, Taylor 1978), M. vitrata damages food legumes at every stage of development, including seedlings and pod development, because they feed on the flowers, stems, peduncles, and pods of the plant.

Yard-long bean cultivation is also seriously threatened by additional aphids, which are the cowpea mosaic virus's vector. Adults and nymphs both contribute to the harm (OFUYA 1993). According to (Asiwe *et al.* 2005). aphids feed by extracting liquid from flowers stem terminal shoots, pods and petioles. Excessive feeding can be fatal to young plants; in the event that it survives, it reduces pod set in plants that survive attack, delays the initiation of flowers, distorts leaves, and stunts plants(Jackai, Daoust 1986; OFUYA 1993; Ofuya 1989). The four main diseases are anthracnose, powdery mildew, rust and cowpea aphid mosaic. A complex infection is one that frequently manifests with a multitude of symptoms that make effective management extremely challenging (Fig. 8).

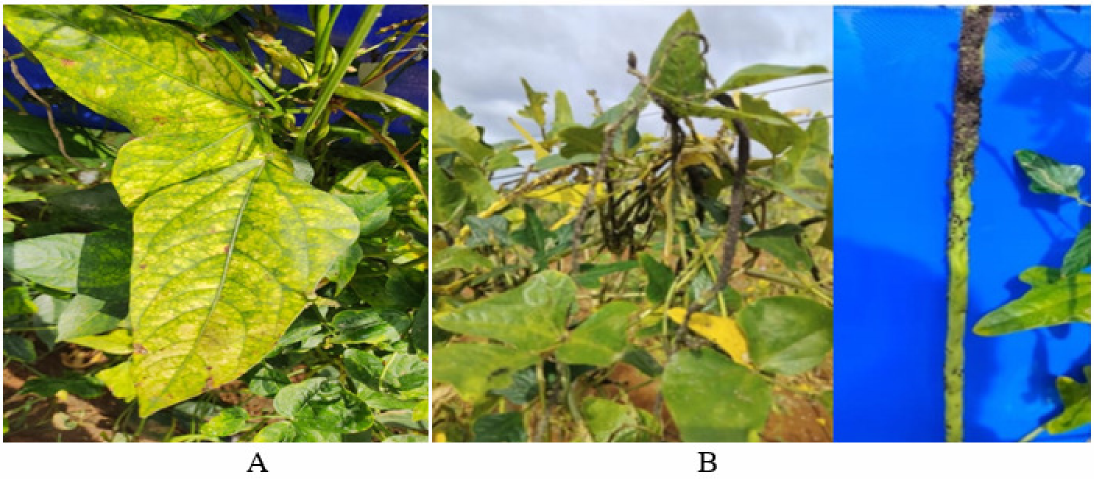

Fig. 8 : (A) Cowpea mosaic virus, **(B)** Aphids incidence in yardlong bean

Ascochyta Blight

This is a major disease that affects grain quality and productivity in some parts of the world. Crop rotation, controlling weeds before planting, and using certified seeds are the main cultural controls for the disease. If there are two mating types and the environment is conducive to sexual reproduction, burning hay in nations where it is not utilized as animal feed can help lower the initial inoculum and decrease the likelihood of sexual reproduction. Fungicides applied topically and as seed treatments are the most popular methods for controlling Ascochyta blight (Ahmed *et al.* 2016; J. A. Davidson, R. B. J. A. b. o. g. l. Kimber 2007). Thiabendazole and benomyl are the most often used fungicides for treating seeds, while Chlorothalonil, Mancozeb, and Azoxystrobin are useful fungicides for foliar spraying. Using partially resistant cultivars in combination with fungicide treatments (foliar sprays and seed treatment), modifying the timing of sowing, and using pathogen-free seeds are all part of integrated Ascochyta blight management (J. A. Davidson, R. B. Kimber 2007; Stoddard *et al.* 2010).

Root Rot Disease

Faba bean root rot diseases are major problems in Ethiopia's high-rainfall regions and in watered land in Egypt and Sudan where there is flooded situation. The main administration techniques include planting faba beans using ridges and beds to drain excess water, modifying plant population, and rotating crops with non host crops. In Ethiopia, liming acidic soils and rotating faba beans with consumable oil crops (*Linum spp*., Brassica, and Guzotia) are advised to prevent faba bean root rots (Tadesse 2008). The best method for controlling complex diseases like root rot is to treat the seeds. Vitaflo 280 (carbathiin1thiram) and Apron Star (mefenoxam, difenoconazole and thiamethoxam) are the fungicides that are most frequently suggested as seed treatments (Chang *et al.*, 2014).

Seed System

Faba Bean

Farmers with small holdings need to embrace new faba bean cultivars through a strong seed chain that guarantees the dissemination of superior cultivars and integrated farming practices technology. The fundamental pillars of the formal seed sector in board, and specifically in the faba bean sector, include: (1) Multiplication of technology and delivery – involving seed production, processing, storage, marketing, and distribution; (2) Quality assurance; (3) Development, release, registration, and maintenance of technology for new varieties and certification; Providing support for policy, regulatory frameworks, and governance. The objective is to produce seed of sufficient quality and ensure its availability to farmers at the appropriate place, time, and affordable prices.

Lima Bean

Seed systems are the mechanisms through which farmers access high-quality seeds of new crop varieties. In the United States, the utilization of certified lima bean seeds, guarantees enhanced seed quality, reduce the risk of disease introduction, and ultimately lead to higher yields as highlighted by (Temegne *et al.* 2021). Such seeds are usually available through research facilities, seed firms and agricultural supply stores.

Yard Long Bean

There are both recognized and unrecognized seed methods in yard-long bean. Kerala has a complementing recognized and unrecognized seed exchange methods in place for the major crops. Farmers engage in seed conservation and exchange practices to prevent genetic erosion and ensure long-term conservation, reflecting an increased awareness of the value of traditional varieties and genetic diversity, influenced by the implementation of IPR regimes in the country. For commercial production, farmers often acquire seeds from market places or use seeds saved from previous crops.

Genetic improvement

Breeding methods

The two breeding techniques used for Faba beans are open pollination, which involves developing lines under naturally occurring pollination conditions and self-pollination, which involves developing lines under insect-proof cages. The goal of self-pollinated breeding techniques, such as pedigree methods and single seed descendance, is to create pure lines with high autofertility. In breeding programmes, using pedigree technique or any other breeding method applied on self-fertilized plants may be challenging due to their allogamous nature and susceptibility to inbreeding depression (Lawes *et al.*, 1983).

In order to produce cultivars exhibiting high tolerance to both biotic and abiotic stresses., new breeding techniques have been implemented as a result of the numerous constraints faced in the production of lima beans. The majority of lima bean breeding has been accomplished through marker-assisted selection, in which a gene is selected using molecular markers that are closely linked to the preferred genes and the markers are employed to track the desirable gene's incorporation. Using this method, the agronomic traits like tolerance to abiotic stress and other traits are associated with markers (Ernest *et al.* 2006) that may have contributed to the divergence of *Phaseolus* species and other legumes after sequencing and putting the lima bean transcriptome to use (Li *et al.* 2015).

Breeding Objective

The primary breeding goals of the international bean breeding program includes enhanced production and production stability by joining multiple contributor for resistance to important foliage diseases.

- **Faba bean -** Enhanced grain quality by adding more protein, iron, and zinc and removing antinutritional elements like tannins, vicine, and covicine. Create lines of resistance to important viruses found in North Africa, with a focus on faba bean necrotic yellow virus (FBNYV) resistance.
- **Yard long bean –** Enhanced quality parameters, such as purple pod color and high anthocyanin content (Kuswanto *et al.*, 2013).

Biotechnological approach

Snap bean

Modern biotechnologies, extending beyond conventional breeding methods, have demonstrated applicability in advancing genetic gains in French beans. These interventions span diverse spheres - from in-vitro culture techniques for germplasm conservation to DNA-based molecular markers enabling genomic selection, genetic transformation methods for developing transgenics, and the exploitation of microbial symbionts. Strategic application aligned with specific breeding bottlenecks holds particular relevance for non-commercial bean improvement, targeting nutritional security and livelihood enhancement in marginal farming environments such as tribal regions.

Genome Sequence of Lima Bean

Recent advances in sequencing throughput and the declining costs per gigabase of sequence have enabled the use of Next-Generation Sequencing (NGS) for mapping and characterizing desirable traits in significantly larger populations. This technology is also applicable for evaluating small subsets of parental inbred lines, as highlighted in the context of yard-long bean (Deschamps *et al.*, 2012). (Fig. 9)

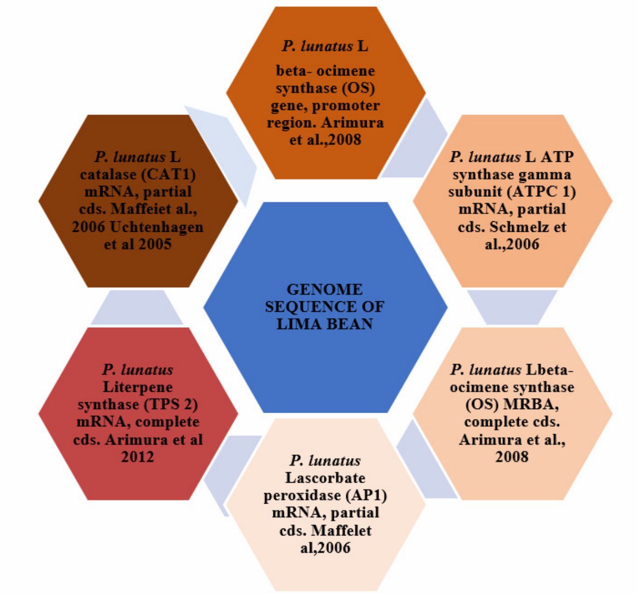

Fig. 9 : Genome sequence of lima bean

Genetic Transformation

Research on modifying the genetic makeup of lima beans has been limited or non-existent. However, lima beans serve as a model plant for certain genetic transformation techniques. Transient transformation induces temporal changes in gene expression, offering a valuable advantage for quick examination, typically within hours or days. This approach provides crucial insights into the functions of the coding region or gene components that influence the timing or intensity of expression. Deoxyribonucleic Acid (DNA) is inserted during transient transformation processes using particle bombardment, agro infiltration, virus-induced gene silencing (VIGS), and protoplast electroporation. (Gunadi *et al.* 2019) have effectively created a technique for inserting large amounts of promoter via particle bombardment. Transient transformation has commonly been employed as a rapid method to assess numerous DNA constructs, serving as a primary level of screening. This approach allows for the quick evaluation before focusing on genes for stable insertion and subsequent plant recovery, particularly in the context of lima beans. Using gene-specific primers (Shirani *et al.*, 2007) cloned the trypsin inhibitor genes from cowpea and yard-long beans. They subsequently introduced the cowpea trypsin inhibitor gene into the tobacco model system to assess its expression within the vegetataion system. Gene-specific PCRs and New Plant Type II (NPT II) were used to confirm the gene's existence. Advancement in yard-long bean breeding could arise from the developing transgenic yard-long bean lines that are resistant to common insect pests and diseases.

Snap Bean

Direct manipulation of genome sequences through transgenic approaches has demonstrated feasibility for mitigating biotic constraints in French beans using Agrobacterium vectors, biolistic gene guns, or protoplast fusion methods. However, limited field releases have occurred, unlike major cereals. Early research since the late 1990s showed promise in increasing resistance levels against Bean golden mosaic geminivirus through inverted repeat DNA sequences, deploying RNAi pathways by transcriptionally silencing viral genes (Nemeskéri *et al.*, 2018). Similar approaches have recently targeted Bean common mosaic virus through transgenic expression of truncated Rep genes, rendering them unable to synthesize intact pathogens post-integration in host cells. Biosafety assessments have spurred debate around risks from gene flow between cultivated and wild beans, unlike self-pollinated grain crops. However, policy evolution expanding the scope for regulated release can foster field-level validation of transgenic beans, where genetic solutions offer the only durable remedy against rapidly evolving strains.

Micropropagation

(Jahan *et al.*, 2015) investigated the establishment of an in vitro propagation protocol for yard-long beans involving the use of nodal segments, leaf segments and shoot tips. In shoot tip and nodal explants supplemented with 0.2 mg/L NAA (1-Naphthaleneacetic acid) and 0.5 mL/L BAP (6-Benzylaminopurine), stem regeneration was successfully accomplished. With leaf segment explants, Murashige and Skoog medium supplemented with 0.2 mg/L NAA and 1.0 mg/L zeatin showed the highest shoot regeneration.

Molecular Markers

A number of studies on the assessment of diversity using different molecular markers, including Random Amplified Polymorphic DNA (RAPD) (Sarutayophat *et al.* 2007) (Pidigam *et al.*, 2019) (Anwar 2019) and sites of sequence-tagged microsatellites by Phansak *et al.* (2005), have already been published. The documentation of the development and application of Simple Sequence Repeats (SSR) markers obtained from Vigna unguiculata L. in yard-long beans (Xu, 2010). Using a subset of the polymorphic markers, they also evaluated the genetic resources of yard-long bean accessions from various geographic regions across China. (Wu *et al.*, 2015) found that 11 and 7 SNPs, respectively, were linked to the degree of leaf damage and vascular discoloration in their genome-wide association study focused on identifying genes associated with Fusarium wilt resistance in yard-long beans. Less than 5% of the phenotypic variation was explained by each of these SNPs, which were spread across nine LGs. Moreover, the SNP marker. In order to aid in subsequent breeding, a cleaved amplified polymorphic sequences marker are transforming into 10981.

Conclusion and Future Perspective

Beans are one of the most crucial staple food and feed legume crops in numerous countries, helping to improve the living standard of smallholder farmers. Beyond their role in food security, these crops play a vital role in promoting sustainable horticulture. With cultivation spanning over 38 countries, the genetic diversity among various accessions, especially among primitive forms and landraces, is notably high. In the coming years, with the increasing populations in major consuming countries, there will be a greater demand for beans and peas. However, in order to meet the growing demand, farmers will need to cultivate varieties which have genetic gains in order to reach appropriate productivity levels. The availability of a highly cost-effective genome, coupled with academic research to optimize genomic selection for the bean reproduction system, holds great potential for enhancing the efficiency of breeding programs. Genomic selection can offer significant benefits in improving the overall effectiveness of breeding initiatives for beans and peas. At the moment, a number of novel varieties and integrated crop management programs are being evolved to boost bean yield. The adoption and demonstration of these new technologies are essential to increase farmer awareness, generate demand, and enhance seed production. Supporting farmer-based seed enterprises is crucial, where farmers are mobilized and engaged in local seed production and marketing, thus contributing to the utilization of high-quality seed of improved bean varieties.

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