Chapter 1
Introduction: Global Status and Production of Faba-Bean

Sneh Punia Bangar and Priyanka Kajla

1.1 Introduction

Kingdom	Plantae
Family	Fabaceae
Subfamily	Faboideae
Tribe	Fabeae
Genus:	*Vicia*
Species:	*V. faba*

The faba bean (*Vicia faba L.*), also known as the fava bean, is an annual herbaceous plant and ancient legume belonging to the family Fabaceae. Faba beans have a vast number of species distributed around the globe ranging from around 16,000–19,000 species in 750 genera in Fabaceae family (Chakraverty et al., 2013). It is a cool-season leguminous crop that dates back to prehistoric times in the Middle East and is traditionally utilized as a major source of protein for both humans and animals (Multari et al., 2015). Regarding economic importance, the Fabaceae family is second only to the Poaceae. Fabaceae species have been reported to be cultivated in varied temperature zones, viz., temperate zones, humid tropics, tropical areas, altitudes, grasslands, & plains; furthermore, even a few aquatic species of these legumes have also been reported (Wrigley et al., 2015). The faba bean is a rich source of fiber, and quality protein, having balanced essential amino acids with high digestibility and low amounts of anti-nutritional factors (Iannotti, 2020). They are reported

S. P. Bangar (✉)
Department of Food, Nutrition and Packaging Sciences, Clemson University, Clemson, SC, USA

P. Kajla
Department of Food Technology, Guru Jambheshwar University of Science and Technology, Hisar, Haryana, India

S. Punia Bangar, S. Bala Dhull (eds.), *Faba Bean: Chemistry, Properties and Functionality*, https://doi.org/10.1007/978-3-031-14587-2_1

to have high-quality protein content owing to the presence of all required essential amino acids (Vogelsang-O'Dwyer et al., 2020). Faba beans are a rotational crop grown in the Mediterranean region and able to fix nitrogen that serves more than 80% of the nitrogen requirements of plants (Denton et al., 2017) therby reducing fertilizer use in agricultural production systems. However, as compared to other field crops, it is extremely sensitive to water scarcity/ drought conditions (Parvin et al., 2019; Desoky et al., 2021). The faba bean ranks third and seventh in area and production among major grain legume crops grown in Europe (Sellami et al., 2021). In 2019, France was the leading producer in Europe, accounting for 34% of total output, followed by Italy, Spain, and Belgium (Table 1.1). The cultivation of this legume has expanded steadily in Italy during the previous 10 years, from over 46,130 hectares to over 60,000 hectares (Sellami et al., 2021). Its global acreage declined from 5.4 to 2.4 million ha between 1980 and 2017, and productivity among countries is very heterogeneous due to varied agronomic conditions and other stresses (FAO, 2017). Heat sensitivity, soil acidity, salinity and other abiotics stress limit the productivity of legumes in different geographical regions as these stress affects its potential of nitrogen fixation.

In this chapter, the worldwide production status of the beans is discussed. Agronomic conditions suitable for the growth and yield of beans as per region specificity are also augmented here.

Table 1.1 Leading faba bean producers, exporters, and importers in 2019

Countries	Quantity (metric tons)
Producers	
China	1,740,945
Ethiopia	1,006,752
United Kingdom	547,800
Australia	327,000
France	177,380
Exporters	
Australia	265,543
United Kingdom	119,071
Lithuania	92,445
Egypt	71,022
Latvia	66,860
Importers	
Egypt	309,355
Norway	6437
Germany	46,707
Saudi Arabia	43,397
France	30,396

Source: FAO (2020) adapted from Dhull et al. (2021)

1.2 Production Status of Faba Beans

The faba bean ranks fifth among pulse crops in terms of annual global production over the last decade. The faba bean is grown in over 66 countries throughout the world. In 2017, the overall area farmed for faba bean production was 2,463,966 hectares, and the total volume produced was 4,840,090 tonnes from year 2008 to 2017 (Merga et al., 2019). As mentioned above, the cropped area for faba bean production has been constantly reducing. The yearly production of this crop is over 4.5 million tonnes on average, according to global pulse crops data from Faba bean production improved from 4,05, 000 tonnes in 1961–65–6,05, 000 tonnes in 2011–14 in North Africa, despite the fact that the area under cultivation has remained constant during the last five decades. Egypt, Morocco, and Sudan are the biggest faba bean-producing countries in North Africa, importing 0.34 MT worth 320 million USD in 2013, while West Asia imported 93,589 tonnes worth 65 million USD in 2011–14 (FAOSTAT, 2016),

Further, the trajectory of legume production in the European Union's main agricultural countries shows significant disparities. As evident from data that France, Germany, the United Kingdom, and Poland have consistently increased (by 29–420%), whilst Italy, Spain, Greece, and Romania have decreased (ranging from 29 to 79 percent) (Confagricoltura, 2019). It should be noted that there has been a surge in global interest in legumes in recent years.

Fava bean production increased from 2.60 million hectares in 1999 to 3.90 million tonnes in 2003 worldwide. China was the leading producer (1.9 million tonnes per year from 1.2 million hectares) (FAO, 2009). From 1999 to 2003, annual production in Sub-Saharan Africa was estimated to be 510,000 tonnes, with almost all of it coming from Ethiopia (405,000 tonnes) and Sudan (100,000 tonnes). It is worth noting that annual productivity in Sub-Saharan African region in the year 2000 increased from 230,000 tonnes (250,000 ha) to 540,000 tonnes (450,000 ha) (Mihailovic et al., 2005). The world production of faba bean crop output was estimated at 5669185 t/year from 2.67 million hectares area, as depicted from Fig. 1.1 with the top faba beans producing country China (1,723,588 t/year), second is Ethopia (1,070,637 t/year) followed by United Kingdom, Australia, Germany producing most of the world faba beans as evident from Fig. 1.1 (FAO, 2020). Green faba bean seed output is extremely low in tropical regions of Africa and Asia (Mihailovic et al., 2005). Egypt is the world's leading consumer of faba beans, with around 75% of daily per capita protein intake coming from plants, primarily cereals, and beans. Much of the protein in the Mediterranean and Chinese diets comes from faba beans (Rahate et al., 2021). The world average faba bean productivity is currently 2.1 kg/ha, with Egypt leading the way with 2.96 t/ha (FAO, 2020).

The area under faba bean cultivation was reported to be increased alongwith significant increase in productivity from 1 t/ha to 1.9 t/ha. Advanced and improved cultivars are reported to produce more (3.5 t/ha) than the average yield (1.8 t/ha).

Over 5 years, from 2013 to 2017, Asia led the world in average productivity (2836.13 kg/ ha), and total production quantity (8,276,692 tonnes) on an average

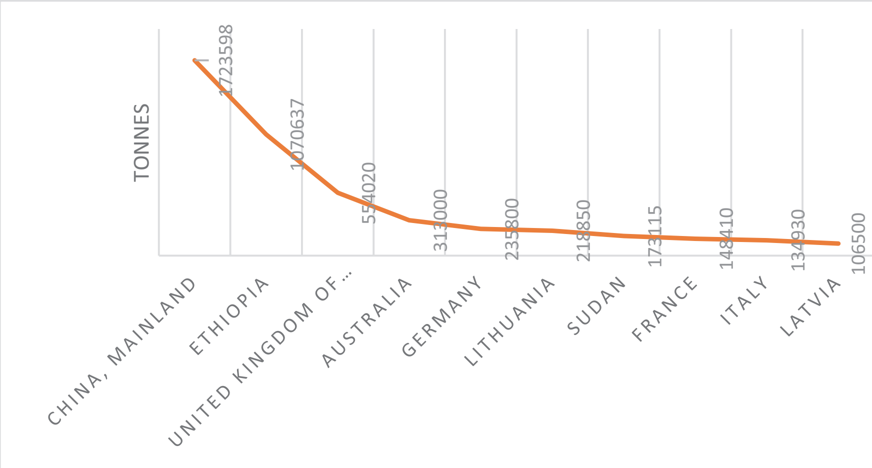

Fig. 1.1 Top ten faba bean producing countries of the world (FAO, 2020)

Table 1.2 Production area and yield status of top five faba bean countries (FAO, 2020)

Country	Area harvested (ha)	Yield (kg/ha)
China	826,597	20,852
Ethiopia	297,600	10,969
UK	181,340	30,551
Australia	36,537	7059
Germany	58,700	40,170

total land area of 4,088,758 ha, followed by Africa with an average total land area cultivated (4,097,769 ha), the average production of 6,873,438 tonnes, and average productivity of 1527.18 kg ha. In terms of faba bean production, China leads the world with 40%, while Ethiopia comes in second with 24% (Table 1.2).

According to FAOSTAT, the world's Faba bean growing area is located in nine different agro-ecological areas, including Ethiopia, Central Asia, and FAO (2016). Northern Europe, Ethiopia, the Mediterranean, Central Asia, Latin America, and East Asia, are other notable producers. Faba beans are virtually primarily utilized for cattle pasturage, hay, and silage in Northern Europe and the United States where they are not widely farmed (Singh & Bhatt, 2012; Oplinger, 1982). Despite the dwindling land size, yield per area has increased due to reduced exposure to varied abiotic and biotic stresses (Singh & Bhatt, 2012). Over the last three decades, fava bean production increased by 2% per year, while the global area has remained unchanged (Abou-Khater et al., 2022). Asia leads the world in overall faba bean output, with 33.55%, followed by Europe and Africa, with 29.36% and 27.04%, respectively.

1.2.1 Global Trade of Faba Bean

The worldwide export of faba beans was about 475,000 tonnes from 1998 to 2002. Global faba bean exports increased modestly between 1994 and 2016, according to FAO data. Ethiopia ranks second only to China in faba bean production, with 930,633 tonnes produced in 2017 and a total value of $315.97 million dollars. Exports of faba beans averaged 41,473.4 tonnes from 2012 to 2016, with a productivity potential of 1995.52 kg ha[1] from 2013 to 2017. In Ethiopia, the faba bean occupies the most land (466,698 hectares) and yields the most pulses (1006751.828 tonnes) (Mekonnen & Mnalku, 2021).

From $3.06 billion in 2020 to $3.18 billion in 2021, the global faba bean market is expected to develop at a compound annual growth rate (CAGR) of 3.77%. The desire for natural and plant-based proteins is driving the increase. At a CAGR of 2.19%, the faba bean market will reach $3.47 billion in 2025. Faba bean production globally reaches 4 million tonnes per year, although only around 2% of that is traded worldwide. Australia, France, and the United Kingdom are the top exporting countries. China used to be a big supplier of faba beans, but it is now a major importer. All of the faba beans grown in Australia are destined for human consumption. The Middle East, particularly Saudi Arabia, Egypt, and the United Arab Emirates, are the biggest purchasers of faba beans. Whole, canned, split, or processed into flour faba beans are commonly consumed. Egypt is the largest importer of food-grade faba beans on the international market, with numerous other nations buying lesser but still important quantities. In addition, several countries are significant importers of faba beans for livestock feed (GRDC, 2017).

Australia is one of the top five exporters of faba beans (308,257.2) followed by Ethiopia (51,456.6), France (157,090.8), and the United Kingdom (152,779.4), and Lithuania (51,090.8) as evident from Fig. 1.2. Egypt is the world's largest faba bean importer, accounting for around 74% of global annual import amounts. Sudan, Saudi Arabia, Norway, and Italy are the following countries on the list (FAO, 2019; Merga et al., 2019).

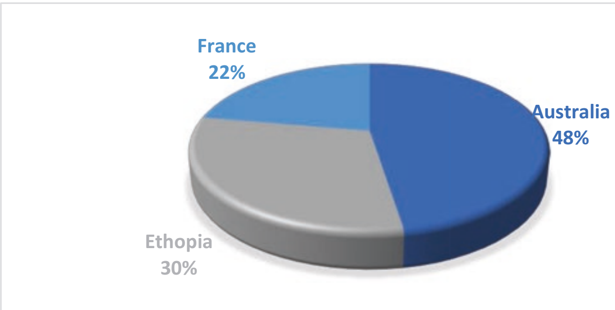

Fig. 1.2 Top three exporters of faba beans

1.3 Agronomic Conditions

1.3.1 Climatic and Geographical Conditions

Faba bean productivity is declining due to different biotic and abiotic stressors. Examples of abiotic issues include waterlogging, moisture stress, soil acidity, and inadequate cultural practices (Keneni et al., 2016). The reproductive phase of the faba bean is very sensitive to these abiotic stresses; especially drought causes yield reductions of up to 79% (Migdadi et al., 2016). The presence of acidic soil, combined with low nutrient availability, is currently the primary constraint to faba bean production (Tadele et al., 2019). Because almost all of the biological and chemical functions of a crop are affected by soil acidity (Jensen et al., 2010). Furthermore, the symbiotic relationship between rhizobia and their host beans can also be destroyed by soil acidity and their survival, growth, and nitrogen fixation efficiency (Chen et al., 1991; Graham, 1992; Zahran, 1999). In many Mediterranean, cultivating beans mostly depends on rainfall for growth and development instead of irrigation practices. The main cause of inconsistency and variations in faba bean production is widely assumed to be disparities in rainfall amount and distribution (Bond et al., 1994). In addition to that, heat stress has also emerged as an impediment to broad bean productivity in some regions consequently shifting from cooler, long-season habitats to warmer, short-season habitats (Gaur et al., 2015). Faba bean cultivation area in Egypt decreased from 113, 000 ha to 46, 000 ha in the period from 2001-2014, while the growing acreage of Sudan climbed from 50, 000 ha to 76, 000 ha in the above said period of 14 years (FAOSTAT, 2016). This is majorly attributed to climate change which is making arid areas get hotter. As depicted from the data as well, heat sensitivity in grain legumes resulted in reduced production and quality while also restricting geographic adaptation. Extreme heat threatens faba bean output in Sudan, southern Egypt, and the lowlands of Ethiopia. Studies also reported that artificially induced terminal heat stress also significantly reduced fava bean genotype yield and yield components (Abdelmula & Abuanja, 2007). The genotype C.52/1/1/1 of faba beans resulted in excellent tolerance to heat stress. They facilitated the cultivation of these beans even in non-traditional sites in Sudan, according to Abdelmula and Abuanja (2007). Drought is frequently regarded as the most critical environmental impediment to crop production, defined as a period of water scarcity that results in a significant decline in crop output (Borlaug & Dowswell, 2005). Despite the fact that genotypic variation in faba bean drought/heat stress response has been well explored (Abdelmula et al., 1999), the tailoring of drought-tolerant genotypes is crucial to boost production sustainability, which NARS partners have assessed at diverse locations (Malouf et al., 2011). In contrast, different research investigations have discovered a variety of frost-tolerant genotypes that could be used in breeding programs). It is reported that fava beans are sensitive to frost throughout the reproductive phases (Maqbool et al., 2010; Sallam et al., 2015). Plant frost tolerance can be improved by hardening seedlings before the onset of winter by exposing them to low non-freezing temperatures (Arbaoui & Link, 2008).

Despite the faba bean's agronomic and economic value, its cultivation is currently limited due to a variety of issues (Torres & Avila, 2011) Several investigations of genotype-environment interactions in faba bean populations have revealed that yield instability is an unfavourable characteristic in this crop (Annicchiarico & Iannucci, 2008; Skovbjerg et al., 2020). The production of faba beans is typically seen as perilous by European farmers, who prefer producing non-legume crops such as cereals, oilseeds, and tubers due to high interannual output fluctuation. (Pahl et al., 2006). The crop sensitivity to weather conditions (particularly cold and drought) as well as its high susceptibility to diseases and pests hinder yield performance (Torres & Avila, 2011). Faba beans are resistant to cold but not to extreme heat or drought. After blossoming, late frosts and cold temperatures can produce a substantial decline in flowers and pods. Faba beans, on the other hand, thrive in sunny locations with cool, deep, well-structured soils rich in lime and clay .Faba beans appear to be shabby and resilient to a variety of conditions in particular. The water availability during the development phases, however, is inherently related to the production output (Flores et al., 2013; Karkanis et al., 2018). Cold tolerance, planting time, geographical regions (Mediterranean, temperate, or arid), and harvesting seasons are all essential characteristics that influence adaptability, selection conditions, production stability, and base material for breeding (Sellami et al., 2021). Seeds of fava bean germinate within a period of 10–14 days under ideal growth conditions (Etemadi et al., 2018a). But dry conditions or if soil temperature is very low, then germination might take significantly longer. On average, the fava bean plant grows by one node per week. As the faba bean stems are rather robust and grow erect, therefore plant grows tall by achieving the height of almost 90–130 cm depending on the genotype. Faba bean produces its first flowers when around 8–10 node has appeared, and the plant is almost around 30 cm tall, this development phase is normally observed in June in the Northeastern United States. Around 20 cm above the ground, flowers and pods appear. Approximately 25% of the flowers develop pods, which typically contain three to six seeds (Etemadi et al., 2019). As a result, good management methods such as soil fertility, irrigation practices, and planting time can greatly minimize the number of aborted blooms, resulting in increased seed/pod production. Generally, low soil temperature affects the germination of most legume seeds as these are frost-sensitive. The fava bean, on the other hand, is a cool-season legume whose germination is more resistant to low/cold soil temperatures in comparison to most grain legumes. Some studies reported similar results that have been obtained by selecting the seeds that have good germination capability at low soil temperatures (below 15 °C). At 12.5 °C, large-seeded cultivars had a higher germination rate than small-seeded cultivars . The faba bean is one of the most significant legume crops around the globe due to its exceptional nutritional properties, which include quality protein, carbs, B-complex vitamins, and minerals (Dhull et al., 2021). In the past few years, faba bean agriculture has received a lot of interest in the United States, Europe and Canada (Etemadi et al., 2018a). In places with a shorter growing season, such as the Northeastern United States, faba bean can be utilised as a cool-season legume in a variety of cropping systems. Only two types of faba bean are now available to gardeners in the Northeastern United States. The existing cultivars have a number of drawbacks, including a high seed price due to the large seed size and poor yield of pod. Along with utilization of faba beans as staple food as well as feed for animals it is also used in crop rotation systems to reduce the incidence of cereal cyst nematode (*Heterdera avenae*) and other soil-related disorders (Landry et al., 2016). Faba bean blooms attract a variety of pollinators, including honey bees, despite the fact that it is partially self-pollinating. Honey bees and other natural pollinators, according to new research, can increase faba bean pollination and, as a result, grain yield. (Marzinzig et al., 2018). It has been discovered that faba beans have the most efficient nitrogen fixation ability among all the short and temperate region legumes (Mekkei, 2014). According to reports, faba beans have the capability to fix approximately 50–330 kg Nhm^{-2} to fix atmospheric nitrogen depending on cultivation practices and other agronomic conditions (Etemadi et al., 2018a).

The faba bean is usually regarded to be a large-seed crop, however seed size varies greatly between species and cultivars. Seed size varies greatly based on pod position among cultivars. Faba bean seeds are broadly categorized into three: large, medium, and small which might show variations within each cultivar, and generally seed size varies widely depending on the position of pods.

1.3.2 Soil Type

The faba bean thrives naturally in fine-textured soils, but it can flourish in almost any type of soil (Jensen et al., 2010). The best soil pH for growing faba bean is 7. The soils in locations with considerable precipitation, such as the Northeastern United States, are acidic. When the pH of the soil falls below 6, liming is essential for faba bean growth and development. While sandy loams are also acceptable for growing faba beans, therefore adequate irrigation is required for the proper development of plants. As faba beans have shallow root system, therefore plants are susceptible to drought stress in rapidly drying soils. The faba bean appears to be resistant to waterlogging for a short duration (Etemadi et al., 2019; Tekalign et al., 2016).

1.3.3 Seed Germination

At optimum conditions coditions of growing, brad beans start sprouting or germinating within 10–15 days of sowing. Germination may also be prolonged if conditions are adverse like if temperature of soil is too low or dry soil conditions are there. Oftenly the seeds of faba beans are sensitive to low temperature but it is comparatively more tolerant than other legumes. (Etemadi et al., 2019). Varieties with large sized seeds tend to show better germination capacity in comparison to small seeded varieties. (Kang et al., 2008). When bfaba bean is grown as cash or cover crop it is recommended to use small seed varieties as it considerably reduces productions as less number of seeds are required per unit of area.

1.3.4 Plantation

The faba bean is planted as a winter or spring crop in cold climates when the temperature and day duration varies significantly from those seen in Mediterranean climates (Luna-Orea et al., 1996). During long growth seasons, plants generally adjust for low plant density of population by producing additional lateral branches. (Etemadi et al., 2015). As a consequence, the cropping cycle (winter season vs. spring season) significantly influences the duration of the vegetative growth stage and thus the final dry matter. Early planted legumes have been shown to increase biomass and grain yield (Etemadi et al., 2018b). López-Bellido et al. (2005) found that delaying faba bean sowing reduced seed yields. In New England, delaying faba bean planting in the spring causes flowering to coincide with high summer temperatures, resulting in more aborted flowers and pods as well as an increase in the prevalence of chocolate spot bacterium illness (Etemadi et al., 2015).

Faba beans are traditionally sown directly into the soil. However, faba bean transplanting may be preferable to direct seeding in shorter-season areas to ensure early sowing (Etemadi et al., 2015). Faba bean transplantation permits for double cropping and eliminates diseases like chocolate spot *(Botrytis fabae)* in places with a short planting season, especially in Northeastern United States (Etemadi et al., 2018b). Furthermore, meteorological variables such as moist soil in early spring may preclude early planting in such locations, therefore transplanting faba beans as a potential substitute to direct sowing should be investigated. Other potential advantages of transplanting seedlings include increased output, enhanced rate of survival, flowering in the early phase of development, and betimely harvest (Lee et al., 2018). Indoor seeding in late March is required for faba bean transplantation, and seedlings must be 15 cm tall before being transplanted into the main field. According to studies, the ideal temperature for producing faba bean in the greenhouses is around 15 °C, and seedlings are ready for transplanting in 12–15 days. (Etemadi et al., 2015). Pro-mix media in a 3.2 cm cell size tray is sufficient for this short greenhouse growing period. Plant faba bean seeds 2.5 cm deep in the field, with 15 or 23 cm spacing between plants on planting rows, depending on plant spacing. This planting design provides approximately 48,000–60,000 plants hm^2 and is provided by approximately this (Etemadi et al., 2015).

1.3.5 Mineral Requirements

Different minerals -nitrogen, phosphorus, potassium, magnesium are required for growth and development of faba beans plants. Alongwith these minerals also plays an important role in improving soil fertility by providing the deficit minerals and hence increase in yield of crop. Major functions of all these required minerals are presented in Fig. 1.3.

1.4 Diseases in Faba Beans

Parasitic weeds (*Orobanche and Phelipanche* spp.), foliar diseases primarily chocolate spot (*Botrytis fabae),* rust (*Uromyces viciae fabae*), Ascochyta blight (*Ascochyta fabae*), powdery mildew (*Microsphaera penicillata var. ludens*), are common diseases of faba beans (Sahar et al., 2011; Maalouf et al., 2016; Hailu et al., 2014). The faba bean necrotic yellow virus decimated the crop in Middle Egypt in 1992, wiping out all beans landraces and cultivars. (Katul et al., 1993). Most of the breeding projects focus on producing resistance genotypes for a single economically relevant disease (Maalouf et al., 2013; Temesgen et al., 2015). Villegas-Fernández et al. (2012) report that efforts are increasingly being devoted toward developing disease-resistant fava bean lines. Due to low resistance, the intricate structure of the resistance mechanism, and poor heredity, breeding for Orobanche resistance in faba bean is difficult. (Rubiales et al., 2012). Despite all the challenges of breeding, Egypt, Spain, Italy, Morocco, and ICARDA (Khalil et al., 2004) have made great progress in continuing to develop tolerant/resistant varieties and breeding materials based on the main source of Orobanche resistance line F402 identified by Egyptian researchers in the early 1970s (Nassib et al., 1982) as well as some minor sources available in different countries.

For the parasite population in Syria, ICARDA has created fava bean lines with varying levels of tolerance and susceptibility to *Orobanche* (Khalil et al., 2004).

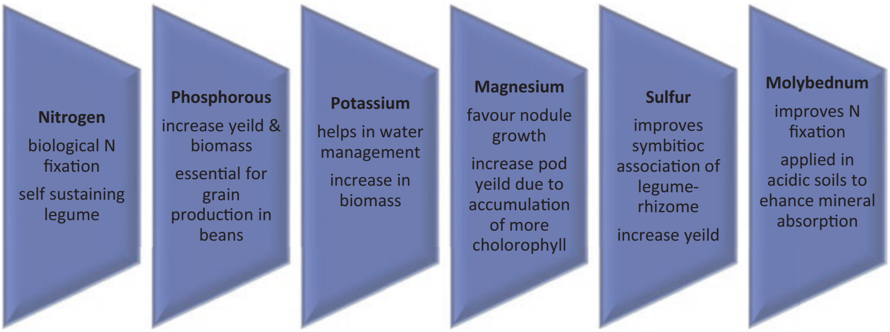

Fig. 1.3 Role of different minerals for growth & development of fab beans

ICARDA revealed the most potential ascochyta blight and chocolate spot resistance sources. (Hanounik & Robertson, 1988, 1989). ICARDA and the National Agricultural Research Systems (NARS) employed these lines to develop breeding lines with great yield potential and resistance. As a result, new varieties have developed in Australia, Ethiopia, China, Canada, Egypt, and Spain (Tivoli et al., 2006; Redden et al., 2008; Villegas-Fernández et al., 2009).

1.5 Conclusion

It is necessary to develop high-yielding, nutritious, and disease-resistant varieties appropriate for various cropping systems found in diverse agro-ecological zones to increase farm profitability through the implementation of enhanced faba bean technology. Climate-smart cultivars must be developed that are heat and drought-tolerant, as well as ideal for waterlogged and acidic soils. Herbicide-tolerant fava bean germplasm is also needed to combat weeds, as well as water and nutrient-efficient cultivars for arid environments. Acidic soils and salinity are becoming an issue for faba bean cultivation and necessitate specific attention. Finally, there is extra value for animal nutrition that should be investigated. Breeding efforts are sluggish because of the nature of the mechanisms of resistance for numerous foliar diseases, Orobanche resistance, main abiotic stresses (heat and drought), and herbicide resistance. New biotechnological approaches are needed to reduce breeding cycles, such as marker-assisted selection, which has not been widely adopted despite significant advancements in quantitative trait loci investigations.

References

Abdelmula, A. A. & Abuanja, I. K. (2007). Genotypic responses, yield stability, and association between characters among some of Sudanese faba bean (*Vicia faba* L.) genotypes under heat stress. In *Conference on International Agricultural Tropentag Research for Development*. University of Kassel-Witzenhausen and University of Göttingen, pp. 1–7.

Abdelmula, A. A., Link, W., Von Kittlitz, E., & Stelling, D. (1999). Heterosis and inheritance of drought tolerance in faba bean (*Vicia faba* L). *Plant Breeding, 118*, 485–490.

Abou-Khater, L., Maalouf, F., Jighly, A., Rubiales, D., & Kumar, S. (2022). Adaptability and stability of faba bean (Vicia faba L.) accessions under diverse environments and herbicide treatments. *Plants, 11*(3), 251.

Annicchiarico, P., & Iannucci, A. (2008). Breeding strategy for faba bean in southern Europe based on cultivar responses across climatically contrasting environments. *Crop Science, 48*(3), 983–991.

Arbaoui, M., & Link, W. (2008). Effect of hardening on frost tolerance and fatty acid composition of leaves and stems of a set of faba bean (*Vicia faba* L.) genotypes. *Euphytica, 162*(2), 211–219.

Bond, D. A., Jellis, G. J., Rowland, G. G., Guen, J. L., Robertson, L. D., Khalil, S. A., & Li-Juan, L. (1994). Present status and future strategy in breeding faba beans (*Vicia faba* L.) for resis-

tance to biotic and abiotic stresses. In *Expanding the production and use of cool season food legumes* (pp. 592–616). Springer.
Borlaug, N., & Dowswell, C. R. (2005). Feeding a world of ten billion people: a 21st century challenge. In R. Tuberosa, R. L. Phillips, & M. D. Gale (Eds.), *In the wake of the double helix: From the green revolution to the gene revolution, 27–31 May 2003*. Avenue Media.
Chakraverty, A., Ramaswamy, H. S., & Mujumdar, A. S. (2013). Structure and composition of cereal grains and legumes. In *Handbook of postharvest technology* (pp. 21–36). CRC Press.
Chen, H., Richardson, A. E., Gartner, E., Djordjevic, M. A., Roughley, R. J., & Rolfe, B. G. (1991). Construction of an acid-tolerant Rhizobium leguminosarum biovar trifolii strain with enhanced capacity for nitrogen fixation. *Applied and Environmental Microbiology, 57*(7), 2005–2011.
Confagricoltura. (2019). *Production and trade of legumes in Italy and in the world*. Available online: http://www.confagricoltura.it/ita/comunicazioni_centro-studi/rapporti-economici/produzione-e-commercio-dei-legumi-in-italia-e-nel-mondo.php?pagina=4
Denton, M. D., Phillips, L. A., Peoples, M. B., Pearce, D. J., Swan, A. D., Mele, P. M., & Brockwell, J. (2017). Legume inoculant application methods: Effects on nodulation patterns, nitrogen fixation, crop growth and yield in narrow-leaf lupin and faba bean. *Plant and Soil, 419*(1), 25–39.
Desoky, E. M., Mansour, E., El-Sobky, E., Abdul-Hamid, M. I., Taha, T. F., Elakkad, H. A., Arnaout, S., Eid, R., El-Tarabily, K. A., & Yasin, M. (2021). Physio-Biochemical and agronomic responses of faba beans to exogenously applied Nano-Silicon under drought stress conditions. *Frontiers in Plant Science, 12*, 637783.
Dhull, S. B., Kidwai, M. K., Noor, R., Chawla, P., & Rose, P. K. (2021). A review of nutritional profile and processing of faba bean (*Vicia faba* L.). *Legume Science*. https://doi.org/10.1002/leg3.129
Etemadi, F., Hashemi, M., Mangan F., & Weis, S. (2015). *Faba beans; Growers guide in New England*. http://ag.umass.edu/sites/ag.umass.edu/files/research-reports/faba_bean_guide_2.pdf
Etemadi, F., Hashemi, M., Zandvakili, O., Dolatabadian, A., & Sadeghpour, A. (2018a). Nitrogen contribution from winter-killed faba bean cover crop to spring-sown sweet corn in conventional and no-till systems. *Agronomy Journal, 110*(2), 455–462.
Etemadi, F., Hashemi, M., Zandvakili, O., & Mangan, F. X. (2018b). Phenology, yield and growth pattern of faba bean varieties. *International Journal of Plant Production, 12*(4), 243–250.
Etemadi, F., Hashemi, M., Barker, A. V., Zandvakili, O. R., & Liu, X. (2019). Agronomy, nutritional value, and medicinal application of faba bean (*Vicia faba* L.). *Horticultural Plant Journal, 5*(4), 170–182.
Flores, F., Hybl, M., Knudsen, J. C., Marget, P., Muel, F., Nadal, S., et al. (2013). Adaptation of spring faba bean types across European climates. *Field Crops Research, 145*, 1–9.
Food and Agriculture Organization (FAO). (2009). *FAOSTAT Statistical Database of the United Nations Food and Agriculture Organization (FAO) statistical division*.
Food and Agriculture Organization (FAO). (2016). *FAOSTAT Statistical Database of the United Nations Food and Agriculture Organization (FAO) statistical division*. Rome.
Food and Agriculture Organization (FAO). (2017). *FAOSTAT Statistical Database of the United Nations Food and Agriculture Organization (FAO) statistical division*.
Food and Agriculture Organization (FAO). (2019). *FAOSTAT Statistical Database of the United Nations Food and Agriculture Organization (FAO) statistical division*.
Food and Agriculture Organization (FAO). (2020). *FAOSTAT Statistical Database of the United Nations Food and Agriculture Organization (FAO) statistical division*. Rome.
Gaur, P., Saminen, S., Krishnamurthy, L., Kumar, S., Ghanem, M., Beebe, S., Rao, I., Chaturvedi, S., Basu, P., Nayyar, H., Jayalakshmi, V., Babbar, A., & Varshney, R. (2015). High temperature tolerance in grain legumes. *Legume Perspectives, 7*, 23–24.
Graham, P. H. (1992). Stress tolerance in Rhizobium and Bradyrhizobium, and nodulation under adverse soil conditions. *Canadian Journal of Microbiology, 38*(6), 475–484.
GRDC. (2017). *Grownote Faba bean. Technical manuals.GRDC grow notes on faba beans*. GrowNotes™ Technical Manuals – GRDC Published in 2017.

Hailu, E., Getaneh, G., Sefera, T., Tadesse, N., Bitew, B., Boydom, A., et al. (2014). Faba bean gall; a new threat for faba bean (*Vicia faba*) production in Ethiopia. *Advances in Crop Science and Technology, 2*(144), 2.

Hanounik, S. B., & Robertson, L. D. (1988). New sources of resistance in Vicia faba to chocolate spot caused by Botrytis fabae. *Plant Disease, 72*(8), 696–698.

Hanounik, S. B., & Robertson, L. D. (1989). Resistance in Vicia faba germplasm to blight caused by Ascochyta fabae. *Plant Disease., 73*, 202–205.

Iannotti, M. (2020). *Fava bean (broad bean) plant profile*. Available online: https://www.thespruce.com/how-to-grow-favabeans-1403460. Accessed on 10 Mar 2021.

Jensen, E. S., Peoples, M. B., & Hauggaard-Nielsen, H. (2010). Faba bean in cropping systems. *Field Crops Research, 115*(3), 203–216.

Kang, S., McKenzie, B. A., & Hill, G. D. (2008). Effect of irrigationon growth and yield of kabuli chickpea (*Cicer arietenium*) and narrow-fed (*Lupinus angustifolis). Agronomy New Zealand, 38*, 11–32.

Karkanis, A., Ntatsi, G., Lepse, L., Fernández, J. A., Vågen, I. M., Rewald, B., et al. (2018). Faba bean cultivation–revealing novel managing practices for more sustainable and competitive European cropping systems. *Frontiers in Plant Science*, 1115.

Katul, U., Vetten, H. J., Maiss, E., Makkouk, K. M., Lesemann, D. E., & Casper, R. (1993). Characterisation and serology of virus-like particles associated with faba bean necrotic yellows. *Annals of Applied Biology, 123*(3), 629–647.

Keneni, G., Fikre, A., & Eshete, M. (2016). Reflections on highland pulses improvement research in Ethiopia. *Ethiopian Journal of Agricultural Sciences Special*, 17–50.

Khalil, S., Malhotra, R., Saxena, M. C., Erskine, W., & Kharrat, M. (2004). Breeding faba bean for Orobanche resistance. In *Expert Consultation on IPM for Orobanche in Food Legume Systems in the Near East and North Africa, Rabat (Morocco), 7-9 Apr 2003*. ICARDA.

Landry, E. J., Coyne, C. J., McGee, R. J., & Hu, J. (2016). Adaptation of autumn-sown faba bean germplasm to southeastern Washington. *Agronomy Journal, 108*(1), 301–308.

Lee, M. K., Kim, D. G., Kim, J. M., Ryu, J., Eom, S. H., Hong, M. J., et al. (2018). Selection of the elite lines with high adaptability to autumn sowing of South Korea in faba bean. *Plant Breeding and Biotechnology, 6*(1), 57–64.

López-Bellido, F. J., López-Bellido, L., & López-Bellido, R. J. (2005). Competition, growth and yield of faba bean (Vicia faba L.). *European Journal of Agronomy, 23*(4), 359–378.

Luna-Orea, P., Wagger, M. G., & Gumpertz, M. L. (1996). Decomposition and nutrient release dynamics of two tropical legume cover crops. *Agronomy Journal, 88*(5), 758–764.

Malouf, F., Muhammad, I., Kumar, S., & Malhotra, R. (2011). Breeding food legumes for enhanced drought and heat tolerance to cope with climate change. *Food Security and Climate Change in Dry Areas, 244*.

Maalouf, F., Nawar, M., Hamwieh, A., Amri, A., Zong, X., Bao, S., & Yang, T. (2013). Faba bean. In M. Singh, H. D. Upadhyaya, & I. S. Bisht (Eds.), *Genetic and genomic resources of grain legume improvement*. Newnes.

Maalouf, F., Ahmed, S., Shaaban, K., Bassam, B., Nawar, F., Singh, M., & Amri, A. (2016). New faba bean germplasm with multiple resistances to Ascochyta blight, chocolate spot and rust diseases. *Euphytica, 211*(2), 157–167.

Maqbool, A., Shafiq, S., & Lake, L. (2010). Radiant frost tolerance in pulse crops—a review. *Euphytica, 172*(1), 1–12.

Marzinzig, B., Brünjes, L., Biagioni, S., Behling, H., Link, W., & Westphal, C. (2018). Bee pollinators of faba bean (*Vicia faba* L.) differ in their foraging behaviour and pollination efficiency. *Agriculture, Ecosystems & Environment, 264*, 24–33.

Mekkei, M. E. (2014). Effect of intra-row spacing and seed size on yield and seed quality of faba bean (*Vicia faba* L.). *International Journal of Agriculture and Crop Sciences, 7*(10), 665.

Mekonnen, M., & Mnalku, A. (2021). Productivity improvement of faba bean (*Vicia faba* L.) through elite rhizobial inoculants in the Central Highlands of Ethiopia. *Current Agriculture Research Journal, 9*(1), 62–70.

Merga, B., Haji, J., & Yildiz, F. (2019). Economic importance of chickpea: Production, value, and world trade. *Cogent Food & Agriculture, 5*(1), 1615718.

Migdadi, H. M., El-Harty, E. H., Salamh, A., & Khan, M. A. (2016). Yield and proline content of faba bean genotypes under water stress treatments. *JAPS: Journal of Animal & Plant Sciences, 26*(6).

Mihailovic, V., Mikic, A., Cupina, B., & ERIc, P. (2005). Field pea and vetches in Serbia and Montenegro. *Grain Legumes, 44*, 25–26.

Multari, S., Stewart, D., & Russell, W. R. (2015). Potential of fava bean as future protein supply to partially replace meat intake in the human diet. *Comprehensive Reviews in Food Science and Food Safety, 14*, 511–522.

Nassib, A. M., Ibrahim, A. A., & Khalil, S. A. (1982). Breeding for resistance to Orobanche. In G. Hawtin & C. Webb (Eds.), *Faba Bean Improvement* (pp. 199–206). Martinus Nijhoff.

Oplinger, E.S. (1982). *Fababeans field crops 32.0 UWEX*. Madison, WI 53706.

Pahl, H., Bouttet, D., Casta, P., Cartrysse, C., Charles, R., & Lafarga, A. (2006). What do European farmers think about grain legumes? *Grain legumes, 45*, 14–15.

Parvin, S., Uddin, S., Tausz-Posch, S., Fitzgerald, G., Armstrong, R., & Tausz, M. (2019). Elevated CO_2 improves yield and N_2 fixation but not grain N concentration of faba bean (*Vicia faba* L.) subjected to terminal drought. *Environmental and Experimental Botany, 165*, 161–173.

Rahate, K. A., Madhumita, M., & Prabhakar, P. K. (2021). Nutritional composition, anti-nutritional factors, pretreatments-cum-processing impact and food formulation potential of faba bean (*Vicia faba* L.): A comprehensive review. *Lwt, 138*.

Redden, R., van Leur, J., Zong, X., Bao, S., Yujioa, L., Paull, J., & Leonforte, T. (2008, September). Evaluation and utilization of pea and faba bean germplasm from China. In *Proceedings, 14th Australian Agronomy Conference, Adelaide, Australia* pp. 21–25.

Rubiales, D., Ávila, C. M., Sillero, J. C., Hybl, M., Narits, L., Sass, O., & Flores, F. (2012). Identification and multi-environment validation of resistance to Ascochyta fabae in faba bean (*Vicia faba*). *Field Crops Research, 126*, 165–170.

Sahar, A., El-Shennawy, R. Z., & Ismail, A. I. (2011). Fungicidal management of chocolate spot of faba bean and assessment of yield losses due to the disease. *Annals of Agricultural Sciences, 56*(1), 27–35.

Sallam, A., Martsch, R., & Moursi, Y. S. (2015). Genetic variation in morpho-physiological traits associated with frost tolerance in faba bean (*Vicia faba* L.). *Euphytica, 205*(2), 395–408.

Sellami, M. H., Lavini, A., Calandrelli, D., De Mastro, G., & Pulvento, C. (2021). Evaluation of genotype, environment, and management interactions on fava beans under mediterranean field conditions. *Agronomy, 11*(6), 1088.

Singh, A. K., & Bhatt, B. P. (2012). *Faba Bean (Vicia faba L.): A potential leguminous crop of India* (p. 518). RC for ER. isbn:978-93-5067-773-5ICAR.

Skovbjerg, C. K., Knudsen, J. N., Füchtbauer, W., Stougaard, J., Stoddard, F. L., Janss, L., & Andersen, S. U. (2020). Evaluation of yield, yield stability, and yield–protein relationship in 17 commercial faba bean cultivars. *Legume Science, 2*(3), e39.

Tadele, M., Mohammed, W., & Jarso, M. (2019). Genetic variability on grain yield and related agronomic traits of faba bean (*Vicia faba* L.) genotypes under soil acidity stress in the central highlands of Ethiopia. *Chemical and Biomolecular Engineering, 4*(4), 52–58.

Tekalign, A., Derera, J., Sibiya, J., & Fikre, A. (2016). Participatory assessment of production threats, farmers' desired traits and selection criteria of faba bean (*Vicia faba* L.) varieties: Opportunities for faba bean breeding in Ethiopia. *Indian Journal of Agricultural Research, 50*(4).

Temesgen, T., Keneni, G., Sefera, T., & Jarso, M. (2015). Yield stability and relationships among stability parameters in faba bean (*Vicia faba* L.) genotypes. *The crop journal, 3*(3), 258–268.

Tivoli, B., Baranger, A., Avila, C. M., Banniza, S., Barbetti, M., Chen, W., et al. (2006). Screening techniques and sources of resistance to foliar diseases caused by major necrotrophic fungi in grain legumes. *Euphytica, 147*(1), 223–253.

Torres, A. M., & Avila, C. M. (2011). Molecular breeding approaches in faba bean. In D. Rubiales (Ed.), *Grain legumes* (Vol. 56, pp. 21–23). European Association for Grain Legume Research (AEP).

Villegas-Fernández, A. M., Sillero, J. C., Emeran, A. A., Winkler, J., Raffiot, B., Tay, J., et al. (2009). Identification and multi-environment validation of resistance to Botrytis fabae in Vicia faba. *Field Crops Research, 114*(1), 84–90.

Villegas-Fernández, A. M., Sillero, J. C., & Rubiales, D. (2012). Screening faba bean for chocolate spot resistance: Evaluation methods and effects of age of host tissue and temperature. *European Journal of Plant Pathology, 132*(3), 443–453.

Vogelsang-O'Dwyer, M., Petersen, I. L., Joehnke, M. S., Sørensen, J. S., Bez, J., Detzel, A., Busch, M., Krueger, M., O'Mahony, J. A., Arendt, E. K., & Zannini, E. (2020). Comparison of faba bean protein ingredients produced using dry fractionation and isoelectric precipitation: Techno-functional, nutritional and environmental performance. *Foods, 9*, 322.

Wrigley, C. W., Corke, H., Seetharaman, K., & Faubion, J. (Eds.). (2015). *Encyclopedia of food grains*. Academic Press.

Zahran, H. H. (1999). Rhizobium-legume symbiosis and nitrogen fixation under severe conditions and in an arid climate. *Microbiology and Molecular Biology Reviews, 63*(4), 968–989.