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Overview of Common Bean (*Phaseolus vulgaris L.*), Economic Importance, Ecological Requirements, and Production Constraints in Kenya

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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Abstract

Common bean (*Phaseolus vulgaris* L.) is a major legume crop of global and national importance, contributing significantly to food security, nutritional diversity, and the livelihoods of households by providing essential dietary protein, minerals and income. In Kenya, common bean production is carried out mainly by small holder farmers as a key food and cash crop. The crop is majorly grown at altitudes ranging from 600 and 2700 m above sea level, with average grain yield of less than 0.85 tons/ha, compared to variety specific potential yields of >2 tons/ha. This below optimum production is attributed to combination of socio economic, biotic and abiotic stresses such as land

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degradation, climate change effects, poor agronomic practices, poor pest and disease management and post-harvest handling, limited access to quality seeds, credit facilitates, value addition and organised markets. Understanding these interlinked factors is critical for designing targeted interventions, developing resilient varieties, and improving overall production efficiency. This review synthesizes current common bean knowledge by integrating fragmented research into a single reference, linking biological, agronomic, ecological, and socio-economic dimensions, and identifying key production constraints and research gaps. The findings provide a basis for future research and evidence-based policy interventions aimed at improving common bean productivity and sustainability in smallholder farming systems.

Keywords: Common bean; Kenya; soil health; pest management; legume.

1. Introduction

Common bean (*Phaseolus vulgaris* L), also referred to as dry bean, is an herbaceous annual plant grown worldwide for its edible dry seeds or green unripe pods. The crop has a long history of cultivation with its origins traced to Afghanistan and the Himalayan foothills (Kaplan, 1981). Early cultivated forms of the crop are documented in Thailand in the early seventh millennium BCE (Gorman, 1969), while the large seeded broad bean was found in Aegean region, Iberia and transalpine Europe in the 2nd millennium BCE (Zohary and Hopf, 2012). According to Tohme et al., 1996, and Mamo et al., 2023 oldest known bean domestication is dated around the 2nd millennium BCE in America; Guitarrero cave and archaeological site in Peru. Genetic analyses of the common bean however, show that most beans utilised today in the globe originated from Andea and Mesoamerica and subsequently spread southward along with traditional companion crops such as maize (Elena et al., 2012; Kaplan, 1981).

Among legumes, common bean holds a prominent position as a staple food and cash crop in many sub-Saharan countries and an important component of agricultural systems globally (FAO, 2021; Aguilar et al., 2025; Ranamukhaarachchi & Nanayakkara, 2025; Beebe et al., 2013). It is an invaluable source of proteins and essential minerals, and plays a role in food diversification and soil health management through its symbiotic association with nitrogen-fixing bacteria primarily from the genus *Rhizobium*, such as *Rhizobium leguminosarum bv. Phaseoli*, *R. etli* and *R. tropici* (Muyonga et al., 2014; Aguilar et al., 2025). In addition to its nutritional importance, common bean cultivation supports livelihoods through direct sales in local and regional markets, serving as a source of raw material for agro-processing industries as well as livestock feed (Kamau et al., 2020; Muteti et al., 2022).

Despite its nutritional and economic significance, common bean productivity in Kenya has remained below 0.85tons/hectare of dry grain for the past six years, far below the yield potential of improved bean varieties that range from 1.5-3 tons/hectare (AFA, 2025; Osogo et al., 2025; FAO, 2025). The low productivity is attributed to myriad of challenges and constraints such as environmental stresses, poor agronomic management, pests and diseases, low use of improved seeds, weak market linkages, lack of machinery and equipment, limited access to credit by value chain actors, context specific barriers that undermine woman and youth involvement, lack of modern storage facilities, and socio-economic constraints (Katungi et al., 2010; Lutomia and Nchanji, 2022).

While previous studies and documentations have addressed specific aspects of bean production such as breeding or market dynamics, there is a need for an integrated synthesis that captures the full spectrum of challenges and opportunities in the country's context. This review aims at providing such synthesis. Specifically, it (i) examines the economic significance of the common bean in Kenya; (ii) explores the ecological and agronomic requirements for optimal bean growth; (iii) identifies major production constraints; and (iv) suggests integrated approaches for sustainable intensification, resilience, and farmer empowerment. By consolidating current knowledge, this review guides research prioritization, extension activities, and policy interventions to support bean-based farming systems in Kenya.

2. Methodology

This review is based on a systematic synthesis of peer-reviewed journal articles, government reports, institutional publications, and international agency documents relevant to common bean production in Kenya and East

Africa. Electronic databases, including Web of Science, Scopus, PubMed, and Google Scholar, were used to retrieve literature published between 1990 and 2025. Keywords employed included “Phaseolus vulgaris Kenya,” “common bean production constraints,” “bean ecological requirements,” “bean economic importance,” and “bean yields.” Reference lists of identified studies were also manually screened to capture relevant publications not indexed in electronic databases. Only studies available in English were included.

The review adopts a narrative synthesis approach, integrating evidence on three main dimensions: (i) economic importance of common bean in Kenya, (ii) ecological and agronomic requirements, and (iii) production constraints and limiting factors. This approach enables the identification of key trends, knowledge gaps, and opportunities for research and policy interventions while upholding an all-inclusive narrative.

3. Biological Overview of Common Bean

3.1 Botanical Description and Taxonomy

Common bean is a member of genus *Phaseolus*, Family Fabaceae and subfamily Papilionoideae (Schmutz et al., 2014; Mesera et al., 2024). *Phaseolus vulgaris L*. is a diploid species with a chromosome number of 2n = 22, exhibiting wide genetic diversity that is categorized into Andean and Mesoamerican gene pools (Blair et al., 2010). The crop is a short-duration (100-130 days) grain legume grown on more than 14 million hectares globally (Singh, 2013: Lone, et al., 2021: De Ron et al., 2015). It is largely a self-pollinated plant though cross-pollination is possible if the stigma contacts with pollen coated bee when extended or in climbers (Singh, 2013). The crop exhibits significant morphological variation in seed size, color, and plant growth habit, ranging from determinate bush types to indeterminate climbing varieties (Beebe et al., 2013). The bushy type is predominant in Africa (Buruchara et al., 2011) while the erect type can be 20-60cm high, with twining and climbing vines up to 2-5m long. Knowledge of these morphological variations informs agronomic practices, adaptability to environmental conditions, and resistance to pests and diseases.

The plant possesses well developed tap root system with many adventitious roots (Pathania et al., 2014: Taba-Morales et al., 2020). The stems of bush type are slender, pubescent and branched sometimes with vinyl and non-vinyl twining at the tips with anthocyanin pigmentation on the stem (Smith & Rao 2021). They can also be divided into spreading, semi- erect, and erect growth type with the spreading growth type more predominant over semi-erect and erect growth types (Mesera et al., 2024). The plant has racemose inflorescence bearing small flowers, exhibiting marked variability; pink, white, red, violet, and yellow (Mesera et al., 2024). However, white flower color is the most predominant, inflorescences are axillary or terminal, 15-35cm long racemes, and flowers are arranged in pairs or solitary along the rachis and typically Papillonaceous (Smith and Rao 2021; Alemayehu et al., 2018; Sahle et al., 2021). The leaves are green, dark green or purple in colour and trifoliate bearing 6-15cm long and 3-11cm broad leaflets. Most leaf size range from large: predominant, medium, and small, with Cordate or ovate leaf shape (Loko et al., 2018: Smith and Rao 2021, Singh 1999).

Common bean pods are generally slender, green, pale green, yellow, black or purple in colour and sometimes stripped. They can be cylindrical, flat, and straight or curved, 1-1.5 cm wide and up to 20cm in length. The pod may contain 4 to 12 seeds, which are 7-16 mm long, kidney-shaped, non-endospermic (Smith and Rao 2021). They vary greatly in size and colour from the small black wild type to the large white, brown, red, black or mottled seeds of cultivars (Smith and Rao 2021; Uebersax, et al., 2022). Quality of the seeds, size and protein content, is majorly influenced by genotype, environmental factors, and post-harvest handling (Muyonga et al., 2014, Sanginga and Woomer 2009).

4. Economic Importance of Common Bean in Kenya

4.1 Source of Income

Beans provide a steady and lucrative source of income for many rural households, helping to improve livelihoods and reduce poverty. Dry beans produced in Kenya in 2024 were valued at 660 million US Dollars (AFA, 2025). There is also unvalued trade in green common bean grains harvested at physiological maturity, marketed through local groceries and supermarkets. Green tender pods of certain cultivars of *Phaseolus vulgaris* (French bean) accounts for about 3% of exotic vegetables produced in Kenya, and mainly exported with an annual value of 32 million US Dollars (AFA, 2024). Common bean value chain creates direct and indirect employment, either through food processors estimated to be 24 (Babirye et al., 2023), dry bean distributors or the 1.5 million farmers directly engaged in bean crop production (KALRO., 2022), and formal and informal seed supply systems. The crop's relatively short growing cycle also allows for multiple harvests within a year, maximizing on the farmer's income (Snapp et al., 2019).

4.2 Food and Nutritional Security

Dry seeds of *Phaseolus vulgaris* are often boiled and then fried and eaten together with carbohydrate rich meals such as maize, rice, pancakes or bananas in most Kenyan homes. The most common meal in school feeding programs in Kenya contains dry beans and maize, showing the invaluable contribution of beans to the United Nation's sustainable development goal 2 (https://sdgs.un.org/goals). Immature seeds, pods and leaves may be consumed as vegetables (Brink and Belay, 2006). Beyond direct consumption, beans can be frozen, canned alone or in tomato for future uses (Brink and Belay, 2006). Common bean is also a useful ingredient in soups, stews, salads, and other dishes (Siddiq, & Sultan, 2011; Howard et al., 2018). The versatility of beans in culinary applications broadens their market appeal and economic value. Common bean is a vital crop in the global economy (Katungi, et al., 2010). It plays a significant role as a food security crop because of its nutritional quality as well as ability to survive in diverse climatic conditions (Rao, 2001; McClean et al., 2011; Jansa et al., 2011). Common bean is a drought-tolerant crop, a trait crucial for food security, particularly in regions prone to erratic weather patterns and where agriculture is a primary livelihood (Asfaw, 2011). Beans are a reliable food source even under challenging growing conditions (Nadeem, et al., 2021).

The common bean has an excellent nutrient profile. Dry beans contain 21-25% crude protein, rich in amino acids such as lysine, but are moderately deficient in sulfur containing amino acids such as methionine and tryptophan (Ahmed, et al., 2023). This makes the bean an important source of protein in developing countries where access to diverse protein sources is limited. In addition, common bean protein is high in lysine, which is relatively deficient in maize, cassava and rice, making it a good complement to these staples in the diet (Beebe et al., 2007; Celmeli et al., 2018). Carbohydrates and dietary fibre make up 50-60% and 15% of the edible portion of common bean, respectively, in addition to important mineral elements, namely calcium, magnesium, phosphorus, iron and zinc (Brink and Belay, 2006; Uebersax et al., 2023). Breeding programs in Kenya have achieved bio-fortification of dry beans with Iron and Zinc (Kimani, 2025) that boosts nutritional security in children, pregnant mothers and other vulnerable groups in society (Ritho A. W et al., 2023).

4.3 Soil Health Improvement

Beans play a crucial role in sustainable agriculture owing to its ability to form symbiotic association with nitrogen fixing bacteria. Common beans in Kenya are nodulated by diverse species of rhizobia in the genus *Rhizobium* (Mwenda et al., 2018), which can fix 19-125 kg N ha^{-1} per season, depending on the host genotype (Akter et al., 2018; Brink and Belay, 2006). Up to 70% of the fixed nitrogen can benefit adjacent intercrops or crops in rotation, either through mycorrhizal mediated nutrient transfer, or decomposition of nodules, plant roots or crop residues (Kebede, 2021). Common bean nodules and rhizosphere was reported to host plant growth promoting bacteria, such as phosphate solubilising bacteria in acidic soils of Western Kenya (Kiprotich et al., 2023), which contribute to soil fertility improvement. Common bean can be grown as green manure, and is also useful in soil and water conservation (Geil and Anderson 1994; Schmutz et al., 2014).

4.4 Health Benefits

Beans are cholesterol free and very low in fats (Geil and Anderson, 1994; Messina, 2014). Consumption of common beans can reduce certain types of cancers such as colon, breast and prostate, and can effectively manage diabetes, coronary heart disease and obesity (Ganesan and Xu, 2017). This could be in part due to the significant amount of antioxidant activity found in the phenolic compounds in the seed coat of beans (Ranilla et al., 2007; Ganesan & Xu 2017; Pitura, and Arntfield, 2019). Further reports show that lectins in dry bean grain have shown inhibitory effects on HIV-1 reverse transcriptase enzyme, and also potentially useful in management of tumours (Fang et al., 2010). It has been further demonstrated that bean lectins can manage liver cancer in humans (Fang et al., 2011). Beans are a rich source of folic acid which is especially important for women of child bearing age as low levels of folic acid during pregnancy can lead to neural tube defects in their infants (Gupta and Gupta, 2004). Dry beans and other pulses promote the growth of beneficial gut bacteria, and plays a role in the production of short chain fatty acids that are important in maintaining gastrointestinal health (Kadyan et al., 2022; Mortensen and Clausen, 1996).

5. Ecological Requirements and Agronomic Practices of Common Bean in Kenya

Common beans are versatile plants adapted to wide range of agro-ecological zones in Kenya. Its effective cultivation depends on the complex interaction of major ecological factors such as climatic and edaphic as well as appropriate agronomic practices that optimize germination, growth, yield, and nutritional quality.

5.1 Ecological Requirements

Bean crop grows well within 600 to 2700 m.a.s.l with an ideal altitude being 900-2100m.a.s. l (Macharia et al., 2016). Altitude below 600 m.a.s.l is associated with high temperatures, flower and pod dropping leading to poor fruit set hence reduced yields. It is also associated with high incidences of bean rust and anthracnose. Altitudes beyond 2100 on the other hand is associated with occasional frost damage.

Bean crop thrives in a warm climate. Optimal vegetative development occurs at temperatures of 18–24°C, while temperatures exceeding 30°C during reproductive growth stages result in a reduction in pod and seed set due to enhanced abscission of flower buds, flowers and pods (Macharia et al., 2016; Ahmed, 2023). Low temperatures below 10°C during germination can delay emergence and increase susceptibility to seedling diseases. These temperatures are also prone to Frost damage. Farmers in Kenya's highland regions experience occasional delayed planting due to cold spells, whereas lowland regions suffer occasional heat stress (Wortmann et al., 1998).

Common bean varieties exhibit differential responses to day length. Photoperiod-sensitive cultivars tend to delay flowering under long days, which can extend the growth cycle and potentially increase exposure to pests and diseases (Mukankusi et al., 2012). Conversely, photoperiod-insensitive varieties are favoured in regions with variable day lengths, allowing farmers greater flexibility in planting schedules and reducing the risk of crop failure.

Bean crop thrives within 600-1500mm of well distributed rain per annum. Water stress during reproductive stages such as flowering and pod-filling stages, leads to reduced pod number, grain size, and overall yield (Beebe et al., 2013; Geleta et al., 2024). In Kenya, seasonal rainfall variability and increasing incidences of drought pose major challenges to bean production. Rainfall distribution also affects planting dates and crop rotation practices. Early planting, aligned with the onset of rains, soil moisture conservation techniques such as mulching and water harvesting or supplemental irrigation is recommended in these regions (Girma et al., 2018, Macharia et al., 2016, Wawire et al. 2021).

According to Lugalichi, (2013), common bean is not sensitive to soil type as long as it is reasonably fertile, well-drained and does not have conditions that inhibit germination and emergence. They grow well in well drained, loamy soil that is rich in organic matter, has at least 90cm depth and slightly acidic (6.0-7.0) pH (Smith & Rao 2021; Macharia et al., 2021). Acidic soils with pH below 5.0 reduce nutrient availability, particularly phosphorus, which is critical for root development and nodulation (Muindi, 2019). Similarly, heavy clay soils with poor drainage restrict root growth and, increase incidences of root rots and other soil borne diseases (Manivannan et al., 2009. Sandy soils on the other hand, are associated with drought stress, soil health and nematode challenges (Kamau et al., 2020; Macharia et al., 2016).

Nutrient management is important in bean cultivation. Beans are nitrogen-fixing legumes, forming symbiotic relationships with *Rhizobium* bacteria that convert atmospheric nitrogen into plant-available forms Erana, 2021). This process is highly dependent on soil health, more so on aggregation, moisture, temperature, pH, and organic matter, and nutrients such as starter nitrogen, phosphorus, calcium, sulfur, iron, molybdenum, cobalt, boron, and nickel (Phiri et al., 2016; Weil and Brady, 2017; Muindi et al., 2020). Crop rotation with cereals and other legumes also plays an important role in soil health improvement pest and weed suppression, promoting sustainable bean production systems (Erana, 2021).

5.2 Crop Establishment, Harvesting and Post-Harvest Practices

Apt planting practises are critical for attaining high yields. In Kenya, farmers typically employ row planting with inter-row spacing ranging from 45 to 75 cm, depending on variety and soil fertility, and intra-row spacing of 10–20 cm to reduce competition for light, nutrients, and water (Ndegwa et al., 2019). Dense planting can increase canopy closure, reducing weed growth, but may also exacerbate disease incidence due to poor air circulation. Contrariwise, wide spacing facilitates air movement, lowering the risk of foliar diseases such as angular leaf spot and rust, while optimizing light penetration to lower leaves (Mukankusi et al., 2012; Odunga, 2022).

Recommended seed rates in Kenya vary with variety, seed size and expected agronomic practices. It ranges from 25 to 90 kg per hectare for bush varieties and 25-70 kg per hectare for climbing types. Planting depth should generally be 3–5 cm (1-2 inches) deep, this strikes a balance between securing enough soil moisture for germination with preventing seeds from sitting too deep and rotting as well as exposure to fungal diseases and damping off.

Weed management is vital, particularly during early growth stages to reduce competition for growth factors such as nutrients, light, and moisture (Baker et al., 2021). It can be carried out using variety of approaches such as manual weeding, herbicide application, mulching, breeding competitive crops and integrating cultural practices such as optimal sowing density, narrow row spacing, and cover cropping (Sila, 2019; Savic et al., 2025). This is, however, farmer-specific depending on factors such as labour availability, economic capacity, and environmental considerations (Sila, 2019; Kisambo et al., 2023). Depending on climatic conditions and soil health status, first weeding is recommended 2-3 weeks after emergence followed by second weeding 3 weeks later, just before flowering in mono cropping systems. It should be noted that weeds weeding requires care to avoid either damaging young roots, shedding flowers, spreading diseases or soil compaction.

Harvest timing and post-harvest handling are critical determinants of bean quality and market value (Salcedo, 2008; Macharia et al., 2016). Common beans are typically harvested when pods reach physiological maturity, indicated by a color change and drying of pod walls (Macharia et al., 2016; Mamo et a., 2023). Harvesting too early results in immature grains with poor storability, while delayed harvesting increases susceptibility to pod shattering and field losses (Ndegwa et al., 2019). According to Macharia et al. (2016), the pods are ready for harvesting when the moisture content drops to 16%, the ideal being 15%.

Post-harvest handling includes drying, threshing, cleaning, and storage. Proper drying to 10-14% moisture content prevents mould development, aflatoxin contamination, and seed deterioration. Storage structures, such as airtight containers or hermetic bags, are increasingly promoted to extend shelf-life, maintain grain quality for both consumption and sale as well as reducing destruction by storage pests such as bean bruchid (MOA, 2011; Macharia et al., 2016; Kumar & Kalita, 2017; Sila, 2019). These practices are essential for ensuring that the economic benefits of bean production are realized and that market standards are met.

5.3 Overview of Common Bean Production in Kenya

Common beans are grown across 44 counties with Meru County in Central Highlands leading in production at 8.3% of the total production volume (AFA, 2025). The production in Kenya is dominated by smallholder farmers with the crop commonly cultivated under rain-fed conditions either as a monocrop or intercropped with maize, sorghum and millet (Jaetzold et al., 2012). Main production areas include: Western Kenya (Bungoma, Kakamega, Busia,Vihiga counties), Rift Valley (Bomet, Kericho, Nakuru, Uasin Gishu, Nandi Counties), and Central and upper eastern Kenya (Kirinyaga, Muranga, Nyeri, Embu, Meru and Tharaka-Nithi counties) (Duku et al., 2020; KNBS, 2025). It is also produced in parts of eastern and coastal Kenya but in lesser quantities.

Common bean varieties in Kenya include Mwitemania (GLP x 92), Rosecoco (GLP 2), Mwezi Moja (GLP1004), Canadian Wonder (GLP-24), Red haricot (GLP-585), KK 15, KK8, KK22, Chelalang', Ciankui, Kazuri, Wairimu Dwarf, Mwezi Mmoja (GLP1127), Mwezi mmoja (GLP92), Kenya safi, Kenya Mavuno, Kenya Tamu, Rose coco (GLP2), Canadian wonder (GLP24), and nwever improved drought tolerant Katumani Beans (KAT-B1, B9, X56, X69) and biofortified beans such as Nyota, Angaza

(KMR11) and Faida (KMR13) (Nchanji, et al., 2021, Macharia et al., 2016; www.infonet-biovision.org)

6. Production and Nutritional Constraints of Common Bean in Kenya

Factors affecting common bean production in Kenya can be broadly grouped into nutritional, biotic, abiotic and socio-economic stresses (Brink and Belay, 2006; Emongor & Uside, 2019; (Ojwang' et al., 2009; Wafula, 2023). Proper understanding of all the factors is important for enhanced productivity, resilience, and farmer livelihoods.

6.1 Nutritional Constraints of Common Bean

Common bean grain contains anti-nutritional compounds that include: lectins, trypsin inhibitors, tannins and flatulence inducing compounds (Brink and Belay, 2006). Flatulence is associated with fermentation of poorly digestible oligosaccharides by microorganisms in the gut, resulting in the production of hydrogen, carbon dioxide and possibly methane gases that cause abdominal discomfort (Kumar et al., 2022). Tannins precipitates proteins, while phytates also contained in bean grain binds proteins and minerals like iron and zinc, hence making them unavailable for absorption and utilisation (Gupta et al., 2015; Nagessa et al., 2023). Trypsin inhibitors reduces the digestibility of protein, which may partly explain why the bean protein is 55-65% digestible (Brink and Belay, 2006; Dalgetty et al., 2003). The anti-nutrient compounds can be reduced through breeding or processing/cooking (Gupta et al., 2015), which is a knowledge gap that has not been exploited in Kenya.

6.2 Abiotic Constraints

Abiotic stresses refer to non-living environmental factors that adversely affect bean growth and productivity. The most significant abiotic constraints in Kenya include Climate Variability and Limited Climate Smart Agriculture Knowledge and Skills, land degradation and soil health limitations.

6.2.1 Climate Variability and Limited Climate Smart Agriculture Knowledge and Skills

Climatic factors such as extreme temperature, irregular rainfall patterns, drought and flooding affects both the quantity and quality of the bean yields (Singh et al., 2013; Autio et al., 2021). These factors pose significant challenge to bean production by affecting growth, increasing vulnerability to pests and diseases and impacting soil health (Uebersax, et al., 2023). Common beans within the country are cultivation within diverse agro-ecological zones, ranging from highlands to semi-arid which are prone to occasional water stress and temperature extremes due to climate variability (Asfaw et al, 2013). The crop is highly sensitive to water stress during the reproductive stages, including flowering and pod filling, where even short periods of water stress can cause flower abortion, reduced pod set, and low seed weight (Beebe et al., 2013). Similarly, temperature stress, particularly above 30°C, negatively impacts flowering, pod set, and grain development. Conversely, low temperatures during early germination and seedling stages in highland areas can delay emergence and increase susceptibility to seedling diseases (Mukankusi et al., 2012). Climate change models for East Africa predict an increase in both frequency and intensity of heat waves, posing long-term challenges for bean production unless heat-tolerant cultivars and adaptive agronomic practices are widely adopted. Adoption of mitigation strategies, such as drought-tolerant varieties, supplemental irrigation, and soil moisture conservation techniques such as mulching, minimum tillage, and rainwater harvesting are progressively emphasized. However, adoption remains low within the country.

6.2.2 Soil Degradation and Soil Health Management Challenges

According to FAO, 2020, Soil degradation refer to decline in soil condition caused by improper use or poor management. This compromises soil physical, chemical and biology balance leading to poor soils response to yield enhancing inputs like fertilizers and improved crop varieties, thereby increasing vulnerability of farmers and rural communities to the impacts of climatic shocks.

According to [Weil and Brady, 2017 and Muindi et al., 2023), adequate availability of nutrients in rightful proportions is paramount in crop growth and productivity. The eighteen nutrients required by plants include: carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), zinc (Zn), iron (Fe), copper (Cu), manganese (Mn), chlorine (Cl), boron (Bo), Nickle (Ni) and molybdenum (Mo) [Weil and Brady, 2017; Muindi et al., 2016). Availability of these nutrients for crop uptake is, however, dictated by prevailing soil physical, chemical and biological properties which are often compromised in un healthy soils. For Example: soil texture, structure, consistence, horizonation and bulk density plays which plays a major role in nutrient and water holding capacity are habitually compromised in most degraded lands. Soil pH on the other hand is a chemical property that regulates solubility and availability of all nutrients as well as soil biota population and activity [Brady and Weil, 2008; Muindi, 2020). Nutrients are soluble and available for uptake at pH range 6.0 - 7. 2. At low pH levels of less than 5.5 most macro nutrients such as Ca, Mg, P and K become unavailable for plant uptake. Majority of micronutrients will, however, be abundant, very soluble and toxic at low pH range (Muindi et al., 2015; Muindi et al., 2017). The opposite is true when pH levels are above 7.2 because most base cations such as calcium, Magnesium and sodium become abundant, soluble and toxic while micronutrients such as Zn, Bo, Mo, and Fe become insoluble and un available [Muindi et al., 2022, Brady and Weil, 2008). These scenario calls for soil fertility management by supplementation of limiting nutrients through application of adequate quantities of organic and inorganic fertilizers (Muindi et al., 2020; Rewe et al., 2022; Rewe et al., 2021). This is challenging in majority of common bean growing areas leading to mining of important nutrients, distressed growth, yields and reduced returns. Farmers who use commercial fertilizers also commonly use straight fertilizers that don't provide all limiting nutrients within their soils. The current withdrawal of Kenyan government from fertilizer market and shift of price controls to encourage private investors have led to improved fertilizer distribution while affecting prices and utilization dynamics by smallholder farmers (Njagi et al., 2024). Additionally, as a leguminous crop with ability to fix atmospheric, application of inorganic fertilizers to bean crop is not generally prioritized (Kiponda et al., 2023).

6.3 Biotic Constraints

Pest, disease and weeds are major production limiting factors for common beans. Insect pests, diseases and weeds not only reduce yield but also compromise grain quality, seed viability, and marketability.

6.3.1 Pests, Diseases and Weed Management

Pest and diseases pose huge production challenge to small scale farmers because of either lack of management knowledge or capital or low farm gate prices that do not offer farmers incentive to invest in control measures (Laizer et al., 2019; Uebersax et al., 2023). According to Ebinu, et al. (2016); Ogecha et al. (2019) and Ojwang et al. (2009), some of the common bean's insect pests are: African bollworm (*Helicoverpa armigera*), bean aphids, Bean leaf beetle (*Cerotoma trifurcate*), bean bruchids (*Acanthoscelides obtectus*), Thrips (*Frankliniella occidentalis*.), spider mites (*Tetranychus urticae*), Cut worm (*Agrotis ipsilon),* Whiteflies (*Bemisia tabaci*), Bean fly (*Ophiomyia phaseoli*) and bean bruchid (*Acanthoscelides obtectus*). Some of the pests such as bean fly maggots, attack seedlings and young plants, often leading to complete stand loss in heavily infested fields while aphids not only reduce photosynthetic capacity but also act as vectors for viral diseases (Beebe et al., 2013). Generally, the pests have been documented to cause between 30-100% losses. Their management also increases cost of production for small scale poor farmers (Birachi et al., 2011: Franke et al., 2019).

The common bean diseases within the country include: Common Bacteria Blight caused by a bacterium (*Pseudomonas phaseolicola*); Anthracnose (*Colletotrichum lindemuthianum*), Bean rust (*Uromyces appendiculatus)*, Angular leaf spot (*Phaeoisariopsis griseola*); Powderly mildew *(Erysiphe polygoni*), root rot (*Fusarium ssp*) Angular Leaf Spot (*Phaeoisariopsis griseola*), bean common mosaic virus and bean golden mosaic virus transmitted by white flies (Beebe et al., 2013; Boersma et al., 2014: Girma et al., 2022). The diseases are transmitted by either contaminated seeds, soil, farm implements or alternate hosts (Chen et al., 2021). Loses of up to 10-45% have been reported due to common blight while 80% loss has been reported due to angular leaf spot disease and 40% from viral infections. The development and deployment of disease-resistant cultivars, combined with good field hygiene, crop rotation, and timely fungicide application, are crucial strategies for managing these threats (Mukankusi et al., 2012). Disease management however contributes to increased production cost for resource poor farmers leading to low return to capital (De Jesus et al., 2001: Wani et al., 2022).

Weeds compete with beans for growth factors such as light, water, and nutrients, significantly affecting growth and yield (Baker et al., 2021; Sila, 2019; Oimbo et al., 2018). Early growth stages are most vulnerable, and poor weed control can reduce yields by 12-60% in high-density infestations (Oimbo et al., 2019; Ndegwa et al., 2019). Farmers commonly use manual weeding, mulching, and herbicide applications, though labor constraints and input costs limit consistent implementation.

6.4 Socio-economic Constraints

Beyond environmental and biological limitations, socio-economic factors significantly influence bean production in Kenya.

6.4.1 Access to Improved Seeds

The availability and adoption of improved bean varieties with traits such as drought tolerance, disease resistance, and early maturity remain limited for many smallholder farmers (Mukankusi et al., 2012; Mwaisoba et al., 2025). This is influenced by several factors, including the availability, distribution networks and institutional support (Rubyogo et al., 2007). Setting up seed production and delivery systems that encourage extensive use of quality seed throughout the marketing chain has been a challenge in Kenya (Muthoni & Nyamongo 2008). Improved bean varieties within the country are developed by agricultural research institutions like the Kenya Agricultural and Livestock Research Organization (KARLO), Kenya Seed company and International bodies like International Centre for Tropical Agriculture (CIAT) (Otieno et al., 2021). Some of the improved varieties rarely reach rural small-scale farmers due to overreliance on informal seed systems and outlets.

6.4.2 Market Access and Price Fluctuations

Common bean production is largely market-driven. Rural small-scale farmers face challenges accessing profitable markets, resulting in low incentives to invest in improved agronomic practices. Price fluctuations, caused by either seasonal oversupply or poor market infrastructure further reduce profitability discouraging modernised investments (Kirimi et al., 2024; Kamau et al., 2020).

6.4.3 Access to Labor

Smallholder farming is often labour-intensive, with weeding, harvesting, and post-harvest handling demanding substantial effort. Labour allocation is greatly affected by seasonality influencing quantity of labour consumed as well as wage rates during peak seasons (Canwat, 2012). This constraint timely operations affecting resultant yields quality and return to investment. Limited financial resources further restrict the ability to purchase inputs such as fertilizers, pesticides, and improved seed varieties (Ndegwa et al., 2019).

6.4.4 Access to Credit Facilities

Access to credit facilities from both formal and informal sources can significantly boosts farmers agricultural productivity and profitability by acting as an enabler to acquisition of modern farming facilities, equipment and inputs. Access such services is however limited in small scale bean farming communities due to low financial literacy and collateral (Miriti et al., 2023; Kazungu et al., 2023). Furthermore, though government policies play a major role in cushioning farmers the benefits of its implementation are yet to reach many small holder farmers within the country.

6.4.5 Limited Farmers Knowledge and Access to Agricultural Information and Extension Services

Access to adequate agricultural information is vital to increased agricultural productivity. This information is largely provided by extension officers in rural farming communities (Kiplang'at & Ocholla 2005: Autio et al., 2021). According to Emongor & Uside, (2019) there exists a highly significant relationship between access to extension and bean production. This is because extension officers play an important role of linking farmers with current technologies and market. Despite the critical role played by agriculture in Kenya, low access to extension support services persists (Kyambo, 2024). The research extension– farmer link in Kenya has continuously weakened over the years with the current extension: farmer ratio standing at 1800:1 compared to the FAO recommendation of 400:1 (Muchomba et al., 2023). As a result, many rural smallholder farmers have limited avenues to source for improved planting techniques, pest and disease management strategies, and post-harvest handling practices, reducing productivity and income potential. Strengthening extension systems and farmer training programs is critical for overcoming these knowledge-based constraints (Miriti et al., 2023; Muyonga et al., 2014; Kazungu et al., 2023; Daniel et al., 2023).

6.4.6 Poor Structured Marketing Systems for Common Beans

Structured market systems help farmers to attain better prices, guarantee quality standards and access to wider markets (McCullough et al., 2012). Farmer's organizations like cooperatives and Associations (Kenya Farmers Association) enhance bargaining power and shared resources. Market Information Systems (MIS) such as Kenya Agricultural Commodity Exchange (KACE) provide market information on prices, demand and supply (Wawire et al., 2017). However, most of Farmers marketing channel choices are, determined by socio-economic, institutional, and farm level factors. This acts as a hinderance for small scale poor famers with limited access to credit facilities, market-based signals and information.

6.4.7 Post-harvest Losses and Management

According to Kiaya (2014) and Kumar et al. (2017), postharvest loss can be broadly categorized as spoilage, quality loss, nutritional loss, seed viability loss and commercial loss attributable to lack of knowledge, inadequate technology and/or poor storage infrastructure. The main cause of these postharvest losses is spoilage, due to poor and prolonged storage, spillage during transportation, breakages during threshing, destruction by rodents such as rats and attack by weevils (Kiaya, 2014). Depending on the levels, postharvest losses arising from poor storage, handling of produce and poor infrastructure, make farmers to lose their crops' full value, forcing them to sell grains at throw away price.

6.4.8 Access to Agro Processing Technologies

Farmers' access to agro processing technologies is key to ensure profitability of a product after harvesting; something that limits crop production in most African countries (Shiferaw 2011; Baributsa and Njoroge, 2020). Most bean farmers within the country either don't have access to agro processing facilities or have access to old or outdated processing methods. This exposes them to high losses leading to low enterprise profitability (Katungi et al., 2010; Wawire et al., 2017).

6.4.9 Land Fragmentation

Land fragmentation is a widespread characteristic of agricultural systems and negatively affects farmland productivity and the efficient use of machinery (Mayele et al., 2024). According to KIPPRA (2023), bulk (98%) of the farm holdings in Kenya are small (average 1.2ha), lie mainly in high potential areas and occupy 46% of the total farmed land area. These small sizes limit mechanization leading to reliance on manual labour, increase cost of production, inconsistent agronomic practices and low profitability. Additionally, fragmentation complicates the collection, transportation and marketing of beans increasing post-harvest losses (Austin et al., 2012).

6.4.10 Financial Constraints

The financial constraints as used in this report refer to lack of money and productive assets, exacerbated by lack of collateral to secure credit from formal financial institutions. Most small-scale farmers in the country are poor and lack cash to purchase inputs such as chemical fertilizers, improved seed and/or hire labour (Waithaka et al., 2007; Chianu et al., 2008). The problem of poverty is further deepened by the recurrent drought and other forms of natural disasters that increase the risk, further lowering the use of improved but high cost technology. (De Haen et al., 2007; Eichsteller et al., 2022)

7. Strategies for Enhancing Common Bean Production in Kenya

Improved common bean production in Kenya requires a multifaceted approach which integrates breeding innovations, strengthened agronomic management and pest and disease control measures, climate smart agriculture practices and enabling policies. Ensuring sustainable intensification and productive resilience also requires incorporation of ecological suitability, farmers capacity and market driven incentives in the matrix.

7.1 Breeding and Improved Germplasm

Breeding programs in Kenya and East Africa has over the years successfully developed varieties tolerance to drought, heat, diseases, heat, diseases, and pests (Mukankusi et al., 2012; Beebe et al., 2013). Biofortified varieties enriched with iron and zinc such as Obwelu and G2333 has also contributed to nutritional security while maintaining agronomic performance (Muyonga et al., 2014). These efforts have however not been fully maximised due to limiting seed dissemination and adoption with informal seed systems dominating most rural seed systems. Wide scale adoption of these improved germplasms and certified seeds require strengthened formal seed multiplication channels, community-based seed production and farmer awareness campaigns.

7.2 Improved Agronomic Practices and soil Health

Sustainable common bean production requires balanced crop agronomy and soil health management. This practice includes timely planting using right spacing, keeping crops weed free, embracing 4R nutrient stewardship (Right source, rate, time and place), adoption of integrated soil fertility management (ISFM), soil and water management and supplemental irrigation (Ndegwa et al., 2019; Beebe et al., 2013; Nalivata et al., 2017). Rotating beans with other crops also reduce pest and diseases build up while improving soil health. Additionally, intercropping beans with cereals such as maize and sorghum in dry land environments optimises land use providing microclimate benefits to mitigate heat stress Intercropping with maize or sorghum not only optimizes land use but also provides microclimatic benefits, such as shade and windbreaks, which can mitigate heat (Kamau et al., 2020).

7.3 Integrated Pest and Disease Management

Susceptibility nature of common beans to multiple pests and diseases calls for integrated management approaches that combines resistant varieties, cultural practices, biological control, and judicious chemical use (Kimutai, 2015, Waswa et a., 2022; Beebe et al., 2013). (i). Cultural practices include: Early planting, field sanitation, removal of infected residues, proper spacing reduce disease incidence and pest infestation and timely weeding to minimise growth factors competition and habitat or alternate hosts for pests (Ndegwa et al., 2019). (ii). Biological control entails encouragement of practices that promote natural enemies, such as parasitoids and predatory insects, that supresses pest populations. They include: ladybird beetles and lacewings that reduce aphid infestations and entomopathogenic fungi which target stem maggots (Beebe et al., 2013). (iii). Chemical interventions on the other hand entail abridged pesticide overreliance encouraging reduced resistance development, environmental contamination, health hazards. (iv). Seed treatment with fungicides or bio inoculants also prevent early stage diseases, enhance nodulation leading to vigorous growth and higher yields (Waswa et al., 2022).

7.4 Climate-smart Interventions

With climate variability posing long-term threat to bean production, embracing climate-smart agricultural practices that strengthens adaptation mitigation and resilience is paramount. Such practices include: (i). Adoption of drought-tolerant and heat-tolerant cultivars, early planting, and water conservation techniques. (ii). Agroforestry and soil water management by integrating trees in bean fields to improve microclimate regulation, reduces wind and water erosion, and contributes to carbon sequestration as well as contour farming and terracing in hilly areas reduce runoff and enhance soil moisture retention (Beebe et al., 2013; Fahad et al., 2022; Jinger et al., 2024). (iii). Provision of c*limate information services by providing farmers with timely forecasts and advisories to inform* planting, irrigation scheduling, and pest management and agronomic practices decisions (Appiah et al., 2025).

7.5 Market and Policy Interventions

Economic incentives and enabling policies are critical for sustainable bean production. This can be achieved through: (i). Connecting farmers to reliable markets, cooperatives, and contract farming arrangements to increase profitability and encourage investment in improved inputs and practices. (ii). Strengthening post-harvest handling, storage, and processing infrastructure to reduce losses and improve market value (Ndegwa et al., 2019; Waswa et al., 2024). (iv). Strengthening government support to government and NGOS input subsides and extension services programs to reinforce wide spread technologies adoption (v). Reinforcing of policies encouraging research funding, seed certification, and farmer training by the government to strengthen overall bean production system. (vi). *Streamlining access to* credit and microfinance by smallholders enabling enhanced investments in inputs, irrigation, and mechanization, overcoming labor and resource constraints (Kipkpsgei et al., 2025)

7.6 Knowledge and Capacity Building

Farmer empowerment is highly correlated with adoption of improved technologies. This can be carried out through (i). Farmer field schools (FFS)- Hands-on training platforms that allow farmers to co-created agronomic, pest and disease management, and post-harvest handling practices and adopt the best (ii). Engaging farmers in selection of preferred varieties through participatory breeding to ensure adoption of germplasm suited to local preferences, agro-ecology, and market requirements. (iii). Embracing information dissemination through mobile-based advisory services, radio programs, and community workshops to enhance awareness and provide timely agronomic and weather recommendations.

8. Conclusion

The review indicates that Common bean plays an important role in the country's food security, nutrition, and rural livelihoods by providing both acting as a direct source of protein and micronutrients for households, and a cash crop that supports smallholder income generation. Despite its potential, bean production faces multiple constraints, ranging from biotic stresses such as pests and diseases, to abiotic stresses including drought, erratic rainfall, and poor soil fertility. Socio-economic factors, including limited access to quality seeds, inputs, extension services, and markets, further compound the challenges for farmers, particularly in marginal areas.

Combination of genetic improvement, agronomic innovation, climate-smart practices, and integrated pest management is highlighted as critical for enhancing productivity and resilience. Although breeding programs have delivered varieties that tolerate drought, heat, and major diseases and biofortification benefits, extensive adoption remains limited owing to seed system inefficiencies. Additionally, though agronomic practices such as timely planting, proper spacing, soil fertility management, intercropping, and water conservation have demonstrated substantial yield improvements when combined with farmer capacity-building initiatives, ensuring sustainable production requires strengthening of integrated pest and disease management, which consists of resistant varieties, cultural practices, biological control, and judicious chemical use.

Buffering small holder systems against climate variability requires adoption of climate-smart interventions, such as drought and heat adaptation, agroforestry, soil and water conservation, and climate information services. Augmenting these strategies with market-oriented and policy-driven interventions enhances the viability and sustainability of bean production. Access to markets, value addition, supportive government policies, and financial inclusion are crucial in incentivizing farmers to adopt improved practices and technologies. Knowledge dissemination and capacity building through extension services, participatory research, and farmer field schools empower communities to make up-to-date decisions that contribute towards improved soil health, crop yields and livelihoods.

Ensuring sustainable common bean production in Kenya therefore requires all-inclusive, integrated approaches that address ecological, agronomic, socio-economic, and policy dimensions concurrently. This means prioritization of research on stress-tolerant and nutritionally enriched varieties, strengthening seed systems, scaling up climate-smart practices, enhancing farmer knowledge and market access should be carried out at same time and dimension.

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Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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