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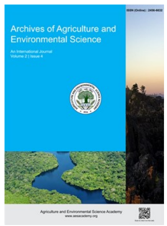

REVIEW ARTICLE

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Production systems and contributions of grain legumes to soil health and sustainable agriculture: A review

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ABSTRACT

Sustainable development of agriculture is essential, and there is unanimity that diversification of the cropping systems could support sustainable production. Grain legumes are essential in farming systems in terms of food and nutrition security and income generation. Under legume-based cropping systems, these crops are a potential remedy to pest and disease issues, low nutrient supply, biodiversity protection, and food and nutrition insecurity. In this chapter, we highlight the production systems of legumes and their use in sustainable agricultural production. Specifically, we have looked at the benefits of having a legume cropping system in the agroecosystem, production, and farming systems. The function of legumes in improving the potential of crop productivity is a promising approach to tackling the challenges of poor crop yields and improvement in sustainable production. Due to health and environmental benefits, the focus should shift to breeding grain legumes that can fully express their biological nitrogen fixation and other potentials under abiotic and biotic limitations.

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INTRODUCTION

Legumes contain over 20,000 species and make the third-largest family (Shafique *et al*., 2014). They are the most valuable food sources consumed after cereals as they contribute to food security globally (Mashungwa *et al*., 2019). Legumes are consumed in complement with cereals as a source of nutritional protein and contribute significantly to total protein intake. The legumes are fascinating plants because they fix atmospheric nitrogen to ammonia through their interaction with specific soil-borne bacteria, the rhizobia, consequently ameliorating soil fertility (Gonzalez-Rizzo *et al*., 2009). Such symbiotic interactions also help them to thrive in harsh and fragile environments and provide nutrients to other crops, such as cereals leading to sustainable food production (Popoola *et al*., 2014). Legumes are produced under various cropping systems: intercrops, sole crops, and rotation systems. According to Foti *et al*. (2020), legumes and legumes-based crop systems are probable solutions to food and nutrition insecurity among various populations. Smallholder farmers in most developing countries are encouraged to grow legumes and legume-based crops (Peterson *et al*., 2010). Intercropping has been practiced for a long time by smallholder farmers in Asia, Africa, and Latin America, and it is becoming widespread due to its capacity to produce high yields with minimal inputs and its ability to conserve space (Yu *et al*., 2015). For example, farmers in drought-prone areas have always used pigeon peas as an intercrop with cereals because of their ability to tolerate drought (Semahegn, 2022). However, due to land limitations, most small-scale farmers grow legumes as intercrops with staple cereals, mainly maize. Farmers benefit from the symbiotic biological commensalism between the legumes and cereal crops as intercrops. Legumes fix N and increase soil organic matter resulting in increased growth and productivity of the cereal crop (Yuvaraj *et al*., 2020). Farmers should consider factors such as compatible species, planting period, physiological characteristics of the intercrop, growth patterns, canopy, root architecture, and water and fertilizer requirements when intercropping (Semahegn, 2022). Farmers also produce legumes as a single crop, which according to Semahegn (2022), is not encouraged as it is prone to soil fertility loss and increased incidences of pests and diseases.

Legumes have been used in crop rotation systems where one grows a sequence of different crop species on the same land. Crop rotations have consistently been demonstrated to reduce soil erosion, increase water usage efficiency, and maintain high yields (Zhen *et al*., 2016). For instance, a two-crop rotation uses maize (*Zea mays*) and soybean (*Glycine max*) or maize and alfalfa (*Medicago sativa*) in alternate years to provide complementary inorganic nitrogen in the soil for the succeeding crops. Legumes can also be produced as mixed crops with legumes, cereals, or tuber crops. This cropping system benefits with complimentary uses of growth factors such as soil nutrients, light, and water, reduced pests and diseases, and reduced soil erosion. This cropping system improves biomass production and yields stability. There has been increased awareness and concern regarding animal and human food and nutrition security and degraded environmental health, especially in smallholder farms, which has intensified the focus on legume production (ICRISAT 2016). Grain legumes are important for food and nutrition, and a production system involving legumes can reduce pests and diseases, soil erosion and increase yields (Considine *et al*., 2017). Because of these benefits, the Food and Agriculture Organization (FAO) of the United Nations (UN) made a declaration to promote the cultivation of pulses and has since declared 2016 the International Year of Pulses (FAO, 2016). This review research therefore aimed to highlight key legume production systems and contributions to soil health and sustainable agriculture.

MATERIALS AND METHODS

The data used here were majorly secondary sourced from various scientific publications and recognized research institutions' websites. The materials were systematically collected through comprehensive desk research, and the relevant materials were downloaded, read, and cited as best practices.

RESULTS AND DISCUSSION

Global status of legumes

As of 2016 – 2020, the average annual world grain legumes production stood at 115.28 million tons (Table 1). India, Myanmar, Canada, China, and Brazil are the five leading legume-producing countries, accounting for half of the grain legumes produced worldwide. Among the legumes, common beans, chickpeas, cowpeas, lentils, pigeon peas, groundnuts, and soybeans are the most important legumes grown worldwide. The average yearly global production of some of the grain legumes is indicated in Table 1. According to Nigrum *et al*. (2021), common bean is the most-grown legume in 126 countries, followed by groundnuts in 114 countries and soybean in 89 countries. Other commonly grown legumes include chickpeas, lentils, cowpea, and pigeon pea. These common legumes are grown on nearly 212 million hectares, producing about 421 million tonnes. In terms of productivity, soybean contributes the highest (56.5%), followed by common bean at 14.2%, and third place is groundnut at 12.8%. Others are chickpeas at 6.0%, cowpea (5.8%), pigeon peas (2.5%), and lentils (2.2%) in the total global area (Nigrum *et al*., 2021).

Table 1. Mean annual global production of grain legumes from 2016 to 2020.

Legume	Production in Million metric tonnes
Field peas	14.9
Chickpeas	50.19
Cowpeas	9.80
Faba beans (Broad beans)	22.55
Lentils	13.34
Pigeon peas	4.50

Table 2. Summary of chemical composition of some legumes as expressed in percentages.

Legumes	Botanical names	Proteins	Fat	Carbohydrates	Fibre	Ash
Soybean	*Glycine max*	37-41	18-21	30-40	4-6	4-5
Cowpea	*Vigna unguiculata*	22-26	1-2	60-65	4-5	3-4
Groundnut	*Arachis hypogaea*	20-33	42-48	22-25	3-4	2-3
Hyacinth beans	*Lablab Purpureus*	24-28	1-2	65-70	7-9	4-5
Common bean	*Phaseolus vulgaris*	20-27	1-2	60-65	4-5	4-5
Pigeon pea	*Cajanus cajan*	15-29	1-3	60-66	5-10	3-4
Lima bean	*Phaseolus lunatus*	19-25	1-2	70-75	4-6	3-5
Winged bean	*Psophocarpus tetragonolobusa*	30-40	15-20	35-45	6-7	3-5
Bambara groundnut	*Vigna subterranean*	16-18	6-8	5057	3-6	3-4

Importance of grain legumes to human and livestock

Legumes play essential roles in soil fertility, food, feed, and fuel industries due to their nutritional and chemical compositions, which vary depending on variety, species, and soil fertility. In this section, we look at the contributions of grain legumes to the three sectors.

Source of food for farming communities

For thousands of years, backdating to the domestication of crops, grain legumes have played an important role in human diets by achieving food and nutritional security in farming communities. Grain legume seeds contain protein, starch, soluble vitamins, insoluble fiber, micro- and macro-nutrients, and numerous bio-phytochemicals (Table 2) (Watson *et al*., 2017). Legumes have three times more protein than cereals- 20%–45% protein compared with 7%–17% in cereals (Day, 2013; Zander *et al*., 2016). They also contain adequate amounts of essential amino acid, lysine, which is necessary for protein synthesis. However, they lack the sulphur-containing amino acids methionine and cysteine, which are essential for maintaining the integrity of cellular systems necessary for normal growth (Friedman, 1996). The majority of legumes, except soybeans and groundnuts, are low in fat. In addition to being good sources of calcium and phosphorus, legumes also contain a variety of other minerals. The health benefits of these legumes are massive and vary depending on the species. Food products based on soybean can potentially reduce heart and blood vessel risks by lowering cholesterol and controlling hypertension (Harland and Haffner, 2008; Sirtori *et al*., 2009). Soybean and lupin products have been reported to reduce cholesterol in humans (Sirtori *et al*., 2012). The important and diverse role played by food legumes in the farming systems and in the diets of poor people makes them ideal crops for achieving developmental goals of reducing poverty and hunger, improving human health and nutrition, and enhancing ecosystem resilience.

Source of feed in the livestock industry

Pulse grains can be used as feed for ruminants, either in concentrated compound feeds or as whole plant feeds (Sherasia *et al*., 2018). The utilization of grain legumes as ruminant feed depends on their chemical makeup, how they complement the forage diet component, and the rate and degree of nutritional breakdown in the rumen (Watson *et al*., 2017). The use of legumes is mainly to supplement protein in animal feeds. The degradability of grain legume protein in the rumen is similar to that of most cereal grains, often over 80% (Luke, 2016). Soybean is the most popular grain legume and the primary supplemental plant protein source in animal feed. Świątkiewicz (2021) estimates that 84% of the high-protein oilseed meals used in compounded livestock rations in the global poultry and pig industries come from soybeans. Soybean meals are heavily relied upon, particularly in the pig sector, because of their high crude protein (CP) content (44%) and beneficial amino acid profile, which are unmatched by other grain legumes that are low in the critical amino acids methionine, cysteine, and tryptophan (Watson *et al*., 2017). However, a lot of research is currently exploring other legume-based feeds to reduce this dependency on soybean. In the fish industry, researchers are trying to examine the potential of using plant-based proteins- a detailed review by Ayadi *et al*. (2012). In fact, researchers have discovered that in the cattle and sheep industries, pea, lupin, rapeseed, or fab beans can be totally or partially substituted for soybean-based meals as the protein source in different phases of lactation of cows without having any negative effects on milk output (Khorasani *et al*., 2001; Froidmont and Bartiaux-Thill, 2004; White *et al*., 2007; Van der Pol *et al*., 2008; Tufarelli *et al*., 2012).

Potential of legumes in nitrogen fixation

These plants increase soil fertility through nitrogen fixation, positively impacting biodiversity and soil quality (Yuvaraj *et al*., 2020; Okumu *et al*., 2017; Couto-Vazquez and González-Prieto, 2016). Legumes exhibit a symbiotic relationship with nitrogen-fixing bacteria belonging to different genera of Alphaproteobacteria, *Azorhizobium*, and Betaproteobacteria (Vasconcelos *et al*., 2020). The bacteria invade the root causing the development of nodules, which are the sites of biological nitrogen-fixing. The bacteria catalyze the conversion of atmospheric N_2 to ammonia, which is easily available N for plant uptake, with the help of the nitrogenase enzyme (Howard and Rees, 1996; Ferguson *et al*., 2013; Ferguson *et al*., 2019). The effectiveness of biological nitrogen fixation depends on legume species, the species of symbiotic bacteria, and abiotic factors (Vasconcelos *et al*., 2020). Their capacity to fix atmospheric nitrogen differentiates them from other crops. The amount of N fixed is dependent on species, cultivars, and environmental factors such as temperatures, water availability, and available mineral N (Otieno *et al*., 2018; Swaroop and Lal, 2018; Kebede, 2021).

Legumes as climate-smart crops

Besides improving soil health, legumes are climate smart as they also improve environmental quality by sequestrating carbon and mitigating other pollutants. A meta-analysis study by Kumar *et al*. (2018) indicated that legumes store 30% more soil organic carbon (SOC) than other plant species. However, the type of legume, growth habits, root morphology and physiology, leaf morphology, climatic factors, soil structure and aggregation, cropping system, and stage of agronomic practice during growth all have an impact on the capacity for carbon sequestration and the amount of organic carbon returned to the soil. (Kumar *et al*., 2018). Guan *et al*. (2016), while working on the effect of perennial legumes on soil carbon sequestration, reported an increase in SOC; however, this depended on the legume species. Factors such as turnover, sloughing off of epidermal cells, and exudation of soluble carbon compounds by the roots of the legumes are all necessary for an increase in SOC stock. Legumes significantly contribute to ecosystem services because of their minimal dependency on synthetic fertilizers, thus lowering greenhouse gas (GHG) emissions (Watson *et al*., 2017; Stagnari *et al*., 2017). For instance, Gregorich *et al*. (2005) reported a linear increase in emissions of nitrous oxide from soils applied with mineral nitrogen fertilizer, while there were lower annual nitrous oxide emissions when legumes were applied as green manures. Therefore, alfalfa and other legume crops should be carefully considered when developing national records of GHG from agriculture (Abberton, 2010). Moreover, legumes are mostly used as intercrops and cover crops, improving soil stability and increasing organic matter- the most important component for soil formation, soil fertility, and yields (Martin Körschens, 2002; Howieson *et al*., 2008). In fact, Otieno *et al*. (2020) observed a sustainable and high production of dry beans on residual fertilizer after the maize crop. However, it is imperative to stress that managing agroecosystems where legumes are present also influence those systems' capacity to cut GHG emissions.

Legumes as biofuels

Legume residues have a greater protein concentration than cereal crops and can reach a high of 10%. Similarly, their biomass has a high protein concentration, making it possible to extract protein as a by-product when using biomass for biofuels (Jensen *et al*., 2012). Since 1906, many plants with high seed oil or starch contents have been utilized as sources of raw materials for biodiesel, including canola (*Brassica napus*), juncea (*B. juncea*), and soybean (*Glycine max*) (Biswas *et al*., 2011). Peanut oil was first used in diesel engines in 1904. Oil from these legumes can be extracted by crushing the seed and squeezing the oil out. The oil is transesterified to make biodiesel. Oil crops can also be converted into high-value biochemicals and biomaterials, reducing the use of fossil fuels. Soybean is currently a major feedstock for biodiesel production in the United States, while canola and rapeseed are common in Europe. These plants have the potential to be excellent for the manufacture of biodiesel due to their high cropping biomass per unit area and capacity to produce seeds with substantial amounts of oil annually. Biomass feedstocks for energy production might come from plants produced specifically for energy or from plant parts, leftovers, industrial wastes, and materials from animal and human activities (US Department of Energy, 2013).

Grain legume production systems

Grain legumes are produced in various ways, including as dry grain, green forage, arable silage, and green manure, depending on climatic and edaphic conditions as well as intended end-use (Watson and Stoddard, 2017). Various species of legumes are grown: pea (*Pisum sativum* L.), lupins (*Lupinus* spp.), faba bean (*Vicia faba* L.), chickpea (*Cicer arietinum* L.), lentil (*Lens culinaris* Medik.), common bean (*Phaseolus vulgaris* L.) and soybean (*Glycine max* (L.) Merr.) (Vanlauwe *et al*., 2019). Legumes can be grown as standalone crops or intercrops with cereals such as maize.

Intercropping

Intercropping comprises growing two or more crops that are from diverse families and species, with the main exclusively of primary importance and the others as secondary crops providing additional benefits such as nitrogen fixation, and soil improvement. Many of these legumes provide excellent opportunities for intercropping with early maturing crops to utilize the resources efficiently. Intercropping is practiced to promote species interaction, increasing biological diversity, and it helps farmers to cope with climate anomalies (Meena and Lal, 2018). The choice for legume intercrop depends on the main crop, legume species available, maturity period, growth stature, and farmer preference. The spacing and planting configuration depends on species, mechanization potential, main crop and intercrop growth status, and prevailing climatic conditions and soil fertility. Legume-based intercropping system results in high production from the same field and improves natural resources' efficiency compared to mono-cropping (Inal *et al*., 2007). According to Fustec *et al*. (2010), leguminous crops improve soil functions through biological nitrogen fixation and therefore have more advantages over the monoculture farming system. Practicing legume-based intercropping is a form of eco-friendly agriculture and relies on minimal use of inorganic N application (Ashoka *et al*., 2017) and, therefore, a form of a sustainable agricultural production system.

Crop rotation

Crop rotation is a system whereby different kinds of crops are grown in recurrent sequence and in definite sequence on the same land (Zhao *et al*., 2020), as distinguished from continuously growing the same crop (monoculture) (Sumner, 2018). Crop rotation can increase productivity and sustainability in crop production systems, where legumes are included in maize/sorghum production systems (Keeler *et al*., 2009). According to Schwember (2020), cultivation of grain legumes as an alternative crop in rotation farming allows soil recovery and diversification of production. Through this, there is enhanced soil biodiversity, improvement in soil fertility, and reduced incidences of pests and diseases (Espinoza *et al*., 2012). Grain legumes are planted as a component of crop rotations, enhancing productivity and improving soil sustainability (Watson and Stoddard, 2017). Crop rotation improves soil structure, soil permeability, microbial activity, water holding capacity, and organic matter, reducing reliance on chemical fertilizers, and increasing biological diversity, thus increasing crop yields and sustainability of production systems. Knight (2012) indicated that nitrogen fixation and soil microbial function are affected by the frequency with which legume is produced. However, according to Brouwer (2006), there is a trend toward specialization of agricultural production systems, which has resulted in a gradual reduction in diversity. Because of this, there has been a degradation of biological functions, such as the replacement of ecological pest management by pesticides or the use of biological nitrogen fixation (BNF) by mineral fertilizers (Zander *et al*., 2021). Farmers are therefore encouraged to have different species of crops having different life cycles as a way of maximizing the management of pests and diseases and, at the same time, take advantage of nutrient availability through crop rotations (Cook, 2013; Garrison *et al*., 2014; Reckling *et al*., 2016).

Mixed cropping

Mixed cropping is the planting of mixtures of legumes and cereals or tuber crops, and it is a common practice in marginal agro-ecological environments. This cropping system has a variety of functions, including the complementary use of growth factors, such as soil nutrients, light, and water (Nigli *et al*., 2008; Dore *et al*., 2011). This system also reduces incidences and prevalence of pests, diseases, and soil erosion and increases biomass and total yields (Staniak *et al*., 2014). Additionally, the combinations can be easily modified to account for variables like the timing of the rainy season's arrival or the level of soil fertility in various fields (Weltzien *et al*., 2017). Legume cereal mixtures require lower doses of nitrogen fertilizers than sole cereal crops. As a result, there is an increase in protein content in the seeds of cereals. Zarea *et al*. (2008), while working on the effects of forage legumes mixed crops on biomass production and bacterial community structure, found that mixed cropping enhanced the number of bacteria, free-living N_2-fixing bacteria, and Azotobacter in the rhizosphere. Studies on cropping mixture of yellow lupine with wheat and oats indicated a competitive potential of a single legume when compared to a single cereal plant (Staniak *et al*., 2014). Mixtures of legumes and cereals create allelopathic conditions that may significantly influence plant stand and yield output (Księżak and Staniak, 2011).

Monocropping

Mono cropping is the practice of growing a single crop year after year on the same land. This practice is discouraged as other farming systems with legumes, rather than monoculture production, results in better economic and environmental effects and discourage incidences of pests, diseases, and weeds (Nigli *et al*., 2008; Dore *et al*., 2011; Kebede, 2020). Similarly, continuous planting of some legume species as mono-crops might lead to nitrate leaching (Vasconcelos *et al*., 2020), while others might lead to high N_2O emissions. For instance, Senbayram *et al*. (2016) reported higher cumulative N_2O emissions than that of fertilized wheat when legumes were grown as mono-crops. Because there are many limitations associated with using legumes as mono-crops, farmers are advised to plant legumes as intercrops, rotational crops, or mixed crops.

Contribution of grain legumes to sustainable agricultural production

A rapidly growing population is affecting food and nutrition security due to the depletion of water and land, which are already under great pressure. Adverse effects on soil health are soil degradation due to global warming, pollution, and loss of soil fertility (Swaroop and Lal, 2018). In these situations, legumes can be used as an alternative to support soil stability when included in crop rotation and intercropping. (Figure 1).

Legumes contribute greatly to integrated soil fertility management because they can fix atmospheric N_2 in symbiosis with rhizobia bacteria. Furthermore, these crops provide organic matter inputs that positively impact soil chemical, physical and biological properties and improve crop yields (Sa *et al*., 2017). According to Choudhary and Choudhury (2018), having legumes as intercrops in maize farms improve productivity and, at the same time, sustains nutrient availability. Chimonyo *et al*. (2019), while working on a grain legume maize-based cropping system, reported an increase in maize productivity, which was attributed to an improvement in soil water holding capacity and fertility. This phenomenon can be explained by the fact that legumes' cropping system improves soil fertility, enhances soil health, and improves soil resilience to various erosion phenomena (Kintl *et al*., 2015).

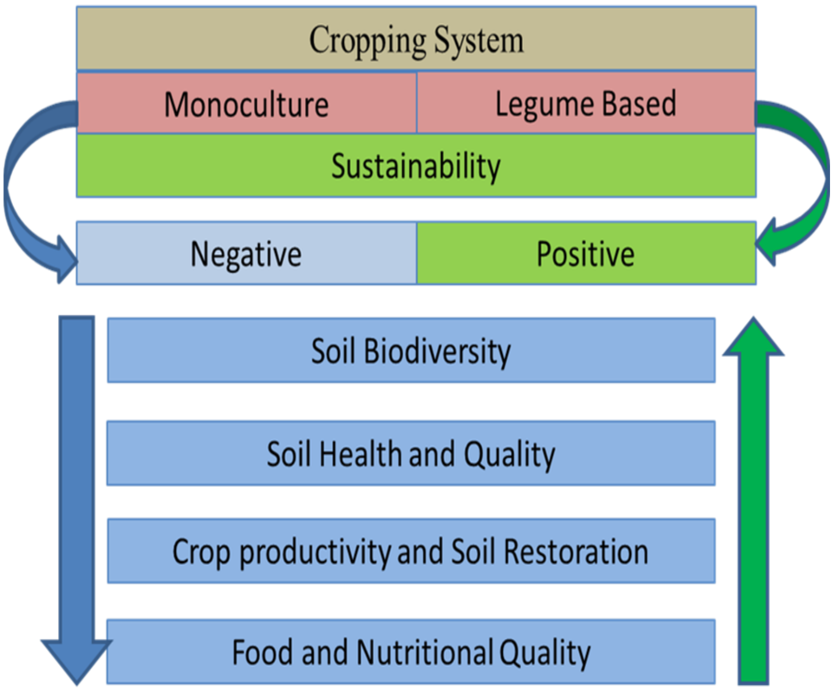

Figure 1. *Response of legume-based cropping system (Swaroop and Lal, 2018).*

Table 3. Summary of legume-based practices and how they impact soil health.

Legume-based system and use of residue	Soil health parameter evaluated	References
Maize-legume rotation	Total N, avail P, exchange K, Mg	Uzoh *et al.* (2019); Jena *et al.* (2022)
Legume residue	Soil organic carbon, total N, exchangeable Ca and Mg	Kolawole (2013); Jena *et al.* (2022)
Legume intercrop	Soil organic carbon, improving chemical, biological, and physical soil environment, reducing pest damage	Hu *et al.* (2021); Kumar *et al.* (2016); Mandal *et al.* (2014); Layek *et al.* (2018); McIntyre *et al.* (2001)
Legume cover crops	Conservation, SOC and nitrogen stocks, BNF, reduction in nitrous oxide emission	Nees *et al.* (2010); Dhakal *et al.* (2016)
Legume residue	Physical properties of soil, i.e., structure, texture, density, stability, porosity	Jena *et al.* (2022)
Green manure	Soil organic carbon, nitrogen, phosphorus and potassium, reduction in population of pathogens	Okumu *et al.* (2018a), Okumu (2018b)

Including legumes in a farming system strengthens the ecosystem by enhancing beneficial soil microbes and improving soil biodiversity (Meena *et al*., 2014). Through mineralization, these crops benefit neighboring plants, guarantee protection from pests and diseases, and reduce soil erosion (Lal, 2013). Legumes have extensive root systems and secrete root exudates that significantly improve soil nutrient dynamics, soil structure, and soil quality (Sugiyama and Yazaki, 2012). These legumes also help recycle nutrients such as nitrogen, phosphorus, and carbon. Many legumes such as lupin (*Lupinus angustifolius* L.), vetches (*Vicia sativa* L.), velvet bean (*Mucuna pruriens* Bak.), fenugreek (*Trigonella foenum-graecum* L.), clovers (*Trifolium* sp.), *Crotalaria spectabilis*, or *Sesbania rostrata*) are also being used as green manure (Swaroop and Lal, 2018). When applied as green manures, these crops boost soil organic matter and nutrient availability, ensuring plants have good nutrient sources. Because of this, including these crops in a rotational system will boost the nitrogen stock for the next crops (Hauggaard-Nielsen and Jensen, 2005).

Sustainable productivity has been a challenge, especially for developing nations. This has been compounded by the misuse of agrochemicals that have had deteriorating impacts on soil health. According to Shahid *et al*. (2020), unnecessary and inappropriate use of fungicides to control soil-borne diseases to improve crop production has deleterious effects on microbial composition, soil fertility, and grain production. Thus legume-based crop rotations are better as a way of protecting the environment. Through crop rotations, soil microbial status is significantly improved because the legume residues are a food base for soil biota that improve nutrient mineralization, soil functions, and productivity. Thus the role of legumes in improving productivity is important as it addresses the challenges of low productivity.

Contribution of legume residues to soil sustainability

The residues of legumes can be a source of mineral nitrogen for succeeding crops because of their relatively high nitrogen content (Kebede, 2021). Nutrients derived from decomposed legume plant parts expressively contribute to below-ground nutrient transfer (Louarn *et al*., 2015). As live and dead soil surface covers, legumes reduce soil moisture loss, evapotranspiration rate, and improve soil root ability (Moura *et al*., 2015). According to Sangare *et al*. (2016), using legume crop residues is an alternative to improving soil fertility. However, legume residues cannot serve as an immediate nitrogen source for plants but contribute to an N pool in the soil with a long-term release (Formowitz *et al*., 2009). Studies have reported increased crop yields when organic residues have been incorporated into the soil (Kouyate *et al*., 2000; Gachengo *et al*., 1999; Shafi *et al*., 2007; Bakht *et al*., 2009). In a study by Moura *et al*. (2014), where legume trees were studied for their effect on soil improvement, the treatment with high biomass had higher carbon stocks in the litter and total organic carbon. According to Moura (2009), a constant addition of residues is important to maintain equilibrium between carbon inputs and high decomposition rates. A combination of mineral fertilizers and organic residues can be considered to increase their efficiency, a more judicious approach is being promoted where mineral fertilizers are combined with soil organic amendments such as legumes (Kouelo *et al*., 2013). As a result, more legumes cover crops have been promoted for use as green manures. Some of the legume-based practices and their benefits are listed in Table 3.

Conclusion

The important and diverse role played by food legumes in the farming systems and in the diets of poor people makes them ideal crops for achieving developmental goals of reducing poverty and hunger, improving human health and nutrition, and enhancing ecosystem resilience. Therefore, legumes must be incorporated into production systems for agricultural livelihoods to be resilient and sustainable. In this context, it is crucial to understand each legume's distinctive characteristics and how they work within an agricultural system because it is a possible strategy for addressing the issues of low crop yields and increasing sustainable production.

Author Contributions

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Conflicts of Interest

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