Chapter

Role of Legumes in Improving Soil Fertility Status

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Abstract

Legume plants have a probably important role to play in growing indigenous nitrogen production besides meeting human demands for protein and energy. Some legumes have the capability to solubilize in any other case unavailable phosphate by excreting organic acids from their roots, in addition to improving soil fertility. Legumes also assist to restoration of soil natural matter and limit pest and disease issues when used in rotation with nonleguminous crops. Research has shown that the organic nitrogen fixation procedure is the most environment friendly way to grant the giant amounts of nitrogen wished through legumes to produce high-yielding crops with an excessive protein content. For the fixation technique to occur, legume vegetation must enter into a "symbiotic" or collectively beneficial partnership with sure microorganism known as rhizobia. Soon after legume seeds germinate, rhizobia current in the soil or delivered as seed inoculum invade the root hairs and go through an infection thread toward the root. The bacteria multiply rapidly in the root, causing the swelling of root cells to structure nodules.

Keywords: legume, soil fertility, greenhouse gas, crop rotation

1. Introduction

Global populace will hit 9.6 billion human beings with the aid of 2050 [1] and will face world challenges among which attaining meals security, reducing the risk of local weather exchange through lowering the net release of greenhouse gases into the ecosystem and assembly the increasing demand for energy are the most critical ones. In particular, the impact of climate trade and related biotic and abiotic stresses to which crop structures will be an increasing number of uncovered pose serious implications for global food production [2].

To meet these challenges, a policy framework needs to be developed in which the sustainability of production consumption patterns turns into central. In this context, meal legumes and legume-inclusive manufacturing systems can play essential roles by means of turning in more than one offerings in line with sustainability principles. Indeed, legumes play central roles [3]: (a) at food-system level, both for human and animal consumption, as a source of plant proteins and with an increasingly importance in enhancing human beings health [4]; (b) at production-system level, due to the capability to fix atmospheric nitrogen making them potentially notably appropriate for inclusion in low-input cropping systems, and due to their function in mitigating greenhouse gases emissions [5]; and (c) at cropping-system levels, as diversification vegetation in agroecosystems primarily based on few important species, breaking the cycles of pests and diseases and contributing to stability the deficit in plant protein manufacturing in many areas of the world.

Legumes have a probably substantial position to play in enhancing soil carbon sequestration. They can also have considerable additional advantages beyond their significance involving nitrogen fixation and excessive protein feeds. These consist of advantageous impacts on biodiversity and soil quality. There is a great need for a strong focus on creating the role of legumes and their contribution to each the sustainable intensification of manufacturing and the livelihoods of small holder farmers in many components of the world [6]. Apart from their makes use of as food and fodder they have a very necessary position in retaining soil fertility by fixing atmospheric nitrogen and enhancing soil structures and adding organic matters. Moreover, it is generally used as an intercrop and covers plants, and sometimes, it is cultivated as emergency vegetation due to its brief life cycle. Since it requires low fertilizer and other inputs this crop is relatively profitable in a most economical point of view. It also improves environmental quality by sequestrating carbon and mitigating other pollutants. Legumes are additionally a potential plant team in which some of the species having a capacity of remediating poisonous metals and organic pollutants [7].

2. Nitrogen fixation

Legume plant and seed tissue is distinctly high in protein. This can be without delay attributed to a legume's capability to supply most of its personal nitrogen wants with the assist of symbiotic Rhizobia microorganism residing in their roots. Inoculated with the applicable stress of Rhizobia bacteria, legumes can furnish up to 90% of their own nitrogen (N). Shortly after a legume seed germinates in the presence of Rhizobia microorganism in the soil, the bacteria penetrate the root hairs and cross into the root itself. The bacteria multiply, inflicting a swelling of the root to shape pale pink nodules. Nitrogen gasoline present in the soil air is then sure by the microorganism which feed on carbohydrates manufactured by the above-ground plant in the course of photosynthesis [8]. The bacteria produce ammonia (NH_3) from the hydrogen obtained from the plant's carbohydrates and nitrogen from the air. The ammonia then provides a supply of nitrogen for the plant to grow. This symbiotic relationship between bacteria and legume lets in them both to flourish and produce a high-protein seed or forage crop. Even although legumes can repair nitrogen from the atmosphere, they can take up large quantities of soil nitrogen if it is available. Nitrogen release from a legume crop occurs as the above-ground plant residues, roots and nodules step by step decompose. Soil microorganisms decompose the highly nitrogen-rich organic cloth and launch the nitrogen to the soil when they die. Usually about two-thirds of the nitrogen fixed through a legume crop becomes handy the subsequent growing season after a legume in a rotation [9].

3. Advantages of legumes in soil quality

Soil quality advantages of legumes include increasing soil natural matter, improving soil porosity, recycling nutrients, improving soil structure, decreasing soil pH, diversifying the microscopic lifestyles in the soil, and breaking disease build-up and weed problems of grass-type crops.

3.1 Soil natural rely

As stated previously, legumes are high in protein, and therefore, nitrogen rich. Because most crop residues incorporate a lot extra carbon than nitrogen, and microorganism in the soil need both, the nitrogen provided by legumes allows the decomposition of crop residues in the soil and their conversion to soil constructing natural matter.

3.2 Soil porosity

Several legumes have aggressive taproots reaching 6–8 feet deep and a half inch in diameter that open pathways deep into the soil. Nitrogen-rich legume residues inspire earthworms and the burrows they create. The root channels and earthworm burrows make bigger soil porosity, promotion air movement and water percolation deep into the soil.

3.3 Recycle vitamins

Because perennial and biennial legumes root deeply in the soil, they have the capability to recycle crop nutrients that are deep in the soil profile. This effects in a more environment friendly use of utilized fertilizer and prevents nutrients (particularly nitrate nitrogen) from being lost due to leaching under the root region of shallower-rooted crops in the rotation (**Figure 1**).

3.4 Improve soil structure

The improvements are attributed to increases in more stable soil aggregates. The protein, glomalin, symbiotically along the roots of legumes and other plants, serves

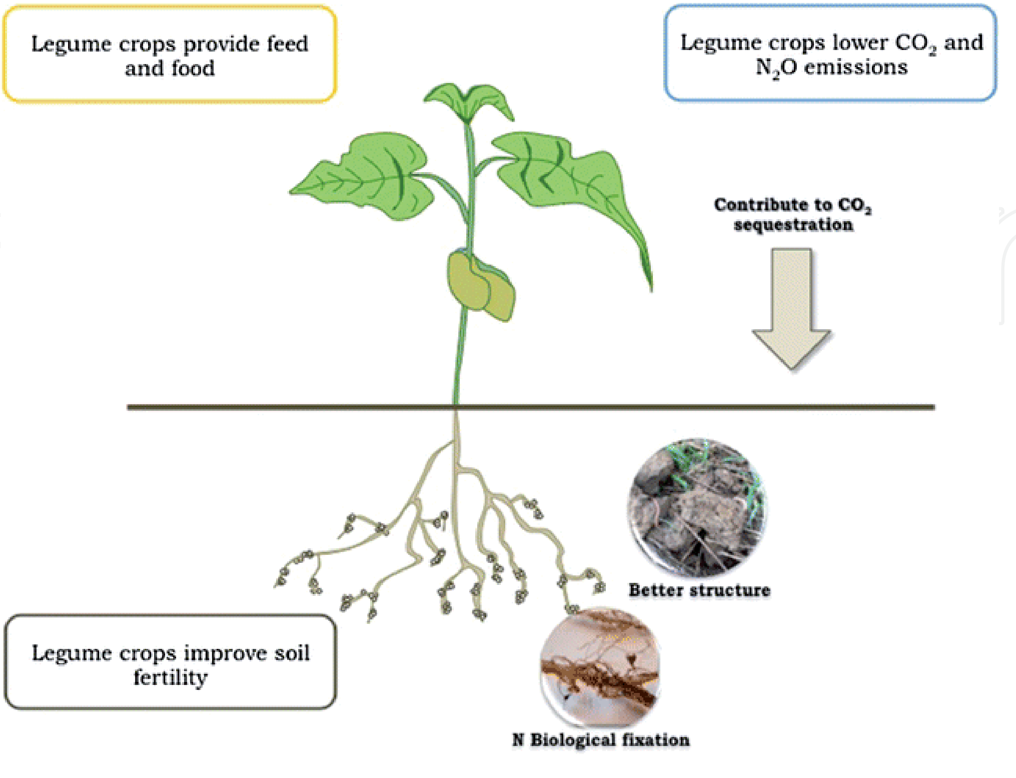

Figure 1.
Benefits of legume crop in improving soil sustainability [10].

as a "glue" that binds soil together into stable aggregates. This aggregate stability increases pore space and tilth, reducing both soil erodibility and crusting.

3.5 Lower soil pH

Because inoculated, nodulated legumes acquire their N from the air as diatomic N rather than from the soil as nitrate, their net effect is to lower the pH of the soil. In greenhouse studies, alfalfa and soybeans lowered the pH in a clay loam soil by one whole pH unit. Legumes could lower the pH and promote increased plant-soil-microbial activity on soils with a pH above the range for optimum crop growth and development.

4. Biological diversity

Legumes contribute to an increased diversity of soil flora and fauna lending a greater stability to the total life of the soil. Legumes also foster production of a greater total biomass in the soil by providing additional N. Soil microbes use the increased N to break down carbon-rich residues of crops like wheat or corn.

4.1 Legumes and carbon sequestration

For a range of years, the practicable importance of legumes in many agro-ecosystems, but also the restrained extent to which this possible has been realized, has been recognized. Legumes do not just contribute in terms of food, feed and fertility, but are also essential as fuelwood and with admire to carbon (C) sequestration. In this chapter we focal point on the extent to which legumes can contribute to greater C sequestration and the delivery of co-benefits including greater biodiversity and reduced greenhouse fuel (GHG) emissions. We additionally consider briefly the main reasons why legumes are currently underutilized and the possibilities for a larger function in the future. Enhancing C sequestration in the soil is linked to elevated biomass and hence to soil fertility. Raising fertility is perchance the most effective way of rapidly growing carbon sink capacity. Clearly, one way of doing this is through elevated addition of nitrogenous fertilizers. However, caution in the enormous use of nitrogenous fertilizers as a strategy to elevated productivity is excellent for a variety of reasons, consisting of the potential for other emissions. By contrast, the role of legumes in supplying nitrogen (N) through fixation is being increasingly more seen as important as an extra beneficial in terms of common GHG stability than had as soon as been thought. The introduction of legumes and their higher utilization as section of a pasture improvement system are consequently probably to be worthy of serious consideration in many circumstances [11].

4.2 Reduction in greenhouse gasoline emissions

Legumes are also possibly to have a position to play in lowering GHG emissions from ruminant systems. An approach to decreasing methane emissions of current interest and supported by some initial evidence is the use of tannin containing forages and breeding of forage species with greater tannin content. Forage legumes such as *Lotus corniculatus* (birds foot trefoil) and *L. uliginosus* (greater trefoil) possess secondary metabolites acknowledged as condensed tannins in their leaves. They are no longer present on the leaves of white or purple clover but are existing in the inflorescences. Methane production values had been lower in housed sheep fed on purple clover and birds foot trefoil than on a ryegrass/white clover pasture [12]. The emissions of nitrous oxide from soils improved linearly with the quantity of mineral nitrogen fertilizer applied and because structures containing legumes produce lower annual nitrous oxide emissions, alfalfa and different legume vegetation need to be regarded differently when deriving national inventories of GHG from agriculture. The nitrous oxide emissions are from soils with alfalfa and soybean cropping, looking at soil floor emissions in evaluation with perennial grass. Low nitrous oxide emissions have been considered under grass and soil mineral N used to be up to ten instances higher beneath legumes however soil mineral N pools were not carefully associated to nitrous oxide emissions. Comparable emissions were viewed under timothy (*Phleum pratense*) as underneath legumes.

Legumes are soil-amendment crops with strong benefits on soil health and need to be an essential element of the farming systems [13]. Legumes have positive effects on soil processes such as benefiting agroecosystems, agricultural productivity, soil conservation, soil biology, SOC and N stocks, soil chemical and bodily properties, BNF, nitrous oxide (N_2O) emission, and nitrate (NO_3) leaching by means of lowering the need for chemical fertilizers. Above all, legumes are now utilized as soil nourishment agents. However, these benefits on soil health need to be quantified, and their mechanisms understood. Thus, incorporating legumes as a section of cropping systems is pertinent to higher soil fitness and productivity [14].

4.3 The potential for legumes to mitigate climate change

The concentrations rise, it has become an increasing number of necessary to account for losses of CO_2 and N_2O arising from agriculture. Emissions of these gases may occur either directly as the result of farming activities (e.g., cultivation and harvesting) or circuitously for the duration of the production and transport of required inputs (e.g., fertilizers, herbicides, and pesticides). The plausible function of N_2-fixing legumes in lowering GHG emissions via direct effects on CO_2 and N_2O fluxes in the production of high-protein grain and forage will be in contrast to the functions of fertilizer N in the following sections. CO_2 emissions bobbing up from N fertilizer manufacturing and symbiotic N_2 fixation.

4.4 Role of legume vegetation on enhancing soil physical properties

Important soil physical properties are bulk density, porosity, combination stability, and texture. These properties are additionally associated with water-related methods including aeration, runoff, erosion, water maintaining capacity, and infiltration rate [15]. Legume vegetation have a manageable to enhance physical properties of soil by being a soil conditioner and enhancing the physical residences [16]. Leguminous cover crops have a tremendous effect on soil physical properties broadly speaking due to the manufacturing ability of large biomass which affords substrata for soil organic undertaking and soil organic matter [17]. Furthermore, leguminous cover vegetation are grown to protect the soil from loss of plant nutrients and erosion, while green manure plants are grown for the motive of improving soil bodily properties. Moreover, some plants can physically modify the types of soil profile. Legumes additionally have an effect on soil shape by means of their impact on aggregation. Leguminous cover crops can expand or keep an appropriate soil C/N ratio and increase in preserving soil organic carbon stock. Legume plants often result in higher infiltration of water, due to direct effects of the crop residue in soil formation and aggregation [18–26].

4.5 Role of legume crops on improving soil chemical properties

Soil chemical properties for sustainability are connected with the capability to provide vitamins for crop and retaining/denaturing hazardous chemical compounds or factors to the agroecosystem. Soil cation alternate capability (CEC), pH, nutrient levels, and soil organic carbon concentration are the primary chemical elements used toward the evaluation of soil fertility. Soil chemical properties have been associated with leguminous crops, and thus, the particulars of a soil property are easily interpreted and permit a rapid enhancement of the soil chemical properties through N-fixation and root biomass. Legume-based rotation induces modifications in the pH of the rhizosphere sector of soil. Root exudation of legumes and change or release of organic acids on the epidermal cell of root surfaces can also enhance P availability [27]. In addition, changes in pH are broadly recognized to affect the increase and undertaking of microorganisms [28], which are additionally necessary aspects in nutrient cycling processes. Leguminous green manure is a well-known generator of soil natural matter. Green manure, apart from increasing soil N, releases P, continues and renews the soil natural carbon, and improves soil chemical characteristics. Incorporation of legume residues is really useful to the soil for growing soil natural carbon awareness which is not only vital to agricultural productiveness however also to sequestration of C from atmospheric CO_2 [29]. Observed that when leguminous cover plants are used as green manure and incorporated into the soil, their residues make bigger availability of N, P, K, and trace elements to the succeeding plants due to the lowering of the soil pH brought about by the CO_2 produced in the process of decomposition [30].

4.6 Role of legume vegetation on enhancing soil microbial biomass

Soil microorganisms have a necessary link between plant productiveness and soil nutrient availability as they are indirectly directly engaged in the nutrients cycling through the conversion of inorganic and organic types of nutrients [31]. Legumes are one of the necessary components to increase soil microbial biomass in soils. Legumes play a necessary function in SMB and energetic key strategies such as nutrient cycling and soil organic matter decomposition and, thus, improve crop productiveness and soil sustainability [32]. Some microorganisms which interact physically with leguminous vegetation in the rhizospheric zone can also enhance crop productivity positively by enhancing plant increase and development [33].

4.7 Role of legume crops in soil carbon sequestration

Sequestration of soil organic carbon is one of the vital determinants of soil fertility, productivity, and quality. Crop residues increase carbon sequestration through decomposition of their residues. Increase in soil natural carbon stock improves soil tilth and workability, stabilizes soil aggregates, will increase soil water preserving and aeration, enhances buffering capacities, and improves availability of nutrients through breakdown of residues [34]. The soil organic carbon inventory depends on soil types, crop and residue management [35], fertilizer N input, and frequency and kind of cropping device [36]. In the agricultural fields, legume plants make contributions positively to the soil natural carbon stock, soil tilth, soil fertility, and universal soil sustainability. Legume-based cropping systems improve mixture balance and lengthen the nutrient dwelling time in soil through decreasing the mineralization rate. Biomass production can be expanded by legume based bi culture, a combination of legume with nonlegume species [8, 37].

4.8 Role of legume vegetation in improving the soil N pool

Nitrogen is vital for the crop growth, solely to water and light. However, most vegetation depend on the consumption of soil N to meet their needs; most highly the legumes, are capable of N-fixation with the symbiotic relationship with rhizobia. The BNF benefits not only the legumes however also improves yield in succeeding crops, in agroforestry systems, and in legume-cereal intercropping system. The N quantity made available to cereal crop derives from the breakdown of legume-biomass residues. However, the affiliation of N tends to cross from crop containing enormously high N (i.e., legumes) to those with an increased N demand (nonlegume). An approach to raise N supply in cropping structures is the inclusion of N-fixing leguminous crops, which can grant N advantages to the vegetation thru N transfer. The extent of biologically fixed N/year by way of legumes varies significantly from zero to several hundred kg N/ha.

4.9 Role of legumes in mitigating greenhouse gas and enhancing soil pleasant

1. Lower the emission of greenhouse gases (GHG) such as carbon dioxide (CO_2) and nitrous oxide (N_2O) compared with agricultural systems based totally on mineral N fertilization.

2. Have an essential role in the sequestration of carbon in soils.

3. Reduce the overall fossil power inputs in the system.

5. Importance of legumes

Increased cultivation of legumes is integral for the regeneration of nutrient-deficient soils and for imparting wanted protein, minerals, and nutritional vitamins to human beings and livestock. Legumes can be an ability of improving the livelihoods of smallholder farmers round the world.

5.1 Legumes in human nutrition

- As a supply of protein, grain legumes (such as pigeon pea, chickpea, soybean or mung bean) are a true supply of protein, with a protein content material ranging from 17 to 40%.

  By combining cereal and grain consumption, farmers and their families can achieve protein stability and dietary improvement.

- As a supply of essential vitamins and minerals, legume seeds contain tremendous quantities of minerals (calcium, zinc, iron) and nutritional vitamins (folic acid and diet B).

5.2 Legumes for animal nutrition

Cereal crop residues supplemented with forage legumes notably increase normal animal productivity. For example, improved fowl egg production has been mentioned when pulse grains are protected in their feed. Adding the residue from legume flora into cattle forage can expand the digestibility and typical quality of cereal crop residues. For example, maize residues tend to be high in carbohydrates however low in protein; therefore, adding leguminous flora will make a contribution to multiplied livestock nutrition.

5.3 Legumes for crop and soil improvement

For most effective yield, plants require a furnish of mineral nutrients, the most essential of which is nitrogen. Exhausted soils are often low in nitrogen, meaning that farmers are usually applying inorganic fertilizers. However, as fertilizer expenses increase, farmers battle to acquire properly yields. This trouble can be addressed by incorporating legumes into the cropping system. Leguminous plant have a close relationship with nitrogen-fixing microorganism known as Rhizobium. By biologically fixing nitrogen ranges in the soil, legumes grant a fantastically low-cost approach of changing nitrogen in the soil, improving soil fertility and boosting subsequent crop yields.

6. Conclusion

The use of nitrogen-fixing legume-based leys, whether they are used for grazing, conservation or mulched to build soil fertility, is the basis of most organic systems. Their use is enshrined in the organic standards, which require the inclusion of legumes in rotations. The wider benefits of legumes, particularly in providing food for pollinators, are also increasingly being recognized. Globally, the amount of carbon di oxide respired from the root systems of N_2-fixing legumes could be comparable to, or higher than, the carbon di oxide generated during nitrogen-fertilizer production. However, the carbon di oxide respired from the nodulated roots of legumes originated from the atmosphere via photosynthesis, so any of the carbon di oxide that was not subsequently recaptured by the plant and eventually escaped from the legume canopy to the atmosphere would essentially be carbon neutral. By contrast, all the carbon di oxide released during the synthesis of fertilizer nitrogen would be derived from fossil energy and represents a net contribution to atmospheric concentrations of carbon di oxide.

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