Role of Legumes in Improving Soil Fertility

Mahalaxmi S Devarnavadgi*, Vidyavathi G Y and Veeresh Katti
Department of Soil Science and Agricultural Chemistry, College of Agriculture, Dharwad, University of Agricultural Sciences, Dharwad, Karnataka, India
*Corresponding Author: mahalaxmi.dgi@gmail.com

Legumes are a group of plants in the family of Fabaceae or Leguminosae. This family is also known as the pea or bean family. Pulses are the dried mature seeds that are grown to maturity and then harvested when they are dry. Common pulses are lentils, chickpeas, red kidney beans and dried peas. These mature seeds are high in protein and easy to store over winter for use in stews, soups and savoury puddings. However, the variety of pulses that we commonly find in shops has diminished over time. There are many forgotten British pulses, which are colourful (red, blue and black), tasty and very nutritious. Red Fox Carlin Peas and Black Badger Carlin Peas, for example, are a much-loved traditional food in the North of England and make a great alternative to chickpeas. Some important food crops are legumes – soya beans, broad beans, green peas, kidney beans, lentils, lima beans, butter beans, chickpeas, peanuts, cowpeas, black-eyed peas and pigeon peas.

Most legume plants can associate with friendly soil bacteria to produce their own nitrogen fertilisers. They allow the bacteria to enter their roots and form roundish structures called nodules to house these bacteria. These nodules then function like tiny factories that can fix nitrogen from the air and provide nitrogen fertilisers for the plant. The seeds of legumes are richer in protein than other staple crops like rice, maize, potatoes, cassava and wheat thanks to their nitrogen-fixing ability. This increased nitrogen gives legumes their high protein content, since nitrogen provides the building blocks for protein. In addition to legume crops, there are many other plants that are legumes. They include gorse, sweet peas, clovers, vetch and trees like acacias, mimosa and tamarind.

Biological nitrogen fixation in legumes

Nitrogen is a critical limiting element for plant growth and production. It is a major component of chlorophyll, the most important pigment needed for photosynthesis, as well as amino acids, the key building blocks of proteins. Even though it is one of the most abundant elements (predominately in the form of nitrogen gas (N_2) in the Earth's atmosphere), plants can only utilize reduced forms of this element. Plants acquire these forms of "combined" nitrogen by: 1) the addition of ammonia and/or nitrate fertilizer (from the Haber-Bosch process) or manure to soil, 2) the release of these compounds during organic matter decomposition, 3) the conversion of atmospheric nitrogen into the compounds by natural processes, such as lightning, and 4) biological nitrogen fixation.

Biological nitrogen fixation (BNF), known as a microbiological process, is used by legumes that transform atmospheric N into a plant in its usable form, which can be this alternative. Mineral N shortage is a recurring character of arid and semi-arid soils. Consequently, it is understood that BNF is a sustainable and environmentally friendly substitution to chemical fertilizers. There exists convincing proof that some non-leguminous crops, in some cases, may benefit from association with diazotrophs. Considerably, a natural association between plants mainly gains the potential benefit from N fixation and bacteria, which is seldom manageable as, part of agricultural practices.

Inclusion of legumes in cropping system:

Sequential cropping

Crop rotation is considered to be incomplete if legumes are not included in a cropping system. The amount of nitrogen addition to soil through legume inclusion depends on the legume crop taken for the system (Squire et al., 2019). Crop rotation through suitable legume inclusion not only improves biomass production but also enhance soil carbon and nitrogen status (Lal 2010). This increased C and N status in soil not only makes soil microbes active and supply N in the current season but also benefits the succeeding crops.

Intercropping

Intercropping is the cultivation of two or more than two crops on the same land as they coexist for some period of their life cycle which is practiced to achieve some ecological goals, i.e., reducing risks of farmers from complete crop failure against climate abnormalities, increasing resource use efficiency, increasing diversity of the farm promoting species interaction and cybernetics. Generally, the main crop or base crop of intercropping should be the dominant crop of the locality and the second or component crop is grown for additional output using the left-out resources.

Crop rotation

Crop rotation is also an intensive strategy with recurrent succession of crops to enhance the output of the system in terms of crop productivity through inclusion of suitable crops. Inclusion of legume in the system is mostly encouraged knowing their multifaceted advantages, i.e., BNF, nutrient recycling, increase soil carbon and nitrogen stock, etc. Leguminous crops produce higher biomass and improve Complimentary Contributor Copy Role of Legumes in Cropping Systems for Soil Ecosystem Improvement 7 soil organic carbon, that further increase the soil microbial population and maintain soil health. The inclusion of legumes in cropping system produces more biomass using limited resource base, improves soil carbon and nitrogen stock and can be adopted suitably in any cropping system as they can complete their life cycle even in a very short time period and can be used in sustainable land development programmes.

Cover crop and bio-mulch

Legumes are close growing crops and hence serves as cover crop. Also, the dense foliage of most legumes reduces the erosive action of rainfall to a large extent. Legumes release many root exudates such as organic acids to the soil which acts as a binding agent and reduces soil erodibility by improving aggregate stability. Legumes can also be grown in alternate strips along with some erosion susceptible crops to keep the soil loss below acceptable threshold. Legume residues are comparatively more succulent and hence easy to manage. This can be a prospect that should be taken into consideration while planning a conservation agriculture based cropping system. Maintaining mulch on the soil surface is beneficial in reduction of erosion, enhancement of soil organic matter, addition of nutrient to soil, improvement in soil microbial status and maintenance of proper soil temperature.

In response to global scale mechanization, increase in oil price and soil erosion, to maintain the soil health, several conservation practices being followed globally and legumes are included in rotation and as cover cropping. The residues of legumes can improve soil physical, chemical and biological health and quality on their incorporation and increase both nutrient and water holding and supplying ability of the soil. It has also been reported that, taking crops having different rooting depths and requiring minimal soil disturbance, i.e., legumes optimize micro and macro- pores in soil that increases infiltration of water to deeper root zone depth. Legume crops along with biological nitrogen fixation can add high quality soil organic matter because of their extensive root system and low C:N ratio, helping the growth of soil micro-flora and nutrient cycling.

Improvement of soil physical properties

Physical properties of soil, i.e., structure, texture, density, stability, porosity, etc. are fairly constant towards crop husbandry practices, but are important criteria associated with aeration, erosion, runoff, infiltration rate, nutrient and moisture holding capacity of soil. Therefore, proper soil physical condition is essential for optimum tillage, root growth, ground water recharge, prolonged soil moisture availability and deprived soil physical condition may lead to difficulty in farm activities. Soil texture is the relative proportion of soil separates, i.e., sand, silt and clays and fairly resistance to change and remain stable for long time, while soil structure can be manipulated using cultural activities i.e., tillage, residue retention, minimum tillage, etc. Bulk density and soil porosity affects root growth significantly and crop management practices, i.e., tillage, residue incorporation, etc. affects these edaphic factors. Soil porosity as influenced by soil texture and structure broadly categorized into micro and macro pores, depending on pore size diameter, which directly influences on the soil moisture holding capacity and availability to crop plant. Inclusion of legumes in soil acts as soil conditioner and improves soil physical properties significantly.

Improvement of soil chemical properties

Soil chemical properties i.e., pH, CEC, SOC, base saturation, buffering capacity and nutrient concentration has direct relationship with the nutrient dynamics and availability in soil to support higher crop yields. Legume crop has the properties to release organic root exudates and their incorporation in soil has significant influence on soil chemical properties through addition of organic matter and BNF, sustaining the soil fertility and optimizing the system productivity. Legume has well known beneficial effect on available nutrients, soil pH and soil organic carbon stock. Further, legumes included in the cropping system changes the soil pH by releasing organic acids which may enhance soil phosphorous availability and growth and activity of soil microbes which significantly influence the diseases and nutrient dynamics. Legume soil inclusion not only adds N to soil but also augments huge quantity of essential nutrients, organic matter and sequester atmospheric carbon dioxide. The legume biomass can either be incorporated in-situ or transferred from another field and incorporated i.e., ex-situ. The quantity of available nutrient depends on the nutrient content, decomposition rate, soil type, climate, plant density, crop management, etc.

Improvement of soil biological properties

Soil biological properties are most sensitive towards soil management and can be considered as an early indicator of change in soil quality on different management practices. Nitrogen is the limiting macro-nutrient in most of the agricultural soil and the requirement of nitrogen in plant is also higher than other mineral nutrients. Rhizobia in association with legume synthesize nitrogenase enzyme which help in atmospheric nitrogen fixation. Nitrogen fixed in biological nitrogen fixation assimilates as protein and glycoproteins in plant biomass. Phosphorous is one of the essential mineral elements for plant growth, but its availability in soil is limited by soil reaction and complexation with Fe, Al, Ca and Mg. Legume inclusion in cropping system help in releasing soil fixed phosphorous by releasing several acids in the form of root exudates and enhancing phosphatase enzyme activity. Hydrogen gas is released as biproduct during biological nitrogen fixation which encourage microbial activity, microbial carbon and microbial nitrogen in root zone.

Conclusion

Legume being a short duration crop, is grown world-wide in resource limited conditions. Inclusion of legume in cropping systems has several advantages such as food as well as nutritional security, ecological soundness and creation of an efficient agroecosystem, reduction of soil erosion, enhancement of water and nutrient use efficiency, sustained soil function, biological nitrogen fixation and improvement of soil health, increase in soil organic carbon and nitrogen stock, soil carbon sequestration, and thus, increase in agricultural productivity. In this chapter, an attempt has been made to collect different research outcome and summarize them in such a way to present the importance of legumes and their inclusion in cropping systems to facilitate qualitative improvement of soil and agroecosystem, and their subsequent benefit on the sustainability of the agricultural system.

* * * * * * * *