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Maximizing Pulse Production in Natural Farming System

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Abstract

Green revolution lead to intensification in cropping, uses of HYV and non judicious use of inorganic fertilizers and other chemical input which changed the scenario of Indian agriculture from a condition of begging bowl to a food sufficiency region. However it also led to serious concern over national food security by its adverse impact on quality of food crops, soil health and soil biota, biodiversity and environment. The demand for organic food enterprise is rising worldwide. Rice-wheat cropping system is predominant cropping system followed in India which are highly nutrient exhaustive and thus causes a nutrient depletion. Thus under such condition pulses can be taken up for improving crop productivity as well as a source for maintaining soil fertility.

Keywords: Green Revolution, Inorganic Fertilizers, National Food Security, Soil Health, Organic Food and Soil Fertility

Introduction

Natural farming or zero budget natural farming is a practice that doesn't depend on external resources and it's a chemical free farming. Increased use of fertilizers contributed to about one fourth of the increased Rice and wheat production. The rice-wheat cropping system removes a large amount of nutrients from soil and annually it removes more than 650kg/ha of N, P and K and 0.5-1.0kg/ha of Zn, 2-3kg /ha of Fe and 3.0-3.5kg/ha of Manganese. In this system long-term effect on productivity is harmful and soil nutrients depletion is considerably high. To achieve the same yield levels which farmers were getting in the recent past years with application of lower dose of chemical fertilizers consequently they have to apply a higher fertiliser dose. As these chemical fertilizers having expensive thus their adequate application by the farmers is not possible in the developing countries in the current scenario [1]. Therefore in improving crop productivity and for maintenance of soil fertility pulses can plays an important role in current situations.

In regions where access to diverse and nutrient-rich diets is limited, pulses can play a vital role in combating malnutrition as well as in promoting food security. These can be consumed in different ways like whole and split grains in Dal form, flour (besan) and ingredients in sweets snacks and also use as green vegetables. It has the capacity to fix atmospheric nitrogen having deep rooting characters which help to remove more water and nutrients from deeper layer. Pulses being associated with VAM can solubilize fixed phosphorus that makes a cropping system more sustainable [2]. It is having versatile in nature so that it adapted in different agro-ecological situations and providing cover crop in terms of conserving soil and water.Biological efficiency is likely to result when urdbean is inter cropped with maize, the dominant millet of *kharif* season [3].

In rice based cropping system the concept of green manures incorporation has developed a sound ecosystem in sustainable rice production. Rice tract soils are often slightly alkaline in nature. Incorporation of green manuring crops help in reducing soil pH, improves soil fertility by increasing biomass in to soil thus increases organic carbon content, soil structures improves. it enhances porosity , reduces the use of nitrogen fertilizers in rice up to some extent and water holding capacity. Being an important component of integrated nutrient management, green manures would enhance efficacy of applied fertilizers and helps in availability of other plant nutrients. Sesbania rostrata, a stem nodulating green manuring crop have high nitrogen fixing legumes can saves the use of Nitrogen upto 50-60% and significantly improve yield of following rice crops [4]. Their continous 3year uses significantly resulted in residual effect on the second wheat crop and improved physico-chemical properties of the soil.

Leguminous crops have root nodules which involves in biological nitrogen fixation without pre rhizobium inoculation. In a field experiment, singh 1990 observed that there was no significant effect found on inoculation on nodulation, nitrogen yield and dry matter production in sesbania crop. Such crop when recently introduced to a region, there is difficulty in obtaining nodulation without rhizobium inoculation that enhance the onset and number of effective nodules and hence improves the nitrogen fixation amount in a legumes [5].

In a cereal-cereal cropping system a negative nitrogen balance in the soil occurs even if all crop components get the required amount of fertilizers. In such rotation inclusion of a legume component helps in maintaining soil nitrogen status which was observed by Muhammad, et al. there is a brief 40-70days fallow period between wheat harvest and paddy planting, during which a summer fodder or grain legume crop can be successfully grown. Many summer legumes have been tried to be grown during this time between rice and wheat. By adopting this practice it provides benefit to the succeeding cereal crop by increasing nitrogen status in soil as well as it provides pulse grains.

According to a study of Bastia, et al. [6] during the year 2008, it is clear that adding pulses like mungbean and cowpeas as well as other leguminous crop to a rice-wheat cropping system can boost agricultural income per unit area while simultaneously enhances soil fertility. these pulses are short duration having growing period 65-70days and can easily be grown during the fallow period.

By addition of green manure legume crop including mungbeans, coepeas, soybeans, pigeonpea and guar, the production of rice grain as well as straw grew significantly higher over the course of three years. However on an average the highest grain and straw yields were recorded for cow pea and sesbania [7]. This results further indicated that inclusion of green manuring or leguminous crops in the existing Rice-wheat system not only increased grain yield but also improved the physic-chemical properties such as increased organic matter contents and nutrients availability in the soil. Soil post harvest study revealed that there was increase of N(0.12%), P(2.8PPM) and K(52 ppm) over initial soil status. Soil Ph lowered from 8.2 to 7.8 and organic carbon content increased from 0.67% -0.72% as reported by Ali, et al. [8].

Legume fixes nitrogen and that's why this crop can be used as green manure crop. About 40-200lbs/acre nitrogen can be accumulated by leguminous green manure crops. A number of factors responsible for the amount of nitrogen available by legumes. Such as legume species, total biomass produced and percentage of nitrogen in plant tissues. In the top growth a highest percentage of biologically fixed nitrogen is available. An agronomist at north Carolina state named Dr Grey Hoyt estimated that 60% of tissue Nitrogen is released when crops are incorporated as green manures. By incorporating green manures once in a year its residual effect are relatively small while the cumulative effects by several annual application are probably high. An increase in soil organic matter and available NPK contents over locations in continous rice –wheat cropping system, followed for 13 years and fed with inoraganic fertilizers in conjuction with organic manures including green manuring [9]. Green manuring of legumes not only helps in addition of nitrogen but also helps in recycling of other nutrients viz., phosphorus, potassium, calcium, magnesium and sulphur. Green manuring also helps in reducing leaching of micronutrients as most of them are bonded with organic matter (Table 1).

Crop	N –fixed(kg/ha)
Urdbean	119-140
Cowpea	09-125
Mungbean	50-66
Pigeonpea	04-200
Rice bean	32-97
Chickpea	23-97
Guar	37-196
lentil	35-100

Table 1: Type of Crop. Wani et al. [10].

Legumes have been used traditionally in cropping system as a part of crop rotation or intercropped especially with cereals. The role for involving in biological nitrogen fixation through the symbiotic relationship with soil bacteria (Rhizobium) Lazali, et al. [11] Further legumes plays an important role in reducing green house gases as this can alleviates nitrogen fertilization based on fossil energy and their ability for carbon sequestration and biomass production [12]. Legumes have a potential role in agro-ecosystem services such as biological pest controls, pollination and nutrient cycling. It has also ability to diversify in farming systems to restore associated biodiversity in agro-ecosystems and serve as a cover crop to inhibit weed growth. Legumes may increase subsequent cereal yields by about 29% on an average. These crops are a sustainable source of protein for healthy human and animal diets as well as produces dry matter [13].

When green manure crop is added to soil a number of biochemical processes such as break down of organic matter are being taken up by micro-organisms. After chemical breakdown compounds that are formed are resistant to decomposition namely gums, waxes and resins. These compounds along with mycelia, mucus and slime that are produced by the micro-organisms responsible for binding of soil particles together as granules or aggregates.

A well aggregated soil tills easily, well aerated and has high water infiltration rate. A study has been reported by Joshi, et al. [14], that green manuring has a significant effect on soil physical properties such as water retention, soil dispersion, settling index, bulk density and hydraulic conductivity. Increased levels of organic matter influences soil humus which provides a wide range of benefits in terms of crop production. In long run these effects is more economically important than value of green manure as a source of nitrogen. Value addition of green manuring is variable under different crops. Thakur, et al. [15] studied the comparison of two green manure crops for its ability in increasing soil health in terms of soil physical, chemical and biological properties of soil. They found that sesbania was significantly more competent than frenchbean.

Benefits of legumes

Food and nutritional security-Legumes are vital for food and nutritional security due to their high protein and fiber content, essential minerals, and vitamins, contributing to a balanced diet and addressing global malnutrition, especially in developing countries.

Human health safeguard: Legumes offer numerous health benefits, acting as a powerhouse of nutrients that can safeguard human health by promoting heart health, aiding in weight management, and potentially reducing the risk of type 2 diabetes and certain cancers.

Climate resilience: Legumes offer significant benefits for climate resilience by reducing greenhouse gas emissions, improving soil health, and enhancing food security in challenging environments.

Increases N and SOC stock: Legumes improve soil health and fertility by increasing nitrogen (N) and soil organic carbon (SOC) stocks through biological nitrogen fixation (BNF) and residue decomposition, ultimately enhancing soil fertility and crop yields.

Low input sustainable agriculture- In low-input sustainable agriculture, legumes offer significant benefits like nitrogen fixation, improved soil health, and increased crop yields, while also reducing reliance on synthetic fertilizers and promoting biodiversity.

Increase crop productivity: Legumes contribute to increased crop productivity by fixing atmospheric nitrogen, improving soil fertility, enhancing soil structure, and reducing the need for synthetic fertilizers, ultimately leading to higher yields and more sustainable agricultural practices.

Enhance soil microbial activity: Legumes improve soil fertility through the symbiotic association with microorganisms, such as rhizobia, which fix the atmospheric nitrogen and make nitrogen available to the host and other crops by a process known as biological nitrogen fixation.

Carbon sequestration: Legumes enhance carbon sequestration in soil, acting as a natural carbon sink, by fixing atmospheric nitrogen, reducing the need for chemical fertilizers, and promoting soil health and organic matter, ultimately contributing to climate change mitigation.

Climate play a crucial role for green manuring crop. For example in cooler climate it has depressive effects. Due to low temperature the process of organic matter decomposition slows down which allow toxicities to build up in soil. In warm and humid climate temperature and water interact together and thus it enhances the decomposition process. Effect of green manuring depends on Soil types also. It is more beneficial for soil having low fertility, saline, alkaline and acid soils, eroded and problematic soils.

Cereal-pulses intercropping is widely known age old practices. In rainfed areas pulses can do wonder when intercropped with crops that are widely spaced such as maize, sorghum, pearlmillet, cotton and sugarcane. Mishra during the year 2014 reported that an extra profit of 85.6% in terms of maize equivalent yield in maize + field pea intercropping system. Development of feasible and economically viable intercropping system depends largely on adoption of suitable planting pattern as well as their suitable package of practices. Efficiency of production in intercropping system could be increased by minimizing inter specific competition between the component crops.

Ramamoorthy, et al. [16] investigated some of these traits in chickpeas and observed that genotypes with higher root length density closer to the soil surface, with greater root dry weight at depth, showed the best tolerance to drought. Similarly, in the year 2015, Kashiwagi, et al. [17] observed that genotypes with deeper roots and more soil exploration capability perform better under drought stress (Figure 1).

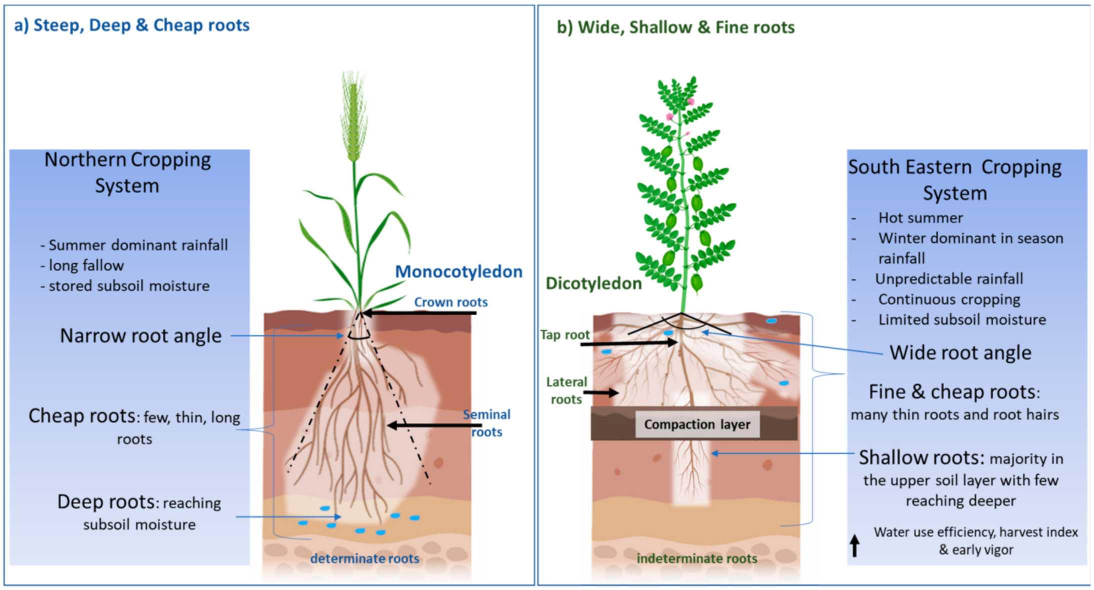

Figure 1: A: The “Steep, Deep and Cheap” root architecture that has been largely investigated and applied to monocotyledons such as maize and wheat cultivated in environments that experience terminal drought with presence of subsoil water. **B:** The proposed alternative, “Wide, Shallow and Fine” roots, for the southeastern cropping system of Australia, which experiences unpredictable rainfall and absence/unavailability of stored subsoil water.

Role of pulses in Rice/Wheat –Pulse cropping Systems

In rice or wheat pulse cropping systems, pulses enhance soil nutrient dynamics by fixing atmospheric nitrogen, improving soil health, and increasing the availability of nutrients like nitrogen, phosphorus, and sulfur, ultimately benefiting subsequent crops.

Nitrogen Fixation

Pulses, being legumes, have a symbiotic relationship with bacteria in their root nodules that convert atmospheric nitrogen into a usable form for plant growth, enriching the soil with nitrogen.

Improved Soil Health: Pulse crops contribute to better soil structure, water infiltration, and water-holding capacity, leading to improved soil health and reduced erosion.

Increased Nutrient Availability: Pulse crops can increase the availability of nutrients like nitrogen, phosphorus, and sulfur, which can then be utilized by subsequent crops in the rotation.

Reduced Fertilizer Needs: By improving soil fertility, pulse cropping systems can reduce the need for synthetic fertilizers, leading to more sustainable and cost-effective agricultural practices.

Nutrient Concentrations in Crop Residues:

Rice: Average nutrient concentrations in rice crop residues are 1.03% N, 0.21% P, 1.12% K.
Wheat: Average nutrient concentrations in wheat crop residues are 1.48% N, 0.23% P, 0.87% K.
Chickpea: Average nutrient concentrations in chickpea crop residues are 1.80% N, 0.27% P, 0.99% K.
Mungbean: Average nutrient concentrations in mungbean crop residues are 2.14% N, 0.22% P, 0.52% K.

Challenges and Limitations in Including pulses into Existing Systems

Integrating pulses into existing agricultural or food systems can face challenges like low yields, pest and disease susceptibility, and market access, but also offers potential benefits like improved soil health and nutrition.

Low Productivity and Yield Gaps

Pulses often have lower yields compared to other crops, and there's a significant gap between potential and realized yields.

Poor adoption of improved technologies and practices contributes to this.

Limited access to quality seeds and resources can also hinder productivity.

Pest and Disease Vulnerability

Pulses are susceptible to various pests and diseases, leading to yield losses.

Specific pests like gram pod borer and pod fly can cause significant damage.

Lack of disease-resistant varieties and effective pest management strategies are challenges.

Socio-Economic Factors

Farmers may face challenges in accessing credit, inputs, and markets for pulses.

Unfavorable prices and trade policies can make pulse production less attractive.

Socio-economic priorities may favor cereals over pulses.

Rainfed Conditions and Irrigation

A large portion of pulse production occurs under rainfed conditions, making it vulnerable to weather variability.

Limited irrigation infrastructure and water availability can further restrict pulse cultivation.

Storage and Post-Harvest Losses

Poor storage facilities and post-harvest handling practices can lead to significant losses of pulses.

System Integration Challenges

Integrating pulses into existing cropping systems (e.g., rice-wheat system) may require adjustments to ensure compatibility and sustainability.

Lack of knowledge and awareness among farmers about the benefits and best practices of pulse cultivation can be a barrier.

Specific to India

The Indian pulses industry faces challenges like a lack of high-yielding varieties, low mechanization, and ineffective government procurement operations.

Trade liberalization can also make pulse production less attractive for farmers [18].

Conclusion

Legumes role as nitrogen fixing capacity can reduce the GHG gases emission like carbon dioxide and nitrous oxide by decreasing less dependency on nitrogenous fertilizers. Legumes have a capacity to release high quality organic matter into the soil to increase carbon sequestration, water retention and circulation of nutrient elements. As these crops are having environmental and socioeconomic benefits, these could be introduced in modern cropping systems to reduce external inputs and increases crop diversity. In developing countries where these legumes perform well in intercropping, in conservation and in agro-forestry systems. Based on these multiple functions, legume crops have high potential for conservation or sustainable agricultural systems although they may require novel solutions of plant management and breeding for producing bio-fuels, materials and chemicals as options in climate change mitigation. One of the key paradigms for future sustainable agriculture is multifunctionality of the same piece of land in order to supply several services with the key principle of diversity in crop species over time and space.

Therefore, legume species should be carefully considered as crucial part of future sustainable food, fiber and energy production systems for human prosperity because of their many potential agro-ecosystemic services, including their capacity to lower green house gas emission and increase soil carbon sequestration.

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