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Effect of green manuring and crop residue incorporation on soil fertility in rice-based cropping system

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Abstract
The mineralization of organic matter and the subsequent release of various nutrients increased the concentration of soluble salts. Because a number of other variables, including soil temperature, porosity, soil texture, soil moisture, and soil mineral content, also have an impact on soil electrical conductivity, soil pH has a negative power function and linear connection with soil electrical conductivity. The extent of N addition leads to the depletion of all the key nutrients. Straw is the sole organic substance that, supplies 30 to 35% of the phosphorus taken up by the rice plant remains in vegetative plant parts at crop maturity. The assimilation of crop residues during fallow periods improves the soil's ability to transfer phosphorus (P) to the subsequent crop under intensive cropping systems, reducing the P losses caused by burning crop residues, which amount to roughly 25%.

Keywords: Green manure, crop residue, soil fertility, nutrient management, cropping system

Introduction

Soil pH, Electrical conductivity and Organic carbon

According to Sadana and Bajwa (1985) [34], the increase in partial pressure of CO_2 and generation of organic acids during the breakdown of organic matter may be responsible for the drop in soil pH in green manured plots. According to Li *et al*. (2012) [18], soil pH and soil microbial biomass N are positively correlated and do not exhibit a linear relationship because they are also influenced by other soil physical and chemical properties, vegetative cover, temperature, moisture content, substrate quality, and the make-up of the plant community. According to Kumari *et al*. (2004) [15], the mineralization of organic matter and the subsequent release of various nutrients increased the concentration of soluble salts. Because a number of other variables, including soil temperature, porosity, soil texture, soil moisture, and soil mineral content, also have an impact on soil electrical conductivity, soil pH has a negative power function and linear connection with soil electrical conductivity. (USDA, 2011).

According to MacRae and Mehuys, organic matter addition through green manuring was critical in raising the soil aggregates by holding the soil particles together. According to Mandal *et al*., 2002 [20], the incorporation of *S. rostrata*, *S. aculeate*, and green gramme increased the overall relative organic matter concentration over fallow by 117.7, 113.7, and 118.1 for 0–15 cm soil depth and 122.2, 119.9, and 125.4 for 15–30 cm soil depths at 65 DAT of rice, respectively. According to Ramesh *et al*. (2004) [32], *Sesbania rostrata* repeated use as a green manure crop increased soil organic carbon and had an impact on both the rate at which soil organic carbon is lost in cropping systems and the soil's overall level. In comparison to the traditional rice-rice cropping system, the cropping system involving three green manures—*S. rostrata*-rice, *S. rostrata*-rice, and *S. rostrata*—recorded significantly higher soil organic carbon and was 10.63% higher. Application of nutrient rich compost or vermicompost from agro wastes (Pandit *et al*., 2020; Patra *et al*., 2022; Padhan *et al*., 2022a; Padhan *et al*., 2022b) [24, 49, 22, 23] increases the bioavailability of essential nutrients as well as soil properties.

According to Ghuman and Sur (2006) [10], green manuring significantly lowers soil pH and bulk density and increases soil organic carbon (OC) levels above FYM and/or control plots, which can also lessen the problem of crusting in the soil. Tan *et al*. (2007) [47] and Jin *et al*. (2009) [12] reported on the beneficial benefits of agricultural residue integration for enhancing soil fertility. According to Knoblauch *et al*. (2014) [14], the rice straw served as the primary source of electrons for the soil's reduction. According to Savant and De Data, 1982, the temporary removal of N from the cropping system is caused by nitrogen immobilisation, which can be prevented by adding carbonaceous plant leftovers. According to Fried *et al*. (1983) [8], green manure crops can provide the rice crop with 50–80 kg N/ha. According to Kuykendall *et al*. (1991) [17], an increase in nitrogen fixation was caused by a rise in nodule mass as a result of a rise in nodule number.

Soil Nitrogen, Phosphorus, Potassium

According to Savant and De Data, 1982, the temporary removal of N from the cropping system is caused by nitrogen immobilisation, which can be prevented by adding carbonaceous plant leftovers. According to Fried *et al*. (1983) [8], green manure crops can provide the rice crop with 50–80 kg N/ha. According to Kuykendall *et al*. (1991) [17], an increase in nitrogen fixation was caused by a rise in nodule mass as a result of a rise in nodule number. According to Mann *et al*. (2000), soil organic matter, N, and P grew to 1.09%, 0.37%, and 10.2 ppm respectively after three years of continuous green manuring. According to Pattanayak and Bhattacharya (2000) [26], the extent of N addition under Odisha conditions can reach 80 kg/ha. In contrast to fertiliser N applied alone, which caused the depletion of all the key nutrients, Saravana and Perumal (2000) [38] found that the addition of green manure (*S. aculeata*) and fertiliser N together enhanced the status of accessible N. According to Mandal *et al*. (2002) [20], *S. rostrata* had the highest total soil nitrogen levels, followed by *S. aculeata*, and green gramme incorporation had the lowest levels. Porpavai *et al.*, 2008 stated that there is a possibility of saving 25% N in the inorganic source by the integration of green manure besides improving the soil fertility status. The native N-fixing specially Rhizobium should emphasized to enhance the soil fertility status and crop productivity (Sethi *et al*., 2019a; Subudhi *et al*., 2020; Verma *et al*., 2022) [42, 46, 49]. The application of efficient rhizobia to the lugumes/pulses enhances the productivity and soil health condition (Sethi *et al*., 2019b; Sethi *et al*., 2021) [43, 44]. In a rice-rapeseed-green gramme cropping sequence, Das *et al*. (2009) [5] conducted an experiment to track the impact of organic manures and inorganic fertilisers on yield and nutrient uptake by green gramme as well as the residual soil fertility after green gramme was harvested. The gain in organic carbon, total nitrogen, and accessible P_2O_5 over the original soil nutrient content was 0.324%, 0.023%, and 2.8 kg/ha, respectively. The integrated nutrient management improved the residual soil fertility following green gramme to a greater extent. According to Mclaughin *et al*. (1989) [21], P has a specific impact on nodule function and the uptake mechanism of rhizobia is particularly effective. According to Di *et al*. (2000), the release of inorganic phosphorus (P) from the mineralization of organic phosphorus causes the availability of phosphorus in agro ecosystems. According to Cavigelli and Thien (2003) [4], the addition of green manure crops can enhance the biological P cycling in soil and enhance the solubility and bioavailability of sparingly soluble phosphate rock.

As organic matter enhances cation exchange capacity, organic acids form complexes with free Ca+2, and organic matter increases titratable acidity, Rajan *et al*. (2004) [31] showed that increasing the soil's organic matter content can improve the efficiency of phosphate rock as a P source. According to Bah *et al*. (2006) [1], the breakdown products of the green manures improved the availability of P or caused the dissolution of phosphate rock, and the phosphorus uptake rose from between 5% and 9%. The integrated nutrient management enhances the crop productivity, improved soil health (Jhankar *et al*., 2017; Sethi *et al*., 2017a; Sethi *et al*., 2017b; Kusumavathi *et al*., 2018; Khuntia *et al*., 2022; Prusty *et al*., 2022; Garnaik *et al* 2022) [11, 40, 41, 16, 13, 30, 6]. Crop residue management also increase the soil fertility status (Pattanayak and Sethi 2022) [13].

According to Becker *et al*. (1991) [2], potassium is a crucial nutrient for a number of physiological processes, including nodulation and N_2 fixation. According to Swarup (1991), the extensive root systems of green manure crops may have improved the physical condition of the soil and released CO_2 and organic acids that assisted in dissolving the native potassium in the soil and thus increased the availability of K. This led to higher exchangeable K being obtained with green manuring along with higher doses of K fertiliser. According to Pattanayak (2001) [27], K was recycled through dhaincha, azolla, and sunhemp at rates ranging from 10.0 to 17.5, 11.7 to 15.9, and 2.7 to 3.0 kg/ha, respectively. According to Eichler *et al*. (2009) [7], the organic forms of P and K bound in the green manure crop may offer a readily accessible form of P and K to the succeeding crops after decomposition. According to Saraswat *et al*. (2016) [37], Sesbania had the highest potassium gain when added to the soil, at 137.6 kg/ha, followed by Crotolaria (130.3 kg/ha), and green gramme had the lowest gain (98.5 kg/ha). According to Dobermann and Fairhurst (2002) [6], N removal with one tonne of straw residue is 5-8 kg/ha), the integration of stubbles and straw into the soil recovers the majority of the nutrients and helps to conserve the soil nutrient reserves over the long run. He said that enhancing N mineralization through early dry shallow tillage at 5 to 10 cm depths to include crop residues and improve soil aeration during fallow periods has positive effects on soil fertility in intensive cropping systems. Additionally, he claimed that at crop maturity, 40% of the nitrogen absorbed by rice plants is still present in vegetative plant portions. Straw is the sole organic substance that, according to Dobermann and Fairhurst (2002) [6], supplies 30 to 35% of the phosphorus taken up by the rice plant remains in vegetative plant parts at crop maturity. Additionally, he claimed that the assimilation of crop residues during fallow periods improves the soil's ability to transfer phosphorus (P) to the subsequent crop under intensive cropping systems, reducing the P losses caused by burning crop residues, which amount to roughly 25%. Dobermann and Fairhurst, 2002 [6] stated that burning of crop residues causes K losses of 20 per cent and the effect of straw removal on long term soil fertility is much greater for K than P. He also reported that at crop maturity, 80 to 85 per cent of the potassium taken up by the plants remains in the vegetative plant parts. Saha *et al.*, 2009 reported that rice straw incorporation with inorganic potassium fertilizer built up potassium level in the soil.

Calcium, Magnesium and Sulphur

According to Dobermann and Fairhurst (2002) [6], straw management has a significant impact on nutritional balance. In rice grain + straw, rice straw, and rice grain, respectively, nutrient removal for Ca and Mg was 4.0 and 3.5, 3.5 and 2.0, and 0.5 and 1.5 kg/tonne. According to Savant *et al*. (1997), the poor mobility of sulphur in soil and the favourable soil conditions for adsorption may have contributed to the persistent availability of sulphur in soil following crop harvest. According to Lupwayi *et al*. (2001) [19], sulphur application had a favourable effect on the microbial biomass carbon in sulphur-deficient soils because microbial carbon is directly related to microbial sulphur. According to Dobermann and Fairhurst, 2002, 0.5 to 1.0 kg/ha of nutrients are removed by 1 tonne of straw, and 40 to 50% of the sulphur that rice absorbs persists in vegetative plant parts at crop maturity. According to Bell and Dell (2008) [3], slower mineralization of organically bound sulphur in submerged rice soil reduces the element's availability, increasing the prevalence of sulphur shortage in wetland rice. According to Singh and Singh (2017) [45], dry tillage prior to green gramme seeding enhances the rate of sulphide oxidation, which improves soil availability of sulphur during the fallow period. According to Richa Kumara *et al*.'s 2017 study, the addition of FYM, green manure, and wheat straw increased the soil's sulphur content over control by 0.17, 0.08, and 0.06%, respectively, by contributing 6.0, 1.12, and 3.6 kg ha-1 of additional sulphur to the soil at a 50% substitution rate.

Micronutrients

When 50% NPK + 50% N through FYM in kharif and 100% NPK in rabi were used, followed by 75% NPK + 25% N through FYM in kharif and 75% NPK in rabi, which were significantly higher than control, the amount of available Fe, Mn, Cu, and Zn (61.80, 41.18, 2.64, and 0.98 mg / kg, respectively) was significantly higher than that of the control. Leguminous and non-leguminous crops are not a significant source of micronutrients, according to Saraswath (2016) [37]. The green manuring, according to her, alters the redox regime of the soil, bringing about a more favourable range ideal for better solubility and availability of Fe, Cu, Mn, and Zn. According to Kumari *et al*. (2004) [15], even after appropriate nutrient uptake by the rice crop, slowly mineralizing organic components under anaerobic lowland circumstances would have left behind the enriched status of soil fertility.

Conclusion

Organic matter mineralization and release of nutrients enhanced the quantity of soluble salts. Edaphic factors like temperature, porosity, soil texture, soil moisture, and soil mineral content, also have an impact on soil chemical properties. The extent of N application is high which caused the depletion of all the key nutrients. Straw is the sole organic substance that, supplies 30 to 35% of the phosphorus taken up by the rice plant remains in vegetative plant parts at crop maturity. the assimilation of crop residues during fallow periods improves the soil's ability to transfer phosphorus (P) to the subsequent crop under intensive cropping systems, reducing the P losses caused by burning crop residues, which amount to roughly 25%. The root systems of crops improved the physical condition of the soil and released CO_2 and organic acids that assisted in dissolving the native potassium in the soil and thus increased the availability of K.

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