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Innovative Farming
-A Quarterly International Journal of Agriculture

Review Article
Article: SAAI/IF/412

Effect of Integrated Use of Lime, Organics, Inorganic Fertilizers and Biofertilizer on Improving Soil Fertility Status and Biological Properties of Soil - A Review

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KEYWORDS:

Biofertilizer, Inorganic fertilizers, Lime, Organic manure, Soil fertility

ARTICLE INFO

Received on: 09.09.2020
Revised on: 15.03.2021
Published on: 22.03.2021

ABSTRACT

This review summarizes the current knowledge on the effect of integrated use of lime, organics, inorganic fertilizers and biofertilizers on improving fertility status and biological properties of soils. Most of the investigators confirmed that combined application of lime, organics, inorganic fertilizers and biofertilizers on improving fertility status and biological properties of soils. Long term application of organics, inorganic fertilizers and biofertilizer resulted in increase in soil organic carbon status. Organic manures improves soil biological properties but as because they are low in nutrient content, so for plant growth it requires larger quantity of organic manures. However, inorganic fertilizer usually releases nutrients immediately and they are directly accessible to plants. But continuous application of inorganic fertilizer is harmful for soil health and it results in environmental pollution. Combined application of lime, organics, inorganic fertilizers and biofertilizer is very much effective for sustainable and cost effective management of soil fertility. The objective of present review is to assess the effect of integrated use of lime, organics, inorganic fertilizers and biofertilizer on improving fertility status and on improving the biological properties of soil.

How to Cite:

Dey, D., Kundu, M.C., Sen, D., 2021. Effect of integrated use of lime, organics, inorganic fertilizers and biofertilizer on improving soil fertility status and biological properties of soil - A review. *Innovative Farming* 6(1), 20-27.

INTRODUCTION

The long-term field experiments are cogitate about to provide the best practical approximation to a test of sustainability of farming practices. The long-term fertilizer experiments that have been in operation in India for last many years have distinctly indicated that they could be used to measure and evaluate the effect of continuous cropping and fertilizer used on soil quality and hence the sustenance of the system (Bhatt *et al.*, 2019). Application of lime to soil progressively increases soil pH and increases the availability of P, Ca, and Mg in soil. Liming increases P availability by releasing P from fixed form (Sultana *et al.*, 2009). Organic amendments including composts, green manures and sewage sludge usually increase the soil microbial biomass, soil respiration and soil enzymes' activity along with SOC and concentration of plant nutrients. Changes in soil microbial community compositions are also observed after the addition of organic and inorganic amendments (Sun *et al*., 2004). Eubacterial community, soil fungal population, ammonium oxidizing bacteria and denitrifying bacterial community are some of the microbial parameters so far reported to be affected by long-term application of organic and inorganic nutrient amendments. However, only few studies have been conducted in India on the influence of long-term addition of mineral fertilizers and manures on the soil biological properties (Vineela *et al.*, 2008).

Effect of Integrated Use of Lime, Organics, Inorganic Fertilizers, and Biofertilizers on the Available Major Nutrient Content of Soil

In many earlier studies, it was reported that the pH of soils after liming increased steadily with the increased rate of liming. The changes in soil properties like pH, organic matter, and some plant nutrient availability significantly increase due to the application of lime. Application of lime increases P, K and available Ca in soil compared to unlimed plots. Increasing rates of lime up to 1000 kg ha^{-1} enhanced K uptake by the plant, and further addition of lime above 1000 kg ha^{-1} decreased K uptake. The decrease in K uptake may be due to the antagonistic effect of Ca and Mg. In contrast, the application of lime at 2000 kg ha^{-1} recorded the highest total Ca uptake (296 mg pot^{-1}) compared to other lime levels (Sarker *et al.*, 2014). An increase in dry matter yield of Indian spinach due to liming is attributed to the beneficial effect of ameliorating the soil, which increases the Ca-saturation and availability of major nutrients, especially N. Addition of $CaCO_3$ increases soil pH and accelerates the process of mineralization of N which in turn promotes the uptake of N (Ranjit *et al.*, 2000). For high-yielding rape crops, liming is very important to adjust and maintain optimum soil structure, tilth, and crumb stability for best-growing conditions. Liming materials also contain Mg due to the Mg content of the rock limestone or dolomite, and these are especially used on Mg deficient acid soils (Orlovius and Kirkby, 2003).

Kumar *et al.* (2012) reported that applying lime can increase the nutrient availability of acid soil (pH around 4.6), reduce Al toxicity, and improve many other soil fertility attributes. He also revealed that seed coating with lime did not positively affect crop yield. Application of lime @ 300 kg ha^{-1} (furrow application) caused yield increase over control. When applied to the soil, lime reacts with water, leading to OH^- ions and Ca^{2+} ions, which displace H^+ and Al^{3+} ions from soil adsorption sites, increasing soil pH (Kisinyo *et al.*, 2012). Liming increases soil pH, exchangeable Mg, Ca, and the Ca/Al molar ratio and decrease the exchangeable Al, mainly in the Ahorizon of the soil layer. The live : dead ratio of fine roots was significantly higher in the limed rhizotrons than in control, indicating lower mortality (higher longevity). Shoot growth showed greater lime-induced stimulation as compared to root growth. As a result, the shoot: root ratio was higher in the limed rhizotrons than in control (Bakker *et al.*, 1999).

Carvalho and van Raji (1997) reported that calcium sulphate and phosphogypsum reduced soil acidity but much smaller than $CaCO_3$. $CaCO_3$ reduced the activity of Al^{3+} because of the increase in pH and resulted in higher pH and lower Al concentration due to the neutralization of soil acidity; the basic cations are also low because of the low ionic strength of the solution. Liming significantly affected the available P, which was increased by 70.2% over unlimed plots. The major role of liming was to overcome soil acidity, and the application of lime increased soil pH from 3.9 to 4.6. Mineral nutrition and liming increased soil P availability, where K gives negative results. In combination with liming, mineral fertilization positively impacted soil pH and increased up to 4.7, where this combination did not influence soil organic matter (Popovic *et al.*, 2010). Lime had a significant effect ($P<0.05$) on soil pH, with the highest rate of 2.0 t ha^{-1} of $CaCO_3$ increasing pH from 4.8 to 6.2 (Kisinyo *et al.*, 2005). The combined use of organic and inorganic sources of plant nutrients pushes the production and profitability of field crops and helps maintain the permanent fertility status of the soil (Kannan *et al.*, 2013).

An investigation was carried out by Tamuli and Boruah (2000) to evaluate the effect of lime sludge on the quantity-intensity relationship of soil potassium. They observed that lime sludge-treated soils (applied at 25% LR) showed an increase in labile Potassium, Potassium potential, and potential buffering capacity of potassium. Juo and Uzu (1977) conducted a short-term pot experiment to study the effects of liming on nutrient availability in maize plants grown in acid Ultisols. They observed that optimum P availability decreased between pH 5 and above. The effect of liming on phosphate availability in acid soils was studied by (Haynes, 1992). He concluded that liming could increase phosphate availability by stimulating the mineralization of soil organic phosphorus. However, at high soil pH, the precipitation of insoluble calcium phosphates can decrease phosphate availability. The increase in N's availability in the soil due to liming increases soil pH, which accelerates the rate of decomposition and mineralization of organic matter. Increased P availability due to liming may be due to the dissolution of complex Fe and Al phosphates making phosphate available in mono-calcium phosphate (Dixit and Sharma, 2004; Singh *et al.*, 2011).

Effect of Integrated Use of Lime, Organics, Inorganic Fertilizers, and Biofertilizers on Oxidizable Organic Carbon of Soil

Increasing soil organic matter is of great importance in cycling plant nutrients, minimizing the need for inorganic fertilizer, and improving soil's physical, chemical, and biological properties.

Mandal *et al.* (2001) conducted a field trial on acid oxisols of West Bengal, and they reported that liming increased percent carbon from 0.47 to 0.65. Murakami *et al.* (2005) observed that adding lime to tropical acid peat soil increases the soluble organic carbon. Due to that, the soil pH rose by liming, and the decomposition of organic matter was enhanced under these conditions. Mondal *et al.* (2009) conducted a field experiment on red and lateritic soils of Sekhampur, Birbhum, West Bengal. They observed that by applying lime in combination with different nutrients, the organic carbon content of the earth was increased.

Dumale Jr. *et al.* (2011) reported increased SOC turnover in all limed soils, confirming the priming effect (PE) of liming. The calculated PE of lime (Kuroboku Andisol, 51.97-114.95%; Kunigami Mahji Ultisol, 10.13-35.61%) confirmed that mineralization of lime-carbonates is the primary source of CO_2 emission from acid soils during agricultural liming. Liming can influence the size of CO_2 evolution of farm ecosystems considering the global extent of acid soils and the current volume of lime utilization. Integrated nutrient management also has a positive influence on soil organic carbon status. Direct application of organic matter in the form of FYM in an integrated plant nutrient supply system could be the reason for increases in soil organic carbon content (Acharya *et al.*, 1988).

Effect of Liming and Integrated Use of Organics, Inorganic Fertilizers, and Biofertilizers on Improving Microbial Population Dynamics in Soil

The microbial biomass is the main living component of soil organic matter. It promotes fundamental functions for the maintenance or improvement of soil quality, primarily affected by the changes in soil use and management. Thus, the agricultural practices with Integrated Nutrient Management can influence the soil microbial biomass and promote changes in soil quality. In the last few years, several studies have been conducted, in the world, to evaluate the effect of the application of organic inputs on soil microbial biomass (Parfitt *et al.*, 2005; Tu *et al.*, 2006; Lima *et al.*, 2007; Oliveira *et al.*, 2007; Stark, 2008; Araújo *et al.*, 2009; Araújo and Melo, 2010). Generally, the results show the positive influence of production systems with high C content on soil microbial biomass.

Araújo and Melo (2010) stated a positive relationship between microbial biomass growth and the function to substrate C input into systems and amending the soil with compost, which induces an increase in soil microbial biomass. On average, soil microbial biomass carbon constitutes only about 1%

of the soil organic carbon (Moore *et al.*, 2000). Yet, it may comprise up to 44% of the active pool of soil nitrogen (Liang *et al.*, 1999). Therefore, the size of the soil C mic pool and its turnover have a significant bearing on the overall productivity of soils. Several studies show a close relationship between soil microbial biomass and nutrient availability to plants (Jenkinson and Ladd, 1981; Houot and Chaussod, 1995). Microbial P is influenced by numerous factors (soil moisture and temperature, management practices, *etc*.). Microbial P is generally higher in permanent grassland compared to arable soil. The soil biomass P content can be increased by adding C (Thien and Myers, 1992) or lime (Condron and Goh, 1990). Soil microorganisms can derive a significant proportion of their requirement through the mineralization of Po (Thien and Myers, 1992). An essential component of soil P is contained within and cycled through the microbial biomass (Richardson, 1994). Beneficial soil organisms are affected by soil acidity and liming. Ca improves soil structure and soil stability. This could be due to its effect on organic matter decomposition yielding humus and promoting root activity (Adams and Early, 2005). Stenberg *et al.* (2000) reported that liming had little effect on soil structure variables but increased microbial activity to some extent.

Brauer *et al.* (2002) revealed that N content was higher in limed soil than in unlimited soils. Changes in nodulation are more closely associated with changes in soil pH than soil Ca. Liming creates favorable conditions for the growth of living organisms and improves plant growth (Peoples *et al.*, 1995; Unkovich *et al.*, 1996). The lime application makes the soil suitable for beneficial microbes, thus increasing the biological properties of soil by supplying the amount of Ca required for microbial activity. Liming has also influenced soil physicochemical characteristics by increasing the yield (Almendras and Bottomley, 1987). The growth and yield is significantly influenced by liming (Halim *et al.*, 2014). Application of 1.5 t ha^{-1} of lime is recommended for the cultivation of summer mungbean (*Vigna radiata*) and the desired soil pH (> 6.5 but < 7.0), which increases the availability of nutrients. Lime significantly affected the number of pea pods (Almendras and Bottomley, 1987). The amelioration of soil acidity by liming and applying animal manure is expected to stimulate the soil microbial activity, which may either reduce or increase the release of N from the soluble acid pool (Edmeades *et al.*, 1981). Application of 100% NPK + 15 t FYM ha^{-1} recorded the highest population of bacteria (24.8 and 29.8 CFU $\times 10^6$ g^{-1}), fungi (25.4 and 25.9 CFU $\times 10^4$ g^{-1}), and actinomycetes (40.1 and 41.9 CFU $\times 10^5$ g^{-1}) after rice and wheat crops, respectively while, lowest in control (Bhatt *et al.*, 2016).

Rankov *et al.* (1981) conducted a field experiment for three years. They reported a positive effect of combined application of NPK fertilizers on microbial development and biological activity of the soil than N, P, and K applied singly. There was a significant positive correlation between bacteria and actinomycetes population with crop yields, while fungi shared a positive effect under inorganic treatments and a negative impact under FYM. Similar results of improvement of the microbial population with the addition of FYM have been reported (Naidu and Pillai, 1991).

CONCLUSION

This review concluded that the incorporation of lime, fertilizers and organic manures, biofertilizers in soil reduce soil acidity as well as it improves the soil fertility. Soil biological processes refer to the processes involving organism that improve plant growth by means of symbiosis, mineralization of organic matter, dissolution of nutrients, soil aggregation, *etc*. A soils capacity to support biological fertility is determined by inherent physical and chemical characteristics as well as management practices. Organic fertilizer improves physical, chemical and biological properties of a soil but the nutrients may not be as readily available to the plants. However, inorganic fertilizer is usually immediately and fast containing all necessary nutrients those are ready for plants. The excess use of chemical fertilizers in agriculture can lead to soil deterioration, soil degradation, soil acidification or alkalization and environmental pollution. The integrated soil fertility management system is an alternative approach for the sustainable and cost-effective management of soil fertility and is characterized by reduced input of inorganic fertilizers. Integrated use of lime, inorganic fertilizers and FYM improved the soil fertility and biological properties. Continuous cropping without fertilizers deteriorated the soil health. In the light of above, holistic, systematic and in depth work is warranted to evaluate the impact of long-term application of fertilizers and organic and inorganic nutrient management practices improved the soil fertility and biological properties, and also improved crop productivity.

Conflict of Interest

The authors declare no conflict of interest.

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