Review Article

Restoring soil fertility through organic amendments: Impacts on agriculture and human health

Abstract

The application of organic amendments in agriculture has become a vital approach to addressing key challenges in Indian agriculture, such as fragmented landholdings, inadequate irrigation, and declining soil fertility. These amendments, which are added to soil to enhance its physical, chemical, and biological properties, play a significant role in promoting sustainable farming. Organic amendments like compost, manure, and green manure serve as excellent sources of organic carbon and essential nutrients. They improve soil structure, enhance drainage, and facilitate nutrient cycling while mitigating soil alkalinity and fostering microbial activity, thereby supporting overall soil health. Research highlights the effectiveness of organic amendments in improving soil quality. Organic amendments also offer notable benefits for human health by reducing dependence on synthetic fertilizers and minimizing toxic residues. They decrease the risks of heavy metal contamination and pesticide exposure. Adopting organic amendments supports the broader goals of sustainable agriculture by enhancing biodiversity, improving soil fertility, and reducing environmental and health risks. Nevertheless, further research is needed to refine these practices, optimize their application, and thoroughly evaluate their effects on human well-being and agricultural productivity. Organic amendments offer a promising solution to meet the growing food demands of an expanding population while maintaining ecological balance and ensuring food security.

Keywords: Human Health, Nutrient Recycling, Organic Amendments, Soil Health, Soil Reclamation

INTRODUCTION

As we know during first quarter of 2023, India emerged as most populous country in the world by surpassing earlier lead China. According to the most recent estimate, India will face the population of 1.5 billion by 2025 (Anon., 2023). To feed these many mouths with

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current food production trend is a challenging task. Therefore, India needs to raise its food grains production at a rate of more than 4-5 m t per annum. The existence of gap between the actual production and required production is because of the constraints associated with Indian agriculture system.

Challenges and constraints of Indian agriculture:

- ✓ Small and Fragmented Land Holdings
- ✓ Shortage of Irrigation Facilities
- ✓ Lack of Mechanisation
- ✓ Absence of sound Agricultural Marketing Facilities
- ✓ Scarcity of Capital

Sl. No.	Agro-chemicals	Effects
1	DDT(Dichloro diphenyl trichloro ethane)	Affects central nervous system, carcinogen
2	Potassium fertilizer	Decreases vitamin C and carotene content in vegetables
3	Nitrogen fertilizers	Infant disease, methemoglobinemia, also amines produced from the nitrogenous fertilizer cause cancer in human beings
4	Aluminium based fertilizers	High levels of lead to birth defects, asthma, Alzheimer and bone diseases
5	Calcium rich fertilizers	Developmental and neurological toxicity, growth retardation, cognitive delay, kidney, nervous and immune system damage
6	Cobalt	At high level leads to lung damage
7	Chlorpyriphos	Causes fetal malnutrition, pneumonia, muscle paralysis and even death to respiratory failure
8	Malathion	Damages nervous system if it enters the body

- ✓ Inadequate Storage and Transport Facilities
- ✓ Climate change

With ushering into the Green Revolution era in mid-1960s through the introduction of fertilizer-responsive high-yielding varieties of rice and wheat, fertilizer consumption in India witnessed a spectacular rise. For example, nutrient consumption rose in 2019-20 to 28.97 million tonnes (m t) against 2.26 m t in 1970-71. However, the partial factor productivity (kg

food grain produced per unit of fertilizer nutrient used) exhibited a decline from 28 kg kg^{-1} in 1970-71 to 10 kg kg^{-1} in 2019-20 which shows the decline in soil fertility over the years (Shukla *et al.,* 2022). Along with declining soil fertility, use of agricultural chemicals as a fertilizer/amendment/pesticide is known to cause various negative effects on human health (Table1). Unscientific agriculture also results in chemical residues in food, posing health risks and reducing consumer confidence. Groundwater depletion, caused by inefficient irrigation techniques and overexploitation of water resources, leads to scarcity and affects both agricultural productivity and local communities' access to clean water. Additionally, decreased input use efficiency, such as inefficient use of fertilizers and irrigation, leads to economic losses and environmental burdens [20].

Table 1: Effects of various agro-chemicals on human and animals

Baweja *et al*. (2020)

The major concern here is soil health where, soil health is deteriorating day by day because of the anthropogenic activities mainly mismanagement of land and resources. Some of the ways to restore the soil health are by –

- ✓ Improving soil organic matter
- ✓ Correcting the nutrient deficiency in the soils
- ✓ Controlling the soil erosion
- ✓ Managing soil ecology
- ✓ Reducing toxic residues in the soil
- ✓ Reclamation of problematic soils

To reclaim the problematic soils, we adopt different methods such as –

1. Physical methods - Levelling, scraping and sanding etc.
2. Hydrological methods - Leaching, drainage and irrigation methods etc.
3. Biological methods - green manuring, mulching etc.
4. Chemical methods – Amendments

Amendments are the substances added to soil to reclaim problematic soils by enhancing its physical, chemical and biological properties**.** Also, organic amendments enhance the growth of beneficial soil microorganisms and boost nutrient cycling to maintain overall soil fertility and productivity.

Classification of amendments:

According to resource:

a) Organic- sphagnum peat, straw, compost, manure, biosolids, sawdust and wood ash.
b) Inorganic- lime, gypsum, vermiculite, perlite, pea gravel and sand.

According to purpose:

a) Improve physical attributes
b) Improve chemical attributes
c) Improve biological attributes

Types of organic amendments:

1. Animal manure.
2. Green manure and crop residues
3. Municipal biosolids and septage
4. Food residues and waste
5. Waste from manufacturing processes
6. Compost

Benefits of using organic amendments:

Organic amendments are great source of organic carbon so they increase organic matter and the availability of different organic sources are listed in the table 2. They contain several plant nutrients (Table 3) that are beneficial for plants growth and development. These amendments improve drainage thereby reduce water use and hence maintains good soil structure. Also, they are capable of correcting soil alkalinity and cutting down expenses.

Table 2: Potential availability of different alternative organic sources in India

Alternative organic sources	Total availability (m t yr^{-1})
Crop residues	500–550
Municipal biosolid	48
Rice husk	20
Sugarcane bagasse	90
Groundnut shell	11
Sugarcane press mud	9.0
Poultry manure	6.25–8
Coir pith	7.5
Food/fruit processing industries	4.5
Seri waste	5
Green manuring crop area	About 7 m ha

Indoria *et al*. (2018)

Table 3: Mean nutrient content of some composted organic sources

Organic source	Organic carbon (%)	Nitrogen (%)	Phosphorus (%)	Potassium (%)	C: N
Paddy straw-based poultry waste compost	23.05	1.89	1.83	1.34	12.20
Coir pith (in deep litter system)	30.03	2.13	2.40	2.03	14.1
Papermill compost	25.46	1.34	0.58	1.12	19
Pressmud compost	33.17	3.1	1.95	3.5	10.7
Sugarcane trash compost	28.6	0.5	0.2	1.10	56.2
Castor cake compost	23.0	3.48	1.24	0.84	10.85
Bio compost	16.0	1.10	0.70	0.64	17.4
Vermicompost	23.1	1.59	1.63	1.07	15.7
Wheat straw compost	35.33	0.92	0.60	1.11	38.4
Mustard straw compost	33.59	1.04	0.54	1.35	33.59

Indoria *et al.* (2018)

With the appropriate use of organic amendments organic farming has been shown to encourage soil health while promoting agroecosystem sustainability, in contrast to conventional farming, which depends heavily on synthetic fertilizers and pesticides (Reganold and Wachter, 2016).

Effect of organic amendments on soil health:

There are several indicators that depict the effect of agricultural inputs on soil health which includes physical properties like soil structure, bulk density, porosity, aggregate stability, and water-holding capacity, chemical properties *viz.*, nutrients (micronutrients and macronutrients), pH, electrical conductivity, organic carbon and cation exchange capacity, and biological properties like microbial population (bacteria, fungi and actinomycetes), enzymatic activities etc. Organic amendments are known to affect the physical properties of soil significantly. Li *et al*. (2004) reported that the application of sphagnum peat @ 68 t ha^{-1} for 3 years recorded significantly higher soil water content (0.32 m^3 m^{-3}), lower bulk density (0.90 Mg m^{-3}) and higher total porosity (86 %) compared to control *i.e.*, no application (0.11 m^3 m^{-3}, 1.49 Mg m^{-3} and 46 %, respectively). Use of press mud, an agro industrial waste as an amendment @ 12.5 t ha^{-1} recorded significantly lower pH, lower EC and higher organic carbon during 2003 and 2004 (8.25 and 8.23, 0.27 and 0.22 dS m^{-1}, 0.45 and 0.47 %, respectively) compared to control (8.45 and 8.45, 0.41 and 0.41 dS m^{-1}, 0.24 and 0.252 %, respectively), thereby improving the soil chemical properties (Rangaraj *et al*., 2007). Sharma and Dhaliwal (2019) recorded that application of 50 % of N + rice straw compost @ 10 t ha^{-1} recorded significantly higher dehydrogenase (72.6 µg g^{-1} ha^{-1}), acid phosphatase (5.59 µg *p*-nitrophenol g^{-1} h^{-1}), urease (222 µg urea g^{-1} min^{-1}) and phytase (0.619 µg g^{-1} h^{-1}) soil enzymatic activities in

comparison to other treatments. Rangaraj *et al*. (2007) observed that application of press mud @ 12.5 t ha^{-1} resulted significantly higher population of bacteria, fungi and actinomycetes during 2003 and 2004 (33.36 and 34.98 × 10^6, 10.32 and 11.59 × 10^3 and 8.58 and 8.75 × 10^3 CFU, respectively) compared to no organics (27.27 and 29.11 × 10^6, 8.23 and 9.29 × 10^3 and 6.96 and 7.12 × 10^3 CFU, respectively). Udaysooriyan *et al*. (2009) they noted that applying 50% of the gypsum requirement (GR) combined with press mud @ 15 t ha^{-1} resulted in significantly increased cation exchange capacity (17.74 and 13.04 cmol (p^+) kg^{-1}) and reduced exchangeable sodium percentage (26.45% and 30.53%).

Effect of organic amendments on crop productivity:

In order to increase the agriculture productivity, the farmers are indiscriminately applying the synthetic chemicals along with over exploitation of natural on farm inputs which proves to be a great concern to the environment. In order to minimize the reliance on chemical external inputs it is necessary to go for the application of different available organic sources to reduce the adverse effects of chemicals on the environment and to maintain good soil health as well. Application of paper mill sludge increased N, P and K uptake significantly from 0 % lime requirement (LR) to 60 % LR. Highest N, P and K uptake of 96.9 kg ha^{-1}, 17.4 kg ha^{-1} and 47.7 kg ha^{-1}, respectively was observed under 60 % (Kar *et al*., 2014). Rohitha (2020) demonstrated that the soil application of the recommended dose of fertilizers (RDF) combined with coconut shell biochar @ 10 t ha^{-1} and 50% of the lime requirement significantly enhanced soybean productivity and profitability. This treatment resulted in a superior seed yield of 26.86 q ha^{-1}, gross returns of ₹1,20,920 ha^{-1}, net returns of ₹68,288 ha^{-1}, and a benefit-cost ratio of 1.32 in contrast to the absolute control which yielded lower outcomes with a seed yield of 18.28 q ha^{-1}, gross returns of ₹53,205 ha^{-1}, net returns of ₹25,655 ha^{-1}, and a benefit-cost ratio of 0.91. Mittra *et al*. (2005) reported that the application of fly ash @ 10 t ha^{-1} + FYM @ 12.5 t ha^{-1} + RDF recorded significantly higher number of pods $plant^{-1}$ (17.9), pod yield (2945 kg ha^{-1}) and haulm yield (4789 kg ha^{-1}) followed by fly ash @ 10 t ha^{-1} + RDF (17.0, 2791 kg ha^{-1} and 4725 kg ha^{-1}, respectively). Sesbania as green manure and gypsum application produced the highest grain yields of 3788 kg ha^{-1} and 3677 kg ha^{-1}, respectively in rice (Baig and Zia, 2006). Kumar *et al*., 2014 reported that application of lime @ up to 0.6 t ha^{-1} produced significantly higher growth traits in ricebean such as pod filling (92.43 %), biological yield (1.88 t ha^{-1}), production efficiency (11.12 kg ha^{-1} day^{-1}), gross returns (₹ 39,098 ha^{-1}) and B-C ratio (2.29) compared to control (81.97 %, 1.22 t ha^{-1}, 6.36 kg ha^{-1} day^{-1}, ₹ 23,064 ha^{-1} and 2.01, respectively). Koushalya, (2018) found that the application of 75 per cent RDF + press

mud @ 5 t ha^{-1} recorded significantly higher grain yield (4043 kg ha^{-1}), higher gross returns (₹ 1,13,708 ha^{-1}) and benefit cost ratio (3.0) of finger millet compared to other treatments.

Effect of organic amendments usage on human health

Not only crop yield and soil health determines the efficiency of an amendment, it is also determined by its effects of human health. Presence of several toxic heavy elements is known to possess cancer risks causing great hazard to human health. So, detoxifying these elements is of huge importance. Application of biochar nano sheets @ 2 per cent (158.69 g pot^{-1}) recorded lower cancer risks in wheat grain which was estimated based on lower potential toxic elements contamination viz., cadmium (1.06×10^{-3} mg kg^{-1}), chromium (1.18×10^{-4} mg kg^{-1}) and lead (2.93×10^{-6} mg kg^{-1}), lower total cancer risk (1.08×10^{-3} mg kg^{-1}) and hazard quotient (1.61×10^{-2} mg kg^{-1}) (Yousaf et al., 2017). Hussain *et al*. (2021) reported that the application of sugarcane bagasse recorded lowest translocation factor (0.08), bioaccumulation factor (1.52) in paddy grown under As-contaminated irrigated water stress. Liu *et al*. (2018) studied that biochar has emerged as a promising material for adsorbing and thus decreasing the bioavailability of pesticides in polluted soils, due to its high porosity, surface area, pH, abundant functional groups, and highly aromatic structure, mainly depending on the feedstock and pyrolysis temperature. Khan *et al*. (2017) reported that amendments bind bioavailable fraction of toxic metals on their binding sites and decrease cadmium availability to plants. Also, these amendments decompose and release a variety of nutrients which may enhance the yield of the crop in contaminated soils. This indicated that amendments could immobilize Cd for longer periods which justified the application of such materials in the Cd-contaminated soils to ensure food security. In this way these amendments help us to escape from the health risks associated with cadmium.

Conclusion

The potential reduction in exposure to synthetic chemicals and the promotion of nutrient-rich crops suggest positive implications, While the direct impact on human health may not be fully understood. The use of organic amendments in long-term agriculture holds promising benefits for soil health, biodiversity and sustainable farming practices. Furthermore, comprehensive research is crucial to assess its effect and ensure a balanced approach to maximize both agricultural productivity and human well-being.

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