Impact of Fertilizer Application on Soil Chemical Parameters: A Case Study (2021-2022)

Sonali Athnere, S.K. Diwakar
Govt. Narmada College, Narmadapuram (M.P.)

Abstract: Fertilizers are pivotal in enhancing crop productivity, but their application significantly impacts soil chemical properties, influencing soil fertility and sustainability. This study examines the variations in key soil chemical parameters, including pH, organic carbon, nitrogen, electrical conductivity (EC), and nutrient concentrations, before and after fertilizer application during the 2021–2022 agricultural year. The findings indicate notable changes, with improved nitrogen and essential nutrient levels contributing to increased soil fertility. However, challenges such as reduced pH, decreased organic carbon, and elevated salinity risk highlight the potential for adverse effects if fertilizers are mismanaged. These results emphasize adopting balanced fertilizer use and integrated soil management practices to maintain long-term soil health and productivity.

Keywords: soil fertility, fertilizers, pH, organic carbon, nitrogen, electrical conductivity, nutrient management, sustainable agriculture

INTRODUCTION

Soil fertility underpins agricultural productivity and sustainability, serving as a cornerstone of crop yield and ecosystem health. Chemical parameters such as pH, organic carbon (C), nitrogen (N), phosphorus (P), and potassium (K) play pivotal roles in maintaining soil functionality and supporting optimal plant growth (Brady & Weil, 2008; Lal, 2020). These factors collectively influence nutrient availability, microbial activity, water retention, and soil structure, directly impacting productivity and environmental sustainability (Oldeman *et al.,* 1991; Henao & Baanante, 2006).

Soil pH and Nutrient Dynamics

The pH of soil significantly affects nutrient solubility and microbial processes. Optimal pH levels (6.5–7.5) ensure the availability of essential nutrients while preventing toxicity. Soils with pH outside this range often suffer from deficiencies in vital nutrients or the presence of toxic elements such as aluminum (Al), which inhibits root development and reduces nutrient uptake (Fageria, 2014; von Uexküll & Mutert, 1995). Acidification, commonly induced by the application of ammonium-based fertilizers, exacerbates aluminum toxicity and further depletes soil health over time (Haynes, 1986; Guo *et al.,* 2010).

Role of Organic Carbon:

Organic carbon is a critical indicator of soil organic matter, essential for water retention, nutrient cycling, and microbial activity (Lal, 2020). However, the continuous use of synthetic fertilizers has been linked to the degradation of soil organic carbon stocks. Fertilizers stimulate microbial activity, accelerating the decomposition of organic matter and leading to a gradual decline in soil carbon levels (Zhou *et al.,* 2015; Geisseler & Scow, 2014). This decline undermines long-term soil fertility and resilience, particularly in intensively cultivated regions (Müller *et al.,* 2011).

Nitrogen Dynamics:

Nitrogen, a key macronutrient, plays a fundamental role in protein synthesis, enzymatic reactions, and overall plant metabolism (Havlin *et al.,* 2016). Fertilizers like urea and ammonium nitrate have been widely recognized for their ability to improve nitrogen availability, significantly enhancing crop productivity (Brady & Weil, 2008; Raun & Johnson, 1999). However, excessive application often leads to nitrogen leaching, groundwater contamination, and emissions of nitrous oxide, a potent greenhouse gas (Tilman *et al.,* 2002; Bouwman *et al.,* 2013). Such practices underscore the importance of balancing nitrogen inputs to optimize benefits while minimizing environmental risks (Sutton *et al.,* 2013).

Phosphorus and Potassium Contributions:

Phosphorus (P) fertilizers, such as di-ammonium phosphate (DAP), are critical for root development, flowering, and seed production. Their application boosts phosphorus availability in soils but, when mismanaged, contributes to issues like eutrophication in aquatic ecosystems due to runoff (Sharpley *et al.,* 2003; Carpenter *et al.,* 1998). Similarly, potassium (K), provided through potash fertilizers, enhances plant resistance to abiotic and biotic stresses, improving yield quality and resilience (White & Karley, 2010). However, an overabundance of potassium can disrupt nutrient balance, affecting magnesium and calcium uptake (Krauss, 2001).

Soil Salinity and Electrical Conductivity:

Elevated electrical conductivity (EC) is an indicator of increased salinity in soils, often exacerbated by the application of chemical fertilizers. High salinity levels impair plant water uptake, leading to reduced productivity and even crop failure under severe conditions (Munns & Tester, 2008; Rengasamy, 2006). Monitoring EC is essential to mitigate the risks of salinity-related stress, particularly in regions with intensive fertilization (Abrol *et al.,* 1988; Zhang *et al.,* 2016).

Study Objectives:

This study aims to quantify changes in soil chemical parameters before and after fertilizer application during the 2021–2022 cropping season. By comparing observed data with established normal ranges, this research identifies potential risks and offers evidence-based recommendations for sustainable fertilizer use. The findings provide valuable insights for integrated soil fertility management, emphasizing the need for balanced nutrient application and periodic soil testing (Zhao *et al.,* 2016; Singh *et al.,* 2018).

MATERIALS AND METHODS

Study Area and Sampling:

Soil samples were collected from a cultivated field in the Hoshangabad district, India, during the 2021–2022 cropping season. The region is characterized by fertile black soil (Vertisols) with intensive agricultural activity, primarily involving wheat, soybean, and paddy cultivation. Fertilizer application practices included urea (nitrogen source), di-ammonium phosphate (DAP) (phosphorus source), and potash fertilizers (potassium source), reflecting common agricultural practices in the region (Lal, 2020). Sampling was conducted before the start of the cropping season (pre-fertilizer) and after harvest (post-fertilizer), following established protocols for soil collection to ensure representative samples (Brady & Weil, 2008).

Sample Collection and Preparation:

Soil samples were taken at a depth of 0–15 cm using a soil auger at multiple random points within the field to minimize variability. The samples were composited, air-dried, and sieved through a 2 mm mesh to remove debris and ensure uniformity for analysis (Fageria, 2014).

Analytical Methods:

The following standard analytical methods were employed to assess soil chemical properties:

1. Soil pH: Measured using a 1:2.5 soil-to-water suspension method with a digital pH meter, which provides insights into soil acidity or alkalinity and its effect on nutrient availability (Munns & Tester, 2008).
2. Organic Carbon (C): Determined using the Walkley-Black titration method, which estimates the organic matter content as a measure of soil fertility (Lal, 2020).
3. Nitrogen (N): Analyzed using the Kjeldahl method, which quantifies total nitrogen content and reflects the soil's nitrogen-supplying capacity (Brady & Weil, 2008).
4. Electrical Conductivity (EC): Measured using an EC meter in a 1:2 soil-to-water extract to evaluate salinity levels (Munns & Tester, 2008).
5. Calcium (Ca) and Magnesium (Mg): Determined using EDTA titration, as these cations are critical for soil structure and plant nutrition (Fageria, 2014).
6. Potassium (K): Extracted using ammonium acetate and analyzed via flame photometry to determine available potassium levels (Sharpley *et al.,* 2003).
7. Aluminum (Al): Measured using a colorimetric method to assess potential toxicity, particularly in acidic soils (Brady & Weil, 2008).
8. Phosphorus (P): Assessed using the Olsen method, suitable for alkaline and neutral soils, to estimate available phosphorus for plant uptake (Sharpley *et al.,* 2003).

Data Analysis:

The analytical results were compared with established normal soil ranges as benchmarks to evaluate the deviations caused by fertilizer application (Munns & Tester, 2008). The variations in soil parameters were statistically analyzed to understand the impact of fertilizers on soil fertility.

The results provided insights into the effects of nitrogen, phosphorus, and potassium fertilizers on the soil's chemical properties, guiding sustainable soil management practices.

RESULTS AND DISCUSSION

1. Soil pH:

The soil pH decreased from 6.8 to 6.5, indicating a shift toward slight acidity after fertilizer application. This change can be attributed to ammonium-based fertilizers such as urea, which undergo nitrification to produce nitrate ions and hydrogen ions, lowering soil pH (Brady & Weil, 2008). Acidification is a common phenomenon in soils with intensive fertilization, potentially affecting nutrient availability. For instance, aluminum and manganese become more soluble in acidic conditions, which may pose risks to plant roots (Fageria, 2014). While the pH remains within the acceptable range (6.5–7.5), continuous monitoring is essential to prevent further acidification and associated challenges.

2. Organic Carbon (C):

A decline in organic carbon content was observed, decreasing from 0.8% to 0.7%. This reduction suggests a decrease in organic matter, likely due to enhanced microbial decomposition driven by the presence of readily available nitrogen and phosphorus from fertilizers (Lal, 2020). Organic matter plays a vital role in maintaining soil structure, moisture retention, and nutrient cycling (Sharpley *et al.,* 2003). The observed reduction underscores the need to supplement fertilizer use with organic amendments, such as compost or green manure, to sustain soil organic matter levels over time.

3. Nitrogen (N):

Nitrogen levels increased from 300 kg/ha to 340 kg/ha following urea application. This aligns with the nitrogen demands of crops, as nitrogen is essential for vegetative growth and chlorophyll production (Brady & Weil, 2008). However, excessive nitrogen application poses risks of nitrate leaching into groundwater and nitrous oxide emissions, contributing to environmental pollution and climate change (Fageria, 2014). Integrating nitrogen-use efficiency strategies, such as split applications and controlled-release fertilizers, can help optimize nitrogen uptake by plants while minimizing environmental impacts.

4. Electrical Conductivity (EC):

The EC increased from 0.6 to 0.8 mS/cm, signaling a heightened risk of salinity. Fertilizers often introduce soluble salts, which can accumulate in the soil and hinder plant water uptake, particularly in arid or semi-arid regions (Munns & Tester, 2008). While the EC remains below the critical threshold of 1 mS/cm, sustained salinity increases could negatively impact crop productivity. Regular soil leaching and the use of salt-tolerant crop varieties are recommended to mitigate salinity risks.

5. Calcium (Ca) and Magnesium (Mg):

Calcium levels decreased slightly from 7.0 to 6.8 meq/100g, while magnesium showed minimal change, declining from 2.5 to 2.4 meq/100g. These minor changes suggest that fertilizer application had a limited impact on these parameters. Calcium and magnesium are vital for soil structure and plant nutrition, influencing cation exchange capacity and photosynthesis (Brady & Weil, 2008). Maintaining balanced fertilizer applications and adding gypsum or dolomite, if necessary, can help sustain these nutrient levels.

6. Potassium (K):

Potassium levels rose significantly from 150 kg/ha to 200 kg/ha, primarily due to potash fertilizer application. Potassium enhances crop resistance to diseases, improves drought tolerance, and supports enzymatic functions essential for plant growth (Sharpley *et al.,* 2003). The increase is beneficial for crop health but highlights the need for site-specific nutrient management to avoid luxury consumption, which may lead to imbalances with other nutrients.

7. Aluminum (Al):

Aluminum concentration increased slightly from 0.05 ppm to 0.06 ppm. While still within acceptable limits, the increase underscores the potential risk of aluminum toxicity under further soil acidification (Fageria, 2014). Aluminum toxicity restricts root elongation and nutrient uptake, particularly in acidic soils. Liming acidic soils can mitigate aluminum toxicity by raising pH levels and precipitating aluminum as non-toxic forms (Brady & Weil, 2008).

8. Phosphorus (P):

Phosphorus levels increased from 30 kg/ha to 45 kg/ha, primarily due to the application of di-ammonium phosphate (DAP). Phosphorus is vital for root development, flowering, and seed formation, making this increase beneficial for crop productivity (Sharpley *et al.,* 2003). However, excessive phosphorus application can lead to environmental challenges such as runoff and eutrophication in nearby water bodies (Lal, 2020). Adopting precision agriculture techniques, such as variable-rate application, can help balance phosphorus inputs and minimize environmental impacts.

CONCLUSION

The application of fertilizers during the 2021–2022 cropping season markedly influenced various soil chemical parameters, reflecting both positive and negative outcomes. On the positive side, the observed increases in nitrogen (N), potassium (K), and phosphorus (P) levels demonstrated the effectiveness of fertilizers in enhancing soil fertility and supporting crop productivity. These nutrients are critical for plant growth, contributing to robust vegetative development, improved resistance to stress, and enhanced yield potential (Brady & Weil, 2008; Fageria, 2014).

However, the study also highlighted several concerns that warrant attention. The reduction in soil pH from 6.8 to 6.5 suggests an increasing trend toward acidity, which, if unchecked, could affect nutrient availability and plant root health in the long term. This acidification is likely linked to the nitrification process of ammonium-based fertilizers, a well-documented phenomenon in intensive agriculture (Fageria, 2014). Similarly, the decline in organic carbon from 0.8% to 0.7% underscores a reduction in organic matter, which is vital for maintaining soil structure, microbial activity, and nutrient cycling.

The rise in electrical conductivity (EC) from 0.6 to 0.8 mS/cm indicates a heightened risk of salinity, which, if exacerbated, could hinder plant water uptake and overall crop performance (Munns & Tester, 2008). These findings emphasize the potential trade-offs associated with fertilizer use, where benefits to nutrient levels may be offset by soil quality degradation.

To mitigate these issues, balanced fertilizer application and integrated soil management practices are essential. Strategies such as combining inorganic fertilizers with organic amendments (e.g., compost or manure), precision agriculture techniques, and crop rotation can help sustain soil fertility while minimizing adverse effects (Lal, 2020; Sharpley *et al.,* 2003). Regular soil testing and the adoption of site-specific nutrient management plans are recommended to optimize fertilizer use and maintain soil health.

Future research should focus on the long-term impacts of fertilizers on soil chemical parameters and the development of innovative, sustainable fertilization practices. Studies on the synergistic effects of biofertilizers, organic amendments, and controlled-release fertilizers could provide valuable insights into reducing soil degradation while enhancing productivity. Additionally, understanding the ecological and environmental implications, such as nutrient runoff and greenhouse gas emissions, is crucial for achieving sustainability in agricultural systems.

In conclusion, while fertilizers play an indispensable role in modern agriculture, their judicious use is vital to ensure the long-term health and productivity of soils. Sustainable soil fertility management must balance immediate agricultural needs with the preservation of soil as a finite resource for future generations.

REFERENCES

[1] Abrol, I.P., Yadav, J.S.P., & Massoud, F.I. (1988). *Salt-affected soils and their management*. FAO Soils Bulletin 39.

[2] Bouwman, A.F., Beusen, A.H.W., & Billen, G. (2013). Human alteration of the global nitrogen and phosphorus soil balances. *Geoscientific Model Development*, 6(1), 356–368.

[3] Brady, N.C., & Weil, R.R. (2008). *The Nature and Properties of Soils*. Pearson Education.

[4] Carpenter, S.R., et al. (1998). Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological Applications*, 8(3), 559–568.

[5] Fageria, N.K. (2014). *Nitrogen Management in Crop Production*. CRC Press.

[6] Geisseler, D., & Scow, K.M. (2014). Long-term effects of mineral fertilizers on soil microorganisms. *Soil Biology and Biochemistry*, 75, 54–63.

[7] Guo, J.H., et al. (2010). Significant acidification in major Chinese croplands. *Science*, 327(5968), 1008–1010.

[8] Havlin, J.L., et al. (2016). *Soil Fertility and Fertilizers*. Pearson.

[9] Haynes, R.J. (1986). The decomposition process: Mineralization, immobilization, and nutrient uptake. *Advances in Agronomy*, 39, 183–224.

[10] Henao, J., & Baanante, C. (2006). Agricultural production and soil nutrient mining in Africa. *International Fertilizer Development Center*.

[11] Krauss, A. (2001). Potassium and stress alleviation: Physiological functions and management of stress. *International Potash Institute Research Findings*.

[12] Lal, R. (2020). Soil organic matter content and its implications. *Nature Sustainability*, 3, 579–580.

[13] Müller, T., et al. (2011). Long-term organic matter turnover and residue decomposition in soils. *Soil Biology and Biochemistry*, 43(9), 1778–1786.

[14] Munns, R., & Tester, M. (2008). Mechanisms of salinity tolerance. *Annual Review of Plant Biology*, 59, 651–681.

[15] Oldeman, L.R., et al. (1991). *Global Assessment of Soil Degradation (GLASOD)*. United Nations Environment Programme.

[16] Raun, W.R., & Johnson, G.V. (1999). Improving nitrogen use efficiency for cereal production. *Agronomy Journal*, 91(3), 357–363.

[17] Rengasamy, P. (2006). World salinization and the global water crisis. *Agricultural Water Management*, 80(1-3), 125–140.

[18] Sharpley, A.N., et al. (2003). Phosphorus management for agriculture and the environment. *Agronomy Journal*, 95(3), 605–615.

[19] Singh, A.K., et al. (2018). Integrated nutrient management and its effect on soil properties. *Journal of Soil Science and Plant Nutrition*, 18(2), 500–515.

[20] Sutton, M.A., et al. (2013). The European Nitrogen Assessment. *Cambridge University Press*.

[21] Tilman, D., et al. (2002). Agricultural sustainability and intensive production practices. *Nature*, 418(6898), 671–677.

[22] von Uexküll, H.R., & Mutert, E. (1995). Global extent and economic impact of acid soils. *Plant and Soil*, 171(1), 1–15.

[23] White, P.J., & Karley, A.J. (2010). Potassium in plants. *Annals of Botany*, 105(3), 487–511.

[24] Zhang, J., et al. (2016). Salinity impacts on soil microbial communities. *Soil Biology and Biochemistry*, 98, 128–136.

[25] Zhou, M., et al. (2015). Long-term fertilizer effects on soil organic carbon. *Journal of Environmental Quality*, 44(5), 1502–1509.