

ASSESSMENT OF SOIL FERTILITY PARAMETERS UNDER MONOCULTURE CROPPING SYSTEMS

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ABSTRACT

The assessment of soil fertility parameters under different monoculture crops is decisive for optimizing agricultural productivity and soil management strategies. The study was conducted in Laksar block of Haridwar, Uttarakhand, India from November 2023 to October 2024. The study investigated the soil nutrient conditions in fields of Poplar, Sugarcane, and Mango, focusing on key fertility parameters (pH, EC, OC, soil macro and micronutrients). The results showed that the pH levels in the soil of the Mango orchard (7.6) and Sugarcane field (7.9) were slightly alkaline as compared to the Poplar field (8.33). EC was found low in all the samples ranging from 0.15 to 0.18 ds m⁻¹. The soil organic carbon was found low in Poplar field (0.37), medium in Mango orchard (0.47), and high in Sugarcane field (0.57) indicating a need for adding organic matter in fields of Poplar and Mango. The nitrogen levels in all three fields (Mango orchard: 213.56 kg ha⁻¹, sugarcane: 241.59 kg ha⁻¹, and Poplar field: 247.71 kg ha⁻¹) indicated moderate to high nitrogen availability. Phosphorus was found low across all three fields ranging from 2.61 kg ha⁻¹ in Poplar, 8.83 kg ha⁻¹ in Sugarcane to 9 kg ha⁻¹ in Mango orchard. The Mango orchard and Poplar fields had moderate potassium availability (178.5 kg ha⁻¹ and 101.3 kg ha⁻¹, respectively), however, the sugarcane field had low potassium availability (83.9 kg ha⁻¹). Mango orchards had a relatively lower calcium content (141.5 kg ha⁻¹) than sugarcane (379.9 kg ha⁻¹) and poplar fields (461.3 kg ha⁻¹). However, the relatively low magnesium content was observed across all fields (16.55 kg ha⁻¹ for Sugarcane, 16.87 kg ha⁻¹ for Poplar, and 17.06 kg ha⁻¹ for Mango). The sulphur was low in all monoculture fields (mango- 2.9 kg ha⁻¹, sugarcane- 2.6 kg ha⁻¹, and poplar- 2.2 kg ha⁻¹). The mango orchard soil had relatively high levels of copper (5.23 ppm) and boron (2.69 ppm) compared to the soil of other monoculture crops, with moderate levels of iron (2.21 ppm) and zinc (1.99 ppm). Sugarcane field had lower levels of copper (1.25 ppm), zinc (1.4 ppm), and boron (0.29 ppm) compared to Mango orchards, with a moderate level of iron ((1.51 ppm). Poplar field showed higher levels of manganese (2.59 ppm) compared to the other two crops but had lower levels of zinc (1.5 ppm) and boron (0.51). These nutrient imbalances highlight the need for targeted fertilization and soil management strategies to improve nutrient availability and support better crop growth and yield in monoculture cropping systems.

(Key words: EC, macronutrients, micronutrients, monocropping, organic carbon, soil health)

INTRODUCTION

Soil fertility is a fundamental determinant of agricultural productivity, influencing crop yields, nutrient cycling, and overall ecosystem health. In modern agriculture, monoculture cropping is a widely adopted practice due to its economic benefits, such as reduced labour costs and simplified management. However, monoculture farming can significantly affect soil fertility, often leading to imbalances in soil nutrient levels and usually causing serious economic losses due to increased vulnerability to diseases and pests, and decreased yield and quality of crops (Belete and Yadete, 2023). The assessment of soil fertility under different monoculture crops is essential to understand how continuous cultivation of specific crops alters soil properties,

nutrient availability, and microbial communities. This understanding can inform sustainable agricultural practices, which are critical for maintaining long-term soil health and productivity. This study aimed to explore the variations in soil fertility parameters under monoculture cropping systems and to compare these changes across different crop species.

Various studies have been conducted to evaluate the soil quality indicators under different land use types (Abbasi *et al.*, 2007). The most popular indicators used to assess soil quality are soil organic carbon (SOC), total nitrogen (TN), and soil pH. A balanced nutrient profile is crucial for supporting healthy crop growth and sustaining soil productivity over time. Several studies have shown that monoculture cropping systems deplete soil nutrients differently depending on the crop grown. For example, studies by Mäder *et al.* (2002) and Drinkwater *et al.* (1998)

found that crops like maize and wheat, when grown in monoculture, require higher inputs of synthetic fertilizers to maintain soil fertility. In contrast, crops such as legumes, which fix nitrogen in the soil, can contribute to maintaining or even improving nitrogen levels, though the overall effect of monoculture is still detrimental when compared to crop rotation.

The depletion of essential nutrients such as nitrogen, phosphorus, and potassium in monoculture fields can lead to nutrient imbalances. Over time, this can result in the need for greater fertilizer inputs to maintain crop yields, which in turn increases production costs and can contribute to environmental degradation, such as water pollution from nutrient runoff (Tilman *et al.*, 2002). The level of organic matter in the soil is another important aspect of soil fertility that is often negatively impacted by monoculture. Crops that are continuously grown without rotation tend to have less diverse root structures and less organic residue left in the soil, reducing the supply of organic matter that enhances soil structure and microbial life. A study by Fierer *et al.*, (2009) showed that monoculture systems often result in reduced microbial biodiversity, which can reduce nutrient cycling efficiency and lead to lower soil fertility. The crop rotation and heterogeneity of the cropping system improve soil performance by increasing crop residues and diverse root systems, as well as ramping up and expanding microbial activity (Studdert and Echeverría, 2000). Specific crops have different interactions with soil microbes; for example, root exudates from leguminous crops can encourage the growth of nitrogen-fixing bacteria, whereas monocultures of cereal crops may lead to a less diverse microbial community, limiting nutrient cycling (Postma-Blaauw *et al.*, 2010). On the other hand, certain crops like legumes may improve soil fertility in monoculture systems by fixing nitrogen, though these benefits are often not enough to counterbalance the depletion of other key nutrients like phosphorus and potassium. The long-term sustainability of any monoculture system depends on the ability to replenish nutrient levels through external inputs like fertilizers or organic amendments, although these solutions may not fully mitigate the loss of biodiversity and organic matter (Bünemann *et al.*, 2006).

MATERIALS AND METHODS

Study area

The study was conducted in an agricultural region of Laksar block of Haridwar district where monoculture is the dominant land-use system. Laksar is a tiny town in the Haridwar district of the Indian state of Uttarakhand with rural and urban areas. The main occupation is agriculture. Wheat, rice, and sugarcane are the main crops of Laksar. Fruits, vegetables, and a few cash crops like Poplar and Eucalyptus are also grown in the area. As the block is close to the Ganga River, which supplies water for crops during the dry season, irrigation systems are frequently used to assist agriculture in the area.

Soil sampling and analysis The soil samples were collected monthly from different sampling sites from November 2023 to September 2024. Five composite soil samples, from 0 cm to 30 cm depths, were collected from each land use system by following the random sampling technique. Seven subsamples were collected at each study site. The collected samples were analyzed using standard procedures for each parameter. Air-dried samples were ground and sieved through a 2 mm sieve. The processed soil samples were analysed for pH by pH meter, Electrical Conductivity by EC meter, and soil organic carbon by Walkley and Black (1934) method; available nitrogen by Kjeldhal distillation method (Bremner and Mulvaney, (1982); available phosphorus by Bray and Kurtz (1945); potassium, calcium and magnesium by Jackson (1973); sulphur by Black (1965); micronutrients by extraction with 1N HCl followed by Lindsay and Norvel (1978) and boron by Wolf (1974) method.

RESULTS AND DISCUSSION

pH: Most crops develop best in soil with a pH of 5.5 to 6.5 (Havlin *et al.*, 1999). Table 1 and Figure 1 shows that the pH levels in the soil of the Mango Orchard (7.6) Sugarcane field (7.9) and Poplar field (8.33) were alkaline. The higher pH of the Poplar field (8.33) suggests that poplar trees may prefer slightly more alkaline conditions.

EC: The low EC across all fields ranging from 0.15 to 0.18 ds m⁻¹ (Table 1 and Figure 1) indicates that the soil had low salinity and this could be due to the prevailing conditions were not favourable for the accumulation of salts (Bhriuvanshi *et al.*, 2014).

Organic Carbon: The soil organic carbon content (Table 1 and Figure 1) was found to be low in the poplar field (0.37), medium in the mango orchard (0.47), and high in the sugarcane field (0.57) indicating a need for improvement in organic matter in the Poplar field and mango orchard. The soil organic carbon can be enhanced by soil and crop management practices such as no-tilling, adding plant residue or organic matter, fertilizer inputs, and changing land use (Dalal *et al.*, 2011).

Macronutrients: The data regarding soil analysis of the Mango orchard, Sugarcane field, and Poplar field reveals several important insights about nutrient availability and its potential impact on plant growth. Table 2 and Figure 2 describe the availability of key nutrients (N, P, K, Ca, Mg, S) for three monoculture crops. Here's a breakdown of the nutrient availability for each crop:

1. Nitrogen: The nitrogen levels in all three fields (Mango orchard- 213.56 kg ha⁻¹, sugarcane- 241.59 kg ha⁻¹, and Poplar field- 247.71 kg ha⁻¹) indicated moderate to high nitrogen availability. Nitrogen is the main nutrient used for vegetation growth and is also used as a key soil quality assessment (Ren *et al.*, 2014). High nitrogen availability is advantageous for ensuring optimal growth in these crops.

2. Phosphorus: Available phosphorus was found low across all three fields ranging from 2.61 kg ha⁻¹ in Poplar, 8.83 kg ha⁻¹ in

Sugarcane to 9 kg ha⁻¹ in Mango orchard which could hinder root development, flowering, and overall plant growth and its deficiency can lead to stunted growth and poor fruit or biomass yield. Lal *et al.* (2022) found that a phosphorus level of 70 kg ha⁻¹ in peas fields resulted in higher growth and yield.

3. Potassium: The potassium levels showed variation across the fields. The Mango orchard and Poplar fields had moderate potassium availability (178.5 kg ha⁻¹ and 101.3 kg ha⁻¹, respectively), which supports overall plant health, water regulation, and disease resistance. However, the sugarcane field had low potassium availability (83.9 kg ha⁻¹), which could compromise water regulation, disease resistance, and overall plant health. In general potassium level was found to be low and the probable reason might be the leaching off brought in by irrigation (Kavitha and Sujatha, 2015).

4. Calcium: Mango orchards had a relatively low calcium content (141.5 kg ha⁻¹), which could potentially limit their growth, as calcium is essential for cell wall structure and overall plant health. In contrast, sugarcane (379.9 kg ha⁻¹) and poplar fields (461.3 kg ha⁻¹) had significantly higher calcium levels. This higher calcium content in sugarcane is likely critical for its rapid growth cycle, while in poplar trees, it supports the development of wood structure and their long-term growth.

5. Magnesium: Magnesium is a key component of chlorophyll, essential for photosynthesis. However, the relatively low magnesium content across all fields (16.55 kg ha⁻¹ for Sugarcane, 16.87 kg ha⁻¹ for Poplar, and 17.06 kg ha⁻¹ for Mango) suggests a potential nutrient imbalance.

6. Sulphur: Sulphur is crucial for protein synthesis and the function of enzymes, particularly those related to sulphur-containing amino acids and proteins. The low sulphur content in all monoculture fields (mango- 2.9 kg ha⁻¹, sugarcane- 2.6 kg ha⁻¹, and poplar- 2.2 kg ha⁻¹) could indicate a deficiency that might affect plant metabolism and growth. The sulphur deficiency can be removed by applying magnesium sulphate (Mini and Usha, 2015).

Micronutrients: Table 3 and Figure 3 shows the micronutrient content in soil samples of three monoculture crops (Mango Orchard, Sugarcane, and Poplar). The mango orchard soil had relatively high levels of copper (5.23 ppm) and Boron (2.69 ppm) compared to the soil of other monoculture crops, with moderate levels of iron (2.21 ppm) and zinc (1.99 ppm). Sugarcane field had a lower value of copper (1.25 ppm), zinc (1.4 ppm), and boron (0.29 ppm) compared to Mango orchards, with a moderate level of iron ((1.51 ppm). The boron (0.51 ppm) content was particularly low. The low level of boron might be due to leaching off by

irrigation or rainfall (Mini and Usha, 2015). Poplar field showed higher levels of manganese (2.59 ppm) compared to the other two crops but had lower levels of zinc (1.5 ppm) and boron (0.51 ppm). Soil nutrients are essential in the intensive production systems and deficiencies of essential micronutrients have a great impact on the productivity and quality of the crop (Kundu, 2023).

Although monoculture farming is economically efficient in the short term, its sustainability is increasingly questioned. Soil fertility degradation, along with the potential for increased pest and disease pressure, can undermine the long-term productivity of monoculture systems. Integrating crop rotations, cover cropping, and organic farming practices have been suggested as methods to mitigate the negative impacts of monoculture on soil fertility (Cavigelli and Dao, 2008). Overall, a multi-pronged approach that incorporates soil amendments, crop rotation, and intercropping, along with a deeper understanding of plant-microbe relations and stress responses, may help us to overcome the obstacles associated with mono-cropping (Belete and Yadete, 2023). Each crop's nutrient profile indicates different fertilization and soil management needs for optimal growth.

While nitrogen availability supports robust growth in all three fields, the low phosphorus and potassium levels in certain crops, particularly sugarcane, could limit optimal development. Supplemental fertilization, particularly for phosphorus and potassium, may be necessary, especially for sugarcane, to enhance growth, improve root development, and optimize productivity. On the other hand, while the calcium content in mango orchards is notably lower than in sugarcane and poplar fields, magnesium and sulphur deficiencies are common across all three types of land use. These nutrient imbalances suggest that targeted fertilization and soil management strategies could enhance nutrient availability, supporting better growth and yield in these monocultures. The available N, P, K, and other soil nutrients can be increased by applying organic manures and fertilizers alone or in combination (Kumar *et al.*, 2022). While monoculture can offer economic advantages, it often leads to soil nutrient imbalances and degradation of soil organic matter. Sustainable agricultural practices, such as crop rotation and the integration of legumes or cover crops, may help alleviate some of these challenges, promoting long-term soil fertility and ecosystem health. Further research is needed to quantify the precise impacts of different monoculture crops on soil fertility and to develop strategies for improving the sustainability of monoculture farming systems.

Table 1. Values of pH, EC and OC in different monoculture crops

Monoculture crops	pH	EC (ds m ⁻¹)	OC (%)
Mango orchard	7.6	0.19	0.46
Sugarcane field	7.9	0.15	0.57
Poplar field	8.33	0.18	0.37

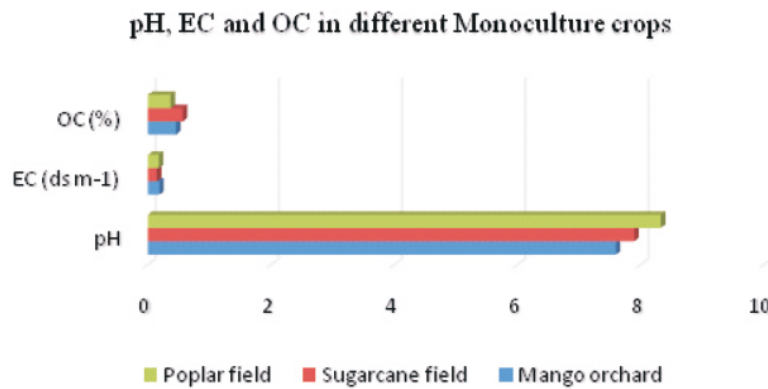


Figure 1. Comparison of pH, EC and OC in different monoculture crops

Table 2. Values of N, P, K, Ca, Mg and S in different monoculture crops

Monoculture crops	Nitrogen (kg ha ⁻¹)	Phosphorus (kg ha ⁻¹)	Potassium (kg ha ⁻¹)	Calcium (kg ha ⁻¹)	Magnesium (kg ha ⁻¹)	Sulphur (kg ha ⁻¹)
Mango orchard	213.56	9.00	178.5	141.5	17.06	2.9
Sugarcane field	241.59	8.83	83.9	379.9	16.55	2.6
Poplar field	247.71	2.61	101.3	461.3	16.87	2.2

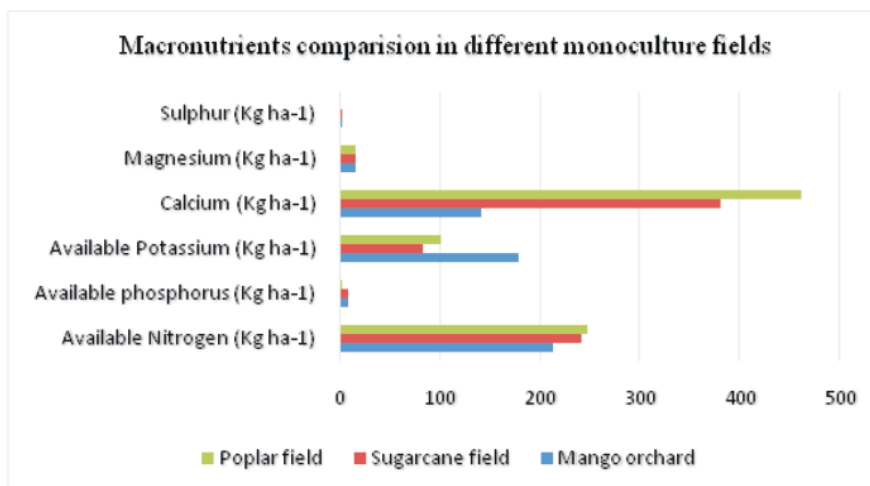


Figure 2. Levels of N, P, K, Ca, Mg and S in different monoculture crops

Table 3. Values of micronutrients in different monoculture crops

Monoculture Crops	Copper (ppm)	Iron (ppm)	Manganese (ppm)	Zinc (ppm)	Boron (ppm)
Mango orchard	5.23	2.21	1.23	1.99	2.69
Sugarcane field	1.25	1.51	1.23	1.40	0.29
Poplar field	1.50	1.50	2.59	0.89	0.51

Micronutrients comparison in different monoculture fields

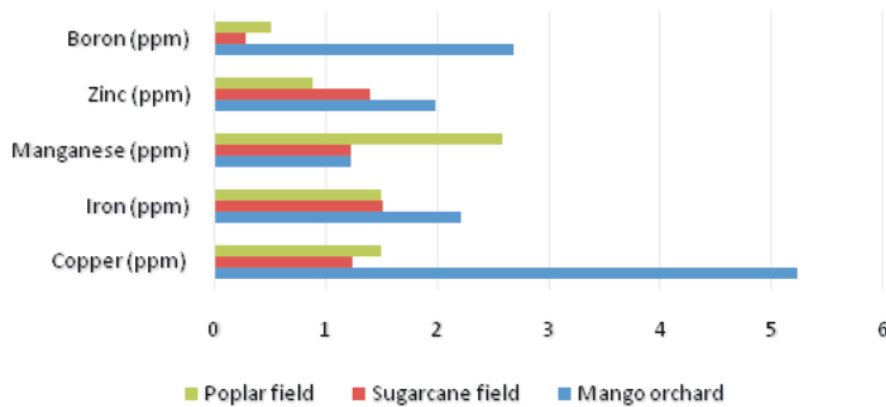


Figure 3. Levels of micronutrients in different monoculture crops

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