International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 14 Issue 4, April-2025

Evaluation of Soil Physico-Chemical Changes Due to Pesticide Use in Chickpea Cultivation

Ware Mohinee Sampatrao[1], Dr. Parasnath Bele[2]

[1]Research Scholar, Department of Chemistry, Mansarovar Global University, Sehore, M.P
[2]Supervisor, Department of Chemistry, Mansarovar Global University, Sehore, M.P

ABSTRACT

Chickpea (*Cicer arietinum L.*) is an essential legume crop, providing dietary protein and enhancing soil fertility through nitrogen fixation. The use of chemical pesticides has become integral to its cultivation to manage pests and diseases. However, these chemicals may induce changes in soil properties, affecting long-term soil health and crop productivity. This theoretical study explores the potential physico-chemical changes in soil caused by pesticide application, focusing on parameters such as pH, organic carbon, nutrient availability, and microbial activity. The paper discusses mechanisms through which pesticides interact with soil components, their potential effects on soil chemistry and biology, and implications for sustainable chickpea cultivation. By understanding these theoretical frameworks, researchers and farmers can better assess the risks associated with pesticide use and adopt management strategies that preserve soil health.

Keywords: Chickpea, Soil health, Pesticides, Physico-chemical properties, Organic carbon, Nutrient dynamics.

INTRODUCTION

Chickpea (*Cicer arietinum L.*) is one of the most important pulse crops cultivated globally, particularly in semi-arid and arid regions, where it provides essential dietary protein and contributes significantly to human nutrition. It is widely recognized for its role in sustainable agriculture due to its ability to fix atmospheric nitrogen through symbiotic relationships with rhizobia bacteria, thereby enhancing soil fertility. This intrinsic ability makes chickpea cultivation an integral component of crop rotation systems, contributing to the maintenance of soil health and reduction of synthetic nitrogen fertilizer dependency. (Gaur, P.M. 2016) As a result, chickpea is not only an important food source but also a critical component in sustainable agricultural practices, especially in developing countries where pulses serve as a major source of protein for large populations. The demand for high-quality chickpea production continues to increase, prompting farmers to adopt intensive cultivation practices that often involve the use of chemical pesticides to protect crops from various insect pests, fungal pathogens, and bacterial diseases.

Pesticides, while effective in reducing crop losses, are complex chemical compounds that interact with the environment in multiple ways. When applied to fields, they do not only target pests but also affect non-target organisms, including beneficial soil microorganisms, earthworms, and other soil fauna. (Vandemark, G.J. 2018) These interactions have the potential to influence the chemical, physical, and biological properties of the soil. Soil is a dynamic ecosystem where physical structure, nutrient content, and microbial activity interact to support plant growth. The introduction of pesticides into this system can result in changes that affect soil pH, organic carbon content, nutrient availability, and microbial biomass. (Kahraman, A. 2017) Such alterations may have cascading effects on soil fertility and long-term sustainability of chickpea production. For instance, pesticide residues may bind with essential nutrients, reducing their bioavailability for plants, or they may directly inhibit the activity of microorganisms responsible for nutrient cycling and organic matter decomposition.

The physico-chemical properties of soil, including pH, electrical conductivity, organic matter content, and the availability of macronutrients like nitrogen, phosphorus, and potassium, are key indicators of soil health. (Ozgun, O.S.2004) Soil pH determines the solubility and uptake of nutrients, while organic carbon provides energy for microbial populations and influences soil structure and water retention. Nitrogen availability is closely tied to microbial activity and organic matter decomposition, and phosphorus and potassium play essential roles in plant growth and metabolism. Theoretical and empirical studies indicate that pesticides can alter these parameters by either directly affecting chemical reactions in soil or indirectly by modifying microbial populations. Changes in soil chemical properties can affect nutrient cycles, reduce soil fertility, and potentially decrease crop productivity. Over time, repeated pesticide applications may exacerbate these effects, leading to cumulative impacts on soil quality, resilience, and overall ecosystem health.

Understanding the influence of pesticides on soil properties is particularly critical in chickpea cultivation due to the crop's reliance on soil fertility and microbial interactions for optimal growth. The relationship between pesticide uses and soil quality is complex and mediated by factors such as soil type, climate, pesticide type and dosage, and cropping patterns. While pesticides play a crucial role in protecting crops from pests and diseases, their long-term impacts on soil health require careful consideration. (Avelar, R.I.S. 2018) The need for sustainable agricultural practices that balance pest control with soil conservation has become increasingly important. Integrated Pest Management (IPM), judicious pesticide application, and the use of organic amendments are strategies that may mitigate adverse effects while maintaining productivity. Studying these interactions theoretically allows for a comprehensive understanding of how pesticides may influence soil physico-chemical properties, microbial activity, and nutrient dynamics in chickpea fields. By examining these effects, researchers and farmers can develop informed management strategies that enhance productivity without compromising soil health and environmental sustainability.

I. SOIL-PESTICIDE INTERACTIONS

Pesticides applied to agricultural soils do not act solely on target pests but interact extensively with the soil environment, influencing its physical, chemical, and biological characteristics. (Sastry, D. 2017) When these chemicals enter the soil, they undergo processes such as adsorption, leaching, volatilization, and degradation, which determine their persistence and mobility. Soil texture, organic matter content, moisture, and pH play a crucial role in these processes, influencing how pesticides bind to soil particles or dissolve in soil water. Clay-rich soils with high cation exchange capacity tend to retain pesticide molecules more effectively, reducing their mobility but potentially prolonging their residence time. Sandy soils, in contrast, allow faster percolation and leaching, which can transport pesticide residues to deeper layers or even groundwater, affecting soil fertility and environmental safety.

The chemical nature of pesticides, including their solubility, polarity, and stability, governs their interaction with soil components. Hydrophilic pesticides are more likely to move with soil water, whereas hydrophobic compounds bind strongly to organic matter. These interactions can alter the chemical composition of the soil, including nutrient availability, pH balance, and the presence of reactive ions. (Biçer, B.T. 2009) For example, repeated application of organophosphate and carbamate pesticides may slightly raise soil pH due to the breakdown of their chemical constituents, potentially influencing the solubility of micronutrients such as iron, zinc, and manganese. In addition, pesticide residues may interact with soil minerals or organic colloids, forming complexes that are less available to plants and microbes, thereby modifying soil fertility dynamics over time.

Biologically, pesticides have a profound effect on soil microorganisms, which are essential for nutrient cycling, organic matter decomposition, and the formation of soil structure. Many pesticides exhibit broad-spectrum toxicity, reducing populations of bacteria, fungi, and actinomycetes that facilitate nitrogen fixation, phosphorus solubilization, and organic carbon turnover. (Upadhyaya, H.D 2006) A decline in microbial biomass and enzymatic activity disrupts soil nutrient transformations and slows the breakdown of organic matter. Such disruptions can create feedback effects, reducing soil resilience and compromising the sustainability of agricultural systems. Conversely, some microbial populations may adapt to pesticide exposure, developing pathways to degrade chemical residues, which contributes to natural attenuation processes but may also produce by-products that influence soil chemistry.

The interaction between pesticides and soil is therefore multidimensional, involving physical adsorption, chemical reactions, and biological effects. These interactions determine not only the effectiveness of the pesticides themselves but also the long-term health and fertility of the soil. Understanding these processes is essential for developing sustainable cultivation practices in chickpea and other crops, where balancing pest management with soil conservation is critical for productivity and environmental sustainability. (Khattak, A.M 2021) Soil-pesticide interactions illustrate the complexity of agroecosystems, highlighting the need for integrated management strategies that reduce chemical stress while maintaining crop protection.

II. PHYSICO-CHEMICAL PARAMETERS AFFECTED

Soil pH and Electrical Conductivity

Soil pH is a critical parameter that regulates nutrient availability, microbial activity, and chemical reactions in the soil. Pesticides can influence soil pH directly through their chemical decomposition or indirectly by affecting microbial populations that produce acids or bases. Repeated pesticide applications may slightly increase or decrease pH depending on the chemical nature of the pesticide and soil buffering capacity. (Ma, S. 2018) A shift in pH can affect the solubility of essential nutrients such as iron, manganese, and zinc, which are vital for chickpea growth. Electrical conductivity (EC), an indicator of soluble salt concentration, may also increase due to pesticide residues and associated adjuvants. High EC can create osmotic stress for plants, reducing water uptake and impacting overall crop productivity.

Organic Carbon Content

Soil organic carbon plays a pivotal role in maintaining soil fertility, structure, and moisture retention. Pesticide applications can influence organic carbon by altering microbial activity responsible for decomposing organic matter. Many pesticides inhibit microbial populations, slowing down decomposition and nutrient cycling, which reduces the formation of stable organic compounds in soil. (Ibrikci, H. 2003) Decreased organic carbon can negatively impact soil structure, porosity, and water-holding capacity, which are essential for chickpea root development and nutrient absorption.

Nutrient Availability

Macronutrients such as nitrogen (N), phosphorus (P), and potassium (K) are directly affected by pesticide use. Nitrogen availability often declines in pesticide-treated soils due to reduced microbial mineralization and nitrification. Phosphorus availability may be influenced by chemical interactions between pesticides and soil minerals, while potassium is generally less affected but can still show variation in highly treated soils. (Yadav, S.S.2007) Changes in nutrient levels can affect plant metabolism, growth, and yield, emphasizing the need for careful monitoring and balanced fertilization in fields under pesticide use.

Microbial Biomass and Soil Enzymes

Microbial biomass and enzymatic activity are critical for nutrient cycling and soil fertility. Pesticides can suppress microbial populations, reducing microbial biomass carbon and enzymatic functions like urease, phosphatase, and dehydrogenase activity. Reduced microbial activity slows organic matter decomposition and nutrient release, indirectly affecting soil physico-chemical conditions and long-term fertility. Maintaining microbial diversity is therefore essential to counteract the negative impacts of pesticide application.

III. IMPLICATIONS FOR CHICKPEA CULTIVATION

The changes in soil physico-chemical properties and microbial activity due to pesticide use have significant implications for chickpea cultivation. Chickpea, being a leguminous crop, relies heavily on a healthy soil ecosystem for nutrient uptake, nitrogen fixation, and overall growth. Alterations in soil pH, organic carbon content, and nutrient availability can directly influence plant metabolism, root development, and yield potential. (Wouterlood, M. 2004) An increase or decrease in soil pH may limit the solubility of essential micronutrients such as iron, zinc, and manganese, which are critical for enzymatic activities and photosynthetic efficiency. As a result, even with adequate fertilization, plants may exhibit nutrient deficiencies, stunted growth, and lower pod formation, reducing overall productivity.

The decline in soil organic carbon and microbial biomass further exacerbates these effects by disrupting nutrient cycling. Microorganisms in the soil play a pivotal role in decomposing organic matter, mineralizing nitrogen, and mobilizing phosphorus. Pesticide-induced reductions in microbial populations can slow these processes, leading to decreased availability of essential nutrients for chickpea plants. This situation can force farmers to rely more on synthetic fertilizers to maintain yields, which may increase production costs and further affect soil health over time. Moreover, reduced microbial diversity may impair soil’s natural disease suppression capabilities, making chickpea crops more vulnerable to soil-borne pathogens and pests.

Another implication is the potential for soil structure degradation due to reduced organic matter content. Organic carbon is essential for maintaining soil aggregation, porosity, and water-holding capacity. Soils with lower organic content tend to compact more easily, restricting root penetration and reducing access to water and nutrients. Chickpea roots, which are vital for nodulation and nitrogen fixation, may not develop optimally in such conditions, further compromising crop performance. (Jadeja, A.S 2019).Additionally, accumulation of pesticide residues and increased soil electrical conductivity can create osmotic stress, affecting water uptake and physiological processes in the plant.

The combined effect of chemical, physical, and biological disturbances highlights the need for careful management of pesticide applications in chickpea cultivation. While pesticides are necessary for controlling pests and ensuring crop protection, excessive or improper use can have long-term negative consequences on soil fertility, plant growth, and sustainable yield. Integrating pest management strategies that balance crop protection with soil conservation becomes essential to maintain productivity. (Shukla, U.C 1982) .Practices such as reducing chemical dependence, using organic amendments, and promoting beneficial microbial activity can mitigate these risks and support sustainable chickpea cultivation.

CONCLUSION

Pesticide use in chickpea cultivation significantly influences soil physico-chemical properties, nutrient dynamics, and microbial activity, with direct implications for soil health and crop productivity. Changes in soil pH, organic carbon content, and nutrient availability can affect root development, nitrogen fixation, and overall plant growth, potentially reducing yield and long-term soil fertility. The decline in microbial biomass and enzymatic activity further disrupts nutrient cycling and organic matter decomposition, making the soil less resilient to environmental stresses and pest pressures. These alterations highlight the complexity of soil-pesticide interactions and emphasize the need for a balanced approach to pest management. Sustainable chickpea cultivation requires strategies that minimize chemical stress on the soil while maintaining effective pest control. Integrated Pest Management, judicious use of pesticides, organic amendments, and regular soil monitoring can help mitigate the adverse effects of chemical inputs. By understanding the theoretical and practical implications of pesticide use on soil properties, farmers and researchers can adopt practices that protect both soil fertility and crop productivity. Maintaining soil health is essential not only for immediate agricultural outcomes but also for the long-term sustainability of chickpea cultivation and the broader agro-ecosystem.

REFERENCES

[1]. Gaur, P.M.; Singh, M.K.; Samineni, S.; Sajja, S.B.; Jukanti, A.K.; Kamatam, S.; Varshney, R.K. Inheritance of protein content and its relationships with seed size, grain yield and other traits in chickpea. Euphytica 2016, 209, 253–260.
[2]. Vandemark, G.J.; Grusak, M.A.; McGee, R.J. Mineral concentrations of chickpea and lentil cultivars and breeding lines grown in the U.S. Pacific Northwest. Crop J. 2018, 6, 253–262.
[3]. Kahraman, A.; Pandey, A.; Khan, M.K. Nutritional Diversity Assessment in Chickpea-A Prospect for Nutrient Deprived World. Harran Tarım Gıda Bilim. Derg. 2017, 21, 357–363.
[4]. Ozgun, O.S.; Bicer, B.T.; Sakar, D. Agronomic and Morphological Characters of Chickpea Under Irrigated Conditions in Turkey. Int. J. Agric. Biol. 2004, 6, 606–610.
[5]. Avelar, R.I.S.; Costa, C.A.D.; Brandão, D.D.S., Jr.; Paraíso, H.A.; Nascimento, W.M. Production and quality of chickpea seeds in different sowing and harvest periods. J. Seed Sci. 2018, 40, 146–155.
[6]. Sastry, D.; Upadhyaya, H.; Gowda, C. Determination of Physical Properties of Chickpea Seeds and their Relevance in Germplasm Collections. Indian J. Plant Genet. Resour. 2014, 27, 1–9.
[7]. Biçer, B.T. The effect of seed size on yield and yield components of chickpea and lentil. Afr. J. Biotechnol. 2009, 8, 1482–1487.
[8]. Upadhyaya, H.D.; Kumar, S.; Gowda, C.L.L.; Singh, S. Two major genes for seed size in chickpea (Cicer arietinum L.). Euphytica 2006, 147, 311–315.
[9]. Khattak, A.M.; Ullah, S.; Anjum, F.; Shah, H.U.; Alam, S. Proximate Composition and Mineral Content of Selected Chickpea Cultivars. Sarhad J. Agric. 2021, 37, 683–689.
[10]. Ma, S.; Khetarpaul, N.; Chand, G. Minerals Profile and Antioxidants Properties of Chickpea Leave of Desi and Kabuli Varieties at Different Stages of Maturity. Int. J. Curr. Microbiol. Appl. Sci. 2018, 7, 3171–3177.
[11]. Ibrikci, H.; Knewtson, S.J.; Grusak, M.A. Chickpea leaves as a vegetable green for humans: Evaluation of mineral composition. J. Sci. Food Agric. 2003, 83, 945–950.
[12]. Yadav, S.S.; Longnecker, N.; Dusunceli, F.; Bejiga, G.; Yadav, M.; Rizvi, A.H.; Manohar, M.; Reddy, A.A.; Xaxiao, Z.; Chen, W. Uses, Consumption and Utilization. In Chickpea Breeding and Management; CABI: Wallingford, UK, 2007; pp. 72–100.
[13]. Wouterlood, M.; Cawthray, G.R.; Turner, S.; Lambers, H.; Veneklaas, E.J. Rhizosphere carboxylate concentrations of chickpea are affected by genotype and soil type. Plant Soil 2004, 261, 1–10.
[14]. Jadeja, A.S.; Rajani, A.V.; Kaneriya, S.C.; Hirpara, D.V. Nutrient Content, Uptake, Quality of Chickpea (Cicer arietinum L.) and Fertility Status of Soil as Influenced by Fertilization of Potassium and Sulphur. Int. J. Curr. Microbiol. Appl. Sci. 2019, 8, 2351–2355.
[15]. Shukla, U.C.; Yadav, O.P. Effect of phosphorus and zinc on nodulation and nitrogen fixation in chickpea (Cicer arietinum L.). Plant Soil 1982, 65, 239–248.