Direct Research Journal of Engineering and Information Technology

Vol. 13(3), Pp. 35-39, September 2025,

Research Article
ISSN: 2354-4155
https://journals.directresearchpublisher.org/index.php/drjeit; https://www.ajol.info/index.php/drjeit

The Impact of Organic and Conventional Farming Methods on Soil Physicochemical Composition and Bioaccumulation of Heavy Metals and Arsenic on Pearl Millet (*Pennisetumglaucum*) Grown in Kaura Namoda, Zamfara State, Nigeria

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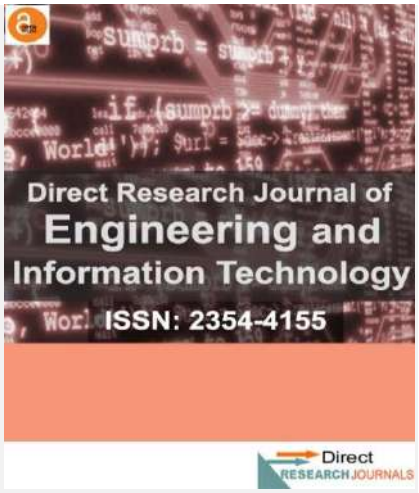
ABSTRACT

The impact of organic and conventional farming practices at four planting fields was carried out to determine the effect on physicochemical properties and heavy metal accumulation on Pearl millet. Pearl millet is used for processing of food products such as tuwo, fura, and kunun- zaki, Cuscus, burabusko, thin and thick porridges, alcoholic, non-alcoholic beverages and some winning foods. Food processors and consumers need to understand what they consume when they adopt any farming system for the production of this important crop. This study was carried out between the month of June and September, 2024 (15weeks). Sasakawa planting method was applied in planting the millet seeds and application of organic and inorganic fertilizers. Results obtained were statistically determined using Minitab software in order to arrive at level of significant difference among the parameters. The outcome of the result of physical parameters showed that conventional farming system produced less leaf size in terms of, width (1.3 to 2.25 cm), length (25.00 to 39.60cm), stalk length (49.00 to 77.00cm) and seed weight (10.50 to12.22g) compared to those of organic farming system. The result of proximate analysis showed that there was significant variation on ash, protein and carbohydrate content of conventional farming seeds (P ≤ 0.05) when compared with organic farming. Heavy metals analysis in pearl millet seeds indicate that the use of synthetic fertilizer did not lead to seed contamination with heavy metals, phosphorus, nitrogen and iron containing compounds. The outcome of this study shows that the type of farming system did not significantly (p ≤ 0.05) affects the quality and safety of the agricultural soil and plant seeds during practices. Farmers can leverage on this data to improve on conventional and organic system for better production of pearl millet to improve food security.

Keywords: *Physicochemical Composition, Bioaccumulation Arsenic, Pearl Millet, Pennisetumglaucum, Kaura Namoda, Zamfara State, Nigeria*



Article information
Received 20 July 2025;
Accepted 25 August 2025;
Published 27 September 2025
DOI: https://doi.org/10.26765/DRJEIT490867589
Citation: Alkali Z.J., Sadiq D.B. , Dayyabu, K.D. (2025). The Impact of Organic and Conventional Farming Methods on Soil Physicochemical Composition and Bioaccumulation of Heavy Metals and Arsenic on Pearl Millet (Pennisetumglaucum) Grown in Kaura Namoda, Zamfara State, Nigeria. Direct Research Journal of Engineering and Information Technology, 13(3), 35-39. This article is published under the terms of the Creative Commons Attribution License 4.0.

INTRODUCTION

The quest for food security in Nigeria and the desire to reduce labour and increase crop yield has become the motivation for the type of farming system to be adopted by most farming communities in Zamfara state. A farming system that work in agreement with nature with minimum or no damage to the natural environment is referred to as Organic Farming System (OFS). While the type of farming system that utilizes chemical inputs such as fertilizers, and other farming inputs in order to sustain and replenish soil nutrients is commonly referred to as conventional farming system (CFS). Organic farming system is fast replacing conventional farming system because of demands for organic food and growing environmental concerns. Studies have shown that organic farming system has the

potentials to increase the level of soil nitrogen and prevents leaching of essential soil nutrients (Diepeningen., Vos, Korthals, Bruggen, 2006; Yung *et al*., 2008). In contrast, conventional farming system most often results in negative impacts such as, nutrient run off, soil erosion,, loss of organic matter, impaired environment quality leading to pollution of underground waters by agricultural chemical inputs.

Furthermore, Diepeningen *et al*., (2006) in another study reported that prolonged use of chemical fertilizers may persist in the soil with consequent effect on food chain. Over the decades, chemicals and heavy metals contamination caused by anthropogenic activities has raised concern over public health and environment quality (Saadia Rashid Tariq Musharaf and, 2016; Sabry, 2015; Tariq *et al*., 2016). The health risk arising from heavy metal pollution have attracted global attention because of its role in the causation of disease to man. According to a study conducted by (Omolar TItilayo Aladesanmi, Jeremiah Gbenga Oroboade, Chisom Peter Obbisiogu, 2019), crop plants especially cereals is capable of accumulating high amount of heavy metal from the soil during conventional farming system. Similarly, Sabry, (2015) reported that fertilizer can seriously deplete the nutritional content of food. Pearl Millet is a vital staple crop in northern Nigeria particularly in semi-arid region of the north-west and north-east (Badau *et al*., 2002; Nkama, and Ikwelle, 1997). The states that farm Pearl millet in large quantities in northern Nigeria are Sokoto, Yobe, Jigawa, Taraba, Borno, Kano and Zamfara. Pearl millet thrives well in harsh climatic condition and support food security for millions in Nigeria. Pearl millet is used for processing of intermediate food products such as tuwo, fura, and kunun- zaki, Cuscus, burabusko, thin and thick porridges, alcoholic, non-alcoholic beverages and some winning foods. Food processors and consumers need to understand what they consume when they adopt any farming system for the production of this important crop. Studies and data provide information into the challenges and health implication on the farming system adopted by farmers in northern Nigeria (Badau *et al*., 2002).

Furthermore, the economic and health benefits of adopting either conventional or organic farming has been a subject of discussion (Doanh *et al*., 2018; Sabry, 2015). Therefore, the need to investigate the impact of OFS and CFS is the focus of this research as a panacea to food security, public health and environmental concerns. The objective of this study therefore was to investigate the impact of organic and conventional farming practice on the quality and safety of Pearl millet grown in Kaura, Namoda, Zamfara state, Nigeria.

METHODOLOGY

Study Area

Kaura Namoda is located at Zamfara. North- West of Nigeria. The temperature ranges from 23^{o}C to 38^{o}C with annual rainfall characteristic of that of typical Sudan Sahel region. The soil use for cultivation of millet is mainly sandy loam texture with pH range of 4.0 to 5.5.

Farmland Preparation

A farmland of half acre that has not been cultivated for 5 years was hired at the School of Agriculture technology site of Federal polytechnic, Kauranamoda main campus. It was cleared, ploughed and harrowed. The research was laid in a split-plot with four replications where Pearl millet cultivar was allocated to represent OFS, CFS as well as the control (CTRFS) (Bagchi *et al*., 2015). The control split-plot represents portion where neither organic nor inorganic fertilizers were applied.

Planting and Fertilizer Application

Sasakawa planting method was applied in planting the Millet seeds. The fertilizers (organic and inorganic) were applied according to standard methods (Sareen, 2016). In brief, organic fertilizers were applied after clearing the plot designated (OFS). It was then harrowed before planting the seeds. For CFS, Inorganic fertilizers were applied two weeks and eight weeks thereafter.

Soil and Seed Plant Analysis for Heavy Metals.

Heavy metal determination was done using the (Ruiz-Huerta *et al*., 2022; Tessier, A., Campbell, PG., 2016). In brief, Soil samples were collected at the depth of about 15cm in all the locations from the farmland and was mixed properly to give a representative sample. It was then air dried and, sieved using a sieve size of 0.63mm mesh. Digestion of the soil samples was carried using strong solution of 1:3 (conc. HNO_3 and conc. HCl) at 170^{o}C for 30 minutes using a microwave accelerated reaction system. The samples were dissolved in deionized water and was filtered using no. 40 Whatman filter paper. The solution was brought to final volume of 100mL. Analysis of Cd, Cu, Pb, Cr Ni and Fe & Zn was carried out using Atomic Adsorption Spectrophotometer (AAS), while AS was analyzed by hydride generation with Perkin-Elmer AAnalyst 100. Calibration of the equipment was done using standard solution of known concentration of each of the mineral elements to be analyzed. Four replicates were used for each of the soil samples analyzed.

For bioaccumulation study, Seeds were digested using open acid digestion with 4:1 concentration of HNO_3 and $HClO_4$ as described by (Ruiz-Huerta *et al*., 2022). Result of heavy metals detected was reported in mg/Kg of dry weight of sample.

Physicochemical Analyses of Soil.

Physicochemical analysis including pH, N and P were measured in triplicate using the method of Ruiz Huerta *et a*l., (2022).

Table 1. Impact of farming system on leaf size of Pearl millet

Farming system	Width of leaf (Cm)	Length of leaf (cm)	Length of stalk (cm)	grain weight ($g500^{-1}$)
OFSPM	2.25^{a}	39.60^{a}	77.00^{a}	12.22^{a}
CFSPM	1.40^{b}	27.50^{b}	65.50^{b}	11.45^{b}
CTRFSPM	1.30^{b}	25.00^{c}	49.00^{c}	10.50^{c}

OFSPM – organic farming system pearl millet
CFSPM – Conventional farming system pearl millet
CTRFSPM – control farming system pearl millet
Means within a column with different letters are statistically significantly different (≤ 0.05)

Table 2. Proximate Composition of Pearl millet grown under different farming Systems

Parameter	Moisture (%)	Crude Fibre (5%)	Ash (%)	Crude fat (%)	Protein (%)	Carbohydrate (%)
OFSPM	11.01^{a}	4.30^{a}	1.90^{a}	4.50^{a}	9.90^{b}	67.30^{c}
CFSPM	10.75^{a}	3.95^{a}	1.58^{b}	4.20^{b}	12.10^{a}	71.62^{a}
CTRFSPM	10.03^{a}	4.57^{a}	1.45^{c}	4.30^{bc}	11.70^{b}	67.95^{b}
BFPM	11.09^{a}	4.45^{a}	1.38^{c}	4.28^{c}	11.68^{b}	67.12^{b}

OFPM – Organic Farming Pearl millet seed
CFPM – Conventional farming Pearl millet seed
CTRFPM - Control farming Pearl millet seed
BFPM – before farming pearl millet seed
Result are Mean of three determination
Means within a column with different letters are statistically significantly different (≤ 0.05).

Physical characteristics

Physical characteristics of leaf determined were width of the leaf, length of Leaf, and length of the stalk and weight of seeds. These were done manually using ruler and analytical weighing balance. Measurement of leaf was done across the centre section of the leaf.

Statistical Analysis

Minitab software version 17 was used for analysis of variance (ANOVA). Results were considered significant at $P \leq 0.05$.

RESULT AND DISCUSSION

In this study we analyzed the impact of different farming system on physical characteristics, proximate composition and bioaccumulation of heavy metals, Arsenic (As), and other chemical elements on Pearl millet seeds.

Effect of Farming System on Pearl Millet Leaf and Stalk and Seed Weight.

Result of the physical Characteristics of pearl millet grown under the different plots is presented in Table 1. Physical characteristics of grains are usually determined because it has correlation with the quality of the grains in terms of nutrient composition and diastatic enzyme activity. In this study the width and length of the leaf range between 1.3 to 2.2cm, and 25.00 to 39.60 cm respectively. While the length of the stalk and weights of the grain (500 seeds) were between 49.00 to 77.00 cm and 10.50 to 12.22 g respectively. Previous studies have reported correlation between the type of farming system on leaf size and seed weight of the plant (Badau *et al*., 2002). It has also been reported that excessive nitrogen in the soil will become toxic thereby retarding plant growth (Willson, & Clifford, 1992).

Impact Conventional and Organic Farming System on Proximate Composition of Pearl Millet Seeds

The result of proximate composition of Pearl millet (Table 2); shows that moisture content was between 10.03 to 11.09%, crude fibre was from 3.95 to 4.57 %, whereas the ash content was in the range of 1.38 to 1.90 %, that of protein was between 9.90 to 12.10 %, crude fat and total soluble carbohydrate were in the range of 4.2 to 4.50 % and 67.12 to 71.62 % respectively. The mean values of the proximate composition showed correlation (≤ 0.05) with a previous study carried out on the physicochemical characteristics of pearl millet cultivated in North –west Nigeria by (Badau *et al.*, 2002).

The type of farming system did not significantly affect the moisture, crude fibre, ash, crude fat composition of the seeds significantly ($p \leq 0.05$). However, there was significant difference in protein and carbohydrate contents of conventional farming system compared with the organic farming system. This may be attributed to the type farming input that is characteristic of organic and conventional farming system.

Although inorganic and organic fertilizers may produce quick and impressive result in farms, where growth and yield are desirable, it has been reported that overly fertilized soils are deficient in iron, zinc, Cu, and protein leading to fertilizer pollution (Sabry, 2015). In this study, the significant difference observed in the protein content of the conventional farming system may be a result of quick action of the fertilizers applied in which nitrates and ammonium radicals formed as a result inorganic fertilizer application influenced proximate composition of the seeds

Table 3. Impact of farming system on accumulation of heavy metal, As and chemical on Pearl millet

Parameters(mg/Kg)	Cd	Cr	Cu	P	N	Fe	As	Ni	Pb	Zn
OFSPM	0.227[a]	0.339a	2.62[b]	3.670[b]	2.75[b]	2.226[a]	0.019[b]	0.074[b]	0.107[c]	1.234[a]
	(6.48)	(1.14)	(1.35)	(18.38)	(3.66)	(1.35)	(1.52)	(3.08)	(0.84)	(0.84)
CFSPM	0.130[a]	0.818[a]	3.30[a]	5.549[a]	4.47[a]	3.407[a]	0.010[a]	1.08[a]	0.046[a]	1.030[a]
	(1.52)	(1.88)	(0.40)	(22.66)	(1.38)	(0.33)	(11.4)	(1.71)	(2.23)	(2.23)
CTRFSPM	0.223[a]	0.405[b]	2.62[b]	3.207[b]	1.50[c]	3.303[a]	0.037[b]	0.112[a]	0.081[a]	1.658[b]
	(1.35)	(1.96)	(0.48)	(14.21)	(1.79)	(0.40)	(0.28)	(2.04)	(2.23)	(2.23)
SPMB	0.129[a]	0.132[b]	2.55[a]	2.862[c]	1.19[c]	2.345[bc]	0.015[a]	0.108[b]	0.070[c]	1.050[b]
	(1.33)	(1.88)	(1.22)	(13.22)	(1.66)	(0.56)	(1.55)	(2.96)	(3.11)	(2.34)

Result are Mean of three determination
Means within a column with different letters are statistically significantly different (≤ 0.05).Numbers inside parenthesis represent RSD values (n = 3)
OFSPM – Organic farming system Pearl millet
CFSPM – conventional farming system Pearl millet
CTRFSPM – control farming system Pearl millet
GFPM – seed of pearl millet before planting

Impact of Farming System on Heavy Metal, Arsenic (as) Accumulation on Pearl Millet Seeds

The effect of farming system on heavy metals and arsenic on pearl millet seeds is as shown on Table 3. This study reveals that the contents of P, N, Fe and Zn, Ni, Pb and Zn accumulation in the seeds of Pearl millet before farming (SPMB) and seed of pearl millet after farming (SPMA) were significantly different (P ≤ 0.05) compared to organic farming system (OFSPM) and Conventional farming system pearl millet (CFSPM). This may be attributed to the application of fertilizers characteristics of organic and conventional farming system. It has been reported that higher concentration of N, P, Cd and lead (Pb) may be due to excessive use of inorganic fertilizer applied during farming (Badau *et al*., 2002; Yung *et al*., 2008). Previous studies have shown bioaccumulation of heavy metals on maize seeds mainly Zinc, Lead, Arsenic, Cadmium, Nickel and copper (Palm, Horvath E, Janda T, Paldi E, 2006; Ruiz-Huerta *et al*., 2022; Tovar- sanchez E, Cervantes Lt, Martinez C, Rojas E, Valverde M, Ortiz-hernandez ML, 2012). Accumulation of heavy metals on plants affects metabolism, produce toxic symptoms and causes developmental and structural changes in humans and plants. Cadmium is known to affect development of chloroplast in stems and leaves. Heavy metals have been known to exert cytotoxic effects in plant cells resulting in physiological, morphological and cellular alteration (Nagajyoti PC, Lee, KD, 2010). Phosphorus, nitrogen, Potassium are important component of the fertilizer usually referred to as triple supper phosphate (NPK). When NPK is applied only small portion is usually available to plant the rest of it is stored in the soil in varying degree of availability (Sabry, 2015 Ma,W,Cl., Brussaard, L. 1990; Sabry 2015; Tee, B.G,, Dudas, J. M., Pawluk S. and Harapiak 1987). Where nutrients are readily available to plants in conventional farming system, it take time before nutrients are accessible to plants when compared to organic farming system(Tisdale S. L, Nelson, 1975).

Nitrogen has been reported as the most important mineral nutrients for cereal production and adequate supply is required for higher yield especially for the cultivars available in north-west, Nigeria. Conventional farming system soil was more acidic compared to organic farming system due nitrogenous fertilizers applied during conventional farming (Yung *et al*., 2008). Arsenic (As) and other heavy metals detected at the different farming system sites in this study were within a range for plants grown in natural environment where similar grain seeds had been practiced (Ruiz-,Huerta *et al.,* 2022).

Although previous studies revealed accumulation and absorption of heavy metals (Cd, Pb Zn and Cu,) in maize kernels (Maksimovic, Kastori Krstics , 2007; Palm, Horvath , Janda , Paldi , 2006; Tovar- sanchez , Cervantes Lt, Martinez , Rojas Valverde , Ortiz-hernandez , 2012).Accumulation of heavy metal on plant is known to produce toxic symptoms, affects metabolic process, and causes physiological and developmental changes (Tessier, A., Campbell, PG., 2016). In this study, application of farming input did not significantly (p ≤ 0.05) affect the quality and safety of the food crop; because the concentration of heavy metals and nutrient chemicals detected were below the limit established by European Union's regulatory commission (EU)2006 (Ruiz-Huerta et al., 2022). The type of farming systems did not negatively affect the level of heavy metals and arsenic on pearl millet seeds cultivated in this study.

CONCLUSION

This study provides information on the impact of farming system on physicochemical characteristics and accumulation of heavy metals on pearl millets seeds. The type of farming system significantly affects the agricultural condition of soil heavy metal profiles. Although the organic farming system has less concentration of heavy metals and other chemical element, the crop quality parameters before and after application farming inputs did not negatively impact the quality and safety of the pearl millet seeds. The type of farming system practiced for farming system did not pose serious threat to the safety of pearl millet seeds to consumers. Farmers within Kaura Namoda can adopt this data to monitor organic and conventional farming system for food security.

Funding

This research was funded through Institutional Basic Research Grant (IBR) no: TETF/DR&D/CE/POLY/KAURA NAMODA/ IBR/2023/VOl.1.,provided by Tertiary Education Research fund (TETfund).

Acknowledgements

Authors acknowledge the efforts of Federal polytechnic KauraNamoda for facilitating the process of accessing funding. Authors also acknowledge, Ibrahim Umar Tambuwal and Umar Adamu of the Department of Biochemistry Federal University Gusau (FUGUS) and Department of Biochemistry Bayaro University Kano (BUK) for their valuable contribution on Laboratory support services during the analysis of samples.

Conflict of Interest

Authors declare that there is no conflict of interest in any form that will influence the outcome this study.

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