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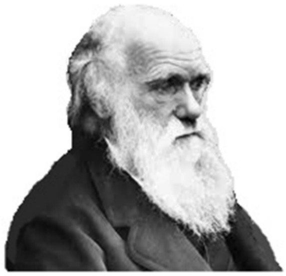

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Impact of combined application of urea and farm yard manure on the growth, yield and nitrate content of spinach (*Spinacia oleracea* L.) in the Nigerian northern Guinea savanna

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ABSTRACT

The type of fertilizer is considered for influencing spinach yield and level of nitrate concentration for normal crop consumption. This experiment investigates plant growth, yield, and nitrate content in spinach with different fertilizer types and levels. In a two-location field experiment involving three rates of farmyard organic manure (6, 8, and 10 t ha^{-1} of FYM) and three levels of N.P.K. fertilizers (100:30:30, 150:30:30, and 200:30:30), three combinations of the two kinds of fertilizers (3 t ha^{-1} FYM + 90 kg N ha^{-1}, 4 t ha^{-1} FYM + 70 kg N ha^{-1}, and 5 t ha^{-1} FYM + 50 kg N ha^{-1}), including a control (without any fertilizer), were laid out in a randomized complete block design and replicated thrice. The result showed that spinach treated with urea fertilizer was superior to those treated with farmyard manure and the control but comparable to those treated with the combined application of the urea and farmyard manure. The relatively higher yield of 39,587.92 and 40,222.0 kg ha^{-1} and 36,895.21; 36,354.5 kg ha^{-1} were obtained from urea application and combined application of urea and farmyard manure at Samaru and Shika, respectively. The study monitored the amount of nitrate in spinach leaves at various intervals following sowing. The findings indicated a correlation between elevated nutrient concentration and nitrate accumulation in urea-fertilized plots. Plants treated with urea in Samaru and Shika had the greatest nitrate buildup (1627 and 1675 mg kg^{-1}). Although the nitrate content dropped with increasing

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levels of farmyard manure combined with urea fertilizer (1101 and 1206 mg kg^{-1}), all amounts fell below the European Safety Union limits.

Keywords**:** Farm yard manure, urea, nitrate concentration, spinach and growth attributes

1. INTRODUCTION

Spinach (*Spinacia oleracea* L.) is a short season vegetable crop that is produced all year round in Nigeria. In the dry season, crop lands are established both along the flood plains and at high elevations with access to other irrigation means. Spinach production from the early times has provided employment and increased the income level of small-scale farmers particularly in northern Nigeria where it is the main leafy vegetable nearly often used in all diets (Obatola and Tanko, 2016). Small scale farming constitutes the nucleus of Nigerian agriculture, producing about ninety percent of food and fibre for the Nigerian population. In addition, it offers employment to about eighty percent of the population (Mgbenka and Mbah, 2016).

In recent decades, global nutrition activities and intervention programs have increased awareness and demand for leafy vegetables, resulting in a shift in diets and increased demand for these foods (FAO, 2024). According to NTI (2003) and Ma et al. (2022), spinach production is influenced by limited knowledge, poor soil fertility, and synthetic nitrogen fertilizer, which can lead to toxic compounds and reduced food preparation quality. Depending on the growing condition of the crop, spinach contains 24-387 mg of nitrate per 100 gm serving, affecting red blood cell oxygen transport and causing loss of biological values, smell, and taste when cultivated with chemical fertilizers. Cultural practices may have contributed to this high nitrate content (Ali *et al*., 2016; Han *et al*., 2023).

Chemical fertilizers have historically been used by farmers as an additional source of nutrients. The nitrate-nitrogen requirements of different crops vary, and the levels applied are either unclear or unknown, or, as in a number of other local communities, were not applied in a balanced proportion where urea is the only fertilizer used by the majority of farms (Plett et al., 2020; Govindasamy et al., 2023; Luna Juncal et al., 2023). Study conducted by Abdelraouf (2016) indicated that an increased nitrogen fertilization rates significantly decrease nitrogen utilization and use efficiency, increasing spinach content of N, P, K, Fe, and Cu but decreasing Mn, with positive effects on yield and adverse effects on quality. According to Fu et al. (2024), organic resources are rarely used to return soil to its native state. It is rare to see soil organic matter serving as a repository for plant nutrients. Therefore, the goal of this experiment is to investigate possible techniques for growing spinach that meet recognized requirements while minimizing yield loss.

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2. MATERIALS AND METHODS

2. 1. Experimental site

In 2019, two field trials were conducted to evaluate the effect of the combined application of urea and farmyard manure (cow dung) on the performance of spinach and nitrate content at the Teaching and Research Farm of the College of Agriculture, Division of Agricultural Colleges, Samaru (Latitude 11° 11’ N, Longitude 07° 38’ E, 679 m above sea level) situated in the Northern Guinea Savanna ecology of Nigeria, and research Farm of the Institute for Agricultural Research (IAR) Shika Metropolis (Latitude 11° 18'N, Longitude 07° 56' E, and 1500 meters above sea level) is located in the northern part of the Guinea savannah belt of Nigeria. The mean annual rainfall ranges between 600 mm and 1015.9 mm in Samaru, while in Shika metropolis, a mean annual rainfall of 479 mm – 1000 mm is observed. The mean maximum and minimum temperatures of 22 °C and 27 °C at Samaru and 29 °C and 34 °C at Shika for minimum and maximum temperatures are observed.

At each site, between 15 and 20 soil cores were taken at a depth of 30 cm using a soil auger 3 cm in diameter on the diagonals of the experimental plots. Soil samples were bulked into composite samples.

The samples were air dried, sieved, and mechanically analyzed using the hydrometer method described by Bouyoucos (1951); pH was measured using a pH meter with a glass electrode, total N was measured using the macro-Kjeldahl procedure described by Jackson (1958), extractable P was determined using the Bray-I method described by Bray and Kurth (1945), organic C was determined using the method described by Walkley and Black (1934), and effective cation exchange capacity (ECEC) was as described.

2. 2. Field layout

The experimental site was plowed and harrowed twice using tractor-drawn implements, and ridges were constructed 75 cm apart. Each plot consisted of six ridges of 2 m long. The inner four ridges were flattened with a small hoe to form planting basins.

2. 3. Treatments and experimental design

The treatments included three fresh farmyard manure (6, 8, and 10 t ha^{-1}) rates, three urea chemical fertilizer rates (100, 150, and 200 kg N ha^{-1}), three combinations of urea chemical fertilizer and organic farmyard manure (3 t ha^{-1} FYM + 90 kg N ha^{-1}, 4 t ha^{-1} FYM + 70 kg N ha^{-1}, 5 t ha^{-1} FYM + 50 kg N ha^{-1}) rates, and a control treatment (without any fertilizer), which were arranged in a randomized complete block design (RCBD) and replicated three times. The farmyard manure, based on treatment levels, was applied on the 15th of May 2019 at DAC and the 20th of May 2019 at IAR Shika.

2. 4. Cultural Practices

The seed of the spinach cultivar "Nigerian spinach," popularly grown in the area, was sown at a spacing of 20 cm × 20 cm on 5th June 2019 at DAC and 10 June 2019 at IAR. The variety, which is broad, dark green leaves, characterized by a smooth texture with an upright growing habit, was sourced from the Kaduna State Agricultural Development Project. All plots received a basal application of single superphosphate at the rate of 30 kg ha^{-1} and muriate of potash at 30 kg ha^{-1} which were incorporated into the soil before planting. Urea (46% N) was applied according to treatments in two equal split doses by band placement between rows. The vegetable was irrigated whenever dry spelt was observed.

Weeds were controlled by spraying metolachlor at the rate of 1.0 kg N ha^{-1} 2 weeks before the final field preparation as pre-planting, and later weeds were controlled by hand pulling. Plants were harvested using a hand sickle at 8 WAS from various plots and weighed using a portable weighing scale with a maximum weighing capacity of 8000 g and a minimum weight of 1.0 g.

2. 5. Data collection and Data Analysis

From five randomly tagged plants, within the net plant height, plant diameter, leaf area, number of leaves, leaf fresh weight, and dry weight at 6 and 8 weeks after sowing (WAS) using standard agronomic procedure. Data collected were subjected to statistical analysis of variance (ANOVA) as described by Snedecor and Cochran (1967). The significant differences between treatment means were separated using the Duncan Multiple Range Test (DMRT) (Duncan, 1955). All statistical procedures were done as described by Gomez and Gomez (1984).

Furthermore, the spinach NO_3 content was determined at 2, 6, and 8 weeks after planting with a spectrometer after micro-Kjeldahl digestion of whole spinach samples that had been ground. The method is based on extracting the organic phase of the slurry previously fractionized with sodium hydroxide, from which the absorbance was read from the spectrometer and used to calculate nitrate contents in mg/g in the spinach using a formula. The results are expressed in milligrams of nitrate per gram of fresh weight of the plant.

Fresh vegetable leaves of spinach were flushed and washed with flowing water and ground using mortar and pestle till a homogenous slurry was formed, and then between 10 g and 20 g of slurry were warmed at 80 °C for 25 mins and shaken. The solution was sieved at 200 µm, 50 µm, and 0–50 µm. The 0-50 aliquot was cooled in ice, then 5% Ag_2SO_4 solution was added, followed by subsequent addition of 98% H_2SO_4 and 5% phenol solution. The solution was allowed to stand for 20 min while shaking occasionally to have a homogenous mixture. The resulting mixture was extracted in a 50 cm separating funnel by adding toluene and shaking for 5 to 10 min. The lower aqueous layer was discarded, and the organic phase was washed twice with 10 ml distilled water by shaking for 2 min and each time discarding the aqueous phase. Then the organic phase was extracted again by shaking for 1 min with 10 ml of 10% Na_2CO_3 solution and collected in a test tube. Then from the spectrometer, the absorbance was read at 407 nm. Since 4 ml of the 100 ml filtrate was used for the analysis.

The following formular:

Nitrate = $A = \frac{\text{C x 100}}{Ws\ x4}$

was used to calculate nitrate µ/g in the spinach

where: C = concentration of nitrate in the sample. Ws = Weight of slurry

3. RESULTS AND DISCUSSION

3. 1. Soil and Farm yard manure analysis

The result of the soil analysis is shown in Table 1. Shows fine sandy loam at Samaru (DAC), while at Shika, it was loam in texture. The soil pH was slightly alkaline at Samaru but moderately acidic in Shika. The available phosphorus and organic carbon were low at Shika but moderately high at Samaru. In general, the soils of Shika had lower CEC (3.89 cmol kg^{-1}) than Samaru (6.30 cmol kg^{-1}), while soil N was the same in both locations.

Table 2 presents the nutrient composition of farmyard manure (FYM) collected from two different locations: Samaru and Shika. Results show that FYM from Samaru has a slightly higher N content (1.73%) compared to that of Shika (1.45%).

Table 1. Physical and chemical properties of the soil at the experimental sites during the 2019 wet season.

Physical properties	Location	
	DAC Samaru	IAR Shika
Sand (%)	58.0	40.0
Silt (%)	30.0	32.0
Clay (%)	12.0	28.0
Textural class	Sandy loam	Loam
Chemical properties		
pH in H_2O	5.56	7.30
pH in $CaCl_2$ (1:2:5)	4.90	7.00
Organic carbon (g kg^{-1})	0.57	1.08
Total Nitrogen (g kg^{-1})	0.36	0.33
Available phosphorus (meq $kg^{-1)}$	12.5	21.88
Exchangeable cations (cmol kg^{-1})		
K++	4.77	2.35
CEC (meq/100 g)	3.89	6.70

Table 2. Chemical composition of the farm yard manure at DAC Samaru and IAR Shika (oven dry basis).

FYM Manure	Samaru	Shika
N (%)	1.73	1.45
P (%)	0.938	1.074
K (%)	1.70	1.25
Na (ppm)	0.20	0.65

The FYM from Shika exhibits a slightly higher P content (1.074%) than Samaru (0.938%). The Samaru FYM has a considerably higher K content (1.70%) than Shika FYM

(1.25%). Shika FYM has a significantly higher Na content (0.65 ppm) compared to that of Samaru (0.20 ppm). Thus, FYM's nutrient composition varies based on source and management, impacting fertilizer value. Both samples show moderate to excellent levels of N, P, and K, indicating potential as organic fertilizers. Farmers in Samaru and Shika may benefit from local FYM due to higher K content, while Shika FYM may be beneficial for higher P requirements.

3. 2. Effects of combined application of farm yard manure on growth characters of spinach

The plant height, plant diameter, number of leaves and leaf area of spinach as affected by farm yard manure and urea fertilizer at Samaru and Shika are shown in Tables 3. The application of 150 and 200 kg N ha^{-1} and the combination of 3 t ha^{-1} FYM + 90 kg N ha^{-1}, 4 t ha^{-1} FYM + 70 kg N ha^{-1}, and 5 t ha^{-1} FYM + 50 kg N ha^{-1} significantly ($P < 0.05$) produced taller plants compared with the control, which resulted in shorter plants, though at par with the application of 6, 8, and 10 t ha^{-1} and 100 kg N ha^{-1} at Samaru, while Shika, the application of 100, 150, and 200 kg N ha^{-1} and the combination of 3 t ha^{-1} FYM + 90 kg N ha^{-1}, 4 t ha^{-1} FYM + 70 kg N ha^{-1}, and 5 t ha^{-1} FYM + 50 kg N ha^{-1} significantly ($P < 0.05$) resulted in taller plants compared with the rest of the treatments that resulted in shorter plants. Plant diameter did not vary significantly ($P > 0.05$) among treatments and locations, respectively. On the other hand, the number of leaves and leaf area were significantly higher with the application of sole 100, 150, 200 kg N ha^{-1}, and the combination of 3 t ha^{-1} FYM + 90 kg N ha^{-1}, 4 t ha^{-1} FYM + 70 kg N ha^{-1} and 5 t ha^{-1} FYM + 50 kg N ha^{-1} which was closely followed by the sole application of 100-200 kg N ha^{-1} compared to the control that had the fewer and narrower leaves, respectively t at both locations. A similar pattern of results was also obtained for fresh weight, dry weight, and grain yield, respectively, across Samuru and Shika (Table 4).

Findings from the study revealed that the combination of organic and inorganic fertilizer management practices has been shown to increase morphological characters more than any single application practice. Thus, the combined applications of FYM and urea also showed significant growth enhancement, suggesting a synergistic effect. Study conducted by Zandvakili et al. (2019 a & b) revealed that while organic fertilizer boosted growth, Hoagland and Arnon solution increased lettuce growth. It's interesting to note that nitrate concentrations were higher in cultivars with loose heads or leaves. Additionally, it has been demonstrated that the combination of organic and inorganic fertilizer management techniques increases morphological features more than any single application technique (Kakar *et al.*, 2019 and 2020). In comparison to recommended dose (RD) of N and P treatment, the study demonstrates that the combination of manure and inorganic fertilizer enhances the number of tillers, panicle length, yield, and physicochemical characteristics of rice grain.

Leafy vegetables show improvement in nitrogen use efficiency due to decreased nitrogen ions and organic material addition. This improvement is related to enhanced soil properties, especially with fresh farmyard manure. The release of nutrients is important for manorial quality, but the contribution to soil organic matter status is more significant, especially in vegetable crops with easily accumulating nitrate. Similar findings were reported by Lyu et al. (2024), Farooq et al. (2024) and Manga et al. (2024). Thus, the variations in the availability of nutritional resources, such as urea, which guarantees quick development and enhanced vegetable production, may be the cause of the variance in the results of various fertilizer treatments.

Table 3. Effect of farm yard manure and urea fertilizer on growth attributes of spinach at Samaru and Shika during 2019 wet season.

Treatment	Samaru				Shika			
	PH	PD	NL	LA	PH	PD	NL	LA
Control	8.59b	0.20	6.085c	11.28c	8.91b	0.22	6.26c	11.22c
FYM 6 t ha^{-1}	8.92b	0.28	8.67b	15.38b	8.54b	0.25	7.37b	14.89b
FYM 8 t ha^{-1}	8.99b	0.30	8.98b	16.40b	9.52b	0.27	7.63b	15.88b
FYM 10 t ha^{-1}	9.22b	0.28	9.27b	15.38b	9.44b	0.25	7.88b	14.88b
100 kg N ha^{-1}	10.92b	0.46	12.17a	21.53a	10.83a	033	10.73a	20.84a
150 kg N ha^{-1}	12.02a	0.44	11.88a	21.03a	12.42a	0.36	10.70a	19.71a
200 kg N ha^{-1}	12.95a	0.40	11.30a	20.03a	12.16a	0.32	10.43a	20.69a
3 t ha^{-1} FYM + 90 kg N ha^{-1}	11.32a	0.41	11.59a	21.13a	11.50a	0.35	10.99a	20.51a
4 t ha^{-1} FYM + 70 kg N ha^{-1}	11.48a	0.42	11.30a	19.82a	10.55a	0.36	10.73a	19.50
5 t ha^{-1} FYM + 50 kg N ha^{-1}	10.98a	0.42	11.59a	20.53a	10.57a	0.34	10.46a	1988a
SE±	0.698	0.113	0.504	1.849	0.668	0.103	0.507	1.003

Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability using DMRT. FYM = Farm yard manure. PH = Plant height (cm), PD = plant diameter (cm), NL = Number of leaves, LA = Leaf area (cm^2)

Table 4. Effect of farm yard manure and Urea fertilizer on growth attributes and yield of spinach at Samaru and Shika during the 2019 wet season.

Treatment	Samaru			Shika		
	FW	DW	GY	FW	DW	GY
Control	2.69c	1.01c	21,077c	2.63c	1.46bc	18,796.31c
FYM 6 t ha^{-1}	3.58b	1.50b	28,278.8b	3.31b	1.65b	25,448.15b
FYM 8 t ha^{-1}	3.80b	1.70b	28,635.20b	3.53b	1.77b	27,304.55b
FYM 10 t ha^{-1}	3.58b	1.49b	28,792.84b	3.31b	1.65b	25,602.85b
100 kg N ha^{-1}	4.76a	2.71a	37,023.76a	4.77a	2.46a	36,895.21a

150 kg N ha^{-1}	5.20a	2.99a	39,587.92a	4.63a	2.38a	35,813.15a
200 kg N ha^{-1}	4.91a	2.89a	37,416.51a	4.56a	2.35a	35,271.60a
3 t ha^{-1} FYM + 90 kg N ha^{-1}	5.12a	3.07a	40,222.02a	4.79a	2.42a	36,354.51a
4 t ha^{-1} FYM + 70 kg N ha^{-1}	5.05a	2.96a	39,284.11a	4.63a	2.38a	35,813.05a
5 t ha^{-1} FYM + 50 kg N ha^{-1}	5.99a	2.88a	38,350.04a	4.41a	2.24a	34,711.35a
SE±	0.401	0.411	5.510	0.403	0.356	4.9611

Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability using DMRT. FYM = Farm yard manure. FW = Fresh weight, DW = Dry weight, GY = Grain yield.

3. 3. Effects of combined application of farm yard manure on Yield and Nitrate content

Table 5 presents the effect of farm yard manure and Urea fertilizer on fresh weight and nitrate concentration in spinach at Samaru and Shika at 4, 6 and 8 WAS. Resulted revealed that fresh weight was significantly affected by various nutrient management schedule. The application of sole 100, 150, 200 kg N ha^{-1}, and the combination of 3 t ha^{-1} FYM + 90 kg N ha^{-1}, 4 t ha^{-1} FYM + 70 kg N ha^{-1} and 5 t ha^{-1} FYM + 50 kg N ha^{-1} significantly resulted in higher fresh weight than the sole application of FYM 6, 8 and 10 t ha^{-1} which resulted in lower weight at 4, 6 and 8 WAS at Samaru and Shika, respectively.

Although the Urea treatments significantly promoted spinach growth, while FYM applications increased fresh weight slightly. The combined treatments of FYM and urea showed intermediate results, suggesting synergistic effects. On the other hand, the application of Urea, particularly at higher rates (150 and 200 kg N), significantly increased nitrate accumulation in spinach leaves at 4, 6 and 8 WAS at both Samaru and Shika compared to the combined applications of FYM and urea showed intermediate nitrate levels while the applications FYM generally resulted in lower nitrate concentrations compared to urea. Urea fertilization boosts spinach fresh weight but increases nitrate accumulation. FYM applications lower nitrate levels, promoting moderate growth. Combining FYM and urea may balance yield enhancement.

This finding corroborates those of (Gülüt and Şentürk, 2024) who asserted that ammonium sulphate (AS), slow release of ammonium sulphate (SRAS), FYM, and a balanced approach may be suitable for spinach growth, with moderate doses promoting fresh weight and nitrate accumulation, respectively. Inorganic fertilizer treated plants showed 16.21 and 12.04% higher nitrate accumulation than medium-occurring urea inorganic fertilizer treatments at 6 WAS in Samaru and Shika areas, respectively. This is in agreement with that of Rahamatullah et al. (2019) who found that inorganic fertilization had the highest nitrate levels in lettuce, with 572-664 mg/kg, compared to 253-432 mg/kg in organic fertilizer treatments. Similarly, Brain et al. (2020) and Luetic et al. (2023) reported separately the reduction in nitrate levels of leafy vegetables owing to use of organic nutrient sources than in organic sources. Thus, leafy vegetables show a decrease in nitrogen ions, reducing NO_3-N accumulation. The improvement in nitrogen use efficiency is attributed to the addition of organic material, including fresh farm yard manure, which enhances soil properties and improves nitrogen use efficiency.

Table 5. Effect of farm yard manure and Urea fertilizer on fresh weight and nitrate concentration in spinach at Samaru and Shika at 4, 6 and 8 WAS during 2019 wet season.

Treatment	Fresh weight (kg plant^{-1})			Nitrate contents (mg kg^{-1})		
	Weeks after planting (WAP)					
	4	6	8	4	6	8
	Samaru					
Control	1.64b	2.14b	2.69b	567b	580c	580c
FYM 6 t ha^{-1}	1.87b	2.88b	3.58b	573b	985b	689b
FYM 8 t ha^{-1}	1.82b	2.97b	3.80b	575b	989b	692b
FYM 10 t ha^{-1}	1.67b	2.59b	3.58b	582b	1001b	700b
100 kg N ha^{-1}	2.42a	3.73a	4.76a	974b	1129b	790b
150 kg N ha^{-1}	2.46a	3.80a	5.20a	1207a	1400a	980a
200 kg N ha^{-1}	2.41a	3.84a	4.91a	1317a	1627a	1168a
3 t FYM + 90 kg N ha^{-1}	2.30a	3.59a	5.12a	640c	1101b	770b
4 t FYM + 70 kg N ha^{-1}	2.15a	3.50a	5.05a	632c	1087b	760b
5 t FYM + 50 kg N ha^{-1}	1.96a	3.47a	4.99a	630c	1083b	758b
SE±	0.255	0.385	0.401	70.212	81.401	56.911
	Shika					
Control	1.70b	2.04bc	2.63b	586c	598c	598d
FYM 6 t ha^{-1}	1.78b	2.67b	3.31b	596c	1045b	717c
FYM 8 t ha-1	1.96b	2.83ab	3.53b	614c	1056b	739c
FYM 10 t ha^{-1}	1.74b	2.49b	3.31b	638c	1077b	747c
100 kg N ha^{-1}	2.50a	3.67a	4.77a	1113b	1275b	922b
150 kg N ha^{-1}	2.51a	3.70a	4.63a	1289a	1495a	1046a
200 kg N ha^{-1}	2.58a	3.69a	4.56a	1444a	1675a	1172a
3 t FYM + 90 kg N ha^{-1}	2.32a	3.03a	4.70a	775c	1301b	888b
4 t FYM + 70 kg N ha^{-1}	2.40a	3.51a	4.41a	755c	1261c	844b
5 t FYM + 50 kg N ha^{-1}	2.34a	3.51a	4.63a	701c	1206c	812b
SE±	0.275	0.280	0.303	73.102	84.752	59.301

Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability using DMRT. FYM = Farm yard manure

Furthermore, the accumulation of NO_3-N in spinach plants grown on plots under the different treatments of urea and FYM fertilizer used at both locations were significantly different, indicating that nitrate accumulation may be accompanied by difference in nutrient composition.

This lends credence to the fact that FYM are generally deficient in available nutrients. This could also have been responsible for the poor morphological performance of FYM compared to urea fertilizer treated plants, observed since the differences were significant. Similar findings by Yeshiwas et al. (2018) reveals that nitrate accumulation in lettuce growth components is influenced by the combined application of urea fertilizer and FYM. Xiao et al. (2022) reported similar finding in rice.

Compared to Shika, spinach at Samaru accumulated less NO3-N, presumably as a result of intensive cultivation and low soil nitrogen levels overall. Other factors, rather than the native soil's N concentration, were responsible for the variation in spinach growth and development and nitrate accumulation. Soil nitrate levels vary based on factors like clay content, pH, temperature, bulk density, organic matter content, and rainfall. Soil at Shika location has higher pH, organic C content, and CEC than Samaru. High organic matter content in Shika leads to higher nitrogen mineralization rate, potentially depressing FYM immobilization in the soil.

Regarding the higher total organic content in Shika than in Samaru could have resulted from the farm management practices such that more of the residues after harvest were left on the field compared to what might at Samaru where more of the residues were used up without replacement, microbial activity decreased and resulted in a lower pH than Shika. However, it appeared that more of the residues from the type of crops cultivated, on Shika soil even though they were retained were not of high quality to effect on increase in the N content of the soil. Farm management techniques that left more residues on the field after harvest, which reduced microbial activity and lowered pH, may be the cause of Shika's higher total organic content than Samaru's. Even though they were kept, the high-quality leftovers from Shika soil did not considerably raise the nitrogen level of the soil.

In a separate study conducted by Das et al. (2024), they found that total mineral nitrogen (NH_4^+ and NO_3^-) in leachates was reduced by adding C only when the C/N ratio exceeded 10:1, equivalent to approximately 50 kg N ha^{-1} Although it is not statistically significant, higher pH in Shika soil may raise nitrate concentration and reduce spinach production. Nitrogen is more vulnerable to leakage when soil bacteria convert ammonium to nitrate, a process known as nitrification. On the other hand, loamy soil makes nitrate more difficult to leach. This is in agreement with the findings of Cuhel et al. (2010), Ferraz-Almeida (2024) and Manga et al. (2024), who independently reported the role of soil pH in maintaining a balance nitrate and ammonium in tropical soils.

4. CONCLUSION

The most important elements influencing plant growth, yield, and quality performances in contemporary agriculture are fertilizer application and nutrient management. The experiment was designed to investigate possible ways to grow spinach that meet recognized standards without significantly compromising yield. Findings revealed the possibility of combining urea with farmyard manure at various proportions that increased yields as well as reduced the nitrate content in spinach. However, the application of 3 t ha^{-1} FYM + 90 kg N ha^{-1} gave better yield than the other combinations with higher nitrate concentration, but 4 t ha^{-1} FYM + 70 kg N ha^{-1} produced a medium yield of spinach greater than 5 t ha^{-1} FYM + 50 kg N ha^{-1} at the same time had moderate nitrate concentration lower than that of 30 t ha^{-1} FYM + 90 kg N ha^{-1} but higher than that of plots treated with 5 t ha^{-1} FYM + 50 kg N ha^{-1}. Thus, among the choices that improved yield and complied with recognized requirements with little yield compromise, this combination (40 t ha^{-1} FYM + 70 kg N ha^{-1}) might be given greater thought.

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