

Full Length Research Paper

The influence of FOMI fertilizers on the yield and quality of flue cured tobacco (*Nicotiana tabacum* L.) in Tanzania

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Eight levels of fertilizers were evaluated in a field experiment laid down in a randomized complete block design (RCBD) with four replications to investigate the effect of FOMI fertilizers on the yield and quality of flue-cured tobacco in 2023 to 2025 and 2024 to 2025 cropping seasons. Data collected includes leaf area, dry leaf yield and grade indices. Data were analysed using STATISTICA 8th edition. Results indicates that application of FOMI SUPA followed by FOMI CANS and standard fertilizer gave the highest dry leaf yields and grade indices during the 2023/2024 growing season with heavy rainfall at 1582.55 ± 69.09 kg/ha and 1389.89 ± 145.72 kg/ha and grade indices of 1.54 ± 0.12 and 1.74 ± 0.15 , respectively. In the second cropping season with moderate rainfall, application of FOMI GREEN followed by FOMI NENEPESHA had higher dry leaf yield of 2190.20 ± 1.13 than the standard fertilizer with 2175.95 ± 1.30 kg/ha. It was concluded that the application of FOMI SUPA followed by FOMI CANS works better in the heavy rain season while that of FOMI GREEN and FOMI NENEPESHA works better for the adequate or average rainfall season.

Key words: FOMI fertilizers, dry leaf yield, grade indices, flue-cured tobacco.

INTRODUCTION

Crops and soil are interconnected; subsequently exert mutual effects on one another for effectiveness of its productivity (Padalia et al., 2018; Shahi et al., 2023). The

quality of soil for agricultural production depends on its sustainable supply of plant nutrients. Soil gives support in terms of moisture, nutrient and anchorage to crop to grow

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effectively on the one hand, and on the other, crop provides protective cover for soil, suppresses soil erosion as well as helps to maintain soil nutrient through litter accumulation and subsequent decay (Bargali et al., 1993; Gonzalez-Quinones et al., 2011; Bargali et al., 2015; Awasthi et al., 2022). Cultivation accelerates the loss of organic matter and microbial activities significantly in the soil (Yadava et al., 2006; Manral et al., 2020; Fartyal et al., 2025). Agricultural trends in the last five decades have intensive production with increased exercise of commercial seeds, pesticides, fertilizers, etc. (Bargali et al., 2022; Shahi et al., 2023). These practices have adverse consequences on soil health, agriculture diversity and hence, the urgency to develop new strategies that use ecological interaction (Vibhuti et al., 2018; Bargali et al., 2019; Negi et al., 2023).

Tobacco (*Nicotiana tabacum* L.) is an important high-value commercial crop in Tanzania. It is grown in an area of 93,969 ha with an annual production of 0.12285864 million tonnes of cured leaf (TTB, 2024). For the 2023/2024 crop season, the export value of tobacco was US\$ 340,600,000 (TTB, 2024). The Flue Cured Virginia (FCV) tobacco used for manufacturing cigarettes is preferably grown in light-textured soils for better quality for exports.

Nitrogen (N) is the most important macronutrient in FCV tobacco production. Appropriate levels of the nutrient are needed to produce a high-yielding, quality leaf with appropriate smoke flavour and aroma. Phosphorus (P) influences tobacco root development, improving leaf colour and quality (Bryson and Mills, 2014). Potassium (K) plays a critical role in growth, stress tolerance, yield and quality of FCV tobacco. The K is absorbed by tobacco in the largest amount as compared to all other essential nutrients (Krishnamurthy and Sigh, 2002; Gurumurthy and Vageesh, 2010). The quantity of K absorbed by tobacco depends on several factors including among others soil type, K availability in soil, control growth conditions, diseases and moisture stress tolerance, variety and fertilizer management practices (Krishna et al., 2009).

Biomass and dry matter production in tobacco plants are influenced by exchangeable Ca, which is also involved in developing the cell elongation hence growth, cell wall and the secretion of an enzyme to improve the colour and leaf quality (Marschner, 1995; Hodges, 2012). Magnesium (Mg) is a constituent of the chlorophyll molecule and influences sugar production (Smith, 2009; Gurumurthy and Vageesh, 2010) through photosynthesis. Sulphur (S) regulates tobacco plant responses to various biological and non-biological stresses, hence inducing resistance to *tobacco mosaic virus* -TMV (Höller et al., 2010). Boron (B) in tobacco plants is required in trace amounts; however, it has a significant role in influencing levels of alkaloids and sugars in tobacco leaves (López-Lefebvre et al., 2001). Appropriate concentration of B increases root system, leaf area, photosynthetic capacity and dry matter accumulation of tobacco plants,

and improves stress resistance, thus laying a good substance foundation for the growth of FCV in the field.

Tropical soils, particularly those available in sub-Saharan Africa and parts of Latin America, are frequently characterised by severe weathering and significant nutrient depletion as a result of prolonged cultivation and intense rainfall (Sanchez, 2002; Van Loon et al., 2022). The high intensity of precipitation in these regions accelerates nutrient leaching, thereby causing the rapid loss of essential elements such as nitrogen, potassium, and magnesium from the root zone, ultimately limiting crop productivity (Baijukya et al., 2020). Miombo woodland soils, especially where tobacco is grown, are characterised by low to moderate levels (0.9 to 20 g/kg organic carbon content). Low soil organic carbon (SOC) levels lead to several problems, primarily negatively impacting soil health, fertility, and food production. Reduced SOC means less food for soil organisms, decreased soil biodiversity, and a higher risk of soil erosion and nutrient imbalances. Additionally, it can negatively affect water infiltration and storage capacity, making soils less resilient to climate change elements, drought and floods. Records show that it even negatively affects the quality of food grown in low SOC content soils (Louwagie et al., 2009).

Miombo woodland soils typically exhibit a range of soil pH values, generally acidic to slightly acidic (5.1 to 5.9). Soils with pH ranging from 5.6 to 6.0 are considered moderately acidic, while strongly acidic and very strongly acidic soils have pH ranging from 5.1 to 5.5, <5.0, respectively. Yes, it's crucial to know that most crops struggle to establish and their productivity decreases in soils with a pH below 6.0. This is because low pH can reduce the availability of essential nutrients like phosphorus and molybdenum, as well as cause toxicity issues with elements like aluminium and manganese.

Organo-mineral fertilizers which are multi-nutrients and which integrate organic matter with mineral nutrients, represent a promising approach to restoring soil fertility while simultaneously enhancing overall soil health (Vanlauwe et al., 2024; Uddin et al., 2025). Empirical evidence from West Africa has demonstrated that combining compost or manure with mineral nitrogen markedly improves maize yields when compared to the application of either input alone (Vanlauwe et al., 2024). The adoption of organo-mineral fertilization strategies emerges as a pivotal component in achieving both immediate productivity gains and long-term sustainability in tropical agricultural systems (Tittonell and Giller, 2013).

In this regard, FOMI fertilizers, produced in Tanzania, provide an appropriate and sustainable solution by enhancing soil fertility, structure, and microbial function (Uddin et al., 2025; Palm et al., 1997). These organo-mineral fertilizers contribute to improved nutrient retention and crop productivity, while simultaneously reducing reliance on expensive imported fertilizers (Syers et al., 2008; Food and Agriculture Organisation [FAO], 2021).

Table 1. Size of experimental unit

Plot size (4.8 m × 3 m)	14.4 m ²	Plants spacing within a row	0.5 m
Number of plants per plot	24	Ridge spacing	1.2 m
number of rows per plot	14	Plot spacing within a block	1 m
Number of plants per row	6	Block spacing	2 m

Block 1	T5	T3	T8	T4	T6	T2	T1	T7
Block 2	T2	T4	T7	T8	T5	T1	T3	T6
Block 3	T7	T5	T1	T2	T4	T6	T8	T3
Block 4	T8	T1	T3	T6	T7	T5	T4	T2

Figure 1. Field layout.

Currently, research findings on the effects of FOMI fertilizers on the yield and quality of flue-cured tobacco in tropical soils are limited.

The objective of this study was to investigate the effect of FOMI fertilizers on the yield and quality of FCV tobacco in major growing areas of Tanzania. It is envisioned that FOMI fertilizers which are produced in the country will be accessible and affordable and hence sustainable fertilisers to smallholder tobacco farmers serving as a game changer for the industry. The application of FOMI fertilizers significantly improves the yield and quality of FCV grown in tropical soils.

MATERIALS AND METHODS

Selected sites and tested variety

The field experiment was conducted during the 2023/2024 and 2024/2025 cropping seasons in three sites:

- Mtanila located at S 7°54'26.02044", E 33°19'21.8226", 1368 m a.s.l in Chunya District, Mbeya Region.
- Tumbi site located at S 5°3'41.96772", E 32°40'13.07892", 1168 m a.s.l in Tabora District, Tabora Region.
- Ibambala located at S 4°7'15.76488", E 32°16'7.61664", 1153 m a.s.l in Ushetu District, Shinyanga Region.

Tobacco variety K326, developed by the Tobacco Research Institute of Tanzania (TORITA), was used to evaluate the agronomic and yield performance of FOMI fertilizers on tobacco production. The nursery was set at TORITA Tumbi in Tabora and Mtanila in Chunya, on 12th September 2023 and 2024 in one seedbed of 18 m² (1.2 m × 15 m). FOMI Fertilizer N₁₀P₁₄K₁₂ (2.5

kg) and 5 kg of tobacco standard fertilizer (N₁₀P₁₈K₂₄) were used in nursery management in two different seedbeds.

Experimental design and field layout

The experimental design was a randomized complete block design (RCBD) with eight treatments, replicated four times. The size of the experimental unit, row spacing and field layout are presented in Table 1 and Figure 1.

Treatments description

The recommended fertilizer nutrients levels for tobacco crop were applied into two splits as follows: Basal fertilizer: (NPK 10:18:24 + 0.5%MgO + 3%CaO + 7%S + 0.012B) at the rate of 500 kg/ha (30 g/plant), and Topdressing fertilizer: CAN (27%N +3 % CaO + 1.7% MgO+ 3%S) at a rate of 133 kg/ha (8 g/plant). This rate was used in the experiment as tobacco standard fertilizer or a positive control (T2). Based on the fertilizer nutrient requirements, ITRACOM Fertilizers Limited (IFL) developed FOMI fertilizers specific for tobacco, composed of FOMI SUPA for planting: Basal fertilizer NPK: 5-9-12 + 10%CaO + 1%MgO + 4%S+ 0.01%B and FOMI CANS Topdressing fertilizer: NPK 18-0-1 + 3%CaO + 1%MgO + 4% S. Therefore, FOMI crop specific (tobacco) was evaluated in three different levels (T3, T4, and T5).

FOMI GREEN (NPK: 10-14-11 + 7%CaO + 1%MgO) and FOMI NENEPESHA (NPK: 11-0-22 + 4%CaO + 2%MgO) fertilizers were combined to meet the fertilizer nutrients of the tobacco standard fertilizer. Three different levels from this combination were evaluated in this experiment (T6, T7 and T8). For research and cost benefit analysis purposes, the zero-fertilizer application was added as a negative control (T1). For each treatment, basal fertilizer was applied 7 days after transplanting, and top dressing was applied 21 days after transplanting. The eight tested treatments are described

Table2. Rates of application and nutrient supply per hectare of each fertilizer treatment.

S/No.	Fertilizer Treatments	Fertilizer type and time of application	Rate (g/plant)	Rate (kg/ha)	N (kg/ha)	P ₂ O ₅ (kg/ha)	K ₂ O (kg/ha)	CaO	MgO	S
T1	NA	NA	0	-	-	-	-	-	-	-
	NA	NA	0	-	-	-	-	-	-	-
T2	NPK standard	7 DAT (Basal)	30	500	50	90	120	15	2.5	35
	CAN standard	21 DAT (Topdressing)	8	133	36	0	0	3.99	2.261	3.99
T3	FOMI SUPA	7 DAT (Basal)	60	1,000	50	90	120	30	10	40
	FOMI CANS	21 DAT (Topdressing)	8	133	25	0	1	4	3	5
T4	FOMI SUPA	7 DAT (Basal)	48	800	40	72	96	24	8	32
	FOMI CANS	21 DAT (Topdressing)	5	83	16	0	1	3	2	3
T5	FOMI SUPA	7DAT (Basal)	36	600	30	54	72	18	6	24
	FOMI CANS	21 DAT (Topdressing)	4	67	13	0	1	2	1	3
T6	FOMI GREEN	7 DAT (Basal)	39	650	65	91	72	46	0	0
	FOMI NENEPESHA	21 DAT (Topdressing)	14	233	26	0	51	9	2	0
T7	FOMI GREEN	7 DAT (Basal)	36	600	60	84	66	42	0	0
	FOMI NENEPESHA	21 DAT (Topdressing)	11	183	20	0	40	7	2	0
T8	FOMI GREEN	7 DAT (Basal)	31	517	52	72	57	36	0	0
	FOMI NENEPESHA	21 DAT (Topdressing)	8	133	15	0	29	5	1	0

DAT-Days after transplanting.

in Table 2.

Data collection**Soil sampling and analysis for site characterization**

Composite soil samples (about 1 kg) at a depth of 0 to 20 cm were collected from 12 zigzag points at each experimental site before setting up the experiment. The samples were sent to Tanzania Agricultural Research

Institute (TARI), Selian-Arusha for analysis. Composite soil samples for each site were air-dried and ground to pass through a 2 mm sieve for laboratory analysis. These soils were tested for soil pH using a soil water ratio of 1:2.5 (Jackson, 1958), organic carbon (OC) was determined by the Walkley Black method (Walkley and Black, 1934), and total N was determined by the Kjeldahl method (Kjeldahl, 1883). Available P was determined by the Bray-1 method, exchangeable bases (Ca, K, and Mg), and extractable S was determined by the Atomic Adsorption Spectrophotometer. Extractable B was determined by hot water extractable boron (Moberg, 2000).

Assessment of leaf area for bottom, middle and upper leaves

Data on leaf size, that is, length and width, was recorded for bottom/lower, middle and upper leaves. Data were collected from 10 sampled plants in each experimental plot based on the surviving plants. Leaf area was determined by using a correction coefficient for flue-cured tobacco taken as 0.64 (Suggs et al., 1960). Data were subjected to an analysis of variance (ANOVA) using the STATISTICA 8th edition statistical software. Treatments means were separated using the Fisher test at $P \leq 0.05$.

The following formula was used to calculate the average leaf area of the tobacco plant:

$$A = C \times L \times W,$$

where L is leaf length, W is leaf width, C is correction coefficient factor, and A is leaf area.

Tobacco grade index analysis

The tobacco grade index (GI) is the ratio of the value of tobacco in the market to the dry tobacco barn weight. The higher the grade index, the higher the quality of tobacco. The weight of each grade scored for each treatment was measured using a digital weighing scale and recorded. The approved price list of FCV tobacco grades for the 2024/2025 cropping season by the Tanzania Tobacco Council (TTC) was used to calculate the value of tobacco produced. The grade index was computed using the following formula:

$$\text{Grade Index (GI)} = \frac{\text{Grade price} \times \text{Graded tobacco weight}}{\text{Dry tobacco barn weight}}$$

Data analysis

Data were statistically analysed by the two-factor analysis (two-way-ANOVA) in STATISTICA 8th edition, Stat-soft, Inc, Tulsa, OK, USA. Treatment effects were considered significant at an alpha equals 0.05 level of probability. Means separation was performed using Fisher's test.

RESULTS

Soil analysis results before tobacco experiments

The chemical properties of the soils from three sites are presented in Table 3. Ratings of the studied parameters in Mtanila-Chunya, Tumbi-Tabora and Ushetu soils were based on the descriptions by Landon (1991). The results indicated that the soil pH in all three sites was strongly acidic with pH values of 5.2 at Ushetu; and 5.1 for both Tumbi-Tabora and Mtanila-Chunya. Soil organic carbon was very low for all three sites, Ushetu and Tumbi-Tabora recording SOC of 0.18% each, and Mtanila-Chunya with SOC of 0.21%. These are very low SOC levels according to London (1991), who indicated that a minimum level of SOC of 2% is generally considered the threshold for sustaining soil quality and preventing deterioration of soil structure and preserving its water and nutrient holding characteristics.

Total nitrogen (N) was very low in soils from all three sites, where Ushetu and Tumbi-Tabora had 0.156% and 0.150%, respectively, and Mtanila-Chunya about 0.139%. Extractable sulphur (S) was medium in Mtanila-Chunya with 48.375 mg kg⁻¹, and there were higher values of sulphur of about 71.708 and 71.917 mg kg⁻¹ for Ushetu and Tumbi-Tabora, respectively. Available phosphorus (P) values were low in all sites, ranging from 3.233 to 8.028 mg kg⁻¹.

Exchangeable calcium (Ca) contents were low with

values ranging from 0.976 to 3.829 cmol (+) kg⁻¹ in all site soils. Soil exchangeable magnesium (Mg) was low, about 0.348 cmol (+) kg⁻¹ in Tumbi-Tabora and very low, with 0.087 and 0.167 cmol (+) kg⁻¹ in Ushetu and Mtanila-Chunya soils, respectively. Exchangeable potassium (K) was very low in all sites, ranging from 0.035 to 0.049 cmol (+) kg⁻¹. Extractable boron (B) was also very low, with values of 0.014 to 0.020 mg kg⁻¹ in the studied soils, however, there was an exception with Manganese (Mn), which had higher values in all three sites, ranging from 6.220 to 8.460 mg kg⁻¹.

Major climate elements for the three experimental sites

Figure 2a presents the temperature and rainfall data for the 2023/2024 cropping season. During the first year (2023/2024), all sites received heavy rains, particularly in November and December. That was the time when tobacco seedlings were being transplanted to the field, followed by the fertilizer application. During the period, soil moisture could have favoured the decomposition of high rates of applied fertilizers to enhance their solubility to plant roots for the application of FOMI SUPA followed by FOMI CANS treatments. However, the Mtanila sites in Chunya Mbeya region received excessive rains of about 1,600 mm cumulatively, which could not favour health growth of tobacco. Likewise, the Ushetu site, in Shinyanga, received heavy rains that exceeded its average rainfall, but it had significantly higher leaf area and dry leaf yields compared to the Tumbi, Tabora, and Mtanila Chunya sites. The excessive rainfall for the Mtanila, Chunya site could have leached the nutrients, and hence their yields did not differ significantly from those of Tumbi and Tabora sites.

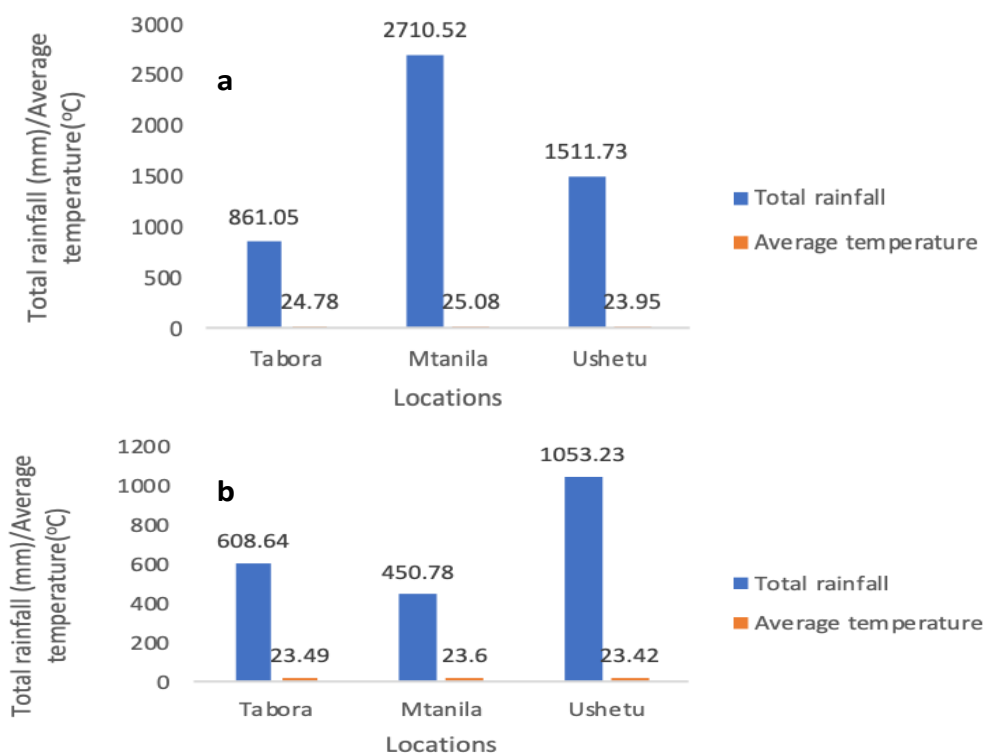
Figure 2b presents the temperature and rainfall data for the 2024/2025 cropping season. During the second year (2024/2025) of trials, all the sites received adequate and average rainfall during the transplanting and application of fertilizers (November to December). Based on the second year's rainfall data, it mostly favoured the application of FOMI GREEN, followed by FOMI NENEPESHA. This meant that 39 g/plant could easily be dissolved and become available for plants uptake, but higher rates of 60 g/plant may not fully be dissolved enough to produce good results. However, the average and below-average rainfall indicated that the tobacco crop growth was favoured, especially in the critical months (November/December), whereby nutrients uptake requires adequate moisture. The Ushetu, Shinyanga site appeared to be favoured by adequate amount of rainfall compared to the rest of the sites.

Effects of FOMI fertilizers on tobacco leaf area

The Ushetu site in Shinyanga region had a significantly

Table 3. Selected chemical soil properties of tobacco growing areas of Tanzania before field experiments were set up.

No.	Parameter	Unit	Ibambala Ushetu	Tumbi Tabora	Mtanila Chunya	Min	Max	Average	Description
1	OC	%	0.18	0.18	0.21	0.18	0.21	0.19	Very low
2	OM	%	0.31	0.31	0.36	0.31	0.36	0.33	Very low
3	pH		5.17	5.11	5.09	5.09	5.17	5.12	Strong acid
4	EC.S	dS/m	1.23	1.05	1.26	1.05	1.26	1.18	Non saline
5	TN	%	0.15	0.15	0.13	0.13	0.15	0.14	Very low
6	C:N		18.62	15.79	17.34	15.79	18.62	17.25	Moderate
7	P	mg kg ⁻¹	4.79	3.23	8.02	3.23	8.02	5.35	Low
8	Ca:Mg		11.19	11.01	9.29	9.29	11.19	10.50	deficiency
9	Ca	Cmol ⁽⁺⁾ kg ⁻¹	0.97	3.82	1.55	0.97	3.82	2.11	low
10	K	Cmol ⁽⁺⁾ kg ⁻¹	0.03	0.03	0.04	0.03	0.04	0.04	Very low
11	Mg	Cmol ⁽⁺⁾ kg ⁻¹	0.08	0.34	0.16	0.08	0.34	0.20	Very low
12	Na	Cmol ⁽⁺⁾ kg ⁻¹	0.02	1.85	0.18	0.02	1.85	0.68	Medium
13	S	mg kg ⁻¹	71.70	71.91	48.37	48.37	71.91	64	High
14	Mn	mg kg ⁻¹	8.46	8.40	6.22	6.40	8.46	7.69	High
15	Al	mg kg ⁻¹	58.45	59.35	54.23	54.23	59.35	57.34	High
16	Zn	mg kg ⁻¹	0.70	0.70	0.73	0.70	0.73	0.71	Medium
17	Fe	mg kg ⁻¹	53.77	45.07	41.668	41.66	53.77	46.83	High
18	B	mg kg ⁻¹	0.01	0.02	0.01	0.01	0.02	0.02	Very low

**Figure 2.** Temperature and rainfall data during (a) 2023/2024 and (b) 2024/2025 growing season. Source: TMA.

larger leaf area of 483.59 ± 33.86 and 1066.91 ± 69.54 cm² for two cropping seasons, respectively, compared to

Mtanila-Chunya and Tumbi-Tabora sites (Table 4). The treatment results for the first season (2023/2024) for the

Table 4. Effect of FOMI fertilizers on leaf area for three sites.

Site	2023/2024	2024/2025
	Leaf area (cm ²)	Leaf area (cm ²)
Mtanila-Chunya	203.01 ± 17.06 ^b	969.63 ± 65.80 ^b
Ushetu-Shinyanga	483.59 ± 33.86 ^a	1066.91 ± 69.54 ^a
Tumbi-Tabora	209.01 ± 17.76 ^b	1021.63 ± 65.80 ^{ab}
Treatments		
T1	99.34 ± 18.00 ^c	313.06 ± 14.70 ^f
T2	379.45 ± 54.75 ^a	1432.56 ± 67.71 ^a
T3	409.95 ± 56.45 ^a	1108.82 ± 49.90 ^c
T4	393.46 ± 52.05 ^a	975.97 ± 45.28 ^{cd}
T5	353.11 ± 49.86 ^a	708.99 ± 66.33 ^e
T6	230.42 ± 53.73 ^b	1380.01 ± 23.77 ^{ab}
T7	277.02 ± 54.62 ^b	1265.44 ± 44.58 ^b
T8	245.51 ± 30.28 ^b	969.13 ± 14.33 ^d
2-WAY ANOVA F-statistics		
Site (S)	98.42 ^{***}	2.70 ^{ns}
Treatment (T)	16.11 ^{***}	59.19 ^{***}
S × T	1.67 ^{ns}	0.01 ^{ns}

Values presented are means ± SE $\bar{x}$ (Standard error of means); *** = significant at $P \leq 0.001$; ns=non-significant. Means in the same category of evaluated interface sharing similar letter(s) do not differ significantly based on their respective Standard error (SE) at 5% error rate.

Table 5. Effect of FOMI fertilizers on dry leaf yield across sites

Site/Season	2023/2024	2024/2025
	Dry leaf yield (kg ha ⁻¹)	Dry leaf yield (kg ha ⁻¹)
Mtanila-Chunya	722.59 ± 90.71 ^b	1794.73 ± 112.52 ^a
Ushetu-Shinyanga	998.20 ± 94.20 ^a	1795.98 ± 112.34 ^a
Tumbi-Tabora	980.76 ± 96.21 ^a	1797.30 ± 112.43 ^a
Treatments		
T1	169.30 ± 25.81 ^d	166.65 ± 1.26 ^h
T2	1389.89 ± 145.72 ^{ab}	2175.95 ± 1.30 ^b
T3	1582.55 ± 69.09 ^a	1946.87 ± 4.58 ^e
T4	1215.41 ± 58.34 ^b	1898.91 ± 1.14 ^f
T5	863.66 ± 104.16 ^c	1879.24 ± 1.13 ^g
T6	358.88 ± 53.48 ^d	2190.20 ± 1.13 ^a
T7	914.05 ± 107.37 ^c	2108.37 ± 1.12 ^c
T8	710.37 ± 50.49 ^c	2001.83 ± 1.14 ^d
2-WAY ANOVA F-statistics		
Site (S)	9.11 ^{***}	1 ^{ns}
Treatment (T)	34.22 ^{***}	104619 ^{***}
S × T	0.07 ^{ns}	0.00 ^{ns}

Values presented are means ± SE $\bar{x}$ (Standard error of means); *** = significant at $P \leq 0.001$; ns=non-significant. Means in the same category of evaluated interface sharing similar letter(s) do not differ significantly based on their respective Standard error (SE) at 5% error rate.

were very different. The standard treatment T2 and the FOMI GREEN treatment T6 had the largest leaf areas,

measuring 1432.56 ± 67.71 cm² and 1380.01 ± 23.77 cm², respectively (Table 4). T1, which is the control (no

fertilizer), had the lowest leaf area for two consecutive seasons (Table 4).

Effects of FOMI fertilizers on tobacco dry leaf yields

Table 5 presents the results of dry leaf yields for two cropping seasons. With the exception of Mtanila site in Chunya Mbeya region for the cropping season 2023/2024, which had the lowest dry leaf yields of 722.59 ± 90.71 kg/ha, the rest of the sites, their dry leaf yields did not differ significantly.

It was observed that the application of FOMI SUPA followed by FOMI CANS (T3) and the Standard NPK fertilizer followed by CAN treatment (T2) gave the highest dry leaf yields during the growing season 2023/2024 with total yield amounting 1582.55 ± 69.09 kg/ha and 1389.89 ± 145.72 kg/ha, respectively. The application of FOMI SUPA followed by FOMI CANS T3 produced more dry leaf yield because it is a multi-nutrients fertilizer that supply NPK plus calcium, magnesium, and sulphur. It is also having farm yard manure which improves soil structure, soil water-holding characteristics and hence create a more conducive growth environment. Also, FOMI SUPA/GREEN, T4-T8 had dry leaf yields that differed significantly. At the same time, the standard NPK treatment T2 had a dry leaf yield of 2175.95 ± 1.30 kg/ha, which was lower than the application of FOMI GREEN followed by FOMI NENEPESHA (T6), which had a dry leaf yield of 2190.20 ± 1.13 kg/ha during the 2024/2025 growing season when rainfall was of the average to adequate (Figure 2b). Following the standard NPK treatment (T2), the application of FOMI GREEN followed by FOMI NENEPESHA T7, T8, and the application of FOMI SUPA followed by FOMI CANS (T3) recorded significant dry leaf yields. These results depict that the application of FOMI SUPA followed by FOMI CANS (T3) works better in the heavy rain season, while the application of FOMI GREEN followed by FOMI NENEPESHA (T6) works better for the adequate or average rainfall seasons. Overall, the results indicate that the dry leaf yield increases as the nitrogen rate increases, depending on the composition and rates of the treatment.

Effects of FOMI fertilizers on tobacco grade index

Table 6 presents the tobacco grade index (GI) of tobacco leaves for two cropping seasons. The Ushetu site in Shinyanga had a significant grade index of tobacco leaf of 1.17 ± 0.11 and 1.37 ± 0.11 , higher than Tumbi-Tabora and Mtanila-Chunya sites with GI of 0.71 ± 0.08 , 1.02 ± 0.1 , 0.71 ± 0.10 and 1.04 ± 0.11 respectively, for the cropping seasons of 2023/2024 and 2024/2025. In terms of treatments for the 2023/2024 cropping season, the standard NPK fertilizer (T2) and the application of FOMI

SUPA followed by FOMI CANS (T3) had a significantly higher-grade index of 1.74 ± 0.15 and 1.54 ± 0.12 , respectively, followed by the application of FOMI SUPA and FOMI CANS -T4 (1.03 ± 0.10). For the 2024/25 cropping season the trend was similar but with improvement of the application of FOMI GREEN followed by FOMI NENEPESHA (T6). The results indicate that the standard NPK fertilizer (T2), the application of FOMI SUPA followed by FOMI CANS (T3) and FOMI GREEN followed by FOMI NENEPESHA (T6) had a significantly higher-grade index of 1.8 ± 0.11 , 1.82 ± 0.09 , and 1.71 ± 0.11 , respectively, followed by the combinations of FOMI SUPA and FOMI CANS -T4 (1.25 ± 0.08). The lowest grade index was recorded from absolute control with a grade index of 0.24 ± 0.04 .

DISCUSSION

Changes in the soil nutrients of experimental sites

Variations in the soil nutrients have been observed in the experimental sites. Generally, the chemical properties of soil vary in space and time because of variation in topography, climate, weathering processes, vegetation types (Paudel and Sah, 2003) and microbial activities (Bargali et al., 2018; Bisht et al., 2025) and several other biotic and abiotic factors (Pandey et al., 2024; Fartyal et al., 2025). In the highly dissected landscapes, bioclimatic conditions change rapidly and may vary within short distances resulting in a pronounced heterogeneity of soil types and their chemical as well as physical properties (Baumler, 2015; Bargali et al., 2019); hence, change the vegetation and litter types (Pandey et al., 2024).

Effects of FOMI fertilizers on tobacco leaf area

The first cropping season 2023/2024 had heavy rainfall across the sites of Mtanila-Chunya, Tumbi-Tabora and Ushetu-Shinyanga, thus, the results indicate that applying the lowest levels of fertilizer had no significant impact on increasing the leaf area. However, the higher rate of fertilizer has had a positive effect on the leaf area, similar to results by Sifola et al. (2022) and Zhou JianFei et al. (2018). According to Kurt and Kinay (2021) fertilizer application in tobacco increase chlorophyll index which support leaf expansion through the process of photosynthesis. Fertilization in tobacco also contributes in the synthesis of proteins and enzymes that drive cell division and expansion, resulting in increased leaf area (Allen et al., 2023).

Effects of FOMI fertilizers on dry leaf yield

The results of the present study indicate that higher dry

Table 6. Effect of FOMI fertilizers on grade index for three sites

Site	2023/2024	2024/2025
	Grade Index	Grade Index
Mtanila-Chunya	0.71 ± 0.10 ^b	1.04 ± 0.11 ^b
Ushetu-Shinyanga	1.17 ± 0.11 ^a	1.37 ± 0.11 ^a
Tumbi-Tabora	0.71 ± 0.08 ^b	1.02 ± 0.1 ^b
Treatments		
T1	0.27 ± 0.05 ^f	0.24 ± 0.04 ^a
T2	1.74 ± 0.15 ^a	1.8 ± 0.11 ^d
T3	1.54 ± 0.12 ^a	1.82 ± 0.09 ^d
T4	1.03 ± 0.10 ^b	1.25 ± 0.08 ^c
T5	0.51 ± 0.08 ^{de}	0.74 ± 0.06 ^b
T6	0.39 ± 0.08 ^{ef}	1.71 ± 0.11 ^d
T7	0.79 ± 0.09 ^c	0.86 ± 0.07 ^b
T8	0.62 ± 0.09 ^{cd}	0.7 ± 0.07 ^b
2-WAY ANOVA F-statistics		
Site (S)	28.18 ^{***}	21.25 ^{***}
Treatment (T)	44.10 ^{***}	73.43 ^{***}
S × T	0.41 ^{ns}	0.28 ^{ns}

Values presented are means ± SE $\bar{x}$ (Standard error of means); *** = significant at $P \leq 0.001$; ns=non-significant. Means in the same category of evaluated interface sharing similar letter(s) do not differ significantly based on their respective Standard error (SE) at 5% error rate.

leaf yield was obtained from treatments with significantly higher N application rates. The result of this study aligns well with studies that showed that nitrogen had more effect on yield and quality of tobacco compared to other elements. Low amount of N was correlated to reduced yield and makes plant leaves yellowish and decreases leaves photosynthesis processing in high temperatures. Su et al. (2021) found that higher fertilizer N rates allowed a significant increase in cured leaf yields. Additionally, a study conducted by Reddy et al. (2017) found that the response for cured leaves with respect to different levels of either nitrogen or potassium was linear. A study conducted by Sifola et al. (2022) showed that the effect of nitrogen on green leaf yield and dry leaf yield was significant. Also, the combined effect of nitrogen and potassium on dry weight was also significant, which aligns well with our finding showing that FOMI Green followed by FOMI Nenepesha significantly increased leaf yield and particularly in average rainfall seasons.

Based on research and fertilizer suggestions, the best N rate for flue-cured tobacco is usually between 40 and 100 kg/ha, though this can change depending on the type of soil (Huan et al., 2024). The results of the study show that the application of FOMI SUPA followed by FOMI CANS (T3-T5) showed higher dry leaf yields in heavy rainfall (Figure 2a), while the adequate rainfall (Figure 2b) for the application of FOMI GREEN followed by FOMI NENEPESHA (T6-8) performing better on dry leaf yields requires more research. However, in terms of

performance, the application of FOMI SUPA followed by FOMI CANS (T3) and FOMI GREEN followed by FOMI NENEPESHA (T6) represent the best treatments for each cropping season, making them both suitable for use in tobacco production, depending on the weather conditions.

Effects of FOMI fertilizers on grade index

Grade index is the ratio between tobacco value and barn weight of the same tobacco leaves after curing. The value of tobacco was estimated by multiplying the weight of grades obtained and their indicative prices. The high ratio reflects tobacco of high quality and vice versa. For the cropping season 2023/2024, the highest grade indices were recorded from treatments which supplied 120 and 121 kg K/ha. Likewise, the second crop season 2024/2025 the highest grade indices were recorded from treatments which supplied 120, 121 and 123 kg K/ha which implies that tobacco of high grade indices were produced from the supply of K between the ranges of 120 to 123 kg K/ha. The results indicate that the quality of tobacco increased with the increased levels of K. Similar findings were also reported by Sabeti et al. (2013) and Tang et al. (2020) who indicated that potassium (K) has more effect on quality of tobacco leaves compared to other elements. This has contributed to production of tobacco of higher grades than the remaining treatments. Low amount of K reduces quality and produces tobacco

of lower grades hence lower grade index (Hu et al., 2021)

Conclusion

FOMI fertilizers which were under trials for two years consecutively demonstrated positive performance on flue-cured tobacco yield and quality. In the first year with a lot of rain, the combination of FOMI SUPA and FOMI CANS fertilizer had a higher leaf yield than the standard NPK fertilizer, but the difference was not statistically significant. In the second cropping season with moderate rainfall FOMI GREEN+FOMI NENEPESHA had a higher dry leaf yield than the standard NPK + CAN fertilizers. Therefore, the application of FOMI SUPA followed by FOMI CANS works better in the heavy rain season, while the application of FOMI GREEN followed by FOMI NENEPESHA works better for the moderate to adequate rainfall.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ABBREVIATIONS

FCV, Flue cured Virginia; **TORITA**, Tobacco Research Institute of Tanzania; **RCBD**, randomized complete block design; **DAT**, days after transplanting; **TARI**, Tanzania Agricultural Research Institute; **OC**, organic carbon; **TTC**, Tanzania Tobacco Council; **ANOVA**, analysis of variance; **TMA**, Tanzania Meteorological Agency,

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