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Agronomic Performance of Mulch Materials and Mulching Rates on Turmeric (*Curcuma longa* L.) Rhizome Yield, Nutritional Quality and Nutrient Uptake in North Central Nigeria

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ABSTRACT

An experiment was carried out from June 2023 to February 2024 at the Biotechnology Advanced Research Centre Farm in Garki-Abuja to evaluate the effects of mulching rates and materials on a local turmeric variety. The 3x3 factorial experiment was set up using a Randomized Complete Block Design (RCBD) and was carried out three times. Three mulching materials (rice husk, soybean straw and sawdust) and three mulching rates (0, 5 and 10 t/ha) made up the treatments. Protein, magnesium, calcium, iron, and manganese were among the nutritional attributes gathered. Calcium, manganese, iron, potassium, magnesium, and nitrogen were the elements concerned with nutrient absorption and potassium, respectively. The analysis of variance (ANOVA) and Least Significant Difference (LSD) were used to compare the significant means of the mineral contents and nutrient uptake.The findings showed that the best calcium content (107.97 mg/100 g) was obtained with a mulching rate of 10 t/ha, whereas the highest magnesium mineral content (33.49 mg 100 g) was created by sawdust mulch material. It is evident that soybean mulch material had the maximum potassium nutrient uptake (110.29 mg 100 g), whereas mulching at a rate of 5 t/ha produced the same nutrient uptake element (100.93 mg 100 g).In the turmeric farming communities in the study region, sawdust mulch material at a rate of 10 t/ha can be suggested for the generation of mineral contents and soybean mulch at a rate of 5 t/ha for nutrient uptake.

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INTRODUCTION

According to research published by Chattopadhyan et al. (2004), Jilani et al. (2012), Olatunde et al. (2014), Nwaekpe et al. (2015), Taoheed et al. (2017), Chanda and Ramachandra (2019), turmeric (*Curcuma longa* L.) is a medicinal plant that is botanically a member of the Zingiberaceae family. It is a rhizomatous perennial erect leafy herb that can grow up to 1 m high, with a short stem, oblong, pointed leaves, and yellow flowers with a funnel shape. Turmeric is originally from Asia and India, it makes for around 6% of India's total area under spices and condiments (Akter et al., 2019). It is sold commercially as a source of industrial starch, oleo-resin, spice, and dye. The primary ingredient in turmeric, curcumin, possesses anti-inflammatory, anti-tumor, anti-cancer, anti-bacterial, anti-oxidant, anti-fungal, and anti-parasitic qualities (Akter et al., 2019; Tomeh et al., 2019; Ahmad et al., 2020).The main benefits of turmeric include its use as orange coloring powder in the food and textile industries, its medicinal value, its flavor, and its oleoresin. According to Sidhu et al. (2016), dry turmeric has approximately 69.43% carbohydrates, 6.30% protein, 5.1% oil, 3.5% mineral, and other significant components. It is an ancient, precious, and revered spice that has significant amounts of protein (6.3%), lipids (5.1%), carbohydrates (69.45%), and fiber (2.6%). It is also rich in minerals like calcium, iron, phosphorus, and vitamin A.Turmeric has an active element called curcumin (3-5%), which has biological action and colors food, fiber, wood, and other preparations (Sidhu et al., 2016).

Nutrition with appropriate, balanced, and healthful diets is one of the most significant issues facing our world today, which is undergoing fast social, cultural, and economic development. From the beginning of time, plants have provided the body with the fundamental nutrients it needs, mostly for metabolic and physiological processes. More plants that have previously not been used for their nutritional benefits are gaining attention as a result of the growing prevalence of food insecurity and the "hidden" hunger of most micronutrients in developing nations. Plants have long served as the foundation for the most sophisticated and conventional ethnobotanical treatment systems worldwide (Ononamdu et al., 2019). Even plants that were only used as culinary spices have been used to treat and control a wide range of diseases and conditions. According to (Enemor et al., 2019), there is growing evidence that even plant seeds that have been overlooked up until now have enormous nutritional and medicinal potential. The potential phytoethnomedicinal qualities and nutritional components of these plants have not been fully utilized. As traditional medicine gains popularity (Ononamadu et al., 2019), more and more authors are demonstrating the scientific value of studying the phytochemical components of these plants (Koneri et al., 2014). Despite its numerous use in industry, medicine, pharmacology, food, and cosmetics, as reported by (Prasad and Aggarwal, 2011), Curcuma longa remains the most underutilized plant in the southeast of Nigeria.

Compared to other major producing nations, Nigeria continues to have low turmeric crop productivity and production. Among the many causes of this output gap are dwindling soil fertility and a lack of relevant and sufficient research data. Turmeric is a crop that is nutrient-exhaustive, according to several research (Singh et al., 2001; Agere and Shiferaw, 2015), particularly since it is a strong feeder of nitrogen. Because of their shallow rooting and capacity to yield a significant amount of dry matter per unit area, turmeric has a high nutritional need (Singh et al., 2001). Furthermore, the crop takes eight to nine months to grow, which means that the time needed for nutrients also needs to be extended in order to increase rhizome yield."Turmeric" is a spice made of boiled, dried, cleaned, and polished rhizome with a modified underground swelling stem (Shirish et al., 2013).

Mulching is a crucial part of turmeric management techniques. It maintains soil moisture and raises soil temperature during the dry months so that the rhizome can germinate properly (Kumar et al., 2022). Additionally, it improves the soil physical characteristics while lowering its fertility (Qin et al., 2014). In addition to improving soil physical characteristics, preventing erosion, improving nitrogen balances, and increasing soil biological activity, organic mulches are effective at reducing nitrate leaching (Bhardwaj, 2011; Iqbal et al., 2020). According to (Indulekha and Thomas, 2018), natural mulches like leaves, straw, sawdust, wasted materials, and crop wastes have been utilized for generations.Following decomposition, organic mulches enhance the soil physical, chemical, and biological characteristics and replenish the soil with organic matter and plant nutrients, thus increasing agricultural output (Thakur and Kumar, 2021). Additionally, it keeps soil nutrients from being washed away during periods of intense rainfall (Iqbal et al., 2020; Mohanty and Panda, 1991). As a result, it enables more soil moisture retention, aids in temperature regulation, and boosts the physical, chemical, and biological characteristics of soils, all of which contribute to the soil nutrient addition and eventually increase crop development, yield, and nutritional value (Kumar et al., 2010). Therefore, considering all these facts, the current study was undertaken to evaluate the effect of mulch materials and mulching rates on rhizome yield, nutritional quality and nutrient uptake of turmeric.

MATERIALS AND METHODS

Site Description

A field trial was carried out during the 2023–24 cropping season at the Sheda Science and Technology Complex Garki-Abuja, Biotechnology Advanced Research Centre Farm, FCT, Nigeria. Abuja climate is chilly and dry from November to March and warm and humid from April to October. It is situated between 8O10'N and 7O 10'N; 35°C is the highest temperature while 27°C is the lowest. All year round, with the exception of January, when a dry wind from the north blows, the area has a high humidity of 74%. Over 1250 mm of rain falls there on average each year.

Treatments and Experimental Design

The marginal Local variety was planted with mulching rates of control (0), 5 t/ha, and 10 t/ha, respectively, utilizing rice husk, soybean, and sawdust mulch materials. The treatments were factorial experiment fitted into Randomized Complete Block Design (RCBD), replicated three times. The turmeric plants nutritional characteristics and nutrient absorption were determined using these variables.

Determination of Nutritional Quality and Nutrient Uptake of Turmeric

The leaves were ground into powder for proximate analysis and the rhizome was examined using standard laboratory techniques. In order to determine the phytochemical contents of the rhizomes at full maturity, five rhizome samples were randomly chosen from each plot and examined for nutritional characteristics such as protein (%), iron (mg/100 g), potassium (mg 100 g), calcium (mg 100 g), manganese (mg 100 g), and magnesium (mg 100 g). In order to evaluate these components, the rhizome samples were oven-dried for 72 hours at 65°C.The dried rhizome samples were pulverized separately using a Wiley mill and then sieved through a 0.5 mm screen in order to analyse the tissue. The atomic absorption spectrophotometer was used to estimate the total K and Ca, whereas the flame photometry was used to determine the Mg and Fe (IITA, 2009). Crude protein was calculated by multiplying total N by a factor of 6.25. Total N was evaluated using the micro-Kjeldahl technique as outlined by (IITA, 2009). Utilizing the same technique, the nutrient absorption was assessed. Five leaves were chosen at random from each plot to determine the phytochemical contents of the leaves. The nitrogen (%), potassium (mg 100 g), calcium (mg 100 g), magnesium (mg 100 g), and manganese (mg 100 g) levels were measured for nutrient absorption. The Chemistry Advanced Research Centre Laboratory of Sheda Science and Technology Complex (SHESTCO), Federal Capital Territory Abuja was the site of the nutrition absorption and proximate analyses.

Statistical Analysis

The Crop STAT software was used to do an analysis of variance (ANOVA) on the data, and the Least Significant Difference (LSD) at a 5% probability level was used to distinguish the significant means.

RESULTS and DISCUSSION

Effect Mulch Materials and Mulching Rates on Rhizome Weight and Rhizome Yield of Turmeric

Mulching materials and rates had no significant ($P \geq 0.05$) effect on rhizome weight (Table 1). On the other hand, rhizome weight was significantly impacted by the interaction between mulching rates and materials ($P \leq 0.05$). However, only the

mulching materials had a substantial impact on the rhizome yield; the mulching rates and types did not significantly interact. The highest turmeric yield (3.74 t ha-1) was obtained from the application of rice husk mulch material, whereas the lowest yields were obtained from sawdust and soybean straw, respectively (Table 1).

Table 1. Effect of mulch materials and mulching rates on rhizome weight and rhizome yield of turmeric in 2023/-24 cropping season

Treatment	Rhizome weight (g)	Rhizome yield (t/ha)
Mulch materials (MM)		
Rice husk	91.11	3.74a
Soybean straw	90.02	2.91b
Saw dust	83.60	2.84b
Level of significance	NS	*
SE±	3.44	0.20
Mulching rates (t/ha) (MR)		
0	91.65	3.37
5	87.61	2.98
10	85.46	3.14
Level of significance	NS	NS
SE±	3.44	0.20
Interaction		
MM X MR	*	NS

Means followed by the same letter (s) within the same column are not significantly different at 5% level of probability,*significant at 5%, NS= Not significant

Effect of Mulch Materials and Mulching Rates on Nutritional Quality of Turmeric

Turmeric protein content was not significantly impacted by mulching rates or materials, but the interaction between the two was ($P \leq 0.05$) strongly impacted. Mulching materials and mulching rates both significantly ($P \leq 0.05$) increased the magnesium content. In terms of magnesium content, plants mulched with sawdust produced the largest amount (33.49 mg 100 g), followed by soybean mulch, while rice husk mulch had the lowest mean value. The plants mulched at a rate of 10 t/ha produced the highest magnesium content (107.97 mg 100 g) compared to other rates assessed, and this difference was significant ($P \leq 0.05$). As a result, the other two rates were comparable. The calcium content was not significantly increased by mulch materials, but it was by the rates; the plants mulched at 10 t/ha had the highest calcium content (107.97 mg g), whereas the control plot had the lowest mean value. There was no significant ($P \geq 0.05$) impact of the interaction between mulching rates and mulch materials (Table 2).

Table 2. Effect of mulch materials and mulching rates on protein, magnesium and calcium nutritional quality of turmeric in 2023/-24 cropping season

Treatment	Protein (%)	Magnesium (mg/100 g)	Calcium (mg/100 g)
Mulching materials (MM)			
Rice husk	10.72	22.70	86.31
Soybean	8. 53	25.94	89.21
Saw dust	9. 78	33.49	86.80
Level of significance	NS	*	NS
SE±	1.04	2.31	10.54
LSD	3.12	6.94	31.59
Mulching rates (t/ha) (MR)			
0	8.97	24.24	65.15
5	9.67	20.22	89.20
10	10.40	37.66	107.96
Level of significance	NS	*	*
SE±	1.04	2.31	10.54
LSD	3.12	6.94	31.59
Interaction			
MM X MR	*	NS	NS

SE = Standard Error, LSD = Least Significant Difference, NS = Not Significant, * Significant at 5%

Mulch materials and mulching rates had a substantial (P≤0.05) impact on iron and manganese contents. Although they were not much different from soybeans, plants mulched with rice husk had the highest iron concentration. Additionally, plants mulched at a rate of 5 t/ha had the maximum iron content, whereas the un-mulched plot had the lowest mean value. However, plants mulched at 10 t/ha produced the maximum manganese mineral content (5.89 mg g), but plants mulched at 5 t/ha and the control plot were comparable. Manganese content was greatly impacted by the interaction between mulching rates and mulch types. Potassium and calcium mineral levels were not significantly impacted by mulching rates or materials, but the interaction between the two was (P≥0.05) strongly impacted (Table 3).

Table 3. Effect of mulch materials and mulching rates on Iron, manganese and Potassium nutritional quality of turmeric in 2023/-24 cropping season

Treatment	Iron (mg/100 g)	Manganese (mg/100 g)	Potassium (mg/100 g)
Mulch materials (MM)			
Rice husk	6.95	4.74	118.30
Soybean	6.51	3.13	133.52
Saw dust	4.79	5.44	122.146
Level of significance	*	*	NS
SE±	0.64	0.54	6.14
LSD	1.93	1.62	18.42
Mulching rates (t/ha) (MR)			
0	4.74	3.61	119.13
5	7.35	3.81	133.97
10	6.16	5.89	120.87
Level of significance	*	*	NS
SE±	0.64	0.54	6.14
LSD	1.93	1.62	18.42
Interaction			
MM X MR	NS	*	*

SE = Standard Error, LSD = Least Significant Difference, NS = Not Significant, * Significant at 5%

Effect of Mulch Type and Mulching Rates on Nutrient Uptake of Turmeric

Calcium nutrient uptake was not significantly (P≥0.05) impacted by mulch materials and mulching rates. However, interaction effect between mulch materials and mulching rates was considerably (P≤0.05) affected. Mulching materials, mulching rates, and their interaction did not significantly (P≥0.05) influence manganese nutrient uptake.

Mulching materials and rates had a substantial (P≤0.05) impact on the uptake of turmeric iron nutrients. Rich husk had the lowest mean value, whereas plants mulched with sawdust had the maximum nutrient uptake (2.46 mg g), which was comparable to soybeans. It is clear that the plants mulched at a rate of 5 t/ha had the greatest mean value (2.37 mg g), which was not substantially different from the plants mulched at a rate of 10 t/ha. The control plot had the lowest mean value. Mulching rates and mulch materials did not significantly (P≥0.05) affect the interaction impact. Mulch materials alone considerably improved turmeric plants uptake of potassium nutrients (Table 4).

Table 4. Effect of mulch materials and mulching rates on calcium, Manganese and Iron nutrient uptake of turmeric in 2023/-24 cropping season

Treatment	Calcium (mg/100 g)	Manganese (mg/100 g)	Iron (mg/100 g)
Mulch materials (MM)			
Rice husk	94.30	4.61	1.71
Soybean	131.07	5.31	2.34
Saw dust	98.44	5.36	2.46
Level of significance	NS	NS	*
SE±	14.17	1.47	0.15
LSD	42.49	4.42	0.46
Mulching rates (t/ha) (MR)			
0	119.45	3.59	1.78
5	99.40	4.99	2.37
10	104.96	6.70	2.36
Level of significance	NS	NS	*
SE±	14.17	1.47	0.15
LSD	42.49	4.42	0.46
Interaction			
MM X MR	*	NS	NS

SE = Standard Error, LSD = Least Significant Difference, NS = Not Significant, * Significant at 5%

The plants mulched with soybean proved its superiority over the ones mulched with saw dust, but was not significantly different from rice husk mulch material. The mulching rates did not prove any level of significance with each other. Also, interaction between mulch materials and mulching rates were not significantly different. On the other hand, magnesium uptake was not significantly ($P \geq 0.05$) affected by mulch materials and mulching rates, but the interaction effect did. Nitrogen nutrient uptake of turmeric plants was significantly ($P \leq 0.05$) inferred by mulch materials, mulching rates and its interaction.Plants mulched with saw dust produced the highest uptake (7.54 mg g) which was concurrent with that of soybean while the least mean value (4.16 mg g) was observed from rice husk. There was no significant effect among the mulching rates; however the highest nutrient uptake was received from plants mulched at 5 t/ha. The interaction between mulch materials and mulching rates was significantly ($P \geq 0.05$) influenced (Table 5).

Table 5. Effect of mulch materials and mulching rates on protein, magnesium and calcium nutrient uptake of turmeric in 2023/-24 cropping season

Treatment	Potassium mg/100 g)	Magnesium (mg/100 g)	Nitrogen (mg/100 g)
Mulch materials (MM)			
Rice husk	102.53	41.92	4.16
Soybean	110.28	46.43	6.02
Saw dust	78.13	44.70	5.38
Level of significance	*	NS	*
SE±	8.76	4.91	0.75
LSD	26.27	14.71	2.24
Mulching rates (t/ha) (MR)			
0	92.93	43.32	6.00
5	100.93	50.55	6.83
10	97.10	39.17	4.89
Level of significance	*	NS	*
SE±	8.76	4.91	0.75
LSD	26.27	14.71	2.24
Interaction			
MM X MR	NS	*	*

SE = Standard Error, LSD = Least Significant Difference, NS = Not Significant, * Significant at 5%

Interaction between Mulch Materials and Mulching Rates on Protein, Manganese and Potassium of Turmeric

The interaction between mulch materials and mulching rates on number of protein content is significant (Table 6). Where plants mulched with saw dust at the rate of 5 t/ha produced higher number of protein content than other interactions.

Table 6. Effect of mulch materials and mulching rates interaction on protein, manganese and potassium contents of turmeric in 2023/-24 cropping season

Mulch materials	Mulching rates	Protein	Manganese	Potassium
1	1	13.19ab	5.96b	111.11b
1	2	7.80bc	3.45bc	122.83ab
1	3	11.18abc	4.82bc	120.97ab
2	1	6.52c	2.65c	148.64a
2	2	7.74c	3.27bc	128.97ab
2	3	11.34abc	3.45bc	122.96ab
3	1	7.20c	2.22c	97.65b
3	2	13.46a	4.72bc	150.11a
3	3	8.69abc	9.39a	118.67ab
SE±		1.80	0.93	10.64
LSD		5.40	2.80	31.90

Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability, SE = Standard Error, LSD = Least Significant Difference

More also, the highest manganese nutritional content was gotten from the plants mulched with saw dust at the rate of 10 t/ha and the least mean values were received from the plants mulched with saw dust.On the other hand, plants mulched with saw dust significantly produced the highest potassium content which was at par with soybean straw compared with the rest of the interactions (Table 6).

Interaction between Mulch Materials and Mulching Rate on Calcium, Magnesium and Nitrogen Uptake of Turmeric

The interactive effect between mulch type and mulching rates on calcium content is significant (Table 7), where plants mulched with soybean straw gave higher protein content than other interactions.

Table 7. Effect of mulch materials and mulching rates interaction on calcium, magnesium and nitrogen uptake of turmeric in 2023/-24 cropping season

Mulch materials	Mulching rates	Calcium	Magnesium	Nitrogen
1	1	103.64abc	32.02b	4.04bc
1	2	120.60abc	60.52a	3.12c
1	3	58.66c	33.21b	5.32bc
2	1	173.20a	64.81a	7.72ab
2	2	67.25c	40.36ab	7.33ab
2	3	152.77ab	34.10b	3.01c
3	1	81.52bc	33.14b	6.24abc
3	2	110.36abc	50.77ab	10.04a
3	3	103.43abc	50.19ab	6.33abc
SE±		24.55	8.50	1.29
LSD		73.60	25.48	3.87

Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability, SE = Standard Error, LSD = Least Significant Difference

Much more, the highest magnesium content was produced from the plants mulched with soybean which was concurrent with the plants mulched with rice husk at 5 t/ha.On the other hand, plants mulched with sawdust at a rate of 5 t/ha had the highest nitrogen content, whereas plants mulched with soybean and rice husk at the rates of 5 and 10 t/ha had the lowest nitrogen content (Table 7).

DISCUSSION

According to the current study, the marginal local variety of turmeric had a magnesium content of 33.49 mg/100 g, which is consistent with the findings of Kumarawa et al. (2007), who found that magnesium as a mineral content can lower blood pressure in humans, resulting in a good, healthy lifestyle. This study found that applying different mulch materials and mulching rates resulted in significant differences in iron and manganese contents.This contradicts the findings of Shirish et al. (2013), who claimed that mulching is a crucial part of turmeric management

techniques that may assist raise the mineral concentrations. According to this study, mulching rates and materials had no discernible effects on the mineral composition of manganese or potassium. This contradicts the findings of a field trial conducted by Kumarawa et al. (2007), who observed a considerable impact on the nutritional value of turmeric.

The present investigation found that mulching rates and materials consistently resulted in considerable improvements in magnesium, iron, and manganese levels. These findings are congruent with those of Quaye et al. (2009) and Prinyawiwatkul et al. (1996) who found that plants have a significant quantity of mineral content overall. Concurrently, this study demonstrated that soybean mulch outperformed other mulching materials in terms of nutritional quality.

This study clearly showed that the best nutritional absorption of potassium was found in soybean mulch. This is enough to state that, when plants were mulched at a rate of 5 t/ha, the best uptake of potassium nutrients was observed compared to other rates assessed. The current study's findings, on the other hand, showed that mulching rates and materials had an impact on iron, potassium, and nitrogen uptakes. This suggests that turmeric plants require these nutrients for metabolism and soil nutrient buildup. The study's findings concur with those of Farooq et al. (2013), who emphasized that normally plants need nutrients for uptake and translocation; otherwise, productivity may suffer to the cost of output. Turmeric mulching should therefore be promoted in order to retain soil moisture for plant growth, yield, and mineral content generation as well as improved nutrient uptake.

As a result, the study's conclusions demonstrated that, with the exception of calcium, manganese, and magnesium, nutrient uptake was noteworthy. Only soybean mulch showed the highest nutrient uptake, according to the study's findings. The study's results are consistent with those of a study on the nutritional intake of two okra cultivars conducted by Tswanya et al. (2020). The current study's findings showed that there was a relationship between mulching rates and materials in terms of nutrient uptake and nutritional quality. However, when turmeric is grown using a variety of mulch materials and mulching rates, better interaction can be produced.

CONCLUSION and RECOMMENDATION

Based on the investigation, it was found that sawdust at a rate of 10 t/ha had the highest magnesium mineral concentration (107.97 mg 100 g). Additionally, at a rate of 5 t/ha, soybean mulch produced the maximum potassium nutritional absorption (110.29 mg 100 g). Therefore, sawdust mulch at a rate of 10 t/ha might yield a higher mineral content and soybean mulch at a rate of 5 t/ha could be utilized for turmeric farming communities in the study area to improve nutrient uptake.

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Conflict of Interest

The authors declare no competing interest.

Authors Contribution

The authors contributed immensely to the article.

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