Amazonian Journal of Plant Research *©2017 Universidade Federal do Pará*
This paper is available online free of all access charges – Faculdade de Engenharia Agronômica
https://www.ajpr.online - Amaz. Jour. of Plant Resear. 4(2):587-593 2020

Original Paper

OPEN ACCESS

Quality and yield of turmeric (*Curcuma longa* linn.) in response to mycorrhiza and nitrogen application

Oladiran Olaleye[1] and Olajire Fagbola[2]

1 National Horticultural Research Institute, Jericho Reservation Area, P.M.B. 5432, Ibadan, Nigeria

2 Department of Agronomy, University of Ibadan, Ibadan, Nigeria

Received: 14 April, 2020. Accepted: 11 May, 2020
First published on the web May, 2020
Doi: 10.26545/ajpr.2020.b00068x

Abstract

Turmeric production is greatly hampered by dearth of knowledge of its agronomic requirements in Nigeria, particularly nitrogen requirement and possible enhancement of nutrient uptake by mycorrhiza. Hence, investigations aimed at examining the effect of nitrogen and the contribution of arbuscular mycorrhizal fungi on the yield and nutrient uptake of turmeric were conducted. It was a potted experiment with 5 levels of nitrogen (0, 45, 90, 135 and 180 kg N ha^{-1}), and two levels of mycorrhiza (with and without). The experiment was arranged in a 5 × 2 factorial fitted into a completely randomized design with three replications. Data were obtained on the dry biomass yield, rhizome yield, curcumin content of the rhizome, nitrogen, phosphorus, calcium, magnesium and potassium uptake in the shoot. A repeat experiment was conducted using the best two treatments and the control in a 3 × 2 factorial experiment replicated thrice. All data were subjected to analysis of variance using SAS PROC. GLM and significant treatment means separated using LSD values. Applications of nitrogen and mycorrhiza independently and in combinations significantly enhanced the yield and curcumin content of turmeric. The rhizome yield in the mycorrhiza infested soil was not significantly different with the non application of mycorrhiza but there was an increase of approximately 15 % in the rhizome yield in the mycorrhiza infested soil. Application of 180 kg N ha^{-1} with mycorrhiza gave the highest biomass and rhizome yield and as such is the most suitable for turmeric production.

Key-words: Curcumin, Nitrogen, Nutrient Content, Turmeric, Mycorrhiza

Introduction

Turmeric (*Curcuma longa* Linn.) is rhizomatous spice crop, native to tropical Southeast Asia. Its centre of domestication is probably the Indian subcontinent (Bose et al., 2008). It is cultivated in diverse tropical conditions up to 1600 m above sea level with a temperature range of 20 to 40 ^{0}C and rainfall above 1500 mm (Olojede et al., 2005).

Turmeric is usually grown for its culinary, cosmetic and medicinal purposes. It is the major ingredient used for curry meant for adding flavour to meals. It can also be used in dye and/or as colouring agent. The medicinal properties of this spice have been exploited over the centuries. The main active compound of turmeric is curcuminoids, and curcumin is the most active curcuminoids found in it. Research has shown that turmeric can be used in treatment of so many medical problems and conditions ranging from constipation to skin diseases, used in the treatment of wounds, infection, dysentery, arthritis, jaundice, liver problems, cancer and Alzheimer's diseases (Hermann and Martine, 1991; Osawa et al., 1995).

Nitrogen (N) is an important nutrient element required by plants. It is a major part of all amino acids, which are the building blocks of all proteins,

Oladiran Olaleye
E-mail: oladiran03@yahoo.com

including the enzymes, which control virtually all biological processes. It is also essential for carbohydrate use within plants.

The beneficial effect of mycorrhiza inoculation in plant nutrient uptake has been studied extensively (Arihara, 2000; Fagbola et al., 1998; Kabir and Koide, 2000; Osonubi et al., 1995). Among the benefits of mycorrhiza to plant include: increased nutrient uptake, tolerance to drought and synergistic interaction with other beneficial soil microorganisms. However, there is little or no information on the contributions of mycorrhiza on nutrient uptake of turmeric. This study was therefore aimed at determining the effect of nitrogen in combination with mycorrhiza on the quality, yield and nutrient uptake of turmeric.

Materials and Methods

It was a pot experiment conducted at the National Horticultural Research Institute (NIHORT), Ibadan using approximately 5 kg soil. Pre-cropping soil analysis was done using standard procedures: soil pH in water, total N by Kjeldahl approach, available P using Bray- P1 extraction followed by molybdenum blue colorimetry, Exchangeable K, Ca and Mg were extracted using ammonium acetate, K was determined on flame photometer and Ca and Mg by EDTA titration. Soil organic matter was determined by wet dichromate method.

The experiment was a 5 × 2 factorial arranged in a completely randomized design. The experiment was replicated three times with two plants per replicate. The factors include 5 levels of N (0, 45, 90, 135 and 180 kg N ha^{-1}), and two levels of mycorrhiza (with and without mycorrhiza). The mycorrhiza was applied at planting with the turmeric rhizome while the N was applied at 2 equal split dose - a month and 3 months after planting. The source of the N was urea. The experiment was repeated using the best two treatments from the first experiment with the control in a 3 × 2 factorial experiment with three replicates. Data were collected on rhizome yield, curcumin content, the dry biomass yield, N, P, Ca, Mg and K uptakes in the shoot.

Plant samples were dried in the oven at a temperature of 65 ^{0}C for 72 hours and thereafter milled into powdery form to determine the plant nutrient content. Phosphorus was determined by digesting with acid mixture i.e. HNO_3 and $HCLO_4$ in ratio 2:1 and the digest was made up to 25 ml with distilled water in a standard volumetric flask. 5ml of aliquot was added. The mixture was made up of 25 ml with distilled water and was later transferred into spectrophotometer at 400 nm wavelength. Nitrogen was determined using the Kjeldhal method and potassium was determined by using atomic absorption spectrophotometer (AAS).

Plant nutrient uptake was determined using the formula: Nutrient uptake (g kg^{-1}) = nutrient content (g kg^{-1}) × dry weight of the biomass

All data were subjected to analysis of variance using SAS software 9.2 version and significant treatment means separated using LSD.

Results

Table I shows the pre-cropping soil analysis which gives a pH of 6.8, the values of the major nutrient elements are as follows: total N 0.9 g kg^{-1}, available P 10 mg kg^{-1}, exchangeable K 0.18 $cmolkg^{-1}$, Ca 1.45 cmol kg^{-1} and Mg 0.72 cmol kg^{-1} (Table 1).

Inoculation with mycorrhiza significantly enhanced the curcumin content, N, P and K uptakes. There was no significant difference in the rhizome yield, Ca and Mg uptakes, although there was approximately 15% increase in the yield due to mycorrhiza inoculation (Table 2).

Table 1. Pre-cropping physical and chemical properties of the soil.

Soil properties	Value
pH (H_2O)	6.8
Ca (cmol kg^{-1})	1.45
Mg (cmol kg^{-1})	0.72
Na (cmol kg^{-1})	0.21
K (cmol kg^{-1})	0.18
ECEC (cmol kg^{-1})	13.92
Org C (g kg^{-1})	10.1
Total N (g kg^{-1})	0.9
Av. P (mg kg^{-1})	10
Cu (mg kg^{-1})	2.02
Zn (mg kg^{-1})	7.20
Fe (mg kg^{-1})	115
Mn (mg kg^{-1})	177.8
Sand (g kg^{-1})	802
Silt (g kg^{-1})	150
Clay (g kg^{-1})	48

Table 2. Effect of mycorrhiza on the curcumin, N, P, Ca, Mg, K, biomass and rhizome yield of turmeric under pot experiment.

Mycorrhiza	Curcumin	N	P	Ca	Mg	K	Biomass Yield	Rhizome Yield
	%			g kg^{-1}			g pot^{-1}	
M+	1.33	77.1	2.3	133.9	3.1	69.3	5.26	100.08
M-	1.24	58.1	1.8	126.7	2.8	57.5	4.57	87.03
LSD	0.03	10.1	0.3	NS	NS	0.9	0.67	NS

M+ - with mycorrhiza inoculation M- - without mycorrhiza inoculation

Table 3. Effect of different rates of nitrogen on the curcumin, N, P, K, Ca, Mg, biomass and rhizome yield of turmeric under pot experiment.

Nitrogen	Curcumin	N	P	Ca	Mg	K	Biomass Yield	Rhizome Yield
kg/ha	%			g kg^{-1}			g pot^{-1}	
0	0.66	40.0	1.4	97.9	2.7	52.1	3.19	65.19
45	0.86	49.2	1.7	109.0	3.1	61.9	4.12	94.41
90	1.19	65.0	2.2	152.0	3.1	53.2	5.18	94.8
135	2.10	85.0	2.7	151.5	2.7	67.0	5.75	104.79
180	1.62	98.9	2.5	141.3	3.2	82.6	6.33	108.6
LSD	0.044	16.0	0.5	28.1	NS	14.4	1.06	21.1

Significant differences ($p<0.05$) was observed in all parameters with the application of N (Table 3). Application of 135 kg N ha^{-1} gave a significantly higher percentage curcumin content compared with other rates, the significant difference was in the other 135 kg N ha^{-1} > 180 kg N ha^{-1} > 90 kg N ha^{-1} > 45 kg Nha^{-1} > 0 kg Nha^{-1}.

The highest N uptake was observed with the application of 180 kg N ha^{-1} and this was significantly higher compared with other treatments except 135 kg N ha^{-1}. The lowest difference in the N uptake with nitrogen application was with 0 kg N ha^{-1}, however this was not significantly different from 45 kg N ha^{-1}. Application of 135 kg N ha^{-1} gave the highest P uptake but this was similar to the applications of 180 and 90 kg N ha^{-1}. The lowest P uptake was with 0 kg N ha^{-1}.

The highest Ca uptake was with the application of 90 kg N ha^{-1}, however this was not significantly different from the applications of 135 and 180 kg N ha^{-1}. There was no significant difference in the Mg uptake among the treatments.

The highest biomass yield resulted from the application of 180 kg N ha^{-1} but this was not significantly different from the application of 135 kg N ha^{-1} while a significantly lower biomass yield resulted from the application of 0 kg N ha^{-1} but this was not significantly different from the application of 45 kg N ha^{-1}. Application of 90 and 135 kg N ha^{-1} were not significantly different from each other with respect to biomass yield. The application of 180 kg N ha^{-1} gave the highest rhizome yield, this was however not significantly different from other treatments except 0 kg N ha^{-1} that was significantly lower.

There were significant interactions ($p< 0.05$) between the nitrogen levels with and without mycorrhiza inoculation in all the parameters observed except for the rhizome yield (Table 4). Application of 135 kg N ha^{-1} without mycorrhiza gave a significantly higher curcumin content compared with other treatments and a significantly lower curcumin content was observed with the application of 0 kg N ha^{-1} with mycorrhiza application. A significantly higher N uptake was observed with the interaction of 180 kg N ha^{-1} with mycorrhiza application compared with other treatments except the application of 135 kg N ha^{-1} with mycorrhiza.

The lowest N uptake was with 0 kg N ha^{-1} without mycorrhiza, this was however, not significantly different from the applications of 0 kg N ha^{-1} with mycorrhiza and 45 kg N ha^{-1} with and without mycorrhiza.

Table 4. Interaction of nitrogen and mycorrhiza on the curcumin, N, P, Ca, Mg, K, biomass and rhizome yield of turmeric under pot.

Nitrogen kg/ha	Mycorrhiza	Curcumin	N	P	Ca	Mg	K	Biomass Yield	Rhizome Yield
			%		g kg^{-1}			g pot^{-1}	
N0	M+	0.55	41.3	1.5	106.5	2.8	55.8	3.34	72.39
N0	M-	0.78	38.7	1.3	89.2	2.6	48.3	3.04	57.99
N1	M+	1.07	54.1	1.9	104.4	3.4	65.0	4.47	96.00
N1	M-	0.65	44.3	1.5	113.5	2.9	58.9	3.76	92.79
N2	M+	1.23	66.0	2.3	146.8	3.2	59.4	5.31	98.01
N2	M-	1.16	64.0	2.1	157.3	3.0	47.0	5.05	91.59
N3	M+	1.97	104.3	3.2	157.8	3.1	77.2	6.58	114.00
N3	M-	2.23	65.8	2.1	145.2	2.3	56.9	4.91	95.61
N4	M+	1.84	120.0	2.7	154.1	3.4	89.1	6.59	120.00
N4	M-	1.40	77.9	2.2	128.5	3.1	76.2	6.08	97.20
LSD		0.063	21.1	0.62	38.2	0.9	19.0	1.4817	NS

Legend N0 - 0 kg N ha^{-1} N1 - 45 kg N ha^{-1} N2 - 90 kg N ha^{-1} N3 - 135 kg N ha^{-1} N4 - 180 kg N ha^{-1}
M+ -with mycorrhiza M- - without mycorrhiza

The highest P uptake was observed with the application of 135 kg N ha^{-1} with mycorrhiza application and this was significantly higher than other treatments except 180 kg N ha^{-1} with mycorrhiza. A significantly lower P uptake was observed with the application of 0 kg N ha^{-1} without mycorrhiza application. The highest Ca uptake was obtained with the application of 135 kg N ha^{-1} with mycorrhiza which was not significantly different from other treatments except the application of 0 and 45 kg N ha^{-1} with and without mycorrhiza application that was significantly lower. Application of 180 kg N ha^{-1} with mycorrhiza gave the highest Mg uptake while the lowest was with 135 kg N ha^{-1} without mycorrhiza. Application of 180 kg N ha^{-1} with mycorrhiza gave a significantly higher K uptake compared with other treatments except the applications of 135 kg N ha^{-1} with mycorrhiza and 180 kg N ha^{-1} without mycorrhiza application. A significantly lower K uptake was observed with the application of 90 kg N ha^{-1} without mycorrhiza.

A significantly higher biomass yield was obtained with the application of 180 kg N ha^{-1} with mycorrhiza but this was not significantly different from the application of 180 kg N ha^{-1} without mycorrhiza and application of 135 kg N ha^{-1} with mycorrhiza. Significantly lower biomass yield was obtained with the application of 0 kg N ha^{-1} without mycorrhiza but this was not significantly different from the application of 0 kg N ha^{-1} with mycorrhiza and application of 45 kg N ha^{-1} with and without mycorrhiza. The rhizome yields were not significantly different from each other with the application of different levels of N with and without mycorrhiza.

In the repeat experiment, although there was an increase in curcomin content, Mg uptake and rhizome yield were not significantly influenced by mycorrhiza inoculation (Table 5). However, other parameters were significantly influenced by mycorrhiza inoculation. With N application, the highest curcumin content was with the application of 135 kg N ha^{-1} which was similar with the application of 180 kg N ha^{-1} while 0 kg N ha^{-1} was significantly lower (Table 6). The N uptake was in the order 180 kg N ha^{-1} > 135 kg N ha^{-1} > 0 kg N ha^{-1}. The highest P uptake was with 180 kg N ha^{-1} which was similar with 135 kg N ha^{-1}. Applications of 135 kg N ha^{-1} and 180 kg K ha^{-1} were also similar in Ca and K uptakes while 0 kg N ha^{-1} was significantly lower. There was no significant difference among the treatments with respect to Mg uptake and rhizome yield. The biomass yield was in the order 180 kg N ha^{-1} > 135 kg N ha^{-1} > 0 Kg N ha^{-1}.

The highest curcumin content with N and mycorrhiza interaction was with 135 kg N ha^{-1} with mycorrhiza which was only significantly higher than 0 kg N ha^{-1} with and without mycorrhizal inoculation (Table 7). A significantly higher N uptake was with the application of 180 kg N ha^{-1} with mycorrhiza compared with other treatments.

The lowest N uptake was with 0 kg N ha^{-1} without mycorrhiza. The highest P uptake was obtained with 135 kg N ha^{-1} with mycorrhiza while 0 kg N ha^{-1} without mycorrhiza gave the lowest P uptake. The highest Ca and K uptakes were observed with 180 kg N ha^{-1} with mycorrhiza while 0 kg N ha^{-1} without mycorrhiza gave the lowest Ca and K uptakes. There was no significant difference among the treatments with respect to Mg uptake and rhizome yield. The highest biomass yield was obtained with 180 kg N ha^{-1} with mycorrhiza. The lowest biomass yield was with 0 kg N ha^{-1} without mycorrhiza but was not significantly different from 0 kg N ha^{-1} with mycorrhiza.

Table 5. Effect of mycorrhiza on the curcumin, N, P, Ca, Mg, K, biomass and rhizome yield of turmeric under second pot experiment.

Mycorrhiza	Curcumin	N	P	Ca	Mg	K	Biomass Yield	Rhizome Yield
	%			g kg^{-1}			g pot^{-1}	
M+	2.32	110.00	2.72	150.1	4.4	90.8	6.22	115.64
M-	2.15	71.21	2.21	120.1	3.1	65.4	5.40	113.69
LSD	NS	10.80	0.30	14.4	NS	6.7	0.56	NS

M+ - with mycorrhiza inoculation M- - without mycorrhiza inoculation

Table 6. Effect of nitrogen on the curcumin, N, P, K, Ca, Mg, biomass and rhizome yield of turmeric under second pot experiment.

Nitrogen	Curcumin	N	P	Ca	Mg	K	Biomass Yield	Rhizome Yield
kg/ha	%			g kg^{-1}			g pot^{-1}	
0	1.78	43.4	1.57	101.82	3.21	60.25	3.55	82.93
135	2.53	102.7	2.9	156.32	4.21	84.99	6.55	129.52
180	2.4	125.6	2.91	147.14	3.84	88.92	7.32	131.54
LSD	0.3	1.32	0.37	17.68	NS	8.15	0.69	44.45

Table 7. Interaction of nitrogen and mycorrhiza on the curcumin, N, P, Ca, Mg, K, biomass and rhizome yield of turmeric under second pot experiment.

Nitrogen kg/ha	Mycorrhiza	Curcumin %	N	P	Ca	Mg	K	Biomass Yield	Rhizome Yield
					g kg^{-1}			g pot^{-1}	
N0	M+	1.92	52.1	1.90	127.36	4.01	75.60	4.22	91.05
N0	M-	1.64	34.8	1.24	76.29	2.41	44.90	2.87	74.8
N3	M+	2.58	118.6	3.24	156.82	5.53	90.47	6.86	118.22
N3	M-	2.47	86.8	2.57	155.82	2.89	79.51	6.24	140.82
N4	M+	2.46	159.3	3.02	166.09	3.60	106.18	7.58	137.64
N4	M-	2.33	92.0	2.79	128.20	4.08	71.66	7.07	125.45
LSD		0.51	37.11	0.99	47.13	NS	28.23	2.14	NS

Legend N0 - 0 kg N ha^{-1} N1 - 45 kg N ha^{-1} N2 - 90 kg N ha^{-1} N3 - 135 kg N ha^{-1} N4 - 180 kg N ha^{-1}
M+ -with mycorrhiza M- - without mycorrhiza

Discussion

The pre-experimental physical and chemical properties of the soil indicated that it was near neutral (pH of 6.8). The N and K content in the soil were very low and below the recommended critical levels of 1.5g kg^{-1} N, and 0.34 cmol kg^{-1} K (Adeoye and Agboola, 1985; Aduayi et al., 2002), hence the need for additional nutrient amendments to the soil.

It was observed that mycorrhiza enhances the curcumin, N, P, Ca, K uptakes and consequently enhanced the biomass yield and increased the rhizome yield of turmeric in both trials/ Turmeric Plant (Figure 1). This could be attributed to the beneficial effect of mycorrhiza as observed on various root crops (Dare et al., 2007; Prabawardanie et al., 2012; Salami et al., 2005; Yamawaki et al., 2013). Application of 180 kg N ha^{-1} resulted in the highest N and K uptakes in the biomass, this implies that the more the N was available in the root zone the more the plants utilization. There was also an increase in the uptakes of other nutrients with N application.

Fig. 1. Turmeric Plant

This culminated in the highest biomass and rhizome yield during the two trials. The highest K uptake was observed without the application of N giving the available K in the root zone enough space to express itself. The highest curcumin and P uptake resulted from the application of 135 kg N ha^{-1}, this also gave a biomass and rhizome yield that was not significantly different from the application of 180 kg N ha^{-1}. This implies that the application of 135 kg N ha^{-1} might be suitable for turmeric production, however, Prabhakaran Nair (2013) noted that the response of turmeric to N application varies with geographical location, type of soil, method of cultivation and the irrigation schedule.

Addition of 135 kg N ha^{-1} without mycorrhiza gave the highest curcumin content in the rhizome in the first trial and 135 kg N ha^{-1} with mycorrhiza gave the highest curcumin content in the second trial, indicating that mycorrhiza inoculation effect on the curcumin content of the plant might require more investigations. It was also observed that the application of mycorrhiza with N enhances the P content in the biomass. This could be associated with an increase in the acquisition of P due to mycorrhiza application (Kwapata and Hall, 1985; Osonubi et al., 1995). The highest biomass and rhizome yield resulted from the application of 180 kg N ha^{-1} with mycorrhiza but was similar with the application of 135 kg N ha^{-1} with mycorrhiza in both trials.

Conflict of interest: The authors declared that there was no conflict of interests regarding the publication of this paper.

References

Adeoye, G.O.; Agboola, A.A. 1985. Critical levels for soil pH, available P, K, Zn and Mn and maize ear leaf content of P, Cu and Mn in sedimentary soils of each south western Nigeria. Fertilizer Research 6: 65-71

Aduayi, E.A.; Chude, V.O.; Adebusuyi, L O.; Olayiwola, S.O. 2002. Fertilizer use and management practices for crops in Nigeria. Federal Ministry of Agriculture and Rural Development, Abuja

Arihara, J. 2000. Cropping systems and their mechanisms of nutrient uptake. Extension bulletin 491. Food fertilizer technology center. 18pp

Bose, P.; Sanyal, D.; Majumdar, K. 2008. Balancing sulfur and magnesium nutrition for turmeric and carrot grown on red lateritic soil. Better Crops 92(1): 23-25

Dare, M.O.; Abaidoo, R.C.; Fagbola, O.; Asiedu, R. 2007. Variability of yam (*Dioscorea* spp.) genotypes in root colonization by arbuscular mycorrhiza in the yam belt of Nigeria. African Crop Science Proceedings 8: 629 - 638

Fagbola, O.; Osonubi, O.; Mulongoy, K. 1998. Contribution of arbuscular mycorrhizal (AM) fungi and hedgerow trees to the yield and nutrient uptake of cassava in alley-cropping system. Journal of Agricultural Sciences 131: 79-85

Hermann, P.T.A.; Martin, A.W. 1991. Pharmacology of *Curcuma longa*. Planta Medicine.57: 1-7

Kahir, Z.R.; Koide, T. 2000. The effect of dandelion or a cover crop on mycorrhizal inoculums potential, soil aggregation and yield of maize. Agricultural Ecosystem and Environment 78: 167-174

Kwapata, M.B.; Hall, A.E. 1985. Effects of moisture regime and phosphorus on mycorrhizal infection, nutrient uptake and growth of cowpeas (*Vigna unguiculata* L.). Field Crops Research, 12:241-250

Olojede, A.O.; Iluebbey P.; Dixon, A.G.O. 2005. IITA/NRCRI Collaborative Germplasm and Data Collection on root and tuber crops in Nigeria. *NRCRI Annual Report*, 2005. Pp 77-81

Osawa, T.; Sugiyama, Y.; Inayoshi, M.; Kawakishi, S. 1995. Antioxidative activity of tetrahydrocurcuminoids. *Bioscience Biotechnology Biochem*istry 59: 1609-1612

Osonubi, O.; Atayese, M.O.; Mulongoy. K. 1995. The effect of vesicular-arbuscular mycorrhizal inoculation on nutrient uptake and yield of alley-cropped cassava in degraded Alfisol of southwestern Nigeria. Biological Fertile Soils 20: 70-76

Prabawardani S.; Wasgito D.P.; Nouke, L.M. 2012. The effectiveness of AM fungal in improving the tolerance of sweet potato plants to drought stress. International Conference on Agricultural, Environment and Biological Sciences (ICAEBS'2012) May 26-27, 2012. Phuket

Prabhakaran Nair, K.P. 2013. The Agronomy and Economy of Turmeric and Ginger. The Invaluable Medicinal Spice Crops. First edition Pp 97 - 103. Elsevier Insight

Salami, A.O.; Odebode, A C.; Osonubi, O. 2005. The use of arbuscular mycorrhizal (AM) as a source of yield increase in sustainable alley cropping system. Archives of Agronomy and Soil Science, 51(4): 385-390

Yamawaki, K.; Matsumura, A.; Hattori, R.; Tarui, A.; Hossain, M.A.; Ohashi, Y.; Daimon, H. 2013. Effect of inoculation with arbuscular mycorrhizal fungi on growth, nutrient uptake and curcumin production of turmeric (*Curcuma longa* L.). Agricultural Sciences (2): 66-71

Cite this article as:

Olaleye, O.; Fagbola, O. 2020. Quality and yield of turmeric (*Curcuma longa* linn.) in response to mycorrhiza and nitrogen application **Amaz. Jour. of Plant Resear.** 4(2): 587-593.

Submit your manuscript at
https:// www.ajpr.online