GROWTH, YIELD AND QUALITY OF TURMERIC (*CURCUMA LONGA LINN.*) AS INFLUENCED BY NITROGEN FERTILIZER RATES AND NITROGEN SPLIT APPLICATION IN OBUBRA, SOUTH-SOUTH NIGERIA

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ABSTRACT: *Most of southern parts of Nigeria normally receives high annual rainfall. Even under best management practices, approximately 30-50% of applied nitrogen is lost through leaching thereby making it unavailable during the critical stages of crop growth. The objective of this research was to investigate the optimum rates of Nitrogen fertilizer and Nitrogen split application that will support maximum growth, yield and quality of turmeric. Field experiments were conducted in 2016 and 2017 in the research farm of Cross River University of Technology, Obubra. Treatments consisted of five Nitrogen rates (0, 50, 100, 150 and 200 kg N ha^{-1}) and five Nitrogen split applications (Sp1; Sp2; Sp3; Sp4 and Sp5)). The experiment was laid out in split plot design with three replicates. Growth and yield attributes were significantly (P<0.05) affected by Nitrogen rates and Nitrogen split application. The fresh and dry rhizome yield, oleoresin content and essential oil content were highest at 200 kg N ha^{-1}and 150 kg N ha^{-1} in three equal split application (SP3) in both years.*

KEYWORDS: turmeric, nitrogen fertilizer rate, split application, rhizome yield.

INTRODUCTION

Turmeric (*Curcuma longa L.*) commonly known as turmeric, is a tropical perennial monocotyledonous herb belonging to the family Zingiberaceae. Principally, turmeric has a wide range of values such as orange coloring powder in textile industry, food industry, medicinal values, flavor and for its oleoresin. A dry turmeric contains about 69.43% carbohydrate, 6.30% protein, 5.1% oil, 3.5% mineral and other important elements (Shakur, 2000). It is an ancient, most valuable, sacred spice that contains appreciable quantities of proteins (6.3%), lipids (5.1%), carbohydrates (69.4%) and fiber (2.6%). Moreover, it is rich in minerals like phosphorus, calcium, iron and vitamin A. Curcumin as an active ingredient present in turmeric (3-5%) which is responsible for biological activity and acts as a coloring agents to food, fiber, wood and several preparations. According to Shrimal (1997) turmeric is used traditionally as a natural medicine due to its anti-inflammatory, anti-bacterial, anti-fungal and anti-tumor activities.

The production and productivity of turmeric crop is still low in Nigeria as compared to other major producer countries. This production gap is due to several factors among which are declining soil fertility, shortage of appropriate and adequate research information. Several studies reported that turmeric is a nutrient exhaustive crop; especially as it is a heavy feeder of N (Singh et al., 2001; Agere and Shiferaw, 2015). The high nutrient requirements of turmeric are due to their shallow rooting and potential to produce large amount of dry matter per unit area (Singh et al., 2001). In addition, the crop has a prolonged growing period (8-9 months) therefore, the nutrient requirement period also becomes prolonged. Nitrogen is commonly the most limiting nutrient for crop production. Several studies reported that application of nitrogen had significant effect on growth, yield and yield component of turmeric (Hikaru et al.,2007; Agere and Shiferaw, 2015). Split application of nitrogen has been observed as one of the strategies of improving nitrogen use by the crops and ensures nutrient availability throughout the active growth stages of turmeric (Jagadeeswaran et al.,2004). The growth period of turmeric can be divided into four phases: a phase of moderate vegetative growth, a phase of active vegetative growth, a period of slow vegetative growth and a phase approaching senescence. Usually, as dry matter increases, the uptake also increases, and the phase of active vegetative growth is also the period during which maximum uptake of nutrients takes place. Even under best management practices, approximately 30-50% of applied nitrogen is lost through different agencies hence, the farmer is compelled to apply more than what the crop needs to compensate for losses through leaching, volatilization, and denitrification making the nutrient unavailable during the critical stages of crop growth. N fertilization and its management techniques on this spice crop is required due to its high N requirement and long duration (8 to 9 months) to attain its physiological maturity. Most of southern parts of Nigeria normally receives high annual rainfall. Even under best management practices, approximately 30-50% of applied nitrogen is lost through leaching thereby making it unavailable during the critical stages of crop growth. N fertilization and its management techniques on this crop is required.

Previous recommendation on N rate for turmeric did not consider the time or frequency of application. Accordingly, this research was initiated to determine the optimum rate of N fertilizer and the right time of N split application that allow maximum growth and yield of turmeric.

MATERIALS AND METHODS

Description of Study Site

Field experiments were carried out during 2016 cropping season and was repeated in 2017, in the Research Farm of Cross River University of Technology, Obubra, located between latitudes 5^o 59′ and 8^o 20′ N and longitudes 6^o 08′ and 8^o 16′ E, Nigeria. Total annual rainfall of 2160 mm in 2016 and 2506 mm in 2017 was recorded during the period of the experiment (May to December).

Experimental Design and Treatments

The experiment was laid out in split plot design with three replicates. The main plot treatment was the N rates whereas the sub-plot treatment was N split application. Treatments consisted of two factors; N rates (0, 50, 100, 150 and 200 Kg N ha^{-1}) and split applications of N (100% complete at emergence (Sp1); 50% at emergence + 50% at 8 Weeks After Planting (WAP) (Sp2); 33.3% at emergence + 33.3% at 8 WAP + 33.3% at tillering stage (Sp3); 25% at emergence + 25% at 8 WAP + 25% at tillering stage + 25% at 16 WAP (Sp4) and 20% at emergence + 20% at 8 WAP + 20% at tillering stage + 20% at 16 WAP + 20% at 20 WAP (Sp5). Each plot was 1.8 m x 1.8 m (3.24 m^2) and consisted of six rows of 1.8 m in length and spaced 30 cm apart.

DATA COLLECTION

Soil sampling and processing: Before planting, a composite soil sample was taken randomly in a zigzag pattern from the entire experimental field using auger to the depth of 0 -30 cm from the top soil layer for both years. The samples were air-dried, sieved through a 2mm mesh and used for the determination of physico-chemical properties.

Soil analysis: In the laboratory, the soil samples collected were subjected to routine analyses at the soil science laboratory of the National Root Crop Research Institute, Umudike, Nigeria. Particle size distribution was determined by the Bouyoucos (hydrometer) hydrometer method as described by Udo et al., (2009). Soil pH was determined from the filtered suspension of 1:2.5 soils to water ratio using a glass electrode attached to a digital pH meter [potentiometer] (Page, 1982). Soil organic carbon content was determined by the wet digestion method as described by Walkley and Black (1954). Total nitrogen was determined using Kjeldhal method (Jackson, 1986). Available phosphorus was determined by the molybdate blue colorimetry method using Spectrophotometer (Olsen,1954). The cation exchange capacity (CEC) was measured after saturating the soil with 1N ammonium acetate (NH4 OAC) and displacing it with 1N NaOAC (Chapman, 1965).

Plant Sampling: A net plot of four middle rows in each plot with 10 tagged plants each was used for data collection and measurements. Data from the ten sampled plants from the inner rows were collected and used for the determination of number of tillers plant-1, number of leaves plant^{-1}, number of mother, primary and secondary rhizome plant^{-1}, weight of mother, primary and secondary finger rhizomes (g plant^{-1}), total above-ground biomass (tons ha^{-1}), fresh rhizome yield (kg ha^{-1}) and dry rhizome yield (kg ha^{-1}). Number of mother rhizomes and finger (primary and secondary) rhizomes were counted during harvesting from sampled plants, after separating the primary and secondary rhizomes from their mother rhizome. Weight of mother and finger rhizomes (g plant^{-1}) was determined during harvesting from sampled plants, rhizomes were cleaned after harvesting and weighed separately using an electronic balance. Fresh rhizome yield was calculated from total (mother, primary and secondary) rhizome weight of sampled plants and the data were expressed in Kg ha^{-1}. The dry rhizome yield (Kg ha^{-1}) was computed after the rhizomes were dried and weighed using an electronic balance. Total fresh biomass (leaves and rhizome) yield was determined by harvesting sampled plants in the net plot area at the ground level with their rhizomes and weighed separately [shoot fresh weight (g plot^{-1}) and rhizome fresh weight (g plant^{-1})]. The dry biomass (leaves and rhizome) yield was determined after the samples were first air-dried and further dried in a ventilated oven at 70 ^{0}C for 24 hours and weighed using an electronic balance. The dry biomass yield was determined after weighing separately and summing up the shoot fresh weight (g plot $^{-1}$) and rhizome fresh weight (g plant^{-1}).

Harvest Index (HI) was calculated as the ratio of rhizome yield to the total biomass yield, and is expressed as a percentage as described by Donald, (1962) to ascertain the productivity or yield of the crop. The above-ground biomass (leaves) and rhizomes were collected from eight sample plants. Weighed using an electronic balance and the yield was converted in plot basis and HI was calculated as follow; **HI (%) = (Rhizome Yield) x 100 / (Total Biomass Yield).**
For quality parameters analysis, the rhizomes were washed, boiled at 100 ^{0}C for 45 minutes. Then, after drying in a ventilated oven at 70 ^{0}C for 48 hours, the rhizomes were ground into a fine powder. Powder of eight sample plants were mixed together for each treatment. Both oleoresin content and essential oil were measured for each treatment using solvent extraction and hydro-distillation method, respectively based on American Spice Trade Association procedure (ASTA, 2002). The oleoresin content was calculated as follows:

Oleoresin content (%) = Weight of oil (g) X 100 / Weight of rhizome sample taken (g).
In case of essential oil, Clevenger apparatus was used to determine percentage of volatile oils present in the oil-bearing plants and their parts. Essential oil content was calculated as follows:
Essential oil content (%) = Weight of essential oil recovered (g) X 100 / Weight of rhizome sample distilled (g).

Statistical Analysis: Analysis of Variance for Split Plot design was performed using the computer software Genstat, (2005 Edition). F-LSD was calculated at the probability levels of $P<0.05$ and $P>0.01$ to separate the means.

RESULTS AND FINDINGS

Pre-treatment soil properties

Results of pre-planting soil properties before the application of treatments is presented in Table 1. The soil was sandy-loam classified as an Alfisol (Tropulstalf). The average soil chemical properties for the two years was 2.82% organic matter; 0.13% N; 16.33 ppm available P; 0.47 Cmol exchangeable K; 0.15 Cmol Na; 2.43 Cmol Ca; 1.16 Cmol Mg and a pH of 5.88 (1: 2.5, soil: water). The pH (H_2O) of the experimental soil was slightly acidic. FAO (2000) reported that the preferable pH ranges for most crops and productive soils are 4 to 8. Thus, the pH of the experimental soil was within the range for productive soils. The organic matter (OM) content of the soil at planting was 2.82%. The soil of the study area falls under moderate OM level as classified by Murphy (1968). Similarly, total N of the experimental field was 0.15%, thus the soil falls under the low N fertility class of Landon (2014). The CEC of the experimental soil was 95.5 Cmole Kg^{-1}. This falls under the very high CEC class of Landon (2014). The cation exchange capacity (CEC) of soil is due to both the clay and to the organic matter it contains. Therefore, this very high CEC of the experimental soil might be due to having high clay and humus content. The organic carbon (OC) content of the experimental soil at planting was 1.69%. Thus, the soil of the study area falls under very low OC level as per the classification of Landon (2014).

Results of leaf number and number of tillers per plant are presented in Table 2. Results showed that nitrogen rate and N-split application significantly ($P<0.05$) affected the leaf number and tiller number produced per plant. The maximum number of leaves and tillers (17.12; 17.44 and 5.37; 5.97 during 2016 and 2017, respectively) were obtained when 150 kg N ha^{-1} and 200 kg N ha^{-1} were applied in 2016 and 2017, respectively and was applied in three equal split application (Sp3) followed by the 100 kg N ha^{-1}. Whereas, the lowest leaf and tiller number was obtained from the unfertilized plot.

The leaf area and leaf area index (LAI) of turmeric were significantly ($P<0.05$) affected by N rate and split application of N fertilizer (Table 3). The maximum leaf area per plant (6132.92 cm^2; 6036.40 cm^2 in 2016 and 2017, respectively) was obtained when N was applied at 200 Kg ha^{-1}. applied in three equal splits (Sp3). This was followed by the treatment which received 150 Kg N ha^{-1}in the same splits and 200 Kg N ha^{-1}in two equal splits (half at emergence + half at lag growth stage). While, the lowest leaf area was recorded from the unfertilized plant. The highest leaf area index (13.63 and 12.97 cm^2 cm^{-2} plant $^{-1}$ during 2016 and 2017, respectively) was obtained when 200 and 150 Kg N ha^{-1} was applied in two and three equal split application (Sp2; and Sp3) during 2016 and 2017, respectively. Whereas, the lowest LAI was obtained from the unfertilized plant.

Results of number of mother and finger rhizomes per plant is presented in Table 4. Number of finger and mother rhizomes were significantly ($P<0.05$) affected by N rates and N-Split application both years. The highest number of finger and mother rhizomes were obtained when 200 Kg N ha^{-1} was applied in three equal split application (Sp3), followed by the two equal split application (Sp2). Whereas, the lowest tiller number, number of leaves, number of finger rhizomes and mother rhizomes were obtained from the unfertilized plot.

Weight of fresh mother and finger rhizomes per plant is presented in Table 5. Weight of fresh mother and finger rhizomes per plant were significantly ($P<0.05$) influenced by N rates and N-Split application. The maximum weight of fresh finger and mother rhizomes were recorded when 200 Kg N

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ha^{-1} was applied in three equal split application (Sp3), followed by the two equal split application (Sp2). The lowest fresh weight of mother and finger rhizomes were recorded from the unfertilized plot. Results of fresh rhizome yield and dry rhizome yield is presented in Table 6. Fresh rhizome yield and dry rhizome yield responded significantly (P<0.05) to N rates and N-Split application of fertilizer, as well as interaction of the two factors in both years. The highest fresh rhizome yield (57139. 33; 50822.0 and 56561.71; 53931.1) kg ha^{-1} were obtained when 200 kg N ha-1 was applied in three splits (Sp3) in 2016 and 2017, respectively. Similarly, highest dry rhizome yield of (11427.9; 10164.4 and 11725.94; 10062.1) kg ha-1 were recorded at the same N rate and N-Split of 200 kg N ha-1 at three equal splits application (Sp3).

Dry biomass yield was significantly (P<0.05) influenced by N rates and N-Split application in 2016 and 2017. Nitrogen applied at the rate of 150 kg ha-1 produced significantly higher yields (19537.02; 20123.51 kg ha-1) and (19653.09; 20124.11 kg ha-1) for 2016 and 2017, respectively.

Results of harvest index (HI) and curcumin content is presented in Table 8. HI was not significantly (P>0.05) influenced by N rates and N Split application in 2016 and 2017. However, curcumin content was significantly (P<0.05) influenced by N rates and N-Split application in 2017 while in 2016, curcumin content was influenced by N-Split application only.

Results of Oleoresin and Essential oil contents is presented in Table 9. Oleoresin content was significantly (P<0.05) higher (15.2; 14.92 %) when N was applied at the rate of 100 kg ha-1 and (15.52; 14.55 %) in three split application (Sp3) in 2016 and 2017, respectively. Essential oil content was also significantly (P<0.05) influenced by N rates and N-Split application. N at the rate of 150 kg ha-1 produced maximum essential oil content (2.90; 4.59 %) while Sp3 produced the highest oil for both years.

DISCUSSION

The increase in number of tillers could be due to its marked influence on the capacity of plants to absorb and utilize optimum amount of N in buildup of plant tissue and vegetative growth (Leva et al., 2013). This can also be attributed to the rapid conversion of synthesized carbohydrates into protein and consequently the increase in number and size of growing cells, resulting ultimately in increased number of tillers (Agarwal & Singh 2009). Similar result has also been reported by Modupeola and Olaniyi (2015) who observed that the maximum tiller number was obtained with the application of N up to 120 Kg ha-^{1} on turmeric.

The increase in number of leaves per plant at higher nitrogen could be attributed to the availability of this growth limiting nutrient in right amount that permit leaves to grow vigorously. It can also be explained on the basis of the physiological fact that N plays a major role in protein and nucleic acids synthesis and protoplasm formation. Similar results have been also reported by Attarde et al., (2003) and Modupeola and Olaniyi (2015) who confirmed the highest number of leaves with the application of N up to 120 Kg ha^{-1}.

The increase dry matter yield with higher dose of N might be the reason for N vital role in build-up of new cells and consequently the better growth. Since N is a constituent of chlorophyll and amino acids, and have a role in cell expansion, the increase in yield and dry matter with applied N was expected.

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The increase in number of mother and finger rhizomes per plant resulting from N application on turmeric may be ascribed to its role in growth in general, and tissue differentiation in particular (Marschner, 2002). Similar results were reported by several researchers, who observed that maximum number of mother, primary and secondary rhizomes per plant were obtained with the application of N up to 120 Kg ha^{-1} (Jadhao et al.,2005; Madhuri et al.,2006). Gill et al. (2001) also confirmed the positive effect of N split application. The decline in the number of mother, primary and secondary rhizome in the control plot (0 Kg N ha^{-1}) could be due to decreases in leaf number and leaf area per plant with reduced nitrogen level so that the net photosynthesis might be lower to supply adequate amount of photosynthates to the sinks/rhizomes. Consequently, the number of rhizome and size of primary and secondary rhizomes become reduced, thereby experiencing a declined in the yield and yield attributes. In general, the beneficial effect of soil applied N from 0 to 200 Kg ha^{-1}on yield attributes of turmeric like mother, primary and secondary rhizomes number per plant agrees with the previous findings by Singh et al., (2008); Parthasarathy et al., (2011); Nanda et al., (2012); and Leva et al., (2013).

The increase in fresh weight of mother, primary and secondary fingers rhizome per plant might be due to high number of mother, primary and secondary finger rhizomes per plant. The higher average rhizome yield could be due to more luxuriant growth, more foliage and higher supply of photosynthates which helped in producing bigger rhizomes, hence resulting in higher yields. Similar results were reported by Jadhao et al. (2005) and Madhuri et al. (2006) who obtained the highest fresh weight of mother, primary and secondary finger rhizome per plant with the application of N dose up to 120 Kg ha^{-1}. Moreover, higher dose of N provides the favorable soil nutrient status during the effective crop growth period in desirable quantity. Therefore, the better nutrient status resulted to increased assimilation and translocation of photosynthates that might have manifested in the improvement of growth and yield attributes leading to a greater rhizome weight from treated plants (Haque et al.,2007). In general, the beneficial effect of soil applied N from 0 to 150 Kg ha^{-1} on yield attributes of turmeric like mother and finger rhizome weight per plant agree with the findings of earlier authors (Nanda et al.,2012; Leva et al.,2013). Whereas, the lowest fresh and dry rhizome yield were recorded from plots treated with 0 Kg N ha-1. Considering the response of turmeric in rhizome yield in this study, it appears the N fertilizer threshold for high turmeric rhizome yield is high. The results showed that N application in splits provided increased growth and yield than one time (full dose) N application. Split N use especially when the last split was scheduled near the phase with high N demand could have more likelihood of being deposited in sink than in other vegetative organs helping development of sink and ultimately the yield parameters. It has been also reported that the highest rhizome yield was found when N was applied in three equal splits, which was significantly higher than in full and two split applications (Gill et al.,2001). Similar results were reported by several authors, who observed an increase in vegetative growth and yield attributes with the increase in application rates of N and the highest rhizome yield was recorded with the application of N up to 120 Kg ha^{-1} (Sanwal et al.,2007; Modupeola and Olaniyi, 2015; Ojikpong, 2018).

CONCLUSION

The higher rates of nitrogen fertilizer and the split application of N were found to be efficient in increasing the yield of turmeric plant. Higher dose of N provided the favorable soil nutrient status during the effective crop growth period in desirable quantity. The better nutrient status resulted to increased assimilation and translocation of photosynthates that might have manifested in the improvement of growth and yield attributes leading to a greater rhizome yield. Split application of N, especially when the last split was scheduled near the phase with high N demand greatly impacted on the growth and ultimately the yield of turmeric.

Table 1: Some Mechanical and Chemical Properties of the Soil of Experimental Sites

Parameter Description	2016	2017	MEAN
Mechanical properties			
Sand (%)	65.8	63.4	**64.6**
Clay (%)	11.4	14.0	**12.7**
Silt (%)	22.8	22.6	**22.7**
Textural Class	Sandy Loam	Sandy Loam	
Chemical Properties			
Soil pH (1: 2.5; soil: water)	6.20	5.56	**5.88**
Total Nitrogen (%)	0.10	0.15	**0.13**
Available Phosphorus (mg Kg-1)	16.66	15.99	**16.33**
Organic Matter (%)	2.65	2.99	**2.82**
Organic Carbon (%)	1.65	1.73	**1.69**
Exchangeable Bases (Cmole/Kg)			
Ca	2.65	2.20	**2.43**
K	0.39	0.54	**0.47**
Na	0.13	0.17	**0.15**
Mg	1.25	1.06	**1.16**
Cation Exchange Capacity (Cmole Kg^{-1})	95	96	**95.5**

Table 2. Effects of N Rates and N Split Application on Leaf Number and Tiller Number.

Treatments	Leaf Number		Tiller Number	
N Rates (kg/ha)	**2016**	**2017**	**2016**	**2017**
0	9.61	9.84	3.37	3.39
50	13.65	13.67	4.51	4.32
100	14.03	14.47	4.74	4.76
150	17.12	15.13	5.37	5.34
200	17.47	17.44	5.66	5.97
LSD (0.05)	0.81	0.88	0.48	0.52
N Split Application				
SP1	14.23	13.41	4.68	4.66
SP2	14.45	14.50	5.04	5.09
SP3	15.57	16.05	5.17	5.37
SP4	13.90	14.28	4.60	4.54
SP5	12.73	12.31	4.15	4.17
LSD (0.05)	0.61	0.78	0.34	0.64
N Rate X N Split				
LSD (0.05)	NS	1.01	NS	NS

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Table 3. Effects of N Rates and N Split Application on Leaf Area and Leaf Area Index.

Treatments	Leaf Area (cm^2)		Leaf Area Index ($cm^2\ cm^{-2}$)	
N Rates (kg/ha)	**2016**	**2017**	**2016**	**2017**
0	2173.39	2265.0	4.83	4.39
50	4122.65	4162.8	9.16	8.32
100	4436.40	4395.5	9.86	9.76
150	5433.87	5512.7	12.08	12.34
200	6132.92	6036.4	13.63	12.97
LSD (0.05)	414.74	421.01	0.92	0.84
N Split Application				
SP1	4342.76	4296.8	9.65	10.66
SP2	5065.34	5123.3	11.26	11.09
SP3	5120.71	5205.2	11.38	12.37
SP4	4328.45	4297.5	9.62	9.54
SP5	3441.97	3389.7	7.65	8.17
LSD (0.05)	404.74	411.01	0.82	0.94
N Rate X N Split				
LSD (0.05)	654.65	546.08	NS	NS

Table 4. Effect of N Rates and N Split Application on Number of Finger and Mother Rhizomes.

Treatments	Number of Finger Rhizome		Number of Mother Rhizome	
N Rates (kg/ha)	**2016**	**2017**	**2016**	**2017**
0	8.06	9.84	2.57	2.61
50	8.81	13.67	3.49	3.51
100	9.35	14.47	3.99	4.05
150	10.24	15.13	4.10	4.10
200	11.04	17.44	4.50	4.46
LSD (0.05)	0.39	0.78	0.16	0.18
N Split Application				
SP1	9.70	11.30	3.17	3.80
SP2	10.17	12.08	3.38	3.95
SP3	9.85	11.44	3.97	3.86
SP4	9.19	10.62	3.63	3.68
SP5	8.58	10.06	3.44	3.44
LSD (0.05)	0.25	0.41	0.16	0.18
N Rate X N Split				
LSD (0.05)	NS	NS	NS	NS

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Table 5. Effects of N Rates and N Split Application on Fresh Weight of Finger and Mother Rhizomes.

Treatments	Fresh Wt. of Finger Rhizome (g/plant)		Fresh Wt. of Mother Rhizome (g/plant)	
N Rates (kg/ha)	**2016**	**2017**	**2016**	**2017**
0	103.88	104.64	44.49	49.60
50	127.56	129.05	51.37	53.63
100	145.65	147.90	56.15	57.78
150	169.30	176.62	64.85	66.43
200	182.28	187.41	74.84	73.97
LSD (0.05)	7.57	8.06	4.79	4.95
N Split Application				
SP1	139.37	142.25	53.41	54.34
SP2	153.63	154.14	60.37	61.63
SP3	163.52	167.90	65.18	68.83
SP4	146.98	170.37	56.94	58.79
SP5	125.17	127.14	55.80	57.81
LSD (0.05)	7.57	8.06	4.79	4.95
N Rate X N Split				
LSD (0.05)	12.64	10.73	NS	NS

Table 6. Effects of N Rates and N Split Application on Fresh Weight of Finger and Mother Rhizomes.

Treatments	Fresh Rhizome Yield (kg/ha)		Dry Rhizome Yield (kg/ha)	
N Rates (kg/ha)	**2016**	**2017**	**2016**	**2017**
0	32970.54	32840.44	6594.1	6528.2
50	39761.19	41469.38	7952.2	8058.09
100	44845.16	45618.62	8969.2	8475.10
150	52034.59	52989.90	10406.9	10075.99
200	57139.33	56561.71	11427.9	11725.94
LSD (0.05)	1830.2	1625.06	366.04	424.64
N Split Application				
SP1	42841.2	37916.9	8568.2	7924.6
SP2	47556.2	45937.5	9511.2	9369.4
SP3	50822.0	53931.1	10164.4	10062.1
SP4	45316.2	46776.1	9063.2	9102.9
SP5	40216.3	41538.3	8043.30	8404.3
LSD (0.05)	1830.2	1625.06	366.04	424.64
N Rate X N Split				
LSD (0.05)	1785.22	1556.04	302.44	415.23

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Table 7. Effects of N Rates and N Split Application on Total Dry Biomass Yield.

Treatments	Dry Biomass Yield (kg ha^{-1})	
N Rates (kg/ha)	**2016**	**2017**
0	9872.79	11672.53
50	14884.61	14725.05
100	17149.13	17284.22
150	19537.02	20123.51
200	20814.33	20764.52
LSD (0.05)	626.51	655.60
N Split Application		
SP1	15285.19	14972.06
SP2	17654.77	17552.00
SP3	19653.09	20124.11
SP4	16022.19	16178.24
SP5	13642.65	13024.53
LSD (0.05)	626.51	568.54
N Rate X N Split		
LSD (0.05)	NS	614.55

Table 8. Effects of N Rates and N Split Application on Harvest Index (HI) and Curcumin Content.

Treatments	Harvest Index (HI) (%)		Curcumin Content (%)	
N Rates (kg/ha)	**2016**	**2017**	**2016**	**2017**
0	0.52	0.53	5.16	5.31
50	0.85	0.84	5.17	5.21
100	0.87	0.85	5.19	5.08
150	0.88	0.86	5.23	5.20
200	0.88	0.86	5.18	5.26
LSD (0.05)	NS	NS	NS	0.02
N Split Application				
SP1	0.82	0.85	5.04	4.94
SP2	0.84	0.85	5.11	5.10
SP3	0.86	0.88	5.38	5.38
SP4	0.85	0.86	5.17	5.34
SP5	0.85	0.83	5.22	5.34
LSD (0.05)	NS	NS	0.04	0.02
N Rate X N Split				
LSD (0.05)	NS	NS	NS	NS

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Table 9. Effects of N Rates and N Split Application on Oleoresin Content and Essential Oil Content.

Treatments	Oleoresin Content (%)		Essential Oil Content (%)	
N Rates (kg/ha)	**2016**	**2017**	**2016**	**2017**
0	13.18	13.82	1.65	1.80
50	13.78	14.72	2.50	2.65
100	15.20	14.92	2.68	3.23
150	14,53	14.32	2.90	4.59
200	13.57	13.90	3.17	4.71
LSD (0.05)	0.21	0.32	0.15	0.32
N Split Application				
SP1	14.48	13.90	2.15	3.85
SP2	15.16	13.95	2.90	4.62
SP3	15.52	14.55	2.38	4.85
SP4	15.24	15.44	2.46	4.22
SP5	14.71	14.14	2.19	4.01
LSD (0.05)	0.21	0.32	0.15	0.32
N Rate X N Split				
LSD (0.05)	NS	NS	NS	NS

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