Effects of nitrogen and potassium rates on growth and yield of red turmeric (*Curcuma longa* L.) on the gray soil in Ho Chi Minh City

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ABSTRACT

The objective of this study was to determine the appropriate rates of nitrogen and potassium fertilizers for growth, yield and economic efficiency of red turmeric cultivated on the gray soil in Ho Chi Minh City. The field experiment was conducted at the Agronomy Research Station in Nong Lam University, Ho Chi Minh City from December 2020 to October 2021. The experiment was laid out in a split-plot design with three replicates. The main plots included four nitrogen rates 60, 90 (control), 120 and 150 kg N/ha. The subplots included four potassium rates 90, 120 (control), 150, and 180 kg K_2O/ha. All treatments were basally applied with 500 kg lime, 10 tons cow manure and 60 kg P_2O_5/ha. The results showed that growth attributes and yield were significantly affected by the rates of nitrogen and potassium. Red turmeric applied with 150 kg N/ha combined with 180 kg K_2O/ha obtained the outstanding results in growth, yield and profit, such as the plant height of 43.0 cm, stem diameter of 19.7 mm, a number of leaves of 8.6 (180 DAP), soil plant analysis development index of 42.1 (120 DAP), actual fresh yield of 33.9 tons/ha, the profit of VND 370.17 million/ha and the benefit-cost ratio of 2.68.

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1. Introduction

In Vietnam, red turmeric (*Curcuma longa* L.) is popularly grown in various types of soil. Turmeric rhizomes are often harvested and used as a spice, cosmetic, and medical plant based on traditional methods (Do, 2004). Besides, turmeric is a horticultural crop demanding heavy fertilization for increasing yield and quality (Yamgar et al., 2001).

Nitrogen (N) plays an important role in accumulating dry matter, which enables to increase the yield and quality of turmeric rhizomes. Besides, N is involved in chlorophyll formation, and its influences stomatal conductance and photosynthetic efficiency (Marschner, 2002). Potassium (K) plays catalytic roles in the plant rather becoming an integral part of plant components. Plants with an inadequate supply of K show the poor fruit or seed formation, yellowing of the leaves, poor growth, and low resistance to coldness and drought. A supply of K promotes N uptake efficiency of plants due to its stimulant effect on plant growth (Oya, 1972).

Although potassium is not an element that engages in any transfer processing, it regulates the permeability of cell wall and activities of various mineral elements as well as neutralizes physiologically important organic acids (Marschner, 2002; Akamine et al., 2007). Therefore, combining nitrogen and potassium in growing red turmeric can enhance the yield of rhizome and the quality of plants.

In term of cultivation, proper fertilizer application is a crucial method that affects not only vegetative parameters, and yield but also economic factors. Hence, enhancing efficiency of red turmeric production on gray soil by combining between organic fertilizers and inorganic ones is necessary (Rao et al., 1975; Gopalakrishna et al., 1997).

Regarding the necessary in practical production in local fields of the research "Effects of nitrogen and potassium rates on growth and yield of red turmeric (*Curcuma longa* L.) on the gray soil in Ho Chi Minh City" was conducted.

2. Materials and Methods

2.1. Time and location

The field experiment was conducted at the Agronomy Research Station in Nong Lam University, Ho Chi Minh City, Vietnam from December 2020 to October 2021.

2.2. Planting material

The red turmeric tuberous roots were collected from a farm in Bu Gia Map district, Binh Phuoc province, Vietnam. Red turmeric rhizomes were then treated with 0.5% chlorine for 30 min before dried and incubated for 2 weeks. When the red turmeric seedlings reached 10 - 15 cm in height and were produced with 1 - 3 leaves, each plant was separated before growing (Mai et al., 2000).

2.3. Fertilizers

Fertilizers used in the experiment included cow manure (1% N, 2% P_2O_5, 1% K_2O); Phu My urea (46.3% N); Lam Thao superphosphate (16% P_2O_5, 10% S, 12 mg Cd/kg); Canadian potassium chloride (61% K_2O).

Before the establishment of the experiment in December 2020, the soil sample from surface (0 - 20 cm depth) was taken about 0.5 Kg to determine soil texture, pH_{KCl} of the soil, the soil organic matter content, total nitrogen, phosphorus and potassium in the soil. The properties of the initial soil are given in Table 1. The data showed that the soil is classified as clay texture (USDA, 1960), moderately acidic, high in soil organic matter, and low in total nitrogen but high in total phophorus and potassium (Slavich & Petterson, 1993; Rayment & Lyons, 2011).

2.4. Experimental design

Two-factor experiment was laid out in split-plot design (SPD) with three replicates. The main plots included four nitrogen rates 60, 90 (control), 120, and 150 kg N/ha. The subplots included four potassium rates 90, 120 (control), 150, and 180 kg K_2O/ha. All treatments were applied basally with the same rate of 500 kg lime, 10 tons cow manure and 60 kg P_2O_5/ha.

Entire amount of cow manure, lime and phosphorus were applied in respective plots as per treatment during the final soil preparation. The amount of nitrogen and potassium were split into three installments: $\frac{2}{4}$ N + $\frac{1}{4}$ K_2O (30 days after planting - hereafter referred to as DAP), $\frac{1}{4}$ N + $\frac{1}{4}$ K_2O (90 DAP), $\frac{1}{4}$ N + $\frac{2}{4}$ K_2O (150 DAP).

The plot size was 6.3 m^2 (4.5 m in length, 1.4 m in width). The health primary rhizomes of red turmeric were planted at the distance of 35 cm $\times$ 25 cm. The spacing between blocks and plots were 1.0 and 0.5, respectively.

2.5. Data collection

Growth attributes were collected at 180 DAP, while biomass (leaves, stem, roots, rhizomes), yield and yield component data were collected at 270 DAP where plant leaves started by drying and withering. Growth attributes such as plant height, stem diameter, number of leaves per plant and soil plant analysis development (SPAD) index were recorded from ten randomly selected plants from middle rows. At 270 DAP, red turmeric was removed from the field, washed free of sand and then separated at the crown into three parts: aboveground (leaves and stem), roots and rhizomes. Once separated, aboveground, roots and rhizomes were washed, dried and weighed (g/plant). The dry biomass data

Table 1. Physical and chemical properties of soil sample used in the experiment

Texture (%)			$pH_{1:5}$	Organic	Total N	Total P_2O_5	Total K_2O
Clay	Silt	Sand	(KCl)	matter (%)	(%)	(%)	(%)
5.3	9.3	85.4	4.85	1.71	0.07	0.06	0.06

Soil samples were analyzed at the Forestry Science Institute of Southern Vietnam, 2021.

was determined after weighing separately fresh biomass data. Actual fresh rhizome yield was calculated from fresh rhizome weight (g per net plot area) and converted onto an ha basis, and then the data were expressed as tons/ha. Economic efficiency including total cost, total revenue, profit and benefit cost ratio (BCR) were computed.

2.6. Statistical analysis

All variables were subjected to analysis of variance as a SPD using R software (R 4.1.0 GUI 1.76, 2021). Differences between treatments were tested using the least significance difference (LSD) test at the probability of 0.05.

3. Results and Discussions

3.1. Growth attributes

The analysis of variance indicated that the growth attributes such as plant height, stem diameter, number of leaves per plant were all significantly ($P < 0.05$) influenced by N and K rates. As shown in Table 2, a non-significant nitrogen × potassium interaction was also observed for all growth attributes, except stem diameter.

The general trend showed that increasing N rate from 60 to 150 kg N/ha increases the growth of the red turmeric plant in this study (Table 2). At 180 DAP, the highest plant height (43.8 cm) was recorded at treatment of 150 kg N/ha application for red turmeric, while the lowest value of plant height was recorded at the rate of 60 kg N/ha. Stem diameter varied in N rate where the largest stem diameter (18.5 mm) was found from plants which received 150 kg N/ha, whereas the smallest value of stem diameter (15.8 mm) was recorded at 60 kg N/ha.

Similar results were also observed in the number of leaves per plant where the greatest number of leaves per plant was also produced when 150 kg N/ha was applied for red turmeric, followed by 120 and 90 kg N/ha, and the lowest number of leaves per plant was recorded at 60 kg N/ha in Table 2.

An increase in red turmeric vegetative growth attributes such as plant height, stem diameter and a number of leaves per plant in treatments receiving higher N rates in current study was consistent with the results reported by Mekonnen & Garedew (2019). This trend could be probably due to its marked influence on the capacity of plants to absorb and utilize optimum amount of N in build up of plant tissue and vegetative growth (Leva et al., 2013). It can also attribute to the rapid conversion of synthesized carbohydrates into protein, which increases in number and size of growing cells, resulting ultimately in increased overall growth (Singh et al., 2001). Similar result has also been reported by Thomas & Utietiang (2019) who indicated that the maximum growth parameters was obtained with the application of N up to 200 kg/ha on turmeric.

Regarding K rates, plant height and stem diameter were significantly affected by K rates. In general, increasing K rate from 90 to 180 kg K_2O/ha decreased plant height, but increased stem diameter and the number of leaves in this study (Table 2). The highest plant height (44.8 cm) was obtained when 90 kg K_2O/ha was applied for red turmeric, and significantly different from other treatments. In contrast, the lowest plant height (42.5 cm) was obtained at the rate of 180 kg K_2O/ha.

A different trend was observed in stem diameter and the number of leaves. The largest stem diameter (18.4 mm) was recorded when 180 kg K_2O/ha was applied for red turmeric, followed by 150 and 120 kg K_2O/ha, and the smallest stem diameter (16.0 mm) was recorded at 90 kg K_2O/ha. A similar trend was also observed in the number of leaves per plant, but there was not significantly different in the number of leaves per plant among K treatments (Table 2).

A significant interaction between N and K was found in stem diameter, particularly the largest one (19.7 mm) recorded when applying a combination of 150 kg N/ha and 180 kg K_2O/ha (Table 2). This was possibly explained that a sufficient supply of K promotes N uptake efficiency of plants due to its stimulant effect on plant growth

Table 2. Effect of N and K rates on plant height, stem diameter and number of leaves of red turmeric at 180 days after planting

Parameters	K rate (kg K_2O/ha) (K)	N rate (kg N/ha) (N)				Average (K)
		60	90[1]	120	150	
Plant height (cm)	90	44.0	44.7	45.3	45.3	44.8^a
	120[2]	43.0	43.3	43.7	43.7	43.4^b
	150	42.0	42.7	42.7	43.0	42.6^c
	180	42.0	42.3	42.7	43.0	42.5^c
	Average (N)	42.8^c	43.3^b	43.6^a	43.8^a	
	CV (%) = 0.8	$F_N = 119.1^{**}$	$F_K = 9.6^{**}$	$F_{N*K} = 0.5^{ns}$		
Stem diameter (mm)	90	15.4^c	15.7^c	16.1^c	16.7^{bc}	16.0^c
	120	15.5^c	17.0^{abc}	16.2^c	17.8^{abc}	16.7^c
	150	15.6^c	17.1^{abc}	17.9^{abc}	19.1^{ab}	17.6^b
	180	16.7^{bc}	17.6^{abc}	19.6^a	19.7^a	18.5^a
	Average (N)	15.8^c	16.8^b	17.7^a	18.5^a	
	CV (%) = 8.5	$F_N = 89.3^{**}$	$F_K = 16.3^{**}$	$F_{N*K} = 3.2^{*}$		
Number of leaves (leaves/plant)	90	7.7	7.9	7.9	8.2	7.9
	120	7.8	8.0	8.2	8.3	8.1
	150	8.1	8.2	8.3	8.4	8.3
	180	8.2	8.3	8.3	8.6	8.4
	Average (N)	8.0^c	8.1^b	8.2^b	8.4^a	
	CV (%) = 4.0	$F_N = 5.9^{*}$	$F_K = 0.7^{ns}$	$F_{N*K} = 0.7^{ns}$		

Within a group of means, values followed by the same letter are not significantly different at 5% level; **: significant at 1% level; *: significant at 5% level; ^{ns}: non significant; [1] 90 kg N/ha (control), [2] 120 kg K_2O/ha (control).

(Oya, 1972).

3.2. SPAD index

SPAD index, which could be converted to chlorophyll content of plant was only significantly influenced by N rates in this study (Table 3). The general trend indicated that SPAD index of the red turmeric increases with increasing N rate from 60 to 150 kg N/ha. At 60 DAP, the highest SPAD (37.5) was recorded when 150 kg N/ha was applied for red turmeric, whereas the lowest value of SPAD (36.1) was recorded at 60 kg N/ha. Similar result was also recorded at 120 DAP. However, SPAD index has not been affected by different rates of K application as well as the combination of N and K treatments. This could be explained on the basis of the physiological fact that N plays an essential role in chlorophyll formation, it influences stomatal conductance and photosynthetic efficiency. The decreases in growth with reduced N rates could be the reason for a decline in the net photosynthesis. In addition, it was evident that the plants grown without or less N application withered earlier resulting in a poorer vegetative growth. N deficiency results in lower chlorophyll in leaves which ultimately causes earlier plant death (Sarker et al., 2002).

3.3. Yield components and yield

The results revealed that both of application N and K were significantly influenced to fresh weight of aboveground, roots and rhizomes per plant of red turmeric at 270 DAP, however the experiment also revealed that there was not interacted between N and K treatments for all above measurements.

In general, an increasing N or K rates increased the fresh weight of aboveground, roots and rhizomes per plant of red turmeric in current study (Table 4). At 270 DAP, the highest fresh weight of aboveground biomass per plant (2091.0 g) was recorded when 150 kg N/ha was applied for red turmeric, while the lowest value was recorded at the rate of 60 kg N/ha. Similarly, a highest fresh weight of roots and rhizomes per plant was obtained from the treatment which had received 150 kg N/ha with the values of 304.3 mg and 406.3 g, respectively, followed by the application of 120, 90 and 60 kg N/ha. This result clearly indicated that the increase fresh biomass and rhizomes due to N application could be ascribed to their roles in growth and tissue differentiation (Marschner,

Table 3. Effects of N and K rates on soil plant analysis development (SPAD) index of red turmeric at 60 and 120 days after planting

Days after planting	K rate (kg K_2O/ha) (K)	N rate (kg N/ha) (N)				Average (K)
		60	90$^{(1)}$	120	150	
60	90	35.5	36.0	36.3	36.5	36.1
	120$^{(2)}$	35.5	36.8	36.9	37.6	36.7
	150	36.6	36.9	37.4	37.7	37.2
	180	36.7	37.1	37.8	38.1	37.4
	Average (N)	36.1^{c}	36.7^{b}	37.1^{a}	37.5^{a}	
	CV (%) = 13.3	$F_N = 1.8^{**}$	$F_K = 0.6^{ns}$	$F_{N*K} = 1.1^{ns}$		
120	90	39.5	40.3	40.5	41.1	40.4
	120	39.9	40.7	40.7	42.1	40.9
	150	40.6	41.1	41.5	42.1	41.3
	180	41.0	41.9	41.9	42.1	41.7
	Average (N)	40.3^{c}	41.0^{b}	41.2^{a}	41.9^{a}	
	CV (%) = 13.2	$F_N = 3.1^{**}$	$F_K = 1.4^{ns}$	$F_{N*K} = 1.0^{ns}$		

Within a group of means, values followed by the same letter are not significantly different at 5% level; **: significant at 1% level; ^{ns}: non significant; $^{(1)}$ 90 kg N/ha (control), $^{(2)}$ 120 kg K_2O/ha (control).

2002). It can be also explained on the basis of the physiological fact that N, which is the principal nutrient of plant significantly increased vegetative growth attributes of turmeric comparison with any other nutrients (Behura, 2001).

The decreases in growth with reduced N rates could be the reason for a decline in growth attributes and the number of rhizomes on the treatment which reveived the lowest N rate as 60 kg N/ha, for example in this study. With such reduced growth components, net photosynthesis would be lower so that it was difficult for the plant to supply adequate amounts of substrate to the sinks, i.e., the rhizomes. In contrast, the plants applied with increasing N stimulated vegetative growth and remained green for longer, which contributed to longer photosynthesis and resulted in a higher biomass.

Similarly to N rates, the fresh weight of aboveground, roots and rhizomes per plant of red turmeric were significantly affected by K rates (Table 4). The highest fresh weight of aboveground biomass (2398.7 g per plant) was obtained at the treatment of 180 kg K_2O/ha for red turmeric, and significantly different from other treatments. Similarly, the highest fresh weight of roots per plant was recorded at the rate of 180 kg K_2O/ha whilst the lowest fresh weight of that was recorded from the treatment of 90 kg K_2O/ha application. Similarly, results were also recorded in the fresh weight of rhizomes (Table 4). A non-significant nitrogen × potassium interaction was also observed in fresh weight of aboveground, roots and rhizomes, but the maximum biomass attributes was always obtained when 150 kg N/ha was applied in combination with 180 kg K_2O/ha for red turmeric (Table 4).

Both the main effects of N and K rates had a significant effect ($P < 0.05$) on the dry weight of aboveground, roots and rhizomes of red turmeric, but there was non-significant nitrogen × potassium interaction for dry biomass attributes (Table 5).

Aboveground dry weight increased with increasing N rates from 60 to 150 kg N/ha. The red turmeric plants which were applied with 150 kg N/ha achieved the highest aboveground dry weight, whereas the lowest aboveground dry weight was recorded from the treatment which received 60 kg N/ha. Similarly, the maximum dry weight of roots and rhizomes per plant was also obtained at the rate of 150 kg N/ha with the respective values of 46.6 mg and 62.4 g, while the minimum dry weight of those values was always obtained at the rate of 60 kg N/ha (Table 5).

In addition, dry biomass attributes increased with increasing K rates from 90 to 180 kg K_2O/ha where aboveground dry weight increased by 137.6 g, root dry weight by 19.7 mg and rhizome dry weight by 12.8 g. The maximum weight of dry aboveground was recorded when 180 kg K_2O/ha was applied, followed by 150 and 120 kg K_2O/ha. The minimum weight of dry aboveground was recorded from the treatment which had received 90 kg K_2O/ha. Similar results were also observed in the dry weight of roots and rhizomes of red

Table 4. Effects of N and K rates on fresh weight of aboveground, roots and rhizomes per plant of red turmeric at 270 days after planting

Parameters	K rate (kg K_2O/ha) (K)	N rate (kg N/ha) (N)				Average (K)
		60	90(1)	120	150	
Above-ground fresh weight (g)	90	1458.3	1604.3	1646.7	1743.3	1613.2^{c}
	120(2)	1540.7	1679.7	1690.7	1916.7	1707.0^{c}
	150	1679.7	1699.7	1843.0	2014.7	1809.3^{b}
	180	2120.0	2348.7	2436.7	2689.3	2398.7^{a}
	Average (N)	1699.7^{c}	1833.1^{b}	1904.3^{b}	2091.0^{a}	
	CV (%) = 18.2	$F_N = 9.0^*$	$F_K = 0.07^*$	$F_{N*K} = 0.8^{ns}$		
Root fresh weight (mg)	90	164.7	168.7	187.3	206.0	181.7^{c}
	120	216.7	253.3	278.0	290.3	259.6^{b}
	150	250.0	261.0	290.7	320.0	280.4^{b}
	180	266.3	287.0	314.0	401.0	317.1^{a}
	Average (N)	224.4^{c}	242.5^{bc}	267.5^{b}	304.3^{a}	
	CV (%) = 24.9	$F_N = 3.4^*$	$F_K = 1.4^*$	$F_{N*K} = 0.9^{ns}$		
Rhizome fresh weight (g)	90	256.8	299.9	332.5	386.1	318.8^{c}
	120	308.1	346.7	360.5	406.4	355.4^{b}
	150	314.7	346.8	375.8	406.4	360.9^{ab}
	180	326.1	351.0	381.2	426.4	371.2^{a}
	Average (N)	301.4^{c}	336.1^{b}	355.0^{b}	406.3^{a}	
	CV (%) = 14.1	$F_N = 3.2^*$	$F_K = 1.9^*$	$F_{N*K} = 0.5^{ns}$		

Within a group of means, values followed by the same letter are not significantly different at 5% level; *: significant at 5% level; ^{ns}: non significant; (1) 90 kg N/ha (control), (2) 120 kg K_2O/ha (control).

Table 5. Effects of N and K rates on dry weight of aboveground, roots and rhizomes per plant of red turmeric at 270 days after planting

Parameters	K rate (kg K_2O/ha) (K)	N rate (kg N/ha) (N)				Average (K)
		60	90(1)	120	150	
Above-ground dry weight (g)	90	213.3	247.3	255.7	288.0	251.1^{c}
	120(2)	245.0	254.0	290.0	292.0	270.3^{bc}
	150	253.0	291.0	291.0	330.3	291.3^{b}
	180	335.7	369.0	384.3	466.3	388.7^{a}
	Average (N)	261.8^{c}	290.3^{b}	305.3^{b}	344.2^{a}	
	CV (%) = 25.5	$F_N = 11.6^{**}$	$F_K = 0.08^*$	$F_{N*K} = 1.0^{ns}$		
Root dry weight (mg)	90	23.7	25.7	29.7	33.7	28.2^{c}
	120	34.0	39.3	41.7	46.0	40.3^{b}
	150	35.7	42.0	43.0	49.3	42.5^{b}
	180	42.0	44.3	48.0	57.3	47.9^{a}
	Average (N)	33.9^{c}	37.8^{b}	40.6^{b}	46.6^{a}	
	CV (%) = 22.6	$F_N = 3.4^*$	$F_K = 1.2^*$	$F_{N*K} = 0.5^{ns}$		
Rhizome dry weight (g)	90	36.5	48.4	48.7	56.4	47.5^{d}
	120	46.2	50.6	52.9	60.0	52.4^{c}
	150	46.3	55.3	59.8	65.7	56.8^{b}
	180	53.0	57.4	63.1	67.5	60.3^{a}
	Average (N)	45.5^{c}	52.9^{b}	56.1^{b}	62.4^{a}	
	CV (%) = 18.7	$F_N = 2.6^*$	$F_K = 2.6^*$	$F_{N*K} = 0.8^{ns}$		

Within a group of means, values followed by the same letter are not significantly different at 5% level; **: significant at 1% level; *: significant at 5% level; ^{ns}: non significant; (1) 90 kg N/ha (control), (2) 120 kg K_2O/ha (control).

Table 6. Effects of N and K rates on actual fresh yield (tons/ha) of red turmeric

K rate (kg K_2O/ha) (K)	N rate (kg N/ha) (N)				Average (K)
	60	90[(1)]	120	150	
90	20.4	23.8	24.3	26.4	23.7^c
120[(2)]	24.5	27.5	28.6	30.6	27.8^c
150	25.0	27.5	29.8	32.3	28.7^b
180	25.9	27.9	30.3	33.8	29.5^a
Average (N)	24.0^d	26.7^c	28.3^b	30.8^a	
CV (%) = 19.6	$F_N = 18.9^*$	$F_K = 17.0^*$	$F_{N*K} = 6.0^{ns}$		

Within a group of means, values followed by the same letter are not significantly different at 5% level; *: significant at 5% level; ns: non significant; (1) 90 kg N/ha (control), (2) 120 kg K_2O/ha (control).

Table 7. Economic efficiency of red turmeric at the different rates of N and K

N rate (kg N/ha)	K rate (kg K_2O/ha)	Actual fresh yield (tons/ha)	(million VND/ha)			BCR
			Total revenue	Total cost	Profit	
60	90	21.3	319.50	136.53	182.97	1.34
	120[(2)]	21.8	327.00	136.86	190.14	1.39
	150	22.1	331.50	137.19	194.31	1.426
	180	22.5	337.50	137.52	199.98	1.45
90[(1)]	90	22.2	333.00	136.80	196.20	1.43
	120[(2)]	23.0	345.00	137.13	207.87	1.52
	150	23.9	358.50	137.46	221.04	1.61
	180	24.8	372.00	137.79	234.21	1.70
120	90	23.4	350.55	137.07	213.48	1.56
	120[(2)]	24.3	364.50	137.40	227.10	1.65
	150	25.3	379.50	137.73	241.77	1.76
	180	32.3	484.50	138.06	346.44	2.51
150	90	24.3	364.50	137.34	227.16	1.65
	120[(2)]	24.4	366.00	137.67	228.33	1.66
	150	26.8	402.00	138.00	264.00	1.91
	180	33.9	508.50	138.33	370.17	2.68

(1) 90 kg N/ha (control), (2) 120 kg K_2O/ha (control).

turmeric (Table 5).

Actual fresh yield of red turmeric in responses to N and K rates was shown in Table 6. The general trend showed that increasing N or K rates increases the yield of red turmeric in current study. The highest actual fresh yield was recorded when 150 kg N/ha was added while the lowest value was recorded at the rate of 60 kg N/ha. Further, potassium application of the rate of 180 kg K_2O/ha produced the highest actual fresh yield (28.3 tons/ha) and significantly different from other treatments (Table 6).

Although there was a non significant interaction between N and K rates, the maximum actual fresh yield (33.9 tons/ha) was obtained at the combination of 150 kg N/ha and 180 kg K_2O/ha (Table 6). The greater rhizome yield from high rates of N application could be associated with more luxuriant growth parameters and the higher supply of substrate which helped in producing larger rhizomes, consequently resulting in higher yields (Imas et al., 1999). The greater yields at higher N rates may also be due to increased stem diameter and the weight of rhizomes per plant, which might result from an increase in the number of leaves per plant.

3.4. Economic efficiency of red turmeric

The results showed that red turmeric plants were treated at 150 kg N/ha combined with 180 kg K_2O/ha achieved the highest revenue of VND 508.5 million/ha, the highest profit of VND 370.17 million/ha and the highest cost benefit ratio of 2.68 (Table 7).

4. Conclusions

The study clearly showed that the higher application rates of nitrogen and potassium fertilizers increased on the growth attributes and yield of turmeric plant on the gray infertile soil in Ho Chi Minh City. Co-application of 150 kg N/ha with 180 kg K_2O/ha obtained the outstanding results in the growth and yield of red turmeric. The maximum yield and yield components of red turmeric were also obtained in this treatment such as plant height of 43.0 cm, stem diameter of 19.7 mm, a number of leaves of 8.6 (180 DAP), SPAD-index of 42.1 (120 DAP), actual fresh yield of 33.9 tons/ha, the profit of VND 370.17 million/ha and the benefit cost ratio of 2.68. Therefore, an application of 150 kg N/ha in combination with 180 kg K_2O/ha can be suggested for the farmers in this area to maximize rhizome yield. Further research should be conducted in the future to determine the optimum doses of nitrogen and potassium to achieve maximum yield and economic of red turmeric crops.

Conflict of interest

The authors declare no conflict of interest.

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