

[Short Report]

## Effects of Application of N, P and K Alone or in Combination on Growth, Yield and Curcumin Content of Turmeric (*Curcuma longa* L.)

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Crops respond differently to different fertilizer elements, and proper fertilizer management for a plant species is important for increasing yield and quality. Nitrogen (N), phosphorus (P) and potassium (K) are the three major nutrients, which individually and/or together maintain growth, yield and quality of plants (Mazid, 1993; Ivonyi et al., 1997). N is involved in chlorophyll formation, and it influences stomatal conductance and photosynthetic efficiency (Mazid, 1993; Ivonyi et al., 1997). N is responsible for 26-41% of crop yields (Mazid, 1993; Maier et al., 1994, 1996).

K plays catalytic roles in the plant rather than becoming an integral part of plant components. It regulates the permeability of cell walls and activities of various mineral elements as well as neutralizing physiologically important organic acids. Plants with an inadequate supply of K show poor fruit or seed formation, yellowing of the leaves, poor growth, and low resistance to coldness and drought (Oya, 1972). A sufficient supply of K promotes N uptake efficiency of plants due to its stimulant effect on plant growth. P indirectly promotes plant growth and absorption of K as well as other nutrients (Oya, 1972).

Turmeric (*Curcuma longa* L.) is used in many countries as a spice and cosmetic (Ishimine et al., 2003; Hossain et al., 2005a, b). It is now a popular medicinal plant worldwide. Curcumin the main component of turmeric functions as a medicine with anti-inflammatory, anti-mutagenic, anti-carcinogenic, anti-tumor, anti-bacterial, anti-oxidant, anti-fungal, anti-parasitic and detox properties (Hermann and Martin, 1991; Osawa et al., 1995; Sugiyama et al., 1996; Nakamura et al., 1998). The efficacy of *C. longa* found on a specific disease varies with the studies, and in some cases no efficacy was found (Hermann and Martin, 1991; Osawa et al., 1995; Sugiyama et al., 1996;

Nakamura et al., 1998). Such differences may be due to variation in the curcumin content which is assumed to depend on the fertilizer elements.

Turmeric is a horticultural crop demanding heavy fertilization for increasing yield and quality (Reddy and Rao, 1978; Govind et al., 1990; Yamgar et al., 2001). We reviewed several papers and found that the chemical fertilizers affect growth, yield and quality of turmeric variously, and the effects of N, P and K alone or in combination are not clear, because farmyard manure was used together and some experiments did not include control treatment (Reddy and Rao, 1978; Govind et al., 1990; Yamgar et al., 2001; Behura, 2001). Turmeric is commercially cultivated in Okinawa, but yield per unit area and curcumin content are very poor, because fertilizer management is not well known to the farmers (Hossain and Ishimine, 2005). In previous studies, we evaluated planting depth, time, pattern, seed size and soil types on growth and yield of turmeric in Okinawa (Ishimine et al., 2003, 2004; Hossain et al., 2005a, b; Hossain and Ishimine, 2005). The present study was undertaken to evaluate the effects of N, P and K alone or in combination on growth, yield and curcumin content of turmeric.

### Materials and Methods

#### 1. Turmeric cultivation

The glasshouse experiment was conducted using dark-red soil (Shimajiri maaji) at the Subtropical Field Science Center of the University of the Ryukyus, from April 15, 2003 to January 14, 2004. Wagner pots (size 0.05 m<sup>2</sup>) were filled with 10 kg of air-dried soil each pot. Table 1 shows the chemical properties of soil (subsoil). No organic fertilizer was added to soil for determining actual effects of chemical fertilizers on growth, yield and curcumin content of turmeric.

Table 1. Chemical properties of dark-red soil in Okinawa, Japan.

Na mg kg <sup>-1</sup> soil	K mg kg <sup>-1</sup> soil	Ca mg kg <sup>-1</sup> soil	Mg mg kg <sup>-1</sup> soil	Al mg kg <sup>-1</sup> soil	Fe mg kg <sup>-1</sup> soil	P mg kg <sup>-1</sup> soil	S mg kg <sup>-1</sup> soil	NO <sub>3</sub> -N mg kg <sup>-1</sup> soil	NH <sub>4</sub> -N mg kg <sup>-1</sup> soil	C mg kg <sup>-1</sup> soil	pH (H <sub>2</sub> O)
30.52	6.39	24.98	5.37	0.54	0.25	0.52	36.68	680	590	2300	5.26

Data are means of 3 replications. Data were recorded on the dry weight basis.

Table 2. Effects of N, P and K applied alone or in combination on plant height, leaf number, tiller number, shoot (dry weight), yield (rhizome dry weight) and curcumin content of turmeric.

Fertilizer treatments	Plant height (cm)	Leaf (no. plant <sup>-1</sup> )	Tiller (no. plant <sup>-1</sup> )	Shoot (g plant <sup>-1</sup> )	Yield (g plant <sup>-1</sup> )	Curcumin content (%)
Control	50.2 ± 3.2d	9.8 ± 2.7d	1.6 ± 0.5d	13.6 ± 2.2d	17.5 ± 1.9e	0.15 ± 0.01de
N	112.8 ± 5.7c	16.0 ± 2.3c	2.6 ± 0.5c	60.4 ± 6.7c	55.1 ± 2.1d	0.14 ± 0.01e
P	41.2 ± 3.9e	9.6 ± 2.7d	1.6 ± 0.5d	13.5 ± 1.9d	20.2 ± 2.4e	0.17 ± 0.01c
K	44.8 ± 4.2de	10.0 ± 3.0d	1.6 ± 0.5d	13.3 ± 2.8d	18.2 ± 2.3e	0.21 ± 0.00a
N plus P	121.4 ± 4.0b	25.8 ± 3.5b	4.0 ± 0.6b	53.6 ± 7.3c	61.4 ± 3.2c	0.18 ± 0.00b
N plus K	149.4 ± 4.1a	25.8 ± 3.7b	4.2 ± 0.7b	73.8 ± 3.8b	148.4 ± 6.1b	0.19 ± 0.00b
P plus K	38 ± 2.3e	10.2 ± 2.6d	1.6 ± 0.5d	12.1 ± 1.0d	8.6 ± 0.8f	0.12 ± 0.00f
N plus P plus K	153.6 ± 3.1a	34.0 ± 2.1a	5.2 ± 0.4a	85.2 ± 10.8a	165.9 ± 8.4a	0.16 ± 0.00cd

Data are means ± SD of replications. Data with the same letters within each column are not significantly different at the 5% level, as determined by LSD test.

One seed-rhizome of 30 g was planted at the depth of 8 cm in each pot on April 15, 2003, and the pots were placed randomly in the glasshouse. The experiment consisted of eight treatments with five replications (5 pots). The treatments were control (Con), N, P, K, N plus P (NP), N plus K (NK), P plus K (PK) and N plus P plus K (NPK). N at 210 kg/ha (3.15 g per pot), P at 150 kg/ha (2.25 g per pot) and K at 150 kg/ha (2.25 g per pot) were applied on June 30 (two- to three-leaf stage), August 15 (vegetative growth and rhizome development stage) and September 30 (vegetative growth and rhizome development stage), 2003 according to the treatment design. One turmeric plant requires approximately 0.15 m<sup>2</sup> in field condition for better growth and higher yield (Hossain et al., 2005b), therefore the fertilizers were applied considering this area (0.15 m<sup>2</sup>), not pot size (0.05 m<sup>2</sup>). We previously reported that chemical fertilizers of 4 g (N = 1 g, P = 1 g, K = 2 g) per pot in dark-red soil without any compost resulted in poor vegetative growth and low yield of turmeric, and the leaves seemed to be light green (Hossain et al., 2005a). Therefore, the fertilizers at the increased rate have been applied to evaluate their effects on turmeric. Water was applied as required everyday for proper seedling emergence and plant growth (leaching was closed with cork).

## 2. Data collection and statistical analysis

Plant height and the number of tillers and leaves were recorded on November 5, 2003 when the main

shoot terminated leaf formation. Plants were harvested at the time its shoots withered which differed with the treatment (Fig. 1). Turmeric plants treated with P, K or PK, and control plant were harvested on December 5, 2003; the plants with N on December 17, 2003; and the plants with NP, NK or NPK on January 14, 2004. Leaves, shoots and rhizomes were collected; and the plant parts were oven-dried at 80°C for 48 hr and weighed. For curcumin analysis, rhizomes were sliced and dried at 60°C for 48 hours, and then ground into a fine powder. Powder of five plants were mixed together for each treatment, and curcumin content was measured three times for each treatment by HPLC (Shimadzu Co. Ltd.). Mean and standard deviation (SD) of replications were determined using analysis of variance (ANOVA), and Fisher's protected least significance difference (LSD) test at the 5% level of significance was used to compare treatment means.

## Results and Discussion

### 1. Effect of chemical fertilizers on growth and yield of turmeric

N applied alone or in combination with P, K or PK resulted in a significantly higher plant height, and number of leaves and tillers (Table 2). N is the principal nutrient of plant, which significantly increases vegetative growth parameters of turmeric than any other nutrients (Govind et al., 1990; Behura, 2001). Turmeric plants grown with P or K did not show improvement in any vegetative growth parameters.

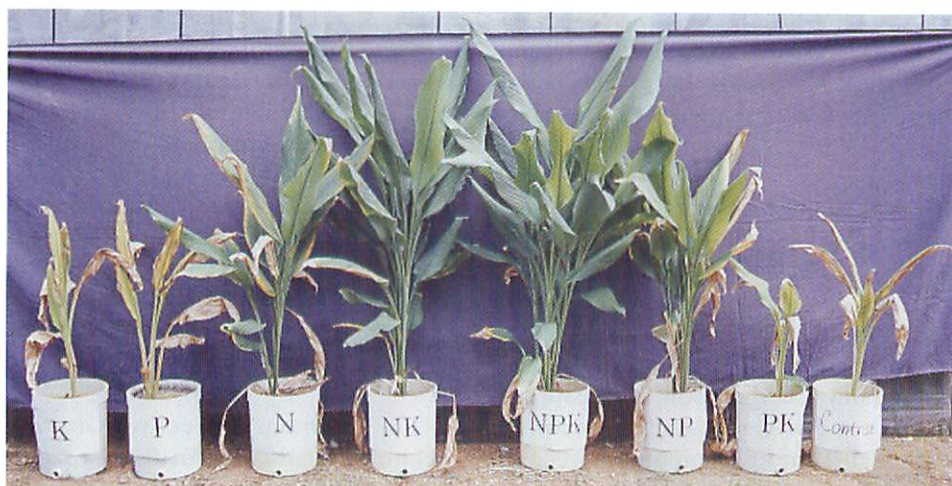


Fig. 1. Effects of separate and combined applications of N, P and K on vegetative growth of turmeric (photograph was taken on November 10, 2003).

Similarly, Behura (2001) and Govind et al. (1990) reported that P or K applied alone could not increase vegetative growth of turmeric. Other studies also reported that vegetative growth responses to P or K are not significant (Maier et al., 1996; Razzaque and Hanafi, 2001). The combined application of P and K showed antagonistic effects on vegetative growth. PK without N probably created nutrient imbalance, which resulted in an antagonistic effect on vegetative growth. An imbalance or excessive of nutrients prevent ion formation, which causes trouble in nutrient absorption for plant (Maier et al., 1994; Ivonyi et al., 1997).

The plants grown without N application withered earlier (Fig. 1) resulting in a poorer vegetative growth. Deficiency of N fertilizer results in lower chlorophyll in leaves which ultimately causes earlier plant death (Sarker et al., 2002).

Turmeric plants achieved 4 to 6 times greater shoot biomass when grown with N, NP, NK or NPK (Table 2). N increased all vegetative growth parameters, which resulted in a higher shoot biomass. Our previous studies revealed that shoot biomass increased with the increasing plant height, leaf number and tiller number of turmeric (Hossain et al., 2005a, b; Hossain and Ishimine, 2005). The plants grown with N, NP, NK or NPK remained green much longer (Fig. 1), which contributed to longer photosynthesis and resulted in a higher shoot biomass. Growth and yield have been reported to be increased in rice plants remaining green longer due to longer duration of photosynthesis (Sarker et al., 2002).

The highest yield was obtained from the turmeric grown with NPK followed by NK (Table 2), because the plants with these treatments remained green longer and they had higher shoot biomass, which ultimately contributed to higher yield. Our previous

studies revealed that turmeric yield increased with the increased shoot biomass (Ishimine et al., 2003, 2004; Hossain et al., 2005b; Hossain and Ishimine, 2005). P applied alone or in combination with K did not increase turmeric yield, but increased the yield slightly in combination with N. K applied alone did not have any effect on turmeric yield, but NK increased the yield around 3 times. This study indicates that K alone cannot increase turmeric yield but enhance N to improve the yield. Behura (2001) also reported that K applied separately could not improve turmeric yield, but improved significantly when applied in combination with N and P. A similar result was obtained in *Cannabis sativa* (Ivonyi et al., 1997). Application of PK showed antagonistic effect on turmeric yield. It was assumed that PK without N created a nutrient imbalance in the plants or formed toxic ions. Other studies reported that imbalance of nutrients could not increase growth and yield of crops (Maier et al., 1994; Razzaque and Hanafi, 2001; Hossain and Ishimine, 2005). It is assumed that the amount of nutrient is not the only factor for better growth and yield; imbalance of nutrients interfere with normal function, which ultimately results in a lower growth and yield of turmeric. Behura (2001) reported that chemical fertilizer of N and K applied in a certain ratio showed higher efficacy on turmeric yield. However, it is assumed the ratio may differ with the soil nutrient status. N applied alone increased turmeric yield significantly. The above results indicate that N itself improves yield and it also enhances the efficacy of other nutrients (P and K) to improve yield of turmeric. It was reported that P, K or PK has a slight positive effect on yield of turmeric cultivated with the farmyard manure (Reddy and Rao, 1978; Govind et al., 1990). It was evident that N is comparatively better



than P or K for increasing turmeric yield but varying with soil nutrient status (Reddy and Rao, 1978; Govind et al., 1990). Other studies reported that N fertilizer is responsible for 26-41% yield of many crops (Maier et al., 1994, 1996).

## 2. Effect of chemical fertilizers on curcumin content in turmeric rhizome

N applied alone could not increase curcumin content of rhizome, whereas P or K increased curcumin content significantly (Table 2). However, this study does not strictly indicate that N is not responsible for curcumin accumulation; it is assumed that N content of the soil was enough for curcumin accumulation. Although P and K promoted curcumin content significantly, combined application of them showed antagonistic effect. It is assumed that PK inhibited ion formation each other or form toxic ion together, which was the cause of antagonistic activities. Hossain and Ishimine (2005) reported that imbalanced fertilization could not promote quality of turmeric. N enhanced P slightly to promote curcumin accumulation, but did not enhance K. This study indicates that K is the principal element involved in curcumin formation in turmeric followed by P. On the other hand, Reddy and Rao (1978) found almost similar effects of N, P and K on curcumin accumulation in turmeric, but they could not confirm whether curcumin was influenced by the individual fertilizer, because farmyard manure was applied and no control treatment was evaluated.

## Conclusion

This experiment indicated that separate application of P and K could not increase growth and yield of turmeric, whereas N alone increased both growth and yield. The combined application of N and K (NK) or N, P and K (NPK) provided 4 to 6 times greater shoot

biomass and 8 to 9 times higher yield. Though K alone provided the highest curcumin content in rhizome, but did not increase turmeric yield. On the other hand, NPK provided the highest yield but did not increase curcumin content. NK provided the second highest yield (8 times greater) with the second highest curcumin content, indicating that this combination is the best for promoting both yield and curcumin content of turmeric. We need further studies to evaluate the critical combination level and timing of N, P and K application on yield and quality of turmeric.

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