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[Short Report]

## Effects of Farmyard Manure on Growth and Yield of Turmeric (*Curcuma longa* L.) Cultivated in Dark-Red Soil, Red Soil and Gray Soil in Okinawa, Japan

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Chemical fertilizer, herbicide and pesticide used in agriculture for increasing yield and controlling weeds and pests can contaminate the water, air and food, decrease soil fertility, inhibit growth of soil microorganisms and hazard human health (Sharifuddin and Zaharah, 1991; Li et al., 1999; Neera et al., 1999; Erisman et al., 2001). In addition, chemicals may destroy many species of plants, insects, fishes and soil microorganisms (Fantroussi et al., 1999). Therefore, utilization of farmyard manure in agriculture is recommended for retaining productivity of problem soils, reducing the usages of chemical fertilizer, improving economy in agriculture and minimizing environmental problems (Sharifuddin and Zaharah, 1991; Neera et al., 1999; Whalen et al., 2003; Xiao et al., 2006).

Turmeric is a horticultural root-crop that is important not only as a spice and cosmetic, but also as a medicinal plant worldwide (Hermann and Martin, 1991; Osawa et al., 1995; Sugiyama et al., 1996; Nakamura et al., 1998; Ishimine et al., 2003; Hossain et al., 2005a, b). Considering the medicinal values of turmeric and environmental problems caused by chemicals application, it is important to cultivate turmeric using organic fertilizer (e.g. farmyard manure). Farmyard manure is regularly applied to many root crops for higher yield (Vanek et al., 2003).

The fertilizers derived from animals, plants and microorganisms, are usually called organic fertilizer or farmyard manure. Many kinds of farmyard manure are locally produced based on available natural resources. Chicken manure, goat manure and cow manure are commercially available in Okinawa. Turmeric is commercially cultivated in dark-red soil (Shimahiri maaji), red soil (Kunigami maaji) and gray soil (Jagaru) in Okinawa (Hossain and Ishimine, 2005). Previously, we evaluated planting depth, time, pattern, seed size and soil types on growth and yield of turmeric (Ishimine

et al., 2003, 2004; Hossain et al., 2005a, b; Hossain and Ishimine, 2005). Here, we evaluated the effects of farmyard manure on growth and yield of turmeric cultivated in dark-red soil, red soil and gray soil.

### Materials and Methods

#### 1. Experiment 1: Effect of different kinds of farmyard manure on turmeric

The experiment was conducted in a glasshouse from April 3 to December 20, 2000 at the Subtropical field Science Center, University of the Ryukyus, Okinawa, Japan. Dark-red soil was collected from the upper 30 cm layer of the field of the Subtropical Field Science Center. Chicken manure and goat manure (grass-based) were purchased from JA, Nishihara branch, Okinawa. Cow manure (pasture-based) was collected from the cattle farm of the Subtropical Field Science Center, University of the Ryukyus. Manure pH in H<sub>2</sub>O was determined with a TOA pH meter HM-20S (Toa Electronic Ltd. Japan), and mineral contents of manure with an Inductively Coupled Plasma Spectrometer (ICPS-2000, Shimadzu Co. Ltd.). Total carbon (C) and nitrogen (N) content was measured by using Shimadzu gas chromatograph (Soil GS-8A) and Sumigraph (NC-90A, Shimadzu). Nitrate nitrogen (NO<sub>3</sub>-N) and ammonium nitrogen (NH<sub>4</sub>-N) were calculated from nitrogen content, which was measured according to Kjeldahl method. Chemical compositions of the manure are presented in the Table 1.

Four treatments with 10 replications of the experiment were (1) control, (2) chicken manure, (3) goat manure and (4) cow manure. Chicken manure in pellet form (around 88% dry matter), and goat (around 35% dry matter) and cow manure (around 34% dry matter) in compost form are commercially available. Each Wagner pot (size 0.05 m<sup>2</sup>) was filled with 12.5 kg of air-dried soil or 12.5 kg of the soil plus 175 g of the manure (dry matter)

Table 1. Chemical compositions of chicken manure, goat manure and cow manure used in this experiment.

Manure type	Na mg kg <sup>-1</sup> manure	K mg kg <sup>-1</sup> manure	Ca mg kg <sup>-1</sup> manure	Mg mg kg <sup>-1</sup> manure	Al mg kg <sup>-1</sup> manure	Fe mg kg <sup>-1</sup> manure	P mg kg <sup>-1</sup> manure	S mg kg <sup>-1</sup> manure	NO <sub>3</sub> -N mg kg <sup>-1</sup> manure	NH <sub>4</sub> -N mg kg <sup>-1</sup> manure	TN mg kg <sup>-1</sup> manure	TC mg kg <sup>-1</sup> manure	pH (H <sub>2</sub> O)
Chicken manure	2.38	21.13	1.12	1.41	0.00	0.05	2.86	3.57	125.29	2682.62	40500	427400	7.63
Goat manure	0.51	25.01	0.41	0.60	0.01	0.01	1.35	1.12	171.44	116.93	26800	404100	10.38
Cow manure	1.54	7.31	0.42	0.25	0.00	0.02	1.04	1.34	85.72	56.79	26200	350000	8.85

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

Table 2. Chemical and physical properties of dark-red soil, red soil and gray soil used in this experiment.

Soil type	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	TC mg kg <sup>-1</sup> soil	pH (H <sub>2</sub> O)	Coarse sand %	Fine sand %	Silt %	Clay %	Apparent density g cm <sup>-3</sup>
Dark-red soil	30.5	6.39	25.0	5.37	0.54	0.25	0.52	36.7	680	590	2300	5.26	2.93	7.33	23.94	57.2	0.87
Red soil	55.9	10.32	15.8	4.15	0.41	0.26	0.76	15.0	480	510	2110	4.43	16.92	20.44	26.62	30.9	0.92
Gray soil	102.4	42.89	2604.2	279.30	5.42	0.16	4.60	2765.1	700	800	9580	7.43	3.61	30.94	24.32	32.8	0.90

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

according to experiment design (175 g dry matter was equal to 200 g of chicken pellet, 500 g of goat manure or 515 g of cow manure. In other word, a completely dried chicken manure, goat manure and cow manure absorbed 62, 65 and 66% moisture of their weight, respectively). Chicken manure (pellet) at 11–12 ton/ha, goat manure at 30–35 ton/ha and cow manure at 30–35 ton/ha were applied. One turmeric plant requires around 0.15 m<sup>2</sup> space in field for better growth and higher yield (Hossain et al., 2005b), therefore the manure was applied considering this area (0.15 m<sup>2</sup>), not pot size (0.05 m<sup>2</sup>). One seed-rhizome of 30 g was planted at the depth of 6 cm in each pot. No chemical fertilizer was applied to soil for evaluating the actual effects of the manure on growth and yield of turmeric. Water was applied as required everyday (leaching was closed with cork) for proper seedling emergence and plant growth.

## 2. Experiment 2: Effect of cow manure on turmeric cultivated in different soils

The experiment was conducted in a glasshouse from April 8 to December 23, 2002. Dark-red soil and gray soil were collected from the layer below 50 cm depth in the fields of the Subtropical Field Science Center, and red soil was collected from the same layer in the field of the Nago Agricultural Experiment Station, Okinawa. Soil physical properties were determined with a Köhn Type Soil Sedimentation Apparatus, and chemical properties of the soil were determined according to those measured for manure in the previous experiment, as shown in Table 2.

Six treatments with six replications in this experiment were (1) dark-red soil, (2) dark-red soil + manure, (3) red soil, (4) red soil + manure, (5) gray soil and (6) gray soil + manure. Cow manure was used in this experiment considering efficacy and availability of different kinds of farmyard manure in Okinawa. Each Wagner pot (size 0.05 m<sup>2</sup>) was filled with 12.5 kg of air-dried soil or 12.5 kg of the soil plus 0.5 kg (170 g dry matter) of the manure according to the experimental design. One seed rhizome of 30 g was planted at the depth of 8 cm in each pot. No chemical fertilizer was applied to soil for evaluating the actual effects of the manure on the growth and yield of turmeric cultivated in different soils. Water was applied as required everyday (leaching was closed with cork) for proper seedling emergence and plant growth.

## 3. Data collection and statistical analysis

Vegetative growth of turmeric continues until October, and shoot begins yellowing usually from the middle of November and withers usually in December and/or January under Okinawa climatic condition. Therefore, in the first experiment, turmeric was harvested at vegetative growth stage (when shoot growth terminated) and at mature stage (when shoot withered completely) to evaluate vegetative growth parameters and yield influenced by the manure. Tiller number, leaf number, leaf area, leaf biomass, shoot biomass and yield (rhizome dry matter) were measured from five plants on October 20, 2000 (200 days after planting (DAP)) when shoot growth terminated. The date of final harvest was December 20, 2000 (261 DAP)

Table 3. Effects of different kinds of farmyard manure on growth parameters, maturity period and yield of turmeric.

Farmyard manure	200 days after planting						261 days after planting			
	Plant height cm	Number of leaves plant <sup>-1</sup>	Number of tiller plant <sup>-1</sup>	Leaf area cm <sup>2</sup> plant <sup>-1</sup>	Leaf biomass g plant <sup>-1</sup>	Shoot biomass g plant <sup>-1</sup>	Yield# g plant <sup>-1</sup>	Maturity period day	Shoot biomass g plant <sup>-1</sup>	Yield# g plant <sup>-1</sup>
Control	166 ± 7c	20.8 ± 1.7a	3.2 ± 0.4a	7447 ± 355c	38.1 ± 1.5d	69.4 ± 3.7d	52.0 ± 3.2c	240	68.2 ± 6.1c	98.6 ± 10.1d
Chicken manure	220 ± 3a	20.8 ± 2.7a	3.2 ± 0.4a	9870 ± 1141b	57.8 ± 3.2c	111.2 ± 7.2c	71.6 ± 7.4b	250	89.6 ± 11.2b	133.0 ± 15.1c
Goat manure	216 ± 8ab	23.8 ± 3.5a	4.0 ± 0.9a	13971 ± 1223a	66.9 ± 1.8a	129.9 ± 4.1a	90.6 ± 9.4a	261	110.8 ± 5.9a	156.0 ± 9.6b
Cow manure	204 ± 13b	21.6 ± 2.2a	3.6 ± 0.5a	13031 ± 556a	62.7 ± 1.8b	121.8 ± 1.2b	93.3 ± 7.1a	261	112.6 ± 9.1a	175.4 ± 7.8a

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

when shoot withered completely; shoot biomass and yield were measured for five plants. In the second experiment, plant height and number of tillers and leaves were measured on November 3, 2002 (209 DAP) when main shoot completed leaf formation. Plants were harvested on December 23, 2002 (259 DAP) when shoots withered completely.

Plant parts were oven-dried at 80°C for 48 hr and weighed. Mean and standard deviation (SD) of replications were calculated using analysis of variance (ANOVA) for growth parameters and yield of turmeric, and Fisher's protected least significance difference (LSD) test at the 5% level was performed to compare treatment means.

## Results and Discussion

### 1. Experiment 1: Effect of different kinds of farmyard manure on turmeric

Growth parameters and yield of turmeric increased with all types of manure, and the plants grown with goat manure or cow manure showed the highest vegetative growth parameters and yield except plant height, leaf number and tiller number (Table 3). However, leaf number and tiller number increased slightly with the goat manure and cow manure than those with the chicken manure (Table 3). The manure provided nutrients (Table 1) to the plants and may improved edaphic factors, which resulted in higher vegetative growth parameters (Table 3). Similarly, other studies reported that organic fertilizer improved soil productivity and fertility, which improved yield and quality of crops (Whalen et al., 2000; Maerere et al., 2001; Vanek et al., 2003). The soil treated with manure was found to be loose, which probably provided adequate aeration into the soil and improved soil microbial activities (Xiao et al., 2006). Higher soil microbial activities may release nutrients from the farmyard manure as well as soil for better plant growth. The soil without manure showed a water logging condition for some time and dried earlier as compared with the soil treated with manure, indicating that the soil without manure has lower porosity and farmyard manure improves water holding capacity of soil. Several studies (Whalen et al., 2000, 2003; Seobi et al., 2005) revealed that organic manure increases pH and water-holding capacity, and decreases bulk density in soil. The loose soil was probably favorable for root growth and rhizome-stub expansion, which ultimately promoted vegetative growth, rhizome size and yield of turmeric. The plants with the manure remained green longer and had higher plant height, larger leaf area and greater leaf biomass (Table 3), which ultimately provided longer and higher photosynthesis process and resulted in a higher yield of turmeric. Similar results were obtained in previous studies (Sarker et al., 2001; Ishimine et al., 2003, 2004; Hossain et al., 2005a, b; Hossain and Ishimine, 2005).

Table 4. Effects of farmyard manure on growth parameters, maturity period and yield of turmeric cultivated in dark-red soil, red soil and gray soil in Okinawa.

Treatments	209 days after planting			Maturity period day	259 days after planting	
	Plant height cm	Number of leaves plant <sup>-1</sup>	Number of tiller plant <sup>-1</sup>		Shoot dry g plant <sup>-1</sup>	Yield (dry) g plant <sup>-1</sup>
Dark-red soil	141 ± 6bc	18.7 ± 2.6cd	2.5 ± 0.5b	230	41.2 ± 4.7b	39 ± 6d
Dark-red soil + manure	201 ± 5a	24.7 ± 3.1a	4.3 ± 0.4a	250	104.7 ± 5.5a	219 ± 16b
Red soil	130 ± 6c	16.2 ± 2.3d	2.3 ± 0.4b	220	27.8 ± 2.4c	26 ± 4d
Red soil + manure	150 ± 13b	23.2 ± 1.9ab	4.0 ± 0.6a	240	44.3 ± 3.6b	110 ± 14c
Gray soil	146 ± 10b	20.2 ± 2.7bc	2.7 ± 0.7b	230	40.7 ± 3.9b	39 ± 4d
Gray soil + manure	204 ± 12a	26.8 ± 4.1a	4.3 ± 0.7a	250	103.7 ± 6.8a	255 ± 18a

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

Cows and goats mainly feed on grasses and/or legume plants, whereas chickens feed on cereal. Turmeric plants treated with goat manure or cow manure remained green longer, and resulted in a higher vegetative growth (except plant height) and yield than the plants treated with the chicken manure (Table 3), because the grass/pasture mixed with goat manure and cow manure probably improved soil physical properties and microbial activities, reduced bulk density, enriched soil fertility and increased water-holding capacity. Mazid (1993) and Seobi et al. (2005) reported that bulk density decreases and porosity increases with the application of grasses to soil. On the other hand, chicken manure was assumed to have an excess of Na, Ca, Mg, P and S, which might interfere with their normal function or function of other nutrients, and resulted in a poorer growth and yield of turmeric (Table 1, 3). Similarly, an excess of minerals has been reported to interfere with the normal function of other elements (Ames and Johnson, 1980). Chicken manure, goat manure and cow manure contained 125.29, 171.44 and 85.72 mg/kg of NO<sub>3</sub>-N, 2682.62, 116.93 and 56.79 mg/kg of NH<sub>4</sub>-N, and 40500, 26800 and 26200 mg/kg of total N, respectively. Though chicken manure contained the more NH<sub>4</sub>-N and total nitrogen than goat manure or cow manure but could not increase growth and yield of turmeric like them, indicated that amount of nutrient was not the only factor for more vigorous growth and higher yield, a proper nutrient combination was needed. Similarly, Mazid (1993) reported that nutrients should be applied in a particular ratio for higher growth and yield of a specific plant species. Nutrient balance in goat manure and cow manure was found to be better and their pH was higher than chicken manure, which was thought to be the reasons for higher efficacy on growth and yield of turmeric.

## 2. Experiment 2: Effect of cow manure on turmeric cultivated in different soils

Vegetative growth parameters and yield of turmeric increased with the manure application in all soil types, as compared to that with the respective control soil (Table 4). All types of soil treated with the manure were found to be loose as in the previous experiment, and were also found to have available soil moisture (hand feeling), which resulted in higher vegetative growth parameters and yield of turmeric (Table 4). The manure provided nutrients and probably enhanced aeration and microbial activities, which were other causes to increase growth and yield of turmeric. Similar results were obtained in previous studies (Whalen et al., 2000, 2003; Bhadoria et al., 2003; Hao and Papadopoulos, 2004; McCrea et al., 2004). Dark-red soil and gray soil were greatly improved with the application of the manure than red soil (Table 4). It was assumed that the manure application rate of 30–35 ton/ha (0.5kg/pot) was not enough for proper improvement of red soil which had a pH of 4.4 and contained 16.92% coarse sand (Table 2). Turmeric in dark-red soil and gray soil treated with the manure had more vigorous vegetative growth and remained green around 20 days longer (Table 4), which probably contributed to greater photosynthesis, and resulted in a higher yield. Similarly, Sarker et al. (2001) reported that longer photosynthesis was the key factor of higher rice-yield. Higher shoot biomass resulted in a higher yield, which was in agreement with the results of previous studies (Ishimine et al., 2003; Hossain et al., 2005a).

The cow manure had different effects on shoot biomass and yield of turmeric grown in dark-red soil in 2000 and 2002. The dark-red soil collected in 2000 from the top 30 cm layer probably contained more organic matter than the soil collected in 2002 from the below 50 cm layer. This is why the yield in 2000

increased by around 80%, whereas the yield in 2002 increased by around 400% with the same manure application.

### Conclusions

Cow manure and goat manure showed an excellent efficacy on growth parameters and yield of turmeric than chicken manure. The yield of turmeric increased four to five times with the application of cow manure in dark-red soil and gray soil, whereas the manure applied in red soil resulted in three times higher yield, compared with that in respective untreated soil. Dark-red soil and gray soil treated with the manure produced two times greater yield than red soil treated with the same manure. Cow manure and goat manure were found to be most effective for increasing the yield of turmeric, and productivity of dark-red and gray soil are greatly improved by applying cow manure. Further studies are needed to evaluate the effects of cow manure on turmeric quality and soil properties.

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