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Addressing the problem of sub-optimal productivity and curcumin content of turmeric in low input rainfed agricultural system

A Mishra*, A Mishra[1], B S Rath, S K Mohanty & B Behera

AICRP for Dryland Agriculture, Orissa University of Agriculture & Technology,
Phulbani-762 001, Odisha.
**E-mail: ashokmishra7686@yahoo.com*

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Abstract

Field experiments were conducted to study the yield performance of 10 important turmeric genotypes, and the effect of five different nutrient management practices on four outstanding varieties in order to address the problem of low rhizome yield and curcumin content of the zone. Based on yield data of 10 turmeric varieties over two years (2007 and 2008), highest rhizome yield of 21.7 t ha^{-1} was observed in Lakdong followed by Rajendra Sonia (16.0 t ha^{-1}). The second experiment involved four varieties and five nutrient treatments. The yield data over five years (2009-10 to 2012-13 and 2014-15) shows Lakdong (9.14 t ha^{-1}) to be the best among varieties and lime @10% LR + 50% organic + 50% inorganic (9.15 t ha^{-1}) among nutrient treatments. Significant variety × nutrient interaction was observed with respect to rhizome yield. Highest rhizome yield was obtained from turmeric variety Lakdong with 100% organic treatment (11.1 t ha^{-1}). While two varieties, Lakdong and Phulbani Local exhibited highest yield with 100% organic treatment, performance of Rajendra Sonia was the best with 50% organic + 50% inorganic + lime @10% LR and Roma with 50% organic + 50% inorganic. Significant variation was observed among nutrient treatments of all four turmeric varieties for NPK content in shoot and rhizome. The interaction between varieties and nutrient management practices for curcumin content was significant.

Keywords: curcumin content, nutrient management, rhizome yield, turmeric, variety

Introduction

Among the spices, turmeric (*Curcuma longa* L., Zingiberaceae) holds an important position in Indian kitchens. It is used in the preparation of dal, curries, upma, palao and many other dishes to impart its unique colour and odour. India is the major producer and exporter of turmeric in the world. In India, turmeric powder, whole rhizomes and leaves are used in different festive occasions and religious ceremonies. Turmeric is gaining importance world wide as a potential source of new drug(s) to combat a variety of ailments as the species contain molecules credited with anti-inflammatory, hypocholestraemic, choleratic,

[1]AICRP on STCR, OUAT, Bhubaneswar-751003, Odisha
*Present address: AICRP on Potato, Orissa University of Agriculture & Technology, Bhubaneswar- 751003, Odisha.

antimicrobial, insect repellent, antirheumatic, antifibrotic, antivenomous, antiviral, antidiabetic, antihepatotoxic as well as anticancerous properties and its oil is also used in aromatherapy and in the perfume industry (Sasikumar 2005; Chattopadhyay *et al*. 2004). It is used as traditional eco-friendly dye, drug for several human and animal diseases, insect repellent and cosmetics. Its powder is the major component (40–50%) of curry powder, used for preparation of Indian dishes containing vegetables, meat, fish or egg.

The importance of turmeric owes mainly to possession of curcumin having anti-oxidant activity, which is either due to the suppression of reactive oxygen species (ROS) or scavenging the free radicals (Joe & Lokesh 1994; Unnikrishnan & Rao 1995). For this antioxidant activity, turmeric is used as a food additive to prevent the oxidation and resultant rancidity of oils and fats during storage (Sharma 1976). Curcumin can also have a protective effect on intestine and liver. The chemoprotective role of curcumin has been reported against human colon cancer (Kawamori *et al.* 1999), human leukaemia HL-60 cells (Kuo *et al*. 1996) and human breast carcinoma (Shao *et al.* 2002).

Odisha is an important turmeric growing state in India. Among different districts of Odisha, Kandhamal ranks first both in area and production of turmeric. As the name indicates, 'Kandhamal' is the home land of naive tribe called 'Kandha' who have their unique life style and practice of crop production. Traditionally, farmers of Kandhamal grow local (traditional) genotype of turmeric in uplands, which is generally planted in the month of May. A thick cover of sal leaves (*Shorea robusta* L) is applied above the field just after planting turmeric. This thick cover of leaves serves both as mulch and nutrient and no other organic or inorganic nutrients are applied. However, this traditional turmeric variety (Phulbani Local) is low in curcumin content and rhizome yield. From export point of view, Kandhamal turmeric fetches low price due to low curcumin content. To address the problem of low rhizome yield as well as curcumin content of Kandhamal turmeric, separate experiments were therefore conducted to- (i) evaluate ten important turmeric varieties/genotypes of Odisha including Phulbani Local for rhizome yield, and (ii) study interaction of four selected varieties with five easy-to-practise nutrient management practices for rhizome yield, curcumin content and several other yield attributing traits.

Materials and methods

Two field experiments were conducted at AICRP for Dryland Agriculture, Orissa University of Agriculture and Technology, Phulbani, Odisha to address the problem of low turmeric yield as well as curcumin content in rainfed uplands. The normal rainfall of the region is 1407 mm in 67 rainy days. During November to January, the mean monthly minimum temperature remains around 10°C and mean maximum temperature 28°C coinciding with rhizome bulking /maturity stage. In contrast, the mean monthly minimum and maximum temperature remains around 23°C and 35°C, respectively in hot summer months of May and June. Moderate temperature is observed during rest of the months of the growing season (July to October). Relative humidity of the atmosphere remains nearly 60% in May but above 85% from June to January.

The first experiment was conducted to evaluate ten genotypes (varieties/ improved lines) of turmeric with respect to rhizome yield for two years from 2007-08 to 2008-09. The varieties/ improved lines were- Rajendra Sonia, Roma, Rashmi, Ranga, Surama, Lakdong, Phulbani Local, PTS 4, PTS 43 and PTS 34. The trial was laid out in red lateritic upland soil having field capacity of 13.1%, permanent wilting point 5.5%, pH 5.4, organic carbon 0.21%, available P_2O_5 29 kg ha^{-1} and K_2O 214 kg ha^{-1} in randomized block design with three replications. Seed rhizomes were planted in raised beds of 5m length and 1m width during May-June at a spacing of 30 cm × 20 cm. Before planting, 20 t FYM along with 30 kg of P_2O_5

and 45 kg of K_2O per hectare were applied (that is full dose of Phosphate along with half dose of Potash). 30 kg N was applied at first top dressing (40-45 days after planting) and 30 kg N + 45 kg K_2O at second top dressing (80-90 days after planting). Green sal leaf mulch @10 t ha^{-1} was applied after planting, which was repeated @5 t ha^{-1} after first top dressing. The crop was raised on entirely rainfed condition and standard agronomic practices were followed for raising the crop.

The second experiment was carried out at the neighbouring site of first Experiment where the land was kept fallow for the last two years. The soil was similar to that in the first experiment with pH 5.7, organic carbon 0.24%, available N 165 kg ha^{-1}, available P_2O_5 31.6 kg ha^{-1} and available K_2O 230.7 kg ha^{-1}. Four turmeric varieties, Lakdong, Rajendra Sonia, Roma and the local check, Phulbani Local were evaluated with five nutrient treatments 100% organic (20 t ha^{-1} FYM), 100% inorganic (60:30:90 kg $N:P_2O_5:K_2O$), 50% organic (10 t ha^{-1} FYM) + 50% inorganic (30:15:45 kg $N:P_2O_5:K_2O$), lime (@10% LR that is 200 kg ha^{-1}) + 50% organic (10 t ha^{-1} FYM) + 50% inorganic (30:15:45 kg $N:P_2O_5:K_2O$), and control (no external nutrient supply). This experiment was laid out in factorial design with three replications. Planting was done on raised beds of 5 m length and 1m width at spacing of 30 cm × 20 cm. All the organic manures and P_2O_5 were applied at planting along with 50% of K_2O. At first top dressing (45 days after planting), 50% N was applied. Second top dressing comprising of 50% N + 50% K_2O was applied at 90 days after planting. Sal leaf mulching @10 t ha^{-1} was applied uniformly in all treatments, which was repeated @5 t ha^{-1} after first top dressing. Statistical analyses were done following Gomez & Gomez (1976).

Observations on shoot and rhizome biomass were taken at the time of harvest from 10 sample plants of each plot representing the population. Fresh rhizomes were weighed whole as well as separately for mother and finger yield $plant^{-1}$. Almost all leaves were dry at the time of harvest which were further dried inside oven at a temperature of 70°C and then weighed plant-wise for determination of dry shoot biomass $plant^{-1}$. Rhizome yield ha^{-1} was estimated from the gross plot yield. Sustainable yield index was derived for different treatments following Singh *et al.* (1990). Soil chemical properties such as pH, content of organic carbon, N, P_2O_5 and K_2O and content of N, P and K of shoot and rhizome were estimated at the end of experimentation in the Laboratory of AICRP on Soil Test Crop Response Correlation, Orissa University of Agriculture & Technology, Bhubaneswar following standard procedure. Curcumin content of turmeric varieties under different nutrient management systems were estimated by simple spectroscopic method using alcoholic extract (Sadasivam & Manickam 1992).

Amount of rainfall in each month during crop growth over the years was recorded (Fig. 1). The crop was planted in the month of May or June (after preparation of land following a pre-monsoon shower) and harvested in January-February.

Results and discussion

Variation in rhizome yield and shoot biomass among turmeric genotypes

Significant variation was observed among 10 turmeric genotypes for mother rhizome yield, finger yield and shoot biomass (Table 1). Based on two years' mean (2007-08 and 2008-09), mother rhizome yield $plant^{-1}$ was the highest in PTS-43 (52.84 g), which was at par with Roma (52 g) and PTS-34 (51.17 g). However, finger rhizome yield $plant^{-1}$ was the highest in Lakdong (176.34 g) followed by Rajendra Sonia (139.33 g). Datta *et al.* (2006) reported that the weight of the primary fingers $clump^{-1}$ had highly positive correlation with yield and thus selection for this character seems to be rewarding for yield improvement in turmeric. In another investigation at Bangladesh, it was observed that mother rhizome yield and primary finger yield were statistically at par (Zaman *et al.* 2005). However, in our study, it is observed that mother rhizome yield has

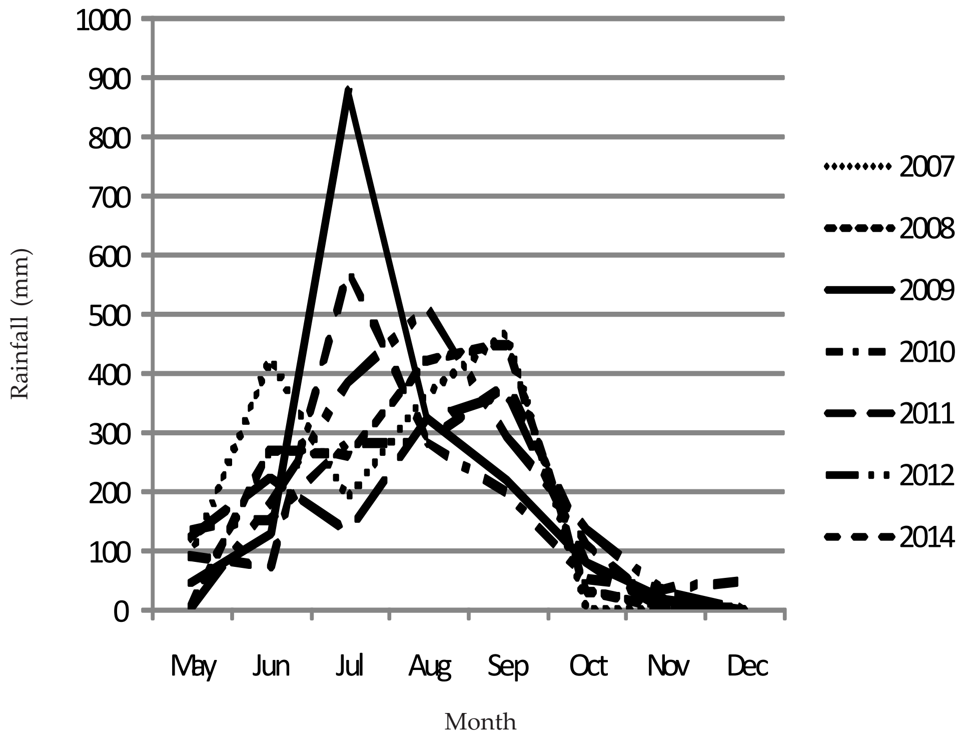

Fig. 1. Monthly rainfall scenario during 2007-2014 from May-December

maximum contribution towards total yield in some varieties like PTS-4 and Roma, while finger yield contributes most in others like Lakdong and Rajendra Sonia. There was prominent variation among turmeric varieties with respect to the ratio of mother rhizome yield: finger rhizome yield, ranging from 0.15 in Rajendra Sonia to 2.15 in PTS-4. Similarly, the ratio of finger rhizome yield: total rhizome yield varied from 0.33 in PTS-4 to 0.88 in Lakdong. This study clearly illustrates that the ratio of mother rhizome yield: finger rhizome yield is governed by genotype and influences total rhizome yield accordingly. Bahl *et al*. (2014) also observed that large variability exists in a set of 84 accessions of turmeric *Curcuma longa* L. collected from various geographical locations in northern India with respect to morphological features, leaf and rhizome essential oil content, yield and quality, curcumin content in rhizome and curcumin yield.

Mean shoot dry mass plant^{-1} varied from 10.99g in PTS-34 to 15.47 g in Lakdong. Shoot weight, mostly influenced by number of leaves, length and breadth of leaf and number of tillers, bears significant positive correlation with yield (Kumar *et al*. 2007). However, the correlation of shoot biomass with mother rhizome yield and finger rhizome yield was non-significant in this study. There was also significantly negative correlation (-0.474) between mother rhizome yield and finger yield.

Highest total fresh rhizome yield was observed in Lakdong (21.7 t ha^{-1}) followed by Rajendra Sonia (16.01 t ha^{-1}) and Phulbani Local (15.06 t ha^{-1}).

Response of genotypes to nutrient management

Year-wise variation in turmeric yield was very high as evidenced from the values of coefficient of variation (C.V.) for different varieties or nutrient management practices (Table 2).

Table 1. Rhizome yield of 10 turmeric varieties over two years (2007-08 and 2008-09)

Genotype	Shoot dry weight plant^{-1} (g)			Mother rhizome yield plant^{-1} (g)			Finger rhizome yield plant^{-1} (g)		
	2007-08	2008-09	Mean	2007-08	2008-09	Mean	2007-08	2008-09	Mean
Rajendra Sonia	12.87	11.83	12.35	26.67	16.00	21.34	159.33	119.33	139.33
Roma	13.93	13.40	13.67	59.67	44.33	52.00	32.33	23.67	28.00
Rashmi	13.40	12.93	13.17	31.0	37.00	34.00	15.0	57.00	36.00
Ranga	14.73	13.57	14.15	46.67	22.67	34.67	47.33	47.33	47.33
Surama	12.67	12.17	12.42	41.67	38.00	39.84	46.33	66.33	56.33
Lakdong	16.17	14.77	15.47	25.33	21.00	23.17	198.67	154.00	176.34
Phulbani Local	15.17	14.43	14.80	28.33	34.00	31.17	128.33	104.00	116.17
PTS 4	14.43	13.67	14.05	50.33	25.67	38.00	18.33	16.67	17.50
PTS 43	13.30	12.67	12.99	53.67	52.00	52.84	62.0	88.67	75.34
PTS 34	11.20	10.77	10.99	70.67	31.67	51.17	38.33	17.67	28.00
SE m +	0.80	0.58		2.23	2.51		6.63	5.47	
CD (P <0.05)	2.37	1.72		6.61	7.45		19.68	16.25	
Genotype	**Mother : Finger rhizome ratio**			**Finger : Total rhizome ratio**			**Total fresh rhizome yield (t ha^{-1})**		
	2007-08	2008-09	Mean	2007-08	2008-09	Mean	2007-08	2008-09	Mean
Rajendra Sonia	0.17	0.13	0.15	0.86	0.88	0.87	19.41	12.61	16.01
Roma	1.85	1.87	1.86	0.35	0.35	0.35	4.60	4.97	4.78
Rashmi	2.07	0.65	1.36	0.33	0.61	0.47	2.20	5.42	3.81
Ranga	0.99	0.48	0.74	0.50	0.68	0.59	6.42	5.08	5.75
Surama	0.90	0.57	0.74	0.53	0.64	0.58	3.27	7.72	5.50
Lakdong	0.13	0.14	0.14	0.89	0.88	0.88	25.96	17.44	21.70
Phulbani Local	0.22	0.33	0.28	0.82	0.75	0.79	16.68	13.44	15.06
PTS 4	2.75	1.54	2.15	0.27	0.39	0.33	10.12	5.76	7.94
PTS 43	0.87	0.59	0.73	0.54	0.63	0.58	11.10	12.10	11.60
PTS 34	1.84	1.79	1.82	0.35	0.36	0.35	6.83	4.09	5.46
SE m +							0.72	0.54	
CD (P <0.05)							2.15	1.60	

Highest mean C.V. in control clearly indicates that turmeric grown under zero nutrient management was more prone to year-wise variation in crop weather situation than those with organic, inorganic or integrated nutrient management. Although lime + 50% organic + 50% inorganic treatment registered highest mean yield (9.15 t ha^{-1}), its C.V. was higher than 50% organic + 50% inorganic. Among varieties, Rajendra Sonia showed least fluctuation in rhizome yield over years and thus was a stable variety, while Phulbani Local exhibited the maximum fluctuation with inconsistent yield. Lakdong and Phulbani Local gave highest mean rhizome yield with 100% organic treatment followed by lime + 50% organic + 50% inorganic treatment. Rajendra Sonia exhibited highest mean rhizome yield with lime + 50% organic + 50% inorganic treatment, while Roma performed best with 50% organic + 50% inorganic treatment. Sustainable yield index (SYI) of Lakdong, Rajendra Sonia, Roma and Phulbani Local under different nutrient treatments varied from 0.23 to 0.39, 0.28 to 0.47, 0.21 to 0.37 and 0.17 to 0.31, respectively. It was the least under control treatment of all varieties. Among the varieties under study, mean SYI varied from 0.23 in Phulbani Local to 0.35 in Rajendra Sonia.

With respect to the 5 years' mean turmeric yield (fresh rhizome) in our study, Lakdong (9.14 t ha^{-1}) was found to be the best among four varieties and lime + 50% organic + 50% inorganic treatment (9.15 t ha^{-1}) among nutrient management practices (Table 3). This partly corroborates earlier findings that application of 75% recommended dose nitrogen as organic manures and remaining 25% as inorganic fertilizers exhibit better plant growth and yield (Isaac & Varghese 2016).

Combined application of organic and inorganic nutrient has been observed earlier to result highest rhizome yield through increase in plant height, number of leaves, size and surface area of leaves, girth of pseudostem and number of tillers per plant (Poinkar *et al.* 2006). Studies also showed that growth, yield attributes, yield and quality were significantly influenced by use of organic and inorganic combinations over recommended fertilizers alone (Rao *et al*. 2005; Nanda *et al*. 2012).

Soil chemical properties as affected by nutrient management options

At the end of experimentation, soil pH varied from 5.93 in 100% inorganic treatment to 7.07 in lime + 50% organic + 50% inorganic treatment (Table 4). Soil organic carbon was the least (0.178%) in control and highest in 100% organic treatment (0.646 %). Available N, P_2O_5 and K_2O in soil were the lowest in control. Highest available N and K_2O were observed in 100% inorganic treatment but highest P_2O_5 content was found in lime + 50% organic+ 50% inorganic treatment. Addition of lime @10% LR reclaimed soil acidity bringing to neutral reaction and increased availability of P_2O_5 in soil. There is distinct possibility of reducing chemical N fertilizer by 50% when applied in combination with organic manure for enhanced soil quality, rhizome yield and nutrient uptake in turmeric (Srinivasan *et al*. 2016).

Shoot and rhizome nutrient content

Significant variation was observed among nutrient treatments of all four turmeric varieties for NPK content in shoot and rhizome (Table 5). Different varieties exhibited variable response to nutrient management practices. However, in all the nutrient treatments of four varieties, shoot N content was higher than the rhizome N content. Highest shoot N content (7.14%) was observed in 50% organic + 50% inorganic treatment of Lakdong followed by 100% organic treatment of Roma (7.00%). Highest rhizome N content (2.54%) was found in 100% organic treatment of Lakdong. In contrast to N content, rhizomes of all treatments had more P and K content than corresponding shoots. Shoot P content varied from 0.16 % in the control treatment of Phulbani local to 0.27% in lime + 50% organic + 50% inorganic treatment of the same variety, but rhizome P content was highest in the 50% organic + 50% inorganic treatment of Lakdong (0.70%).

Table 2. Rhizome yield of turmeric varieties under different nutrient management practices during 2009 to 2014

Variety	Nutrient management options	Rhizome yield (t ha^{-1})							SYI*
		2009-10	2010-11	2011-12	2012-13	2014-15	Mean	C.V. (%)	
Lakdong	Control	4.10	11.44	3.72	4.67	5.07	5.80	55	0.23
	100% N (organic)	8.66	20.44	8.39	10.21	7.83	11.11	48	0.28
	100% N (inorganic)	7.23	14.22	7.33	7.30	7.17	8.65	36	0.39
	50% organic + 50% inorganic	8.85	16.53	8.48	8.27	6.30	9.69	41	0.35
	Lime (10% LR) + 50% organic + 50% inorganic	7.38	19.00	8.19	9.80	7.90	10.45	47	0.29
Rajendra Sonia	Control	3.58	10.78	4.44	4.33	6.96	6.02	49	0.28
	100% N (organic)	4.80	13.84	6.70	6.64	7.10	7.82	45	0.31
	100% N (inorganic)	4.55	14.36	9.54	7.09	7.83	8.67	42	0.35
	50% organic + 50% inorganic	4.86	13.69	7.96	6.99	7.68	8.24	40	0.36
	Lime (10% LR) + 50% organic + 50% inorganic	5.77	14.33	13.80	10.32	7.83	10.41	36	0.47
Roma	Control	6.55	12.00	2.76	4.31	4.86	6.10	59	0.21
	100% N (organic)	7.05	15.67	5.33	8.51	5.80	8.47	50	0.27
	100% N (inorganic)	8.05	14.00	2.93	8.28	5.51	7.75	53	0.26
	50% organic + 50% inorganic	8.44	14.20	6.04	8.62	5.87	8.63	39	0.37
	Lime (10% LR) + 50% organic + 50% inorganic	8.46	14.78	3.22	9.01	6.01	8.30	52	0.27
Phulbani Local	Control	2.75	10.89	3.35	4.92	3.99	5.18	64	0.17
	100% N (organic)	5.24	13.89	6.39	7.10	6.30	7.79	45	0.31
	100% N (inorganic)	3.41	12.89	4.98	6.54	4.86	6.54	57	0.22
	50% organic + 50% inorganic	3.64	13.20	4.94	6.49	5.73	6.80	55	0.23
	Lime (10% LR) + 50% organic + 50% inorganic	5.55	14.44	4.35	6.83	5.94	7.42	54	0.24

*Sustainable yield index

Table 3. Performance of turmeric varieties under different nutrient management practices (Mean of five years)

Nutrient	Rhizome yield (t ha^{-1})				
	Lakdong	Rajendra Sonia	Roma	Phulbani Local	Mean
Control	5.80	6.02	6.10	5.18	5.77
100% N (organic)	11.11	7.82	8.47	7.79	8.80
100% N (inorganic)	8.65	8.67	7.75	6.54	7.90
50% Organic + 50% inorganic	9.69	8.24	8.63	6.80	8.34
Lime (10% LR) + 50% organic+ 50% inorganic	10.45	10.40	8.30	7.42	9.14
Mean	9.13	8.23	7.85	6.75	

Component	SE m +	CD (P<0.05)
Variety (V)	1.35	3.85
Nutrient (N)	1.51	4.30
V x N	3.01	8.61

Table 4. Soil chemical properties under different nutrient management practices (pooled over varieties) at the end of experimentation

Chemical properties	N_1	N_2	N_3	N_4	N_5	CD (P<0.05)
pH	6.2	6.7	5.93	6.25	7.07	0.13
Organic Carbon %	0.178	0.646	0.418	0.494	0.532	0.01
N (kg ha^{-1})	150	175	200	180	175	5.32
P_2O_5 (kg ha^{-1})	29.44	37.33	38.83	43.07	49.98	0.74
K_2O (kg ha^{-1})	227.17	247.30	255.36	240.51	239.13	NS

N.B.- N_1: Control ; N_2: 100% N (organic); N_3: 100% N (inorganic); N_4: 50% N (organic) + 50% N (inorganic); and N_5: 50% N (organic) + 50% N (inorganic) + lime @10% LR

Shoot K content ranged from 0.23% in untreated control of Lakdong and Phulbani local to 0.48% in 100% organic treatment of Phulbani local. Similarly, rhizome K content was the lowest in the control of Roma (1.64%) and highest in 100% organic treatment of Lakdong (1.98%). Correlations between N-P, N-K and P-K contents of rhizome were found significant but it was non-significant between N-P, N-K and P-K contents of shoot. There was no significant relationship between shoot and rhizome with respect to N, P and K contents.

The correlation coefficient values between N, P and K contents of shoot and rhizome shows that there was significant positive correlation between N and K contents of shoot; N and P, N and K, and P and K contents of rhizome; and P content of shoot and rhizome.

Curcumin variation

Rhizome curcumin content varied from 2.49% in Phulbani Local to 6.52% in Lakdong among turmeric varieties and from 5.09% in lime + 50%

Table 5. Shoot and rhizome nutrient content of turmeric varieties under different nutrient management practices (Final)

Variety	Nutrient	Shoot nutrient content (%)			Rhizome nutrient content (%)		
		N	P	K	N	P	K
Lakdong	Control	4.31	0.20	0.23	1.69	0.54	1.70
	100% N (organic)	4.16	0.21	0.27	2.54	0.67	1.98
	100% N (inorganic)	6.02	0.22	0.37	2.29	0.67	1.84
	50% organic + 50% inorganic	7.14	0.23	0.47	2.36	0.70	1.90
	Lime (10% LR) + 50% organic + 50% inorganic	6.43	0.23	0.38	2.42	0.68	1.94
Rajendra Sonia	Control	4.60	0.21	0.29	1.61	0.54	1.69
	100% N (organic)	5.45	0.23	0.32	2.13	0.55	1.71
	100% N (inorganic)	4.98	0.21	0.35	2.25	0.66	1.87
	50% organic + 50% inorganic	5.62	0.22	0.37	2.20	0.57	1.84
	Lime (10% LR) + 50% organic + 50% inorganic	5.19	0.24	0.31	2.39	0.68	1.90
Roma	Control	6.62	0.18	0.27	1.57	0.54	1.64
	100% N (organic)	7.00	0.19	0.35	2.22	0.63	1.82
	100% N (inorganic)	6.39	0.19	0.43	2.16	0.57	1.69
	50% organic + 50% inorganic	6.60	0.21	0.40	2.23	0.67	1.83
	Lime (10% LR) + 50% organic + 50% inorganic	5.88	0.21	0.39	2.20	0.58	1.81
Phulbani Local	Control	5.05	0.16	0.23	1.27	0.43	1.72
	100% N (organic)	4.81	0.21	0.48	1.67	0.66	1.84
	100% N (inorganic)	6.07	0.23	0.45	1.40	0.56	1.78
	50% organic + 50% inorganic	6.73	0.25	0.45	1.48	0.60	1.81
	Lime (10% LR) + 50% organic + 50% inorganic	6.55	0.27	0.34	1.55	0.62	1.73
MSS	Var	4.617	0.0023	0.0107	1.8033	0.0157	0.0369
	Fert.	3.597	0.0038	0.0490	0.7826	0.0336	0.0553
	Var x Fert	1.634	0.0008	0.0086	0.0443	0.0074	0.0135
	Error	0.063	0.0001	0.0009	0.0009	0.0004	0.0006
SEm±	Var	0.065	0.003	0.008	0.008	0.002	0.006
	Fert.	0.072	0.003	0.008	0.008	0.002	0.007
	Var x Fert	0.144	0.006	0.017	0.017	0.004	0.014
CD ($P<0.05$)	Var	0.184	0.008	0.022	0.022	0.005	0.017
	Fert.	0.206	0.009	0.024	0.024	0.005	0.019
	Var x Fert	0.412	0.018	0.048	0.048	0.011	0.039
CV (%)		4.32	5.03	8.22	1.47	1.05	1.31

organic+ 50% inorganic treatment to 5.37% in 100% organic treatment (Table 6). Earlier studies showed that curcumin content under integrated nutrient management was higher than its content under application of recommended fertilizers alone (Rao *et al*. 2005) and highest dry turmeric yield as well as curcumin content could be obtained through application of FYM, neem cake and recommended fertilizer dose. However, variation in curcumin content among nutrient treatments was not significant in our study. Highest curcumin content of 6.9% was observed in 100% organic treatment of Lakdong. Addition of lime to soil decreased the curcumin content, particularly of Roma and Phulbani Local. The result clearly shows that low curcumin problem of turmeric in Kandhamal district could be better addressed through adoption of improved varieties like Lakdong, Roma and Rajendra Sonia instead of Phulbani Local along with appropriate nutrient management practices.

In spite of spectacular variation with respect to total crop seasonal rainfall as well as its distribution in seven years of study, the impact of variety and nutrient management has been clearly marked in the present investigation and thus can be taken into consideration for improving turmeric productivity in the low input rainfed hilly agro-ecosystems. A stable variety or sustainable nutrient treatment is expected to exhibit good yield over years, low coefficient of variation and high sustainable yield index. In our study, turmeric variety, Rajendra Sonia and integrated manure and fertilizer application (50% organic + 50% inorganic) exhibited the highest sustainable yield index.

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Table 6. Curcumin content (%) of turmeric varieties under different nutrient management practices

Nutrient	Variety Lakdong	Rajendra Sonia	Roma	Phulbani Local (Check)	Mean
Control	6.25	5.56	6.15	2.82	5.20
100% N (organic)	6.90	5.62	6.22	2.75	5.37
100% N (inorganic)	6.35	5.70	6.40	2.40	5.21
50% organic + 50% inorganic	6.50	5.75	6.06	2.40	5.18
Lime (10% LR) + 50% organic + 50% inorganic	6.80	5.65	5.85	2.05	5.09
Mean	6.52	5.66	6.14	2.49	5.21

Factor	SEm±	CD (P<0.05)
Variety (V)	0.063	0.180
Nutrient (N)	0.070	NS
V x N	0.141	0.403

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