Journal of Crop and Weed, 14(3): 69-74 (2018)

Potash fertilization of turmeric using organic as well as inorganic sources

M. CHANCHAN, [1]D. K. GHOSH AND [1]J. K. HORE

Department of Horticulture, CAU, Imphal
[1]Department of Spice and Plantation Crops, Faculty of Horticulture
Bidhan Chandra Krishi Viswavidyalaya, Mohanpur-741252, Nadia, West Bengal

Received : 02-03-18 ; Revised : 30-10-18 ; Accepted : 04-11-18

ABSTRACT

The combination of organic manures viz., compost/vermicompost, potassic mobilising inoculants along with graded (100, 75 and 50%) levels of inorganic potassium were tried for partial substitution of inorganic potassium with organic source in turmeric cv. Suguna. The experiment was laid out at Horticultural Research Station, Mondouri, BCKV, Nadia, West Bengal in RBD with three replications and thirteen treatments for consecutive two years (May, 2012 to January, 2014). The recommended dose of NPK was 150:60:150 kg ha^{-1}. The uniform dose of inorganic N and P were applied to all treatments. The manures namely compost and vermicompost were applied @ 20 t and 5t ha^{-1} respectively and potassic mobiliser (Fraturia aurantea) was applied @12 kg ha^{-1} directly to the soil. Maximum plant height (181.70 cm), leaf number (19.65), clump weight (335.38 g), plot yield (32.35 t ha^{-1}) were recorded in vermicompost + K (100%) + K- mobiliser but maximum tiller (3.46), curcumin (6.52%) and maximum dry recovery (22.84%) were observed in compost + K (100%) + K-mobiliser. The rhizomes from vermicompost + K (75%) + K-mobiliser exhibited maximum oleoresin content. Considering the yield, the vermicompost + inorganic K (100%) + K mobiliser is the best treatment and there is a chance of reduction of 25% inorganic potassic fertilizer through inoculation of potassic mobiliser as yield under the treatment Vermicompost + K (75%) + K-mobiliser (30.65 t ha^{-1}) is more than the treatment Vermicompost + inorganic K (100%)[29.93 t ha^{-1}].

***Keywords*:** Compost, organic manures, potassic mobilizer, turmeric and vermicompost

The spice turmeric or *Haldi* constitute boiled, dried, cleaned and polished rhizome (The underground swollen stem of plant) of *Curcuma longa* L. is a rhizomatous herbaceous perennial plant, important spice crop of the family, Zingiberaceae, has deep orange fleshy roots or tubers. At present turmeric is widely cultivated throughout the tropics, but commercial production is concentrated in South-East Asia. Turmeric being a rhizome crop requires a heavy input of fertilizers. Organic manures not only increase the yield but also improve physical, chemical and bio-logical properties of soil that improve fertility, productivity, water holding capacity of soil (Singh, 2012). Potassium, although not itself a constituent of any metabolite, plays a key role in functions of plant physiology and metabolism (Marschner, 2012). These functions relate directly to the beneficial effects of K on both crop yield and quality. Potassium activates numerous enzymes, is required in high concentrations for protein synthesis and is needed in both the light and dark reactions of photosynthesis. Additionally it plays a major role in osmoregulation and is thus directly involved in growth in cell extension. Spice crops like turmeric is highly sensitive to a lack of K and require a large amount of available soil K which must be maintained because much of the K taken up by the roots is removed by the harvested crop. Crop response studies to K fertilization in different spice crops showed that among the three major nutrients, K is required in greatest amounts (Sadanandan *et al.*, 2002). In general, adequate K nutrition has been shown to enhance yields and disease resistance of roots and tubers (Jansson, 1978). It also favors the establishment of root crops in the field (Rabindran and Nirmal, 2005). Potassium also increases resistance of plants against both biotic and abiotic stresses which is of high importance in crop production. Potassium from water-soluble and exchangeable pools is directly available for plant uptake (Memon *et al*., 1988). Some microorganisms in the soil are able to solubilise unavailable forms of K- bearing minerals such as micas, illite and orthoclase, by excreting organic acids which either directly dissolves rock K or by chelating silicon ions to bring the K into solution (Barker *et al.*, 1998).These microorganism commonly known as potassium solubilizing bacteria or potassium dissolving bacteria or silicate dissolving bacteria and the use of potassium dissolving bacteria is termed as 'biological potassium biofertilizer'. Therefore, application of KSB holds a promising approach for increasing K availability in soil (Basak *et al*., 2009).

Gradual deficiency in soil organic matter and reduced yield of crops are alarming factors and burning issues for the farmers and agriculturists. All efforts should be made to develop consciousness of the farmers about the importance of soil organic matter and sustainable soil productivity for getting higher yield of crops. To maintain the soil fertility on long term basis integrated nutrient management especially with biofertilizers is crucial in rhizomatous crops like turmeric (Kale *et al.*, 2005). The use of biofertilizer in combination with other organic manures and chemical fertilizer will help to increase crop

Email: chanchan.meinam17@gmail.com

productivity to a considerable extent. Being on the note of importance of potassium as in improving yield and quality, the present investigation was designed to supplement the inorganic potash with the incorporation of biofertilizers that could ensure ecofriendly environment and economically sustainable cropping.

MATERIALS AND METHODS

The experiment was carried out at Horticultural Research station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal during last week of May, 2012 to January, 2014. The soil at the experimental plot was sandy clay loam with pH 6.8 and 0.58% organic carbon. Available N, P and K in soil were 223.45 kg ha^{-1}, 18.07 kg ha^{-1} and 194.49 kg ha^{-1}, respectively. The experiment was laid out in RBD with three replications. Raised beds of 3.0×1.0 m and 15 cm high were prepared. Turmeric variety was Suguna planted in 20×25 cm spacing

The organic inputs namely compost and vermicompost were applied basally during final land preparation @ 20.0 t and 5.0 t ha^{-1} respectively. K mobilizer (*Fraturia aurantea*) was applied @12 kg ha^{-1} directly to the soil along with compost or vermicompost. Recommended dose of inorganic fertilizers was 150:60:150 kg NPK per hectare (Medda and Hore, 2003). The total amount of fertilizers was applied in three split doses. 1/3rd of N and full dose of P was applied after 15 days of planting whereas each split of 1/3rd N and ½ K was applied after 45 and rest split of 1/3rd N and ½ K at 90 days after planting. Urea, SSP and MOP were used as inorganic source of N, P and K respectively.

Healthy seed rhizomes (30-35g of each) of turmeric were planted to a depth of 3-4 cm, in the last week of April. The beds were mulched with paddy straw at the rate of 10 t ha^{-1} immediately after planting and 5t ha^{-1} at 45 and 90 days after planting. Earthing up was done before second and third mulching. Three to four hand weedings were done. Irrigation was given as per requirement.

The crop was harvested 8 months after planting, observations on different growth (at 180 days after planting) and yield attributing parameters were recorded from five randomly selected plants per replication. Rhizome yield was taken on net plot basis at harvest and projected yield was calculated on the basis of yield per plot, considering the 75 per cent area occupied by the crop (Anon., 1995).

For determination of dry recovery the composite sample were kept at 70^{0}C till constant weight. The curcumin and oleoresin content were estimated using air condenser and chromatographic column respectively. (Sadasivam and Manickam, 1996).

RESULTS AND DISCUSSION

Data furnished in the tables 1 to 4, clearly revealed a number of interesting features on growth, yield and quality parameters of turmeric.

In pooled data, at 180 DAP, the plants fed with vermicompost + K (100%) + K mobilizer recorded maximum plant height (181.70 cm) followed by compost + K (100%) + K mobilizer (178.23 cm) followed by compost + K (75%) + K mobilizer (172.77 cm). The minimum height was observed in vermicompost + K (50%) [152.57 cm] combination as compared to 159.07 cm height under recommended NPK applied as inorganic (Table 1). The favourable effect of organic manures over sole inorganic was well documented and some additive effects were also observed with K mobilizer over recommended NPK (inorganic) application.

At 180 DAP, the plants grown under compost + K (75%) + K mobilizer produced maximum tiller of 3.46 followed by compost + K (100%) + K mobilizer (3.16) in pooled data (Table 1). In respect of tiller production the application of compost seems better as compared to vermicompost and K mobilizer acts in better way with 75% inorganic potash as compared to 100% potash. The additive effects of biofertilizer were also noticed.

At 180 DAP, in pooled data the combination of vermicompost + K (100%) + K mobilizer produced maximum leaf number of 19.65 followed by compost + K (100%) + K mobilizer (19.35) and the least leaf number of 16.93 was noticed with vermicompost +K (50%). The leaf number of 17.32 was observed under recommended NPK (inorganic) at 180 DAP, respectively (Table 1).

Maximum clump weight of 301.04 g, 369.68 g and 335.36 g were noticed in the year 2012, 2013 and in pooled data, respectively under vermicompost + K (100%) + K mobilizer combination (Table 2). But the minimum clump weight of 193.56 g 216.64 g and 205.10 g were recorded under compost + K (50%) combination. The next best treatment in this respect was vermicompost + K (75%) + K mobilizer (307.23 g) as per pooled data. The plants fed with recommended NPK (inorganic) recorded the clump weight of 252.88 g.

With regard to length, the longest clump of 17.73 cm and 19.88 cm were recorded with vermicompost + K (50%) + K mobilizer and vermicompost + K (75%) + K mobilizer during the year 2012 and 2013, respectively (Table 2). As per pooled data, the maximum length (17.85 cm) was recorded with vermicompost + K (100%) + K mobilizer followed by compost + K (100%) + K mobilizer (17.76 cm) and vermicompost + K (75%) + K mobilizer (17.64 cm) as compared to minimum length of 15.71 cm under vermicompost + K (75%). The plants raised under recommended NPK (inorganic) produced the clump of 16.40 cm length.

Table 1: Influence of manures and potassic mobiliser on growth of turmeric at 180 DAP

Treatments	Plant height (cm)			No. of tillers clump^{-1}			No. of leaves clump^{-1}		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Compost + K 100% + KM	169.34	187.12	178.23	3.35	2.97	3.16	20.34	18.36	19.35
Compost + K 75% + KM	161.20	184.33	172.77	3.64	3.28	3.46	16.32	20.14	18.23
Compost + K 50% + KM	158.02	178.31	168.17	2.51	2.35	2.43	15.66	19.73	17.70
Vermicompost + K 100% + KM	178.07	185.33	181.70	2.90	2.62	2.76	19.06	20.24	19.65
Vermicompost + K 75% + KM	148.20	192.16	170.18	2.62	2.22	2.42	16.48	19.04	17.76
Vermicompost + K 50% + KM	143.21	164.12	153.67	2.15	1.77	1.96	15.62	18.86	17.24
Compost + K 100%	149.53	162.66	168.10	2.63	2.09	2.36	17.37	20.93	19.15
Compost + K 75%	141.60	182.66	162.13	2.16	1.68	1.92	16.53	20.39	18.46
Compost + K 50%	148.09	179.25	163.67	2.28	1.84	2.06	15.33	19.67	17.50
Vermicompost + K 100%	151.26	169.78	160.52	2.33	1.95	2.14	18.29	16.63	17.46
Vermicompost + K 75%	148.53	164.91	156.72	2.20	1.72	1.96	18.46	16.51	17.50
Vermicompost + K 50%	141.13	164.01	152.57	1.96	1.50	1.73	14.66	19.20	16.93
Recommended NPK (inorganic)	148.80	169.33	159.07	2.34	1.96	2.15	18.59	16.05	17.32
SEm (±)	**3.39**	**4.32**	**2.58**	**0.22**	**0.25**	**0.25**	**1.037**	**0.45**	**0.30**
LSD (0.05)	**9.90**	**12.61**	**7.33**	**0.65**	**0.74**	**0.70**	**NS**	**1.31**	**0.86**

Note: DAP = days after planting; KM = potassic mobilizer; NS = non significant

Table 2: Influence of manures and potassic mobilizer on clump characters of turmeric

Treatments	Weight of clump (g)			Length of clump (cm)			Breadth of clump (cm)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Compost + K 100% + KM	276.67	328.23	302.45	16.14	19.38	17.76	23.55	21.63	22.59
Compost + K 75% + KM	268.84	306.22	287.53	17.66	16.25	16.96	24.83	23.71	24.27
Compost + K 50% + KM	218.33	242.79	230.56	15.87	17.58	16.73	21.35	22.29	21.82
Vermicompost + K 100% + KM	301.04	369.68	335.36	17.44	18.25	17.85	22.89	25.61	24.25
Vermicompost + K 75% + KM	266.12	348.34	307.23	15.39	19.88	17.64	20.74	24.12	22.43
Vermicompost + K 50% + KM	238.46	240.38	239.42	17.73	16.33	17.03	19.70	21.94	20.82
Compost + K 100%	231.12	319.20	257.16	15.72	16.45	16.09	22.88	21.76	22.32
Compost + K 75%	242.34	262.72	252.53	16.27	17.65	16.96	25.15	22.13	23.64
Compost + K 50%	193.56	216.64	205.10	15.94	16.54	16.24	19.82	22.28	21.05
Vermicompost + K 100%	287.94	317.18	302.56	16.50	16.17	16.37	23.22	22.09	22.65
Vermicompost + K 75%	263.04	276.21	269.62	16.45	16.29	15.71	22.56	20.29	21.43
Vermicompost + K 50%	201.51	230.55	216.03	14.83	16.58	16.21	18.84	21.96	20.46
Recommended NPK (inorganic)	248.70	257.06	252.88	16.22	16.58	16.40	20.62	22.50	21.56
SEm (±)	**6.33**	**5.46**	**4.24**	**0.09**	**0.57**	**0.25**	**0.95**	**1.09**	**1.05**
LSD (0.05)	**18.47**	**15.92**	**12.05**	**0.25**	**NS**	**0.71**	**NS**	**NS**	**NS**

Maximum breadth of clump of 25.15 cm and 25.61 cm were noticed with treatment combination of compost + K (75%) and vermicompost + K (100%) + K mobilizer during the year 2012 and 2013, respectively (Table 2). As per pooled data, maximum breadth of clump of 24.27 cm was noticed in compost + K (75%) + K mobilizer followed by vermicompost + K (100%) + K mobilizer (24.25 cm) and compost +K (75%) [23.64 cm] as compared to minimum breadth of 20.46 cm under vermicompost + K (50%). The plant grown under recommended NPK (inorganic) recorded clump breadth of 21.56 cm.

The plants raised under treatment vermicompost + K (100%) + K mobilizer recorded maximum plot yield

Table 3: Influence of manures and potassic mobilizer on yield of turmeric

Treatments	Yield per plot (kg)			Projected yield (t ha^{-1})		
	2012	2013	Pooled	2012	2013	Pooled
Compost + K 100% + KM	11.23	13.67	12.45	28.08	34.18	31.13
Compost + K 75% + KM	10.68	12.48	11.58	26.70	31.20	28.95
Compost + K 50% + KM	8.79	10.33	9.56	21.98	25.83	23.90
Vermicompost + K 100% + KM	11.84	14.04	12.94	29.60	35.10	32.35
Vermicompost + K 75% + KM	11.06	13.46	12.26	27.65	33.65	30.65
Vermicompost + K 50% + KM	9.06	11.18	10.12	22.65	27.95	25.30
Compost + K 100%	10.11	12.45	11.28	25.28	31.13	28.20
Compost + K 75%	9.66	11.64	10.65	24.15	29.10	26.63
Compost + K 50%	8.35	9.59	8.97	20.88	23.98	22.43
Vermicompost + K 100%	11.16	12.78	11.97	27.90	31.95	29.93
Vermicompost + K 75%	10.36	12.14	11.25	25.90	30.35	28.13
Vermicompost + K 50%	8.74	10.26	9.50	21.85	25.65	23.75
Recommended NPK (inorganic)	9.43	12.27	10.85	23.58	30.68	27.13
SEm (±)	**0.23**	**0.35**	**0.35**	**1.07**	**0.83**	**0.96**
LSD (0.05)	**0.67**	**1.03**	**1.03**	**3.13**	**2.43**	**2.72**

Table 4: Effect of manures and potassic mobilizer on quality of turmeric

Treatments	Dry recovery (%)			Curcumin (%)			Oleoresin (%)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Compost + K 100% + KM	22.52	23.16	22.84	6.33	6.71	6.52	10.56	10.88	10.72
Compost + K 75% + KM	21.92	22.64	22.28	6.12	6.26	6.19	9.68	10.64	10.16
Compost + K 50% + KM	21.68	21.38	21.53	5.42	5.94	5.68	9.84	9.72	9.78
Vermicompost + K 100% + KM	21.9	22.74	22.32	5.73	6.19	5.96	10.36	10.92	10.64
Vermicompost + K 75% + KM	22.27	21.43	21.85	6.38	6.47	6.43	11.22	11.34	11.28
Vermicompost + K 50% + KM	21.4	20.92	21.16	5.26	5.72	5.49	10.84	11.08	10.96
Compost + K 100%	20.9	21.62	21.26	5.61	5.81	5.71	9.42	9.74	9.58
Compost + K 75%	20.13	21.53	20.83	5.34	5.74	5.54	9.64	10.28	9.96
Compost + K 50%	18.92	20.12	19.52	5.03	5.25	5.14	9.44	10.32	9.88
Vermicompost + K 100%	20.69	21.83	21.26	5.56	5.96	5.76	9.98	10.38	10.18
Vermicompost + K 75%	20.42	21.24	20.83	6.05	5.77	5.91	10.15	9.65	9.90
Vermicompost + K 50%	19.58	21.36	20.47	5.06	5.58	5.67	10.24	9.72	9.98
Recommended NPK (inorganic)	19.92	20.56	20.24	5.32	4.94	5.13	9.57	10.15	9.86
SEm (±)	**0.73**	**0.47**	**0.62**	**0.15**	**0.13**	**0.14**	**0.19**	**0.14**	**0.11**
LSD (0.05)	**2.13**	**1.38**	**1.74**	**0.43**	**0.37**	**0.39**	**0.56**	**0.42**	**0.33**

(12.94 kg) followed by compost + K (100%) + K mobilizer (12.45 kg) (Table 3). The plot yield under recommended NPK (inorganic) was 10.85 kg. The highest yield per hectare (32.35 t ha^{-1}) was recorded with vermicompost + K (100%) + K mobilizer followed by compost + K (100%) + K mobilizer (31.13 t/ha) and vermicompost + K (75%) + K mobilizer as compared to lowest yield (22.43 t ha^{-1}) under compost + K (50%) combination. The projected yield under recommended NPK (inorganic) was 27.13 t ha^{-1}. The results indicated the better performance of bio-inoculants with vermicompost as compared to compost and additive effects of organics with recommended dose of inorganics was also observed. Results also indicate the chances of 25% saving of inorganic potassium through biofertilizer.

Maximum dry recovery of 22.52, 23.16 and 22.84 per cent were noticed in combination of compost + K 100% + K mobilizer during the year 2012, 2013 and in pooled data (Table 4). Minimum dry recovery (19.52%) was observed in compost + K (50%). As per the pooled data maximum curcumin content was recorded with compost + K (100%) + K mobilizer (6.52%) followed by vermicompost + K (75%) +K mobilizer (6.43%) as compared to the lowest curcumin content (5.13%) in recommended NPK (inorganic). According to pooled data the plants raised under vermicompost + K (75%) + K mobilizer recorded the highest oleoresin content (11.28%) of followed by vermicompost + K (50%) + K mobilizer (10.96%) as compared to the lowest oleoresin (9.58%) content under compost + K (100%).

The combination of potassic mobilizer along with inorganic fertilizer and compost or vermicompost performed better over cent per cent inorganic nutrition. The higher and easily available nutrient content in vermicompost and their better uptake by the plants might be the reason for the highest rhizome yield in this treatment (Shamrao *et al*., 2013). Vermicompost contains a higher percentage of nutrients necessary for plant growth in readily available forms. The higher nutrient content in vermicompost coupled with their easy and extended availability and better uptake brought about by the microbial action might have resulted in higher yield in this treatment. The superiority of vermicompost in increasing the yield and net returns in kasthuri turmeric has already been reported by Nirmalatha (2009). Combined application of biofertilizers and inorganic fertilizers had beneficial effect on yield and yield attributing characters. The increase in yield was largely as consequence of the cumulative effect of plant growth. Potassium nutrition of spices showed that potassium is the second most important nutrient element next to nitrogen for growth and development of spice crops. It helps is several physiological processes and uptake of other nutrient elements. It improves quality (oil and oleoresins) and yield of spices (Sadanandam, 1993). An increased in yield was noticed in treatment combination of 100% NPK + compost or vermicompost + K mobilizer as compared to NPK (100%) inorganic + compost or vermicompost. K mobilizer increased K availability in soils and increased mineral content in the plant (Sheng *et al*., 2002). K mobilizer causes significantly higher release of potassium at 60 days after inoculation. The uptake of P and K was also increased significantly by applying these inoculants in the soil. The inoculants K mobilizer may resulted in solubilizing the non-exchangeable potassium to exchangeable form and same trend of results were recorded by Richards and Bates (1989). Studies conducted by different workers on effect of KSB inoculation on crop yields indicate increase in yield by 10-20% with increased K-uptake by the crop uptake of P also increased due to inoculation of K mobilizer (Yadav and Chandra, 2012). The increase in growth attributes due to increase in fertilizer application may be ascertained to increased amount of nutrients such as nitrogen, phosphorus and potassium in plants, leading to increased formation of plant metabolites that help to build up the plant tissues (Claypool, 1936 and Childers, 1996). Application of compost or vermicompost improves the soil tilth and aeration, increases the water holding capacity of the soil and stimulates the activity of micro-organisms that makes the plant food elements in the soil readily available to the crops as compared to only NPK (100%) without any organic inputs. The positive influence of biofertilizers on the various growth and yield parameters observed in the present study were due to enhanced uptake of nutrients by the plants (Borea, 1991). Manohar Rao *et al.* (2005) recorded the highest curcumin and oleoresin with Neem cake + FYM + NPK (100%) as compared to recommended dose of fertilizer alone. Higher curcumin content in turmeric with organic amendment was also reported by Rao and Swamy (1978). Improvement in quality parameters might be due to increased uptake of NPK due to bio inoculants. utilization of organic fertilizer could be better preposition for improving biological attributes of soil, which in turn may increase quality and productivity potential of various crops (Allen *et al.*, 2002). Under integrated nutrient management (INM) *i.e*. with manures, potassic biofertilizers and inorganic potassic fertilizers, the most effective treatment was compost + K (100%) + K mobilizer followed by vermicompost + K (100%) + K mobilizer for production of turmeric under new alluvial plains of West Bengal. The favourable effect of biofertilizers over recommended dose of NPK was observed. The results also indicate the chance of reduction of 25% inorganic potassic fertilizer through inoculation of potassic mobilizer.

REFERENCES

Allen, M. F., Jasper, D. A. and Zak, J. C. 2002. Micro-organisms. In: *Handbook of Ecological Restoration* Vol 1. *Principles of Restoration*, (Davy, A.J. and Perrocw, M. Eds.) Cambridge University Press, pp. 257-78.

Anonymous, 1995. *Annual Report*. All India Coordinated Research Project on Spices. Indian Institute of Spices Research. Calicut 12, Kerala, pp.45

Barker, W.W., Welch, S. A., Chu, S. and Banfield, J. F. (1998). Experimental observations of the effect of bacteria on alumino silicate weathering. *Amer. Mineral*, **83**: 1551-63.

Basak, B. B. and Biswas, D. R. (2009). Influence of potassium solubilising microorganism (*Bacillus mucilaginous*) and waste mica on potassium uptake dynamics by Sudan grass (*Sorghum vulgare* Pers.) grown under two Alfisols. *Pl. Soil*, **31**: 235-55.

Borea, J. M. 1991. Vesicular arbuscular mycorrhizae as modifiers of soil fertility. *Adv. in Soil Sc,* **15**: 2-31.

Chachan, M., Ghosh,D. K., Hore,J.K. and Anitha, M.2017. Studies on response of aures and bio fertilizers on growth and yield of turmeric (*Curcuma longa* L.) *J. Crop and Weed*, **13**:112-15.

Childers, N. F. 1996. *Fruit Nutrition*. Horticultural Publications. Rntgert State University, Nichole Avenue, New Jwersey. USA.

Claypool, L. L. 1936. Irrigation of orchards. *Proc. Wash. A Hort. Soc*., **30**: 78-104.

Jansson, S.L. 1978. *In:* Potassium Requirements of Crops. *Proceedings of the 11th Congress* (CPRRT'78). International Potash Institute, Bern, Switzerland. IPI Research Topics. No. 7, pp. 267-73.

Manohar Rao, A., Venkata Rao, P., Narayana Reddy, Y. and Reddy, M. S. N. 2005. Effect of organic and inorganic manorial combination on growth, yield and quality of turmeric (*Curcuma longa* L.). *J. Plantn. Crops*. **33**: 198-205.

Marschner, P. (ed.) 2012. *Marschner's Mineral Nutrition of Higher Plants*. Third Edition Elsevier.

Medda, P. S. and Hore, J. K. 2003. Effect of N and K on growth and yield of turmeric in alluvial plains of West Bengal. *Indian J. Hort.*, **60**: 84-88

Memon, Y. M., Fergus, I. F., Hughes, J. D. and Page, D. W. (1988).Utilization of non -exchangeable soil potassium in relation to soil types, plant species and stage of growth. *Australian J. Soil Res*., **26**: 489-96.

Nirmalatha, J. D. 2009. Standardization of organic manures and effect of microbial inoculants on growth, yield and quality of kasthuri turmeric (*Curcuma aromatic Salisb.*)"*Ph.D. (Hort.) Thesis*, Kerela Agricultural University, Thrissur, pp. 270.

Ravindran, P.N. and Nirmal, B.K. 2005. *Ginger, the Genus Zingiber*. CRC Press. Boca Raton, FL, USA, ISBN 9780849320217. pp. 1-552.

Rao, D. V. R. and Swamy, G. S. 1978. Effect of graded doses of farm yard manure on growth and yield of turmeric variety, Mydukur. *Res. APAU.,* **5**: 8-12.

Richards, J.E. and Bates, T.E. 1989. Studies on the potassium supplying capacities of Southern Ontario soils, III. Measurement of available K. *Canadian J. Soil Sc.*, **69**: 597-10.

Sadanandan, A.K., Peter, K.V. and Hamza, S. 2002. Role of Potassium Nutrition in Improving Yield and Quality of Spice Crops in India. *In: Potassium for Sustainable Crop Production*. Pasricha, N.S., and S.K. Bansal (eds.). Potash Research Institute of India, Gurgaon, Haryana and International Potash Institute, Switzerland. pp. 445-54.

Sadanandan, A.K. 1993. Potassium in soils growing black pepper (*Piper nigrum* L.) and response of applied potash. In: "*Potassium for Plantation Crops*". (Eds. Singh, M. and Mishra, M. K.). Potash Research Institute of India. Gurgaon, Haryana, pp. 75-78.

Sadasivam, S. and Manickm, A. 1996. *Biochemical Methods* . 2nd Edn. New Age International Publisher, pp. 191-92.

Shamrao, B.S., Jessykutty, P.C., Duggi, S., Magadum, S., Handral, H.K. and Shruthi, S.D. 2013. Studies on growth, yield and economic parameters of kasthuri turmeric (*Curcuma aromatic* Salisb.) under organic manuring practices. *Int. J. Res. Tech.,* **2**: 2278-63

Sheng, X.F., He, L.Y. and Huang, W.F. 2002. The conditions of releasing potassium by a silicate dissolving bacterial strength NBT. *Agric. Sci.*, China, **1**:662-66.

Singh, S.P. 2012. Effect of integrated nutrient management on growth, yield and economics of turmeric (*Curcuma longa* L.) var. RAJENDRA SONIA, *Asian J. Hort.*, **7**: 478-80.

Yadav, A.K. and Chandra, K. 2012. Three new biofertilizer formulations being commercialized. *Biofert News L*etter, **20**: 9-13