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Identification of suitable management system for enhancing yield of rainfed turmeric (*Curcuma longa* L.)

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Abstract
Turmeric (*Curcuma longa* L.) is an herbaceous perennial belongs to the family Zingiberaceae is one of the export oriented crop. Turmeric is grown for its underground rhizome which is mainly used as spice or condiments. Use of organic manure for crop production is gaining momentum as the organically produce products get high economic return and they are environmentally safe compared with inorganic fertilizers. Response of turmeric varieties to different nutrient regimes is diverse. Present experiment is aimed to study the influence of various management systems on yield of turmeric varieties under rain fed conditions. The experiment was conducted for the period of 2019-2022 using the varieties Prathibha, Alleppey supreme, Varna, Shoba, Sona, Kanthi, Suvarna, Suguna, Sudarsana, Kedaram, Prabha and Pragati. Maximum yield was recorded by the treatment Integrated Nutrient Management (INM) 50%+50% (30.3 t/ha) that was on par with organic 100% (29.8 t/ha). Soil enzymes are known to play significant roles in improving soil health and its environment. In the present study, maximum acid phosphatase activity was noticed in organic 100% followed by INM 50%+50%. Similarly, maximum alkaline phosphatase activity was noticed in organic 100% followed by organic 75% and then INM 50%+50%. Maximum dehydrogenase activity was noticed in organic 100% followed by organic 75% and then INM 75+25%. Correlations between soil microbiological and soil nutrient variables were studied and found that soil nitrogen content is correlated with dehydrogenase, acid phosphatase, and alkaline phosphatase activity and is highly correlated with dehydrogenase enzyme activity. Soil phosphorus content is well correlated with alkaline phosphatase and there is no correlation between soil potassium content with any of the enzymes. Both Integrated nutrient management (50%+50%) and organic management 100% are suggested to improve yield and soil microbial properties of the turmeric crop.

Keywords: Turmeric, organic manures, fertilizers, soil enzymes

Introduction

Turmeric (*Curcuma longa* L.) belongs to the family Zingiberaceae is one of the export oriented spice crop, cultivated widely in tropical and subtropical regions of the world [11]. Turmeric rhizomes contain 1.8 to5.4 percent curcumin, a crystalline substance ($C_{21}H_{20}O_6$) which imparts yellow colour, 2.5 to 7.2 percent of essential oil, turmerol, 5.0 percent fat, 3.5 percent minerals and 69.4 percent carbohydrates [5]. It is widely used in food, beverages, confectionery and medicine and because of its myriad uses the demand for trading is increasing day by day. Being a long duration crop, turmeric extracts a immense amount of nutrients from the soil. The organic manure gives better quality produce as compared to those grown with inorganic sources of fertilizers [1]. They are superior with respect to desirable ingredients such as carbohydrates, proteins, minerals, vitamins (B1, B2 and C), and contain free amino acids and organic acid [35]. Moreover, organic manures have beneficial effects on soil health and productivity. The adverse effects of continuous use of high dose of chemical fertilizers on soil health and environment were realized by [10]. Soil biochemical parameters are considered as potential indicators of soil microbiological health and overall soil quality [32]. The present study was aimed to determine the yield and soil microbial properties of turmeric varieties under different nutrient management systems. The experiment was conducted from 2019-2022 using the varieties Prathibha, Alleppey supreme, Varna, Shoba, Sona, Kanthi, Suvarna, Suguna, Sudarsana, Kedaram, Prabha and Pragati.

Materials and Methods

Location: The experiment was laid out at the Experimental Farm, Peruvannamuzhi, Indian Institute of Spices Research, Kozhikode (110350 N 75049 0E) from 20192021 characterized by a humid tropical climate with a mean annual rainfall of 4047.0 mm, with most of the rainfall occurring between May and December. The relative humidity ranges between 75.0 and 90.0%, and the average temperature from 22.62 to 27.09. The soil is a Ustic Humitropept with clay loam texture. In general, soils were acidic (range 4.55.5), while EC levels were very low (0.150.28 dSm^{-1}). Likewise, very little variation existed in CEC 12.613.2 me 100 g^{-1}) and organic carbon content (16.017.6 g kg^{-1}) of soils during various years of experimentation. Among the available nutrient levels, mineral N levels were low to medium (111152 mg kg^{-1}), Bray P levels were medium (2.58.9 mg kg^{-1}), while exchangeable K levels were low to medium (67195 mg kg^{-1}). In case of secondary nutrients, both exchangeable Ca and Mg levels were found to be low (275350 and 3755 mg kg^{-1}, respectively). With regard to available micronutrients, the levels of available Fe (3441 mg kg^{-1}) and available Mn (10.615.2 mg kg^{-1}) were high, but the levels of available Zn (0.621.2 mg kg^{-1}) and Cu (0.661.2 mg kg^{-1}) were low. Since turmeric is a nutrient exhaustive crop, and due to serious incidence of diseases when grown in the same soil, the field experiments were not conducted at the same site during the subsequent years but were conducted in different sites in the same location with similar soil type.

Experimental Details: The land was prepared by removing the weeds, stones, ploughed to a fine tilth followed by application of lime @ 1000 kg ha^{-1} by thorough mixing and levelling. Beds of the 3x1 m dimensions were made by maintaining a space of 40 cm between beds. During planting, shallow pits were made on the beds with a spacing of 25x25 cm and seed rhizomes (25 g) of turmeric varieties Prathibha, Alleppey supreme, Varna, Shoba, Sona, Kanthi, Suvarna, Suguna, Sudarsana, Kedaram, Prabha and Pragati. Seed rhizomes were placed on the beds at a depth of 4.05.0 cm and covered with soil. Subsequently, mulching with *Gliricidia sepium* (Jacq.) Kunth ex Walp., @ 15 t ha^{-1} was done to all the beds to prevent the planted rhizomes from being exposed during heavy showers as well as to secure the beds against soil erosion. At 45 and 90 days after planting (DAP), weeding of the beds was done, followed by fertilizer application as per the treatments and application of green leaf mulch @ 7.5 t ha^{-1}. Nutrient Management Schedules adopted for the study are as follows: Organic 100%: 20 t FYM 2 t Neem cake 1 t Ash (basal) 4 t Vermicompost/ha (at 60 DAP), Azospirillum and Pseudomonas sp. as seed treatment and spray of BM and neem oil for disease and pest control. Organic 75%: 15 t FYM 1.5 t Neem cake 0.75 t Ash (basal) 3 t Vermicompost/ha (at 60 DAP), Azospirillum and Pseudomonas sp. as seed treatment and spray of BM and neem oil for disease and pest control. Towards organic: (Org 25% Chem): 15 t FYM 1.5 t Neem cake 0.75 t Ash (basal) 3 t Vermicompost/ha (at 60 DAP), N, P, K (25% Recommended). Towards organic: (50% Org 50% Chem): FYM (10 t/ ha) (basal) N, P, K (Half Recommended) (at 60 & 90 DAP) P Solubilizing Bacteria and spray with Mancozeb and Chlorontraniliprole for disease and pest control. 100% Inorganic: Recommended fertilizer dose NPK 60:50:120 kg/ha (at 30, 60 & 90 DAP) and chemical management (Mancozeb and Chlorontraniliprole for disease and pest control.)

The relevant chemical constituents of FYM, VC, NC and ash are given in Table 1 [12]. The turmeric seed rhizomes of each variety were dipped in biofertilizer GRB 35 solution for 30 minutes before planting in beds. Neem cake, VC, FYM and ash were incorporated manually into the soil. The crop was harvested at maturity (240 DAP). The design of the experiment followed was randomized block with four replications.

Table 1: Initial nutrient content in manures used in the Experiment

Item	Nitrogen (%)	Phosphorus (%)	Potassium (%)
Farmyard manure	0.75	1.0	0.55
Neem Cake	1.50	0.36	1.51
Ash	-	0.20	6.30
Vermicompost	0.76	0.88	0.65

Estimation of macro and micro nutrients

The treatment wise soil samples were taken 120 days after planting, removed organic/plant debris, and transferred into plastic bags. Prior to the analysis, the soil samples were sieved to 2.0 mm. After estimation of moisture content, subsamples for determination of biochemical parameters were stored at 400C. For the determination of mineral nitrogen second set of subsamples were sieved using 0.5 mm meshes. Available P was estimated using the Bray extractant [19], mineral N by steam distillation [16] and exchangeable K [18],

Estimation of Soil enzyme activities: Dehydrogenase [DHA, Enzyme Commission (EC) number 1.1.1.] activity was estimated by the addition of 3% aqueous solution of 2,3,5triphenyltetrazolium chloride (TTC) to 6 g soil followed by incubation at 37 °C for 24 h. The triphenyl formazan (TPF) was then extracted with methanol and estimated colorimetrically at 485 nm [7]. Acid and alkaline phosphatase (E.C.3.1.3.2) activity was determined by incubating soils at 37 °C for 1 h in modified universal buffer (pH 6.5 or pH 11) with p-nitrophenyl phosphate as the substrate [27].

Statistical analysis: The replication wise data on soil nutrient availability, soil enzymes and yield were analyzed by the IBM SPSS v 25 and the means were compared with the standard error and the CD values of the estimates at 5% levels of significance. Correlation coefficients were also worked between the observed soil fertility, enzyme and yield parameters.

Results and Discussion

Recording of yield: The yield of turmeric varieties was significantly affected by different management systems. The yield ranged from 25.8 to 30.3 t/ha and maximum yield was recorded under the treatment INM 50% 50% (30.3 t/ha) which was 14.7% higher than the yield in chemical treatment while it was on par with 100% organic (29.8 t/ha). It is observed that treatments organic 75%, INM 75+25%, chemical treatments were on par with respect to yield. Lowest yield (26.4 t/ha) was recorded by complete inorganic management. In INM 50:50, integrated application of organic manure, inorganic fertilizer supplied all essential nutrients in balanced ratio might have made a favorable effect in better photosynthate translocation and resulted in maximum yield. This result was in conformation with findings of [13, 2]. Application of organics along with inorganic manures increased the yield, improved fertility status of soil by improving physical, chemical biological properties of soil [31]. Pronounced yield improvement in organic treatment might be due to sustained availability of nitrogen throughout the growing phase and also due to enhanced photosynthates and effective translocation of them to the sink i.e., rhizomes. The beneficial effect of organics was obtained in many crops [25]. The usefulness of biofertilizers [24, 21, 15] along with organic manures and inorganic fertilizers on growth and yield of turmeric rhizomes was reported by [30, 6] Integrated application of nutrients is more advantageous than chemical fertilizers [33] and [23, 36]. Lowest yield in chemical nutrient treatment may be due to reduced availability of nutrients and decreased microbial activity seem to have seriously hampered nutrient cycling, thereby inhibiting rhizome development. The variety Suguna recorded maximum yield (50.2 t/ha) that was on par with yield of Sudarsana (49.4 t/ha) and Pragati (48.9 t/ha) and lowest yield was noticed in Sona 14.3 t/ha. The variation in rhizome yield could be due to genetic variations among the varieties as also reported [26].

Estimation of plant nutrients: Significant difference was noticed in pH and nutrient content in soil due to application of different nutrient management system. Maximum organic carbon, nitrogen, calcium, magnesium, were recorded by the treatment organic 100% followed by organic 75%. The treatment organic 100% recorded maximum phosphorus and potassium followed by

Table 3 Effect of different management systems on soil nutrient availability of turmeric (120 DAP)

Management system	pH (1:2)	OC %	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
			kg/ha			ppm					
Organic 100%	5.81	2.89	446.93	249.73	241.27	1243.32	688.6	47.29	19.45	4.34	2.44
Organic 75%	5.77	2.44	404.58	179.42	162.32	1165.92	584.58	39.86	13.62	2.8	1.9
INM (75%+25%)	5.44	2.16	359.44	180.57	345.83	913.4	496.2	44.5	21.71	2.9	2.52
INM (50%+50%)	5.38	2	314.73	189.27	425.76	941.48	399.15	41.39	17.21	3.32	2.16
Inorganic 100%	4.92	1.76	271.23	101.7	378.18	576.38	187.42	37.49	15.26	1.09	3.19
CD(0.05)	0.14	0.1	7.81	2.38	5.41	8.15	11.06	0.76	1.68	1.13	0.1

Table 2: Effect of Different Management Systems on Yield of Turmeric Varieties (t/ha)

Treatments Varieties	Organic 100%	Organic 75%	INM1 (75%+25%)	INM1 (50%+50%)	Inorganic 100%	Mean
Prathibha	27.5 f	27.4 d	24.3 c	29.4 bc	26.8 c	27.1
Aleppey supreme	20.5 g	23.7 e	23.8 cd	27.0 c	24.2 cd	23.8
Varna	17.6 h	14.1 h	15.2 f	19.2 de	18.0 e	16.8
Shoba	12.3 j	13.0 h	15.8 f	17.4 ef	18.0 e	15.3
Sona	15.1 i	11.5 i	14.6 f	15.9 f	14.3 f	14.3
Kanthi	16.3 hi	17.0 g	18.3 e	18.9 def	15.7 ef	17.2
Suvarna	19.4 g	16.4 g	19.1 e	20.9 d	17.5 e	18.7
Suguna	59.1 a	52.6 a	43.6 b	50.5 a	45.4 a	50.2
Sudarsana	51.6 c	44.7 b	51.0 a	52.0 a	47.6 a	49.4
Kedaram	32.8 d	29.0 c	18.7 e	30.3 b	26.3 c	27.4
Prabha	29.4 e	19.7 f	22.8 d	29.7 bc	23.1 d	24.9
Pragati	56.3 b	52.5 a	42.4 b	52.9 a	40.7 b	48.9
Mean	29.8	26.8	25.8	30.3	26.4	27.8

INM 50% + 50%. The treatment organic 100% recorded maximum iron followed by INM 75+25%. Similarly, the treatment organic 100% recorded maximum zinc followed by INM 50% + 50%. Maximum manganese content was noticed in INM 7525 followed by organic 100%. In organic management, a combination of FYM Neem cake Ash Vermicompost, Azospirillum and Pseudomonas sp. were used. Turmeric being a heavy feeder of nutrients, the application of neem cake possessing pesticidal properties and less leaching losses would have helped to avoid loss of nitrogen and might have enhanced availability of nitrogen and organic carbon content in soil. Biofertilizer also might have played a vital role in increasing the rhizome yield by improving soil microbial activity. The addition of vermicompost and FYM would have improved the physical, chemical and biological properties of soil which helps in better nutrients absorption and utilization by plant resulting higher rhizome yield. Application of organic manures increased the nutrient availability, improved the physical conditions of the soil, and increased the yield [22].

Enzymes activities: The activities of the enzymes, namely acid phosphatase, alkaline phosphatase and dehydrogenase activity were presented in table 5, 6 and 7. In the study, the highest level of acid phosphatase activity was observed in the organic 100% treatment. The acid phosphatase level was 235% higher in the organic 100% treatment compared to 191% in the 75% 25% treatment, 149% in the 50% + 50% inorganic treatment, and 110% in the organic 75% treatment, all in the variety Sudarsana. The study found that the maximum alkaline phosphatase activity was present in the organic 100% treatment, followed by organic 75% and INM 50% +50%. In the variety Suguna, the alkaline phosphatase activity in the organic 100% treatment was 170% higher compared to inorganic, 138% higher compared to 75%+ 25%, 110% higher compared to INM 50% 50%, and 79% higher compared to only organic 75%. Soil enzymes are known to play significant roles in improving soil health and its environment. Agronomic practices and nutrient management systems (organic or conventional) are the major influencing factors on soil microbial biomass and activity [9]. Phosphatase enzymes are widespread in soils, primarily produced by microorganisms, as reported by [17]. The activity of these enzymes is impacted by the composition of the soils microbial community and the rhizo deposits, as noted by [34]. Phosphatases are capable of breaking down different substrates linked to free phosphoryl and sulfate groups [29]. This study also found that acid phosphatase, alkaline phosphatase, and dehydrogenase activities showed a significant variation in response to the nutrient management practices of turmeric crops. Dehydrogenases are considered as best indicators of the respiratory metabolism of microbes and they are commonly found in soils having high organic matter content [20]. The enhanced soil enzymatic activity in the organic system can be attributed to a relatively high organic matter content and a fast decomposition rate, according to Avellaneda [4]. Higher dehydrogenase activity was noticed in organic 100% followed by organic 75% and then INM 75+25% were found in our study. In fact, in the organic 100% treatment, alkaline phosphatase activity was greater by 88% compared to inorganic, by 84% compared to 75%+25%, by 105% compared to INM 50%+50% and 85% compared to only organic 75% in variety Suguna. Soil enzymatic activities was greater in the organic management system compared to conventional systems for all enzymes in tea, sugar beet, barley, oats and wheat [14]. This improvement is largely due to the presence of beneficial microorganisms in the organic management systems, which increase nutrient availability by impacting the root morphology and physiology of the turmeric plant and producing soil enzymes. Thus, organic amendments *viz*., FYM, vermicompost and plant growth promoting bacteria etc. can stimulate microbial biomass differently through increases in labile organic matter [14].

Table 5: Effect of different management systems on alkaline phosphatase activities in soil

Alkaline Phosphatase					
Variety	**Organic 100%**	**organic 75%**	**50%+50%**	**75%+25%**	**Inorganic**
Prathibha	35.93 cd	26.686 a	18.663 a	16.211 cd	11.59 cd
Aleppey supreme	35.398 de	26.126 a	19.708 a	16.193 cd	8.406 f
Varna	33.809 f	25.974 a	19.5 a	15.046 de	11.845 bcd
Shoba	27.589 i	22.093 c	19.005 a	15.87 de	11.68 cd
Sona	29.745 h	23.735 b	17 b	17.086 abc	11.711 cd
Kanthi	31.811 g	21.985 c	15.505 c	17.673 ab	11.017 de
Suvarna	39.086 ab	19.31 d	16.025 bc	17.909 a	12.166 bc
Suguna	39.998 a	22.03 c	18.969 a	16.78 bcd	14.793 a
Sudarsana	38.838 b	21.881 c	17.054 b	16.326 cd	11.316 cde
Kedaram	36.886 c	18.891 d	16.028 bc	15.969 de	10.354 e
Prabha	34.428 ef	21.385 c	15.486 c	13.845 f	12.8 b
Pragati	36.915 c	21.865 c	18.726 a	16.64 bcd	12.84 b

Table 6: Effect of different management systems on acid phosphatase activities in soil

ACID PHOSPHATASE					
Variety	**Organic 100%**	**organic 75%**	**50%+50%**	**75%+25%**	**Inorganic**
Prathibha	48.52 d	29.465 cd	23.178 bcd	17.964 bc	17.15abcd
Aleppey supreme	41.40 f	26.197 f	21.301 e	17.3 c	16.349 cde
Varna	32.535 i	30.397 bc	21.882 de	19.069 b	18.628 a
Shoba	35.245 h	27.57 ef	22.359 cde	18.949 b	16.849 cde
Sona	43.083 e	28.286 de	20.96 e	19.166 b	15.928 de
Kanthi	48.651 d	26.792 ef	22.373 cde	21.103 a	16.589 cde
Suvarna	43.551 e	26.549 f	21.873 de	18.896 b	16.951 bcde
Suguna	58.885 b	33.519 a	23.52 abc	21.839 a	17.758 abc
Sudarsana	62.078 a	29.474 cd	24.894 a	21.32 a	18.48 ab
Kedaram	44.346 e	31.24 b	21.696 de	19.151 b	16.544 cde
Prabha	38.073 g	29.343 cd	21.476 e	22.523 a	15.575 e
Pragati	51.035 c	30.835 bc	24.256 ab	21.17 a	16.069 de

Table 7: Effect of different management systems on dehydrogenase activities in soil

Dehydrogenase					
Variety	**Organic 100%**	**organic 75%**	**50%+50%**	**75%+25%**	**Inorganic**
Prathibha	8.897 b	4.911 abcd	3.43 c	4.589 abc	2.849 ab
Aleppey supreme	8.098 c	4.307 cd	3.956 bc	4.534 abc	2.665 ab
Varna	7.861 cd	4.836 abcd	3.976 bc	3.654 de	2.955 ab
Shoba	7.47 cde	4.479 bcd	4.05 abc	4.085 cde	2.969 ab
Sona	6.628 f	4.934 abcd	3.911 bc	3.361 e	2.64 ab
Kanthi	7.47 cde	4.961 abcd	4.044 abc	3.703 de	2.745 ab
Suvarna	7.611 cde	5.004 abc	4.144abc	4.5 bc	2.837 ab
Suguna	9.715 a	5.226 a	4.716 a	5.259 a	3.31 a
Sudarsana	9.266 ab	5.53 a	4.349 ab	4.684 abc	2.895 ab
Kedaram	7.829 cd	4.268 d	4.099 abc	4.118 cd	2.99 ab
Prabha	7.299 def	5.09 ab	3.521c	4.611 abc	2.402 b
Pragati	6.957 ef	4.947 abcd	4.306 ab	5.2 ab	3.017 ab

Table 8: Correlation analysis on enzyme activities in relation with nutrients in soil

Correlations						
		AcdPhos	AlklPhos	DhG	N	P
AcdPhos	Pearson Correlation	1				
	Sig. (2-tailed)					
	N	480				
AlklPhos	Pearson Correlation	.777**				
	Sig. (2-tailed)	0				
	N	480				
DhG	Pearson Correlation	.634**	.242**			
	Sig. (2-tailed)	0	0			
	N	480	480			
N	Pearson Correlation	.490**	.188**	.795**		
	Sig. (2-tailed)	0	0	0		
	N	480	480	480		
P	Pearson Correlation	.400**	.557**	0.025	-0.009	
	Sig. (2-tailed)	0	0	0.586	0.851	
	N	480	480	480	480	
K	Pearson Correlation	-.267**	0.017	-.585**	-.573**	.169**
	Sig. (2-tailed)	0	0.716	0	0	0
	N	480	480	480	480	480
** Correlation is significant at the 0.01 level (2-tailed).						

Correlations between soil microbiological and soil nutrient variables were studied and found that soil nitrogen content is positively correlated with dehydrogenase, acid phosphatase and alkaline phosphatase activity. Among the enzymes, it is highly correlated with dehydrogenase enzyme. The phosphorus content of the soil is well correlated with alkaline phosphatase. There is no correlation between soil potassium content with any of the enzymes. Based on the results, the yield was significantly highest in plants supplied with INM 50% 50% followed by organic 100% management. Among the varieties Suguna recorded maximum yield that was on par with Sudarsana and Pragati. Integrated application of nutrients has proven beneficial in turmeric than application of chemical fertilizers alone. Application of organic and bio fertilizers to soil, in long run helps in restoring and improving the soil fertility status which in turn might help in reducing the level of application of inorganic fertilizers. The soil enzymes are assumed to be indicators of soil quality and this study sheds light on the relationship between nutrient management systems and soil enzymatic activity and turmeric yield. The results also suggest that organic management practices are effective in maintaining soil health and improving soil microbial properties, which contributes to increased turmeric crop yield. The findings reinforce the sustainability of using organic management practices for maintaining soil health.

Conclusion
In conclusion, the study demonstrates the significant impact of different management systems on turmeric yield and soil health. Integrated nutrient management, especially the INM 50% 50% approach, yielded the highest results, emphasizing the importance of balanced nutrient supply. Varietal variations were evident, with Suguna exhibiting the highest yield. Organic management systems enriched soil nutrient content and promoted enzymatic activity, underscoring their role in enhancing soil fertility and crop yield. Correlation analysis highlighted the positive relationships between soil nutrients and enzyme activity. Overall, the study advocates for sustainable agricultural practices, emphasizing the benefits of integrated nutrient management and organic amendments for improving turmeric yield and soil health.

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