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Responses of organic manures and inorganic fertilizers on growth, yield and economics of turmeric (*Curcuma longa* Linn.)

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Abstract
Experiment was carried out at the College of Horticulture, R.V.S.K.V.V., Mandsaur, M.P. during 2019-2020 in RBD design with three replications. All the parameters significantly influenced with the application of organic manures and inorganic fertilizers. However, the maximum leaf area (520.91, 790.35, 919.20, 1314.28 and 859.98 cm plant^{-1}), LAI (0.583, 0.733, 0.966 and 0.966), LAD (19668.90, 24743.20, 32602.15 and 32613.90 cm^2 day^{-1}) were registered under in RDF 50% + VC 100% at different growth stages, CRG in RDF 50% + VC 100% (0.00185) at 60-90 DAS, in RDF 75% + VC 75% (0.00204) at 90-120 DAS, in RDF 100% + FYM 50% (0.00238) at 120-150 DAS and in FYM 25% + VC 25% + NC 25% (0.00253) at 150 DAS - at harvest. Wherever, the maximum RGR in RDF 100% + NC 50% (0.0776) at 60-90 DAS, in RDF 75% + VC 75% (0.0187) (0.0279) at 90-120 DAS and at 120-150 DAS, FYM 25% + VC 25% + NC 25% (0.01804) at 150-at harvest. However, RDF 50% + VC 100% was registered the highest fresh rhizomes yield (332.237 g plant^{-1}) and chlorophyll content (72.83). The highest net return (Rs. 431546.00) and benefit: cost ratio (4.31:1) was obtained from RDF 50% + VC 100%. All the weather data were shown significant sign with most of the parameters, resulted in a better physiological functioning which contributed to higher growth and yield in turmeric.

Keywords: *Curcuma longa* L., organic manure, inorganic fertilizers, correlations, CGR and RGR

Introduction
Turmeric (*Curcuma longa* L.) belongs to the Zingiberaceae family and is an important spice. It is known as the "Indian saffron" and is generally referred to as the golden spice of life. The history of medicinal uses of this spice is very long. For so long, India has held the most important role in the global turmeric trade. It is used to cleanse blood, destroy germs, protect the liver and eliminate digestive disorders. It is being used for stomach diseases, blood purification, eliminate germs, liver protection and cholesterol level reduction [1]. An underground turmeric rhizome that results in primary and secondary rhizomes known as fingers and also known as daughter rhizomes. Turmeric is cultivated at temperatures ranging from 20 °C to 35 °C in both tropical and subtropical areas, but is susceptible to low atmospheric temperatures. Organic farming implies substantial ecological production and efficiency progression of turmeric worldwide. It has great role in soil structure refinement, fertility and better water holding ability for improved turmeric rhizomatous growth and production [2, 3]. Organic manures rapidly increase the activity of soil microbial biomass and play an important role in the transfer of plant nutrients from inaccessible to usable forms [4].

Materials and Methods
Site of the experiment
The field experiment was carried out at the Department of Plantation, Spices, Medicinal and Aromatic Crops, College of Horticulture, RVSKVV, Mandsaur Madhya Pradesh, India during the rainy season in the year 2019-2020. Mandsaur is located in the Malwa plateau in the western part of Madhya Pradesh and belongs to sub-tropical and semi-arid climatic conditions.

Applied design and treatments
The experiment was laid out in Randomized Block Design with three replications. The experimental material consisting of twelve configurations of organic manures (farm yard

manure + vermicompost + neemcake) and inorganic fertilizers (recommended fertiliser dose as NPK Kg ha-1) was used. The half dose of nitrogen and the full dose of potassium and phosphorus were added as basal dressing, while the remaining half dose of nitrogen was applied as top dressing at 30 and 60 days after sowing, at two equivalent split doses. No inputs were applied in the control.

Plant sampling

Ten plants were randomly picked from each plot in the net plot and tagged for data collection and calculation and further used to calculate dry weight, moisture content, leaf area, leaf area index, leaf area duration, relative growth rate and crop growth rate at an interval of 30 days starting from 60 days after sowing to harvest. The fresh rhizome yield was determined using electronic balance from the complete (mother, primary and secondary) rhizome weight of the sampled plants and was expressed in quintal ha^{-1}.

The correlations of all possible pairs of characters for organic manures and inorganic fertilizers are discussed in the present study. The data was further evaluated and the correlation coefficient was determined in line with the procedure proposed by [5].

Statistical analysis

The statistical analysis of variance for the applied design (RBD) was analysed using Genstat software (2005 Edition). The F-test was measured at the $P<0.05$ level of significance.

Results and Discussion

All the growth parameter and dry matter production were significantly influenced with the application of organic manures and inorganic fertilizers. Results showed that the highest dry weight (12.87, 75.42, 141.20, 213.43 and 252.00 g $plant^{-1}$) and moisture content (88.87, 69.52, 76.15, 78.99 and 70.33%) were accumulated in treatment T_6-RDF 50% + vermicompost 100% and lowest was recorded in T_{12}-control (6.37, 52.61, 104.27, 133.67 and 198.73 g $plant^{-1}$) and (80.17, 57.17, 59.13, 45.14 and 66.23%) at 60, 90, 120, 150 DAS and at harvest respectively. Vermicompost contains growth promoting substance and other nutrients which promote microbial activity and prevent nitrogen loss by leaching [6] and these might be the reason for highest dry weight and moisture content [7] found that the turmeric shows better response to organic manures and inorganic fertilizers had significantly increased the total dry matter production, it might be due to provide longer and faster photosynthesis procedure [2]. Present investigation revealed that highest leaf area was accumulated in T_6-RDF 50% + vermicompost 100% (520.91, 790.35, 919.20, 1314.28 and 859.91 cm^2 $plant^{-1}$) while, lowest in T_{12}-control (346.99, 692.07, 699.13, 969.44 and 527.44 cm^2 $plant^{-1}$) at 60, 90, 120, 150 DAS and at harvest respectively. This might be due to the higher uptake of nutrients especially iron and magnesium from applied organic manures in soil, resulting in greater photosynthetic area and therefore overlong and wider leaves. The increased growth parameters were recorded with organic manures in combination with in organic treatments over the RDF as inorganic fertilizers alone [2, 8]. The significant variances were exhibited among the treatments for fresh rhizomes yield of turmeric and chlorophyll content. The study confirmed that fresh yield of per plant and chlorophyll content was found highest in T_6 - RDF 50% + vermicompost 100% (332.56 g $plant^{-1}$ and 72.83 SPAD). But at same weather condition and other edaphic factor the minimum result was recorded in T_{12} - control (199.56 g $plant^{-1}$ and 26.17 SPAD). 29.49% fresh rhizomes yield was increased with the application of vermicompost and inorganic fertilizers as compared to control. The vegetative growth of the turmeric as influenced by the use of various organic manures (FYM and vermicompost) revealed an increase in crop yield as well as soil health [9]. Organic manure applied as alone or mixed with inorganic fertilizers are supplied the nutrients content throughout the growth period in balanced form which increased the quality and yield of turmeric as compared to no application. These trends agree with the contribution of [6, 10, 11]. The treatment T_6-RDF 50% + vermicompost 100% was found highest in leaf area index (0.583, 0.733, 0.966 and 0.966), leaf area duration (19668.97, 24743.22, 32602.11 and 32613.98cm^2 $days^{-1}$) but, it was lowest in T_{12}-control (0.468, 0.615, 0.736 and 0.695) and (15797.21, 20765.85, 24837.52 and 23471.69 cm^2 $days^{-1}$) at 60-90, 90-120, 120-150 and 150 DAS and at harvest respectively. This could be due to mixed application of vermicompost and fertilizers that influence soil health through supplying nutrients and higher uptake of nutrients to plants especially iron and magnesium resulting in greater photosynthetic activity and leading to enhance the plant growth and development. This trend agreed with the observation of [10] organic compost produced maximum number of leaves as compared to control. A significant and growth enhancement pattern of RGR and CGR was increased at 120-150 DAS and there after it declined till harvest. It may be due to associated with the decrease in magnitude of photo assimilatory area of the plant. The study confirmed that T_7 - RDF 100% + neem cake 50% (0.0777 and 0.0187g $g^{-1}day^{-1}$) at 60-90 and 120-150 DAS, T_5-RDF 75% + vermicompost 75% (0.0279 g g^{-1} day^{-1}) at 90-120 DAS and T_{11}-FYM 25% + vermicompost 25% + neemcake25% (0.0180 g g^{-1} day^{-1}) at 150 DAS-at harvest were found highest relative growth rate but T_{12}-control remain lowest for the same traits. The possible clarification for the positive effect of vermicompost may be due to accumulation of mobile substances in earthworm casts as reported by many researches. Organic manures improved the soil aggregates resulting in favorable pore geometry, which in turn increased the soil porosity thereby paving the way for respectable growth and development of plants. These findings are agreements with the findings of [10]. Treatment T_6-RDF 50% + vermicompost 100% (0.0019 and 0.0021) at 60-90 and 90-120 DAS and T_1-RDF 100% + FYM 50% (0.0024) at 120-150 DAS and T_{11}-FYM 25% + vermicompost 25% + neem cake 25% (0.0025) at 150-at harvest were found highest while, the lowest in T_{12}-control at 60-90, 90-120, 120-150 and 150 DAS-at harvest respectively. This might be possible because the application of organic manure in the form of vermicompost in combination with inorganic fertilizers which improves soil physical and chemical property and most important to the adequate supply of nutrients to the plants which is directly responsible to promote the vegetative growth. Similar findings were reported by [12, 13]. Owing to the use of conventional manures and inorganic fertilizers, the economies of the various treatments have been influenced in the present research. The highest net returns (Rs. 431546.00) and benefit: cost ratio (4.31:1) were recorded in treatment with T6-RDF 50 percent + vermicompost 100 percent compared to other treatments and the lowest net returns in T12-control (Rs. 205626.7) and (2.46:1) B:C ratio were recorded in treatment with T6-RDF 50 percent + vermicompost 100 percent compared with other treatments [6].

Correlation studies

The minimum temperature showed significant and strong positive correlation with maximum temperature (0.875**) white, remaining variables exhibited positive but non-significant effects (Table 6). The maximum temperature had positive non-significant association among the variables, except relative growth rate (-0.130) and crop growth rate (-0.042) which were negatively affected. It is evident from the past observations and present study that higher air temperature at early and low temperature at later part turmeric is essential [14] have observed that low temperature favors the allocation of dry matter towards storage organs in tuber crops. It is assumed that some physiological process function properly at moderate temperature [15]. High temperature was showed negative sign with relative and crop growth rate as mentioned in this study. When the temperature was slightly higher assumed that, leaf stomatal functions in the plant grown were affected by strong irradiance, which agrees with the results of previous studies [16]. Moreover, the relative humidity was found to be negatively correlated with most of the variables, except dry weight (0.0001), leaf area (0.085) and relative growth rate (0.240). The positive influence of relative humidity with leaf area, relative and crop growth rate was observed in the present study [14] has affirmed that the beneficial effects ascribed to high relative humidity might be due to the equable temperature regime and the consequent reduction of heat load associated with them, which might have reduced the respiration loss, which resulted in better yield due to higher stem elongation, increased leaf area and higher shoot root ratio. Dry weight was exhibited positive correlation with wholly the traits but significantly only with moisture content (0.659*), chlorophyll content (0.684*) and fresh rhizomes yield (0.829**). Moisture content was revealed highly significant and positive relationship with leaf area (0.698*), leaf area index (0.708*), leaf area duration (0.708**), chlorophyll content (0.795**) and fresh rhizomes yield (0.806**). However, Leaf area had significant and strong positive effect on leaf area index (0.932**), leaf area duration (0.929**), chlorophyll content (0.650*) and fresh rhizomes yield (0.784**). Thereafter, Leaf area index was exhibited highly significant and positive association with leaf area duration (0.921**), chlorophyll content (0.727**) and fresh rhizomes yield (0.862**). Leaf area duration was found to be highly significant and positive correlation with chlorophyll content (0.726**) and fresh rhizomes yield (0.825**). Afterward, relative growth rate showed significant and positive effect on crop growth rate (0.982**). Relative growth rate was found significantly correlated with chlorophyll content (0.002) and fresh rhizomes yield (0.049). There are positive and significant correlations among the SPAD value, plant growth parameters and yield (0.729**). A higher SPAD value may resulted in a better photosynthesis which contributed to higher yield in turmeric and is the indication of higher chlorophyll content in leaf, which ultimately results higher photosynthesis [15, 17].

Table 1: Effect of organic manures and inorganic fertilizers on dry weight and moisture content in turmeric

Treatments	Dry weight (g plant-1)					Moisture content plant-1 (%)				
	Days after sowing and at harvest					Days after sowing and at harvest				
	60	90	120	150	At	60	90	120	150	At
T1- RDF 100% + FYM 50%	12.40	65.81	125.03	133.67	237.31	87.47	67.39	74.03	70.47	69.84
T2 - RDF 75% + FYM 75%	10.33	64.12	121.03	197.90	214.23	82.27	61.70	68.98	53.24	68.84
T3 - RDF 50% FYM 100%	6.97	62.28	106.72	162.33	224.47	87.35	59.84	64.82	69.09	66.28
T4 - RDF 100% + VC 50%	6.67	59.74	107.17	153.13	233.70	84.72	64.66	63.46	67.31	68.02
T5 - RDF 75% + VC 75%	8.30	52.97	121.43	181.07	230.30	84.17	66.76	69.77	66.47	68.26
T6 - RDF 50% + VC 100%	12.87	75.42	141.20	213.43	252.00	88.87	69.52	76.15	78.99	70.33
T7 - RDF 100% + NC 50%	8.27	65.05	106.27	182.70	234.43	81.65	62.07	70.80	67.77	67.78
T8 - RDF 75% + NC 75%	8.23	52.77	113.20	182.77	236.50	86.31	62.20	69.92	66.79	68.14
T9 - RDF 50% + NC 100%	9.00	58.91	110.17	168.10	215.90	82.45	67.36	70.82	68.31	68.48
T10 - RDF 100%	8.40	63.27	105.93	182.47	230.20	87.12	64.83	68.15	67.77	68.22
T11- FYM 25% + VC 25% + NC 25%	12.50	70.70	136.40	205.30	237.47	88.44	67.50	74.04	70.92	70.13
T12 - control	6.37	52.61	104.27	133.67	198.73	80.17	57.17	59.13	45.14	66.23
S.Em.±	0.52	3.66	6.96	9.58	6.12	1.37	1.74	2.63	2.21	0.80
CD at 5%	1.52	10.73	20.41	28.11	17.96	4.03	NS	7.73	6.49	NS

Table 2: Effect of organic manures and inorganic fertilizers on leaf area, chlorophyll content and fresh rhizomes yield in turmeric

Treatments	Leaf area (cm^2 plant-1)					SPAD values	Fresh rhizomes yield (g plant-1)
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest		
T1- RDF 100% + FYM 50%	500.89	780.53	874.16	1085.47	805.72	59.37	306.30
T2 - RDF 75% + FYM 75%	388.24	774.63	831.87	1068.80	798.86	48.07	238.00
T3 - RDF 50% FYM 100%	383.88	741.39	817.13	1046.84	743.42	31.13	263.20
T4 - RDF 100% + VC 50%	429.24	753.61	845.20	997.00	723.21	27.37	252.78
T5 - RDF 75% + VC 75%	487.10	751.17	841.27	1040.73	666.95	57.33	267.16
T6 - RDF 50% + VC 100%	520.91	790.35	919.20	1314.28	859.98	72.83	332.56
T7 - RDF 100% + NC 50%	407.03	745.25	773.50	1016.70	684.14	58.4	252.21
T8 - RDF 75% + NC 75%	432.10	747.67	802.67	996.17	569.86	31.97	253.29
T9 - RDF 50% + NC 100%	379.64	771.62	847.10	1037.33	646.60	32.17	257.88
T10 - RDF 100%	361.07	769.61	800.63	987.47	634.63	51.1	243.95
T11- FYM 25% + VC 25% + NC 25%	506.96	783.25	915.03	1102.80	816.76	63.4	305.46
T12 - control	346.99	692.07	699.13	969.44	527.44	26.17	199.56
S.Em.±	38.59	14.73	39.56	28.41	43.96	2.122	21.22
CD at 5%	113.18	43.22	116.03	83.32	128.94	6.224	62.23

Table 3: Effect of organic manures and inorganic fertilizers on leaf area index and leaf area duration in turmeric

Treatments	Leaf area index				Leaf area duration (cm^2 days-1)			
	60-90 DAS	90-120 DAS	120-150 DAS	150 DAS-harvest	60-90 DAS	90-120 DAS	120-150 DAS	150 DAS-harvest
T1- RDF 100% + FYM 50%	0.570	0.709	0.844	0.841	19221.20	23920.31	28494.45	28367.87
T2 - RDF 75% + FYM 75%	0.517	0.687	0.818	0.830	17442.91	23197.42	27610.04	28014.84
T3 - RDF 50% FYM 100%	0.500	0.666	0.802	0.796	16879.17	22477.99	27059.63	26853.94
T4 - RDF 100% + VC 50%	0.489	0.684	0.780	0.752	16509.17	23082.22	26319.63	25389.76
T5 - RDF 75% + VC 75%	0.550	0.681	0.810	0.759	18574.15	22986.68	27330.04	25615.24
T6 - RDF 50% + VC 100%	0.583	0.733	0.966	0.966	19668.97	24743.22	32602.11	32613.98
T7 - RDF 100% + NC 50%	0.512	0.659	0.760	0.756	17284.23	22246.69	25657.58	25512.62
T8 - RDF 75% + NC 75%	0.524	0.662	0.773	0.696	17696.54	22355.14	26082.58	23490.40
T9 - RDF 50% + NC 100%	0.512	0.693	0.811	0.730	17268.92	23380.86	27366.55	24654.06
T10 - RDF 100%	0.533	0.637	0.768	0.721	17982.77	21490.58	25921.42	24331.44
T11- FYM 25% + VC 25% + NC 25%	0.573	0.728	0.870	0.853	19353.22	24574.37	29367.56	28793.44
T12 - control	0.468	0.615	0.736	0.695	15797.21	20765.85	24837.52	23471.69
S.Em.±	0.020	0.019	0.021	0.022	666.98	628.15	722.64	750.94
CD at 5%	0.058	0.055	0.063	0.065	1956.21	1842.28	2119.44	2202.45

Table 4: Effect of organic manures and inorganic fertilizers on relative growth rate and crop growth rate in turmeric

Treatments	Relative growth rate (g g-1 day-1)				Crop growth rate (g cm-2 day-1)			
	60-90 DAS	90-120 DAS	120-150 DAS	150 DAS-harvest	60-90 DAS	90-120 DAS	120-150 DAS	150 DAS-harvest
T1- RDF 100% + FYM 50%	0.0616	0.0212	0.0167	0.0048	0.0016	0.0018	0.0024	0.0010
T2 - RDF 75% + FYM 75%	0.0611	0.0200	0.0055	0.0149	0.0016	0.0016	0.0008	0.0023
T3 - RDF 50% FYM 100%	0.0721	0.0184	0.0142	0.0108	0.0016	0.0013	0.0017	0.0018
T4 - RDF 100% + VC 50%	0.0736	0.0195	0.0117	0.0143	0.0016	0.0014	0.0014	0.0024
T5 - RDF 75% + VC 75%	0.0618	0.0279	0.0131	0.0082	0.0013	0.0020	0.0018	0.0015
T6 - RDF 50% + VC 100%	0.0584	0.0207	0.0140	0.0055	0.0019	0.0021	0.0021	0.0011
T7 - RDF 100% + NC 50%	0.0777	0.0234	0.0187	0.0083	0.0017	0.0012	0.0023	0.0015
T8 - RDF 75% + NC 75%	0.0620	0.0252	0.0160	0.0088	0.0013	0.0018	0.0021	0.0016
T9 - RDF 50% + NC 100%	0.0623	0.0206	0.0143	0.0055	0.0015	0.0015	0.0017	0.0009
T10 - RDF 100%	0.0672	0.0172	0.0181	0.0078	0.0016	0.0013	0.0023	0.0014
T11- FYM 25% + VC 25% + NC 25%	0.0576	0.0221	0.0145	0.0180	0.0017	0.0020	0.0022	0.0025
T12 - control	0.0550	0.0158	0.0053	0.0040	0.0013	0.0016	0.0006	0.0008
S.Em.±	0.0034	0.0026	0.0029	0.0032	0.0001	0.0002	0.0004	0.0005
CD at 5%	0.0091	0.0065	NS	0.0094	0.0003	0.0006	0.0011	0.0014

Table 5: Effect of organic manures and inorganic fertilizers on the economics of turmeric

Treatments	Cost of cultivation	Gross return	Net profit	B:C ratio
T1 - RDF 100% + FYM 50%	103090.00	514080.00	410990.00	3.99:1
T2 - RDF 75% + FYM 75%	93590.00	399451.50	305861.50	3.27:1
T3 - RDF 50% + FYM 100%	84090.00	441749.70	357659.70	4.25:1
T4 - RDF 100% + VC 50%	116090.00	424248.30	308158.30	2.65:1
T5 - RDF 75% + VC 75%	121090.00	448383.60	327293.60	2.70:1
T6 - RDF 50% + VC 100%	100030.00	531576.00	431546.00	4.31:1
T7 - RDF 100% + NC 50%	123590.00	429126.52	305536.52	2.47:1
T8 - RDF 75% + NC 75%	121340.00	440862.80	319522.80	2.63:1
T9 - RDF 50% + NC 100%	119090.00	435100.00	316010.00	2.65:1
T10 - RDF 100%	98590.00	409430.70	310840.70	3.15:1
T11 - FYM25% + VC25% + NC25%	94840.00	488250.00	393410.00	4.15:1
T12 - control	83580.00	289206.72	205626.72	2.46:1

Table 6: Coefficients of correlation of among the different characteristics of turmeric for organic manures and inorganic fertilizers

Variables	T Min	T Max	RH	DW	MC	LA	LAI	LAD	RGR	CGR	Chl	FRY
T Min	1.000											
T Max	0.875**	1.000										
RH	0.405	0.020	1.000									
DW	0.229	0.160	0.001	1.000								
MC	0.060	0.196	-0.266	0.659*	1.000							
LA	0.457	0.392	0.085	0.557	0.698*	1.000						
LAI	0.379	0.416	-0.096	0.570	0.708*	0.923**	1.000					
LAD	0.377	0.415	-0.097	0.569	0.708**	0.923**	0.921**	1.000				
RGR	0.059	-0.130	0.173	0.119	0.172	0.398	0.166	0.166	1.000			
CGR	0.177	-0.042	0.240	0.180	0.130	0.382	0.143	0.142	0.982**	1.000		
Chl	0.123	0.186	-0.168	0.648*	0.759**	0.650*	0.727**	0.726**	0.023	0.002	1.000	
FRY	0.226	0.221	-0.022	0.829**	0.806**	0.784**	0.826**	0.825**	0.067	0.049	0.729**	1.000

Correlation is significant at the 0.05 level (*) and 0.01 (**)

T Min = Temperature minimum (°C), T Max = Temperature maximum (°C), RH = Relative humidity (%), DW = Dry weight (g $plant^{-1}$), MC = Moisture content (%), LA = Leaf area, LAI = Leaf area index, LAD = Leaf area duration, RGR = Relative growth rate, CGR = Crop growth rate, Chl = Chlorophyll content (SPAD) and FRY = Fresh rhizomes yield (g $plant^{-1}$).

Conclusion

On the basis of one year of research, it could be concluded that the application of organic manures and inorganic fertilizers @ RDF 50% + vermicompost 100% are found to be the best for achieving the highest turmeric growth, yield and quality.

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