International Journal of Research in Agricultural Sciences
Volume 1, Issue 4, ISSN (Online) : 2348 – 3997)

Physiological Parameters and Yield Characters of Turmeric (*Curcuma longa* L.) cv. BSR 2 as Influenced by Fertigation

C. Krishnamoorthy Chinnusamy
Assistant Professor,
Vanavarayar Institute of Agriculture, Manakkadavu, Pollachi,
Contact: plantdoctorkrishna@gmail.com, +91 9659498935

K. Soorianathasundaram
Professor and Head, Department of Fruit Crops,
Tamil Nadu Agricultural University, Coimbatore - 641 003,
Contact: sooriak@tnau.ac.in, 0422 6611269

***Abstract* – A field experiment to study the influence of fertigation of N and K fertilizers on physiology and yield of turmeric (*Curcuma longa* L.) cv. BSR 2 was carried out during June 2007 to February 2008. The experiment consisted of seven treatments replicated four times in a randomized block design. The physiological parameters *viz*., crop growth rate, chlorophyll a, chlorophyll b, total chlorophyll, soluble protein and yield parameters *viz*., number of mother, primary and secondary rhizomes, length and girth of mother, primary and secondary rhizomes, weight of mother, primary and secondary rhizomes, fresh, cured rhizome yield plant^{-1} and estimated cured rhizome yield hectare^{-1} were recorded. The study revealed that the fertigation treatments were significantly superior over the control. Among the treatments, N + K @ 100 % level (150 : 108 NK kg ha^{-1}) by fertigation using water soluble fertilizers *viz*., Urea and Multi 'K' registered the highest values for the above parameters**.

***Keywords* – Fertigation, Fertilizers, Physiology, Yield.**

I. Introduction

India is the largest producer, consumer and traditional exporter of turmeric in the global arena. Indian turmeric is regarded as the best in the world market because of its high curcumin content. In turmeric, improper nutritional management practices and inadequate irrigation during critical crop growth stages can be considered as foremost contributing to low yields. Among the sophisticated hi-tech methods practiced, drip irrigation has proved its superiority due to direct application of water in the vicinity of root zone. Under drip irrigation, the spatial distribution of soil moisture and consequently crop roots are restricted to a small volume of soil directly below the emitters such as restriction has important implications for optimum fertilizer placement (Selvakumar, 2006). Of late, fertigation *i.e*. application of fertilizer through drip irrigation has been found to dramatically improve the physiological parameters and yield of many horticultural crops (Selvaraj *et al.,* 1997; Salo *et al.,* 2000). The influence of water soluble fertilizers on crop physiology and yield of turmeric has not been so far investigated in detail. Hence, the present study was taken up in turmeric cv. BSR 2 with the objective of assessing the influence of fertigation on physiological attributes and yield parameters using water soluble fertilizers in comparison with conventional fertilizers.

II. Materials and Methods

The field experiment was conducted at the Agricultural Research Station, Bhavanisagar, Erode district. The seed rhizomes obtained from primary fingers from the previous crop of the turmeric cultivar BSR 2 was used. Each treatmental plot measured 7.8 m length and 3 m width. Finger rhizomes of BSR 2 turmeric weighing about 25 grams were selected, treated with Copperoxychloride 0.25 per cent for 20 minutes, shade dried and used for sowing in paired row system. A spacing of 45 cm between rows within a paired row, 55 cm between two adjacent paired rows and 15 cm within each row was maintained. Thus each plant occupied an area of 0.075 m2. In treatments receiving fertigation, drip laterals were laid along the length of each paired row at the centre with the spacing kept at 1 m between two adjacent laterals. In control plot, instead of drip laterals, provision for surface irrigation was provided for the paired rows. A venturi assembly was used for mixing fertilizer with irrigation water. Fertigation to individual plot in each replication was controlled by providing a manual regulating valve fixed to the lateral lines to ensure precise delivery of the required inputs thus enabling full control of experimental setup. The crop was grown under drip system of irrigation with the following design: 3 Hp motor, pump discharge of 2.2 lps, main line diameter was 75 mm, sub main diameter was 63 mm, lateral diameter was 12 mm, lateral spacing was 1m, emitter spacing was 60 cm, emitter type was PC dripper, emitter model was outline, emitter discharge rate was 4 lph and filter size (screen filter) was 63 mm.

The field experiment was laid out with seven treatments in four replications adopting randomized block design (RBD). The details of the treatments were as follows,

T_1 - Recommended dose of NPK (150: 60: 108 kg ha^{-1}) through straight fertilizers i.e. Urea and MOP by soil application + surface irrigation (control).

T_2 - N+K@ 100 % level by fertigation using straight fertilizers

T_3 - N+K@ 75 % level by fertigation using straight fertilizers

T_4 - N+K@ 50 % level by fertigation using straight fertilizers

T_5 -N+K@ 100 % level by fertigation using water soluble fertilizers

T_6 - N+K@ 75 % level by fertigation using water soluble fertilizers

T_7 - N+K@ 50 % level by fertigation using water soluble fertilizers

The forms of fertilizers involved were

Straight fertilizers : Urea (46 % N) and Muriate of Potash (MOP-60 % K_2O)

Water soluble fertilizers : Urea (46 % N) and proprietary water soluble form of N and K fertilizer containing 13 % N and 45 % K (Multi 'K').

In all the fertigation treatments, the full dose of phosphorus (60 kg ha^{-1}) was applied as basal using single super phosphate (16 % available P) as the source. The standard recommended cultural practices (TNAU, 2004) were followed for managing the crop except for the fertigation treatments envisaged in the study. The fertilizers were applied through drip irrigation at weekly intervals by following the schedule by which 50 % of total N and 30 % of total K were applied from 4th to 11th weeks, 40 % of total N and 50 % of total K are applied from 12th to 23rd weeks. The remaining quantity of 10 % N and 20 % K were applied from 24th to 28th weeks. The crop growth rate was analyzed from the procedure given by Watson (1958), chlorophyll by Yoshida *et al.* (1971) and soluble protein by Lowery *et al*. (1957). The third youngest leaf was used as the standard leaf for physiological parameters estimation (Saifudeen, 1981). The crop was harvested after ascertaining the maturity. Yellowing and drying of the leaves as well as cracking of the soil were considered as indications of maturity. The yield observations were taken randomly from ten plants in each plot (23.4 m^2).

III. Results and Discussion

The physiological attributes are normally closely related to yield and quality parameters. The fertigation treatments registered significantly higher crop growth rates than T_1 upto 90 DAS. The crop growth rate ranged from 1.09 (T_1) to 2.40 (T_5) upto 90 DAS. The crop growth rate was observed to be maximum and in the range of 6.15 to 7.53 between 90 to 150 DAS (Table 1). The treatment T_6 was on par with T_5 during this stage. Similarly, the treatments T_3, T_4 and T_7 registered lower crop growth rates and were on par with T_1 at this stage. The treatment T_5 registered higher crop growth rate of 4.36 between 150 to 210 DAS and 1.48 between 210 to 240 DAS as compared to other treatments. The crop growth rate ranged from 3.83 (T_1) to 4.69 (T_5) in 90 DAS to harvest stage.

The crop growth rate was higher between 90 to 150 DAS followed by the stage from 150 to 210 DAS. It is essential that the required nutrients are made available in proper proportions during these phases as it has direct relevance to the performance of the crop. Reduction in fertigation level from 100 to 50 %, reduced the crop growth rates indicating positive growth response to higher nutrient availability. Rapid decline of crop growth rate from 210 days after sowing to harvest indicates that crop growth rate cannot be sustained after seven months in BSR 2 turmeric and that nutritional practices should be targeted to achieve maximum rate of growth before 5th month and it is necessary to sustain the rate of growth at least upto 7th month.

The leaf chlorophyll content, key factor in determining the rate of photosynthesis, is also considered as an index of the metabolic efficiency of plants. This pigment, responsible for harnessing solar energy and converting it into chemical energy, exhibits a differential pattern in its accumulation in response to nutrients applied through fertigation. Chlorophyll content in the leaves was estimated at four stages viz., 90, 150, 210 and 240 DAS. The chlorophyll 'a' content in the leaves was significantly the highest in treatment T_5 at all the four stages of observation (Table 2). The treatment T_1 registered significantly the least chlorophyll 'a' content during these stages. T_6 registered higher chlorophyll 'a' content on par with T_5 in all the four stages. Treatments T_2 and T_3 were also on par with T_5 at 210 and 240 DAS. Among the four stages, higher chlorophyll 'a' contents in the range of 0.764 (T_1) to 0.915 (T_5) mg g^{-1} were recorded at 210 DAS. Chlorophyll 'b' contents were higher in T_5 at all the four stages of observation. T_1 registered significantly the least chlorophyll 'b' content in these stages. Chlorophyll 'b' contents were higher at 210 DAS and in the range of 0.489 mg g^{-1} (T_1) to 0.564 mg g^{-1} (T_5). T_6 was on par with T_5 at 150, 210 and 240 DAS. The phenomenon of increased chlorophyll content with increased nutrition, as observed in the present study, was also reported earlier by several workers (Josefina *et al*., 2003; Prabhu and Balakrishnamoorthy, 2006; Sivakumar, 2007).

Among the different treatments, the total chlorophyll contents were significantly least at T_1 in the four stages of observations (Table 3). The highest total chlorophyll contents were recorded in the four stages by T_5. At 210, DAS maximum total chlorophyll contents were observed in the different treatments as compared to other stages. At this stage, the total chlorophyll contents ranged from 1.253 mg g^{-1} (T_1) to 1.503 mg g^{-1} (T_5). The treatments T_2 and T_6 were on par with T_5 at 150, 210 and 240 DAS. T_3 and T_7 also registered higher total chlorophyll contents which are comparable with T_5 at 150 and 210 DAS. In the present study, general increases in chlorophyll content were noted upto 210 days and then a declining trend was observed which coincided with the onset of leaf senescence. In many crop plants chlorophyll degradation has been observed with leaf senescence (Selvaraj *et al.*, 1997).

The soluble protein contents ranged from 41.54 mg g^{-1} (T_1) to 50.19 mg g^{-1} (T_5) at 90 DAS (Table 3). Among the four stages, the highest soluble protein contents in the range of 61.80 to 74.53 mg g^{-1} were recorded at 210 DAS in different treatments. The treatments T_2 and T_6 also registered higher soluble protein contents comparable with T_5 at 150, 210 and 240 DAS. In the present study, the soluble protein content was higher with fertigation using water soluble fertilizers. Similar to chlorophyll levels, soluble protein also increased upto 210 DAS and started declining after that indicating lowered physiological efficiency of the leaves after 210 DAS. Availability of nitrogen in sufficient levels was ensured in T_5 and T_6 which could have contributed to higher protein synthesis. Soluble protein constitutes for more than 40 per cent of RuBP carboxylase, an enzyme responsible for CO_2 fixation in leaves of higher plants (Sivakumar, 2007).

Noggle and Fritz (1986) stated that RuBP carboxylase enzyme, the most abundant protein in plant kingdom, was found relatively at high concentrations in soluble protein fraction of leaves. An increase in soluble protein content denotes the increasing ability of plants to fix CO_2 effectively. Hence, a level of soluble protein content is considered as an index for the assessment of photosynthetic efficiency.

The impact of fertigation could be clearly observed from the increased number of rhizomes, enhanced rhizome sizes and higher rhizome weights as compared to conventional fertilizer application. Fertigation using water soluble fertilizers at 100 and 75 % recommended levels, significantly and consistently proved better for these parameters. Though fertigation using straight fertilizers at 100 % level improved these parameters, fertigation using water soluble fertilizers proved to be still better.

Among the treatments, T_5 registered significantly the highest number of mother (3.65), primary (12.24) and secondary rhizomes (17.84) while T_1 registered the least (2.08, 6.82 and 10.67) as compared to other treatments. The highest length and girth of mother (4.98 and 3.94cm), primary (10.47 and 2.14 cm) and secondary rhizomes (2.26 and 1.36 cm) was recorded in the treatment T_5 while T_1 recorded the least (3.54 and 3.14 cm, 9.18 and 1.48 cm, 1.68 and 1.10 cm) (Table 4). The treatment T_5 registered the highest weight of mother (0.089 kg), primary (0.169 kg) and secondary rhizomes (0.087 kg) while T_1 recorded the least (0.054, 0.109 and 0.057 kg).

The fresh rhizome yield per plant ranged from 0.220 kg (T_1) to 0.340 kg (T_5) (Table 5). The treatment T_1 registered significantly the lowest yield while T_5 the highest. The estimated fresh rhizome yield was the highest in T_5 with 43196.57 kg ha^{-1} followed in T_6 with 75 % level of N and K by fertigation using water soluble fertilizers (41205.12 kg ha^{-1}). Soil application of straight fertilizers (T_1) registered the lowest fresh rhizome yield of 28662.39 kg ha^{-1}. The highest estimated cured rhizome yield of 7408.21 kg ha^{-1} was obtained in T_5 where as the lowest was in T_1 (4878.34 kg ha^{-1}). The estimated cured rhizome yields ranged from 6313.40 kg ha^{-1} to 6551.03 kg ha^{-1} in the other four treatments.

At fertigation of 50 % level recommended N and K, the differences in straight and water soluble fertilizers in respect of these parameters are generally not significant. This may be because, the plant could not be significantly influenced with lower nutrient pool in the soil solution. The fact that the plant is able to perform better even with 50 % level of N and K fertigation as compared to 100 % level N and K fertilizers application in the conventional manner indicates poor or less availability of nutrients to the plants in the conventional system. Enhanced yield parameters with 75 and 100 % levels N and K fertilizer application demonstrates better response of the crop to improved nutrient availability. Increased yield under drip ferigation with water soluble fertilizers were reported by Shivashankar (1999) in capsicum and Veeranna et al. (2000).

Fertigation with the higher levels of N and K especially in water soluble forms has definitely influenced the growth and physiological attributes, which reflected in higher growth, dry matter production, yield and yield related traits. Better nutrient availability in these treatments could be the crucial factor as Fontes *et al.* (2000) pointed out that application of N and K in combination with drip irrigation maximizes the mobility of nutrients around the root zone. The results obtained in the present study are also corroborated by similar yield improvements in capsicum (Muralidhar, 1998) and in onion (Muralikrishnasamy *et al.*, 2005).

IV. Conclusion

Studies taken up indicated that a dosage of N + K @ 100 % level by fertigation using water soluble fertilizers can resulted in 50 % higher yield in BSR 2 turmeric, compared to conventional method of soil application and surface irrigation.

Acknowledgment

We acknowledged the Agricultural Research Station, Bhavanisagar for providing research area for this study.

References

[1] A.P. Muralidhar, "Effect of fertigation with normal and water soluble fertilizers compared to drip and furrow systems in capsicum - Maize - sunflower cropping sequence," 1998, *Ph.D. Thesis*, submitted to UAS, Bangalore, India.

[2] B. Josefina, Q. Ana, M. Bernardo, P. Millo Eduardo, and L. Francisco, "Effects of the frequency of iron chelate supply by fertigation on iron chlorosis in Citrus," *J. Plant Nutrition*, 2003, pp. 1985-1996.

[3] C.R. Noggle, and C.J. Fritz, "Introductory plant physiology", Prentice Hall of India Pvt. Ltd. New Delhi, 1986, pp. 171.

[4] D.J. Watson, "The dependence of net assimilation rate on leaf area index," Ann. Bot. Lond. N.S., 1958, pp. 37-45.

[5] H.K. Veeranna, Abdul Khalak, A.A. Farooqi, and G.M. Sujithi, "Effect of fertigation with normal and water soluble fertilizer compared to drip and furrow methods on yield, fertilizer and irrigation water use efficiencies in chilli," *Proc.* International conference on micro and sprinkler irrigation systems, February 8-10, Jalgaon, Maharashtra, 2000, pp. 78.

[6] K. Shivashankar, "Fertigation in crop production a must for higher yields and returns," *In:* ICAR summer short source on Advances in Micro Irrigation and Fertigation, UAS, Dharward, Karnataka, India, 1999, pp. 48 - 52.

[7] N. Saifudeen, "Foliar diagnosis, yield and quality of turmeric (*Curcuma longa* L.) in relation to nitrogen, phosphorus and potassium," 1981, *M.Sc. (Ag.) Thesis*, submitted to Kerala Agricultural University, Thrissur, Kerala, India.

[8] O.H. Lowery, N.T. Rose Brought, L.A. Farr, and R.J. Randall, "Protein measurement with folin phenol reagent," *J. Biol. Chem.*, 1957, pp. 265-275.

[9] P.C.R. Fontes, R.A. Sampaio, and F.L. Finger, "Fruit size, mineral composition and quality of trickle irrigated tomatoes as affected by potassium rates," *Pesquisa Agropecuaria Brasileira*, 2000, pp. 21-25.

[10] P.K. Selvaraj, V.V. Krishnamurthi, P.G. Manickasundaram, James Martin, and M. Ayyaswamy, "Effect of irrigation schedules and nitrogen levels on the yield of turmeric through drip irrigation," *Madras Agric. J.*, 1997, 347-348.

[11] S. Muralikrishnasamy, V. Veerabadran, S. Krishnasamy, V. Kumar, and S. Sakthivel, "Micro sprinkler irrigation and fertigation", 7^{th} international micro irrigation congress, 2005, pp. 49-57.

[12] S. Yoshida, D.A. Forno, and J.H.Cock, Laboratory manual for physiological studies of rice, IRRI, Philippines, 1971, pp. 36-37.

[13] T. Prabhu, and G. Balakrishnamoorthy, "Standardisation of fertigation techniques in paprika (*Capsicum annuum* var. *longum* L.) under open and coconut shade conditions," 2006, *Ph. D. Thesis*, submitted to Tamil Nadu Agricultural University, Coimbatore.

[14] T. Salo, T. Seojala, and Kallelam, "The effect of fertigation on yield and nutrient uptake of cabbage, carrot and onions" *Acta Hort.*, 2000, 235-241.

[15] T. Selvakumar, "Performance evaluation of drip fertigation on growth, yield and water use in hybrid chillies," 2006, *Ph.D. Thesis*, submitted to Tamil Nadu Agricultural University, Coimbatore.

[16] TNAU, "Crop Production Techniques of Horticultural Crops," Tamil Nadu Agricultural University, Coimbatore and Directorate of Horticulture and Plantation Crops, Chennai, 2004, pp. 289.

[17] V. Sivakumar, "Influence of fertigation on mango with varying levels of nutrients," 2007, *Ph. D Thesis*, submitted to Tamil Nadu Agricultural University, Coimbatore.

Table 1: Influence of straight and water soluble fertilizers on crop growth rate (g m^{-2} day^{-1})

Treatments	CGR upto 90 DAS (g m^{-2} day^{-1})	CGR at 90-150 DAS (g m^{-2} day^{-1})	CGR at 150-210 DAS (g m^{-2} day^{-1})	CGR at 210 DAS - to harvest (g m^{-2} day^{-1})	CGR at 90 - to harvest (g m^{-2} day^{-1})
T_1	1.09	6.15	3.20	1.67	3.83
T_2	2.02	6.71	3.92	2.12	4.42
T_3	1.84	6.26	3.98	2.32	4.33
T_4	1.55	6.27	3.24	2.22	4.04
T_5	2.40	7.53	4.36	1.48	4.69
T_6	2.12	7.12	4.28	1.61	4.55
T_7	1.61	6.23	3.76	1.96	4.14
SEd	0.056	0.204	0.118	0.059	0.132
CD (0.05)	0.119	0.430	0.249	0.125	0.278

Table 2: Influence of straight and water soluble fertilizers on chlorophyll 'a' and chlorophyll 'b' contents (mg g^{-1})

Treatments	Chlorophyll 'a' (mg g^{-1})				Chlorophyll 'b' (mg g^{-1})			
	90 DAS	150 DAS	210 DAS	240 DAS	90 DAS	150 DAS	210 DAS	240 DAS
T_1	0.310	0.524	0.764	0.676	0.211	0.322	0.489	0.386
T_2	0.398	0.647	0.876	0.780	0.244	0.374	0.540	0.450
T_3	0.374	0.613	0.862	0.767	0.236	0.361	0.529	0.434
T_4	0.358	0.598	0.846	0.748	0.223	0.340	0.507	0.420
T_5	0.428	0.679	0.915	0.813	0.270	0.401	0.588	0.489
T_6	0.405	0.667	0.892	0.796	0.252	0.382	0.564	0.462
T_7	0.362	0.605	0.851	0.754	0.229	0.356	0.519	0.427
SEd	0.011	0.019	0.026	0.023	0.007	0.009	0.016	0.013
CD (0.05)	0.024	0.041	0.055	0.048	0.015	0.020	0.034	0.028

Table 3: Influence of straight and water soluble fertilizers on total chlorophyll and soluble protein content (mg g^{-1})

Treatments	Total Chlorophyll (mg g^{-1})				Soluble protein (mg g^{-1})			
	90 DAS	150 DAS	210 DAS	240 DAS	90 DAS	150 DAS	210 DAS	240 DAS
T_1	0.521	0.846	1.253	1.062	41.54	55.08	62.81	53.33
T_2	0.642	1.021	1.416	1.230	44.58	58.94	71.64	58.75
T_3	0.610	0.974	1.391	1.201	43.84	58.19	70.82	56.76
T_4	0.581	0.938	1.353	1.168	42.86	56.84	67.26	54.83
T_5	0.698	1.080	1.503	1.302	50.19	62.21	74.53	62.19
T_6	0.657	1.049	1.456	1.258	48.10	61.86	72.21	60.15
T_7	0.591	0.961	1.370	1.181	43.18	57.46	68.76	55.84
SEd	0.019	0.030	0.043	0.037	1.390	1.815	2.158	1.776
CD (0.05)	0.040	0.063	0.090	0.078	2.922	3.814	4.535	3.733

Table 4: Influence of straight and water soluble fertilizers on rhizome characters

Treatments	Number plant^{-1}			Length (cm)			Girth (cm)		
	Mother rhizomes	Primary rhizomes	Secondary rhizomes	Mother rhizomes	Primary rhizomes	Secondary rhizomes	Mother rhizomes	Primary rhizomes	Secondary rhizomes
T_1	2.08	6.82	10.67	3.54	9.18	1.68	3.14	1.48	1.10
T_2	3.10	10.47	15.40	4.55	10.10	2.08	3.61	1.91	1.25
T_3	2.85	10.05	14.28	4.30	9.81	1.95	3.49	1.76	1.21
T_4	2.64	9.24	13.50	4.00	9.64	1.76	3.28	1.57	1.14
T_5	3.65	12.24	17.84	4.98	10.47	2.26	3.94	2.14	1.36
T_6	3.40	11.85	16.21	4.72	10.24	2.14	3.76	2.01	1.30
T_7	2.75	9.85	13.85	4.15	9.75	1.82	3.36	1.63	1.18
SEd	0.091	0.314	0.453	0.133	0.305	0.061	0.109	0.055	0.038
CD (0.05)	0.191	0.661	0.951	0.281	0.642	0.128	0.230	0.116	0.080

Table 5: Influence of straight and water soluble fertilizers on yield parameters

Treatments	Weight (kg plant^{-1})			Fresh rhizome yield plant^{-1} (kg plant^{-1})	Estimated fresh rhizome yield (kg ha^{-1})	Estimated cured rhizome yield (kg ha^{-1})
	Mother rhizomes	Primary rhizomes	Secondary rhizomes			
T_1	0.054	0.109	0.057	0.220	28662.39	4878.34
T_2	0.083	0.152	0.085	0.320	38512.81	6551.03
T_3	0.078	0.161	0.072	0.311	37482.90	6390.83
T_4	0.074	0.147	0.075	0.296	36568.37	6260.50
T_5	0.089	0.169	0.087	0.340	43196.57	7408.21
T_6	0.083	0.165	0.082	0.335	41205.12	7029.59
T_7	0.076	0.148	0.078	0.302	37094.01	6313.40
SEd	0.002	0.004	0.002	0.009	1167.634	199.291
CD (0.05)	0.005	0.009	0.005	0.019	2453.143	418.701