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Impact of gamma rays on turmeric crop (*Curcuma longa* L.)

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ABSTRACT

Experiments were carried out during 2000-2003 at the Department of Spices and Plantation Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, to assess the impact of gamma irradiation on days to maturity, yield and curing per cent in turmeric (*Curcuma longa L.*). The experiment was laid out in Factorial Randomized Block Design with two replications. Three genotypes namely, Salem Local - G_1 (CL144), Alleppy finger turmeric - G_2 (CL146) and PTS 43 - G_3 (CL147) were treated with seven doses of gamma rays (1.0, 1.5, 2.0, 2.5, 3.0, 3.5 and 4.0 kR) along with control. The plants matured earlier and yield per plant and curing percentage improved at 2.0 kR, followed by 2.5 kR, whereas, higher doses of gamma rays had a negative effect on yield and curing percentage and these higher doses prolonged maturity. Among the genotypes used, G_1 (CL144) was found to show a good response to gamma irradiation.

Key words : Gamma rays, turmeric crop, irradiation, yield, curing percentage

INTRODUCTION

Turmeric (*Curcuma longa* L.) is one of the important spices grown in India and plays an important role in the national economy. Turmeric types can be grouped into three, based on the time taken to harvest, as short, medium and long-duration types. Short -duration types are known as Kasturi. They mature in seven months. Medium-duration Kesari types (Bontha) mature in eight months. Long-duration types mature in nine months and are superior to the above two groups in rhizome yield and other quality parameters. Flowering is rare in these types (Rao *et al*, 1975). Cultivated turmeric, *C. longa* is considered to be a sterile triploid with somatic chromosome number of sixty three (2n= 3x=63), while, *C. aromatica* is a tetraploid (2n=4x=84) and sets seeds. *Curcuma langa* being a sterile triploid, it is flowers fail to set seed. The variable success rate of seed set in ‘Prabha’ and ‘Prathiba’ (which are open - pollinated progenies in turmeric under Kerala conditions) by recombination breeding programme has been reported by Sasikumar *et al* (1994). Turmeric is asexually propagated with no seed production under Tamil Nadu conditions, restricting the breeder to rely on clonal selection, which is the major mode for its improvement. The first step in improvement of this clonally propagated crop is to exploit the variability existing among the land races and to create more variability through mutation and somaclonal variation. It being a polyploid (amphidiploid), use of mutagens in turmeric for inducing variability assumes greater significance. Success in mutation breeding depends largely on understanding the process of induction and recovery of mutants and screening methods for evaluating desired mutants. In turmeric, systematic attempts for induction of mutation are scanty and methodologies for induction and recovery of mutants are yet to be standardized. An attempt was therefore made to induce variability for days to maturity, yield and curing percentage by irradiation with gamma rays.

MATERIAL AND METHODS

The present investigation was carried out during 2000 - 2003 at the Department of Spices and Plantation Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore. The experiment was laid out in Factorial Randomized Block Design and replicated twice under open field condition. Three genotypes, namely, Salem Local - G_1 (CL144), Alleppy finger turmeric - G_2 (CL146) and PTS 43 - G_3 (CL147) were used. Gamma ray source was Cobalt - 60 in 1000 Ci, emitting 5000 rads per minute at the time of irradiation. Uniform sized finger rhizomes (approximately 10g each) were selected and cut into pieces, having 3 nodes per cutting. These rhizome bits, subjected to seven doses of gamma rays (1.0, 1.5, 2.0, 2.5, 3.0, 3.5 and 4.0 kR) along with control, were used as the planting material. Treated rhizome bits were planted on one side of the ridge at 5 cm depth at 45 x 15 cm spacing. After planting, a basal manurial dose comprising 25 kg N, 60 kg P and 18 kg k ha^{-1} was applied. It received a top dressing of 25 kg N and 18 kg k ha^{-1} at 30, 60, 90 and 120 days after planting. The field was irrigated before planting. Life irrigation was given on the third day of planting. Thereafter, irrigation was given at weekly intervals depending on weather and soil conditions. Ten plants in each genotype per replication were tagged randomly for recording observations and mean values were subjected to statistical scrutiny.

Days to maturity

The period from planting to harvest was recorded as the days taken to maturity. Yellowing and drying of the leaves as well as cracking of the soil were considered as indications of maturity.

Yield per plant

Fresh rhizomes harvested from each plant were weighed and the mean was expressed as grame (g) per plant.

Curing per cent

One hundred grames of fresh rhizomes from each treatment plot (comprising 30% mother rhizomes and 70% primary and secondary rhizomes) were boiled in pure water for 45-60 minutes till the rhizomes became soft and emitted the typical turmeric odour (Natarajan and Lewis, 1980). After boiling, the rhizomes were dried under sun until attaining 8% moisture content (Philip and Sethumadhavan, 1980). Curing per cent of the rhizomes was calculated using the following formula and was expressed as per cent:

$$\text{Curing per cent} = \frac{\text{Weight of the cured rhizome}}{\text{Fresh weight of the rhizome}} \times 100$$

RESULTS AND DISCUSSION

Days to maturity

vM_0 generation

Among the different treatments in genotype G_1 (CL144), treatment T_3 (2.0 kR) exhibited earliness in days to maturity (223.11), followed by T_4 (2.5 kR) with 230.92 days. Delayed maturity (282.02 days) was seen in T_7 (4.0 kR), whereas, the control (T_0) took 235.23 days to mature. In G_2 (CL146), treatment T_3 (2.0 kR), followed by T_4 (2.5 kR), expressed earliness in days taken to mature (219.02 and 221.53, respectively) and T_7 (4.0 kR) showed delayed maturity (268.65 days), while, the control (T_0) registered 260.06 days. Similarly, in G_3 (CL147), treatment T_3 (2.0 kR) showed earliness in days to maturity (221.83) and T_7 (4.0 kR) recorded delayed maturity (288.10 days), whereas, the control (T_0) registered 246.13 days.The treatment combination G_2T_3 (CL146, 2.0 kR) exhibited earliness in days to maturity (219.02), followed by G_2T_4 (CL146, 2.5 kR) which required 221.53 days. Delayed maturity (288.10 days) was observed in G_3T_7 (CL147, 4. 0 kR) (Table 1)

vM_1 generation

Among the different treatments, T_3 (2.0 kR) of the genotype G_1 (CL144) showed earliness in days to maturity (232.99). This was followed by T_3 (2.0 kR) of G_2 (CL146) which required 233.00 days. Delayed maturity (269.97 days) was expressed in T_7 (4.0 kR) of G_3 (CL147) followed by T_7 (4.0 kR) of G_1 (CL144) with 268.00 days, whereas the days to maturity exhibited in the control (To) of G_2 (CL146) was 248.17 days. The treatment combination G_1T_3 (CL144, 2.0 kR) showed earliness in days to maturity (232.99 days), followed by G_2T_3 (CL146, 2.0 kR) which required 233.42 days. Delayed maturity (269.97 days) was observed in G_3T_7 (CL147, 4.0 kR) (Table 1).

Yield per plant

vMo generation

Among the different treatments of G_1 (CL144), treatment T_3 (2.0 kR) produced the highest yield per plant (373.75 g) and the lowest yield (137.50 g) was recorded in T_7 (4.0 kR), whereas, the control (T_0) registered 301.50 g. In G_2 (CL146), treatment T_3 (2.0 kR) registered increased yield (266.25 g) and T_7 (4.0 kR) obtained decreased yield (63.75 g), while, the yield per plant observed in the control (T_0) was 97.88 g. Similarly, in G_3 (CL147), higher yield (241.25g) was expressed in T_3 (2.0 kR) and lower yield (127.50g) was seen in T_7 (4.0 kR), while, yield per plant obtained in the control (T_0) was 135.00 g. Genotype G_1 (CL144) exhibited higher yield per plant (373.75 g), followed by G_2 (CL146) and G_3 (CL147) with 266.25 and 241.25 g, respectively, in T_3 (2.0 kR). Increased yield (373.75 g) was noticed in the treatment combination G_1T_3 (CL144, 2.0 kR), whereas, decreased yield (63.75 g) was observed in G_2T_7 (CL146, 4.0 kR) (Table 2).

Table 1. Effect of gamma irradiation in turmeric genotypes on days to maturity in vM_0 and vM_1 generation

Genotype	Treatment	Days to maturity	
		vM_0 generation	vM_1 generation
G_1(CL144)	T_1(1.0kR)	270.20	251.32
	T_2(1.5kR)	260.88	245.59
	T_3(2.0kR)	223.11	232.99
	T_4(2.5kR)	230.92	233.42
	T_5(3.0kR)	234.13	239.98
	T_6(3.5kR)	271.08	261.88
	T_7(4.0kR)	282.02	268.00
	T_0(Control)	235.23	256.63
	Mean	250.95	248.73
G_2(CL146)	T_1(1.0kR)	257.11	245.00
	T_2(1.5kR)	249.69	240.09
	T_3(2.0kR)	219.02	233.00
	T_4(2.5kR)	221.53	235.15
	T_{5-}(3.0kR)	227.09	235.00
	T_6(3.5kR)	264.09	250.13
	T_7(4.0kR)	268.65	253.88
	T_0(Control)	260.06	245.99
	Mean	245.91	242.03
G_3(CL147)	T_1(1.0kR)	266.80	263.82
	T_2(1.5kR)	246.01	250.01
	T_3(2.0kR)	221.83	241.97
	T_4(2.5kR)	227.28	242.00
	T_5(3.0kR)	242.28	244.22
	T_6(3.5kR)	269.72	268.12
	T_7(4.0kR)	288.10	269.97
	T_0(Control)	246.13	255.93
	Mean	251.02	254.51
	Grand Mean	249.30	248.17
	CV(%)	5.92	4.51
vM_0 generation	Sed	CD*(P=0.05)*	CD*(P=0.01)*
T	8.38	17.33	23.51
G	5.13	10.61	14.40
GxT	14.51	30.01	40.73
vM_1 generation			
T	6.66	13.78	18.70
G	4.08	8.44	11.45
GxT	11.54	23.87	32.39

T-Treatment ; G-Genotype ; GxT- Genotype x Treatment

vM_1 generation

Among the treatments, T_3 (2.0 kR), T_4 (2.5 kR) and T_5 (3.0 kR) of G_1 (CL144) registered higher yield per plant (381.13, 360.00 and 330.12 g, respectively), whereas, a lower yield of 153.38g was obtained in T_7 (4.0 kR) as against the control (T_0) with 300.15 g. In G_2 (CL146), treatment T_{3-} (2.0 kR) produced the highest yield (260.19 g) and T_7 (4.0 kR) registered the lowest yield (73.15g) as against the control (T_0), with 100.02g. In G_3 (CL147), higher yield (250.12g) and lower yield (121.02g) were recorded in T_3 (2.0 kR) and T_7 (4.0 kR), respectively, as against the control (T_0) with 130.00g. Among the three genotypes, G_1 (CL144) produced an increase in yield (381.13 g), followed by G_2 (CL146) with 260.19 g and G_3 (CL147) with 250.12g in T_3 (2.0 kR), whereas, the control (T_0) of G_1 (CL144) obtained 300.15g. The treatment combination G_1T_3 (CL144, 2.0 kR) produced the highest yield (381.13 g), whereas, the lowest yield (73.15 g) was registered in G_2T_7 (CL146, 4.0 kR) (Table 3).

Curing percentage

vMo generation

Among the different treatments of G_1 (CL144), T_3 (2.0 kR) followed by T_4 (2.5 kR) registered higher curing percent of 19.44 and 19.00, respectively and T_7 (4.0 kR) expressed a lower curing per cent of 15.22, whereas, the control (T_0) recorded 17.45 curing percent of. In G_2 (CL146), the highest curing per cent (19.00) was observed in T_3 (2.0 kR) and the lowest curing per cent (15.54) was obtained in T_7 (4.0 kR), while, curing percentage recorded in the control (T_0) was 17.05. In G_3 (CL147), treatment T_3 (2.0 kR) exhibited greater curing per cent (8.21) and T_7 (4.0 kR) showed lesser curing per cent (14.92), whereas, the control (T_0) expressed curing percent of 16.00 percent. Increased curing per cent (19.44) was obtained in G_1 (CL144), followed by G_2 (CL146) and G_3 (CL 147) with curing percent of 19.00 and 18.21, respectively in T_3 (2.0 kR) (Table 2).

vM_1 generation

Among the treatments, T_3 (2.0 kR), followed by T_4 (2.5 kR) of G_1 (CL144) obtained a higher curing per cent of 20.41 and 19.95, respectively. A lower curing per cent of 15.07 was exhibited in T_7 (4.0 kR) of G_3 (CL147). Among the three genotypes, G_1 (CL144) exhibited the highest curing per cent (20.41) followed by G_2 (CL146) and G_3 (CL 147) with curing percent of 19.57 and 18.39, respectively, in T_3 (2.0 kR), whereas, the control of G_1 (CL144) registered 18.32 curing percent of (Table 3).

In the present investigation, treatment combination G_2 with 2.0 kR showed earliness in days to maturity compared to the other combinations. Delay in maturity was observed with increase in the dose of gamma rays. Delayed maturity at higher doses in the present investigation could be attributed to delay in plant growth caused by gamma rays. Physiological damage from gamma rays is generally higher in the initial stages of plant growth than at later stages. Induction of mutation generally occurs when DNA synthesis and chromosomal reproduction are in progress.

Mature or differentiated cells are incapable of responding to mutagenic treatments. Earliness in maturity may be attributed to the triggering of metabolic activities by lower doses of gamma rays. The trigger in metabolism would have resulted in changing the source – sink relationship, thereby, breaking the vegetative state at an advanced phase. The fact could be well understood from a study of the anatomy. The rhizome consists of multilayered, thin–walled cells in radial rows forming the cork tissue, with tangential epidermal cells, oblong in shape on the outside and thin walled parenchymatous cells of the cortex on the inside. The central cylinder of parenchymatous cells is separated from the cortex by a thin layer of oblong cells of the endoderm. Scattered throughout the parenchymatous tissue are starch granules (the dominant constituent) which are 15 to 30 mm in size, flat or disc shaped bodies, oleoresin cells containing oil and scattered particles of an orange–yellow component. All the important steps involved in the process of growth and development of turmeric rhizome were seriously influenced by growth period (maturity) which, in turn, was affected by an increase in the dose of gamma rays. This is in concordance with earlier reports by Jayachandran (1989) in ginger.

Yield obtained on per plant basis was the highest at 2.0 kR, followed by 2.5 kR. Increased yield was noticed in the treatment combination G_1 with 2.0 kR. Increased yield at lower doses of gamma rays may be due to an increase in

Table 2. Effect of gamma irradiation in turmeric genotypes on yield per plant (g) and curing per cent in vM_0 generation

Genotype	Treatment	Yield per plant (g)	Curing per cent
G_1(CL144)	T_1(1.0kR)	302.50	16.23 (23.75)
	T_2(1.5kR)	325.00	18.00 (25.10)
	T_3(2.0kR)	373.75	19.44 (26.16)
	T_4(2.5kR)	353.75	19.00 (25.84)
	T_5(3.0kR)	336.25	18.73 (25.64)
	T_6(3.5kR)	226.25	15.75 (22.96)
	T_7(4.0kR)	137.50	15.22 (23.38)
	T_0(Control)	301.50	17.45 (24.69)
	Mean	294.56	17.48 (24.69)
G_2(CL146)	T_1(1.0kR)	111.25	16.73 (24.14)
	T_2(1.5kR)	130.00	17.54 (24.75)
	T_3(2.0kR)	266.25	19.00 (25.84)
	T_4(2.5kR)	240.00	18.33 (25.34)
	T_{5-}(3.0kR)	181.25	17.92 (25.04)
	T_6(3.5kR)	93.75	16.02 (23.59)
	T_7(4.0kR)	63.75	15.54 (23.21)
	T_0(Control)	97.88	17.05 (24.38)
	Mean	148.02	17.27 (24.54)
G_3(CL147)	T_1(1.0kR)	160.00	15.67 (23.31)
	T_2(1.5kR)	173.75	16.73 (24.14)
	T_3(2.0kR)	241.25	18.21 (25.20)
	T_4(2.5kR)	221.25	17.83 (24.97)
	T_5(3.0kR)	216.25	16.92 (24.28)
	T_6(3.5kR)	136.25	15.00 (22.78)
	T_7(4.0kR)	127.50	14.92 (22.72)
	T_0(Control)	135.00	16.00 (23.57)
	Mean	176.41	16.41 (23.87)
	Grand Mean	206.33	17.05 (24.37)
	CV(%)	13.08	4.04

	Yield per plant (g)			Curing per cent		
	SEd	C.D *(P=0.05)*	C.D *(P=0.01)*	SEd	C.D *(P=0.05)*	C.D *(P=0.01)*
T	14.99	31.01	42.08	0.54	1.12	1.52
G	9.18	18.99	25.77	0.33	0.69	0.93
GxT	25.96	53.71	72.89	0.94	1.94	2.64

T : Treatment
G : Genotype, GxT : Genotype x Treatment
Figures in parentheses indicate arc sine transformed values

Table 3. Effect of gamma irradiation in turmeric genotypes on yield per plant (g) and curing per cent in vM_1 generation

Genotype	Treatment	Yield per plant (g)	Curing per cent
G_1(CL144)	T_1(1.0kR)	312.62	17.04 (24.37)
	T_2(1.5kR)	321.43	18.90 (25.77)
	T_3(2.0kR)	381.13	20.41 (26.85)
	T_4(2.5kR)	360.00	19.95 (26.52)
	T_5(3.0kR)	330.12	19.67 (26.32)
	T_6(3.5kR)	253.17	16.54 (23.99)
	T_7(4.0kR)	153.38	15.98 (23.56)
	T_0(Control)	300.15	18.32 (25.34)
	Mean	301.50	18.35 (25.34)
G_2(CL146)	T_1(1.0kR)	123.00	17.23 (24.52)
	T_2(1.5kR)	142.29	18.07 (25.15)
	T_3(2.0kR)	260.19	19.57 (26.25)
	T_4(2.5kR)	243.35	18.88 (25.75)
	T_{5-}(3.0kR)	200.42	18.46 (25.44)
	T_6(3.5kR)	98.83	16.50 (23.96)
	T_7(4.0kR)	73.15	16.01 (23.58)
	T_0(Control)	100.02	17.56 (24.77)
	Mean	155.16	17.79 (24.93)
G_3(CL147)	T_1(1.0kR)	171.11	15.83 (23.44)
	T_2(1.5kR)	194.22	16.90 (24.27)
	T_3(2.0kR)	250.12	18.39 (25.39)
	T_4(2.5kR)	248.00	18.01 (25.11)
	T_5(3.0kR)	220.73	17.09 (24.41)
	T_6(3.5kR)	152.00	15.15 (22.90)
	T_7(4.0kR)	121.02	15.07 (22.84)
	T_0(Control)	130.00	16.16 (23.70)
	Mean	185.90	16.45 (20.96)
	Grand Mean	225.90	17.57 (24.76)
	CV(%)	13.00	4.04

	Yield per plant (g)			Curing per cent		
	SEd	C.D *(P=0.05)*	C.D *(P=0.01)*	SEd	C.D *(P=0.05)*	C.D *(P=0.01)*
T	15.43	31.93	43.33	0.55	1.14	1.55
G	9.45	19.55	26.53	0.34	0.70	0.95
GxT	26.73	55.30	75.05	0.96	1.98	2.68

T : Treatment
G : Genotype, GxT : Genotype x Treatment
Figures in parentheses indicate arc sine transformed values

the level of enzymes, which activate metabolism of the cells responsible for translocation of metabolites from source to sink. Lower doses of gamma rays may have enhanced the enzymatic processes involved in plant growth and development such as proper stomatal functioning, photosynthetic efficiency in terms of net assimilation rate and partitioning efficiency from the source to the sink, and, in related biochemical reactions. Yield per plant decreased as the dose of gamma rays increased. Low yield at increased dose obtained in the present investigation can be attributed to reduction plant in growth, leaf area and size and growth of rhizomes, particularly, secondary rhizomes by gamma rays. Increased dose adversely affected tiller and leaf production and height of the plant, especially, during the early stages of growth. As the growth period advanced, the plants could, more or less, recover from the adverse effects during early stages noted in the above characters. However, recovery in growth achieved during the later stages of growth did not appear to have sufficient contribution to rhizome development. This may be the reason for the yield that resulted at higher doses of gamma rays, irrespective of the fact that the plants could recover from the shock of gamma ray treatments later in their growth period. Similar line of work had been reported by Raju *et al* (1980) who reported weaker and elongated underground rhizomes in ginger with application of 2.0 kR gamma rays. In *Costus speciosus*, Gupta *et al* (1982) observed increased rhizome production at 1.5 kR gamma ray treatment. However, the yield of rhizomes decreased at higher doses of 2.0, 2.5 and 3.0 kR. Shah *et al* (1982) observed high yields in turmeric as a result of X-ray irradiation.

Significant variation was noticed in curing percentage among treatments. Curing per cent was higher in the treatment 2.0 kR, followed by 2.5 kR and was found to decrease with increase in the dose of gamma rays. Variation in curing percentage among the treatments was chiefly due to genetic factors rather than the type of processing used. Expression of low curing per cent at higher doses of gamma rays may be attributed to lesser resource utilization by the rhizomes at the rhizome bulking stage as a result of gamma irradiation. Resource utilization was affected due to a lower net assimilation rate, which was mainly characterized by enhanced physiological parameters such as crop growth rate, relative growth rate, photosynthetically active radiation (PAR) and higher net assimilation rate during the early stages of plant growth and rhizome development upto seven months after planting. Present findings are in corroboration with earlier work carried out by Subramanian *et al* (2002) in CO 1 and BSR 1 clones of turmeric. Higher curing per cent was mainly due to production of slender rhizomes, perhaps due to lower moisture retention at harvest. Low curing per cent was mainly due to the fact that feeder roots are present near the soil surface under irrigated conditions, and these absorb more water and ought to have higher moisture content. As a result, the rhizome becomes plump and after curing, the yield gets reduced. This is in accordance with previous work of Philip (1983) and Reddy *et al* (1989) in turmeric.

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