INDUCTION OF MUTAGENESIS IN TURMERIC (*Curcuma longa* L.) THROUGH GAMMA RAYS FOR VARIABILITY AND QUALITY IMPROVEMENT

*Thesis submitted in partial fulfilment of the requirements for the degree of "**DOCTOR OF PHILOSOPHY in HORTICULTURE**" to the Tamil Nadu Agricultural University, Coimbatore – 641 003.*

By

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CERTIFICATE

This is to certify that the thesis entitled **"INDUCTION OF MUTAGENESIS IN TURMERIC (*Curcuma longa* L.) THROUGH GAMMA RAYS FOR VARIABILITY AND QUALITY IMPROVEMENT**" submitted in partial fulfillment of the requirements for the award of the degree of **Doctor of Philosophy (Horticulture)** to the **Tamil Nadu Agricultural University,** Coimbatore is a record of **bonafide** research work carried out by **Mrs. H. Usha Nandhini Devi** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

(Dr. N. CHEZHIYAN)
Chairman

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(H. USHA NANDHINI DEVI)

ABSTRACT

INDUCTION OF MUTAGENESIS IN TURMERIC (*Curcuma longa* L.) THROUGH GAMMA RAYS FOR VARIABILITY AND QUALITY IMPROVEMENT

By

H. USHA NANDHINI DEVI

Degree : **Doctor of Philosophy in Horticulture**

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2004

The present investigation was carried out during the year 2000-2003 in 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 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 a control.

There was a reduction in the growth of the plants as the dose of gamma rays increased in both vM_o and vM_1 generations. The morphological and biochemical traits such as sprouting per cent, height of the plant, number, length, breadth and area of the leaf, number of tillers per plant, days to maturity, number, weight, length and girth of mother, primary and secondary rhizomes, rhizome to core diameter ratio, yield per plant, curing per cent, curcumin content, oleoresin content and essential oil content were

improved at 2.0 kR followed by 2.5 kR, whereas higher doses of gamma rays showed an inhibitory effect on the growth parameters.

In vM_1 generation, chlorophyll mutations were observed. Among the treatments employed, the highest mutation frequency (1.20) was obtained at 2.0 kR in the genotypes G_1 (CL144) and G_2 (CL146). Four different types of chlorophyll mutants *viz.*, xantha, albina, chlorina and deep green were recorded. A high percentage of deep green (36.51 per cent), followed by xantha, albina and chlorina were registered (19.04, 6.35 and 3.34 per cent respectively). The mutagenic effectiveness was the highest (60.00 per cent) at 2.0 kR in the genotype, G_1 (CL144). The mutagenic efficiency in terms of lethality and injury was high (3.88 and 7.73 per cent respectively) at 2.0 kR in G_1 (CL144).

The viable mutation frequency was higher (2.40 per cent) at 2.0 kR in G_1 (CL144). Six types of viable mutants *viz.*, plant stature (tall and dwarf), number of tillers (more and less), maturity (early and late), yield (high and low), curcumin content (high and low) and oleoresin content (high and low) were obtained.

In vM_o and vM_1 generations, number of primary rhizomes exhibited the highest PCV and GCV. Heritability in broad sense was the highest (90.00 per cent) for essential oil content followed by curcumin content (83.00 per cent) in vM_o generation, whereas in vM_1 generation, greater heritability (67.00 per cent) was recorded for height of the plant followed by number of primary rhizomes (60.00 per cent). GA as per cent of mean was high for number of secondary rhizomes (66.84 per cent), followed by yield per plant (41.60 per cent) in vM_o generation, whereas greater value (53.00 per cent) was expressed by number of primary rhizomes in vM_1 generation.

The correlation study established that the weight of mother rhizomes, number, length and girth of primary rhizomes and number of secondary rhizomes expressed

positive correlation with yield per plant in vM_o generation. Similarly, the number, weight, length and girth of primary rhizomes, number, weight and length of secondary rhizomes and curing per cent were positively correlated with yield per plant in vM_1 generation.

Path analysis in vM_o generation projected girth of primary rhizomes and weight and girth of secondary rhizomes as dominating contributors towards yield.

The present study broadly indicated that the lower doses of gamma rays (2.0 and 2.5 kR) were effective in creating variability for most of the characters. Among the genotypes used, G_1 (CL144) was found to show good response to gamma irradiation.

LIST OF TABLES

Cont..

Cont..

LIST OF FIGURES

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CONTENTS

LIST OF ANNEXURES

LIST OF PLATES

CHAPTER - I

INTRODUCTION

Turmeric (*Curcuma longa* L.) is one of the important spices grown in India, which plays an important role in the national economy. It is a member of the family, Zingiberaceae and is of wild origin from South – East Asia. India accounts for more than 70 per cent of global production. Turmeric is cultivated in an area of about 1,55,800 hectares in the country with a production of 5, 98, 400 tonnes. (Johny and Ravindran, 2002). The major items of export are raw and dry rhizomes, turmeric powder and curcumin. States like Andra Pradesh, Orissa, Kerala, Tamil Nadu, Karnataka, Maharashtra and West Bengal are in the forefront in turmeric cultivation and research. In Tamil Nadu, the major turmeric growing districts are Erode, Salem, Coimbatore and Namakkal. It is commonly used as a spice and colouring agent. Curcumin is gaining importance in food industry, pharmaceuticals, preservatives and cosmetics. The ban on artificial colours has promoted the use of curcumin as a food colourant. In pharmaceuticals, it is valued for the anti-cancerous, anti-inflammatory and anti-septic properties.

The genus *Curcuma* consists of about 70-80 species of rhizomatous herbs distributed in Indo-Malaysian region (Purseglove *et al.,* 1981). In India, about 40 species are found. Among them, *C. longa* L./*C. domestica* Val., *C. aromatica* Salisb., *C. amada* Roxb., *C. angustifolia* Roxb., *C. caesia* Roxb., *C. mangga* Val. and *C. zeodoria* (Beng.) Rosc. are some of the economically important ones (Purseglove *et al.*, 1981). *C. longa* L./ *C. domestica* Val. is the source of turmeric which is used as a spice, food colourant, dye and in medicine. *C. zeodoria* (Beng.) Rosc. is the wild turmeric or yellow zeodory, used as a dye, cosmetic and drug but not as a condiment. This species is found wild in India. The rhizomes have the smell of camphor (Purseglove *et al.,* 1981).

Turmeric types can be grouped into three, based on the time taken for harvest as short, medium and long duration types. Short duration types are known as Kasturi. They

mature in seven months, rhizomes possess pleasant aroma, good yielders of dried turmeric and rich in volatile oil content but low in curcumin and used in culinary preparation. Flowering is common in these types and seeds can produce gametic seedlings. Medium duration Kesari types (Bontha) mature in eight months referred as intermediary types and are high yielders of fresh rhizomes than Kasturi types and moderately rich in curcumin and volatile oil. They are susceptible to leaf blotch and rhizome rot. Long duration types mature in nine months, which are superior to the above groups in rhizome yields and other quality parameters. Flowering is rare in these types (Rao *et al.,* 1975). Erode and Salem are popular cultivars of Tamil Nadu with curcumin content of 3.9 and 4.75 per cent respectively (Muthuswamy and Shah, 1982). Alleppy turmeric has a yield potential of 25 t ha^{-1} and high curcumin content of 6.5 per cent, however, with slightly low curing percentage of 19.00 (Lewis, 1973 and Purseglove, *et al.,* 1981). Turmeric produced in different localities vary in quality and price. Alleppy, Salem, Erode Rajapuri and Nizamabad fingers are popular trade names of Indian turmeric.

Cultivated turmeric, *Curucma longa* L. is considered to be a sterile triploid with a somatic chromosome number of sixty three (2n= 3x=63), while, *C. aromatica* is a tetraploid (2n=4x=84) and set seeds. *C. longa* being a sterile triploid, flowers, however, fail to set seed. The success of viable seed set of 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. Since turmeric is an asexually propagated crop with no seed production under Tamil Nadu conditions, the breeder has to rely upon clonal selection which is the major mode for its crop improvement. The first step in the improvement of this clonally propagated crop is to exploit the variability existing among the land races, create more variability through mutation and somaclonal variation. Being a polyploid (amphidiploid), the use of mutagens for inducing variability assumes greater significance. The success of mutation breeding largely depends on

understanding of the process of induction and recovery of mutants and of the screening methods for evaluating the desired mutants. In turmeric, systematic attempts on induction of mutation are scanty and the methodologies for induction and recovery of the mutants are yet to be standardized. An attempt was therefore made to induce variability by irradiation with gamma rays with the following objectives:

1. To identify high yielding superior performing mutants,
2. to isolate short duration mutants,
3. to screen mutants with high curcumin and oleoresin contents,
4. to assess the genetic variability of the yield components,
5. to study association of yield components with the yield and their inter-relationship and
6. to estimate the direct and indirect effects of the yield components on yield.

CHAPTER - II

REVIEW OF LITERATURE

Turmeric is an important commercial spice crop and has immense use. Though the importance of turmeric as a spice and medicinal plant is well known to Indians from time immemorial and a number of turmeric land races are being grown in different parts of the country, not much research work has been undertaken on mutation breeding for the improvement of this crop. In this chapter, an attempt has been made to trace the available research information on "Induction of mutagenesis in turmeric through gamma rays for variability and quality improvement".

The literature reviewed in this section covers topics as follows :

1. Crop improvement in turmeric and other rhizomatous plants.
2. Effect of mutagens on plant growth in turmeric and other rhizomatous plants.
3. Genetic variability in turmeric.
4. **Heritability and genetic advance in turmeric.**
5. Correlation studies in turmeric.
6. Path analysis in turmeric.

2.1. Crop improvement in turmeric and other rhizomatous plants

In turmeric, crop improvement should be attempted through clonal selection for exploiting the naturally occurring variation which is high in this crop. Mutation breeding could be the best tool since conventional breeding is beset with problems such as high degree of heterozygosity which causes a complex inheritance of genetic factors as well as the frequent polyploidy.

2.1.1. Mutation breeding

Mutation breeding is one of the methods available to the breeders when the crop is amenable to vegetative propagation. Vegetatively propagated crops are a very suitable group of plants for the application of mutation breeding methods. The high degree of heterozygosity which causes a complex inheritance of genetic factors as well as the frequent polyploidy, both serious handicaps in conventional methods of breeding, are advantageous in mutation breeding, as large variations can often be observed in the irradiated population. Further, mutation is the only source of variability in sterile plants or in obligate apomicts. The possibility of inducing mutation by x-rays was first suggested by Koernicke (1905) and Gager (1908). Even before the discovery of the mutagenic effects of x-rays, the search for chemicals capable of causing mutations began (Schiemann, 1912).

Reports of Gager and Blakeslee (1927), Stadler (1928), and Goodspeed (1929) indicated the use of ionising radiations for inducing mutation in plants. The historically important findings of this period were followed in the next three to four decades by investigations of a purely experimental nature, such as the sensitivity of the crop towards the mutagen, morphological variations and cytological characteristics.

The seventies witnessed the practical utilization of induced mutation in a wide range of crops (Gregory, 1972).

According to Broertjes (1977), too many mutation experiments had been carried out in the past with no other objective than "to see what might come out". These early works did not contribute much to plant improvement.

The most promising aspects of mutation induction in the vegetatively propagated plants, compared to the cross breeding methods, was the ability to change only a very few characters of an otherwise good cultivar without altering significantly the remaining and often unique genotype (Broertjes, 1977). Mutation breeding, therefore, must be considered as the obvious means to perfect the leading products of conventional plant

breeding and as a possible shortcut for inducing desired genetic alterations in the outstanding cultivars. Broertjes (1977) described the methods of mutation induction applicable to vegetatively propagated crops.

Broertjes and Van Harten (1978) reviewed the mutation work in various vegetatively propagated crops. The success of mutation breeding depends largely on the choice of appropriate plant materials, mutagens and selection procedures.

Physical mutagens are widely used for treating the different plant parts. Though a variety of ionizing radiations are available, only X-rays and gamma rays are generally used.

CO1, a vegetative mutant clone derived by x-ray irradiation of Erode local turmeric at 5 kR was a highly promising variety that has been released from Tamil Nadu Agricultural University, Coimbatore (Shah *et al.*, 1982).

Janick (1986) emphasised the need for artificial induction of mutation for creating changes that have not occurred naturally in asexually propagated plants.

The rapid increase in the release of mutants in the recent years showed unmistakably that induced mutations have been used successfully in plant breeding programmes (Sigurbjornsson, 1977; Rangaswamy, 1986).

2.2. Effect of mutagens on plant growth in turmeric and other rhizomatous plants

The mutagenic sensitivity of plants is usually assessed by parameters such as sprouting, survival, height of the plant, flowering behaviour and morphological variations.

2.2.1. Sprouting

The effect of mutagen on sprouting and/or germination has been reckoned as one of the reliable estimates of seedling lethality by several workers. In ginger, 5.0 krad gamma rays prevented total germination of the rhizomes (Gonzalez *et al*., 1969). Uzenbaev and Nazernko (1969) observed delayed germination of canna rhizomes at increased dose of gamma rays.

Mukherjee and Khoshoo (1970) treated rhizomes of canna with 1, 2 and 3 krad of gamma rays and found that a dose of 3 krad was lethal to the diploids but not to the triploids.

According to Gonzalez *et al*. (1969) germination was completely inhibited by 5 krad of gamma rays in ginger. However, Raju *et al*. (1980) observed 32 per cent germination in ginger at 2.0 krad as against 96 per cent in control. In mango-ginger (*Curcuma amada* Roxb.) irradiated with gamma rays at 2.0 krad, the germination percentage was 64, which reduced to 16 per cent at 5.0 krad (Raju *et al*, 1980). Radiosensitivity studies undertaken by these scientists indicated that mango-ginger and ginger were more sensitive than turmeric.

Gupta *et al*. (1982) observed that gamma rays induced variability in Costus species. Rhizome pieces were exposed to 1.5, 2.0, 2.5 and 3.0 Krad of gamma rays and planted. Lower doses showed no effect on sprouting while marked decrease in sprouting was observed at 3.0 krad. On the basis of survival LD_{50} dose was fixed as 3.0 krad.

Giridharan (1984) observed graded decrease in the sprouting percentage as the dose of gamma rays increased in ginger cultivars, Rio-de-Janeiro and Maran. At 2.0 krad, the sprouting percentage of the cultivars Rio-de-Janeiro and Maran were 33 and 19 per

cent respectively. Sprouting was completely inhibited by gamma rays at 4.0 krad and above doses.

Rao (1999) treated the rhizomes of turmeric with gamma irradiation (0.3, 0.6 and 0.9 krad). With increased doses of irradiation sprouting was reduced.

2.2.2. Survival

The survival count is a better estimate of lethality than the germination percentage as it accounts for post-germination lethality also.

In *Costus speciosus* Linn., the rhizome pieces when exposed to 1.5, 2.0, 2.5 and 3.0 krad of gamma rays showed a reduction in survival per cent at higher dose levels. At a dose of 2.5 and 3.0 krad, there was no survival of plants (Gupta *et al*., 1982).

2.2.3. Vegetative growth

Rhizomes of the young plants of canna were irradiated with gamma rays at 1.0, 1.5 and 2.0 krad by Nakornthap (1965) and he observed stunted plant growth and variegated leaves at 2.0 krad.

Raju *et al*. (1980) treated ginger rhizomes with 2.0 to 6.0 krad gamma rays. The height of the plant decreased as the dose of gamma rays increased. The average height of the plants treated with 2.0 and 5.0 krad gamma rays was 6.5 and 3.0 cm respectively while the height of the control plants was 35.0 cm.

Gamma irradiation in mango-ginger revealed a decreasing trend in height of the plant as the doses increased. The mean height of the control plants was 40 cm which was reduced to 35 and 7 cm respectively at 2.0 and 5.0 krad gamma rays (Raju *et al*., 1980). They further observed that the lowest dose of gamma rays applied (2.0 krad) did not alter

the height of the turmeric plants. However, at 5.0 krad the height was reduced to 18 cm from 60 cm recorded for the control.

Gupta *et al*., (1982) irradiated the rhizomes of *Costus speciosus* with 1.5, 2.0, 2.5 and 3.0 kR of gamma rays. They observed growth stimulation at 1.5 krad. At 2.0, 2.5 and 3.0 krad treatment, height of the plant, number of branches and size of the leaves were reduced. At 3.0 krad a drastic reduction of height from 48.7 to 17.7 cm resulted.

Rattan (1988) irradiated the rhizomes pieces of ginger having 1-2 buds with 0.25, 0.50, 0.75, 1.00, 1.25, 1.50, 1.75 and 2.00 kR. Almost all the induced mutations appearing in the vM_1 generation were in chimeric forms and had an effect on growth which showed a stunted or semidwarf effect.

Jayachandran and Mohanakumaran (1992) irradiated single budded rhizome bits of ginger cv. Rio-de-Janeiro with gamma rays at five doses (0.50, 0.75, 1.00, 1.25 and 1.50 krads). In the vM_1 generation, sprouting, survival, height of the plant, number of tillers and leaves and rhizome yield decreased as the doses of gamma rays increased. Chlorophyll chimera was produced by all doses of gamma rays to a limited extent between 2.5 and 6.5 per cent of the sprouted plants.

Rao (1999) treated the rhizomes of turmeric with gamma radiation (0.3, 0.6 and 0.9 kR). With increase in the doses of irradiation, height of the plant was affected.

2.2.4. Chlorophyll chimera

In ginger, Giridharan (1984) reported appearance of yellow streaks as a result of gamma irradiation in the cvs. Rio-de-Janeiro and Maran.

Rao (1999) treated the rhizomes of turmeric with gamma radiation (0.3, 0.6 and 0.9 kR). At a higher dose of 0.9 kR chlorophyll mutants *viz.*, xantha, albina, chlorina and deep green were recorded.

2.2.5. Morphological abnormalities

Rhizomes of the young plants of canna were irradiated with gamma rays at 1.0, 1.5 and 2.7 krad. The treatments resulted in stunted plants. (Nakornthap, 1965).

Raju *et al*. (1980) observed formation of weak and elongated underground rhizomes in ginger on treatment with 2.0 krad gamma rays. In turmeric and mango-ginger, the same treatment showed almost normal growth, however, the leaves showed yellow streaks. The rhizomes were stored separately and planted in the next year. They produced normal plants in the vM_2 generation. However, the leaves at the lower nodes showed yellow streaks.

2.2.6. Yield

Raju *et al*. (1980) found formation of weaker and elongated underground rhizomes in ginger due to 2.0 krad of gamma ray treatment.

In costus, Gupta *et al*. (1982) observed increased rhizomes production at 1.5 krad treatment. However, the yield of rhizome decreased at 2.0, 2.5 and 3.0 kR treatments.

2.2.7. Quality

Quality of ginger rhizomes are mainly determined by the content of volatile oil, Non-Volatile Ether Extract, fibre and starch. According to Jayachandran *et al*. (1980), the average percentage content of the above components in ginger cv. Rio-de-Janeiro were volatile oil (2.7), Non-Volatile Ether Extract (8.3), fibre (6.6) and starch (40.2). Good quality ginger contains less fibre, but more volatile oil and Non-Volatile Ether Extract.

In costus, diosgenin content increased as a result of 2.0 krad gamma ray treatment whereas it decreased at 3.0 krad (Gupta *et al.,* 1982).

Giridharan (1984) found that the quality in terms of the spice oil and oleoresin content was not altered by irradiation of ginger rhizomes with gamma rays.

Rao (1999) treated the rhizomes of turmeric with 0.3, 0.6 and 0.9 kR gamma rays. Treatment with 0.6 kR resulted in an increase in curcumin content.

2.3 Genetic variability in turmeric

2.3.1. Height of the plant

Among the short duration cultures screened under Andhra Pradesh conditions, Reddy *et al.* (1989) documented that greater height of the plant (35.70 cm) was observed in PCT 8 and lesser height of the plant (19.10 cm) was obtained in PCT10.

Under coastal regions of Karnataka, Indiresh *et al.* (1990) reported that the cultivar PCT8 produced the highest height of the plant (98.50 cm), while the cultivar M221 registered the lowest height of the plant (46.26 cm).

Kurian and Valsala (1995) documented that the height of plant exhibited significant differences among the locally cultivated turmeric genotypes in Kerala and increased height of the plant (141.67 cm) was observed in VK 146. Radhakrishnan *et al.* (1995) observed that BSR1 recorded the tallest plants (48.25 cm) among the varieties studied under Kerala condition. In yet another study by Ramakrishna *et al.* (1995) the tallest plant (95.30 cm) was observed in the genotype PCT13 while the shortest plant (47.70 cm) was recorded in PCT 10. Kurian and Nair (1996) found that the height of plant alone exhibited significant deviation among the traits studied and greater height of the plant (156.00 cm) was recorded in VK 112 followed by VK 99 (141.00 cm).

Rajeshkumar and Jain (1998) observed that Roma was the tallest (103.00 cm) followed by Suroma (102.67 cm) and Sonali (92.00 cm) under plateau regions of Bihar. Shanmugasundaram (1998) found that PTS 43 recorded greater height of the plant (102.85 cm) and the genotype VK 5 registered lesser height of the plant.

Jana and Bhattacharya (2001) reported that the tallest plant was obtained in the genotype PTS 19 (160.13cm). Vijayalatha (2002) noticed that the genotype CL2 (48.56cm) was the tallest and the genotype CL20 (29.05cm) was the shortest among the 224 turmeric genotypes tested under Tamil Nadu condition. Arunkumar (2003) found that the genotype CL2 produced the tallest plant (46.86 cm).

2.3.2. Number of tillers per plant

Shah *et al.* (1982) documented that number of tillers per plant in cultivar CO1 varied from 3.70 to 5.00. In Mannuthy local and Dindigam, the number of tillers per plant were 3.40 and 2.15 respectively (Philip, 1983) and it was further stated that, there was no significant difference for number of tillers per plant among the genotypes evaluated. Sathyanarayana and Reddy (1986) obtained greater number of tillers per plant in the clone CLS 3D (3.20) and the lower in CII 326 (1.20). There was no significant difference for number of tillers per plant among the short duration cultures. The culture PCT 8 showed the highest number of tillers per plant (1.40) and the lowest (0.40) in Kasturi (Reddy *et al.*, 1989).

Patil *et al.* (1995) noted that the cultivar Suvarna possessed the largest number of tillers per plant (4.76) however, it was found inferior to other cultivars with regard to other attributes. The various cultivars of turmeric did not exhibit any significant deviation with respect to tiller production (Ramakrishna *et al.*, 1995; Kurian and Nair, 1996).

In contrary, Vijayalatha (2002) obtained a wide and significant variation among the turmeric genotypes for number of tillers per plant under Coimbatore condition and it ranged between 1.00 and 5.50. Arunkumar (2003) registered the highest number of tillers (4.89) in the genotype CL2.

2.3.3. Number of leaves

Number of leaves varied from eight to nine in the variety Dindigam as reported by Rao *et al.* (1975). Pillai *et al.* (1976) recorded 9-12 leaves per plant in cultivar CO1. Philip (1983) observed that the highest number of leaves was registered in the genotype Duggirala (21.00) and the lowest in Mannuthy local (5.60). Under Kerala conditions, Philip and Nair (1983) found that number of leaves per plant varied from 11.20 in Ca 89 to 20.70 in Mannuthy local.

According to Reddy *et al.* (1989), the leaf number varied from 7.10 in PCT5 to 8.27 in PCT11 among the short duration types. Studies by Indiresh *et al.* (1990) on number of leaves under coastal regions of Karnataka have indicated that Sugandham produced more leaves (24.88) followed by Duggirala (24.66). In contrast, very low number of leaves (16.59) was seen in PCT 8. Hegde (1992) observed the largest number of leaves per main shoot (9.10) in the cultivar Cuddapah and Bidar (9.10) and the lowest (6.93) in Moovattupuzha.

Ramakrishna *et al.* (1995) observed that the variety PCT13 exhibited significantly the highest score for number of tillers per plant in Reshmi, which was on par with Suroma and Morangia. Shanmugasundaram (1998) recorded more number of leaves in PTS 43 (25.56). Vijayalatha (2002) opined that the number of leaves at 180 days after planting varied significantly among the 224 turmeric genotypes and it varied from 10.25 in CL149 to 17.92 in the cultivar CL47 under Coimbatore conditions.

2.3.4. Length, breadth and area of leaf

Under Kerala conditions, Philip and Nair (1983) evaluated nineteen genotypes and noticed that the area of leaf varied significantly. It ranged between 696.6 cm^2 in Armoor C11-24 and 1214.3 cm^2 in Amruthapani.

Reddy *et al*. (1989) recorded the broadest area of leaf in the genotype PCT11 (1908.3cm^2) and the narrowest in PCT10 (387.2cm^2) followed by PCT13 (726.7cm^2).

Kurian and Valsala (1995) noticed the highest length of the leaf and breadth in the genotype VK5. Kurian and Nair (1996) reported that length of the leaf varied from 45.67cm in VK96 to 63.67cm in VK112. Rajeshkumar and Jain (1998) observed that the largest area of leaf was obtained in the genotype Sonali (529.62cm^2). Shanmugasundaram (1998) documented that the length of the leaf and breadth of the leaf varied significantly among the genotypes under Coimbatore condition. The length of the leaf ranged between 21.21cm in RH5 and 51.08cm in PTS43. The breadth of the leaf varied from 9.03 cm in VK5 to 16.38cm in PTS43.

Vijayalatha (2002) found significant variations for length and breadth of leaves. The longest leaf was recorded in the genotype CL43 (56.31 cm) and the shortest leaf in CL213 (31.19 cm). The broadest leaf was observed in the genotype CL129 (16.05 cm) and the narrowest leaf was registered in CL33 (10.05 cm). Arunkumar (2003) observed that CL2 produced the longest leaf (49.13 cm) as well as the broadest leaf (14.16 cm).

2.3.5. Rhizome characters

The important yield contributing traits are number, weight and girth of mother rhizomes, primary and secondary fingers. The reviews relating to these characters are presented as follows.

2.3.5.1. Mother rhizomes

Under Coimbatore condition, Muthuswamy and Shah (1982) observed that the mean length and girth of mother rhizomes were not significant among the genotypes. Philip and Nair (1983) registered significant variations for girth of mother rhizomes. It ranged between 11.50 cm in Armoor Ca324 and 17.30 cm in the cultivar Kodur.

Indiresh *et al*. (1990) noticed that the largest and the smallest mother rhizomes were observed in the genotype PCT8 and Duggirala respectively. Hegde (1992) noted that the genotypes Rajapuri and Moovattupuzha varied significantly for number of mother rhizomes.

Shanmugasundaram (1998) reported that the genotypes varied significantly for number, weight and girth of mother rhizomes. The girth of mother rhizome ranged between 6.87cm in VK5 and 12.79 cm in JTS1. The highest and the lowest number of mother rhizomes were produced by JTS2 (4.30) and VK5 (1.55) respectively. The weight varied from 25.48 to 129.16g in VK5 and PTS62 respectively and the genotype Kanthi (30.95g) was on par with VK5.

Vijayalatha (2002) observed that the genotypes varied significantly for number of mother rhizomes and it varied from 1.67 in CL43 to 4.00 in CL193. The weight of mother rhizomes ranged between 10.10g in CL110 and 110.00g in CL153. The widest was recorded in the genotype CL154 (13.29cm) and the narrowest (2.12cm) in CL123.

2.3.5.2. Primary rhizomes

Philip and Nair (1983) opined that number of primary fingers per plant varied from 4.20 to 7.20 in Tekurpet and Mannuthy local respectively. The girth also varied significantly and it ranged between 7.10cm in Dindigam and 10.50cm in Chayapasupa.

The cultivar BSR1 produced the highest number of primary fingers (13.00) and the lowest (3.26) in Moovattupuzha (Hegde, 1992). It was also mentioned that the genotype Amalapuram recorded the longest finger (9.70cm) and the clone 46T was the shortest (3.17cm). The girth of finger varied from 5.03cm in Moovattupuzha to 7.86cm in Rajapuri.

Shanmugasundaram (1998) registered a significant variation for number, weight, length and girth of primary fingers. Number of primary rhizomes varied from 5.16 (RH5) to 14.74 (PTS43). The weight of primary rhizomes ranged between 22.98g in VK5 and 162.80g in JTS1. The genotypes VK5 (6.09cm) and PTS12 (9.20cm) produced the shortest and the longest primary rhizomes respectively. The girth of primary rhizomes varied from 5.75cm in VK5 to 8.98cm in PTS12 and the genotype PTS62 (8.91cm) was on par with PTS12.

According to Vijayalatha (2002), the weight of primary rhizomes ranged between 9.45g (CL65) and 219.50 g in CL114. The genotype CL89 (205.83g) was on par with CL114. The length of primary rhizomes varied significantly and it ranged between 1.20cm in CL19 and 10.77cm in CL 75. The broader (10.30cm) rhizome was in CL135 and slender (2.30cm) in the genotype CL110.

2.3.5.3. Secondary rhizomes

According to Philip and Nair (1983), there was significant variation among the nineteen genotypes for number and girth of secondary rhizomes. Number of secondary fingers varied between 8.30 in G.L. Puram and 20.90 in Mannuthy local. The genotypes, Chayapasupa (19.80) and Armoor (19.80) were on par with Mannuthy local. The girth of fingers varied from 5.1 cm in Armoor C11-324 to 7.4cm in Kuchupudi.

Indiresh *et al.* (1990) found that, number of secondary fingers was the highest (9.51) in PCT8 and the lowest (3.99) in Kasturi, while the genotype Alleppy (3.83) was on par with PCT8. The length of secondary fingers differed significantly from 4.00cm in Erode to 7.50cm in PCT8.

Shanmugasundaram (1998) revealed that the length of secondary rhizome varied significantly from 2.10 cm in VK5 to 5.25cm in BSR2. The genotype PTS12 expressed the broadest (6.38cm) secondary rhizomes and the genotypes that were on par were BSR2 (6.33cm) and JTS1 (6.32cm). The highest and the lowest number of secondary rhizomes were noted in the genotypes PTS62 (34.95) RH5 (4.02) respectively. The heavier rhizome (249.62g) was accomplished in the genotype PTS 62 while the lighter ones (12.15g) in the genotype VK5.

Vijayalatha (2002) opined that the number of secondary rhizomes varied significantly among the genotypes evaluated and it ranged between 1.15 in CL 123 to 10.33 in CL175. The difference in the weight of secondary rhizomes extended from 2.37 in CL19 and 144.00g in CL114.

2.3.6. Yield

Satheesan and Ramadasan (1982) recorded the highest dry recovery yield of 4.8t ha^{-1} as an intercrop and 7.0 t ha^{-1} as a pure crop in turmeric Sel-24. Sathyanarayana and Reddy (1986) reported that, there was a significant variation for the mean yield among the genotypes. The yield ranged between 27.80 t ha^{-1} in Cls-9A and 14.04 t ha^{-1} in Cls-21A. The genotypes Cls2A (26.98 t ha^{-1}) and Ca 66J (25.91 t ha^{-1}) were on par with Cls-9A and Cls -2A with Cls-8D.

Reddy *et al*. (1989) evaluated short duration cultivars under Andhra Pradesh conditions and revealed that the genotypes PCT13 and PCT14 recorded the highest fresh rhizome yield of 28.04 and 26.71 t ha^{-1} respectively.

Indiresh *et al*. (1990) noticed that the highest quantity of cured turmeric was recorded in PCT8 (6.5 t ha^{-1}) followed by Waigon (6.2 t ha^{-1}) and the lowest in M211 (1.38 t ha^{-1}). Nandi (1990) opined that a heavier rhizome yield was found in the genotypes PTS25 (27.00 t ha^{-1}) and Cls-9 (24.60 t ha^{-1}). Hegde (1992) noted the highest fresh rhizome yield of 22.19 t ha^{-1} in Cuddapah and the lowest of 3.73 t ha^{-1} in Moovattupuzha. The genotype Bidar (21.69 t ha^{-1}) was on par with Cuddapah. Ratnambal *et al*. (1992) observed the fresh rhizome yield of 29.00 t ha^{-1} in PCT13 and 28.00 t ha^{-1} in PCT14.

Radhakrishnan *et al*. (1995) could find a significant variation among the genotypes. CO1 was reported to produce fresh rhizome yield of 16.54 t ha^{-1} and BSR1 (14.47 t ha^{-1}) and they were on par.

Ramakrishna *et al*. (1995) found that the genotype PCT13 was the greatest among the genotypes evaluated in terms of fresh rhizome yield (19.15 t ha^{-1}) and the least (9.00 t ha^{-1}) was observed in the genotype PCT10.

Kurian and Nair (1996) documented that the genotypes VK141 (43.02 t ha^{-1}) and VK116 (8.43 t ha^{-1}) produced heavier green turmeric and cured rhizome yield respectively. Maurya *et al*. (1998c) obtained greater green turmeric yield of 24.98 t ha^{-1} in the genotype RH10.

Shanmugasundaram (1998) opined that there was a significant difference among the fifteen genotypes evaluated and it ranged between 6.94 t ha^{-1} in VK5 and 36.86 t ha^{-1} in JTS1. Lynrah and Chakrabarthy (2000) obtained higher fresh rhizome yield in Ouguri,

Nepali and PCT13 genotypes and lower in "Tall clone". Under Andhra Pradesh condition, BSR1 exhibited higher productivity of fresh rhizomes (36.50 t ha $^{-1}$) among the seven cultivars and it was on par with the selection PTS 62 (Naidu *et al.* 2000).

Jana and Bhattacharya (2001) noticed that there was a significant variation among the genotypes. The genotypes such as Sugandham (28.63 t ha^{-1}), Kasturi (27.64 t ha^{-1}) and PCT13 (25.98 t ha^{-1}) recorded the highest fresh rhizome yield than the other genotypes.

Johny and Ravindran (2002) observed that the fresh rhizome yield differed significantly and it ranged between 4.80 t ha^{-1} in Rajendra Sonia and 39.10 t ha^{-1} in cultivar Prathiba. Poduval *et al*. (2002) opined that the fresh yield was heavier in *C.aromatica* than *C.domestica*. Vijayalatha (2002) registered significant variations for yield of fresh rhizomes and ranged between 0.15 and 12.82kg per 3m^2 plot in 224 accessions evaluated under Coimbatore conditions of Tamil Nadu. Arunkumar (2003) reported that the fresh yield of rhizomes per plot was the highest (12.12 kg/3 m^2) in the genotype CL101 and the lowest (0.15 kg/3m^2) in CL110.

2.3.7. Curing per cent

Turmeric yield also depends on the curing per cent. The curing per cent varies depending upon the type of cultivars and the conditions under which they are grown.

Philip and Sethumadhavan (1980) observed that the genotype Ca69 Dindigam expressed the highest curing per cent (28.20) among the genotypes evaluated. Shah *et al.* (1982) opined that the genotype CO1 exhibited the highest curing per cent (19.50). Patil and Sakpal (1983) reported that the genotype Erode and Kasturi recorded a curing per cent of 19.15 and 14.00 respectively.

Ratnambal and Nair (1986) noted that the curing per cent ranged between 13.50 and 32.40 per cent among the one hundred and eighty four accessions studied.

According to Ratnambal *et al*. (1992), the cultivar PCT13 acquired greater curing per cent of 20.60 and the genotype PCT14 (20.40 per cent) which was on par with PCT13. Venkatesha (1994) documented that the genotype Bangalore local attained the highest curing per cent (23.50) followed by CO1 (21.83) and Mydukur (19.00). Patil *et al*. (1995) observed that a curing per cent of 22.78 was recorded by the genotype Lakadong. Radhakrishnan *et al*. (1995) accomplished that the genotype BSR1 obtained the highest curing per cent (27.33) among the genotypes studied. Sasikumar *et al*. (1996) opined that, cultivar Prabha and Prathibha recorded higher curing per cent of 19.50 and 18.90 respectively.

Shanmugasundaram (1998) reported that the curing per cent differed significantly and it varied from 16.00 per cent in JTS1, JTS2 and BSR1 to 22.67 per cent in the cultivar Shoba. The genotype Alleppy (22.50 per cent), Prathiba (22.33 per cent) and Kanthi (22.00 per cent) were on par with Shoba.

Panja *et al*. (2002) found that the genotype PTS62 recorded greater curing per cent of 24.40 under Terai region of West Bengal. Vijayalatha (2002) registered significant variations in terms of curing per cent and it ranged between 12.23 in CL187 and 23.35 in CL157. According to Arunkumar (2003), the curing per cent ranged between 12.39 in CL137 and 22.47 per cent in CL223.

2.3.8. Quality characters

Rosengarten (1969) opined that fingers showed the best quality as compared to rounds and splits. Lewis (1973) documented distinct differences in respect of quality and quantity of oil and oleoresin. The turmeric that was grown in hilly regions had better

quality than those raised in the plains (Chaurasia *et al*., 1974). Pruthi (1976) observed that the quality attributes of the commercial produce were its colour, maturity, length of fingers, breadth of fingers and its aroma.

2.3.8.1. Curcumin content

Krishnamurthy *et al.* (1975) documented that curcumin content of *Curcuma longa* and *Curcuma aromatica* varied from 3.00 to 3.90 and 1.20 to 1.50 per cent respectively. According to Rao *et al.* (1975), the curcumin content of eight varieties grown in Andhra Pradesh varied from 1.24 to 3.87 per cent. Krishnamurthy *et al.* (1976) noticed a variation of 1.80 to 5.40 per cent in curcumin content. Among the 20 selected clones studied, Muralidharan and Ramankutty (1976) reported the highest curcumin content from Alleppy (6.20 per cent) followed by Etamulaka (5.63 per cent), Kharadi local (4.35 per cent) and Wynad local (4.17 per cent).

Induced mutagenesis using single cell cultures to isolate chimera free mutant types for various characters including curcumin and yield was initiated by Shetty *et al.* (1980).

Ghosh and Govind (1982) noticed that the No.24 and C11-323 Avamigadda exhibited the highest curcumin content (7.40 to 7.90 per cent). Muthuswamy and Shah (1982) reported that the cultivar Salem recorded the highest curcumin (4.75 per cent) than Erode type (3.90 per cent). Philip (1983) registered significant differences in curcumin content among the 32 varieties. The highest content was found in Mannuthy local (7.58 per cent) and the lowest in Amalapuram (3.00 per cent).

Hegde (1992) obtained the highest curcumin of 6.46 per cent in Moovattupuzha followed by Cls114 (6.36 per cent) and the lowest in Bidar (2.37 per cent). Ratnambal *et al.* (1992) found that PCT14 was superior in curcumin content (7.90 per cent).

Vijayakumar *et al.* (1992) noted that the Duggirala cultivar was superior to Mydukur variety with respect to curcumin content. Suvarna (PCT8) contained the highest curcumin content of 4.95 per cent.

Ramachandra *et al.* (1994) opined that RCT1 expressed 6.80 per cent curcumin content under Meghalaya conditions. Sasikumar *et al*. (1994) observed many land races that contained more than 6.00 per cent curcumin. Among them, Aieng turmeric of Manipur, Wynad local, Edepalayam, Thodupuzha, Mananthody, Pulally types of Kerala, Aizwal type of Mizoram, Sugandham of Gujarat were rich in curcumin content. Venkatesha (1994) reported that the highest curcumin (8.20 per cent) was in PCT8 followed by PCT13 (4.50 per cent), BSR1 (4.20 per cent) and the least (1.69 per cent) in Mydukur.

Patil *et al.* (1995) observed higher curcumin content in Lakadong (5.44 per cent) followed by Suvarna (4.68 per cent) and CO1 (3.79 per cent). Radhakrishnan *et al.* (1995) noticed the highest curcumin content (4.40 per cent) in BSR1 under Idukki district of Kerala.

Kurian and Nair (1996) recorded the highest curcumin content in VK96 (7.85 per cent) followed by VK112 (7.23 per cent) and these were the collections from Kerala representing Alleppy type.

Shanmugasundaram (1998) reported that curcumin level was of high order (4.87 per cent) in RH5 and it was lower in VK5 (1.29 per cent). Rumikotoky *et al.* (1999) analysed the curcumin content of seven C*urcuma longa* cultivars of which Tamenlong recorded the highest curcumin content (7.30 per cent). Arunkumar (2003) obtained the highest curcumin content (6.00 per cent) in CL67 and the lowest (1.67 per cent) in CL26.

2.3.8.2 Oleoresin content

Krishnamurthy *et al.* (1972) found that the oleoresin content in turmeric varied from 4.00 to 7.50 per cent. Lewis (1973) reported that the turmeric contained 6-7 per cent oleoresin. Mathai (1974) estimated the oleoresin content of six types of turmeric and recorded the highest (24.30 per cent) in Alleppy finger turmeric.

Ratnambal and Nair (1986) reported that the cultivar Konni was superior for oleoresin content (19.20 per cent). Ratnambal *et al.* (1992) registered that the genotype PCT 14 was superior in oleoresin content (15.00 per cent). Sasikumar *et al.* (1996) observed an oleoresin content of 15.00 and 16.20 per cent in cultivar Prabha and Prathibha respectively.

Under Coimbatore condition, the highest oleoresin (8.47 per cent) was estimated in PTS 43 followed by Prabha (7.73 per cent) and the lowest in JTS 1 (3.53 per cent) was reported by Shanmugsasundaram (1998). Vijayalatha (2002) could not find any significant variations for oleoresin content in turmeric genotypes under Coimbatore conditions. Arunkumar (2003) found that the oleoresin content varied from 3.65 in CL195 to 5.24 per cent in CL195.

2.3.8.3 Essential oil

Ratnambal and Nair (1986) opined that the oil content of *Curcuma aromatica* was higher than C*urcuma domestica*.

Volatile oil was estimated in 23 collections of C*urcuma longa* by Pathania *et al.* (1990). Among them, higher per cent (11.20) was observed in IC 29909 and lower per cent (10.90) was obtained in IC 29798. Reddy *et al.* (1990) reported that variability for oil content was more in *Curcuma longa* than *Curcuma aromatica.*

Ratnambal *et al.* (1992) demonstrated that the volatile oil content ranged between 6.00 and 7.00 per cent in PCT 13 and PCT 14 respectively. Sasikumar *et al.* (1996) recorded an oil content of (6.20 and 6.50 per cent) in cultivar Prathibha and Prabha respectively.

Rumikotoky *et al.* (1999) evaluated the essential oil content of seven *Curcuma longa* cultivars under Manipur conditions, of which Thoubal exhibited the highest essential oil content (4.00 per cent). Vijayalatha (2002) could not register any significant variation for essential oil content among the 224 genotypes studied under Coimbatore condition. Arunkumar (2003) obtained the highest essential oil content (2.10 per cent) in CL2 and the lowest (1.37 per cent) in CL78.

2.4. Heritability and genetic advance in turmeric

Mohanty (1979) observed that the values of heritability and expected genetic gain for rhizome yield, number of tillers per plant, breadth of fully opened leaf and height of the aerial shoot in turmeric to be high. Mukhopadhyay *et al*. (1986) opined that in turmeric, heritability estimates were the highest for shoots per clump. Philip and Nair (1986) noticed that the fresh rhizome yield, curing per cent and height of the plant recorded heritability estimates of 0.52, 0.99 and 0.70 respectively and genetic advance as per cent of mean as high as 62.59, 44.96 and 29.64 respectively indicating high scope for improvement of these characters through selections in turmeric. The oleoresin and curcumin contents showed heritability estimate of 0.96 each and exhibited genetic advance as per cent of mean as high as 27.08 and 54.00 respectively indicating scope for quality improvement.

Subramanian (1986) reported that the diameter of the mother rhizome expressed the highest per cent of heritability and genetic advance. Geetha and Prabhakaran (1987) found that height of the plant exhibited high heritability combined with genetic advance

and genetic gain, which indicated the importance of this character in selections for turmeric.

Reddy (1987) observed that rhizome yield, crop duration, number of leaves, number of primary fingers and height of pseudostem expressed high heritability along with medium genetic advance.

Pathania *et al.* (1988) observed higher estimates of heritability for volatile oil content, curcumin content, length of finger and drying per cent. Leaf size and yield per plant showed high heritability value with comparatively lesser genetic advance.

Jalgaonkar *et al.* (1990) showed that the characters like yield of cured turmeric, number of primary fingers and yield of secondary fingers exhibited higher magnitude of heritability and appreciable expected genetic advance.

Pathania *et al*. (1990) recorded high heritability (99.54 per cent) and high genetic advance (90.33 per cent) for volatile oil content. Indiresh *et al.* (1992) stated that the rhizome yield, internodal distance of primary and secondary fingers and number of secondary fingers per plant recorded higher heritability estimates as well as high genetic advance. Yadav and Singh (1996) reported that the length and width of rhizome showed high heritability and per plant yield expressed high genetic advance.

Lynrah *et al.* (1998) studied the pattern of genetic variability in 25 genotypes of turmeric collected in Assam, North Eastern hills and Shillong. Curcumin content, tillers per clump and yield of mother rhizome exhibited high genetic variation and high broad sense heritability.

The highest phenotypic and genotypic variances for fresh rhizome per plant were 34810.22 and 34679.48 respectively, while the lowest (1.19 and 0.63 respectively) was

recorded for number of mother rhizomes (Shanmugasundaram, 1998). The order of difference between PCV and GCV was high for area of leaf (146.18) and the least for number of tillers per plant (0.48). High heritability estimates was recorded for crop duration (99.65 per cent) followed by weight of mother rhizome (98.63 per cent).

Investigation by Hazra *et al.* (2000) revealed that number of leaves per plant at 180 days after planting exhibited high heritability and high genetic gain. Jana *et al.* (2001) opined that the genetic parameters and degree of mutual associations were assessed in relation to yield in cv. Nadia, West Bengal. The characters of fresh rhizome yield, number of rhizomes, weight of secondary fingers exhibited high genetic advance. The fresh rhizome yield was significantly correlated with length of secondary fingers and weight of primary and secondary fingers.

Out of the 26 characters evaluated in turmeric, days to maturity, weight of primary rhizomes , girth of primary rhizomes, weight of secondary rhizomes, length of secondary rhizomes, girth of secondary rhizomes, rhizome to core diameter ratio, curing per cent and yield showed high heritability estimates (Vijayalatha, 2002). Arunkumar (2003) observed higher values for heritability and genetic advance as per cent of mean for traits like yield (99.40 and 218.45 per cent respectively), total phenols at stage 1 (99.80 and 113.01 per cent respectively) and stage 2(99.60 and 104.02 per cent respectively).

2.5. Correlation studies in turmeric

Natarajan (1975) noticed that length of leaf exerted greater influence on yield followed by breadth of leaf, height of plant, number of leaves, primary and secondary fingers. Mohanty (1979) reported that the rhizome yield was positively and significantly associated with number of leaves and shoot height of the plant and negatively associated

with number of tillers per plant. The genotypic and phenotypic correlation coefficients between breadth of fully opened leaf and height of plant were significant and positive.

George (1981) found that the yield per plant was highly associated with length of primary fingers, length and girth of secondary fingers. The correlation coefficients of these yield components were positive and significant. Pathania *et al.* (1981) also observed that the rhizome yield was positively and significantly correlated with height of plant, number of secondary fingers, number of tillers per plant, number of leaves and leaf size.

According to Philip and Nair (1983), height of the plant (0.63), number of leaves per tiller (0.59), and area of the (0.74) was highly significant and positively correlated with the yield of turmeric. The number of tillers per plant (0.22) and leaves per plant (0.44) were not significantly correlated with yield. Among the yield components, though the girth of mother rhizome (0.56) and length of fingers were significant and positively correlated with yield, internodal length, girth of primary fingers and number of nodes did not have significant correlation with yield.

Subramanian (1986) reported that diameter of mother rhizome exhibited significant and positive associations with yield of rhizome. Reddy (1987) showed that the number of leaves, number of primary fingers and period of crop duration expressed strong associations with yield of rhizome at both genotypic and phenotypic levels. Jalgaonkar *et al.* (1988) observed significant and positive correlation between cured yield and girth, weight of mother rhizome, length of primary finger and number and girth of secondary fingers.

Jalgaonkar *et al.* (1990) reported that the yield of cured turmeric was significantly correlated with yield of secondary fingers. The significant relationship of quantitative characters of secondary fingers among each other and with those of primary fingers suggested the scope for obtaining a good response to selection through direct as well as indirect means.

Cholke (1993) recorded significant and positive correlation between yield and primary fingers (0.95) and height of plant (0.71). However, positive and non significant correlation were observed with number of leaves (0.58), number of tillers per plant (0.42), number of mother rhizomes (0.61), number of secondary fingers (0.58) and length of primary fingers (0.55).

Venkatesha (1994) reported that height of the plant, area of leaf and number of leaves exhibited positive correlation with fresh rhizome yield. Among the yield components, weight of mother rhizomes, primary and secondary fingers and length of primary and secondary fingers expressed positive and significant correlation with the yield.

Shanmugasundaram (1998) observed genotypic coefficient of variation for weight of secondary rhizomes (60.43) and weight of primary rhizomes (53.62). A significant and positive correlation with rhizome yield was exhibited for height of the plant, area of leaf, number of leaves, number and weight of primary and secondary fingers, weight of mother rhizomes and duration except for number of tillers per plant and number of mother rhizomes. Curing per cent exerted a high negative association with core diameter.

Height of the plant, length and breadth of leaf, weight of primary rhizomes and rhizome yield per hectare were significant and positively associated with fresh rhizome yield per plant. A negative correlation between dry rhizome recovery and fresh rhizome yield per clump was opined by Chandra *et al.* (1999).

Hazra *et al.* (2000) revealed that number of leaves 180 days after planting exhibited positive phenotypic correlation and direct contribution to yield of rhizome in turmeric.

Vijayalatha (2002) documented that among the 26 traits evaluated in turmeric, the positive association was noticed for all the biometric traits except number of mother rhizomes and quality characters (oil, oleoresin and curcumin) and curing per cent indicating the possibility of simultaneous improvement of component characters and yield. According to Arunkumar (2003), the rhizome yield was positively correlated through sprouting, height of the plant, number, length and breadth of leaves, weight and girth of mother rhizomes, number, weight, length and girth of primary and secondary rhizomes, rhizome diameter and core diameter.

2.6. Path coefficient analysis in turmeric

Natarajan (1975) reported that length of the leaf exerted the highest direct effect on yield followed by number of secondary fingers and leaves. Pathania *et al.* (1981) observed that height of plant showed higher direct contribution towards yield followed by number of secondary fingers and number of leaves. Lal *et al.* (1986) recorded that out of nine yield contributing characters, the number and length of primary rhizomes expressed the highest direct and positive effect on yield among the thirteen varieties evolved. Therefore, greater emphasis should be given to these two characters for the improvement of turmeric by selection.

Subramanian (1986) recorded that the diameter of mother rhizome was the main determinant of the yield. According to Geetha and Prabhakaran (1987), path coefficient analysis indicated that height of the plant and length of secondary fingers were the major contributors towards rhizome yield. Direct effects of number of leaves per tiller and length and girth of mother rhizome were positive whereas, number of nodes per primary finger showed high negative direct effects on rhizome yield.

Nandi *et al.* (1992) reported that the greatest direct effect was exerted by girth of finger, followed by weight of finger. Indirect effects of high magnitude were also exerted by girth of finger in relation to most of the other components.

Path coefficient analysis projected the characters like weight of primary fingers (0.482), weight of secondary rhizomes (0.459) and weight of mother rhizomes (0.218) as the primary contributors of the yield (Shanmugasundaram, 1998).

Arunkumar (2003) documented that the primary rhizome diameter, number and weight of mother rhizomes and length of leaf were the major contributing characters towards yield due to high positive direct effects.

CHAPTER - III

MATERIALS AND METHODS

The present investigation on "Induction of mutagenesis in turmeric (*Curcuma longa* L.) through gamma rays for variability and quality improvement", was carried out during the year 2000 - 2003 in the Department of Spices and Plantation Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore. The materials utilized and the methods followed are reported hereunder.

3.1. Materials

3.1.1. Genotypes

Totally 224 genotypes of turmeric are being maintained in the germplasm of the Department of Spices and Plantation Crops. Out of the 224 genotypes available, three genotypes namely, Salem local (CL 144) which is a promising cultivar under Salem conditions with fresh rhizome yield and dry recovery, Alleppy finger turmeric (CL 146) with higher curcumin content and high dry recovery and PTS 43 (CL147) with higher curcumin content, high fresh rhizome yield and dry recovery were chosen for the experiment.

Genotypes	Notation
Salem local (CL144)	G_1
Alleppy finger turmeric (CL146)	G_2
PTS 43 (CL147)	G_3

3.1.2. Mutagen

Physical mutagen (gamma ray) was employed in the present investigation. The gamma ray treatments were given in the gamma chamber installed at the orchard of

Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore. Gamma ray source was cobalt - 60 in 1000 Ci, emitting 5000 rads per minute at the time of irradiation.

3.1.3. Mutagen treatment

Based on the earlier studies conducted at the Department of Spices and Plantation crops using, Salem local (CL 144), Alleppy finger turmeric (CL 146) and PTS 43 (CL 147) to identify the optimum dosage of treatment, 2.5 kR was fixed as the LD_{50} value (the dosage which resulted in a 50 per cent survival rate). Dosages higher (3.0, 3.5 and 4.0 kR) and lower (1.0, 1.5 and 2.0 kR) were chosen for the irradiation purpose.

Treatments	Notation
1.0 kR	T_1
1.5 kR	T_2
2.0 kR	T_3
2.5 kR	T_4
3.0 kR	T_5
3.5 kR	T_6
4.0 kR	T_7
Control	T_8

3.1.4. Planting material

Uniform sized finger rhizomes were selected and cut into pieces having 3 nodes per cutting (approximately 10g). These rhizome bits subjected to gamma irradiation were used as planting material for the present investigation.

3.2. Methods

3.2.1. Design of the experiment

The experiment was laid out in Factorial Randomized Block Design with two replications.

3.2.2. Season

The investigation was carried out during May 2001 (vM_o generation) and May 2002 (vM_1 generation).

3.2.3. Land preparation

The land was prepared to a fine tilth. At the time of last ploughing, 10 tonnes of FYM was incorporated. Ridges and furrows were formed at 45 cm spacing.

3.2.4. Planting

Rhizome bits having 3 nodes which were subjected to gamma irradiation 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 of 25 kg of N, 60 kg of P and 18 kg of K/ha was applied. A top dressing of 25 kg N and 18 kg K/ha at 30, 60, 90 and 120 days after planting was also applied.

3.2.5. Irrigation

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 the weather and soil conditions.

3.2.6. Weeding

Depending upon the weed growth, the plots were weeded at weekly intervals manually.

3.3. vM_o – Generation

3.3.1. Sprouting per cent

The number of sprouts emerged after 45 days of planting was counted in each plot and the mean was expressed as per cent and for analysis these mean values were transformed by arc sine transformation method (Panse and Sukhatme, 1985).

3.3.2. Biometric observations

Ten plants in each genotype per replication were tagged randomly for recording the observations on vegetative and rhizome characters, and the mean values were subjected to statistical scrutiny. The following observations were recorded.

3.3.2.1. Height of the plant

The height of the plant was measured at 45 days interval from 90 days after planting, till maturity from the collar region of the pseudostem to the tip of the fully opened top most leaf and the mean was expressed as centimetre per plant.

3.3.2.2 Number of leaves per plant

Fully opened leaves from third leaf till maturity were counted and the mean was expressed as number per plant.

3.3.2.3. Length of the leaf

The length of the fully opened third leaf was measured from the base of the lamina to the tip using a metre scale and the mean was expressed as centimetre.

3.3.2.4. Breadth of the leaf

The breadth of the fully opened third leaf was measured at the broadest point on the lamina using a metre scale and the mean was expressed as centimetre.

3.3.2.5. Area of the leaf

Area of the leaf was determined by multiplying the length and breadth of the leaf with leaf area constant K = 0.72 (Vijayalatha, 2002) and expressed as square centimetre.

Area of the leaf (cm^2) = length of the leaf x breadth of the leaf x 0.72

3.3.2.6. Number of tillers per plant

The tillers arising from base of the pseudostem were counted at 45 days interval starting from 90 days after planting till 225 days and the mean was expressed as number per plant.

3.3.2.7. 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 the indications of maturity.

3.3.3. Yield and its components

3.3.3.1. Number of mother rhizomes

The number of mother rhizomes per plant was recorded in ten randomly selected plants and the mean was expressed as number per plant.

3.3.3.2. Weight of mother rhizomes

The mother rhizomes per plant of ten randomly selected plants were pooled, weighed and the mean was expressed as gramme (g) per plant.

3.3.3.3. Length of mother rhizomes

The length was measured in ten randomly selected mother rhizomes using a metre scale and non-stretchable string and the mean was expressed as centimetre per rhizome.

3.3.3.4. Girth of mother rhizomes

The girth at the broadest point was measured using a non-stretchable string and metre scale in ten randomly selected mother rhizomes and the mean was expressed as centimetre.

3.3.3.5. Number of primary rhizomes

The primary rhizomes arising from the mother rhizomes in ten randomly selected clumps were counted and the mean was expressed as number per clump.

3.3.3.6. Weight of primary rhizomes

The primary rhizomes arising from the mother rhizome in ten randomly selected clumps were weighed and the mean was expressed as gramme (g) per clump.

3.3.3.7. Length of primary rhizomes

The length was measured in ten randomly selected primary rhizomes using a metre scale and non-stretchable string and the mean was expressed as centimetre per rhizome.

3.3.3.8. Girth of primary rhizomes

The girth was measured in ten randomly selected primary rhizomes using non-stretchable string and a metre scale and the mean was expressed as centimetre per rhizome.

3.3.3.9. Rhizome to core diameter ratio

The rhizome diameter and internal core diameter of primary rhizomes were measured using string and a metre scale, by making a cross section and the ratio was computed.

Rhizome to core diameter ratio = Rhizome diameter / Core diameter

3.3.3.10. Number of secondary rhizomes

The secondary rhizomes arising from the primary rhizomes in ten randomly selected clumps were counted and the mean was expressed as number per clump.

3.3.3.11. Weight of secondary rhizomes

The secondary rhizomes arising from the primary rhizomes in ten randomly selected clumps were weighed and the mean was expressed as gramme (g) per plant.

3.3.3.12. Length of secondary rhizomes

The length of secondary rhizome was measured in ten randomly selected rhizomes using a metre scale and the mean was expressed as centimetre.

3.3.3.13. Girth of secondary rhizomes

The girth of secondary rhizome was measured in ten randomly selected secondary rhizomes using a non-stretchable string and a metre scale and the mean was expressed as centimetre.

3.3.3.14. Yield per plant

The fresh rhizomes harvested from each plant were weighed and the mean was expressed as gramme (g) per plant .

3.3.3.15. Curing per cent

One hundred grammes of fresh rhizomes from each treatment plot (comprising 30 per cent mother rhizomes and 70 per cent primary and secondary rhizomes) were boiled in pure water for 45-60 minutes till the rhizomes became soft and emitted a typical turmeric odour (Natarajan and Lewis, 1980). After boiling, the rhizomes were dried under sun to attain eight per cent moisture content (Philip and Sethumadhavan, 1980). Curing

per cent of the rhizomes was calculated by using the following formula and expressed in per cent.

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

3.3.4. Biochemical attributes

3.3.4.1. Curcumin content

The curcumin content was estimated as per the method of ASTA, 1968 proposed by Manjunath *et al*. (1991). Turmeric powder @ 0.1g was refluxed with 30 ml of 95 per cent ethanol for 2½ hours. The extract was cooled and filtered quantitatively into a 100ml volumetric flask. The residue was then transferred to the filter, washed throughly and volume was made upto 100 ml with 95 per cent ethanol. Twenty ml of this filtered extract was pipetted out into a 250 ml volumetric flask and volume was made up using 95 per cent ethanol. The extract and standard solution (25mg of standard curcumin obtained from E. Merck. (India) Limited, Chennai) was taken in a 100 ml volumetric flask which was dissolved in 95 per cent ethanol after adding small quantity of acetone (since curcumin is miscible with acetone) and the volume was made up with the same. Again one ml of this solution was transferred into 100 ml volumetric flask and volume made up with 95 per cent ethanol. This standard solution (containing 0.0025 gramme (g) per litre) was read at 425 nm against alcohol blank in spectrophotometer and curcumin content was computed as detailed below and expressed in per cent.

$$\text{Absorptivity of curcumin (a)} = \frac{\text{Absorbance of standard solution at 425 m}\mu}{\text{Cell length (cm) x Concentration (g /1)}}$$

$$\text{Curcumin (per cent)} = \frac{\text{Absorbance of extract at 425 m}\mu \text{ x 125}}{\text{Cell length (cm) x a x Sample weight (g)}}$$

$$= \frac{\text{OD value} \times 125 \times 0.0025}{0.42 \times 0.1 \times 1}$$

3.3.4.2. Oleoresin content

Ten grammes of sieved turmeric powder was loaded in glass columns blocked with non-absorbant cotton. Acetone (30ml) was allowed to percolate down into the glass column and kept in contact overnight. Soluble extracts were then drained off into a pre weighed 100 ml beaker. Again 100 ml of acetone was used to wash the residue and all the extracts were pooled which was then evaporated to near dryness in a water bath and the final weight recorded. The oleoresin content was calculated using the following formula and expressed in per cent (AOAC, 1975).

$$\text{Oleoresin content (\%) (Air dry)} = \frac{W_2 - W_1}{10} \times 100$$

Where,

W_1 = Weight of empty beaker

W_2 = Weight of beaker with air dried oleoresin

3.3.4.3 Essential oil content

The essential oil content was estimated as per the methods suggested by ASTA, 1968. Thirty grammes of turmeric powder was transferred into the flask with a few glass beads to avoid frothing. The flask was then fitted to an essential oil extraction apparatus (Clevenger's apparatus). The distillation was made on a thermostatically controlled heating mantle. A temperature of 90^0 C was maintained till boiling and subsequently at 70^0C for 3 hours during the distillation.

The distillate was cooled down to room temperature and allowed to settle till the oil layer was clear. The volume was measured and the oil content was calculated as

$$\text{Volatile oil (\%) (v/w)} = \frac{\text{Volume of oil (ml)}}{\text{Weight of sample (g)}} \times 100$$

3.4. vM_1 Generation

The rhizomes harvested from the plants of vM_o generation were used as planting material to raise vM_1 generation. In vM_1 generation also the following observations were recorded as done in vM_o generation.

3.4.1. Biometric observations

3.4.1.1 Sprouting per cent

3.4.1.2. Height of the plant (cm)

3.4.1.3 Number of leaves per plant

3.4.1.4 Length of the leaf (cm)

3.4.1.5 Breadth of the leaf (cm)

3.4.1.6. Area of the leaf (cm^2)

3.4.1.7 Number of tillers per plant

3.4.1.8 Days to maturity

3.4.2 Yield and its components

3.4.2.1. Number of mother rhizomes

3.4.2.2. Weight of mother rhizomes (g)

3.4.2.3 Length of mother rhizomes (cm)

3.4.2.4. Girth of mother rhizomes (cm)

3.4.2.5. Number of primary rhizomes

3.4.2.6. Weight of primary rhizomes (g)

3.4.2.7. Length of primary rhizomes (cm)

3.4.2.8. Girth of primary rhizomes (cm)

3.4.2.9. Rhizome to core diameter ratio

3.4.2.10 Number of secondary rhizomes

3.4.2.11 Weight of secondary rhizomes (cm)

3.4.2.12 Length of secondary rhizomes (cm)

3.4.2.13 Girth of secondary rhizomes (cm)

3.4.2.14 Yield per plant (g)

3.4.2.15 Curing per cent

3.4.3 Biochemical attributes

3.4.3.1. Curcumin content (%)

3.4.3.2. Oleoresin content (%)

3.4.3.3. Essential oil content (%)

3.5. Isolation of mutants

The treated populations in vM_1 generation were screened for deviant phenotype from control for increased or decreased height of the plant, higher or lower number of tillers per plant, early or late maturity, higher or lower yield per plant and high or low curcumin and oleoresin content.

3.5.1. Chlorophyll mutants

The plants with variegated leaves in vM_o and vM_1 populations were recorded. The frequency of occurrence of chlorophyll mutants was calculated for each mutagenic treatment in the vM_1 generation. The cholorophyll mutants were classified according to the system proposed by Gustafsson (1938).

3.5.2. Viable mutants

The viable mutants in vM_1 plants were periodically observed from sprouting to crop maturity and viable mutations were scored as deviation from normal plants, labelled and harvested separately. The viable macromutations isolated in vM_1 were classified as tall mutants, dwarf mutants, tiller mutants and early maturing mutants.

3.5.3. Economic mutants

The economic mutants were scored as deviation from normal plants, labelled and harvested separately. The economic mutants isolated in vM_1 were classified as high yield mutants, mutants with high curcumin content and mutants with high oleoresin content.

3.5.4. Mutagenic effectiveness and efficiency

The effectiveness and efficiency of the mutagen in inducing chlorophyll and viable mutations were estimated adopting the formulae suggested by Konzak (1957) and expressed in per cent.

$$\text{Mutagenic effectiveness (per cent)} = \frac{M \times 100}{\text{Krad}}$$

$$\text{Mutagenic efficiency per cent} = \text{i)} \frac{M \times 100}{L} \quad \text{ii)} \frac{M \times 100}{I}$$

Where,

M = Chlorophyll or viable mutations per 100 vM_1 plants

L = Percentage of lethality (i.e)., percentage reduction in survial of seedlings

I = Percentage of injury

3.6. Statistical analysis

3.6.1. Variability analysis

a. Unit analysis

The statistical parameters such as mean, variance, standard deviation, coefficient of variation and standard error were calculated for each genotype. The following formulae were utilized for the calculations as suggested by Panse and Sukhatme (1985).

$$\text{General mean} = \frac{\text{Grand total}}{N}$$

Where,

N = number of observations

$$\text{Variance} = \frac{SS - CF}{df}$$

Where,

SS - sum of squares of all observations of a variable

$$CF = \frac{(\text{grand total})^2}{N}$$

df = Degrees of freedom

Standard deviation (SD) = √Variance

$$\text{Standard error (SE)} = \frac{SD}{\sqrt{N}} \times 100$$

$$\text{Coefficient of variation (CV)} = \frac{SD}{\text{Mean}} \times 100$$

b. Analysis of variance

The replicated values of different quantitative characters in vM_o and vM_1 were subjected to statistical analysis of variance as prescribed by Panse and Sukhatme (1985). In the case of sprouting, curing, curcumin, oleoresin and essential oil content, the percentage values were transformed into arc sine values and analysed statistically.

i) Phenotypic and genotypic variances

The phenotypic and genotypic variances were computed as per the methods suggested by Johnson *et al*. (1955).

Phenotypic variance = $(\sigma^2 p) = (\sigma^2 g) + (\sigma^2 e)$

Where,

$(\sigma^2 e)$ = environmental variance

$$\text{Genotypic variance } (\sigma^2 g) = \frac{M_1 - M_2}{r}$$

Where,

M_1 = mean sum of squares for genotypes

M_2 = mean sum of squares for error

r = Number of replications

Environmental variance $(\sigma^2 e) = \Sigma (X ij - Xi - Xj + X)$

Where,

Xij = Mean sum of treatments and replications

Xi = Mean of treatments

Xj = Mean of replications

X = Grand mean

ii) Phenotypic Coefficient of Variation (PCV) and Genotypic Coefficient of Variation (GCV)

The phenotypic and genotypic coefficients of variation were worked out as per the methods suggested by Burton (1952).

$$\text{Phenotypic coefficient of variation} = \frac{(\sigma^2 p)}{\text{Mean}} \times 100$$

$$\text{Genotypic coefficient of variation} = \frac{(\sigma^2 g)}{\text{Mean}} \times 100$$

$$\text{Environmental coefficient of variation} = \frac{(\sigma^2 e)}{\text{Mean}} \times 100$$

Where,

$\sigma^2 p$ and $\sigma^2 g$ are phenotypic and genotypic variances respectively.

iii) Heritability and genetic advance as per cent of mean

Heritability in the broad sense (h^2) was derived based on the formula proposed by Allard (1970) and expressed in per cent.

$$\text{Heritability } (h^2) = \frac{(\sigma^2 g)}{(\sigma^2 p)} \times 100$$

Where,

$(\sigma^2 g)$ = Genotypic variance; $(\sigma^2 p)$ = Phenotypic variance

Genetic advance was estimated by the following formula as per the methods of Johnson *et al*., (1955).

Genetic advance = $\sqrt{\sigma^2 p} \times h^2 \times k$

Where,

$\sigma^2 p$ = Phenotypic variance

h^2 = Heritability

k = selection differential constant, 2.06 at 5 per cent selection intensity (Falconer, 1967).

Classification of genetic parameters proposed by Philomina (2000) was followed

Genetic Parameter	Low	Moderate	High
GCV and PCV	0 to 20 %	21 to 30 %	above 30%
Heritability	0 to 30 %	31 to 60 %	above 60%
Genetic advance as per cent of mean	0 to 10 %	11 to 20 %	above 20%

iv) Correlation coefficients

Phenotypic and genotypic correlation coefficients were worked out using the following formulae as outlined by Johnson *et al*. (1955).

Phenotypic correlation coefficient

$$rph\ 1.2 = \frac{Cov.p.1\&2}{\sqrt{}^{2}p^{1} \times {}^{2}p^{2}}$$

Where,

rph 1.2 = Phenotypic correlation coefficient

cov.p.1&2 = Phenotypic covariance between the traits 1&2

$^{2}p^{1}$ and $^{2}p^{2}$ = Phenotypic variance of the traits 1 & 2 respectively.

Genotypic correlation coefficient

$$rgh\ 1.2 = \frac{Cov.g.1\&2}{\sqrt{}^{2}g^{1} \times {}^{2}g^{2}}$$

Where,

rgh 1.2 = Genotypic correlation coefficient

Cov.g.1& 2 = Genotypic covariance between the traits 1&2

$^{2}g^{1}$ and $^{2}g^{2}$ = Genotypic variance of the traits 1 &2 respectively.

The significance of these correlation coefficients was tested by referring to the table given by Panse and Sukhatme (1985)

c. Path coefficient analysis

The estimated genotypic correlation coefficients were partitioned into direct and indirect effects for all characters to rhizome yield as per the procedure given by Wright (1921) and later adopted by Dewey and Lu (1959).

Lenka and Mishra (1973) suggested the following scales for the categorization of direct and indirect effects.

Scale	**Category**
0.00 to 0.09	Negligible
0.10 to 0.19	Low
0.20 to 0.29	Medium
0.30 to 0.99	High
$\geq$ 1.00	Very high

CHAPTER - IV

EXPERIMENTAL RESULTS

A study on the "Induction of mutagenesis in turmeric (*Curcuma longa* L.) through gamma rays for variability and quality improvement" was carried out during the year 2000-2003. Observations on biometric characters, yield and its components and biochemical attributes were made during vM_o and vM_1 generations. The results obtained are presented in this chapter.

4.1. Mean performance of biometric characters in vMo generation

The effect of gamma rays on the biometric parameters such as sprouting per cent, height of the plant, number of leaves per plant, length of the leaf, breadth of the leaf, area of the leaf and number of tillers per plant at 90, 135, 180 and 225 days after planting and days to maturity were recorded and are presented.

4.1.1. Sprouting per cent (Table 1; Fig. 1)

The rhizomes were irradiated with gamma rays and the doses ranged between 1.00 and 4.00 kR. There were significant differences in the sprouting per cent among the various treatments. However, the genotypes did not exhibit significant variations for the sprouting per cent. There was proportionate reduction in the sprouting per cent with increase in the dose of gamma rays.

Among the different treatments of the genotype G_1 (CL144), the highest sprouting per cent (88.24) was obtained in the treatment T_3 (2.0 kR) followed by T_4 (2.5 kR) and T_5 (3.0 kR) with 75.42 and 74.56 per cent respectively. The lowest sprouting per cent (58.40) was exhibited in T_7 (4.0 kR) whereas the control (T_0) recorded 91.36 per cent. In the genotype G_2 (CL146), treatment T_3 (2.0 kR) registered hundred per cent sprouting followed by T_4 (2.5 kR) with 83.71 per cent. The least per cent (61.79) was registered in

T_7 (4.0 kR), whereas the control (T_0) showed 69.10 per cent. Similarly in G_3 (CL147), maximum sprouting per cent (100.00) was expressed in T_3 (2.0 kR) and the lowest (57.50 per cent) was obtained in T_7 (4.0 kR) while the control (T_0) recorded 59.80 per cent.

The interaction effect of the treatments and the genotypes was also highly significant. Cent per cent sprouting was obtained in the treatment combinations G_3T_3 (CL147, 2.0 kR) and G_2T_3 (CL146, 2.0 kR). The least per cent of 57.05 was registered in the combination G_3T_7 (CL147, 4.0 kR) whereas the grand mean observed was 73.94 per cent (Table 1; Fig. 1)

The coefficient of variation for the sprouting per cent was found to be 6.50 per cent.

4.1.2. Height of the plant (Table 2; Fig. 2)

The effects of various doses of gamma rays on the height of the plant at different stages of plant growth were studied and the data indicated that there were significant variations between the treatments, genotypes and their interaction. The data exhibited a progressive reduction with an increase in the doses of gamma rays.

Among the different treatments of the genotypes G_1 (CL144), treatment T_3 (2.0 kR) increased height of the plant (54.11, 64.00, 73.08 and 87.14 cm), followed by T_4 (2.5 kR) with 54.00, 63.49, 72.15 and 86.34 cm at 90, 135, 180 and 225 DAP respectively. Decreased height of the plant (45.00, 50.05, 66.81 and 73.89 cm) at 90, 135, 180 and 225 DAP was obtained in T_7 (4.0 kR), whereas the control (T_0) recorded 47.88, 53.25, 67.72 and 78.27 cm at 90, 135, 180 and 225 DAP respectively. In G_2 (CL146), treatment T_3 (2.0 kR) showed greater height of the plant (50.99, 63.99, 72.11 and 88.19 cm) whereas lesser height of the plant (40.55, 48.00, 63.08 and 72.35 cm) at 90, 135, 180 and 225 DAP respectively was obtained in T_7 (4.0 kR) as against the control (T_0) which registered (45.33, 55.08, 67.03 and 80.77 cm) at 90, 135, 180 and 225 DAP respectively. Likewise in G_3 (CL147), the height of the plant was higher (52.19, 62.75, 71.14 and 89.00 cm) in

T_3 (2.0 kR) and lower (44.02, 48.33, 65.55 and 74.45 cm) in T_7 (4.0 kR) whereas the control (T_0) expressed (46.00, 51.33, 66.21 and 76.05 cm) at 90, 135, 180 and 225 DAP respectively. (Table 2; Fig. 2).

Among the three genotypes, G_1 (CL144) recorded greater height of the plant (54.11, 64.00 and 73.08 cm) at 90, 135 and 180 DAP respectively in T_3 (2.0 kR) while G_3 (CL147) registered increased height of the plant (89.00 cm) at 225 DAP in T_3 (2.0 kR). A lesser height of the plant (40.55, 48.00, 63.08 and 72.35 cm) at 90, 135, 180 and 225 DAP respectively was observed in G_2 (CL146) at T_7 (4.0 kR).

The highest height of the plant (89.00 cm) was registered in the treatment combination, G_3T_3 (CL147, 2.0 kR) at 225 DAP whereas the lowest height of the plant (72.35 cm) was obtained in G_2T_7 (CL146, 4.0 kR) at 225 DAP while the grand mean registered was 47.87, 56.21, 68.42 and 80.71 cm at 90, 135, 180 and 225 DAP respectively. The coefficient of variation for the height of the plant were (0.81, 1.07, 11.74 and 12.12 per cent) at 90, 135, 180 and 225 DAP respectively (Table 2; Fig. 2).

4.1.3. Number of leaves per plant (Table 3)

Number of leaves due to irradiation of gamma rays varied significantly. With increase in the doses of irradiation, proportionate reduction was observed in the production of number of leaves per plant. Significant difference for number of leaves was observed among the genotypes used and treatment combinations.

Among the different treatments of the genotype G_1 (CL144), treatment T_3 (2.0 kR) exhibited higher number of leaves (7.94, 11.02, 15.97 and 18.07) and treatment T_7 (4.0 kR) expressed lower number of leaves (2.00, 4.00, 4.33 and 10.99) whereas the control (T_0) showed 5.00, 6.27, 8.11 and 14.22 leaves at 90, 135, 180 and 225 DAP respectively. In G_2 (CL146), the highest number of leaves (8.02, 12.00, 16.00 and 18.34) was obtained

in T_3 (2.0 kR) and the lowest number of leaves (2.09, 3.75, 4.27 and 11.21) was recorded in T_7 (4.0 kR) while the control (T_0) registered (3.87, 4.00, 6.27 and 12.03 leaves) at 90, 135, 180 and 225 DAP respectively. Similarly in G_3 (CL147), treatment T_3 (2.0 kR) recorded higher number of leaves (8.11, 11.35, 16.24 and 17.92) and T_7 (4.0 kR) obtained lower number of leaves (2.34, 3.98, 4.95 and 10.84) whereas the number of leaves registered in the control (T_0) was (4.21, 5.00, 6.22 and 12.19) at 90, 135, 180 and 225 DAP respectively.

Among the three genotypes, G_3 (CL147) showed more number of leaves (8.11 and 16.24) at 90 and 180 DAP respectively in the treatment T_3 (2.0 kR) whereas G_2 (CL146) exhibited greater number of leaves at 135 and 225 DAP (12.00 and 18.34 respectively) at T_3 (2.0 kR). Lesser number of leaves (10.84) at 225 DAP was recorded in the genotype G_3 (CL147) at T_3 (2.0 kR). The control (T_o) of G_1 (CL144) registered higher number of leaves (14.22) at 225 DAP than the control of other genotypes. (Table 3).

Greater number of leaves was expressed in the treatment combination G_2T_3 (CL146, 2.0 kR) with 18.34 (225 DAP). A lesser number of leaves (10.84) was exhibited in the treatment combination G_3T_7 (CL147, 4.0 kR) whereas the grand mean registered were 5.58, 7.39, 9.76 and 14.81 at 90, 135, 180 and 225 DAP respectively. The co-efficient of variation for the number of leaves was found to be 7.93, 8.04, 8.00 and 7.49 per cent at 90, 135, 180 and 225 DAP respectively (Table 3).

4.1.4. Length of the leaf (Table 4)

The length of the leaf varied significantly with irradiation of gamma rays at 90, 135, 180 and 225 DAP. Significant variations were noticed between the treatments, genotypes and their interaction. The length of the leaf was found to decrease with an increase in the dose of gamma rays.

Among the different treatments of the genotype G_1 (CL144), treatment T_3 (2.0 kR) registered a higher length of the leaf (20.98, 37.08, 47.33 and 53.00 cm) and lower length of the leaf (14.00, 25.98, 38.99 and 46.94 cm) was obtained in T_7 (4.0 kR) whereas the control (T_o) exhibited (17.01, 29.94, 42.85 and 49.35 cm) at 90, 135, 180 and 225 DAP respectively. In G_2 (CL146), greater length of the leaf (21.24, 37.20, 47.18 and 53.22 cm) was observed in T_3 (2.0 kR) and lesser length of the leaf (15.84, 27.74, 39.00 and 48.88 cm) was obtained in T_7 (4.0 kR) while the length recorded in the control (T_o) was 16.88, 29.00, 40.91 and 49.69 cm at 90, 135, 180 and 225 DAP respectively. Similarly in G_3 (CL147), increased length of the leaf (20.21, 36.99, 47.09 and 51.25 cm) and decreased length of the leaf (14.19, 26.94, 40.00 and 47.35 cm) was registered in treatments T_3 (2.0 kR) and T_7 (4.0 kR) respectively while the length of the leaf recorded in the control (T_0) was 19.45, 35.52, 48.03 and 50.90 cm at 90, 135, 180 and 225 DAP respectively (Table 4).

Among the three genotypes, G_2 (CL146) showed greater length of the leaf (21.24, 37.20, 47.18 and 53.22 cm) at 90, 135, 180 and 225 DAP respectively at T_3 (2.0 kR). This was followed by genotype G_1 (CL144) with (20.98, 37.08, 47.33 and 53.00 cm) at 90, 135, 180 and 225 DAP respectively at T_3 (2.0 kR). The control (T_o) plants of G_3 (CL147) expressed higher length of the leaf (50.90 cm) at 225 DAP than the control of other genotypes.

The interaction of treatments and genotypes also exhibited significant difference for the length of the leaf. The treatment combination G_2T_3 (CL146, 2.0 kR) expressed the highest length of the leaf (21.24, 37.20, 47.18 and 53.22 cm) at 90, 135, 180 and 225 DAP respectively. The least length of the leaf (14.00 cm) at 90 DAP, (25.98 cm) at 135 DAP, (38.99 cm) at 180 DAP and (46.94 cm) at 225 DAP was recorded in G_1T_7 (CL144, 4.0 kR) while the grand mean was found to be 17.86, 32.02, 43.88 and 49.98 cm at 90,

135, 180 and 225 DAP respectively. The coefficient of variation obtained were 4.57, 4.44, 4.50 and 4.54 per cent at 90, 135, 180 and 225 DAP respectively (Table 4).

4.1.5. Breadth of the leaf (Table 5)

Application of gamma rays expressed significant variation in the breadth of the leaf with different treatments and genotypes at all stages of plant growth. Similar results were obtained in the interaction effect of the treatments and genotypes.

Among the different treatments of the genotype G_1 (CL144), treatment T_3 (2.0 kR) exhibited the highest breadth of the leaf (7.99, 12.00, 16.03 and 18.59 cm) and T_7 (4.0 kR) registered the lowest breadth of the leaf (5.01, 8.55, 12.94 and 14.00 cm) whereas the breadth of the leaf recorded in the control (T_0) was (6.52, 10.97, 14.12 and 16.59 cm) at 90, 135, 180 and 225 DAP respectively. In G_2 (CL146), increased breadth of the leaf (8.13, 12.59, 16.15 and 18.84 cm) was obtained in T_3 (2.0 kR) and decreased breadth of the leaf (4.95, 9.99, 13.03 and 15.15 cm) was observed in T_7 (4.0 kR) while the breadth of the leaf expressed in the control (T_o) was (5.76, 10.09, 14.78 and 16.73 cm) at 90, 135, 180 and 225 DAP respectively. In G_3 (CL147), greater breadth of the leaf (8.13, 12.21, 15.99 and 17.84 cm) and lesser breadth of the leaf (4.92, 8.55, 12.21 and 14.00 cm) was exhibited in T_3 (2.0 kR) and T_7 (4.0 kR) respectively, whereas the breadth of the leaf obtained in the control (T_0) was (7.16, 11.99, 15.24 and 17.04 cm) at 90, 135, 180 and 225 DAP respectively.

Among the three genotypes, G_2 (CL146) showed higher breadth of the leaf followed by G_1 (CL144) and G_3 (CL147). In G_2 (CL146), greater breadth of the leaf (8.13, 12.59, 16.15 and 18.84 cm) at 90, 135, 180 and 225 DAP respectively was found in the treatment T_3 (2.0 kR). Likewise T_3 (2.0 kR) of G_1 (CL144) and G_3 (CL147) registered the highest breadth of the leaf (18.59 and 17.84 cm respectively) at 225 DAP. In the case of the control (T_o), greater breadth of the leaf (7.16, 11.99, 15.24 and 17.04 cm) was

obtained in G_3 (CL147) at 90, 135, 180 and 225 DAP respectively than the control of other genotypes (Table 5).

Increased breadth of the leaf (8.13 cm) at 90 DAP, (12.59 cm) at 135 DAP, (16.15 cm) at 180 DAP and (18.84 cm) at 225 DAP was obtained in the treatment combination G_2T_3 (CL146, 2.0 kR). Decreased breadth of the leaf (4.92, 8.55, 12.21 and 14.00 cm) at 90, 135, 180 and 225 DAP respectively was observed in treatment combination, G_3T_7 (CL147, 4.0 kR) whereas the grand mean obtained was 6.62, 10.77, 14.59 and 16.76cm at 90, 135, 180 and 225 DAP respectively. The coefficient of variation recorded for the breadth of the leaf were (3.02, 3.03, 3.01 and 2.94 per cent respectively (Table 5).

4.1.6. Area of the leaf (Table 6)

Area of the leaf exhibited significant difference at all stages of plant growth for the application of gamma rays, genotypes and their interaction effect. With increase in the doses of gamma rays, proportionate reduction was observed in the area of the leaf.

Among the different treatments of the genotype G_1 (CL144), treatment T_3 (2.0 kR) registered the highest area of the leaf (120.69, 320.37, 546.26 and 709.39 cm^2) and the lowest area of the leaf (57.14, 159.93, 363.26 and 473.16 cm^2) was obtained in T_7 (4.0 kR) whereas the control (T_0) recorded (79.85, 236.48, 435.63 and 589.48 cm^2) at 90, 135, 180 and 225 DAP respectively. In G_2 (CL146), higher area of the leaf (122.34, 337.21, 568.61 and 718.35 cm^2) was recorded in T_3 (2.0 kR) and lower area of the leaf (49.90, 159.53, 365.88 and 533.18 cm^2) was expressed in T_7 (4.0 kR) while the area of the leaf registered in the control (T_0) was 69.88, 210.68, 435.35 and 598.55 cm^2 at 90, 135, 180 and 225 DAP respectively. In G_3 (CL147), treatments T_3 (2.0 kR) and T_7 (4.0 kR) exhibited increased area of the leaf (118.30, 325.19, 565.16 and 658.30 cm^2) and decreased area of the leaf (50.27, 190.67, 351.65 and 495.70 cm^2) respectively at 90, 135,

180 and 225 DAP' respectively while the area of the leaf obtained in the control (T_0) was 100.27, 306.64, 527.02 and 624.46 cm^2 at 90, 135, 180 and 225 DAP respectively.

Among the three genotypes, G_2 (CL146) showed an increase in the area of the leaf followed by G_1 (CL144) and G_3 (CL147). The highest area of the leaf (718.35 cm^2) at 225 DAP was observed at T_3 (2.0 kR) in the genotypes G_2 (CL146). Similarly, T_3 (2.0 kR) of G_1 (CL144) and G_3 (CL147) exhibited greater area of the leaf (709.39 and 658.30 cm^2) respectively at 225 DAP. Increased area of the leaf (624.48 cm^2) was obtained in the control (T_o) of G_3 (CL147) plants than the control of other genotypes (Table 6).

The treatment combination, G_2T_3 (CL146, 2.0 kR) showed greater area of the leaf (122.34, 337.21, 568.61 and 718.35 cm^2) at 90, 135, 180 and 225 DAP respectively and G_2T_7 (CL146, 4.0 kR) recorded lesser area of the leaf (49.90 cm^2) at 90 DAP and (159.53 cm^2) at 135 DAP, whereas G_3T_7 (CL147, 4.0 kR) registered reduced area of the leaf (351.65 cm^2) at 180 DAP and (495.70 cm^2) at 225 DAP. The grand mean recorded was (87.15, 252.20, 463.04 and 604.29 cm^2) at 90, 135, 180 and 225 DAP respectively.

The coefficient of variation obtained for the area of the leaf were 4.69, 4.58, 4.45 and 4.56 per cent at 90, 135, 180 and 225 DAP respectively (Table 6).

4.1.7. Number of tillers per plant (Table 7; Fig. 3)

Irradiation with gamma rays showed significant difference on number of tillers per plant at different growth stages. Similarly, the interaction effect of the genotypes and treatment documented significant effect on number of tillers per plant. However, the genotypes did not exhibit significant variation. There was drastic reduction in the number of tillers as the dose increased.

Among the different treatments of the genotype G_1 (CL144), treatment T_3 (2.0 kR) recorded the highest number of tillers (4.88), followed by T_4 (2.5 kR) with 4.67 tillers at 225 DAP respectively. The lowest number of tillers (2.23) was obtained in T_7 (4.0 kR) whereas the control (T_o) recorded 1.54, 1.85, 2.72 and 3.27 tillers at 90, 135, 180 and 225 DAP respectively. In G_2 (CL146), higher number of tillers (2.00, 2.94, 3.98 and 4.49) was observed in T_3 (2.0 kR) and lower number of tillers (1.23, 1.50, 2.10 and 2.36) was registered in T_7 (4.0 kR) while the control (T_0) showed 1.54, 1.88, 2.22 and 2.55 tillers at 90, 135, 180 and 225 DAP respectively. In G_3 (CL147), more number of tillers (2.11, 3.00, 3.99 and 4.51) was expressed in T_3 (2.0 kR) and less number of tillers (1.33, 1.73, 2.50 and 2.66) was found in T_7 (4.0 kR) whereas the control (T_0) obtained 1.70, 2.54, 2.81 and 3.62 tillers at 90, 135, 180 and 225 DAP respectively.

Treatment combination G_1T_3 (CL144, 2.0 kR) exhibited greater number of tillers (2.25) at 90 DAP, (3.01) at 135 DAP, (4.00) at 180 DAP and (4.88) at 225 DAP. The least was seen in G_1T_7 (CL144, 4.0 kR) with 1.00 tiller (225 DAP), whereas the grand mean recorded was 1.76, 2.36, 3.19 and 3.70 at 90, 135, 180 and 225 DAP respectively (Table 7; Fig. 3).

The coefficient of variation obtained for the number of tillers per plant were (12.15, 11.88, 12.34 and 12.17 per cent) at 90, 135, 180 and 225 DAP respectively (Table 7; Fig. 3).

4.1.8. Days to maturity (Table 8; Fig. 4)

Varied response for the days to maturity was noticed in respect of different doses of gamma rays. The three genotypes did not show significant difference for the days to maturity. However, the interaction effect of treatments and genotypes varied significantly.

Among the different treatments of the genotype G_1 (CL144), treatment T_3 (2.0 kR) exhibited earliness in the days to maturity (223.11) followed by T_4 (2.5 kR) with 230.92 days. Delayed maturity (282.02 days) was expressed in T_7 (4.0 kR) whereas the control (T_0) showed 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 the days to maturity (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) observed earliness in the days to maturity (221.83) and T_7 (4.0 kR) recorded delayed maturity (288.10 days) whereas the control (T_o) registered 246.13 days.

The treatment combination, G_2T_3 (CL146, 2.0 kR) exhibited earliness in the 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). The coefficient of variation for the days to maturity was found to be 5.92 per cent (Table 8; Fig.4).

4.2. Yield and its components

4.2.1. Number of mother rhizomes (Table 9)

Irradiation with gamma rays exerted significant effect on number of mother rhizomes. Similarly, the genotypes used and the interaction between treatments and genotypes also revealed significant variations.

Among the different treatments of the genotype G_1 (CL144), treatment T_3 (2.0 kR) followed by T_4 (2.5 kR) recorded higher number of mother rhizomes (2.17 and 2.00 respectively) whereas lower number of mother rhizomes (1.00) was observed in T_7 (4.0 kR) and the control (T_0). In G_2 (CL146), increased number of mother rhizomes (1.50) was registered in T_3 (2.0 kR) and decreased number of mother rhizomes (1.00) was obtained in T_1 (1.0 kR), T_6 (3.5 kR) and T_7 (4.0 kR) whereas the control (T_0) showed 1.10 rhizomes. Similarly in G_3 (CL147), treatment T_3 (2.0 kR) exhibited more number of

mother rhizomes (2.50) whereas less number of mother rhizomes (1.00) was found in T_1 (1.0 kR), T_2 (1.5 kR), T_6 (3.5 kR) and T_7 (4.0 kR). The number of mother rhizomes registered in the control (T_0) was1.10. (Table 9).

Among the genotypes, G_3 (CL147) registered higher number of mother rhizomes (2.50) at T_3 (2.0 kR) followed by G_1 (CL144) and G_2 (CL146) with 2.17 and 1.50 respectively at T_3 (2.0 kR) whereas the control (T_o) recorded 1.10 rhizomes.

Greater number of mother rhizomes (2.50) was observed in the treatment combination, G_3T_3 (CL147, 2.0 kR) followed by G_1T_4 (CL144, 2.5 kR) with 2.17 rhizomes whereas the grand mean observed was 1.26 rhizomes.

The coefficient of variation recorded for the number of mother rhizomes was 6.31 per cent (Table 9).

4.2.2. Weight of mother rhizomes (Table 9; Fig. 5)

Varied response for the weight of mother rhizomes was found in respect of various treatments, genotypes and their interaction

Among the different treatments of the genotype G_1 (CL144), treatment T_3 (2.0 kR) recorded an increased weight of the mother rhizomes (43.34g). This was followed by T_4 (2.5 kR) and T_5 (3.0 kR) with 35.63 g. Decreased weight (25. 63g) was obtained in T_7 (4.0 kR), whereas the weight of the mother rhizome observed in the control (T_0) was 27.70 g. In G_2 (CL146), treatment T_3 (2.0 kR) registered the highest weight of the mother rhizome (72.51 g) and the lowest weight (16.25g) was expressed in T_7 (4.0 kR), while the weight of the mother rhizome exhibited in the control (T_o) was 20.02 g. In G_3 (CL147), higher weight (58.75) was obtained in T_3 (2.0 kR) and lower weight (31.25g) was recorded in T_7 (4.0kR). The weight of the mother rhizome registered in the control (T_0) was 31.50 g.

The genotype, G_2 (CL146) showed heavier weight (72.51 g) at T_3 (2.0 kR) followed by G_3 (CL147) and G_1 (CL144) with 58.75 and 43.34 g respectively at T_3 (2.0 kR). Among the controls (To) of the three genotypes, more weight (31.50 g) was obtained in G_3 (CL147).

The highest weight of the mother rhizomes (72.51 g) was observed in the combination G_2T_3 (CL146, 2.0 kR) whereas the lowest weight (16.25 g) was seen in G_2T_7 (CL146, 4.0 kR). The grand mean observed was 34.69 g. The coefficient of variation observed for the weight of mother rhizomes was 4.68 per cent (Table 9; Fig. 5).

4.2.3. Length of mother rhizomes (Table 9)

Length of mother rhizomes was significant in the treatments and genotypes. However, the treatment combination did not exhibit significant variations for the length of mother rhizomes.

Among the different treatments of the genotype G_1 (CL144), treatments T_3 (2.0 kR) T_4 (2.5 kR) and T_5 (3.0 kR) exhibited greater length of the mother rhizome (7.55, 7.53 and 7.50 cm respectively). A lesser length of the mother rhizome (5.95 cm) was obtained in the treatment T_7 (4.0 kR) whereas the length observed in the control (T_0) was 6.00 cm. In G_2 (CL146), the highest length of mother rhizome (8.53 cm) was obtained in T_3 (2.0 kR) and the lowest length (4.30 cm) was recorded in T_7 (4.0 kR), while the control (T_0) expressed 4.99 cm. Similarly in G_3 (CL147), higher length of mother rhizome (8.05 cm) was observed in T_3 (2.0 kR) and lower length (5.05 cm) was expressed in T_7 (4.0 kR) whereas the control (T_0) exhibited 5.99 cm.

Among the three genotypes, G_2 (CL146) produced lengthier mother rhizomes (8.53 cm) at T_3 (2.0 kR) followed by G_3 (CL147) and G_1 (CL144) with (8.05 and 7.55 cm respectively) at T_3 (2.0 kR), whereas the grand mean recorded was 6.35 cm.

The coefficient of variation observed for the length of mother rhizomes was 12.75 per cent. (Table 9).

4.2.4. Girth of mother rhizomes (Table 9)

The girth of mother rhizomes varied significantly with the treatments. However, the girth did not vary significantly with the genotypes and their interaction effect. The girth of the mother rhizomes reduced with increasing dose of gamma rays.

Among the different treatments, T_3 (2.0 kR) of the genotype G_2 (CL146) expressed an increased girth of mother rhizomes (13.70 cm) followed by G_3 (CL147) with 12.43 cm at T_3 (2.0 kR). Decreased girth of mother rhizomes (6.93 cm) was exhibited in the treatment T_7 (4.0 kR) of the genotype G_2 (CL146). The girth of the mother rhizome observed in the control of G_1 (CL144), G_2 (CL146) and G_3 (CL147) were 8.75, 8.70 and 6.76 cm respectively.

The coefficient of variation exhibited by the girth of mother rhizome was 20.24 per cent (Table 9).

4.2.5. Number of primary rhizomes (Table 10; Fig. 6)

The different doses of gamma rays exhibited considerable variation for number of primary rhizomes. Significant variations were recorded among the three genotypes and treatment combinations. With increasing dose of gamma rays there was reduction in the number of primary rhizomes.

Among the treatments T_3 (2.0 kR) followed by T_4 (2.5 kR) and T_5 (3.0 kR) of the genotype G_1 (CL144) showed more number of primary rhizomes (12.25, 11.50 and 10.50 respectively). Less number of primary rhizomes (6.25) was observed in T_7 (4.0 kR) whereas the control (T_0) recorded 9.65 rhizomes. In G_2 (CL146), treatment T_3 (2.0 kR) expressed greater number of primary rhizomes (5.25) and T_7 (4.0 kR) exhibited lesser number of primary rhizomes (2.25) while the control (T_0) registered 4.65 rhizomes.

Similarly in G_3 (CL147), treatment T_3 (2.0 kR) obtained higher number of primary rhizomes (7.25) and treatment T_7 (4.0 kR) recorded lower number (4.50) whereas the number of primary rhizomes observed in the control (T_0) was 4.70.

Among the three genotypes, the highest number of primary rhizomes (12.25) was observed in G_1 (CL144) followed by G_3 (CL147) and G_2 (CL146) with 7.25 and 5.25 respectively at T_3 (2.0 kR). The lowest number of primary rhizomes (2.25) was recorded in G_2 (CL146) at T_7 (4.0 kR) (Table 10; Fig. 6).

Treatment combinations G_1T_3 (CL144, 2.0 kR) and G_1T_4 (CL144, 2.5 kR) produced more number of primary rhizomes (12.25 and 11.50 respectively) than the other combinations. The lowest number (2.25) was recorded in G_2T_7 (CL146, 4.0 kR).

The coefficient of variation recorded for the number of primary rhizomes was found to be 6.36 per cent (Table 10; Fig. 6).

4.2.6. Weight of primary rhizomes (Table 10)

A significant variation was exhibited for the weight of primary rhizomes with the application of different doses of gamma rays and between the treatment combinations. However, the genotypes did not show significant variation.

Among the different treatments of the genotype G_1 (CL144), treatment T_3 (2.0 kR) followed by T_4 (2.5 kR) increased the weight of the primary rhizomes (20.26 and 18.05 g respectively) and decreased weight (11.37g) was obtained in T_7 (4.0 kR) whereas the weight of primary rhizomes recorded in the control (T_0) was 12.63 g. In G_2 (CL146) treatment T_3 (2.0 kR) exhibited greater weight (27.34 g) and T_7 (4.0 kR) expressed lesser weight (6.94g) while the control (T_0) registered 12.64g. Likewise in G_3 (CL147), the highest weight (22.15g) and the lowest weight (12.14g) were observed in T_3 (2.0 kR) and T_7 (4.0 kR) respectively while the control (T_0) recorded 14.00 g.

Among the treatment combinations, G_2T_3 (CL146, 2.0 kR) showed higher weight (27.34 g) than the other combinations. A lesser weight (6.94 g) was recorded in G_2T_7 (CL146, 4.0 kR). The coefficient of variation exhibited by the weight of primary rhizomes was 4.69 per cent (Table 10).

4.2.7. Length of primary rhizomes (Table 10)

The length of primary rhizomes was also significantly influenced by the treatments, genotypes and their interaction.

Among the different treatments in the genotypes G_1 (CL144), treatment T_3 (2.0 kR) recorded higher length of primary rhizomes (7.55 cm) and lower length (5.95 cm) was obtained in T_7 (4.0 kR) whereas the control (T_0) registered 6.76 cm. In G_2 (CL146), the highest and the lowest length (6.24 and 4.56 cm) was observed in T_3 (2.0 kR) and T_7 (4.0 kR) respectively. The length of primary rhizome recorded in the control (T_0) was 5.05 cm. In G_3 (CL147), treatments T_3 (2.0 kR) and T_7 (4.0 kR) expressed increased and decreased length of the primary rhizomes (7.28 and 4.43 cm respectively) while the control (T_0) registered 5.61 cm.

The highest length of primary rhizome (7.55 cm) was observed in T_3 (2.0 kR) followed by T_4 (2.5 kR) with 7.32 cm, as against the the control (T_0) with 6.76 cm in the genotype G_1 (CL144). This was followed by G_3 (CL147) and G_2 (CL146) with 7.28 and 6.24 cm respectively at T_3 (2.0 kR).

Increased length of the primary rhizome (7.55 cm) was found in the treatment combination G_1T_3 (CL144, 2.0 kR) whereas decreased length (4.43 cm) was observed in G_3T_7 (CL147, 4.0 kR). The coefficient of variation observed for the length of primary rhizomes was 7.54 per cent (Table 10).

4.2.8. Girth of primary rhizomes (Table 10)

The effect of different doses of gamma rays on the girth of primary rhizomes was significant. However, the genotypes and treatment interaction did not show significant variations. There was proportionate reduction in the girth of primary rhizomes with the increase in the dose of gamma rays. Among the different treatments, higher girth of primary rhizomes (8.05, 7.98 and 7.50 cm) was recorded at T_3 (2.0 kR) in the genotypes G_3 (CL147), G_2 (CL146) and G_1 (CL144) respectively. A lower girth of the primary rhizomes (5.55 cm) was observed at T_7 (4.0 kR) of the genotypes G_3 (CL147). The control (T_0) of the genotypes G_1 (CL144), G_2 (CL146) and G_3 (CL147) registered 6.41, 6.44 and 6.66 cm respectively.

The coefficient of variation for the girth of primary rhizomes was found to be 9.22 per cent (Table 10).

4.2.9. Rhizome to core diameter ratio (Table 10)

Significant difference for the rhizome to core diameter ratio was observed among the treatments, genotypes and their interaction.

Among the treatments of the genotype G_1 (CL144), treatment T_3 (2.0 kR) registered higher rhizome to core diameter ratio (1.74). This was followed by T_4 (2.5 kR) and T_5 (3.0 kR) with 1.69 whereas the control (T_o) showed a ratio of 1.41. In G_2 (CL146), treatment T_3 (2.0 kR) exhibited the highest ratio (2.11) and T_7 (4.0 kR) expressed the lowest ratio (1.37) while the ratio obtained in the control (T_0) was 1.78. In G_3 (CL147), treatment T_3 (2.0 kR) followed by T_4 (2.5 kR) exhibited higher ratio (1.94 and 1.90 respectively) whereas the rhizome to core diameter ratio observed in the control (T_0) was 1.64. (Table 10).

Greater ratio of rhizome to core diameter (2.11) was recorded in G_2 (CL146) followed by G_3 (CL147) and G_1 (CL144) with 1.94 and 1.74 respectively at T_3 (2.0 kR). The grand mean obtained was 1.64.

Higher ratio (2.11) was found in the treatment combination G_2T_3 (CL146, 2.0 kR) whereas lower ratio (1.37) was obtained in G_2T_7 (CL146, 4.0 kR). The coefficient of variation obtained was 2.86 per cent (Table 10).

4.2.10. Number of secondary rhizomes (Table 11; Fig. 7)

Significant variation was exhibited for number of secondary rhizomes with application of gamma rays.

Among the different treatments of the genotype G_1 (CL144), treatment (2.0 kR) showed more number of secondary rhizomes (17.75) followed by T_4 (2.5 kR) and T_5 (3.0 kR) with 14.75, whereas the control (T_0) recorded 11.53 rhizomes. In G_2 (CL146), greater number of secondary rhizomes (8.25) was observed in T_3 (2.0 kR) and lesser number of secondary rhizomes (2.50) was obtained in T_7 (4.0 kR), while the control (T_o) registered 4.92 rhizomes. In G_3 (CL147), treatments T_3 (2.0 kR) followed by T_4 (2.5 kR) expressed the highest number of secondary rhizomes (11.75 and 11.50 respectively) whereas the control (T_0) obtained 9.67 rhizomes (Table 11; Fig. 7).

Among the three genotypes, higher number of secondary rhizomes (17.75) was recorded in G_1 (CL144) followed by G_3 (CL147) and G_2 (CL146) with 11.75 and 8.25 respectively at T_3 (2.0 kR). The grand mean for the number of secondary rhizomes was found to be 9.06.

Increased number of secondary rhizomes (17.75) was observed in treatment combination G_1T_3 (CL144, 2.0 kR) whereas decreased number (2.50) was recorded in

G_2T_7 (CL146, 4.0 kR). Number of secondary rhizomes registered a coefficient of variation of 6.40 per cent (Table 11; Fig.7).

4.2.11. Weight of secondary rhizomes (Table 11)

There were significant differences in the weight of secondary rhizomes among the treatments, genotypes and treatment combination. With increase in the dose of gamma rays there was reduction in the weight of secondary rhizomes.

Among the different treatments of the genotype G_1 (CL144), treatment T_3 (2.0 kR) increased the weight of secondary rhizomes (81.25g). Decreased weight of 28.00 g was obtained in T_7 (4.0 kR) whereas the control (T_0) recorded 46.09g. In G_2 (CL146), higher weight (52.50 g) was observed in T_3 (2.0 kR) and T_4 (2.5 kR) and lower weight (18.75 g) was expressed in T_7 (4.0 kR) while the control (T_0) registered 25.50 g. In G_3 (CL147), treatment T_3 (2.0 kR) exhibited greater weight (72.50g) and treatment T_7 (4.0 kR) showed lesser weight (30.00 g) whereas the weight of secondary rhizomes recorded in the control (T_0) was 50.00 g.

Among the three genotypes, G_1 (CL144) produced more weight (81.25g) followed by G_3 (CL147) and G_2 (CL146) with 72.50 and 52.50 g respectively at T_3 (2.0 kR). The grand mean observed was 46.78g (Table 11)

Increased weight of 81.25 g was obtained in treatment combination G_1T_3 (CL144, 2.0 kR) whereas reduced weight of 18.75 g was noticed in G_2T_7 (CL146, 4.0 kR). The coefficient of variation recorded for the weight of secondary rhizomes was 4.82 per cent (Table 11).

4.2.12. Length of secondary rhizomes (Table 11)

Variation due to the treatments and genotypes was significant for the length of secondary rhizome whereas the interaction effect did not produce significant difference. At higher doses the length of secondary rhizome was considerably reduced.

Among the different treatments of the genotype G_1 (CL144), treatment T_3 (2.0 kR) followed by T_4 (2.5 kR) produced higher length of secondary rhizome (4.30 and 4.25 cm respectively). A lower length of 3.13 cm was observed in T_7 (4.0 kR) whereas the control (T_0) recorded 3.55 cm. In G_2 (CL146), the highest length (4.70 cm) was expressed in T_3 (2.0 kR) and the lowest length (2.10 cm) was exhibited in T_7 (4.0 kR) while the control (T_0) registered 3.55 cm. In G_3 (CL147), treatments T_3 (2.0 kR) and T_4 (2.5 KR) observed greater length (4.30 cm) whereas the length of secondary rhizome obtained in the control (T_0) was 3.70 cm.

Among the three genotypes, G_2 (CL146) showed an increase in the length of secondary rhizome (4.70 cm) followed by G_1 (CL144) and G_3 (CL147) with 4.30 cm respectively at T_3 (2.0 kR). The grand mean obtained was 3.68cm. The coefficient of variation recorded for the length of secondary rhizomes was 12.89 per cent (Table 11).

4.2.13. Girth of secondary rhizome (Table 11)

The effect of treatments, genotypes and their interaction on the girth of secondary rhizomes was significant. With increase in the dose of gamma rays there was proportionate reduction in the girth of secondary rhizome.

Among the different treatments of G_1 (CL144), treatment T_3 (2.0 kR) recorded the highest girth of secondary rhizomes (5.98 cm) and the lowest girth (3.90 cm) was obtained in T_7 (4.0 kR) whereas the control (T_0) registered 4.00 cm. In G_2 (CL146), higher girth of 7.53 cm was expressed in T_3 (2.0 kR) and lower girth of 4.10 cm was observed in T_7 (4.0 kR) while the the control (T_0) exhibited 4.65 cm. Likewise in G_3 (CL147), greater girth (6.35 cm) was obtained in T_3 (2.0 kR) and lesser girth (5.43 cm)

was recorded in T_7 (4.0kR) while the girth of secondary rhizomes registered in the control (T_0) was 5.95 cm. (Table 11)

Increased girth (7.53 cm) was found in G_2 (CL146) followed by G_3 (CL147) and G_1 (CL144) with 6.35 and 5.98 cm respectively at T_3 (2.0 kR). The grand mean observed was 5.45 cm.

Treatment combination, G_2T_3 (CL146, 2.0 kR) recorded the highest girth (7.53 cm) whereas the lowest girth (3.90 cm) was observed in G_1T_7 (CL144, 4.0 kR). The coefficient of variation was found to be 2.99 per cent (Table 11).

4.2.14. Yield per plant (Table 12; Fig. 8)

The treatments, genotypes and their interaction exhibited significant variations in the yield per plant. There was reduction in the yield per plant with increase in the dose of gamma rays.

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 exhibited in T_7 (4.0 kR) while the yield per plant obtained in the control (T_0) was 135.00 g.(Table 12;Fig.8)

Genotype G_1 (CL144) exhibited more yield per plant (373.75 g) followed by G_2 (CL146) and G_3 (CL147) with 266.25 and 241.25 g respectively at T_3 (2.0 kR) whereas the grand mean observed was 206.33 g.

Increased yield (373.75 g) was noticed in 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). The coefficient of variation recorded for yield per plant was found to be 13.08 per cent (Table 12;Fig.8).

4.2.15. Curing per cent (Table 12)

The treatments and genotypes varied significantly for the curing per cent. However, the interaction effect did not produce significant variation. The curing per cent was found to reduce with the increase in the dose of gamma rays.

Among the different treatments of G_1 (CL144), T_3 (2.0 kR) followed by T_4 (2.5 kR) registered higher curing per cent (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 per cent. 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 the curing per cent 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 16.00 per cent.(Table 12)

Increased curing per cent (19.44) was obtained in G_1 (CL144) followed by G_2 (CL146) and G_3 (CL 147) with 19.00 and 18.21 per cent respectively at T_3 (2.0 kR), whereas the grand mean observed was 17.05 per cent. The coefficient of variation obtained for curing per cent was 4.04 (Table 12).

4.3. Biochemical attributes

4.3.1. Curcumin content (Table 13; Fig. 9)

Varied response for the curcumin content was noticed in respect of different doses of gamma rays. The curcumin content was found to reduce with increase in the dose of

gamma rays. The genotypes and the treatment combinations did not exhibit significant differences for the curcumin content.

Among the different treatments, T_3 (2.0 kR) of the genotype G_3 (CL147) showed higher curcumin content (5.92 per cent). This was followed by T_3 (2.0 kR) of G_2 (CL146) and G_1 (CL144) with 5.89 and 5.88 per cent respectively. Lower curcumin content of 3.48 per cent was obtained in T_7 (4.0 kR) of the genotype G_1 (CL144), whereas the control (T_o) of G_1 (CL144), G_2 (CL146) and G_3 (CL147) recorded 4.49, 4.50 and 4.52 per cent respectively. The coefficient of variation for the curcumin content was found to be 3.84 per cent.(Table 13;Fig.9)

4.3.2. Oleoresin content (Table 13; Fig. 10)

There was significant variation for the oleoresin content due to the treatments. However, the genotypes and the treatment combinations did not show significant difference for the oleoresin content. Among the different treatments, an increased oleoresin content (12.99 per cent) was observed in T_3 (2.0 kR) of the genotype G_3 (CL147). This was followed by T_3 (2.0 kR) and T_4 (2.5 kR) of G_2 (CL146) with 12.90 and 12.88 per cent respectively.

Decreased oleoresin content of 8.66 per cent was obtained in T_7 (4.0 kR) of the genotype G_3 (CL147) whereas the control (T_o) of G_1 (CL144), G_2 (CL146) and G_3 (CL147) registered oleoresin content of 11.08, 11.48 and 10.55 per cent respectively.(Table 13;Fig.10)

The coefficient of variation recorded for the oleoresin content was found to be 3.84 per cent.

4.3.3. Essential oil content (Table 13; Fig. 11)

Irradiation with gamma rays exhibited significant variation in the essential oil content among the treatments whereas the genotypes and the treatment combinations did not show significant differences for the essential oil content.

Among the treatments, T_3 (2.0 kR) of the genotype G_2 (CL146) produced higher essential oil content (6.06 per cent) followed by T_3 (2.0 kR) of the genotypes G_3 (CL147) and G_1 (CL144) with 6.01 and 5.98 per cent respectively. A lower essential oil content of 3.48 per cent was obtained in T_7 (4.0 kR) of the genotype, G_2 (CL146) whereas the control (T_o) of G_2 (CL146) recorded an essential oil content of 4.62 per cent.

The coefficient of variation recorded for the oleoresin content was found to be 3.84 per cent.(Table 13;Fig.11)

4.4. Mean performance of biometric characters in vM_1 generation

4.4.1. Sprouting per cent (Table 14; Fig. 1)

Highly significant difference was found among the different treatments. However, insignificant variation was observed among the genotypes used and the treatment combinations.

Among the treatments, the highest sprouting per cent (96.00) was observed in T_3 (2.0 kR) in the genotypes G_2 (CL146) and G_3 (CL147). The lowest sprouting per cent (58.22) was obtained in the genotype G_1 (CL144) at T_7 (4.0 kR) whereas the untreated the control (T_o) registered 70.00 per cent sprouting in G_1 (CL144) and G_2 (CL146). The coefficient of variation exhibited by the sprouting per cent was 7.39 per cent.(Table 14;Fig.1)

The coefficient of variation registered for the essential oil content was 2.97 per cent.

4.4.2. Height of the plant (Table 15; Fig. 2)

The height of the plant was enhanced significantly at 90, 135, 180 and 225 DAP and there was significant difference between the treatments and genotypes. However, the interaction effect of treatments and genotypes did not exhibit significant differences.

Among the different treatments of the genotype G_1 (CL144), treatment T_3 (2.0 kR) exhibited greater height of the plant (56.70, 67.20, 76.74 and 91.50 cm) and treatment T_7 (4.0 kR) showed lesser height of the plant (47.25, 52.55, 70.15 and 77.58 cm) whereas the control (T_0) recorded 50.27, 55.91 71.11 and 82.20 cm at 90, 135, 180 and 225 DAP respectively. In G_2 (CL146), increased height (56.82, 69.11, 77.88 and 95.25 cm) and decreased height of the plant (45.34, 52.92, 68.13 and 78.14 cm) were obtained in treatments T_3 (2.0 kR) and T_7 (4.0 kR) respectively while the control (T_0) registered (48.96, 59.49, 72.39 and 87.23 cm) at 90, 135, 180 and 225 DAP respectively. Similarly in G_3 (CL147), treatments T_3 (2.0 kR) expressed the highest height of the plant (53.76, 64.53, 73.27 and 91.67 cm) and T_7 (4.0 kR) obtained the lowest height of the plant (43.79, 49.78, 67.52 and 76.68 cm) whereas the control (T_0) registered (47.3, 52.87, 68.20 and 78.33 cm) at 90, 135, 180 and 225 DAP respectively.(Table 15;Fig.2)

Among the three genotypes, G_2 (CL146) exhibited an increase in the height of the plant (95.25 cm) at 225 DAP followed by G_3 (CL147) and G_1 (CL144) with 91.67 and 91.50 cm respectively (225 DAP) at T_3 (2.0 kR). The coefficient of variation was found to be 7.57, 7.69 9.21 and 10.28 per cent at 90, 135, 180 and 225 DAP respectively (Table 15;Fig.2).

4.4.3. Number of leaves per plant (Table 16)

The effect of various doses of gamma rays on the number of leaves at different stages of plant growth improved significantly. Likewise, the genotypes and the treatment combinations exhibited significant variation. The data indicated a progressive reduction in the number of leaves with increase in the doses of gamma rays.

Among the different treatments of the genotype G_1 (CL144),treatment T_3 (2.0 kR) showed more number of leaves per plant (8.00, 11.22, 15.10 and 17.35) at 90, 135, 180 and 225 DAP respectively. Less number of leaves (2.23, 4.25, 5.00 and 10.55) at 90,135, 180 and 225 DAP respectively was obtained in T_7 (4.0 kR) whereas the control (T_0) recorded (5.11, 7.00, 9.01 and 13.75) at 90, 135, 180 and 225 DAP respectively. In G_2 (CL146), greater number of leaves (8.92, 11.57, 16.02 and 18. 25) was observed at T_3 (2.0kR) and lesser number of leaves (3.21, 4.81, 5.22 and 12.00) was obtained in T_7 (4.0 kR) at 90, 135, 180 and 225 DAP respectively while the control (T_0) registered 4.51, 5.32, 7.81 and 12.99 at 90, 135, 180 and 225 DAP respectively. Similarly in G_3 (CL147), treatment T_3 (2.0 KR) expressed higher number of leaves (7.98, 10.97, 15.89 and 18.23) and treatment T_7 (4.0kR) exhibited lower number of leaves (3.55, 5.11, 5.11 and 10.95) at 90, 135, 180 and 225 DAP respectively while the control (T_0) recorded (4.66, 6.25, 8.00 and 13.28) at 90, 135, 180 and 225 DAP respectively.(Table 16)

Among the three genotypes, G_2 (CL146) was found to produce more number of leaves at 90, 135, 180 and 225 DAP. This was followed by genotypes G_3 (CL147) and G_1 (CL144).In G_2 (CL146) number of leaves was the highest (18.25) in T_3 (2.0 kR) at 225 DAP. Similarly in G_3 (CL147) and G_1 (CL144), the treatment T_3 (2.0 kR) increased the number of leaves (18.23 and 17.35 respectively) at 225 DAP whereas number of leaves observed in the control (T_0) at 225 DAP was 13.75 in G_1 (CL144) (Table 16).

Treatment combination, G_2T_3 (CL146, 2.0 kR) produced the highest number of leaves (8.92, 11.57, 16.02 and 18.25) at 90, 135, 180 and 225 DAP respectively. The lowest number of leaves (2.23, 4.25, 5.00 and 10.55) at 90, 135, 180 and 225 DAP respectively was obtained in the combination G_1T_7 (CL144, 4.0 kR). The coefficient of variation recorded for the number of leaves was 7.96, 7.80, 7.85 and 7.66 per cent at 90, 135, 180 and 225 DAP respectively (Table 16).

4.4.4. Length of the leaf (Table 17)

Length of the leaf was significant among the treatments, genotypes and their interaction. The length of the leaf was found to decrease with an increase in the dose of gamma rays.

Among the different treatments of G_1 (CL144), treatment T_3 (2.0 kR) recorded greater length of the leaf (21.00, 37.21, 49.67 and 54.22 cm) and T_7 (4.0 kR) registered lesser length (14.73, 24.49, 38.00 and 45.57 cm) at 90, 135, 180 and 225 DAP respectively whereas the control (T_0) expressed (18.21, 30.41, 43.11 and 48.81 cm) at 90, 135, 180 and 225 DAP respectively. In G_2 (CL146),treatments T_3 (2.0 kR) and T_7 (4.0 kR) obtained higher and lower lengths (20.75, 36.77, 47.00 and 51.97 cm) and (13.21, 24.45, 38.00 and 43.07 cm) at 90, 135, 180 and 225 DAP respectively while the control (T_0) registered (15.33, 28.33, 40.00 and 47.00 cm) at 90, 135, 180 and 225 DAP respectively. Likewise, in G_3 (CL147) increased length of the leaf (22.15, 38.11, 50.12 and 57. 34 cm) and decreased length of the leaf (13.25, 25.49, 39.81 and 45.21 cm) was found in T_3 (2.0 kR) and T_7 (4.0 kR) respectively while the control (T_0) recorded (19.22, 36.05, 49.00 and 53.82cm) at 90, 135, 180 and 225 DAP respectively (Table 17).

Lengthier leaf, 57.34 cm at 225 DAP was observed in G_3 (CL147) at T_3 (2.0 kR) followed by G_1 (CL144) and G_2 (CL146) with 54.22 and 51.97 cm (225 DAP respectively) at T_3 (2.0 kR). However, the control (T_o) plants of G_3 (CL147) registered 53.82 cm at 225 DAP.

The highest length of the leaf (22.15, 38.11, 50.12 and 57.34 cm) at 90, 135, 180 and 225 DAP respectively was found in treatment combination, G_3T_3 (CL147, 2.0 kR). The lowest length of the leaf 13.21, 24.45, 38.00 and 43.07 cm) at 90, 135, 180 and 225 DAP respectively was recorded in G_2T_7 (CL146, 4.0 kR). The coefficient of variation was

found to be 4.46, 4.53, 4.55 and 4.41 per cent at 90, 135, 180 and 225 DAP respectively (Table 17).

4.4.5. Breadth of the leaf (Table 18)

Irradiation with gamma rays exhibited significant variations in the breadth of leaf among the treatments, genotypes and their interaction.

Among the different treatments of the genotype G_1 (CL144), treatment T_3 (2.0 kR), exhibited greater breadth of the leaf (8.02, 12.59, 15.97 and 17.35 cm) and T_7 (4.0 kR) showed lesser breadth of the leaf (4.54, 9.52, 12.35 and 14.59 cm) whereas the control (T_0) registered (6.23, 11.08, 13.99 and 15.99 cm) at 90, 135, 180 and 225 DAP respectively. In G_2 (CL146), the highest breadth of the leaf (7.24, 12.00, 16.00 and 18.00 cm) was obtained in T_3 (2.0 kR) and the lowest breadth of the leaf (4.89, 9.72, 13.21 and 15.73 cm) was observed in T_7 (4.0 kR) while the control (T_0) recorded (5.95, 10.63, 14.52 and 16.67 cm) at 90, 135, 180 and 225 DAP respectively. Likewise in G_3 (CL147), increased breadth (8.51, 13.11, 16.27 and 18.72 cm) was found in T_3 (2.0 kR) and decreased breadth (5.00, 9.87, 12.88 and 15.28 cm) was registered in T_7 (4.0 kR) while the control (T_0) obtained (7.25, 12.05, 15.86 and 17.86 cm) at 90, 135, 180 and 225DAP respectively.(Table 18)

Among the three genotypes, G_3 (CL147) expressed higher breadth of the leaf (18.72 cm) at 225 DAP in the treatment T_3 (2.0 kR) followed by G_2 (CL146) and G_1 (CL144) with 18.00 and 17.35 cm respectively at T_3 (2.0 kR) whereas in the case of the control (T_o) the breadth of the leaf observed was 17.86 cm in G_3 (CL147) at 225 DAP.(Table 18)

Increased breadth of the leaf (8.51, 13.11, 16.27 and 18.72cm) at 90, 135, 180 and 225 DAP respectively was obtained in the treatment combination G_3T_3 (CL147, 2.0 kR). Decreased breadth of the leaf (4.54, 9.52, 12.35 and 14.59 cm) at 90, 135, 180 and 225

DAP respectively was observed in treatment combination, G_1T_7 (CL144, 4.0 kR), whereas the grand mean was found to be 6.54, 11.24, 14.60 and 16.73cm at 90, 135, 180 and 225 DAP respectively.

The coefficient of variation observed was 3.04, 2.95, 3.01 and 2.94 per cent at 90, 135, 180 and 225 DAP respectively.

4.4.6. Area of the leaf (Table 19)

Application of gamma rays exerted significant differences among the treatments, genotypes and their interaction. With increase in the dose of gamma rays, proportionate reduction was observed in the area of the leaf.

Among the different treatments of G_1 (CL144), treatment T_3 (2.0 kR) registered increased area of the leaf (119.82, 345.46, 571.12 and 677.32 cm^2) and T_7 (4.0 kR) recorded decreased area of the leaf (43.31, 167.60, 337.90 and 452.44 cm^2) whereas the control (T_0) recorded (81.68, 242.60, 434.24 and 561.94 cm^2) at 90, 135, 180 and 225 DAP respectively. In G_2 (CL146), greater area of the leaf (115.46, 317.69, 541.44 and 673.53 cm^2) was observed in T_3 (2.0 kR) and lesser area of the leaf (46.51, 178.39, 368.37 and 515.88cm^2) was expressed in T_7(4.0kK) while the control (T_0) exhibited (65.67, 216.83, 446.98 and 564.11 cm^2) at 90, 135, 180 and 225 DAP respectively. Similarly in G_3 (CL147) higher area of the leaf (128.67, 351.23, 587.12 and 772.85 cm^2) was observed in T_3 (2.0 kR) and lower area of the leaf (53.03, 180.72, 369.98 and 495.07 cm^2) was documented in T_7 (4.0 kR) whereas the control (T_0) produced (100.33, 312.77, 559.12 and 572.85 cm^2) at 90, 135, 180 and 225 DAP respectively (Table 19).

The highest area of the leaf (772.85 cm^2) at 225 DAP was observed at T_3 (2.0 kR) in the genotype G_3 (CL147). Similarly, T_3 (2.0 kR) of G_1 (CL144) and G_2 (CL146) exhibited the highest area of the leaf (677.32 and 673.53 cm^2 respectively) at 225 DAP.

The treatment combination, G_3T_3 (CL147, 2.0 kR) produced greater area of the leaf (128.67, 351.23, 587.12 and 772.85 cm^2) at 90, 135, 180 and 225 DAP respectively, whereas G_1T_7 (CL144, 4.0 kR) recorded lesser area of the leaf (43.31, 167.60, 337.90 and 452.44 cm^2) at 90, 135, 180 and 225 DAP respectively (Table 19).

The coefficient of variation observed was 4.67, 4.63, 4.56 and 4.44 per cent at 90, 135, 180 and 225 DAP respectively.

4.4.7. Number of tillers per plant (Table 20; Fig. 3)

Number of tillers due to irradiation of gamma rays varied significantly. Similarly the genotypes and the treatment combinations also showed significant variation.

Among the different treatments of G_1 (CL144), greater number of tillers (2.11, 3.00, 3.89 and 5.00) was recorded in T_3 (2.0 kR) and lesser number of tillers (1.00, 1.97, 2.01 and 8.28) was observed in T_7 (4.0 kR) whereas the control (T_0) registered (1.37, 2.19, 2.55 and 4.39) at 90, 135, 180 and 225 DAP respectively. In G_2 (CL146), the highest number of tillers (2.10, 3.13, 4.07 and 4.98) was found in T_3 (2.0 kR) and the lowest number of tillers (1.13, 2.00, 2.97 and 3.52) was expressed in T_7 (4.0 kR) while the control (T_0) exhibited (1.30, 2.12, 3.00 and 3.55) at 90, 135, 180 and 225 DAP respectively. In G_3 (CL147), higher number of tillers (2.18, 3.17, 4.15 and 5.03) was obtained in T_3 (2.0 kR) and lower number was expressed in T_7 (4.0 kR) while the control (T_0) recorded (1.22, 2.77, 3.62 and 4.00) at 90, 135, 180 and 225 DAP respectively. (Table 20; Fig. 3).

Among the three genotypes, G_3 (CL147) registered the highest number of tillers followed by G_1 (CL144) and G_2 (CL146). In G_3 (CL147), treatment T_3 (2.0 kR) recorded more number of tillers (5.03) at 225 DAP. Similarly, in G_1 (CL144) and G_2 (CL146) greater number of tillers (5.00 and 4.98 respectively) was observed in T_3 (2.0 kR) at 225 DAP whereas the control (T_o) of G_1 (CL144) registered 4.39 tillers at 225 DAP.

Treatment combination, G_3T_3 (CL147, 2.0 kR) recorded more number of tillers (2.18, 3.17, 4.15 and 5.03) at 90, 135, 180 and 225 DAP respectively than other combinations whereas G_1T_7 (CL144, 4.0 kR), produced lesser number of tillers (1.00, 1.97, 2.01 and 3.28) at 90, 135, 180 and 225 DAP respectively. The coefficient of variation observed was 12.46, 11.87, 12.22 and 11.99 per cent at 90, 135, 180 and 225 DAP respectively (Table 20; Fig. 3).

4.4.8. Days to maturity (Table 21; Fig. 4)

Days to maturity varied significantly with the treatments and the treatment combinations. However, the three genotypes did not show significant difference for the days to maturity.

Among the different treatments, T_3 (2.0 kR) of the genotype G_1 (CL144) showed earliness in the 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. (Table 21; Fig. 4).

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). The coefficient of variation for the days to maturity was 4.51 per cent.

4.5. Yield and its components

4.5.1. Number of mother rhizomes (Table 22)

The different doses of gamma rays produced considerable variations in the number of mother rhizomes. Similarly, the interaction effect of treatments and genotypes showed significant differences.

Among the different treatments of G_1 (CL144), treatment T_3 (2.0 kR) produced higher number of mother rhizomes (2.00) and treatment T_7 (4.0 kR) and the control (T_0) recorded (1.00) rhizome. In G_2 (CL146), the number of mother rhizome expressed in T_3 (2.0 kR) was greater (2.00) than the other treatments whereas the control (T_0) registered 1.00 number of mother rhizome. In G_3 (CL147), the highest number of mother rhizomes (3.00) was exhibited in T_3 (2.0 kR) whereas treatments T_1 (1.0 kR), T_2 (1.5 kR), T_6 (3.5 kR) and T_7 (4.0 kR) produced 1.00 mother rhizome as against the control which recorded 1.15 mother rhizome. (Table 22).

Treatment combination, G_3T_3 (CL147, 2.0 kR) registered 3.00 mother rhizomes, followed by 2.50 in G_1T_4 (CL144, 2.5 kR). The coefficient of variation for the number of mother rhizomes was found to be 6.33 per cent (Table 22).

4.5.2. Weight of mother rhizomes (Table 22; Fig. 5)

Weight of mother rhizomes showed significant differences among the treatments, genotypes and treatment combinations.

Among the different treatments of G_1 (CL144), treatment T_3 (2.0 kR) expressed the highest weight of mother rhizomes (45.15 g) followed by T_4 (2.5 kR) and T_5 (3.0 kR) with 35.73 and 35.89 g respectively and the lowest weight (25.15 g) was exhibited in T_7 (4.0 kR) as against the control (T_0) which recorded 29.92g. In G_2 (CL146), increased weight (74.18 g) was obtained in T_3 (2.0 kR) and decreased weight (16.59 g) was observed in T_7 (4.0 kR) as against the control (T_o) with 22.23g.Likewise in G_3 (CL147), greater weight (60.00g) and lesser weight (31.72 g) of mother rhizomes was registered in T_3 (2.0 kR) and T_7 (4.0 kR) respectively as against the control (T_0) with 32.02 g.

Among the three genotypes, increased weight (74.18 g) was observed in G_2 (CL146) at T_3 (2.0 kR) followed by 60.00 and 45.15 g in G_3 (CL147) and G_1 (CL144) respectively at T_3 (2.0 kR). (Table 22; Fig. 5).

The treatment combination, G_2T_3 (CL146, 2.0 kR) recorded the highest weight (74.18 g) whereas the lowest (16.59 g) was obtained in the treatment combination G_2T_7 (CL146, 4.0 kR). The coefficient of variation was 4.77 per cent.

4.5.3. Length of mother rhizomes (Table 22)

Irradiation with gamma rays influenced the length of mother rhizome significantly. Similarly, variation was observed with genotypes and the treatment combinations.

Among the different treatments of G_1 (CL144), treatment T_3 (2.0 kR) registered an increased length of mother rhizome (7.83 cm) followed by T_4 (2.5 kR) and T_5 (3.0 kR) with 7.78 and 7.69 cm respectively and decreased length (5.69 cm) was observed in T_7 (4.0 kR) as against the control (T_0) which expressed 5.99 cm. In G_2 (CL146), the highest length of mother rhizome (8.78 cm) and the lowest length of mother rhizome (4.62 cm) was obtained in T_3 (2.0 kR) and T_7 (4.0 kR) respectively as against the control (T_0) with 5.00 cm. Similarly in G_3 (CL147), higher length (8.00 cm) and lower length of mother rhizome (5.66 cm) was expressed in T_3 (2.0 kR) and T_7 (4.0 kR) respectively whereas the control (T_0) recorded 6.00 cm. (Table 22).

Among the three genotypes G_2 (CL146) produced an increase in the length of mother rhizome (8.78 cm) followed by G_3 (CL147) and G_1 (CL144) with 8.00 and 7.83 cm respectively at T_3 (2.0 kR). However, the length of the mother rhizome registered in the control (T_o) of G_3 (CL147) was (6.00 cm).

Greater length of mother rhizome (8.78 cm) was obtained in the treatment combination, G_2T_3 (CL146, 2.0 kR) whereas lesser length (4.62 cm) was observed in G_2T_7 (CL146, 4.0 kR). The coefficient of variation obtained was 6.11 per cent (Table 22).

4.5.4. Girth of mother rhizomes (Table 22)

Significant difference was observed among the treatments for the girth of mother rhizome. However, the genotypes and the treatment combination did not exhibit significant variation for the girth of mother rhizomes. The girth of mother rhizomes decreased with increase in the dose of gamma rays. Among the different treatments, T_3 (2.0 kR) of G_2 (CL146) recorded increased girth of mother rhizomes (13.81 cm) followed by T_3 (2.0 kR) of G_3 (CL147) with 12.81 cm. Decreased girth of mother rhizome (5.00 cm) was obtained in T_7 (4.0 kR) of G_3 (CL147) followed by T_7 (4.0 kR) of G_1 (CL144) with 6.00 cm whereas the control (T_0) of G_1 (CL144) registered 8.52 cm. The coefficient of variation expressed for the girth of mother rhizome was 19.21 per cent (Table 22).

4.5.5. Number of primary rhizomes (Table 23; Fig. 6)

There were significant variations for the number of primary rhizomes due to the treatments, genotypes and their interactions.

Among the different treatments, higher number of primary rhizomes (12.50) was recorded in T_3 (2.0 kR) of G_1 (CL144). This was followed by T_4 (2.5 kR) and T_5 (3.0 kR) with 11.00 and 10.65 respectively. Lower number of 6.00 was obtained in T_7 (4.0 kR) whereas the control (T_o) registered 10.00 rhizomes. In G_2 (CL146), treatment T_3 (2.0 kR) exhibited greater number of primary rhizomes (5.55) whereas T_7 (4.0 kR) recorded lesser number of primary rhizomes (2.50) as against the control (T_0) with 4.55 rhizomes. In G_3 (CL147), increased number (7.00) and decreased number of primary rhizomes (4.33) was expressed in T_3 (2.0 kR) and T_7 (4.0 KR) respectively whereas the control (T_0) recorded 4.75. (Table 23; Fig. 6)

The genotype, G_1 (CL144) produced more number of primary rhizomes (12.50) than G_3 (CL147) and G_2 (CL146) with 7.00 and 5.55 respectively at T_3 (2.0 kR).

Treatment combination, G_1T_3 (CL144, 2.0 kR) registered the highest number of primary rhizomes (12.50), whereas the lowest number (2.50) was recorded in G_2T_7 (CL146, 4.0 kR). The coefficient of variation recorded was 6.47 per cent. (Table 23; Fig. 6)

4.5.6. Weight of primary rhizomes (Table 23)

The different treatments, genotypes and their interactions exhibited significant differences for the weight of primary rhizomes.

Among the different treatments of G_1 (CL144), treatment T_3 (2.0 kR) registered higher weight of primary rhizomes (20.00g) and T_7 (4.0 kR) produced lower weight (11.22 g) as against the control (T_0) with 12.00g. In G_2 (CL146), the highest weight (27.00g) and the lowest weight (7.00g) was obtained in T_3 (2.0 kR) and T_7 (4.0 kR) respectively whereas the control (T_0) recorded 12.77 g. Similarly, in G_3 (CL147), greater weight (22.00 g) and lesser weight (12.02 g) was found in T_3 (2.0 kR) and T_7 (4.0 kR) respectively as against the control (T_0) with 14.00 g. (Table 23).

The genotype, G_2 (CL146) produced more weight (27.00 g) than G_3 (CL147) and G_1 (CL144) with 22.00 and 20.00 g respectively at T_3 (2.0 kR).

An increase in weight (27.00 g) was observed in treatment combination G_2T_3 (CL146, 2.0 kR) and decreased weight (7.00 g) was recorded in treatment combination G_2T_7 (CL146, 4.0 kR). The coefficient of variation observed was 4.63 per cent (Table 23).

4.5.7. Length of primary rhizomes (Table 23)

The treatments and genotypes exhibited significant differences for the length of primary rhizome. However, the interaction effect did not have significant variations for the length of primary rhizomes.

Among the different treatments of G_1 (CL144), treatment T_3 (2.0 kR) produced the highest length of primary rhizomes (7.59 cm) and T_7 (4.0 kR) recorded the lowest length (6.00cm) as against the control (T_0) with 6.50 cm. In G_2 (CL146), higher length (6.92 cm) and lower length (4.23 cm) was observed in T_3 (2.0 kR) and T_7 (4.0 kR) respectively, while the control (T_0) obtained 5.00 cm. In G_3 (CL147), increased length (7.59cm) and decreased length (3.15 cm) was expressed in T_3 (2.0 kR) and T_7 (4.0 kR) respectively as against the control (T_0) with 6.00 cm.

Among the three genotypes, G_1 (CL144) and G_3 (CL147) registered greater length of the primary rhizome (7.59 cm). Lesser length of 3.15 cm was expressed in T_7 (4.0 kR) of G_3 (CL147) whereas the the control (T_o) of G_2 (CL146) exhibited 6.50 cm. The coefficient of variation for the length of primary rhizomes was 15.74 per cent (Table 23).

4.5.8. Girth of primary rhizomes (Table 23)

The girth of primary rhizomes exhibited significant difference among the treatments. However, significant variation was not observed with the genotypes and the treatment combinations.

Among the different treatments, T_3 (2.0 kR) followed by T_4 (2.5 kR) of the genotype G_3 (CL147) produced the highest girth of primary rhizomes (8.00 and 7.95 cm respectively). The lowest girth of 5.09 cm was recorded in T_7 (4.0 kR) of G_3 (CL147), whereas the control (T_o) of G_3 (CL147) registered 6.55 cm. (Table 23).

The coefficient of variation expressed by the girth of primary rhizomes was 9.57 per cent.

4.5.9. Rhizome to core diameter ratio (Table 23)

Irradiation with gamma rays showed a significant effect on the rhizome to core diameter ratio. Similarly, the genotypes and the treatment combinations produced significant variation.

Among the different treatments of G_1 (CL144), treatment T_3 (2.0 kR) produced the highest ratio of rhizome to core diameter (1.94) and the lowest ratio (1.25) was expressed in T_7 (4.0 kR) as against the control (T_0) with 1.60. In G_2 (CL146), higher ratio (1.80) and lower ratio (1.21) were observed in T_3 (2.0 kR) and T_7 (4.0 kR) respectively whereas the control (T_0) obtained 1.61. Similarly, in G_3 (CL147) treatment T_3 (2.0 kR) produced an increased ratio of 1.56 and T_7 (4.0 kR) exhibited decreased ratio (1.19) as against the control (T_0) with 1.45. (Table 23)

Greater ratio of rhizome to core diameter (1.94) was observed in G_1 (CL144) followed by G_2 (CL146) and G_3 (CL147) with 1.80 and 1.56 respectively at T_3 (2.0 kR), whereas the control (T_o) of G_2 (CL146) recorded a ratio of 1.61.

A higher ratio (1.94) was found in treatment combination, G_1T_3 (CL144, 2.0 kR) whereas lower ratio (1.19) was obtained in treatment combination G_3T_7 (CL147, 4.0 kR). The coefficient of variation was 3.04 per cent. (Table 23).

4.5.10. Number of secondary rhizomes (Table 24; Fig. 7)

There were significant differences in the number of secondary rhizomes among the treatments, genotypes and treatment combinations. With an increase in the dose of gamma rays there was reduction in the number of secondary rhizomes.

Among the treatments of the genotype G_1 (CL144), treatment T_3 (2.0 kR) produced the highest number of secondary rhizomes (17.59) and T_7 (4.0 kR) obtained the lowest number (10.51) as against the control (T_0) with 11.82 rhizomes. In G_2 (CL146), increased number of secondary rhizomes (8.00) and decreased number of secondary rhizomes (3.21) were found in T_3 (2.0 kR) and T_7 (4.0 kR) respectively, whereas the control (T_0) obtained 5.00 rhizomes. In G_3 (CL147), greater number (11.50) and lesser number (6.00) were exhibited in T_3 (2.0 kR) and T_7 (4.0 kR) respectively as against the control (T_0) with 10.04 rhizomes. (Table 24; Fig. 7).

Among the three genotypes, G_1(CL144) produced more number of secondary rhizomes (17.59) than G_3 (CL147) and G_2 (CL146) with 11.50 and 8.00 respectively at T_3 (2.0 kR) whereas the control (T_o) of the genotype G_1 (CL144) obtained 11.82 rhizomes.

Among the treatment combinations, the highest number (17.59) was observed in G_1T_3 (CL144, 2.0 kR) and the lowest number (3.21) was found in G_2T_7 (CL146, 4.0 kR). The coefficient of variation for the number of secondary rhizomes was found to be 6.52 per cent (Table 24; Fig. 7).

4.5.11. Weight of secondary rhizomes (Table 24)

Varied response for the weight of secondary rhizomes were found in respect of the various treatments, genotypes and their interaction.

Among the different treatments of G_1 (CL144), treatment T_3 (2.0 kR) followed by T_4 (2.5 kR) and T_5 (3.0 kR) recorded an increased weight of the secondary rhizomes

(80.14, 74.52 and 73.00g respectively) whereas decreased weight of 30.19 g was observed in T_7 (4.0 kR) as against the control (T_0) which registered 45.66g. In G_2 (CL146), the highest weight (54.00g) and the lowest weight (18.00g) were obtained in T_3 (2.0 kR) and T_7 (4.0 kR) respectively as against the control (T_0) with 26.13 g. In G_3 (CL147), greater weight (71.43g) and lesser weight (40.00g) were recorded in T_3 (2.0 kR) and T_7 (4.0 kR) respectively whereas the control (T_0) expressed 52.00 g. (Table 24).

Among the three genotypes, G_1 (CL144) produced 80.14 g of secondary rhizomes followed by G_3 (CL147) with 71.43 g and G_2 (CL146) with 54.00 g at T_3 (2.0 kR), whereas the control (T_o) of G_3 (CL147) registered 52.00g.

Treatment combination, G_1T_3 (CL144, 2.0 kR) registered the highest weight (80.14 g) whereas G_2T_7 (CL146, 4.0 kR) expressed the lowest weight of secondary rhizome (18.00 g). The coefficient of variation observed was 4.81 per cent (Table 24).

4.5.12. Length of secondary rhizomes (Table 24)

The length of secondary rhizome varied significantly with the treatments, genotypes and their interaction effect.

Among the different treatments of G_1 (CL144), treatment T_3 (2.0 kR) expressed increased length of secondary rhizomes (4.52 cm) and T_7 (4.0 kR) exhibited decreased length of 3.22 cm as against the control (T_0) with 3.62 cm. In G_2 (CL146), greater length (4.66 cm) and lesser length (3.20 cm) were observed in T_3 (2.0 kR) and T_7 (4.0 kR) respectively whereas the control (T_0) recorded 3.53 cm. In G_3 (CL147), treatment T_3 (2.0 kR) expressed the highest length (4.50 cm) and T_7 (4.0 kR) observed the lowest length (3.50 cm) as against the control (T_0) with 3.80 cm. (Table 24).

Among the three genotypes, higher length (4.66 cm) was observed in G_2 (CL146) followed by G_1 (CL144) and G_3 (CL147) with 4.52 and 4.50 cm respectively at T_3 (2.0 kR), whereas the control (T_o) of G_3 (CL147) obtained 3.80 cm.

Greater length of secondary rhizome (4.66 cm) was registered in G_2T_3 (CL146, 2.0 kR) whereas lesser length (2.20 cm) was obtained in G_2T_7 (CL146, 4.0 kR). The coefficient of variation noticed for the length of secondary rhizomes was 7.62 per cent (Table 24).

4.5.13. Girth of secondary rhizomes (Table 24)

The girth of secondary rhizomes showed significant variation due to the treatments, genotypes and their interaction effect.

Among the three genotypes, G_2 (CL146) exhibited the highest girth (7.00 cm) followed by G_3 (CL147) with 6.59 cm and G_1 (CL144) with 5.89 cm at T_3 (2.0 kR) whereas the control (T_o) of G_3 (CL147) recorded 6.00 cm.

Among the treatment combinations, increased girth (7.00 cm) was obtained in G_2T_3 (CL146, 2.0 kR) and decreased girth (4.00 cm) was recorded in G_1T_7 (CL144, 4.0 kR) and G_2T_7 (CL146, 4.0 kR) which were on par. The coefficient of variation registered for the girth of secondary rhizomes was 3.00 per cent. (Table 24).

4.5.14. Yield per plant (Table 25; Fig 8)

The different treatments, genotypes and their interaction exhibited significant variations in the yield per plant. There was reduction in the yield per plant with an increase in the dose of gamma rays.

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

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) expressed 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. (Table 25; Fig. 8).

Among the three genotypes, G_1 (CL144) produced an increase in the yield (381.13 g) followed by G_2 (CL146) with 260.19 g and G_3 (CL147) with 250.12g at T_3 (2.0 kR) whereas the control (T_o) of G_1 (CL144) obtained 300.15g.

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). The coefficient of variation observed was 13.00 per cent (Table 25; Fig. 8)

4.5.15. Curing per cent (Table 25)

There was significant difference in the curing per cent among the treatments and genotypes. However, the treatment combinations did not exhibit significant variation for the curing per cent.

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). (Table 25).

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 19.57 and 18.39 per cent respectively at T_3 (2.0 kR), whereas the control of G_1 (CL144) registered 18.32 per cent.

The coefficient of variation for the curing per cent was found to be 4.04 per cent (Table 25).

4.6. Biochemical attributes

4.6.1. Curcumin content (Table 26; Fig 9)

There was significant difference in the curcumin content among the different treatments. The curcumin content decreased with increase in the gamma rays. However, the genotypes and treatment combinations did not exhibit significant differences for the curcumin content.

Among the different treatments, T_3 (2.0 kR) of the genotype G_1 (CL144) expressed higher curcumin content (6.06 per cent). This was followed by T_3 (2.0 kR) of G_2 (CL146) and G_3 (CL147) with 6.01 and 5.98 per cent respectively. A lower curcumin content of 3.48 per cent was exhibited in T_7 (4.0 kR) of G_1 (CL144), whereas the control of G_1 (CL144) obtained 3.48 per cent. The coefficient of variation for the curcumin content was 3.07 per cent. (Table 26; Fig.9).

4.6.2. Oleoresin content (Table 26; Fig. 10)

The different treatments exhibited significant variation for the oleoresin content. However, the genotypes and the treatment combination did not express significant differences for the oleoresin content. Among the treatments, higher oleoresin content (13.47 per cent) was observed in T_3 (2.0 kR) of G_1 (CL144). This was followed by T_3 (2.0 kR) of G_3 (CL147) and G_2 (CL146) with 13.38 and 13.16 per cent respectively, whereas the control (T_0) of G_2 (CL146) obtained 11.71 per cent.

A lower content of 8.92 per cent was expressed in T_7 (4.0 kR) of G_3 (CL147). The coefficient of variation for the oleoresin content was found to be 3.95 per cent. (Table 26; Fig. 10).

4.6.3. Essential oil content (Table 26; Fig 11)

Variation due to the different treatments was significant for the essential oil content. However, the genotypes and the treatment combination did not exhibit significant difference for the essential oil content.

Among the different treatments, T_3 (2.0 kR) of G_1 (CL144) expressed higher essential oil content (6.28 per cent). This was followed by T_3 (2.0 kR) of the genotypes G_3 (CL147) and G_2 (CL146) with 6.19 and 6.18 per cent respectively. A lower essential oil content of 3.55 per cent was recorded in T_7 (4.0 kR) of G_2 (CL146) whereas, the control (T_0) of G_2 (CL 146) registered 4.71 per cent. The coefficient of variation was found to be 3.00 per cent. (Table 26; Fig. 11).

4.7. Chlorophyll mutations

The frequency and spectrum of chlorophyll mutants were scored to assess the mutability due to the mutagens. The frequencies of chlorophyll mutations were estimated in vM_1 generation by individual plant basis.

4.7.1. Frequency of chlorophyll mutations (Table 27; Fig. 12)

In the genotype G_1 (CL144), the mutation frequency ranged between 0.40 and 1.20 per cent. A higher mutation frequency (1.20 per cent) was observed in T_3 (2.0 kR) and T_4 (2.5 kR).

In the genotype G_2 (CL146), the mutation frequency ranged between 0.40 and 1.20 per cent. Treatment T_4 (2.5 kR) recorded higher mutation frequency (1.20 per cent). (Table 27; Fig. 12).

In the genotype G_3 (CL147), the mutation frequency ranged between 0.40 and 0.80 per cent. Among the treatments employed for G_3 (CL 147) the mutation frequency was higher (0.80 per cent) in T_3 (2.0 kR) and T_4 (2.5 kR). (Table 27; Fig. 12).

4.7.2. Types of chlorophyll mutants (Table 28)

The spectrum of chlorophyll mutants showed four different types viz., xantha, albina, chlorina and deep green (AnnexureII). The spectrum varied with increasing dose of gamma rays. A high per centage of deep green (36.51) was recorded. This was followed by xantha (19.04 per cent) albina (6.35 per cent) and chlorina (3.34 per cent).

In the genotype G_3 (CL147), a higher per centage of deep green (57.14) was observed. This was followed by chlorina (14.29 per cent), xantha (7.14 per cent) and albina (7.14 per cent). In G_1 (CL144), greater per centage of chlorina (45.24) was obtained followed by xantha (38.09 per cent), deep green (11.90 per cent) and albina (4.76 per cent). Similarly, a higher per centage of deep green and chlorina with 40.48 per cent followed by xantha (11.90 per cent) and albina (7.14 per cent) was registered in G_2 (CL146). (Table 28).

4.7.3. Mutagenic effectiveness and efficiency (Table 29; Fig. 13)

The effectiveness of chlorophyll mutation ranged between 10.00 and 60.00 per cent. Among the three genotypes used, the effectiveness was more in G_1 (CL144) followed by G_2 (CL146) and G_3 (CL147). In G_3 (CL147), higher mutagenic effectiveness (40.00 per cent) was observed in T_3 (2.0 kR) and T_1 (1.0 kR) and lower mutagenic effectiveness (10.00 per cent) was seen in T_7 (4.0 kR). Similarly, in G_1 (CL144) greater mutagenic effectiveness (60.00 per cent) was obtained in T_3 (2.0 kR) whereas a lesser value (10.00 per cent) was recorded in T_7 (4.0 kR). In G_2 (CL146), effectiveness was higher (48.00 per cent) at T_4 (2.5 kR) while a lower value (10.00 per cent) was registered in T_7 (4.0 kR). (Table 29; Fig. 13).

The efficiency of mutagens in terms of lethality and injury varied among the treatments and genotypes. In G_3 (CL147), the efficiency in terms of lethality was higher (2.32 per cent) at T_3 (2.0 kR) followed by T_4 (2.5 kR) with (2.17 per cent) while it was lower (0.93 per cent) in T_6 (3.5 kR). Similarly, in G_1 (CL144), T_3 (2.0 kR) recorded greater efficiency (3.88 per cent). In G_2 (CL146), T_4 (2.5 kR) expressed increased efficiency (3.51 per cent).

The efficiency in terms of injury was higher (4.20 per cent) in T_3 (2.0 kR) in the genotype, G_3 (CL147) and lower (1.60 per cent) in T_7 (4.0 kR). Similarly, in G_1 (CL144)

more efficiency (7.73 per cent) and less efficiency (1.66 per cent) was observed in T_3 (2.0 kR) and T_7 (4.0 kR) respectively. In G_2 (CL146), increased efficiency (7.53 per cent) was recorded in T_4 (2.5 kR) and decreased efficiency (1.81 per cent) was obtained in T_7 (4.0 kR). (Table 29; Fig. 13).

4.8. Viable mutations

4.8.1. Frequency of viable mutations (Table 30; Fig 14)

The frequency of viable mutations ranged between 0.80 and 2.00 per cent in G_3 (CL147). A higher frequency (2.00 per cent) was observed in T_3 (2.0 kR) and T_4 (2.5 kR) and a lower frequency (0.80 per cent) was obtained in T_7 (4.0 kR). Similarly, in the genotype G_1 (CL144) frequency of viable mutation was greater (2.40 per cent) in T_3 (2.0 kR) and was smaller (0.80 per cent) in T_7 (4.0 kR). In G_2 (CL146), increased frequency (2.00 per cent) was registered in T_3 (2.0 kR) and T_4 (2.5 kR) and decreased frequency (0.80 per cent) was recorded in T_6 (3.5 kR). (Table 30; Fig. 14).

4.8.2. Spectrum of viable mutants (Table 31)

Different types of viable mutants for plant stature, tillers, maturity, yield, curcumin and oleoresin content were observed in vM_1 generation. Plant stature includes tall and dwarf mutants. Tall mutants of higher proportion (25.00 per cent) occurred in T_4 (2.5 kR) in the genotype G_3 (CL147), followed by T_3 (2.0 kR) with 20.84 per cent in the genotype G_1 (CL144). The proportion of dwarf mutants was higher (40.00 per cent) in T_1 (1.0 kR) in the genotype G_1 (CL144).

Tiller mutants comprised of mutants with more number of tillers and mutants producing less number of tillers. A higher proportion of mutants with more number of tillers (40.00 per cent) was observed in T_5 (3.0 kR) of G_1 (CL144) while the proportion of mutants with lesser number of tillers was the highest (50.00 per cent) in T_2 (1.5 kR) of G_1 (CL144). (Table 31).

On the basis of days to maturity, the viable mutants were categorised into early maturing and late maturing mutants. Greater proportion of early maturing mutants (29.16 per cent) was registered in T_4 (2.5 kR) of G_1 (CL144) whereas the proportion of mutants maturing late (50.00 per cent) was observed in T_7 (4.0 kR) of G_3 (CL147).

The viable mutants for yield were grouped into mutants with high and low yield. The proportion of mutants with high yield (20.83 per cent) was recorded in T_3 (2.0 kR) of G_1 (CL144) and T_3 (2.0 kR) and T_5 (3.0 kR) of G_2 (CL146). Similarly, a higher proportion of low yield mutants (50.00 per cent) was noticed in T_7 (4.0 kR) of G_3 (CL147) and T_2 (1.5 kR) of G_1 (CL144) (Table 31).

The viable mutants for curcumin content were classified into mutants with high and low curcumin content. A higher proportion (40.00 per cent) of mutants with high curcumin content was obtained in T_5 (3.0 kR) of G_1 (CL144). Similarly, a higher proportion (40.00 per cent) of mutants with low curcumin content was registered in T_6 (3.5 kR) of G_2 (CL146).

Mutants for oleoresin content were grouped into mutants with high and low oleoresin content. The occurrence of these two mutants was relatively low compared to the other mutants. Higher proportion of high oleoresin mutants (50.01 per cent) were seen in T_5 (3.0 kR) of G_2 (CL146) while greater proportion (26.67 per cent) of low oleoresin mutants was recorded in T_7 (4.0 kR) of G_1 (CL144) (Table 31).

4.9. Effect of gamma rays on genetic parameters

4.9.1. Effect of gamma rays on genetic parameters in vMo generation (Table 32)

The estimates of variability on the basis of PCV, GCV, heritability, and genetic advance as per cent of mean for twenty one traits in vMo generation are presented.

In general, the phenotypic coefficient of variation was more than the genotypic coefficient of variation. The phenotypic coefficient of variation ranged between 5.06 and

44.71 per cent and the genotypic coefficient of variation ranged between 3.28 and 38.33 per cent.

The yield per plant exhibited the highest phenotypic coefficient of variation (44.71 per cent) followed by number of primary rhizomes (44.48 per cent). Lower value for phenotypic coefficient of variation (5.06 per cent) was observed in curing per cent. (Table 32).

The highest genotypic coefficient of variation (38.33 per cent) was expressed in number of primary rhizomes followed by number of secondary rhizomes (37.77 per cent). The lowest value (3.28 per cent) was obtained in curing per cent followed by rhizome to core diameter ratio (3.86 per cent).

Heritability in broad sense was the highest (90.00 per cent) for essential oil content followed by curcumin content (83.00 per cent) and length of primary rhizomes (81.00 per cent). The lowest heritability was recorded by number of mother rhizomes (5.50 per cent) followed by number of tillers per plant (8.00 per cent).

Increased genetic advance as per cent of mean (68.04 per cent) was exhibited by number of primary rhizomes followed by number of secondary rhizomes (66.84 per cent) and yield per plant with 41.60 per cent. Decreased value (2.59 per cent) was obtained in rhizome to core diameter ratio followed by number of mother rhizomes (3.59).

4.9.1.1. Sprouting per cent

The PCV and GCV recorded in respect of sprouting per cent were low (12.43 and 10.61 per cent respectively). Heritability in broad sense was high (73.00 per cent) and genetic advance as per cent of mean was moderate (18.65 per cent) (Table 32).

4.9.1.2. Height of the plant

The height of the plant exhibited lower PCV and GCV of 10.83 and 8.84 per cent respectively. The heritability was high (67.00 per cent) whereas genetic advance as per cent of mean was moderate (10.83 per cent).

4.9.1.3. Number of tillers per plant

The genetic parameters for the number of tillers per plant *viz.*, GCV, heritability and genetic advance as per cent of mean were low (6.21, 8.00 and 3.64 per cent respectively) whereas PCV was moderate (21.83 per cent) (Table 32).

4.9.1.4. Days to maturity

The PCV and GCV recorded in respect of days to maturity were low (9.34 and 7.31 per cent respectively) whereas genetic advance as per cent of mean was moderate (11.78 per cent) and heritability in broad sense was high (61.00 per cent) (Table 32).

4.9.1.5. Number of mother rhizomes

High PCV of 31.99 per cent, low GCV of 7.47 per cent, low heritability of 5.00 per cent and low genetic advance as per cent of mean (3.59 per cent) were estimated for number of mother rhizomes.

4.9.1.6. Weight of mother rhizomes

The PCV recorded in respect of weight of mother rhizomes was high (37.56 per cent) whereas GCV was low (11.96 per cent). Heritability in broad sense and GA as per cent of mean were low (10.00 and 7.84 per cent respectively) (Table 32).

4.9.1.7. Girth of mother rhizomes

The girth of mother rhizomes, exhibited moderate PCV of 23.95 and low GCV of 13.92 per cent respectively whereas the heritability and genetic advance as per cent of mean were moderate (34.00 and 16.67 per cent respectively).

4.9.1.8. Number of primary rhizomes

The PCV and GCV recorded in respect of number of primary rhizomes were high (44.48 and 38.33 per cent respectively). Heritability in broad sense and genetic advance as per cent of mean were high (74.00 and 68.04 per cent respectively).

4.9.1.9. Weight of primary rhizomes

For the weight of primary rhizomes, the estimates of GCV and heritability were low (12.30 and 18.00 per cent respectively). On the contrary, the PCV and genetic advance as per cent of mean were moderate (28.74 and 10.84 per cent respectively).

4.9.1.10. Length of primary rhizomes

The PCV and GCV recorded for the length of primary rhizomes were low (15.20 and 16.89 per cent respectively) whereas heritability and GA as per cent of mean were high (81.00 and 28.17 per cent respectively) (Table 32).

4.9.1.11. Girth of primary rhizomes

For the girth of primary rhizomes, the estimates of PCV,GCV and GA as per cent of mean were low (10.68, 5.97 and 6.87 per cent respectively) whereas heritability in broadsense was moderate (31.00 per cent).

4.9.1.12. Rhizome to core diameter ratio

The rhizome to core diameter ratio exhibited low PCV and GCV (11.85 and 3.86 per cent respectively), and low heritability and genetic advance as per cent of mean (11.00 and 2.59 per cent respectively).

4.9.1.13. Number of secondary rhizomes

The number of secondary rhizomes recorded high PCV of 43.96 per cent, high GCV of 37.77 per cent, high heritability of 74.00 per cent and the genetic advance as per cent of mean was also high (66.84 per cent).

4.9.1.14. Weight of secondary rhizomes

For the weight of secondary rhizomes, the PCV was high (42.21 per cent), the GCV and heritability in broad sense were moderate (28.82 and 47.00 per cent respectively) whereas the GA as per cent of mean was high (40.55 per cent).

4.9.1.15. Length of secondary rhizomes

Low PCV of 15.99 per cent, GCV of 9.14 per cent and moderate heritability and genetic advance as per cent of mean of 33.00 and 10.77 per cent respectively were recorded for the length of secondary rhizomes.

4.9.1.16. Girth of secondary rhizomes

The estimates of phenotypic and genotypic coefficients of variation, heritability and GA as per cent of mean for the girth of secondary rhizomes were low (16.63, 7.67, 21.00 and 7.30 per cent respectively) (Table 32).

4.9.1.17. Curing per cent

The estimates of phenotypic and genotypic coefficients of variation, and GA as per cent of mean for curing per cent were low (5.06, 3.28 and 4.38 per cent respectively), whereas heritability was moderate (42.00 per cent).

4.9.1.18. Curcumin content

For the curcumin content, the PCV and GCV were low (8.03 and 8.83 per cent respectively), genetic advance as per cent of mean was moderate (15.04 per cent) and heritability was high (83.00 per cent).

4.9.1.19. Oleoresin content

For the oleoresin content, the estimates of PCV, GCV and genetic advance as per cent of mean were low (5.75, 6.87 and 9.91 per cent respectively) whereas heritability was high (70.00 per cent).

4.9.1.20. Essential oil content

The PCV and GCV recorded in respect of the essential oil content were low (8.94 and 9.41 per cent respectively). Heritability was high (90.00 per cent) and genetic advance as per cent of mean was moderate (17.49 per cent) (Table 32).

4.9.1.21. Yield per plant

The yield per plant exhibited high PCV, GCV and GA as per cent of mean (44.71, 30.05 and 41.60 per cent respectively). The heritability for yield per plant was moderate (45.00 per cent).

4.9.2. Effect of gamma rays on genetic parameters in vM_1 generation (Table 33)

The estimates of variability on the basis of PCV, GCV, heritability and genetic advance as per cent of mean for fifteen traits in vM_1 generation are presented. In general, phenotypic coefficient of variation was more than the genotypic coefficient of variation. The phenotypic coefficient of variation ranged between 5.38 and 42.74 per cent and genotypic coefficient of variation ranged between 3.73 and 33.16 per cent.

The number of primary rhizomes exhibited the highest phenotypic coefficient of variation (42.74 per cent) followed by 42.45 per cent in number of secondary rhizomes. The phenotypic coefficient of variation was the lowest (5.38 per cent) in curing per cent. The highest genotypic coefficient of variation (33.16 per cent) was observed in number of primary rhizomes followed by weight of secondary rhizomes with 31.61 per cent. The

lowest genotypic coefficient of variation (3.73 per cent) was registered in length of secondary rhizomes.

Heritability in broad sense ranged between 6.00 and 67.00 per cent. The highest heritability in broad sense (67.00 per cent) was recorded in height of the plant followed by number of primary rhizomes (60.00 per cent) whereas the lowest heritability (6.00 per cent) was observed in length of secondary rhizomes followed by girth of secondary rhizomes with 9.00 per cent. (Table 33).

Greater value of genetic advance as per cent of mean (53.00 per cent) was expressed in number of primary rhizomes whereas a lesser value (1.88 per cent) was exhibited in the length of secondary rhizomes.

4.9.2.1. Height of the plant

The PCV and GCV recorded in respect of height of the plant were low (8.92 and 10.89 per cent respectively). Genetic advance as per cent of mean was moderate (15.06 per cent) whereas heritability was high (67.00 per cent).

4.9.2.2. Number of tillers per plant

For the number of tillers per plant, the estimates of PCV and GCV were low (19.03, and 12.53 per cent respectively) whereas the heritability and genetic advance as per cent of mean were moderate (43.00 and 17.01 per cent respectively) (Table 33).

4.9.2.3. Number of mother rhizomes

The number of mother rhizomes exhibited high PCV (37.51 per cent), whereas the GCV, heritability and genetic advance as per cent of mean were low (11.71, 10.00 and 7.53 per cent respectively).

4.9.2.4. Weight of mother rhizomes

For the weight of mother rhizomes the estimates of PCV was high (37.98 per cent), GCV and heritability were low (14.28 and 14.00 per cent respectively) whereas the genetic advance as per cent of mean was moderate (11.06 per cent).

4.9.2.5. Number of primary rhizomes

The genetic parameters for the number of primary rhizomes *viz.*, PCV, GCV, heritability and genetic advance as per cent of mean were high (42.74, 33.16, 60.00 and 53.00 per cent respectively). (Table 33).

4.9.2.6. Weight of primary rhizomes

The weight of primary rhizomes exhibited moderate PCV (29.81 per cent) whereas the GCV, heritability and genetic advance as per cent of mean were low (10.98, 14.00 and 8.33 per cent respectively).

4.9.2.7. Length of primary rhizomes

The estimates of PCV and GCV were low (12.31 and 19.55 per cent respectively) while moderate heritability and GA as per cent of mean (40.00 and 15.98 per cent respectively) was exhibited for the length of primary rhizomes.

4.9.2.8. Girth of primary rhizomes

Low PCV of 11.94 per cent, GCV of 7.03 per cent and moderate heritability of 35.00 per cent and low genetic advance as per cent of mean of 8.53 per cent was recorded for girth of primary rhizomes (Table 33).

4.9.2.9. Number of secondary rhizomes

For the number of secondary rhizomes the PCV was high (42.45 per cent), GCV was moderate (30.43 per cent), and GA as per cent of mean was high (44.94 per cent) while the heritability in broad sense was moderate (51.00 per cent).

4.9.2.10. Weight of secondary rhizomes

For the weight of secondary rhizomes, PCV of 41.33 per cent, GCV of 31.61 per cent, and genetic advance as per cent of mean of 49.82 per cent was observed. The heritability in broad sense was moderate (59.00 per cent).

4.9.2.11. Length of secondary rhizomes

The genetic parameters for the length of secondary rhizomes *viz.*, PCV, GCV, heritability and genetic advance as per cent of mean were low (15.24, 3.73, 6.00 and 1.88 per cent respectively) (Table 33).

4.9.2.12. Girth of secondary rhizomes

The PCV and GCV recorded in respect of girth of secondary rhizomes were low (16.18 and 4.90 per cent respectively). Heritability in broad sense and genetic advance as per cent of mean were also low (9.00 and 3.05 per cent respectively).

4.9.2.13. Curing per cent

The PCV and GCV was found to be low (5.38 and 3.74 per cent respectively) and the heritability was moderate (0.48 per cent) whereas GA as per cent mean was low (5.36 per cent) for the curing per cent.

4.9.2.14. Oleoresin content

The PCV recorded in respect of oleoresin content was moderate (22.00 per cent). GCV, heritability in broad sense and GA as per cent of mean were low (7.56, 19.00 and 5.35 per cent respectively). (Table 33).

4.9.2.15. Yield per plant

The yield per plant exhibited high PCV (41.91 per cent), low GCV and heritability (18.86 and 20.00 per cent respectively) and moderate GA as per cent of mean (17.49 per cent).

4.10. Correlation studies in vMo generation (Table 34 to Table 36)

The phenotypic, genotypic and simple correlation coefficients estimated between yield and its component characters and inter correlations among the different yield components indicated that the genotypic correlation coefficients and simple correlation coefficients were higher than the phenotypic correlation coefficients. However, simple correlation coefficients were lesser than the genotypic correlation coefficients.

4.10.1. Simple correlation of biometric and biochemical characters on yield per plant in vMo generation (Table 34)

The yield per plant exhibited highly significant and positive correlation with number of tillers per plant (0.545**) and weight of secondary rhizomes (0.669**). It exerted positive and significant correlation through number of mother rhizomes (0.431*), number of primary rhizomes (0.526*), girth of primary rhizomes (0.425*) and number of secondary rhizomes (0.454*).

It expressed positive but non significant correlation with height of the plant (0.260), weight of mother rhizomes (0.268), weight of primary rhizomes (0.387), length of primary rhizomes (0.393) and length of secondary rhizomes (0.210).It exerted negative but non significant correlation with sprouting per cent (-0.333), rhizome to core diameter ratio (- 0.362) and curcumin content (-0.109).

4.10.1.1. Association of plant and rhizome *inter se* (Table 34)

Sprouting per cent

Sprouting per cent showed highly significant and positive correlation with curcumin content (0.737**), oleoresin content (0.803**) and essential oil content (0.783 **) and negative correlation with curing per cent (-0.636**). It exerted negative and significant correlation with weight of mother rhizomes (-0.522*) and negative non significant correlation with number tillers per plant (-0.301), girth of mother rhizomes (-0.210), weight of primary rhizomes (-0.387), length of primary rhizomes (-0.125), girth of primary rhizomes (-0.323), weight of secondary rhizomes (-0.244), length of secondary rhizomes (-0.248), girth of secondary rhizomes (-0.362), and yield per plant(-0.333) (Table 34).

It expressed positive but non significant correlation with days to maturity (0.103), rhizome to core diameter ratio (0.116) and number of secondary rhizomes (0.106).

Height of the plant

Height of the plant was found to have positive and highly significant correlation with number of tillers per plant (0.639^{**}) whereas it exhibited negative non significant correlation with rhizome to core diameter ratio (-0.262) and curing per cent (-0.172). It attributed positive non significant correlation with days to maturity (0.247), number of mother rhizomes (0.272), weight of mother rhizomes (0.325), girth of mother rhizomes (0.206), number of primary rhizomes (0.176), weight of primary rhizomes (0.249), girth of primary rhizomes (0.209), number of secondary rhizomes (0.220), weight of secondary rhizomes (0.422), girth of secondary rhizomes (0.236), oleoresin content (0.163), essential oil content (0.155) and yield per plant (0.260) (Table 34).

Number of tillers per plant

The number of tillers per plant showed highly significant and positive correlation with yield per plant (0.545**). It exhibited positive and significant correlation with number of mother rhizomes (0.457*), weight of mother rhizomes (0.472*), girth of

primary rhizomes (0.444*), weight of secondary rhizomes (0.535*) and length of secondary rhizomes (0.423*). It exerted negative and significant correlation with rhizome to core diameter ratio (-0.470*).

It expressed positive but non significant correlation with number of primary rhizomes (0.359), weight of primary rhizomes (0.397), length of primary rhizomes (0.203), number of secondary rhizomes (0.300) and girth of secondary rhizomes (0.313). It expressed negative but non significant correlation with curcumin content (-0.125).

Days to maturity

This trait exhibited positive but non significant correlation with number of secondary rhizomes (0.142), curcumin content (0.228), oleoresin content (0.266) and essential oil content (0.225). It showed negative non significant association with weight of mother rhizomes (-0.101), girth of mother rhizomes (-0.195), length of primary rhizomes (-0.229), rhizome to core diameter ratio (-0.110), length of secondary rhizomes (-0.137) and curing per cent (-0.221). (Table 34).

Number of mother rhizomes

This character exerted positive and highly significant correlation with number of primary rhizomes (0.576**) and weight of secondary rhizomes (0.611 **). It showed positive and significant correlation with number of secondary rhizomes (0.480*) and yield per plant (0.431*).

It registered positive and non significant correlation with length of primary rhizomes (0.252), girth of primary rhizomes (0.197), oleoresin content (0.154) and essential oil content (0.111). It exhibited negative and non significant correlation with girth of mother rhizomes (-0.222), rhizomes to core diameter ratio (-0.542), girth of secondary rhizomes (-0.262) and curing per cent (-0.115). (Table 34).

Weight of mother rhizomes

This trait was found to exhibit positive and highly significant correlation with weight of primary rhizomes (0.802**) and girth of secondary rhizomes (0.639**). This trait showed significant and positive correlation through girth of primary rhizomes (0.436*).

It expressed positive but non significant correlation with girth of mother rhizomes (0.305), weight of secondary rhizomes (0.449), length of secondary rhizomes (0.374), curing per cent (0.224) and yield per plant (0.268) and negative with rhizome to core diameter ratio (-0.271), curcumin content (-0.307), oleoresin content (-0.301) and essential oil content (-0.326).

Girth of mother rhizomes

This trait exerted highly significant and positive correlation with girth of primary rhizomes (0.716**) and girth of secondary rhizomes (0.652**). It recorded positive and significant correlation with weight of primary rhizomes (0.502*). (Table 34).

It registered positive but non significant correlation with length of primary rhizomes (0.370), length of secondary rhizomes (0.240) and curing per cent (0.190). It showed negative and non significant correlation with number of secondary rhizomes (-0.126), oleoresin content (-0.131) and essential oil content (-0.120). (Table 34).

Number of primary rhizomes

Number of primary rhizomes showed positive and highly significant correlation with length of primary rhizomes (0.685**), number of secondary rhizomes (0.913**) and weight of secondary rhizomes (0.674**). It showed positive and significant correlation with yield per plant (0.526*).

It attributed positive and non significant correlation with weight of primary rhizomes (0.131), girth of primary rhizomes (0.248) and length of secondary rhizomes (0.372). It showed negative and highly significant correlation with rhizome to core diameter ratio (-0.590**) and negative non significant correlation with curcumin content (-0.146).

Weight of primary rhizomes

This trait exhibited positive and highly significant correlation with girth of primary rhizomes (0.627**) and girth of secondary rhizomes (0.643**). It expressed positive and significant correlation with weight of secondary rhizomes (0.491*).

It showed positive and non significant correlation with length of primary rhizomes (0.250), length of secondary rhizomes (0.190), curing per cent (0.226) and yield per plant (0.387). The traits like rhizome to core diameter ratio (-0.220), curcumin content (-0.257), oleoresin content (-0.135) and essential oil content (-0.205) exhibited negative correlation. (Table 34).

Length of primary rhizomes

Length of primary rhizomes recorded highly significant and positive correlation with number of secondary rhizomes (0.642**) and exhibited positive significant correlation with girth of primary rhizomes (0.461*) and weight of secondary rhizomes (0.462*).

The characters like length of secondary rhizomes (0.417), curing per cent (0.321) and yield per plant (0.393) exerted positive but non significant correlation with length of primary rhizomes. The traits like rhizome to core diameter ratio (-0.113), curcumin content (-0.335), oleoresin content (-0.220) and essential oil content (-0.243) exhibited negative and non significant correlation.

Girth of primary rhizomes

The girth of primary rhizomes exerted positive and highly significant correlation with girth of secondary rhizomes (0.640**) and showed positive and significant correlation with weight of secondary rhizomes (0.427*) and yield per plant (0.425*).

The characters such as number of secondary rhizomes (0.229) and curing per cent (0.113) recorded positive and non significant correlation while rhizome to core diameter ratio (-0.113) and curcumin content (-0.117) exhibited non significant negative association. (Table 34).

Rhizome to core diameter ratio

This trait registered positive and non significant correlation with curcumin content (0.220), whereas the traits such as number of secondary rhizomes (-0.502*) and weight of secondary rhizomes (-0.469*) exhibited significant and negative correlation. It showed non significant and negative correlation with length of secondary rhizomes (-0.375), girth of secondary rhizomes (-0.161) and yield per plant (-0.362) (Table 34).

Number of secondary rhizomes

The number of secondary rhizomes attributed positive and highly significant correlation with weight of secondary rhizomes (0.741 **) and positive and significant correlation with length of secondary rhizomes (0.450*) and yield per plant (0.454*).

The traits like oleoresin content (0.150) and essential oil content (0.149) showed positive and non significant correlation whereas curing present (-0.130) expressed negative and non significant correlation.

Weight of secondary rhizomes

Weight of secondary rhizomes was positively correlated and highly significant with yield per plant (0.669**). The traits such as length of secondary rhizomes (0.332) and girth of secondary rhizomes (0.191) showed positive and non significant correlation whereas curcumin content (-0.107) expressed negative non significant correlation. (Table 34).

Length of secondary rhizomes

The length of secondary rhizomes showed positive and significant correlation with girth of secondary rhizomes (0.474*). The yield per plant (0.210) registered positive and non significant correlation whereas the traits like curcumin content (-0.109) and oleoresin content (-0.224) was negatively correlated with no significance.

Girth of secondary rhizomes

Girth of secondary rhizomes exhibited negative and non significant correlation with curcumin content (-0.131) and oleoresin content (-0.157). (Table 34).

Curing per cent

The curing per cent expressed highly significant and negative correlation with curcumin content (-0.872**), oleoresin content (-0.810**) and essential oil content (-0.924**).

Curcumin content

The curcumin content recorded highly significant and positive correlation with oleoresin content (0.906**) and essential oil content (0.939**). However, it expressed negative and non significant correlation with yield per plant (-0.109). (Table 34).

Oleoresin content

The oleoresin content registered highly significant and positive correlation with essential oil content (0.954**) while non significant positive association was observed with yield per plant (0.007). (Table 34).

Essential oil content

The essential oil content showed negative and non significant correlation with yield per plant (-0.048).

4.10.2. Phenotypic correlation of biometric and biochemical characters on yield per plant in vM_o generation (Table 35)

The phenotypic correlation coefficients of biometric and biochemical characters on yield per plant were lower than the genotypic correlation coefficients (Table 35).

4.10.3. Genotypic correlation of biometric and biochemical characters on yield per plant in vM_o generation (Table 36)

Weight of mother rhizomes (0.584**), number of primary rhizomes (0.556**), length of primary rhizomes (0.550**), girth of primary rhizomes (0.716**) and number of secondary rhizomes (0.566**) expressed highly significant and positive association with yield per plant. Highly significant and negative correlation was observed through sprouting per cent (-0.557**) and rhizome to core diameter ratio (-0.886**).

Positive non significant association was accomplished with height of the plant (0.296), number of tillers per plant (0.400), number of mother rhizomes (0.249), weight of primary rhizomes (0.136), length of secondary rhizomes(0.377), curing per cent (0.335) and oleoresin content (0.108) and negative with days to maturity (-0.199), girth of mother rhizomes (-0.207) and essential oil content (-0.114).

4.10.3.1. Association of plant and rhizome *inter se* (Table 36) Sprouting per cent

Sprouting per cent registered positive and highly significant association with curcumin content (0.847**), oleoresin content (0.971**) and essential oil content (0.778**). It expressed highly significant and negative correlation with number of tillers per plant (-0.682**), weight of primary rhizomes (-0.588**), girth of primary rhizomes (-0.521**), girth of secondary rhizomes (-0.565**), curing per cent (-0.892**) and yield per plant (-0.557**).

Positive and non significant association was found with rhizome to core diameter ratio (0.414) and number of secondary rhizomes (0.164). Number of mother rhizomes (-0.173), weight of mother rhizomes (-1.158), girth of mother rhizomes (-0.301), length of primary rhizomes (-0.142), weight of secondary rhizomes (-0.369) and length of secondary rhizomes (-0.417) exhibited negative and non significant correlation (Table 36).

Height of the plant

Number of mother rhizomes (0.970**), weight of mother rhizomes (0.717**), weight of primary rhizomes (0.585**), weight of secondary rhizomes (0.565**) and girth of secondary rhizomes (0.542**) attributed highly significant and positive correlation. Highly significant and negative correlation was found with rhizome to core diameter ratio (-0.778**).

Positive and non significant correlation was accomplished through number of tillers per plant (0.130), days to maturity (0.192), girth of mother rhizomes (0.382), number of primary rhizomes (0.221), length of primary rhizomes (0.159), girth of primary rhizomes (0.401), number of secondary rhizomes (0.317), length of secondary rhizomes (0.209), curcumin content (0.114), oleoresin content (0.231), essential oil content (0.174) and yield per plant (0.296), while negative and non significant correlation was observed with curing per cent (-0.198). (Table 36).

Number of tillers per plant

This trait attributed highly significant and positive correlation with number of mother rhizomes (0.782**), weight of mother rhizomes (0.948**), number of primary rhizomes (0.938**), number of secondary rhizomes (0.839**), weight of secondary rhizomes (0.579**) and girth of secondary rhizomes (0.597**). Significant and positive association was found with days to maturity (0.511*), weight of primary rhizomes (0.518*), length of primary rhizomes (0.523*), girth of primary rhizomes (0.501*) and negative with rhizome to core diameter ratio (-0.473*) and curcumin content (-0.458*).

Positive and non significant correlation was exerted with girth of mother rhizomes (0.174) and yield per plant (0.400) whereas curing per cent (-0.365) and oleoresin content (-0.205) exhibited negative and non significant correlation.

Days to maturity

At genotypic level, number of mother rhizomes (0.448*) exerted significant and positive correlation with days to maturity. This trait exhibited positive and non significant correlation with number of secondary rhizomes (0.257), girth of secondary rhizomes (0.307), curcumin content (0.321), oleoresin content (0.403) and essential oil content (0.184) while non significant and negative association was through weight of mother rhizomes (-0.247), girth of mother rhizomes (-0.309), length of secondary rhizomes (-0.295), curing per cent (-0.218) and yield per plant (-0.199). (Table 36).

Number of mother rhizomes

The number of mother rhizomes showed highly significant and positive correlation with length of primary rhizomes (0.645**) and girth of primary rhizomes (0.636**). It registered highly significant and negative association with length of

secondary rhizomes (-0.735**) and girth of secondary rhizomes (-0.807**). Positive and significant correlation was observed with number of secondary rhizomes (0.440*).

It expressed positive and non significant correlation with weight of mother rhizomes (0.327), girth of mother rhizomes (0.108), weight of primary rhizomes (0.391), oleoresin content (0.220), essential oil content (0.327) and yield per plant (0.249) and negative with rhizome to core diameter ratio (-0.281), and curcumin content (-0.213).

Weight of mother rhizomes

This trait exhibited highly significant and positive association with girth of mother rhizomes (0.555**), weight of primary rhizomes (0.546**), girth of primary rhizomes (0.878**), length of secondary rhizomes (0.767**) and yield per plant (0.584**). There was highly significant and negative association with curcumin content (-0.783**), oleoresin content (-0.861**) and essential oil content (-0.691**). Rhizome to core diameter ratio (-0.438*) expressed negative and significant correlation.

Positive but non significant association was obtained with length of primary rhizomes (0.307), weight of secondary rhizomes (0.252) and curing per cent (0.290) while negative and non significant correlation was through number of primary rhizomes (-0.133). (Table 36).

Girth of mother rhizomes

Weight of primary rhizomes (0.990**), length of primary rhizomes (0.593**), girth of primary rhizomes (0.837**) and girth of secondary rhizomes (0.953**) expressed positive and highly significant correlation with girth of mother rhizomes.

Non significant and positive correlation was found with rhizome to core diameter ratio (0.122), weight of secondary rhizomes (0.120) and curing per cent (0.366), while

negative and non significant correlation was observed with number of primary rhizomes (-0.274), number of secondary rhizomes (-0.344), curcumin content (-0.123), oleoresin content (-0.193), essential oil content (-0.154) and yield per plant (-0.207).

Number of primary rhizomes

There was highly significant and positive correlation with length of primary rhizomes (0.802**), weight of secondary rhizomes (0.979**), length of secondary rhizomes (0.679**) and yield per plant (0.556**). The trait exhibited negative and highly significant association with rhizome to core diameter ratio (-0.354**). Weight of primary rhizomes (0.444*) registered significant and positive correlation.

Girth of primary rhizomes (0.313), curing per cent (0.143) and oleoresin content (0.176) showed positive non significant association while curcumin content (-0.125) was non significant and negatively correlated.

Weight of primary rhizomes

This trait attributed positive and highly significant correlation with girth of mother rhizomes (0.826**) and length of secondary rhizomes (0.544**) while negative correlation was found with rhizome to core diameter ratio (-0.567**) and curcumin content (-0.625**). There was positive and significant association with length of primary rhizomes (0.489*) whereas negative with oleoresin content (-0.471*).

It registered positive and non significant association with girth of primary rhizomes (0.194), curing per cent (0.137) and yield per plant (0.136), while negative correlation was observed with essential oil content (-0.252). (Table 36).

Length of primary rhizomes

Length of primary rhizomes registered highly significant and positive correlation with girth of primary rhizomes (0.718**), number of secondary rhizomes (0.725**), weight of secondary rhizomes (0.672**), length of secondary rhizomes (0.565**) and yield per plant (0.550**), while it exhibited negative and highly significant correlation with rhizome to core diameter ratio (-0.792**).

It accomplished positive and non significant correlation with girth of secondary rhizomes (0.198) and curing per cent (0.326), while negative non significant with curcumin content (-0.418), oleoresin content (-0.322) and essential oil content (-0.264).

Girth of primary rhizomes

This trait showed highly significant and positive association with weight of secondary rhizomes (0.825**), length of secondary rhizomes (0.681**), girth of secondary rhizomes (0.993**) and yield per plant (0.716**). Negative and highly significant association was observed through rhizome to core diameter ratio (-0.650**).

At genotypic level, number of secondary rhizomes (0.362) alone expressed positive and non significant correlation, while curcumin content (-0.226), oleoresin content (-0.132) and essential oil content (-0.133) showed negative association. (Table 36).

Rhizome to core diameter ratio

Rhizome to core diameter ratio exhibited positive and highly significant correlation with curcumin content (0.709**), while highly significant and negative association was observed through number of secondary rhizomes (-0.183**), weight of secondary rhizomes (-1.449**) and yield per plant (-0.886**). It accomplished positive and significant association with curing per cent (0.504*) and oleoresin content (0.491*),

while negative with girth of secondary rhizomes (-0.505*). Positive non significant association was through essential oil content (0.140).

Number of secondary rhizomes

This trait showed positive and highly significant correlation with length of secondary rhizomes (0.726**) and yield per plant (0.566**). It registered positive non significant association with oleoresin content (0.162) and essential oil content (0.196) whereas negative non significant correlation was found with girth of secondary rhizomes (-0.169) and curing per cent (-0.219).

Weight of secondary rhizomes

Weight of secondary rhizomes was found to have highly significant and positive association with length of secondary rhizomes (0.752**). Girth of secondary rhizome (0.414) exhibited positive non significant correlation whereas curing per cent (-0.264) and curcumin content (-0.177) showed negative and non significant correlation. (Table 36).

Length of secondary rhizomes

At genotypic level, this trait exerted highly significant and positive association with girth of secondary rhizomes (0.929**). Oleoresin content (-0.446*) exhibited negative and significant correlation. It registered positive non significant association with yield per plant (0.377), while negative with curing per cent (-0.143), curcumin content (-0.230) and essential oil content (-0.167).

Girth of secondary rhizomes

Girth of secondary rhizomes expressed negative and non significant association with curing per cent (-0.219), curcumin content (-0.303) and oleoresin content (-0.393).

Curing per cent

This trait registered highly significant and negative correlation with oleoresin content (-0.544**), negative and significant correlation with curcumin content (-0.458*). It showed positive non significant association with yield per plant (0.335) and negative non significant correlation with essential oil content (-0.218). (Table 36).

Curcumin content

Curcumin content expressed positive and highly significant correlation with oleoresin content (0.899**).

Oleoresin content

This trait attributed positive and non significant association with yield per plant (0.108).

Essential oil content

Essential oil content expressed non significant and negative correlation with yield per plant (-0.114).

4.10.4. Path analysis in vMo generation (Table 37)

The genotypic correlation coefficients of yield per plant with other fourteen traits which exhibited positive correlation *viz.*, height of the plant, number of tillers per plant, number of mother rhizomes, weight of mother rhizomes, number of primary rhizomes, weight of primary rhizomes, length of primary rhizomes, girth of primary rhizomes, number of secondary rhizomes, weight of secondary rhizomes, length of secondary rhizomes, girth of secondary rhizomes, curing per cent and oleoresin content on yield per plant were further apportioned into direct and indirect effects. The residual effect for the path coefficient analysis in vM_o generation was found to be 0.132. (Table 37).

4.10.4.1. Direct effect

Out of the fourteen characters studied, eight traits showed positive, direct effect on yield per plant. Weight of secondary rhizomes (0.844) recorded the highest direct effect followed by girth of primary rhizomes (0.740) and number of primary rhizomes (0.446). The traits such as girth of secondary rhizomes (0.273) and weight of mother rhizomes (0.211) exhibited moderate effect whereas number of secondary rhizomes (0.094), number of mother rhizomes (0.084) and weight of primary rhizomes (0.066) registered negligible effect.

The direct effects of height of the plant (-0.307), number of tillers per plant (-0.051), length of primary rhizomes (-0.762), length of secondary rhizomes (-0.628), curing per cent (-0.072) and oleoresin content (-0.072) were in the negative direction.

4.10.4.2. Indirect effect (Table 37)

Height of the plant

The positive, indirect effects of height of the plant through number of mother rhizomes (0.081), number of primary rhizomes (0.099), weight of primary rhizomes (0.039), girth of primary rhizomes (0.297), number of secondary rhizomes (0.030), weight of secondary rhizomes (0.476), girth of secondary rhizomes (0.148) and curing per cent (0.014) accounted for the observed positive correlation with yield per plant.

The indirect effects through number of tillers per plant (-0.058), weight of mother rhizomes (-0.151), length of primary rhizomes (-0.121), length of secondary rhizomes (-0.131) and oleoresin content (-0.119) were negative.

Number of tillers per plant

Number of tillers per plant exerted positive and indirect effect through number of mother rhizomes (0.232), number of primary rhizomes (0.418), weight of primary

rhizomes (0.166), girth of primary rhizomes (0.111), number of secondary rhizomes (0.079), weight of secondary rhizomes (0.332), girth of secondary rhizomes (0.436), curing per cent (0.026) and oleoresin content (0.106).

The indirect effects through height of the plant (-0.347), weight of mother rhizomes (-0.410), length of primary rhizomes (-0.398) and length of secondary rhizomes (-0.300) were negative.

Number of mother rhizomes

This character exerted positive indirect effect via number of primary rhizomes (0.914), weight of primary rhizomes (0.092), girth of primary rhizomes (0.471), number of secondary rhizomes (0.136), weight of secondary rhizomes (0.834), length of secondary rhizomes (0.462) and curing per cent (0.073).

Negative indirect effects were observed through height of the plant (-0.297), number of tillers per plant (-0.142), weight of mother rhizomes (-0.279), length of primary rhizomes (-0.491), girth of secondary rhizomes (-0.493) and oleoresin content (-0.113). (Table 37).

Weight of mother rhizomes

The indirect effect of this trait through number of mother rhizomes (0.111), weight of primary rhizomes (0.102), girth of primary rhizomes (0.650), number of secondary rhizomes (0.005), weight of secondary rhizomes (0.213), girth of secondary rhizomes (0.593) and oleoresin content (0.443) were positive.

Negative indirect effects were accomplished through height of the plant (-0.220), number of tillers per plant (-0.099), number of primary rhizomes (-0.059), length of

primary rhizomes (-0.234), length of secondary rhizomes (-0.110) and curing per cent (-0.021).

Number of primary rhizomes

The highest positive indirect effect for number of primary rhizomes was through weight of secondary rhizomes (0.826), followed by girth of primary rhizomes (0.232) and number of mother rhizomes (0.171). The lowest positive indirect effect was observed in traits like weight of mother rhizomes (0.028), weight of primary rhizomes (0.029) and number of secondary rhizomes (0.096). The highest negative indirect effects was through length of secondary rhizomes (-0.427) followed by length of primary rhizomes (-0.611) and the lowest was through height of the plant (-0.068), number of tillers per plant (-0.048), girth of secondary rhizomes (-0.017), curing per cent (-0.010) and oleoresin content (-0.091). (Table 37).

Weight of primary rhizomes

The indirect effect for weight of primary rhizomes through number of mother rhizomes (0.116), number of primary rhizomes (0.198), girth of primary rhizomes (0.884), number of secondary rhizomes (0.005), weight of secondary rhizomes (0.697), girth of secondary rhizomes (0.284) and oleoresin content (0.242) were positive.

Negative indirect effects were accomplished through height of the plant (-0.179), number of tillers per plant (-0.128), weight of mother rhizomes (-0.326), length of primary rhizomes (-0.373), length of secondary rhizomes (-0.355) and curing per cent (-0.023). (Table 37).

Length of primary rhizomes

Length of primary rhizomes registered positive indirect effects through number of mother rhizomes (0.054), number of primary rhizomes (0.357), weight of primary

rhizomes (0.032), girth of primary rhizomes (0.531), number of secondary rhizomes (0.068), weight of secondary rhizomes (0.567), girth of secondary rhizomes (0.054) and oleoresin content (0.166).

Negative indirect effects were exhibited through height of the plant (-0.049), number of tillers per plant (-0.027), weight of mother rhizomes (-0.065), length of secondary rhizomes (-0.355) and curing per cent -0.023). (Table 37).

Girth of primary rhizomes

The highest positive indirect effect of girth of primary rhizomes was observed through weight of secondary rhizomes (0.696), followed by girth of secondary rhizomes (0.271) and number of primary rhizomes (0.140). The lowest positive indirect effect was through number of mother rhizomes (0.053), weight of primary rhizomes (0.079), number of secondary rhizomes (0.034), and oleoresin content (0.068).

The highest negative indirect effects were observed through length of primary rhizomes (-0.547), length of secondary rhizomes (-0.428), weight of mother rhizomes (-0.185) and height of the plant (-0.123). The lowest negative indirect effects were expressed through number of tillers per plant (-0.077) and curing per cent (-0.006).

Number of secondary rhizomes

The indirect effect of this trait through number of mother rhizomes (0.120), number of primary rhizomes (0.452), weight of primary rhizomes (0.004), girth of primary rhizomes (0.268), weight of secondary rhizomes (0.901) and curing per cent (0.016) were positive.

Height of the plant (-0.097), number of tillers per plant (-0.043), weight of mother rhizomes (-0.011), length of primary rhizomes (-0.552), length of secondary rhizomes (-0.456), girth of secondary rhizomes (-0.046) and oleoresin content (-0.083) registered negative indirect effects.

Weight of secondary rhizomes

The highest positive indirect effect for this trait was observed through girth of primary rhizomes (0.611) followed by number of primary rhizomes (0.437), number of mother rhizomes (0.182), girth of secondary rhizomes (0.113) and number of secondary rhizomes (0.101). The lowest positive direct effects was through weight of primary rhizomes (0.055), curing per cent (0.019) and oleoresin content (0.006).

The highest negative effects were noticed through length of primary rhizomes (-0.512) followed by length of secondary rhizomes (-0.472) and height of the plant (-0.173). The lowest negative indirect effect was observed through number of tillers per plant (-0.080) followed by weight of mother rhizomes (-0.053). (Table 37).

Length of secondary rhizomes

The indirect effects of length of secondary rhizomes through number of primary rhizomes (0.303), weight of primary rhizomes (0.036), girth of primary rhizomes (0.504), number of secondary rhizomes (0.069), weight of secondary rhizomes (0.634), girth of secondary rhizomes (0.253), curing per cent (0.010) and oleoresin content (0.230) were positive.

Negative indirect effects through height of the plant (-0.064), number of tillers per plant (-0.105), number of mother rhizomes (-0.061), weight of mother rhizomes (-0.372) and length of primary rhizomes (0.430) were observed for this trait. (Table 37).

Girth of secondary rhizomes

This character exerted positive indirect effects via weight of primary rhizomes (0.069), girth of primary rhizomes (0.735), weight of secondary rhizomes (0.349), curing per cent (0.016) and oleoresin content (0.202).

Negative indirect effects were noticed through height of the plant (-0.166), number of tillers per plant (-0.081), number of mother rhizomes (-0.151), weight of mother rhizomes (-0.458), number of primary rhizomes (-0.029), length of primary rhizomes (-0.151), number of secondary rhizomes (-0.016) and length of secondary rhizomes (-0.584).

Curing per cent

The indirect effects for curing per cent through height of the plant (0.061), number of tillers per plant (0.019), number of primary rhizomes (0.064), weight of primary rhizomes (0.009), girth of primary rhizomes (0.065), length of secondary rhizomes (0.090) and oleoresin content (0.795) were positive.

Negative indirect effects were noticed through number of mother rhizomes (-0.085), weight of mother rhizomes (-0.061), length of primary rhizomes (-0.248), number of secondary rhizomes (-0.223), and girth of secondary rhizomes (-0.060).

Oleoresin content

The indirect effects of this trait through number of tillers per plant (0.010), number of mother rhizomes (0.018), weight of mother rhizomes (0.181), number of primary rhizomes (0.078), length of primary rhizomes (0.245), number of secondary rhizomes (0.015), length of secondary rhizomes (0.280) and curing per cent (0.111) were positive.

The indirect effects via height of the plant (-0.071), weight of primary rhizomes (-0.031), girth of primary rhizomes (-0.097), weight of secondary rhizomes (-0.010) and girth of secondary rhizomes (-0.107) were negative. (Table 37).

4.10.5. Correlation studies in vM_1 generation (Table 38 to Table 40)

The phenotypic, genotypic and simple correlation coefficients estimated between yield and its component characters and inter correlations among the different yield components indicated that the genotypic correlation coefficients and simple correlation coefficients were higher than the phenotypic correlation coefficients (Table 39). However, simple correlation coefficients were lesser than the genotypic correlation coefficients.

4.10.5.1.Simple correlation of morphological and biochemical characters on yield per plant in vM_1 generation (Table 38).

The yield per plant exhibited significant and positive correlation with number of primary rhizomes (0.524*), length of primary rhizomes (0.529*) and number of secondary rhizomes (0.489*).

Yield per plant exerted positive and non significant correlation through number of mother rhizomes (0.118), weight of primary rhizomes (0.346), girth of primary rhizomes (0.161), weight of secondary rhizomes (0.382), length of secondary rhizomes (0.266) and curing per cent (0.415). The traits like number of tillers per plant (-0.127), weight of mother rhizomes (-0.237) and girth of secondary rhizomes (-0.221) showed negative non significant correlation. (Table 38).

4.10.5.2. Association of plant and rhizome *interse* (Table 38)

Height of the plant

The trait, height of the plant was found to have positive and highly significant correlation with number of tillers per plant (0.555**).

It attributed positive and non significant correlation with number of mother rhizomes (0.207), length of primary rhizomes (0.337), girth of primary rhizomes (0.172), number of secondary rhizomes (0.188), weight of secondary rhizomes (0.283), length of secondary rhizomes (0.249) and oleoresin content (0.260) and negative non significant correlation with weight of primary rhizomes (-0.080), girth of secondary rhizomes (-0.144) and curing per cent (-0.160).

Number of tillers per plant

The number of tillers per plant showed positive non significant correlation with number of mother rhizomes (0.253), weight of mother rhizomes (0.200), weight of primary rhizomes (0.300), girth of primary rhizomes (0.290), weight of secondary rhizomes (0.102), girth of secondary rhizomes (0.349) and oleoresin content (0.110).

It attributed negative and non significant association with number of primary rhizomes (-0.276), number of secondary rhizomes (-0.120), curing per cent (-0.354) and yield per plant (-0.127). (Table 38).

Number of mother rhizomes

This character exerted positive and non significant correlation with length of primary rhizomes (0.186), girth of primary rhizomes (0.298), weight of secondary rhizomes (0.177), curcumin content (0.123), and yield per plant (0.118).

It registered negative and non significant association with weight of mother rhizomes (-0.108) and curing per cent (-0.132). (Table 38)

Weight of mother rhizomes

This trait was found to exhibit positive and highly significant correlation with girth of primary rhizomes (0.552**) and girth of secondary rhizomes (0.599**).

It showed positive but non-significant correlation with weight of primary rhizomes (0.350), length of primary rhizomes (0.117), weight of secondary rhizomes (0.201), length of secondary rhizomes (0.290), and oleoresin content (0.210) whereas the traits such as number of primary rhizomes (-0.113) and yield per plant (- 0.237) exhibited negative and non significant correlation.

Number of primary rhizomes

Number of primary rhizomes showed positive and highly significant correlation with length of primary rhizomes (0.638**) and number of secondary rhizomes (0.815**). It registered positive and significant association with weight of secondary rhizomes (0.535*), length of secondary rhizomes (0.423*) and yield per plant (0.524*).

It attributed positive and non significant correlation with girth of primary rhizomes (0.278) and curing per cent (0.121). It showed negative and non significant correlation with weight of primary rhizomes (-0.120) and girth of secondary rhizomes (-0.416). (Table 38).

Weight of primary rhizomes

This trait registered positive and highly significant correlation with girth of secondary rhizomes (0.683**). It expressed positive and non significant correlation with length of primary rhizomes (0.264), girth of primary rhizomes (0.328), length of

secondary rhizomes (0.222), curing per cent (0.185) and yield per plant (0.346) and negative with number of secondary rhizomes(-0.125) (Table 38).

Length of primary rhizomes

Length of primary rhizomes showed highly significant and positive correlation with girth of primary rhizomes (0.639**) and number of secondary rhizomes (0.595**). The traits like weight of secondary rhizomes (0.451*) and yield per plant (0.529*) exhibited positive and significant correlation.

Length of secondary rhizomes (0.340) and curing per cent (0.300) expressed positive but non significant correlation.

Girth of primary rhizomes

Girth of primary rhizomes exerted positive but non significant correlation with number of secondary rhizomes (0.314), weight of secondary rhizomes (0.308), length of secondary rhizomes (0.160), girth of secondary rhizomes (0.311), curing per cent (0.105), oleoresin content (0.118) and yield per plant (0.161). (Table 38).

Number of secondary rhizomes

Number of secondary rhizomes attributed positive and highly significant correlation with weight of secondary rhizomes (0.846**). The traits such as length of secondary rhizomes (0.477*) and yield per plant (0.489*) showed significant and positive correlation.

Girth of secondary rhizomes (-0.401) and oleoresin content (-0.167) exhibited negative and nonsignificant association.

Weight of secondary rhizomes

The weight of secondary rhizomes registered positive but non significant correlation with length of secondary rhizomes (0.399) and yield per plant (0.382) whereas girth of secondary rhizomes (-0.159) and curing per cent (-0.174) were negative and non-significant.

Length of secondary rhizomes

Girth of secondary rhizomes (0.138), oleoresin content (0.163) and yield per plant (0.266) exhibited positive and non significant correlation. (Table 38)

Girth of secondary rhizomes

Girth of secondary rhizomes expressed positive and non significant association with oleoresin content (0.138). This trait recorded negative and non significant correlation with curing per cent (-0.115) and yield per plant (-0.221).

Curing per cent

Curing per cent exerted positive but non significant correlation with yield per plant (0.415) whereas it was negative with oleoresin content (-0.202).

Oleoresin content

Oleoresin content exhibited positive and non significant correlation with yield per plant (0.082).

4.10.6. Phenotypic correlation of morphological and biochemical characters on yield per plant (Table 39.)

The phenotypic correlation coefficients of biometric and biochemical characters on yield per plant were lower than the genotypic correlation coefficients. (Table 39).

4.10.7. Genotypic correlation of vM_1 generation

4.10.7.1. Genotypic correlation of morphological and biochemical characters on yield per plant (Table 40)

Number of primary rhizomes (0.906**), weight of primary rhizomes (0.624**), length of primary rhizomes (0.584**), girth of primary rhizomes (0.609**), number of secondary rhizomes (0.710**), weight of secondary rhizomes (0.901**), length of secondary rhizomes (0.558**), and curing per cent (0.882**) expressed highly significant and positive correlation with yield. Highly significant and negative correlation was observed through number of tillers per plant (-0.624**) and weight of mother rhizomes (-0.966**). It had negative and significant association with girth of secondary rhizomes (-0.427*).

Positive and non significant association was accomplished with height of the plant (0.159) and oleoresin content (0.349).

4.10.7.2. Association of plant and rhizome *inter se* (Table 40)

Height of the plant

Height of the plant registered positive and highly significant association with number of tillers per plant (0.615**), number of mother rhizomes (0.585 **), length of secondary rhizomes (0.762**) and oleoresin content (0.758**).

Positive and non significant correlation was observed with weight of mother rhizomes (0.185), length of primary rhizomes (0.351), girth of primary rhizomes (0.329), number of secondary rhizomes (0.260) and weight of secondary rhizomes (0.329), while girth of secondary rhizomes (-0.178) and curing per cent (-0.188) registered negative and non significant correlation.

Number of tillers per plant

Weight of primary rhizomes (0.705**), girth of primary rhizomes (0.790**) and oleoresin content (0.788**) attributed highly significant and positive correlation. Highly significant and negative association was observed with curing per cent (-0.653**) and yield per plant (-0.624**).

Positive and non significant correlation was accomplished with number of mother rhizomes (0.221), weight of mother rhizomes (0.348), weight of secondary rhizomes (0.141) and girth of secondary rhizomes (0.278) while negative with number of primary rhizomes (- 0.400), number of secondary rhizomes (-0.113) and length of secondary rhizomes (-0.306). (Table 40).

Number of mother rhizomes

This trait attributed highly significant and positive correlation with length of primary rhizomes (0.686**), weight of secondary rhizomes (0.662**) and length of secondary rhizomes (0.698**). Highly significant and negative correlation was found with curing per cent (-0.592**) and oleoresin content (-0.780**).

At genotypic level, girth of secondary rhizomes (0.527*) exerted positive and significant association. Positive and non significant correlation was registered with number of primary rhizomes (0.364), weight of primary rhizomes (0.371), girth of primary rhizomes (0.269) and number of secondary rhizomes (0.296). (Table 40)

Weight of mother rhizomes

At genotypic level, girth of primary rhizomes (0.945**) and oleoresin content (0.915**) exerted highly significant and positive association with weight of mother rhizomes while it was negative with curing per cent (-0.567**) and yield per plant (-0.966**). This trait exhibited significant and positive association with weight of primary rhizomes (0.470*).

Positive and non significant association was through length of primary rhizomes (0.176), number of secondary rhizomes (0.228), length of secondary rhizomes (0.377) and girth of secondary rhizomes (0.181), while negative and non significant association was through number of primary rhizomes (-0.119).

Number of primary rhizomes

Number primary rhizomes showed highly significant and positive correlation with length of primary rhizomes (0.956**), weight of secondary rhizomes (0.800**) and yield per plant (0.906**). It registered highly significant and negative association with girth of secondary rhizomes (-0.894**).

Positive and non significant correlation was observed with girth of primary rhizomes (0.334), number of secondary rhizomes (0.180), length of secondary rhizomes (0.105) and curing per cent (0.310) whereas it was negative with weight of primary rhizomes (-0.191). (Table 40)

Weight of primary rhizomes

This trait exhibited highly significant and positive association with curing per cent (0.730**), oleoresin content (0.747**) and yield per plant (0.624**). Girth of primary rhizomes (0.523) exhibited positive and significant correlation.

Positive but non significant association was observed with girth of secondary rhizomes (0.223).

Length of primary rhizomes

Length of primary rhizomes exhibited highly significant and positive correlation with girth of primary rhizomes (0.997**), number of secondary rhizomes (0.743**),

weight of secondary rhizomes (0.660**), length of secondary rhizomes (0.815**) and yield per plant (0. 584**).

Non significant and positive correlation was found with girth of secondary rhizomes (0.351), curing per cent (0.400) and oleoresin content (0.279).

Girth of primary rhizomes

There was highly significant and positive association through number of secondary rhizomes (0.568**), girth of secondary rhizomes (0.695**) and yield per plant (0.609**). This trait exhibited positive and significant correlation with weight of secondary rhizomes (0.504*). (Table 40)

Number of secondary rhizomes

This trait attributed positive and highly significant correlation with length of secondary rhizomes (0.924**) and yield per plant (0.710**) whereas it was negative with girth of secondary rhizomes (-0.736**).

It registered positive and non significant association with weight of secondary rhizomes (0.248), while negative correlation was found with curing per cent (-0.101) and oleoresin content (-0.402).

Weight of secondary rhizomes

Weight of secondary rhizomes registered highly significant and positive correlation with yield per plant (0.901**) while negative with girth of secondary rhizomes (-0.678**). It accomplished positive and significant correlation with oleoresin content (0.482*).

It exhibited positive non significant correlation through length of secondary rhizomes (0.387), while negative with curing per cent (-0.327).

Length of secondary rhizomes

Length of secondary rhizomes showed highly significant and positive association with oleoresin content (0.858**) and yield per plant (0.558**).

At genotypic level, curing per cent (-0.238) expressed negative and non significant correlation. (Table 40)

Girth of secondary rhizomes

This trait showed positive and highly significant correlation with oleoresin content (0.611**). The negative and significant association was observed through yield per plant (-0.427*). It registered negative and non significant correlation with curing per cent (-0.136).

Curing per cent

At genotypic level, this trait exerted highly significant and positive association with yield per plant (0.882**). Oleoresin content (-0.483*) exhibited negative and significant correlation.

Oleoresin content

Oleoresin content accomplished positive and non significant correlation with yield per plant (0.349). (Table 40).

CHAPTER – V

DISCUSSION

The role of mutation breeding in the improvement of vegetatively propagated crops has been increasingly realized in the recent years. Genetic improvement of such crops (which, in addition to being vegetatively propagated, exhibit very rare seed set) through methods involving crossing is limited due to obvious difficulties. Further, the plants are often polyploids. These intricacies cause complicated segregation patterns and make the determination of useful recombinants rather difficult. Incompatibility which exists in some of these crops also renders the task of the breeders extremely difficult.

Induction of mutation and isolation of desirable mutants obviously are the means for producing genetic variability in vegetatively propagated (sterile) and obligatory apomictic crop plants. Seed production and propagation of turmeric through sexual methods have not been reported. Turmeric is, therefore, universally propagated by vegetative means. Hence, the use of mutations for inducing variability assumes greater significance. The heterozygosity of this crop has remained more or less fixed unlike in the seed propagated plants, is an advantage.

The success in mutation breeding largely depends on understanding of the process of induction and recovery of the mutants and of the screening methods for evaluating the desired mutants. In turmeric, systematic attempts on induction of mutation are very scanty and the methodologies for induction and recovery of the mutants are yet to be standardized. Therefore "Induction of mutagenesis in turmeric through gamma rays for variability and quality improvement" was taken up. The investigation was carried out at the Department of Spices and Plantation Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore with the objective of induction of variability and recovery of the desirable mutants. An attempt has been made to throw

light on the basic aspects of induced mutagenesis in turmeric and to open out new avenues in the genetic improvement of the crop. Under the present endeavour physical mutagen (gamma rays) was employed. The results of the studies are discussed in this chapter.

Mean performance of vM_o and vM_1 generation

Morphological characters

Basic information on the sensitivity of plant material to the mutagens is essential for aiming to optimize the dose of mutagens. In the present investigation, sprouting per cent, height of the plant, number of leaves per plant and number of tillers per plant were considered as the parameters for assessing the sensitivity of turmeric rhizomes.

The sprouting per cent decreased with an increase in dose of gamma rays. The highest sprouting per cent was recorded at 2.0 kR followed by 2.5 kR. Hundred per cent sprouting was obtained in the treatment combinations, G_1 with 2.0 kR and G_2 with 2.0 kR. The observations recorded in the present investigation indicated that there was gradual reduction in the sprouting per cent for every rise in the dose of gamma rays. Higher sprouting per cent at lower doses may be due to the radiation resistant nature of the biological material upto a certain dose and also due to the break in the dormancy, which resulted in stimulation of sprouting. This is evident from the present finding that all the higher doses of gamma rays exhibited reduced sprouting per cent. The decrease in the sprouting per cent with an increase in dose might be due to the lethal effect of mutagens on genes and higher rate of ionization in the nucleii produced at higher concentration of gamma rays.

The decrease in sprouting may be due to lethality caused in sprouts, physiological injuries and the gamma ray reaction with the nucleic acid like DNA by alkylating their phosphate group. The hydrolytic products also damage the cell membrane and other cell

constituents at molecular level leading to breaks, physiological injuries and ultimately stopping the metabolic activity of the cells resulting in the decrease of the sprouting per cent. The reduction in the sprouting per cent due to higher doses of gamma irradiation might also be attributed to drop in auxin level (Skoog, 1935) or due to induction of chromosomal aberrations as reported by Read (1959) and Sparrow (1961) and also the toxic effect of higher doses of gamma rays might have killed or inactivated the growing points. Such inhibitory effects on the sprouting in vegetatively propagated crops has been documented by many workers. Inverse relationship between mutagen dose and the sprouting per cent had been reported in general by Sparrow *et al.* (1956). The mutagenic sensitivity of a biological material might be attributed to the level of differentiation and development of sprouting at the time of treatment. The extent of damage to the growth processes like rate of cell elongation and cell division varies at different stages of hormone synthesis and biosynthetic pathways. The present investigation is in corroboration with Mukherjee and Khoshoo (1970) who found that a dosage of 3 kR gamma rays was lethal for germination of canna rhizomes. Dosage of 5 kR gamma rays prevented total sprouting in ginger, according to Gonzalez *et al.* (1969). Raju *et al.* (1980) could obtain only sprouting to a tune of 32 per cent by irradiating ginger rhizomes with 2 kR gamma rays. In *Costus speciosus*, 3 kR treatment inhibited sprouting of rhizomes as reported by Gupta *et al.* (1982). Giridharan (1984) made corroborative findings in ginger. He observed total failure in sprouting at 4.00 kR and above doses of gamma rays.

The height of the plant recorded at different stages of plant growth indicated a progressive reduction with an increase in the doses of gamma rays. Among the treatments, 2.0 kR increased height of the plant at 90, 135, 180 and 225 DAP. Treatment combination, G_1 with 2.0 kR promoted height of the plant at different stages of plant growth. Gamma irradiation may cause destruction or damage to apical meristems or partial failure of the internodes to elongate so as to result in decreased number of proliferating cells. The height reduction with increase in dose may be interpreted in

cytological, physiological, biochemical and anatomical view points such as auxin destruction (Skoog, 1935), interference in normal mitosis and mitotic aberrations (Wertz, 1940), failure of assimilatory mechanisms (Quastler and Baer, 1950), production of diffusible growth retarding substance (Mackey, 1951), inhibition of auxin synthesis (Gordon, 1954), inhibition in the rate of assimilation and consequent changes in the nutrient level of plants (Ehrenberg, 1955), changes in the specific activity of enzymes (Haskins and Chapman, 1956; Natarajan, 1958; Cherry and Lessman, 1967; Endo, 1967) and delay in the onset of first mitosis. Various other explanations could also be offered for the reduced growth at various stages following mutagenic treatments such as inactivation of vital enzymes especially those concerned with respiration (Casarett, 1968) and inhibition of DNA synthesis (Mikaelson, 1968). A similar line of work had been documented by Gupta *et al.* (1982) in *Costus.* Giridharan (1984) in ginger cultivars Rio-de-Janeiro and Maran noticed gradual decrease in height of the plant as the irradiation doses increased from 0.7 kR to 2.0 kR gamma rays.

With increase in the doses of irradiation, proportionate reduction was caused in leaf production, length, breadth and area of the leaf. Treatment with 2.0 kR recorded the highest number, length, breadth and area of leaf followed by 2.5 kR. Greater number, length, breadth and area of leaf were expressed in the treatment combination G_2 with 2.0 kR. Reduced height of the plant and tiller production might be contributory factors for reduction in the leaf characters. It may also be due to the direct effect of the gamma rays on the growing points. Some of the growing points depending upon the physiological and developmental stages might have been killed or inactivated by dose of gamma rays toxic to them and hence reduction in number of leaves were observed at higher doses. In the cells of growing shoot, mitotic and meiotic aberrations occur during mutation which may cause inhibitory effect on growth rate. Inhibition of vegetative growth may be due to radiation effect on the chromosomal material, genetic injury induced in dividing cells and deficiency of some physiological pre requisite to cell division. This is in consonance with

the findings of Natarajan (1975) in turmeric. The present investigation also is in agreement with the earlier work of Gupta *et al.* (1982) who observed that gamma irradiation caused reduction in leaf production and size of leaf in *Costus speciosus*. Giridharan (1984) indicated a reduction in leaf production as a result of radiation treatments in ginger.

There was drastic reduction in the production of tillers, as the dose of gamma rays increased. Tillering was the highest in the treatment 2.0 kR followed by 2.5 kR. Similarly treatment combination, G_3 with 2.0 kR exhibited greater number of tillers than the other combinations. The reduction in the number of tillers at higher doses in the present study may be due to the direct effect of radiation treatments on the growing points which are responsible for tiller production. These observations are in conformity with earlier works. According to Davies (1974), the increase in vegetative growth occurred not by direct stimulation but as a consequence of radiation injury elsewhere in the plant. It was likely that increased tillering was initiated by the damage to the primary growth meristems. Gupta *et al.* (1982) recorded that in costus, the number of tillers per plant increased at 1.5 kR, however, it decreased at 3.0 kR treatment. Giridharan (1984) opined that in ginger cultivar Rio de – Janeiro, more tiller production was observed as a result of gamma ray treatments at 0.7 and 1.0 kR 180 days after planting. However, the highest dose of 2.0 kR gamma rays reduced the number of tillers produced.

Varied response for days to maturity was noticed in respect of different doses of gamma rays. Treatments 2.0 kR followed by 2.5 kR exhibited earliness in the days to maturity. Likewise, in the present investigation, treatment combination G_2 with 2.0 kR showed earliness in the days to maturity than the other combinations. Delay in the maturity was observed as the doses of gamma rays increased. The delayed maturity at higher doses in the present investigation could be attributed to the delay on the plant growth caused by the gamma rays.

The physiological damage of the gamma rays is generally more in the initial stages of plant growth than at the later stages. The induction of mutation generally occurs necessarily when DNA synthesis and chromosomal reproduction are progressing. Matured cells or differentiated cells are incapable of responding to mutagenic treatments. Earliness in maturity may be attributed to the triggering of metabolic activities by the lower doses of gamma rays. The triggering of metabolism would have resulted in diverting the source – sink relationship and thereby breaking the vegetative phase in an advanced phase. The fact could easily be well understood from 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 parenchymal cells of the cortex on the inside. The central cylinder of parenchymal cells is separated from the cortex by a thin layer of oblong cells of the endoderm. Scattered throughout the parenchymatal 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 the growth period (maturity) which inturn was affected by an increase in the dose of gamma rays. This is in concordance with the earlier reports of Jayachandran (1989) in ginger.

Significant variations in rhizome characters like the number, weight, length and girth of mother, primary and secondary rhizomes and rhizome to core diameter ratio were observed at different doses of gamma rays in the present investigation. This is in conformity with the previous works of Natarajan (1975) in turmeric and Jayachandran (1989) in ginger. The mean number of mother rhizomes progressively decreased with an increase in the dose of gamma rays. The highest number of mother rhizomes was observed at 2.0 kR. Similarly, higher number of mother rhizomes was recorded in treatment combination, G_3 with 2.0 kR. Increased weight of the mother and primary rhizomes, girth of secondary rhizomes and rhizome to core diameter ratio were observed

in the combination, G_2 with 2.0 kR. The dosages, 2.0 kR and 2.5 kR caused an increased length and girth of mother rhizomes. Treatment combination, G_1 with 2.0 kR expressed greater number and length of primary rhizomes and number and weight of secondary rhizomes. Lower doses of gamma rays would have helped in the synthesis of cytokinin hormone which hastens the cell elongation of the underground rhizomes. Higher rhizome growth might be attributed to greater absorption of nutrients from the soil as enhanced by the gamma ray treatment. It may also be due to the fact that high yielding plants exhibited erect, narrow leaves, while low yielding ones showed drooping and wide leaves. The low yielding plants reached 95 per cent light interception when half of the total area had been produced. This means that they produced double the leaf area required to intercept more photosynthetically active radiation. In the high yielding plants, 95 per cent light interception occurs when the vegetative growth decreases and the photosynthate was utilized for rhizomes production. Early bulking with progressive accumulation of photosynthates from the tiller leaves even after the later stages of the plant growth enhances the weight of the rhizomes in proportion to their dimensions of mother, primary and secondary rhizomes. The yielding capability of the genotypes can be improved from knowledge about the optimum dosage of gamma rays on the morphological and physiological characters of the plant such as height of the plant, leaf and tiller production, crop growth rate, relative growth rate, photosynthetically active radiation and net assimilation rate.

The yield obtained on per plant basis was the highest at 2.0 kR followed by 2.5 kR. Increased yield was noticed in treatment combination, G_1 with 2.0 kR. Increased yield at lower doses of gamma rays may be due to the increase in the enzyme level which activates metabolism of cells responsible for translocation of source to sink. The lower doses of gamma rays might have enhanced the enzymatic processes involved in the plant growth and development phase such as proper stomatal functioning, enzyme production, photosynthetic efficiency in terms of net assimilation rate and portioning efficiency from

the source to sink and related biochemical reactions. The yield per plant decreased as the dose of gamma rays increased. The low yield at increased dose obtained in the present investigation could be attributed to the reduction caused by the gamma rays on plant growth, area of leaf and size and growth of rhizomes particularly secondary rhizomes. 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 effect noted during early stages in respect of the above characters. However, the recovery of growth parameters achieved during the later stages of growth did not appear to have sufficient contribution to the rhizome development. This may be the reason for low yield 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 had reported weaker and elongated underground rhizome in ginger due to 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 2.0, 2.5 and 3.0 kR treatments. Shah *et al.* (1982) observed high yield in turmeric as a result of X-ray irradiation.

Significant variation was noticed for the curing per cent among the treatments. The curing per cent was higher in treatment 2.0 kR, followed by 2.5 kR and was found to reduce with increase in the dose of gamma rays. The variation in the curing per cent among the treatments was chiefly due to the genetic factors rather than the type of processing followed. 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. The resource utilization was affected due to the lower net assimilation rate, which were mainly characterized by enhanced physiological parameters such as crop growth rate, relative growth rate, photosynthetically active radiation and high net assimilation rate during the early stages of plant growth and

rhizome development upto seven months after planting. The present findings are in corroboration with the earlier works carried out by Subramanian *et al.* (2002) in CO 1 and BSR 1 clones of turmeric. Higher curing per cent was mainly due to the production of slender rhizomes, perhaps due to lower moisture retention at harvest. The low curing per cent was mainly due to the fact that feeder roots are present near the surface soil under irrigated conditions, which absorb more water and ought to have higher moisture content. As a result, the rhizome will become plump and after curing, the yield get reduced. This is in accordance with the previous works of Phillip (1983) and Reddy *et al.* (1989) in turmeric.

Quality characters

In the present study, significant variation was noticed among the treatments for curcumin, oleoresin and essential oil contents. Treatment 2.0 kR, followed by 2.5 kR, exhibited higher values for the above characters, while it was in the decreasing trend with an increase in the dose of gamma rays. The biosynthesis and content of curcumin involves various steps hastened by different enzymes. The mevalonic acid pathway is the prime route for the synthesis of this Xanthophyll pigment, curcumin. Enzymes involved at different stages for biosynthesis of curcumin would have become more active thereby influencing the increased curcumin content at lower doses of gamma rays. Synthesis of curcumin content has been found to be highly influenced by the microclimate namely leaf temperature, relative humidity and the inherent fertility status of the soil in which the crop was grown which might have been affected by the gamma rays, thereby inhibiting the enzymes production and related biochemical reactions at higher dosage levels. Anatomical features namely central cylinder and cortex with more congregation of specialized cells which are the oleoresin bearing cells act as the site of curcumin accumulation. These specialized cells might have been increased at lower doses of gamma rays thereby favouring greater accumulation of curcumin content. The variation in the curcumin content might also be due to the effect of temperature, relative humidity and

soil factors and the stage of harvest. Similarly the variations in the synthesis of oleoresin and essential oil might have been due to the promotive or inhibiting influence exercised by gamma rays at different dosages causing physiological and biochemical reactions leading to the synthesis of these compounds. The gamma rays act to disturb various enzymes controlling the different steps involved in the biosynthesis of these compounds, thereby the altering either increasing or decreasing the proportion in their levels. This is in accordance with the earlier works of Gupta *et al.* (1982) who found that diosgenin content increased at 2.0 kR, whereas it decreased at 3.0 kR in Costus.

Evaluation of the vM_1 generation

For various reasons, vegetatively propagated crops are a suitable group of plants for the application of mutation breeding methods. The main advantage of mutation induction in vegetatively propagated crops is the ability to change one or a few characters of an otherwise outstanding cultivar without altering the remaining and often unique part of the genotype. Moreover, mutations are the only source of variability in sterile plants like turmeric. Nevertheless, mutation breeding of vegetatively propagated plants is associated with several major bottlenecks. A mutation is single – cell event. The multicellular nature of the apex causes complicated problems like chimera formation and diplontic selection. The result is a relatively low mutation frequency and probably a limited mutation spectrum while selection procedures cannot be applied before a stable periclinal chimera stage has been reached. If, therefore, multicellular apices are irradiated, measures should be taken to promote an increase in sector size and to obtain complete periclinal chimeras as soon as possible. Selection and further propagation could then begin.

Dermen (1967) observed that periclinal chimerism was a common situation in mutated (vegetatively propagated) plants after one or a few cycles of vegetative propagation. In the present investigation, vM_1 generation was studied in comparison with the treated and untreated plants in the vM_o generation. The mean values in respect of sprouting per cent, height of the plant, number, length, breadth and area of the leaves,

number of tillers per plant, number, weight, length and girth of mother, primary and secondary rhizomes, rhizome to core diameter ratio, yield per plant, curing per cent, curcumin, oleoresin and essential oil contents of vM_1 generation were comparable with those of the vM_o generation. A decreasing tendency of the above parameters as the doses of gamma rays increased was the general tendency in both vM_o and vM_1 generations. An analysis of the variation due to the gamma rays treatments indicated that lower doses of gamma rays (2.0 and 2.5 kR) induced greater variation in both the generations, whereas the range of variation was limited at higher doses. This is in agreement with the findings of Raju *et al.*, (1980) and Gupta *et al.*, (1982).

Gupta and Jugran (1983) concluded that screening for somatic mutation should not be confined to vM_1, however, it should be continued in vM_2 and subsequent vegetative generations for the success of mutation breeding programme.

The output of mutations in vM_1 and subsequent generations is determined by the mode of action of the mutagen and interaction of many factors in the treated material. The results were expressed qualitatively by the mutation spectrum and quantitatively by the mutation rate. The mutation rate is the proportion of mutated plants to the normal plants. Three methods are employed to estimate the frequency of mutation *viz.*, M_1 spike basis, M_1 plant basis and M_2 plant basis (i.e.) mutation per 100 M_1 plants as expressed by Gaul (1977). He also suggested that the mutation per 100 M_1 plant basis would be the best index since it was independent of variation in the progeny size and size of mutated sector. Hence, in the present investigation, mutations per 100 vM_1 plants were used to estimate the frequency of mutation in the vM_1 generation.

Chlorophyll mutations

Changing the spectrum of mutations in a predictable manner and thereby achieving directed mutagenesis is an important goal of current mutation research (Auerbach, 1967). Sato (1966) expressed that a close relationship exists between the

chlorophyll and viable mutations. In the present study, there were differences in the frequency of chlorophyll mutations due to the doses of gamma rays. The frequency of chlorophyll mutants was high in the treatment 2.0 kR, followed by 2.5 kR. The occurrence of chlorophyll chimera in the present investigation could be attributed to chromosomal aberrations, change in the route of auxin synthesis, distribution or disruption of mineral metabolism or accumulation of free amino acids. It may also be due to the multicellular nature of the tissues treated. Nuclear and / or plastid mutations were thought to cause variegations in leaves (Kirk and Bassett, 1967). Laxmi *et al.* (1980) considered that chimera formation in leaves as a result of gamma irradiation might be due to the multicellular nature of the tissues treated. Leaf variegation due to gamma irradiation had been documented in Canna (Nakornthap, 1965). Raju *et al.* (1980) obtained such a phenomenon in ginger. Variation in leaf shape and colour had been observed in costus by Gupta *et al.* (1982). In ginger, Giridharan (1984) recorded yellow streaks as a result of radiation treatments in the cultivars Rio-de-Janeiro and Maran.

The spectrum of chlorophyll mutants spotted comprised of deep green, which was of greater magnitude, followed by xantha, albina and chlorina. In G_3 (CL147), higher percentage of deep green was observed followed by chlorina, xantha and albina. In the genotype G_1, higher percentage of chlorina followed by xantha, deep green and albina were accounted. Similarly, a higher percentage of deep green and chlorina followed by xantha and albina was registered in genotype G_2. This may be due to the intergenic difference in mode of action of the gamma rays. Different spectra were known to be induced by the same mutagen in different varieties of crop plants. (D'Amato *et al.*, 1962, Gustafsson, 1963 and Heslot, 1964).

The concept of mutagenic effectiveness and efficiency was reported by Konzak *et al.* (1965). The efficiency is considered an estimate of biological effects induced via lethality, injury and sterility, while the effectiveness is a measure of gene mutations in

relation to dose concentration. Hence to get high efficiency, the mutagenic effects must surpass other effects in the cell, such as chromosomal aberrations and other toxic effects, which results in damages. Doll and Sandfaer (1969) found a close relationship between chlorophyll mutations and viable mutations. In the present investigation, the reduction in lethality and injury showed a concomitant increase in the dosage levels. The mutagenic efficiency in terms of lethality and injury was found to be the highest in 2.0 kR followed by 2.5 kR. High efficiency of gamma rays at lower doses may be due to the enhanced activity perhaps as a result of gene interactions arising due to the positive effect of mutated genes. Further, a mutagen with localized action influencing the ontogenic physiological development of the selected material can alter its efficiency and effectiveness as postulated by Mikaelson (1968) and Swaminathan (1965) in turmeric.

Viable and macromutations

All the macro mutants have pleiotropic and linkage effects for various quantitative traits. The pleiotropic gene action had been a handicap because many progressive mutants have some negative feature combined with useful character (Gaul, 1977).

In the present investigation, a number of viable and economic macromutants were isolated for plant stature, number of tillers, maturity, yield, curcumin and oleoresin contents in vM_1 generation. However, their frequency was erratic and not dose dependant. The frequency was greater at treatment 2.0 kR and was lesser at 4.0 kR.

The plant stature mutants obtained in the present study consisted of tall and dwarf mutants. The percentage of tall mutants was high at the lower dose of gamma rays (2.5 kR), whereas the dwarf mutants were relatively in a high proportion and were found to be of high magnitude at the lowest dose of gamma rays (1.0 kR). Gamma irradiation may cause destruction or damage to apical meristems or partial failure of the internodes to elongate so as to result in decreased number of proliferating cells thereby resulting in

dwarf plants. Similar findings on stature mutants were obtained by Sanjeeviah (1967), Gupta and Jugran (1983), Sambandamurthi (1983) and Raghava *et al.* (1988).

Two types of tiller mutants were observed in this investigation. They were mutants with more number of tillers and mutants producing less number of tillers. A higher proportion of mutants with more number of tillers was observed in 3.0 kR, while the proportion of mutants with lesser number of tillers was higher in lower dose of 1.5 kR. It was likely that increased tillering was initiated by the damage to the primary growth meristems as influenced by the gamma ray treatment. The variability observed in the present investigation indicates the ability of gamma rays to induce variability for this character in turmeric. Creation of variability for quantitative traits due to mutagen treatments was reported by Gregory (1955), Rawlings *et al.* (1958), Bhaskaran and Swaminathan (1962), Gaul *et al.* (1966), Goud (1967), Shroff (1974), Conger *et al.* (1976), Rao and Siddiq (1976), Kumar and Das (1977) and Ravi *et al.* (1979).

On the basis of days to maturity, the viable mutants were categorized into early maturing and late maturing. Greater proportion of early maturing mutants was registered at 2.5 kR, whereas the proportion of mutants maturing late was observed at higher dose of 4.0 kR. The earliness in the days to maturity might be due to the triggering of metabolic activities at lower doses of gamma rays. This inturn might have resulted in diverting the source – sink relationship and resulted in breaking of the vegetative phase in an advanced phase. Similar findings were obtained by Jayachandran (1989) in ginger.

In the present investigation, the viable mutants for yield were grouped into mutants with high yield and low yield. The proportion of mutants with high yield was recorded at 2.0 kR. Similarly, a higher proportion of low yield mutants was obtained at the higher dose of 4.0 kR. The lower doses of gamma rays might have enhanced the enzymatic processes involved in the plant growth and development phase such as proper

stomatal functioning, enzyme production, photosynthetic efficiency in terms of net assimilation rate and portioning efficiency from the source to sink and related biochemical reactions. The low yield mutants with increased dose of gamma rays in the present study could be attributed to the reduction caused by the gamma rays on the plant growth. It may also be due to the inability of some of the mutated plants to survive upto maturity. Such yield mutants were also reported by Jayachandran (1989) in ginger.

A higher proportion of mutants with high curcumin content and oleoresin content was obtained at 3.0 kR, while a higher proportion of mutants with low curcumin and oleoresin content was registered at the higher doses of 3.5 and 4.0 kR respectively. Anatomical features namely central cylinder and cortex with more congregation of specialized cells which are the oleoresin bearing cells act as the site of curcumin accumulation. These specialized cells might have been increased at lower doses of gamma rays thereby favouring greater accumulation of curcumin and oleoresin contents. The low curcumin and oleoresin mutants occurred only at higher doses of gamma rays which indicated that higher doses of the gamma rays damaged the metabolic activity for the synthesis of these compounds. Similar findings on alkaloid mutants were obtained by Rajadurai (2001) in gloriosa.

Effect of gamma rays on genetic parameters

Variability

Induction of mutations in polygenic quantitative traits can be well detected by the estimation of variances, genetic advance and other genetical parameters of gamma ray treated population. Yield, being a complex trait, influenced by the contributing characters was found to be unstable due to contributing factors. Further, environment also played an important role, which can be deduced by the greater difference recorded by PCV. Many researchers have emphasized the role of induced mutations in producing useful genetic variation in quantitative characters. The success achieved through this line of crop

improvement work has been well documented (Brock, 1967). The information obtained on the range of variability, present in respect of different quantitative characters especially when grouped on the basis of heritable and non-heritable variation is of great significance because such estimation will be useful to determine with considerable accuracy, the extent to which a character will respond to selection process. It is evident from the current study that the analysis of variance indicated significant differences among the treatments for most of the traits.

The phenotypic coefficient of variation (PCV) measures the total variability available in the population and it does not provide information on the genetic portion of it. Hence, genotypic coefficient of variation (GCV) was reckoned as a better estimate for assessment of inherent variability (Allard, 1970). As the generations advanced, the genotypic coefficient of variation and phenotypic coefficient of variation reduced, indicating the poor chances of selecting progenies in later generations. Estimates of phenotypic coefficient of variation for all the traits in both the generations in the present investigation was in general slightly higher than the genotypic coefficient of variation indicating the influence of environmental factors on the traits.

In vM_o and vM_1 generations, genotypic correlation coefficient was higher than the phenotypic correlation coefficient, thus, revealing a strong association at genotypic level between the characters. This might be due to the masking effect of environment in modifying the total expression of the genotypes and hence phenotypic expression was reduced. This is in agreement with the previous findings of Reddy (1987), Maurya *et al.* (1998a) and Shanmugasundaram (1998) in turmeric.

In vM_o generation, the characters, yield per plant, number of primary rhizomes and number of secondary rhizomes recorded high PCV and GCV emphasizing these characters to be potentially variable. It was also observed that the differences between PCV and GCV were meagre revealing the fact that these traits were less influenced by the

environment. In vM_1 generation, the traits, yield per plant, number of primary rhizomes and weight of secondary rhizomes exhibited high PCV and GCV accentuate these characters to be potentially variable. Hence, selection will be more effective with respect to these characters. These findings are in corroboration with the earlier works of Indiresh *et al.* (1992), Radhakrishnan *et al.* (1995), Yadav and Singh (1996), Maurya *et al.*(1998b) and Shanmugasundaram (1998) in turmeric.

Heritability and genetic advance

Estimates of heritability appreciate the proportion of variation. "Heritability was in reality a measure of the efficiency of a selection system in separating genotypes". However, it provides no indication of the amount of genetic progress that would result from selecting the superior individuals. According to Robinson (1966), heritability was classified as low, medium and high. High heritability was indicative of genetic nature of induced mutations (Scossiroli, 1966). Low heritability and increased genetic advance highlight the greater role of non-additive genes than additive gene. Gaul *et al.* (1969) explained the inconsistency in estimates from generation to generation was due to limitation of the method used to estimate the variance. High genetic advance as per cent of mean for the yield per plant in the present study, indicates that selection can be relied upon for improvement of this parameter among the progenies.

High heritability recorded for sprouting per cent, height of the plant, days to maturity, number and length of primary rhizomes, number of secondary rhizomes, curcumin, oleoresin and essential oil contents indicated that selection of such characters is easy because of the close correspondence between the phenotype and genotype due to relatively smaller contribution of the environment to genotype. However, the estimates of heritability was low for number of tillers, number and weight of mother rhizomes, weight of primary rhizomes, rhizome to core diameter ratio and girth of secondary rhizomes for

which, selection may be considerably difficult or virtually impracticable due to the masking effect of the environment on genotypic effects.

Heritability along with genetic advance was more helpful in predicting the gain under selection than heritability estimates alone. Higher genetic advance was observed for yield per plant, number of primary rhizomes, length of primary rhizomes, number of secondary rhizomes and weight of secondary rhizomes in vM_o and vM_1 generations. High genetic advance was governed by additive genes and pave the way for improvement of those characters in individual plant selection (Panse, 1957). So the predominance of additive genetic variance in expression of these traits is the most reliable indices for effective selection These findings are in agreement with earlier reports by Maity *et* al. (1989) in ginger and Pandey and Dhobal (1993), Yadav and Singh (1996), Yadav (1999) and Shanmugasundaram *et al.* (2000) in turmeric.

Correlation

The ultimate goal of crop improvement in turmeric is to achieve a higher level of rhizome yield. Being a complex trait, the rhizome yield is largely influenced by many component characters. So information on strength and direction of correlation of these component characters on rhizome yield and *inter se* association among them would be useful in designing breeding programmes for yield improvement.

The relationship between yield and its component characters is likely to vary according to the genetic material used and environment under which the material is evaluated as well as due to interaction of these factors. Therefore, it is worthwhile to study the heritable association between variables (Genotypic correlation) for identification of important yield components so that due weightage can be given to the characters of importance in further breeding programmes (Johnson *et al.* 1955).

Among the twenty one characters studied, the positive association was noticed for height of the plant, number of tillers per plant, number and weight of mother rhizomes, number, weight, length and girth of primary and secondary rhizomes, curing per cent and oleoresin content, indicating the possibility of simultaneous improvement of component characters and yield per plant. The traits such as sprouting per cent, days to maturity, girth of mother rhizomes, rhizome to core diameter ratio, curcumin content and oleoresin content showed negative association with the yield. This apparent negative correlation at genetic level would have arisen from repulsion linkage of gene(s), controlling the direct and indirect effects. In vM_1 generation, yield per plant exhibited positive correlation with number of mother rhizomes, number, weight, length and girth of primary and secondary rhizomes and curing per cent. Conversely, the positive association was due to the coupling phase of linkage. This is in agreement with the earlier findings of Geetha and Prabhakaran (1987) and Shanmugasundaram (1998) with respect to number of mother rhizomes in turmeric. Correlation coefficients between the characters revealed that those characters that exerted positive association among others are prone for improvement and underlined the fact that one component character leads to the concurrent improvement of the other component characters. The findings are concurrent with Shanmugasundaram (1998) in turmeric.

Path analysis

Correlation coefficient between any two characters would not give a complete picture for a situation like yield which is controlled by several other traits, either directly or indirectly. In such situations, path coefficient analysis furnishes a means of measuring the direct effect of each trait as well as the indirect effect via other characters on yield. So information on the direct and indirect effect on yield is important which is explicable by path analysis proposed by Wright (1921) and illustrated by Dewey and Lu (1959). The interrelationships of the component characters on yield provide the likely consequences of their selection for simultaneous improvement of desirable characters with yield.

In vM_o generation, positive and direct effects on yield were high for weight of secondary rhizomes, followed by girth of primary rhizomes and number of primary rhizomes. Since the correlation of these characters with yield is positive, preference should be given to these characters in the selection programme to isolate superior lines with genetic potential for improving yield. Direct effect of height of the plant, number of tillers per plant, length of primay rhizomes, length of secondary rhizomes, curing per cent and oleoresin content on yield was negative. However, it exhibited a positive association phenotypically. This vivid conflict between the correlation and path coefficient analysis arouse largely from the fact that correlation simply measures the mutual association without regard to causation, while path specifies the relative importance of each causal factor. It is also evident from the study that direct selection can be made on rhizome characters as they are true components relating to yield and selection on these will be rewarding. This is supported by the earlier works of Nandi *et al.* (1992), Maurya *et al.* (1998a) and Shanmugasundaram (1998) in turmeric. Since the residual effects are low, it indicates that there were no other attributes than the selected variables which contributed for the yield per plant of turmeric.

As mentioned elsewhere in the discussion, the major barriers in the improvement of vegetatively propagated plants where vegetative plant parts have to be irradiated, are the chimera formation and diplontic selection. These are the complications caused by the multicellular nature of bud apex and the fact that mutation is a single cell event. This perforce results in a relatively low mutation frequency and probably a limited mutation spectrum. Stable periclinal chimeras cannot be expected in the early generations and selection has to wait till such time where stable periclinal chimera stage has been reached. These difficulties can be overcome to a large extent by the use of *in vivo* or *in vitro* adventitious bud technique as described by Broertjes *et al.* (1968). This technique is based on the phenomenon that the apex of the adventitious buds, such as may be found at

the base of the petiole of the detached leaves, originate from only one epidermal cell. Consequently, adventitious plantlets either are completely normal or are complete solid mutants. In otherwords, chimera formation does not take place. Moreover diplontic selection is restricted to the very initial stage of bud formation.

Turmeric being a sterile crop, mutation breeding is the only method of inducing variability where vegetative parts have to be subjected to mutagenic treatments. The findings of the investigations reveal that induction of variability in turmeric is possible but somatic sieve is very active and a serious diplontic drift is the consequence. Further studies are required for assessing the possibility of using *in vivo* and *in vitro* adventitious bud techniques and somaclonal variations.

Another suggestion is to irradiate or treat the rhizome buds at the earliest possible stage of development in order to give a mutated cell the best chance to take part in the formation of the rhizome (Broertjes and Van Harten, 1978). Mutagenic treatment should therefore take place immediately after harvest when no visible bud can be detected on the rhizome since buds are in ontogenetically young stage of development. Normally in Tamil Nadu, turmeric is harvested during January and sown during May, after nearly 3 to 4 months of storage. In the present study, such stored rhizome bits were treated immediately prior to planting. The method of treatment of the rhizomes immediately following harvest may be tried in future studies. To facilitate this, artificial conditions as provided by green houses or the conditions for raising summer crop is essentially required. This type of turmeric cultivation irrespective of the season will also help to avoid mortality occurring during the storage period of the rhizomes, in between generations. It is also suggested that the mutated genes be studied for the change in the ploidy level due to induction of mutation.

If these conditions can be taken care of, it is worthwhile trying mutagen treatment of turmeric rhizomes immediately after harvest and raising subsequent generations, without storage of the seed material, to get greater recovery of solid mutants.

CHAPTER -VI

SUMMARY

The present investigation on "Induction of mutagenesis in turmeric (*Curcuma longa* L.) through gamma rays for variability and quality improvement", was carried out during the year 2000 - 2003 in the Department of Spices and Plantation Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore. The salient findings of the present investigation are summarized hereunder:

vM_o generation

1. One hundred per cent sprouting was obtained in the treatment combinations, G_3T_3 (CL147, 2.0 kR) and G_2T_3 (CL146, 2.0 kR). The least per cent of 57.05 was registered in the treatment combination, G_3T_7 (CL147, 4.0 kR) as against the control (T_0) of G_3 (CL147) which recorded 59.80 per cent.
2. A progressive reduction with increase in the doses of gamma rays was observed with respect to the height of the plant. Greater height of the plant (89.00 cm) was exhibited in the treatment combination, G_3T_3 (CL147, 2.0 kR) at 225 DAP. Lesser height of the plant (72.35 cm) was obtained in G_2T_7 (CL146, 4.0 kR), whereas the control (T_0) of G_3 (CL147) registered 76.05 cm at 225 DAP.
3. With an increase in the doses of gamma radiation, proportionate reduction was observed in the number, length, breadth and area of leaves. The highest number of leaves (18.34) at 225 DAP was expressed in the treatment combination G_2T_3 (CL146, 2.0 kR), whereas the lowest number of leaves (10.84) was exhibited in the treatment combination G_3T_7 (CL147, 4.0 kR). The treatment combination G_2T_3 (CL146, 2.0 kR) exhibited the highest length, breadth and area of the leaf (53.22 cm, 18.84 cm and 718.35 cm^2 respectively) at 225 DAP as against the control (T_0) of G_1 (CL144) which recorded 14.22 leaves, a length of 49.35 cm, breadth of 16.59 cm and area of 589.48 cm^2 at 225 DAP.

4. There was drastic reduction in the number of tillers as the dose increased. Treatment combination G_1T_3 (CL144, 2.0 kR) registered greater number of tillers (4.88) at 225 DAP. Lesser number (2.23) was observed in G_1T_7 (CL144, 4.0 kR) at 225 DAP, while the control (T_0) of G_2 (CL146) obtained 2.36 tillers at 225 DAP. The treatment combination G_2T_3 (CL146, 2.0 kR) showed earliness in the 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), whereas the control (T_0) of G_2 (CL146) registered 260.06 days.

5. Higher number of mother rhizomes (2.50) was observed in the treatment combination G_3T_3 (CL147, 2.0 kR) followed by G_1T_4 (CL144, 2.5 kR) with 2.17, whereas the control (T_0) of G_1 (CL144) registered 1.00 mother rhizome. Increased weight of the mother rhizomes (72.51g) was observed in the combination G_2T_3 (CL146, 2.0 kR) as against the control (T_0) of G_2 (CL146) which exhibited 20.02 g. Lengthier mother rhizomes (8.53 cm) was produced by G_2 (CL146) at T_3 (2.0 kR). Treatment T_3 (2.0 kR) of G_2 (CL146) expressed an increased girth (13.70 cm) than the other treatments, whereas the control (T_0) of G_3 (CL147) expressed a length of 4.99 cm and a girth of 6.76 cm. The number, weight, length and girth of mother rhizomes reduced with increasing dose of gamma rays.

6. Treatment combination G_1T_3 (CL144, 2.0 kR) produced more number of primary rhizomes (12.25) and increased length of primary rhizomes (7.55 cm) whereas G_2T_3 (CL146, 2.0 kR) obtained the highest weight (27.34 g) and higher rhizome to core diameter ratio (2.11). Treatment T_3 (2.0 kR) recorded the highest girth of primary rhizomes (8.05 cm) in the genotype G_3 (CL147). The weight, girth and rhizome to core diameter ratio of primary rhizomes, registered in the control (T_0) of G_1 (CL144) were 12.63g, 6.41 cm and 1.41 respectively. Likewise, the number and length of primary rhizomes in the control (T_0) of G_2 (CL146) were 4.65 and 5.05 cm respectively.

7. Increased number of secondary rhizomes (17.75) and the highest weight of secondary rhizomes (81.25 g) was obtained in G_1T_3 (CL144, 2.0 kR). Genotype G_2 (CL146) produced greater length of secondary rhizomes (4.70 cm) whereas G_2T_3 (CL146, 2.0 kR) recorded the highest girth (7.53 cm). The number, weight and length of secondary rhizomes registered in the control (T_0) of G_2 (CL146) were 4.92, 25.50 g and 3.55 cm respectively whereas the girth of secondary rhizome in the control (T_0) of G_1 (CL144) was 4.00 cm.

8. There was reduction in the yield per plant and curing per cent with an increase in the dose of gamma rays. G_1T_3 (CL144, 2.0 kR) exhibited high yield per plant (373.75 g) whereas increased curing per cent (19.44) was obtained in G_1 (CL144) at T_3 (2.0 kR) as against the control (T_0) of G_2 (CL146) and G_3 (CL147) which obtained 97.88 g and 16.00 per cent respectively. Genotype, G_3 (CL147) at T_3 (2.0 kR) showed higher curcumin and oleoresin content (5.92 and 12.99 per cent respectively) whereas the highest essential oil content (6.06 per cent) was noticed in G_2 (CL146) at T_3 (2.0 kR). The curcumin, oleoresin and essential oil content in the control of G_1 (CL144), G_3 (CL147) and G_2 (CL146) were found to be 4.49, 10.55 and 4.62 per cent respectively.

9. Yield per plant exhibited greater PCV (44.71 per cent), followed by number of primary rhizomes (44.48 per cent). The highest GCV (38.33 per cent) was expressed in number of primary rhizomes followed by number of secondary rhizomes (37.77 per cent). Heritability in broad sense was high (90.00 per cent) for essential oil content followed by curcumin content (83.00 per cent), whereas increased GA as per cent of mean (66.04 per cent) was exhibited by number of primary rhizomes followed by yield per plant (41.60 per cent).

10. At genotypic level, weight of mother rhizomes (0.584**), number of primary rhizomes (0.556**), length of primary rhizomes (0.550**), girth of primary rhizomes (0.716**) and number of secondary rhizomes (0.566**) expressed highly significant and positive correlation with yield per plant, whereas sprouting

per cent (- 0.557**) and rhizome to core diameter ratio (-0.886**) exhibited highly significant and negative correlation.

11. Out of the fourteen characters studied for the path coefficient analysis, weight of secondary rhizomes (0.844), girth of primary rhizomes (0.740) and number of primary rhizomes (0.446) were the major contributing characters towards the yield per plant due to high positive direct effects. The traits such as height of the plant (-0.307), number of tillers per plant (-0.051), length of primary rhizomes (-0.762), length of secondary rhizomes (-0.628), curing per cent (-0.072) and oleoresin content (-0.072) were in the negative direction.

vM_1 generation

12. The highest sprouting per cent (96.00) was observed at T_3 (2.0 kR) in the genotypes G_2 (CL146) and G_3 (CL147) as against the control (T_0) of G_1 (CL144) and G_2 (CL146) with 70.00 per cent. Genotype, G_2 (CL146) promoted height of the plant (95.25 cm) at 225 DAP in the treatment T_3 (2.0 kR) while the control (T_0) of G_3 (CL147) recorded 78.33 cm. There was progressive reduction in the height of the plant with increase in the dose of gamma rays.

13. Treatment combination, G_2T_3 (CL146, 2.0 kR) produced the highest number of leaves (18.25) at 225 DAP, whereas greater length of leaf (57.34 cm) was exhibited by G_3T_3 (CL147, 2.0 kR). Increased breadth and area of the leaf (18.72 cm and 772.85 cm^2 respectively) were obtained in G_3T_3 (CL147, 2.0 kR).

14. More number of tillers (5.03) at 225 DAP was obtained in the treatment combination G_3T_3 (CL147, 2.0 kR) as against the control (T_0) of G_2 (CL146) which obtained 3.55 tillers. The treatment combination, G_1T_3 (CL144, 2.0 kR) showed earliness in the days to maturity (232.99 days), followed by G_2T_3 (CL146, 2.0 kR) (233.42 days). Delayed maturity (269.97 days) was observed in G_3T_7 (CL147, 4.0 kR), whereas the control (T_0) of G_2 (CL146) exhibited 248.17 days.

15. Greater number of mother rhizomes (3.00) was registered in the treatment combination G_3T_3 (CL147, 2.0 kR), whereas the highest weight and length of

mother rhizomes (74.18 g and 8.78 cm respectively) was obtained in G_2T_3 (CL146, 2.0 kR). A higher girth of mother rhizomes (13.81) was expressed in T_3 (2.0 kR) of the genotype G_2 (CL146). The number, weight, and length of mother rhizomes in the control (T_0) of G_2 (CL146) recorded were 1.00, 22.23 g and 5.00 cm respectively whereas control (T_0) of G_1 (CL144) registered a girth of 8.52 cm.

16. The highest number of primary rhizomes (12.50) and rhizome to core diameter ratio (1.94) were expressed in G_1T_3 (CL144, 2.0 kR), whereas G_2T_3 (CL146, 2.0 kR) recorded increased weight of primary rhizomes (27.00 g). The length of the primary rhizomes was greater (7.59 cm) at T_3 (2.0 kR) in the genotypes G_1 (CL144) and G_3 (CL147). The number and length of primary rhizomes in the control (T_0) of G_2 (CL146) were 4.55 and 5.00 cm respectively, the weight obtained in control (T_0) of G_1 (CL144) was 12.00 g while the girth and rhizome to core diameter ratio of primary rhizomes of G_3 (CL147) was found to be 6.55 cm and 1.45 respectively.

17. Increased number and weight of secondary rhizomes (17.59 and 80.14 g) were observed in G_1T_3 (CL144, 2.0 kR), while greater length and girth of secondary rhizomes (4.66 and 7.00 cm) were obtained in G_2T_3 (CL146, 2.0 kR). The number, weight and length of secondary rhizome recorded in the control (T_0) of G_2 (CL146) were 5.00, 26.13 g and 3.53 cm respectively and the girth obtained in the control (T_0) of G_3 (CL147) was found to be 6.00 cm.

18. The yield per plant was the highest (381.13 g) in the treatment combination G_1T_3 (CL144, 2.0 kR) as against the control (T_0) of G_2 (CL146) which exhibited 100.02 g whereas increased curing per cent (20.41) was exhibited by G_1 (CL144) at T_3 (2.0 kR) as against the control (T_0) of G_1 (CL144) which expressed 18.32 per cent.

19. Lower doses of gamma rays favoured for increase in the curcumin, oleoresin and essential oil contents. The highest curcumin, oleoresin and essential oil content (6.06, 13.47 and 6.28 per cent respectively) were exhibited in G_1 (CL144) at T_3

(2.0 kR). The control (T_0) of G_1 (CL144) recorded a curcumin content of 3.48 per cent while the control (T_0) of G_2 (CL146) registered 11.71 and 3.55 per cent of oleoresin and essential oil respectively.

20. In vM_1 generation, chlorophyll mutations were observed. Among the treatments employed, the highest mutation frequency (1.20) was observed at T_3 (2.0 kR) in the genotypes G_1 (CL144) and G_2 (CL146). Four different types of chlorophyll mutants *viz.*, xantha, albina, chlorina and deep green were observed. A high percentage of deep green (36.51) was recorded followed by xantha, albina and chlorina (19.04, 6.35 and 3.34 per cent respectively).

21. The mutagenic effectiveness was the highest (60.00 per cent) at T_3 (2.0 kR) in G_1 (CL144). The mutagenic efficiency in terms of lethality and injury were high (3.88 and 7.73 per cent respectively) at T_3 (2.0 kR) in G_1 (CL144).

22. The viable mutation frequency was higher (2.40 per cent) at T_3 (2.0 kR) in G_1 (CL144). Six types of viable mutants *viz.*, plant stature, number of tillers, maturity, yield, curcumin and oleoresin contents were obtained.

23. Two types of plant stature mutants viz., tall and dwarf were frequented. Greater magnitude of tall mutants (25.00 per cent) occurred at T_4 (2.5 kR) in G_3 (CL147), whereas dwarf mutant was higher (40.00 per cent) at T_1 (1.0 kR) in the genotype G_1 (CL 144). A higher proportion of mutants with more number of tillers (40.00 per cent) was observed in T_5 (3.0 kR) of G_1 (CL144) while lesser number of tillers was the highest (50.00 per cent) in T_2 (1.5 kR) of G_1 (CL144). Greater proportion of early maturing mutants (29.16 per cent) was registered in T_4 (2.5 kR) of G_1 (CL 144) whereas mutants maturing late (50.00 per cent) were observed in T_7 (4.0 kR) of G_3 (CL147).

24. The proportion of mutants with high yield (20. 83 per cent) was recorded in T_3 (2.0 kR) of G_1 (CL 144) and T_3 (2.0 kR) and T_5 (3.0 kR) of G_2 (CL 146). Similarly, low yield mutant (50.00 per cent) was noticed in T_7 (4.0 kR) of G_3 (CL147) and T_2 (1.5 kR) of G_1 (CL 144).

25. Greater magnitute of mutants with high and low curcumin content (40.00 per cent) was obtained in T_5 (3.0 kR) of G_1 (CL 144) and T_6 (3.5 kR) of G_2 (CL146) respectively. Likewise mutants with high and low oleoresin contents (50.01 and 26.67 per cent respectively) were seen in T_5 (3.0 kR) of G_2 (CL146) and T_7 (4.0 kR) of G_1 (CL 144) respectively.

26. Number of primary rhizomes exhibited the highest PCV and GCV (42.74 and 33.16 per cent respectively). Heritability in broad sense was high (67.00 per cent) for the height of the plant, followed by number of primary rhizomes (60.00 per cent). Greater value of genetic advance as per cent of mean (53.00 per cent) was expressed in number of primary rhizomes.

27. At genotypic level, number of primary rhizomes (0.906**), weight of primary rhizomes (0.624**), length of primary rhizomes (0.584**), girth of primary rhizomes (0.609**), number of secondary rhizomes (0.710**), weight of secondary rhizomes (0.901**), length of secondary rhizomes (0.558**) and curing per cent (0.882**) expressed highly significant and positive correlation with the yield per plant.

Table 1.Effect of gamma irradiation in turmeric genotypes on sprouting per cent in vM_0 generation.

Genotypes	**Treatments**	Sprouting per cent
G_1(CL144)	T_1(1.0kR)	70.91 (57.40)
	T_2(1.5kR)	73.25 (58.91)
	T_3(2.0kR)	88.24 (70.28)
	T_4(2.5kR)	75.42 (60.35)
	T_5(3.0kR)	74.56 (59.77)
	T_6(3.5kR)	60.47 (51.06)
	T_7(4.0kR)	58.40 (49.85)
	T_0(Control)	91.36 (73.53)
	Mean	74.08(60.14)
G_2(CL146)	T_1(1.0kR)	68.92 (56.15)
	T_2(1.5kR)	77.18 (61.55)
	T_3(2.0kR)	100.00 (67.42)
	T_4(2.5kR)	83.71 (66.37)
	T_5(3.0kR)	80.72 (64.07)
	T_6(3.5kR)	67.12 (55.04)
	T_7(4.0kR)	61.79 (51.84)
	T_0(Control)	69.10 (56.27)
	Mean	76.07 (59.84)
G_3(CL147)	T_1(1.0kR)	69.38 (56.44)
	T_2(1.5kR)	71.16 (57.56)
	T_3(2.0kR)	100.00 (65.81)
	T_4(2.5kR)	82.38 (65.33)
	T_5(3.0kR)	74.12 (59.48)
	T_6(3.5kR)	59.43 (50.45)
	T_7(4.0kR)	57.05 (49.06)
	T_0(Control)	59.80 (50.66)
	Mean	71.67 (56.85)
	Grand Mean	73.94 (58.94)
	CV(%)	6.50

	SEd	**CD(p=0.05)**	**CD(p=0.01)**
T	2.20	4.56	6.19
G	1.35	2.79	3.79
GxT	3.82	7.90	10.72

T-Treatment
G-Genotype
GxT-Genotype xTreatment
Figures in the parenthesis indicate arc sine transformed values.

Table 2. Effect of gamma irradiation in turmeric genotypes on height of the plant (cm) in vM$_0$generation.

Genotypes	Treatments	Height of the plant (cm)			
		90 DAP	135 DAP	180 DAP	225 DAP
G_1(CL144)	T_1(1.0kR)	48.07	52.97	68.89	80.58
	T_2(1.5kR)	51.95	59.55	69.48	83.92
	T_3(2.0kR)	54.11	64.00	73.08	87.14
	T_4(2.5kR)	54.00	63.49	72.15	86.34
	T_5(3.0kR)	53.22	62.08	70.84	84.22
	T_6(3.5kR)	46.73	57.22	67.00	76.81
	T_7(4.0kR)	45.00	50.05	66.81	73.89
	T_0(Control)	47.88	53.25	67.72	78.29
	Mean	45.36	57.83	69.50	81.40
G_2(CL146)	T_1(1.0kR)	42.11	50.07	65.49	75.22
	T_2(1.5kR)	44.25	52.81	67.00	77.42
	T_3(2.0kR)	50.99	63.99	72.11	88.19
	T_4(2.5kR)	48.74	60.73	70.89	85.34
	T_5(3.0kR)	47.00	58.11	69.21	83.25
	T_6(3.5kR)	43.87	54.22	64.81	73.00
	T_7(4.0kR)	40.55	48.00	63.08	72.35
	T_0(Control)	45.33	55.08	67.03	80.77
	Mean	50.12	55.50	67.45	79.44
G_3(CL147)	T_1(1.0kR)	46.92	52.19	68.12	79.84
	T_2(1.5kR)	48.00	56.92	69.00	82.19
	T_3(2.0kR)	52.19	62.75	71.14	89.00
	T_4(2.5kR)	51.98	61.94	70.83	87.64
	T_5(3.0kR)	50.75	58.67	69.54	86.22
	T_6(3.5kR)	45.18	50.22	65.99	75.00
	T_7(4.0kR)	44.02	48.33	65.55	74.45
	T_0(Control)	46.00	51.33	66.21	76.05
	Mean	48.13	55.29	68.30	81.30
	Grand Mean	47.87	56.21	68.42	80.71
	CV(%)	0.81	1.07	11.74	12.12

	90 DAP			135 DAP			180 DAP			225 DAP		
	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)
T	0.25	0.52	0.70	0.34	0.71	0.96	4.56	9.43	12.80	5.40	11.16	15.15
G	0.15	0.32	0.43	0.21	0.43	0.59	2.79	5.78	7.84	3.31	6.84	9.28
GxT	0.43	0.90	1.22	0.59	1.22	1.66	7.90	16.34	22.17	9.35	19.34	26.24

T-Treatment
G-Genotype
GxT-Genotype xTreatment
DAP – Days After Planting

Table 7. Effect of gamma irradiation in turmeric genotypes on number of tillers per plant in vM_0 generation.

Genotypes	Number of tillers per plant				
	Treatments	**90 DAP**	**135 DAP**	**180 DAP**	**225 DAP**
		1.87	1.99	3.50	3.82
	T_2(1.5kR)	1.92	2.52	3.61	4.00
	T_3(2.0kR)	2.25	3.01	4.00	4.88
	T_4(2.5kR)	2.18	2.79	3.98	4.67
	T_5(3.0kR)	2.09	2.65	3.72	4.21
	T_6(3.5kR)	1.01	1.72	2.55	2.88
	T_7(4.0kR)	1.00	1.59	2.16	2.23
	T_0(Control)	1.54	1.88	2.72	3.27
	Mean	1.73	2.27	3.28	3.75
G_2(CL146)	T_1(1.0kR)	1.72	1.99	2.97	3.73
	T_2(1.5kR)	1.81	2.25	3.08	3.95
	T_3(2.0kR)	2.00	2.94	3.98	4.49
	T_4(2.5kR)	1.98	2.87	3.77	4.75
	T_5(3.0kR)	1.85	2.78	3.65	4.00
	T_6(3.5kR)	1.68	1.90	2.35	2.88
	T_7(4.0kR)	1.23	1.50	2.10	2.36
	T_0(Control)	1.54	1.88	2.22	2.55
	Mean	1.73	2.26	3.02	3.59
G_3(CL147)	T_1(1.0kR)	1.88	2.74	3.00	3.34
	T_2(1.5kR)	1.96	2.69	3.66	4.00
	T_3(2.0kR)	2.11	3.00	3.99	4.51
	T_4(2.5kR)	2.01	2.99	3.84	4.20
	T_5(3.0kR)	2.00	2.81	3.75	4.18
	T_6(3.5kR)	1.59	2.00	2.73	3.00
	T_7(4.0kR)	1.33	1.73	2.50	2.66
	T_0(Control)	1.70	2.54	2.81	3.62
	Mean	1.82	2.56	3.28	3.69
	Grand Mean	1.76	2.36	3.19	3.70
	CV(%)	12.15	11.88	12.34	12.17

	90 DAP			**135 DAP**			**180 DAP**			**225 DAP**		
	SEd	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**
T	0.12	0.25	0.33	0.16	0.33	0.45	0.22	0.45	0.61	0.25	0.52	0.70
G	0.07	0.15	0.20	0.10	0.20	0.28	0.13	0.28	0.37	0.15	0.32	0.43
GxT	0.21	0.43	0.58	0.28	0.58	0.78	0.38	0.78	1.06	0.43	0.90	1.22

T-Treatment
G-Genotype
GxT-Genotype xTreatment
DAP – Days After Planting

Table 3. Effect of gamma irradiation in turmeric genotypes on number of leaves per plant in vM_0 generation.

Genotypes	Treatments	Number of leaves per plant			
		90 DAP	135 DAP	180 DAP	225 DAP
G_1(CL144)	T_1(1.0kR)	4.33	5.88	6.34	13.18
	T_2(1.5kR)	5.93	7.81	9.81	15.11
	T_3(2.0kR)	7.94	11.02	15.97	18.07
	T_4(2.5kR)	7.88	10.29	13.49	18.00
	T_5(3.0kR)	6.24	9.13	11.08	16.83
	T_6(3.5kR)	3.21	4.27	5.01	12.06
	T_7(4.0kR)	2.00	4.00	4.33	10.99
	T_0(Control)	5.00	6.27	8.11	14.22
	Mean	5.32	7.33	9.27	14.81
G_2(CL146)	T_1(1.0kR)	5.04	7.00	9.67	14.13
	T_2(1.5kR)	5.08	7.72	10.84	16.84
	T_3(2.0kR)	8.02	12.00	16.00	18.34
	T_4(2.5kR)	8.00	11.79	14.19	17.22
	T_5(3.0kR)	7.35	10.08	12.81	17.00
	T_6(3.5kR)	5.00	5.27	8.43	14.00
	T_7(4.0kR)	2.09	3.75	4.27	11.21
	T_0(Control)	3.87	4.00	6.27	12.03
	Mean	5.56	7.70	10.31	15.10
G_3(CL147)	T_1(1.0kR)	5.66	6.11	8.33	14.22
	T_2(1.5kR)	7.79	8.00	9.87	15.01
	T_3(2.0kR)	8.11	11.35	16.24	17.92
	T_4(2.5kR)	8.00	9.99	14.99	17.00
	T_5(3.0kR)	7.85	8.25	12.08	16.99
	T_6(3.5kR)	3.00	4.45	5.00	11.99
	T_7(4.0kR)	2.34	3.98	4.95	10.84
	T_0(Control)	4.21	5.00	6.22	12.19
	Mean	5.87	7.14	9.71	17.40
	Grand Mean	5.58	7.39	9.76	14.81
	CV(%)	7.93	8.04	8.00	7.49

	90 DAP			135 DAP			180 DAP			225 DAP		
	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)
T	0.12	0.25	0.33	0.16	0.33	0.45	0.22	0.45	0.61	0.25	0.52	0.70
G	0.07	0.15	0.20	0.10	0.20	0.28	0.13	0.28	0.37	0.15	0.32	0.43
GxT	0.21	0.43	0.58	0.28	0.58	0.78	0.38	0.78	1.06	0.43	0.90	1.22

T-Treatment
G-Genotype
GxT-Genotype xTreatment
DAP – Days After Planting

Table 4. Effect of gamma irradiation in turmeric genotypes on length of the leaf (cm) in vM_0 generation.

Genotypes	Treatments	Length of the leaf (cm)			
		90 DAP	135 DAP	180 DAP	225 DAP
G_1(CL144)	T_1(1.0kR)	16.11	28.12	40.11	48.84
	T_2(1.5kR)	17.33	32.77	44.39	50.33
	T_3(2.0kR)	20.98	37.08	47.33	53.00
	T_4(2.5kR)	20.02	35.99	46.46	52.54
	T_5(3.0kR)	19.43	34.02	45.08	51.14
	T_6(3.5kR)	15.92	26.15	39.15	47.73
	T_7(4.0kR)	14.00	25.98	38.99	46.94
	T_0(Control)	17.01	29.94	42.85	49.35
	Mean	17.60	31.26	43.05	49.98
G_2(CL146)	T_1(1.0kR)	17.65	29.91	42.39	50.00
	T_2(1.5kR)	18.81	31.94	44.14	50.09
	T_3(2.0kR)	21.24	37.20	47.18	53.22
	T_4(2.5kR)	21.12	36.44	45.59	52.01
	T_5(3.0kR)	20.05	35.83	45.03	51.54
	T_6(3.5kR)	15.55	28.85	40.12	49.21
	T_7(4.0kR)	15.84	27.74	39.00	48.88
	T_0(Control)	16.88	29.00	40.91	49.69
	Mean	18.39	32.11	43.05	50.58
G_3(CL147)	T_1(1.0kR)	17.26	30.17	44.14	48.84
	T_2(1.5kR)	17.94	32.81	45.92	49.00
	T_3(2.0kR)	20.21	36.99	47.09	51.25
	T_4(2.5kR)	19.90	36.00	48.17	51.01
	T_5(3.0kR)	18.08	34.12	46.64	49.54
	T_6(3.5kR)	15.59	28.85	42.35	48.19
	T_7(4.0kR)	14.19	26.94	40.00	47.35
	T_0(Control)	19.45	35.52	48.03	50.90
	Mean	17.83	32.68	45.54	49.51
	Grand Mean	17.86	32.02	43.88	49.98
	CV(%)	4.57	4.44	4.50	4.54

	90 DAP			135 DAP			180 DAP			225 DAP		
	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)
T	0.45	0.94	1.27	0.81	1.67	2.26	1.09	2.26	3.07	1.25	2.59	3.52
G	0.28	0.57	0.78	0.49	1.02	1.38	0.67	1.39	1.88	0.77	1.59	2.15
GxT	0.78	1.62	2.20	1.40	2.89	3.92	1.90	3.92	5.32	2.17	4.49	6.09

T-Treatment
G-Genotype
GxT-Genotype xTreatment
DAP – Days After Planting

Table 5. Effect of gamma irradiation in turmeric genotypes on breadth of the leaf (cm) in vM_0 generation

Genotypes	Treatments	Breadth of the leaf (cm)			
		90 DAP	135 DAP	180 DAP	225 DAP
G_1(CL144)	T_1(1.0kR)	6.01	9.45	13.14	16.22
	T_2(1.5kR)	6.76	11.00	14.86	17.32
	T_3(2.0kR)	7.99	12.00	16.03	18.59
	T_4(2.5kR)	7.84	11.76	15.89	18.11
	T_5(3.0kR)	7.05	11.66	15.72	17.81
	T_6(3.5kR)	5.26	9.00	13.00	15.23
	T_7(4.0kR)	5.01	8.55	12.94	14.00
	T_0(Control)	6.52	10.97	14.12	16.59
	Mean	6.55	10.55	14.46	16.73
G_2(CL146)	T_1(1.0kR)	6.11	11.00	15.04	17.03
	T_2(1.5kR)	6.85	11.23	15.26	17.18
	T_3(2.0kR)	8.13	12.59	16.15	18.84
	T_4(2.5kR)	7.94	12.00	16.02	18.19
	T_5(3.0kR)	7.20	11.45	15.66	17.66
	T_6(3.5kR)	5.00	10.01	14.11	16.26
	T_7(4.0kR)	4.95	9.99	13.03	15.15
	T_0(Control)	5.76	10.09	14.78	16.73
	Mean	6.48	11.05	15.01	17.13
G_3(CL147)	T_1(1.0kR)	6.54	10.00	13.01	15.77
	T_2(1.5kR)	6.98	10.08	14.26	16.65
	T_3(2.0kR)	8.13	12.21	15.99	17.84
	T_4(2.5kR)	8.00	12.19	15.87	17.31
	T_5(3.0kR)	7.11	10.76	14.79	16.90
	T_6(3.5kR)	5.59	9.97	12.95	15.12
	T_7(4.0kR)	4.92	8.55	12.21	14.00
	T_0(Control)	7.16	11.99	15.24	17.04
	Mean	6.80	10.88	14.29	16.40
	Grand Mean	6.62	10.77	14.59	16.76
	CV(%)	3.02	3.03	3.01	2.94

	90 DAP			135 DAP			180 DAP			225 DAP		
	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)
T	0.11	0.23	0.31	0.18	0.37	0.51	0.24	0.50	0.68	0.28	0.58	0.78
G	0.07	0.14	0.19	0.11	0.23	0.31	0.15	0.31	0.42	0.17	0.35	0.48
GxT	0.19	0.40	0.54	0.31	0.65	0.88	0.42	0.87	1.18	0.48	1.00	1.36

T-Treatment
G-Genotype
GxT-Genotype xTreatment
DAP – Days After Planting

Table 6. Effect of gamma irradiation in turmeric genotypes on area of the leaf (cm^2) in vM_0 generation.

Genotypes	Treatments	Area of the leaf (cm^2)			
		90 DAP	135 DAP	180 DAP	225 DAP
G_1(CL144)	T_1(1.0kR)	69.71	191.33	379.47	570.37
	T_2(1.5kR)	84.22	259.54	474.94	627.64
	T_3(2.0kR)	120.69	320.37	546.26	709.39
	T_4(2.5kR)	113.01	304.48	531.54	685.08
	T_5(3.0kR)	98.63	285.60	510.23	655.78
	T_6(3.5kR)	60.18	169.45	366.44	523.39
	T_7(4.0kR)	57.14	159.93	363.26	473.16
	T_0(Control)	79.85	236.48	435.63	589.48
	Mean	85.43	240.90	450.97	604.29
G_2(CL146)	T_1(1.0kR)	77.65	236.89	459.03	613.08
	T_2(1.5kR)	92.77	258.25	484.66	619.59
	T_3(2.0kR)	122.34	337.21	568.61	718.35
	T_4(2.5kR)	120.74	314.84	525.85	681.16
	T_5(3.0kR)	108.76	295.38	507.72	655.34
	T_6(3.5kR)	55.98	207.93	407.59	575.76
	T_7(4.0kR)	49.90	159.53	365.88	533.18
	T_0(Control)	69.88	210.68	435.35	598.55
	Mean	87.25	257.59	466.84	623.13
G_3(CL147)	T_1(1.0kR)	81.27	217.22	413.47	554.55
	T_2(1.5kR)	92.55	238.12	471.14	587.41
	T_3(2.0kR)	118.30	325.19	565.16	658.30
	T_4(2.5kR)	114.64	315.96	550.41	635.75
	T_5(3.0kR)	90.16	264.09	496.66	602.87
	T_6(3.5kR)	62.75	207.10	394.87	524.64
	T_7(4.0kR)	50.27	190.67	351.65	495.70
	T_0(Control)	100.27	306.64	527.02	624.48
	Mean	88.78	258.12	471.30	585.46
	Grand Mean	87.15	252.20	463.04	604.29
	CV(%)	4.69	4.58	4.45	4.56

	90 DAP			135 DAP			180 DAP			225 DAP		
	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)
T	2.26	4.67	6.34	6.38	13.21	17.92	11.70	24.20	32.84	15.20	31.44	42.67
G	1.38	2.86	3.88	3.91	8.09	10.97	7.16	14.82	20.11	9.31	19.23	26.13
GxT	3.91	8.09	10.97	11.06	22.87	31.04	20.26	41.91	56.87	26.33	54.46	73.91

T-Treatment
G-Genotype
GxT-Genotype xTreatment
DAP – Days After Planting

Table 8. Effect of gamma irradiation in turmeric genotypes on days to maturity in vM_0 generation.

Genotypes	Treatments	Days to maturity
G_1(CL144)	T_1(1.0kR)	270.20
	T_2(1.5kR)	260.88
	T_3(2.0kR)	223.11
	T_4(2.5kR)	230.92
	T_5(3.0kR)	234.13
	T_6(3.5kR)	271.08
	T_7(4.0kR)	282.02
	T_0(Control)	235.23
	Mean	250.95
G_2(CL146)	T_1(1.0kR)	257.11
	T_2(1.5kR)	249.69
	T_3(2.0kR)	219.02
	T_4(2.5kR)	221.53
	T_5(3.0kR)	227.09
	T_6(3.5kR)	264.09
	T_7(4.0kR)	268.65
	T_0(Control)	260.06
	Mean	245.91
G_3(CL147)	T_1(1.0kR)	266.80
	T_2(1.5kR)	246.01
	T_3(2.0kR)	221.83
	T_4(2.5kR)	227.28
	T_5(3.0kR)	242.28
	T_6(3.5kR)	269.72
	T_7(4.0kR)	288.10
	T_0(Control)	246.13
	Mean	251.02
	Grand Mean	249.30
	CV(%)	5.92

	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

T-Treatment
G-Genotype
GxT-Genotype xTreatment

Table 9. Effect of gamma irradiation in turmeric genotypes on number, weight (g) , length (cm) and girth of mother rhizomes (cm) in vM_0 generation.

Genotypes	Treatments	Number of mother rhizomes	Weight of mother rhizomes (g)	Length of mother rhizomes (cm)	Girth of mother rhizomes (cm)
G_1(CL144)	T_1(1.0kR)	1.17	27.50	6.55	9.03
	T_2(1.5kR)	1.17	32.50	6.68	9.23
	T_3(2.0kR)	2.17	43.34	7.55	11.63
	T_4(2.5kR)	2.00	35.63	7.53	10.38
	T_5(3.0kR)	1.50	35.63	7.50	10.24
	T_6(3.5kR)	1.17	26.04	5.98	8.73
	T_7(4.0kR)	1.00	25.63	5.95	5.30
	T_0(Control)	1.00	27.70	6.00	8.75
	Mean	1.40	31.75	6.74	9.16
G_2(CL146)	T_1(1.0kR)	1.00	21.88	5.45	9.50
	T_2(1.5kR)	1.70	28.75	5.63	9.88
	T_3(2.0kR)	1.50	72.51	8.53	13.70
	T_4(2.5kR)	1.17	51.00	7.10	12.18
	T_5(3.0kR)	1.17	31.25	5.83	11.33
	T_6(3.5kR)	1.00	17.50	5.03	8.05
	T_7(4.0kR)	1.00	16.25	4.30	6.93
	T_0(Control)	1.10	20.02	4.99	8.70
	Mean	1.34	32.40	5.86	10.03
G_3(CL147)	T_1(1.0kR)	1.00	33.75	6.25	9.50
	T_2(1.5kR)	1.00	41.25	6.33	10.30
	T_3(2.0kR)	2.50	58.75	8.05	12.43
	T_4(2.5kR)	1.17	46.25	7.05	10.60
	T_5(3.0kR)	1.17	43.50	6.93	10.30
	T_6(3.5kR)	1.00	33.13	6.05	6.25
	T_7(4.0kR)	1.00	31.25	5.05	4.78
	T_0(Control)	1.10	31.50	5.99	6.76
	Mean	1.24	39.92	6.44	8.87
	Grand Mean	1.26	34.69	6.35	9.35
	CV(%)	6.31	4.68	12.75	20.24

	1			2			3			4		
	SEd	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**
T	0.04	0.09	0.13	0.90	1.86	2.53	0.54	1.12	1.51	1.05	2.18	2.96
G	0.03	0.06	0.08	0.55	1.41	1.55	0.33	0.68	0.93	0.64	1.33	1.81
GxT	0.08	0.16	0.22	1.56	3.23	4.38	0.93	1.93	2.62	1.82	3.77	5.12

T-Treatment
G-Genotype
GxT-Genotype xTreatment

Table 10. Effect of gamma irradiation in turmeric genotypes on number, weight (g), length (cm) , girth (cm) and rhizome to core diameter ratio of primary rhizomes in vM_0 generation.

Genotypes	Treatments	Number of primary rhizomes	Weight of primary rhizomes (g)	Length of primary rhizomes (cm)	Girth of primary rhizomes (cm)	Rhizome to core diameter ratio
G_1(CL144)	T_1(1.0kR)	10.25	15.88	6.39	7.23	1.53
	T_2(1.5kR)	10.50	16.20	6.85	7.38	1.53
	T_3(2.0kR)	12.25	20.26	7.55	7.50	1.74
	T_4(2.5kR)	11.50	18.05	7.32	7.48	1.69
	T_5(3.0kR)	10.50	16.80	7.11	7.45	1.69
	T_6(3.5kR)	6.75	13.24	6.37	6.78	1.46
	T_7(4.0kR)	6.25	11.37	5.95	6.63	1.41
	T_0(Control)	9.65	12.63	6.76	6.41	1.58
	Mean	9.71	15.55	6.79	7.11	1.58
G_2(CL146)	T_1(1.0kR)	3.25	12.29	5.23	6.85	1.56
	T_2(1.5kR)	4.25	12.75	5.53	6.93	1.67
	T_3(2.0kR)	5.25	27.34	6.24	7.98	2.11
	T_4(2.5kR)	4.75	23.13	5.87	7.93	1.95
	T_5(3.0kR)	4.75	16.67	5.87	7.30	1.70
	T_6(3.5kR)	3.00	11.88	4.96	5.95	1.53
	T_7(4.0kR)	2.25	6.94	4.56	5.85	1.37
	T_0(Control)	4.65	12.64	5.05	6.44	1.78
	Mean	4.02	15.46	5.41	6.90	1.71
G_3(CL147)	T_1(1.0kR)	4.75	14.54	4.87	7.29	1.55
	T_2(1.5kR)	5.00	14.55	5.17	7.30	1.60
	T_3(2.0kR)	7.25	22.15	7.28	8.05	1.94
	T_4(2.5kR)	5.50	20.00	7.10	7.93	1.90
	T_5(3.0kR)	5.25	17.30	6.26	7.65	1.69
	T_6(3.5kR)	4.75	13.72	4.70	6.00	1.41
	T_7(4.0kR)	4.50	12.14	4.43	5.55	1.39
	T_0(Control)	4.70	14.00	5.61	6.66	1.64
	Mean	5.21	16.05	5.68	7.05	1.64
	Grand Mean	6.31	15.69	5.96	7.02	1.64
	CV(%)	6.36	4.69	7.54	9.22	2.86

	1			2			3			4			5		
	SEd	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**
T	0.23	0.48	0.65	0.41	0.84	1.14	0.25	0.52	0.71	0.36	0.74	1.01	0.03	0.06	0.08
G	0.14	0.29	0.40	0.25	0.52	0.70	0.16	0.32	0.44	0.22	0.45	0.62	0.02	0.03	0.05
G x T	0.40	0.83	1.12	0.70	1.46	1.98	0.44	0.91	1.23	0.29	0.62	1.75	0.05	0.10	0.13

T-Treatment,
G-Genotype
GxT-Genotype xTreatment

Table 11. Effect of gamma irradiation in turmeric genotypes on number, weight (g) , length (cm) and girth of secondary rhizomes (cm) in vM_0 generation.

Genotypes	Treatments	Number of secondary rhizomes	Weight of secondary rhizomes (g)	Length of secondary rhizomes (cm)	Girth of secondary rhizomes (cm)
G_1(CL144)	T_1(1.0kR)	12.00	57.50	3.65	4.93
	T_2(1.5kR)	12.25	71.25	3.95	4.98
	T_3(2.0kR)	17.75	81.25	4.30	5.98
	T_4(2.5kR)	14.75	72.50	4.25	5.80
	T_5(3.0kR)	14.75	71.25	3.95	5.75
	T_6(3.5kR)	11.25	45.00	3.38	4.63
	T_7(4.0kR)	10.50	28.00	3.13	3.90
	T_0(Control)	11.53	46.09	3.55	4.00
	Mean	13.10	59.11	3.79	5.00
G_2(CL146)	T_1(1.0kR)	3.75	20.50	3.00	4.60
	T_2(1.5kR)	4.75	21.25	3.30	5.30
	T_3(2.0kR)	8.25	52.50	4.70	7.53
	T_4(2.5kR)	5.50	52.50	3.73	6.35
	T_5(3.0kR)	5.25	23.75	3.63	6.03
	T_6(3.5kR)	3.25	20.00	2.55	4.60
	T_7(4.0kR)	2.50	18.75	2.10	4.10
	T_0(Control)	4.92	25.50	3.55	4.65
	Mean	4.77	29.35	3.32	5.40
G_3(CL147)	T_1(1.0kR)	8.25	43.75	4.03	5.88
	T_2(1.5kR)	8.25	55.00	4.13	6.10
	T_3(2.0kR)	11.75	72.50	4.30	6.35
	T_4(2.5kR)	11.50	63.75	4.30	6.18
	T_5(3.0kR)	9.50	60.00	4.25	6.15
	T_6(3.5kR)	9.25	40.13	3.50	5.58
	T_7(4.0kR)	6.23	30.00	3.43	5.43
	T_0(Control)	9.67	50.00	3.70	5.95
	Mean	9.30	51.89	5.95	3.94
	Grand Mean	9.06	46.78	3.68	5.45
	CV(%)	6.40	4.82	12.89	2.99

	1			2			3			4			5		
	SEd	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**
T	0.33	0.68	0.92	1.26	2.90	3.53	0.28	0.35	0.78	0.09	0.12	0.26	0.03	0.06	0.08
G	0.20	0.42	0.56	0.77	1.59	2.16	0.17	0.58	0.58	0.06	0.19	0.16	0.02	0.03	0.05
G x T	0.57	1.18	1.60	2.18	4.51	6.12	0.48	1.00	1.36	0.16	0.33	0.45	0.05	0.10	0.13

T-Treatment
G-Genotype
GxT-Genotype xTreatment

Table 12. Effect of gamma irradiation in turmeric genotypes on yield per plant (g) and curing percent in vM_0 generation.

Genotypes	Treatments	Yield per plant (g)	Curing percent
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 percent		
	SEd	**CD (p=0.05)**	**CD (p=0.01)**	**SEd**	**CD (p=0.05)**	**CD (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 xTreatment
Figures in the parenthesis indicate arc sine transformed values.

Table 13. Effect of gamma irradiation in turmeric genotypes on curcumin content (%),oleoresin content (%) and essential oil content (%) in vM_0 generation.

Genotypes	Treatments	Curcumin content (%)	Oleoresin content (%)	Essential oil content (%)
G_1(CL144)	T_1(1.0kR)	4.08 (11.65)	10.77 (19.15)	4.04 (11.59)
	T_2(1.5kR)	4.66 (12.46)	11.65 (19.95)	4.75 (12.59)
	T_3(2.0kR)	5.88 (12.76)	12.83 (20.98)	5.98 (14.15)
	T_4(2.5kR)	5.70 (12.52)	12.69 (20.86)	5.73 (13.85)
	T_5(3.0kR)	5.54 (13.61)	11.90 (20.18)	5.50 (13.56)
	T_6(3.5kR)	3.83 (11.28)	10.00 (18.43)	3.86 (11.33)
	T_7(4.0kR)	3.48 (10.75)	9.72 (18.16)	3.62 (10.97)
	T_0(Control)	4.49 (12.23)	11.08 (19.44)	4.56 (12.33)
	Mean	4.71 (12.16)	11.33 (19.64)	4.76 (12.55)
G_2(CL146)	T_1(1.0kR)	4.33 (12.01)	10.52 (18.92)	4.20 (11.82)
	T_2(1.5kR)	4.73 (12.56)	11.66 (19.96)	4.80 (12.65)
	T_3(2.0kR)	5.89 (14.04)	12.90 (21.05)	6.06 (14.25)
	T_4(2.5kR)	5.67 (13.77)	12.88 (21.03)	5.87 (14.02)
	T_5(3.0kR)	5.25 (13.24)	12.70 (20.88)	5.71 (13.82)
	T_6(3.5kR)	3.78 (11.21)	9.73 (18.17)	3.94 (11.45)
	T_7(4.0kR)	3.66 (11.03)	8.88 (17.33)	3.48 (10.75)
	T_0(Control)	4.50 (12.25)	11.48 (19.80)	4.62 (12.41)
	Mean	4.73 (12.51)	11.34 (19.64)	4.84 (12.65)
G_3(CL147)	T_1(1.0kR)	4.00 (11.53)	10.00 (18.43)	4.42 (12.13)
	T_2(1.5kR)	4.70 (12.52)	10.67 (19.06)	4.82 (12.68)
	T_3(2.0kR)	5.92 (14.08)	12.99 (21.12)	6.01 (14.19)
	T_4(2.5kR)	5.67 (13.77)	12.72 (20.89)	5.78 (13.91)
	T_5(3.0kR)	5.45 (13.50)	11.78 (20.07)	5.35 (13.37)
	T_6(3.5kR)	3.82 (11.27)	9.87 (18.31)	3.85 (11.31)
	T_7(4.0kR)	3.59 (10.92)	8.66 (17.11)	3.73 (11.13)
	T_0(Control)	4.52 (12.27)	10.55 (18.95)	4.59 (12.37)
	Mean	4.71 (12.48)	10.90 (19.24)	4.82 (12.64)
	Grand Mean	4.71 (12.39)	11.19 (19.51)	4.80 (12.61)
	CV(%)	3.84	3.94	2.97

	1			2			3		
	SEd	**CD (p=0.05)**	**CD (p=0.01)**	**SEd**	**CD (p=0.05)**	**CD (p=0.01)**	**SEd**	**CD (p=0.05)**	**CD (p=0.01)**
T	0.26	0.54	0.74	0.42	0.88	1.19	0.21	0.44	0.60
G	0.16	0.33	0.45	0.26	0.54	0.73	0.13	0.27	0.37
GxT	0.45	0.94	1.28	0.73	1.52	2.06	0.37	0.76	1.04

T-Treatment
G-Genotype
GxT-Genotype xTreatment
Figures in the parenthesis indicate arc sine transformed values.

Table 14. Effect of gamma irradiation in turmeric genotypes on sprouting per cent in vM$_1$generation.

Genotypes	Treatments	Sprouting per cent
G_1(CL144)	T_1(1.0kR)	68.10 (55.63)
	T_2(1.5kR)	71.15 (57.54)
	T_3(2.0kR)	95.88 (80.29)
	T_4(2.5kR)	90.13 (71.99)
	T_5(3.0kR)	75.00 (60.04)
	T_6(3.5kR)	66.34 (54.55)
	T_7(4.0kR)	58.22 (49.74)
	T_0(Control)	70.00 (56.81)
	Mean	74.35 (60.82)
G_2(CL146)	T_1(1.0kR)	71.09 (57.50)
	T_2(1.5kR)	75.54 (60.40)
	T_3(2.0kR)	96.00 (80.73)
	T_4(2.5kR)	88.14 (70.07)
	T_5(3.0kR)	79.98 (63.49)
	T_6(3.5kR)	69.35 (56.41)
	T_7(4.0kR)	67.79 (55.44)
	T_0(Control)	70.00 (56.81)
	Mean	77.24 (62.61)
G_3(CL147)	T_1(1.0kR)	69.93 (56.77)
	T_2(1.5kR)	70.00 (56.81)
	T_3(2.0kR)	96.00 (80.73)
	T_4(2.5kR)	87.88 (69.83)
	T_5(3.0kR)	72.12 (58.16)
	T_6(3.5kR)	66.72 (54.79)
	T_7(4.0kR)	60.00 (50.78)
	T_0(Control)	67.33 (55.16)
	Mean	73.75 (60.38)
	Grand Mean	75.11 (61.27)
	CV(%)	7.39

	SEd	CD(p=0.05)	CD(p=0.01)
T	2.50	5.18	7.03
G	1.53	3.17	4.30
GxT	4.33	8.97	12.17

T-Treatment
G-Genotype
GxT-Genotype xTreatment
Figures in the parenthesis indicate arc sine transformed values.

Table 15. Effect of gamma irradiation in turmeric genotypes on height of the plant (cm) in vM$_1$generation.

Genotypes	Treatments	Height of the plant (cm)			
		90 DAP	135 DAP	180 DAP	225 DAP
G_1(CL144)	T_1(1.0kR)	50.47	55.62	72.33	84.61
	T_2(1.5kR)	54.55	62.53	72.95	88.12
	T_3(2.0kR)	56.70	67.20	76.74	91.50
	T_4(2.5kR)	55.07	66.66	75.76	90.66
	T_5(3.0kR)	55.88	65.18	74.38	88.43
	T_6(3.5kR)	49.07	60.08	70.35	80.65
	T_7(4.0kR)	47.25	52.55	70.15	77.58
	T_0(Control)	50.27	55.91	71.11	82.20
	Mean	52.41	60.72	72.97	85.47
G_2(CL146)	T_1(1.0kR)	45.48	54.08	68.76	78.98
	T_2(1.5kR)	46.46	57.03	72.36	83.61
	T_3(2.0kR)	56.82	69.11	77.88	95.25
	T_4(2.5kR)	52.64	65.59	76.56	92.17
	T_5(3.0kR)	50.76	62.76	74.75	89.91
	T_6(3.5kR)	47.38	58.56	69.99	78.84
	T_7(4.0kR)	45.34	52.92	68.13	78.14
	T_0(Control)	48.96	59.49	72.39	87.23
	Mean	49.23	59.94	72.60	85.52
G_3(CL147)	T_1(1.0kR)	48.33	53.76	70.17	82.24
	T_2(1.5kR)	49.44	58.63	71.07	84.66
	T_3(2.0kR)	53.76	64.53	73.27	91.67
	T_4(2.5kR)	53.54	63.80	72.95	90.27
	T_5(3.0kR)	52.27	60.43	71.63	88.81
	T_6(3.5kR)	46.54	51.73	67.97	77.25
	T_7(4.0kR)	43.79	49.78	67.52	76.68
	T_0(Control)	47.38	52.87	68.20	78.33
	Mean	49.38	56.94	70.35	92.15
	Grand Mean	50.34	59.20	71.54	84.91
	CV(%)	7.57	7.69	9.21	10.28

	90 DAP			135 DAP			180 DAP			225 DAP		
	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)
T	2.10	4.35	5.91	2.59	5.35	7.26	3.73	7.72	10.48	4.85	10.03	13.61
G	1.29	2.67	3.62	1.58	3.28	4.45	2.29	4.73	6.42	2.95	6.14	8.34
GxT	3.64	7.54	10.23	4.48	9.27	12.58	6.47	13.38	18.16	8.40	17.38	23.58

T-Treatment
G-Genotype
GxT-Genotype xTreatment
DAP – Days After Planting

Table 20. Effect of gamma irradiation in turmeric genotypes on number of tillers per plant in vM_1generation.

Genotypes	Treatments	Number of tillers per plant			
		90 DAP	**135 DAP**	**180 DAP**	**225 DAP**
G_1(CL144)	T_1(1.0kR)	1.67	2.45	2.78	4.52
	T_2(1.5kR)	1.98	2.66	2.98	4.63
	T_3(2.0kR)	2.11	3.00	3.89	5.00
	T_4(2.5kR)	2.08	2.96	3.67	4.91
	T_5(3.0kR)	2.00	2.78	3.54	4.79
	T_6(3.5kR)	1.19	2.08	2.37	3.90
	T_7(4.0kR)	1.00	1.97	2.01	3.28
	T_0(Control)	1.37	2.19	2.55	4.39
	Mean	1.68	2.51	2.97	4.43
G_2(CL146)	T_1(1.0kR)	1.51	2.57	3.29	4.28
	T_2(1.5kR)	1.63	2.66	3.55	4.54
	T_3(2.0kR)	2.10	3.13	4.07	4.98
	T_4(2.5kR)	2.01	3.08	4.00	4.94
	T_5(3.0kR)	1.97	2.89	3.89	4.88
	T_6(3.5kR)	1.44	2.38	3.19	3.68
	T_7(4.0kR)	1.13	2.00	2.97	3.52
	T_0(Control)	1.30	2.12	3.00	3.55
	Mean	1.64	2.60	3.50	4.30
G_3(CL147)	T_1(1.0kR)	1.57	2.96	3.88	4.68
	T_2(1.5kR)	1.88	3.00	3.96	4.75
	T_3(2.0kR)	2.18	3.17	4.15	5.03
	T_4(2.5kR)	1.98	3.03	4.00	4.87
	T_5(3.0kR)	1.97	3.09	4.04	4.90
	T_6(3.5kR)	1.11	2.57	3.18	3.88
	T_7(4.0kR)	1.00	2.00	2.99	3.59
	T_0(Control)	1.22	2.77	3.62	4.00
	Mean	1.61	2.82	3.73	4.46
	Grand Mean	1.64	2.65	3.40	4.40
	CV(%)	12.46	11.87	12.22	11.99

	90 DAP			**135 DAP**			**180 DAP**			**225 DAP**		
	SEd	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**
T	0.11	0.23	0.32	0.18	0.37	0.50	0.23	0.47	0.64	0.29	0.60	0.82
G	0.07	0.14	0.19	0.11	0.23	0.31	0.14	0.29	0.39	0.18	0.37	0.50
GxT	0.20	0.40	0.55	0.31	0.64	0.87	0.40	0.82	1.12	0.51	1.05	1.42

T-Treatment
G-Genotype
GxT-Genotype xTreatment
DAP – Days After Planting

Table 16 Effect of gamma irradiation in turmeric genotypes on number of leaves per plant in vM_1generation.

Genotypes	Treatments	Number of leaves per plant			
		90 DAP	135 DAP	180 DAP	225 DAP
G_1(CL144)	T_1(1.0kR)	4.48	4.99	7.77	13.09
	T_2(1.5kR)	6.65	9.82	10.05	14.45
	T_3(2.0kR)	8.00	11.22	15.10	17.35
	T_4(2.5kR)	7.91	11.08	14.03	17.00
	T_5(3.0kR)	7.53	10.36	12.13	16.95
	T_6(3.5kR)	3.19	4.89	5.88	12.00
	T_7(4.0kR)	2.23	4.25	5.00	10.55
	T_0(Control)	5.11	7.00	9.01	13.75
	Mean	5.64	7.95	9.87	14.39
G_2(CL146)	T_1(1.0kR)	5.42	7.75	10.22	15.67
	T_2(1.5kR)	6.73	8.35	11.73	17.01
	T_3(2.0kR)	8.92	11.57	16.02	18.25
	T_4(2.5kR)	7.59	11.25	15.11	18.00
	T_5(3.0kR)	6.85	10.98	13.17	17.54
	T_6(3.5kR)	4.55	6.00	9.07	14.22
	T_7(4.0kR)	3.21	4.81	5.22	12.00
	T_0(Control)	4.51	5.32	7.81	12.99
	Mean	5.85	8.25	1103	15.71
G_3(CL147)	T_1(1.0kR)	6.32	8.28	9.45	14.12
	T_2(1.5kR)	6.85	9.13	10.07	14.37
	T_3(2.0kR)	7.98	10.97	15.89	18.23
	T_4(2.5kR)	8.55	10.00	15.11	17.88
	T_5(3.0kR)	8.12	9.72	13.17	16.65
	T_6(3.5kR)	4.01	6.01	6.16	11.15
	T_7(4.0kR)	3.55	5.11	5.11	10.95
	T_0(Control)	4.66	6.25	8.00	13.28
	Mean	6.37	8.18	10.39	14.58
	Grand Mean	5.96	8.13	10.43	14.89
	CV(%)	7.96	7.80	7.85	7.66

	90 DAP			135 DAP			180 DAP			225 DAP		
	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)
T	0.26	0.54	0.73	0.35	0.73	0.99	0.46	0.95	1.29	0.63	1.30	1.77
G	0.16	0.33	0.45	0.22	0.45	0.60	0.28	0.58	0.79	0.39	0.80	1.08
GxT	0.45	0.94	1.27	0.61	1.26	1.71	0.80	1.65	2.24	1.09	2.25	3.06

T-Treatment
G-Genotype
GxT-Genotype xTreatment
DAP – Days After Planting

Table 17. Effect of gamma irradiation in turmeric genotypes on length of the leaf (cm) in vM_1 generation.

Genotypes	Treatments	Length of the leaf (cm)			
		90 DAP	135 DAP	180 DAP	225 DAP
G_1(CL144)	T_1(1.0kR)	16.04	27.57	40.78	46.72
	T_2(1.5kR)	18.82	33.18	45.02	50.25
	T_3(2.0kR)	21.00	37.21	49.67	54.22
	T_4(2.5kR)	20.75	36.22	48.77	53.18
	T_5(3.0kR)	20.00	35.55	46.88	50.75
	T_6(3.5kR)	15.23	25.72	38.15	44.17
	T_7(4.0kR)	14.73	24.49	38.00	45.57
	T_0(Control)	18.21	30.41	43.11	48.81
	Mean	18.10	31.40	43.80	49.21
G_2(CL146)	T_1(1.0kR)	16.88	28.85	40.84	47.18
	T_2(1.5kR)	17.29	32.64	42.91	49.65
	T_3(2.0kR)	20.75	36.77	47.00	51.97
	T_4(2.5kR)	21.66	35.89	46.27	51.23
	T_5(3.0kR)	19.73	34.25	44.14	50.75
	T_6(3.5kR)	14.42	26.73	39.22	46.34
	T_7(4.0kR)	13.21	24.45	38.00	43.07
	T_0(Control)	15.33	28.33	40.00	47.00
	Mean	17.41	31.12	42.39	48.40
G_3(CL147)	T_1(1.0kR)	16.15	31.99	43.97	47.75
	T_2(1.5kR)	17.05	33.31	46.72	49.25
	T_3(2.0kR)	22.15	38.11	50.12	57.34
	T_4(2.5kR)	20.01	36.81	49.65	55.26
	T_5(3.0kR)	17.73	35.75	47.31	50.14
	T_6(3.5kR)	15.45	29.52	41.17	45.21
	T_7(4.0kR)	13.25	25.49	39.81	45.57
	T_0(Control)	19.22	36.05	49.00	53.82
	Mean	17.63	33.26	45.97	50.54
	Grand Mean	17.71	31.93	44.05	49.36
	CV(%)	4.46	4.53	4.55	4.41

	90 DAP			135 DAP			180 DAP			225 DAP		
	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)
T	0.45	0.93	1.26	0.80	1.66	2.25	1.11	2.29	3.11	1.24	2.56	3.47
G	0.27	0.57	0.77	0.49	1.01	1.38	0.68	1.40	1.90	0.76	1.56	2.12
GxT	0.77	1.60	2.18	1.39	2.87	3.89	1.92	3.96	5.38	2.14	4.43	6.01

T-Treatment
G-Genotype
GxT-Genotype xTreatment
DAP – Days After Planting

Table 18. Effect of gamma irradiation in turmeric genotypes on breadth of the leaf (cm) in vM_1 generation.

Genotypes	Treatments	Breadth of the leaf (cm)			
		90 DAP	135 DAP	180 DAP	225 DAP
G_1(CL144)	T_1(1.0kR)	6.00	10.86	13.10	15.45
	T_2(1.5kR)	7.22	11.55	14.21	16.25
	T_3(2.0kR)	8.02	12.59	15.97	17.35
	T_4(2.5kR)	8.11	12.05	15.65	17.01
	T_5(3.0kR)	7.65	11.87	14.98	16.92
	T_6(3.5kR)	5.35	9.97	12.77	15.07
	T_7(4.0kR)	4.54	9.52	12.35	14.59
	T_0(Control)	6.23	11.08	13.99	15.99
	Mean	6.76	11.19	14.13	16.08
G_2(CL146)	T_1(1.0kR)	6.25	10.99	14.67	16.92
	T_2(1.5kR)	6.53	11.07	15.02	17.00
	T_3(2.0kR)	7.24	12.00	16.00	18.00
	T_4(2.5kR)	7.00	11.91	15.92	17.89
	T_5(3.0kR)	6.92	11.87	15.54	17.24
	T_6(3.5kR)	5.72	10.00	14.28	16.02
	T_7(4.0kR)	4.89	9.72	13.21	15.73
	T_0(Control)	5.95	10.63	14.52	16.67
	Mean	6.31	11.02	14.90	16.93
G_3(CL147)	T_1(1.0kR)	5.99	10.89	14.11	16.89
	T_2(1.5kR)	6.59	11.13	14.66	17.00
	T_3(2.0kR)	8.51	13.11	16.27	18.72
	T_4(2.5kR)	7.97	12.99	16.00	18.31
	T_5(3.0kR)	6.77	11.75	15.35	17.22
	T_6(3.5kR)	5.22	10.22	13.00	16.11
	T_7(4.0kR)	5.00	9.87	12.88	15.28
	T_0(Control)	7.25	12.05	15.86	17.86
	Mean	6.54	11.50	14.77	17.17
	Grand Mean	6.54	11.24	14.60	16.73
	CV(%)	3.04	2.95	3.01	2.94

	90 DAP			135 DAP			180 DAP			225 DAP		
	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)
T	0.11	0.23	0.31	0.19	0.39	0.53	0.24	0.50	0.68	0.28	0.58	0.78
G	0.07	0.14	0.19	0.11	0.24	0.32	0.15	0.31	0.42	0.17	0.35	0.48
GxT	0.19	0.39	0.53	0.32	0.67	0.91	0.42	0.87	1.18	0.48	1.00	1.35

T-Treatment
G-Genotype
GxT-Genotype xTreatment
DAP – Days After Planting

Table 19. Effect of gamma irradiation in turmeric genotypes on area of the leaf (cm^2) in vM_1 generation.

Genotypes	Treatments	Area of the leaf (cm^2)			
		90 DAP	135 DAP	180 DAP	225 DAP
G_1(CL144)	T_1(1.0kR)	69.29	215.58	384.63	519.71
	T_2(1.5kR)	97.83	275.92	460.61	587.93
	T_3(2.0kR)	119.82	345.46	571.12	677.32
	T_4(2.5kR)	121.16	314.24	549.54	651.31
	T_5(3.0kR)	110.16	303.82	505.63	618.26
	T_6(3.5kR)	58.67	184.63	350.77	479.26
	T_7(4.0kR)	43.31	167.60	337.90	452.44
	T_0(Control)	81.68	242.60	434.24	561.94
	Mean	90.06	256.23	449.31	568.52
G_2(CL146)	T_1(1.0kR)	75.96	228.28	431.27	374.77
	T_2(1.5kR)	81.29	260.15	464.05	607.72
	T_3(2.0kR)	115.46	317.69	541.44	673.53
	T_4(2.5kR)	109.97	307.76	530.37	659.88
	T_5(3.0kR)	98.30	292.71	493.87	629.95
	T_6(3.5kR)	59.39	192.46	403.24	534.50
	T_7(4.0kR)	46.51	178.39	368.37	515.88
	T_0(Control)	65.67	216.83	446.98	564.11
	Mean	81.47	249.28	459.96	595.04
G_3(CL147)	T_1(1.0kR)	77.22	266.93	493.13	602.82
	T_2(1.5kR)	69.65	250.83	446.70	580.68
	T_3(2.0kR)	128.67	351.23	587.12	772.85
	T_4(2.5kR)	114.83	344.28	571.97	728.50
	T_5(3.0kR)	86.42	302.45	522.87	621.66
	T_6(3.5kR)	58.07	217.22	385.35	524.40
	T_7(4.0kR)	53.03	180.72	369.98	495.07
	T_0(Control)	100.33	312.77	559.12	572.85
	Mean	83.71	278.30	492.08	627.26
	Grand Mean	85.08	261.27	467.10	600.31
	CV(%)	4.67	4.63	4.56	4.44

	90 DAP			135 DAP			180 DAP			225 DAP		
	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)
T	2.20	4.54	6.17	6.68	13.82	18.76	11.77	24.34	33.03	15.03	31.08	42.18
G	1.35	2.78	3.78	4.09	8.47	11.49	7.21	14.91	20.23	9.20	19.04	25.83
GxT	3.81	7.87	10.68	11.57	223.94	32.49	20.38	42.16	57.21	26.03	53.84	73.07

T-Treatment
G-Genotype
GxT-Genotype xTreatment
DAP – Days After Planting

Table 21. Effect of gamma irradiation in turmeric genotypes on days to maturity in vM_1generation.

Genotypes	Treatments	Days to maturity
G_1(CL144)	T_1(1.0kR)	251.32
	T_2(1.5kR)	245.59
	T_3(2.0kR)	232.99
	T_4(2.5kR)	233.42
	T_5(3.0kR)	239.98
	T_6(3.5kR)	261.88
	T_7(4.0kR)	268.00
	T_0(Control)	256.63
	Mean	248.73
G_2(CL146)	T_1(1.0kR)	245.00
	T_2(1.5kR)	240.09
	T_3(2.0kR)	233.00
	T_4(2.5kR)	235.15
	T_5(3.0kR)	235.00
	T_6(3.5kR)	250.13
	T_7(4.0kR)	253.88
	T_0(Control)	245.99
	Mean	242.03
G_3(CL147)	T_1(1.0kR)	263.82
	T_2(1.5kR)	250.01
	T_3(2.0kR)	241.97
	T_4(2.5kR)	242.00
	T_5(3.0kR)	244.22
	T_6(3.5kR)	268.12
	T_7(4.0kR)	269.97
	T_0(Control)	255.93
	Mean	254.51
	Grand Mean	248.17
	CV(%)	4.51

	SEd	CD(p=0.05)	CD(p=0.01)
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 xTreatment

Table 22. Effect of gamma irradiation in turmeric genotypes on number, weight (g) , length (cm) and girth of mother rhizomes (cm) in vM_1 generation.

Genotypes	Treatments	Number of mother rhizomes	Weight of mother rhizomes (g)	Length of mother rhizomes (cm)	Girth of mother rhizomes (cm)
G_1(CL144)	T_1(1.0kR)	1.20	27.53	6.63	9.00
	T_2(1.5kR)	1.20	34.12	6.77	9.69
	T_3(2.0kR)	2.00	45.15	7.83	11.98
	T_4(2.5kR)	2.50	35.73	7.78	10.57
	T_5(3.0kR)	1.50	35.39	7.69	10.50
	T_6(3.5kR)	1.20	26.62	5.73	8.50
	T_7(4.0kR)	1.00	25.15	5.69	6.00
	T_0(Control)	1.00	29.92	5.99	8.52
	Mean	1.45	32.45	6.76	9.35
G_2(CL146)	T_1(1.0kR)	1.00	23.55	5.54	9.83
	T_2(1.5kR)	1.75	28.73	5.89	9.99
	T_3(2.0kR)	2.00	74.18	8.78	13.81
	T_4(2.5kR)	1.75	53.21	7.25	12.22
	T_5(3.0kR)	1.75	34.19	6.00	11.54
	T_6(3.5kR)	1.00	17.51	5.00	8.12
	T_7(4.0kR)	1.00	16.59	4.62	7.03
	T_0(Control)	1.50	22.23	5.00	9.00
	Mean	1.47	33.77	6.01	10.19
G_3(CL147)	T_1(1.0kR)	1.00	34.02	6.57	10.00
	T_2(1.5kR)	1.00	42.00	6.78	10.50
	T_3(2.0kR)	3.00	60.00	8.00	12.81
	T_4(2.5kR)	2.00	48.12	7.12	10.98
	T_5(3.0kR)	2.00	45.39	7.02	10.67
	T_6(3.5kR)	1.00	33.14	6.25	6.55
	T_7(4.0kR)	1.00	31.72	5.66	5.00
	T_0(Control)	1.15	32.02	6.00	6.89
	Mean	1.52	40.80	6.68	9.18
	Grand Mean	1.48	35.68	6.48	9.57
	CV(%)	6.33	4.77	6.11	19.21

	1			2			3			4		
	SEd	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**
T	0.05	0.11	0.15	0.95	1.96	2.67	0.22	0.45	0.61	1.00	2.07	2.82
G	0.03	0.07	0.09	0.58	1.20	1.63	0.13	0.28	0.38	0.61	1.27	1.73
GxT	0.09	0.19	0.26	0.65	3.40	4.62	0.38	0.78	1.06	1.74	3.58	4.88

T-Treatment
G-Genotype
GxT-Genotype xTreatment

Table 23. Effect of gamma irradiation in turmeric genotypes on number, weight (g), length (cm), girth (cm) and rhizome to core diameter ratio of primary rhizomes in vM_1 generation.

Genotypes	Treatments	Number of primary rhizomes	Weight of primary rhizomes (g)	Length of primary rhizomes (cm)	Girth of primary rhizomes (cm)	Rhizome to core diameter ratio
G_1(CL144)	T_1(1.0kR)	10.25	15.94	6.22	7.00	1.26
	T_2(1.5kR)	10.55	16.80	6.92	7.25	1.32
	T_3(2.0kR)	12.50	20.00	7.59	7.72	1.94
	T_4(2.5kR)	11.00	18.75	7.25	7.55	1.69
	T_5(3.0kR)	10.65	16.99	7.03	7.41	1.36
	T_6(3.5kR)	6.95	13.45	6.13	6.59	1.25
	T_7(4.0kR)	6.00	11.22	6.00	6.25	1.25
	T_0(Control)	10.00	12.00	6.50	6.00	1.60
	Mean	9.74	15.64	6.79	6.54	1.46
G_2(CL146)	T_1(1.0kR)	4.25	12.00	5.66	6.98	1.46
	T_2(1.5kR)	4.50	12.95	5.73	7.00	1.47
	T_3(2.0kR)	5.55	27.00	6.92	7.77	1.80
	T_4(2.5kR)	4.75	24.11	6.55	7.68	1.69
	T_5(3.0kR)	4.65	16.65	6.00	7.54	1.66
	T_6(3.5kR)	3.00	11.12	4.58	5.78	1.45
	T_7(4.0kR)	2.50	7.00	4.23	5.55	1.21
	T_0(Control)	4.55	12.77	5.00	6.50	1.61
	Mean	4.22	15.45	5.41	5.74	1.54
G_3(CL147)	T_1(1.0kR)	4.99	14.23	5.23	7.00	1.36
	T_2(1.5kR)	5.22	14.00	5.50	7.29	1.45
	T_3(2.0kR)	7.00	22.00	7.59	8.00	1.56
	T_4(2.5kR)	5.67	21.12	7.00	7.95	1.53
	T_5(3.0kR)	5.50	18.00	6.85	7.55	1.48
	T_6(3.5kR)	4.83	13.54	4.04	6.12	1.33
	T_7(4.0kR)	4.33	12.02	3.15	5.09	1.19
	T_0(Control)	4.75	14.00	6.00	6.55	1.45
	Mean	5.29	16.11	5.68	5.67	1.42
	Grand Mean	6.41	15.74	5.99	6.92	1.47
	CV(%)	6.47	4.63	15.74	9.57	3.04

	1			2			3			4			5		
	SEd	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**	**SEd**	**CD (p= 0.05)**	**CD (p= 0.01)**
T	0.23	0.48	0.65	0.41	0.85	1.15	0.52	1.09	1.47	0.39	0.80	1.08	0.02	0.05	0.07
G	0.14	0.29	0.40	0.25	0.52	0.70	0.32	0.66	0.90	0.24	0.49	0.66	0.02	0.03	0.04
G x T	0.40	0.83	1.13	0.71	1.47	1.99	0.91	1.88	2.55	0.67	1.38	1.87	0.04	0.09	0.12

T-Treatment
G-Genotype
GxT-Genotype xTreatment

Table 24. Effect of gamma irradiation in turmeric genotypes on number, weight (g), length (cm) and girth of secondary rhizomes (cm) in vM$_1$generation.

Genotypes	Treatments	Number of secondary rhizomes	Weight of secondary rhizomes (g)	Length of secondary rhizomes (cm)	Girth of secondary rhizomes (cm)
G_1(CL144)	T_1(1.0kR)	12.00	55.49	3.77	4.98
	T_2(1.5kR)	12.00	72.88	3.99	5.00
	T_3(2.0kR)	17.59	80.14	4.52	5.89
	T_4(2.5kR)	15.89	74.52	4.50	5.72
	T_5(3.0kR)	14.59	73.00	4.00	5.63
	T_6(3.5kR)	11.34	48.09	3.58	4.75
	T_7(4.0kR)	10.51	30.19	3.22	4.00
	T_0(Control)	11.82	45.66	3.62	4.50
	Mean	13.22	60.00	3.90	5.06
G_2(CL146)	T_1(1.0kR)	3.78	20.72	3.00	4.63
	T_2(1.5kR)	4.98	21.50	3.42	6.00
	T_3(2.0kR)	8.00	54.00	4.66	7.00
	T_4(2.5kR)	6.20	53.15	3.83	6.93
	T_5(3.0kR)	5.63	22.12	3.72	6.50
	T_6(3.5kR)	3.50	20.00	3.00	4.52
	T_7(4.0kR)	3.21	18.00	2.20	4.00
	T_0(Control)	5.00	26.13	3.53	5.00
	Mean	5.04	29.45	3.42	5.57
G_3(CL147)	T_1(1.0kR)	9.00	45.33	3.89	5.92
	T_2(1.5kR)	9.52	57.19	3.99	6.20
	T_3(2.0kR)	11.50	71.43	4.50	6.59
	T_4(2.5kR)	11.00	64.00	4.29	6.25
	T_5(3.0kR)	9.77	62.12	4.00	6.22
	T_6(3.5kR)	8.53	41.09	3.55	5.00
	T_7(4.0kR)	6.00	40.00	3.50	4.85
	T_0(Control)	10.04	52.00	3.80	6.00
	Mean	9.42	54.15	3.94	5.89
	Grand Mean	9.23	47.88	3.75	5.51
	CV(%)	6.52	4.81	7.62	3.00

	1			2			3			4		
	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)	SEd	CD (p= 0.05)	CD (p= 0.01)
T	0.33	0.69	0.93	1.28	2.66	3.60	0.28	0.58	0.44	0.09	0.19	0.26
G	020	0.42	0.57	0.79	1.63	2.21	0.17	0.35	0.27	0.06	0.12	0.16
GxT	0.58	1.19	1.62	2.22	4.60	6.24	0.48	1.00	0.77	0.16	0.33	0.44

T-Treatment
G-Genotype
GxT-Genotype xTreatment

Table 25. Effect of gamma irradiation in turmeric genotypes on yield per plant (g) and curing percent in vM_1 generation.

Genotypes	Treatments	Yield per plant (g)	Curing percent
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 percent		
	SEd	**CD (p=0.05)**	**CD (p=0.01)**	**SEd**	**CD (p=0.05)**	**CD (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 xTreatment
Figures in the parenthesis indicate arc sine transformed values.

Table 26. Effect of gamma irradiation in turmeric genotypes on curcumin content (%),oleoresin content (%) and essential oil content (%) in vM_1generation.

Genotypes	Treatments	Curcumin content (%)	Oleoresin content (%)	Essential oil content (%)
G_1(CL144)	T_1(1.0kR)	4.20 (11.82)	11.31 (19.65)	4.24 (11.88)
	T_2(1.5kR)	4.80 (12.65)	12.23 (20.46)	4.99 (12.91)
	T_3(2.0kR)	6.06 (14.25)	13.47 (21.53)	6.28 (14.51)
	T_4(2.5kR)	5.87 (14.02)	13.07 (21.19)	6.02 (14.20)
	T_5(3.0kR)	5.71 (13.82)	12.50 (20.70)	5.78 (13.91)
	T_6(3.5kR)	3.94 (11.45)	10.50 (18.91)	4.05 (11.61)
	T_7(4.0kR)	3.48 (10.75)	10.21 (18.63)	3.80 (11.24)
	T_0(Control)	4.62 (12.41)	11.63 (19.93)	4.79 (12.64)
	Mean	4.84 (12.65)	11.87 (20.13)	4.99 (12.86)
G_2(CL146)	T_1(1.0kR)	4.42 (12.13)	10.73 (19.12)	4.28 (11.94)
	T_2(1.5kR)	4.82 (12.68)	11.89 (20.17)	4.90 (12.79)
	T_3(2.0kR)	6.01 (14.19)	13.16 (21.26)	6.18 (14.39)
	T_4(2.5kR)	5.78 (13.91)	12.14 (21.25)	5.99 (14.16)
	T_5(3.0kR)	5.35 (13.37)	12.95 (21.09)	5.82 (13.96)
	T_6(3.5kR)	3.85 (11.31)	9.92 (18.35)	4.02 (11.56)
	T_7(4.0kR)	3.73 (11.13)	9.06 (17.51)	3.55 (10.86)
	T_0(Control)	4.59 (12.37)	11.71 (20.01)	4.71 (12.53)
	Mean	4.82 (12.64)	11.45 (19.85)	4.93 (12.77)
G_3(CL147)	T_1(1.0kR)	4.04 (11.59)	10.30 (18.72)	4.55 (12.31)
	T_2(1.5kR)	4.75 (12.59)	10.99 (19.36)	4.96 (12.87)
	T_3(2.0kR)	5.98 (14.15)	13.38 (21.45)	6.19 (14.40)
	T_4(2.5kR)	5.73 (13.85)	13.10 (21.22)	5.95 (14.12)
	T_5(3.0kR)	5.50 (13.56)	12.13 (20.38)	5.51 (13.57)
	T_6(3.5kR)	3.86 (11.33)	10.17 (18.59)	3.97 (11.49)
	T_7(4.0kR)	3.62 (10.97)	8.92 (17.37)	3.84 (11.30)
	T_0(Control)	4.56 (12.33)	10.87 (19.25)	4.73 (12.56)
	Mean	4.76 (12.55)	11.23 (19.54)	4.96 (12.83)
	Grand Mean	4.80 (12.61)	11.51 (19.84)	4.96 (12.82)
	CV(%)	3.07	3.95	3.00

	1			2			3		
	SEd	**CD (p=0.05)**	**CD (p=0.01)**	**SEd**	**CD (p=0.05)**	**CD (p=0.01)**	**SEd**	**CD (p=0.05)**	**CD (p=0.01)**
T	0.21	0.44	0.60	0.43	0.90	1.21	0.22	0.45	0.61
G	0.13	0.27	0.37	0.26	0.55	0.74	0.13	0.28	0.37
GxT	0.37	0.76	1.04	0.75	1.55	2.10	0.38	0.78	1.06

T-Treatment
G-Genotype
GxT-Genotype xTreatment
Figures in the parenthesis indicate arc sine transformed values.

Table 27. Frequency of chlorophyll mutants (%) of turmeric genotypes in vM_1 generation.

Genotypes	Treatments	Total M_1 plants studied	Total number of chlorophyll mutants	Mutation frequency (%)
G_1(CL144)	T_1(1.0kR)	250.00	1.00	0.40
	T_2(1.5kR)	250.00	1.00	0.40
	T_3(2.0kR)	250.00	3.00	1.20
	T_4(2.5kR)	250.00	3.00	1.20
	T_5(3.0kR)	250.00	2.00	0.80
	T_6(3.5kR)	250.00	1.00	0.40
	T_7(4.0kR)	250.00	1.00	0.40
	Mean	250.00	1.71	0.69
G_2(CL146)	T_1(1.0kR)	250.00	1.00	0.40
	T_2(1.5kR)	250.00	1.00	0.40
	T_3(2.0kR)	250.00	2.00	0.80
	T_4(2.5kR)	250.00	3.00	1.20
	T_5(3.0kR)	250.00	2.00	0.80
	T_6(3.5kR)	250.00	1.00	0.40
	T_7(4.0kR)	250.00	1.00	0.40
	Mean	250.00	1.57	0.63
G_3(CL147)	T_1(1.0kR)	250.00	1.00	0.40
	T_2(1.5kR)	250.00	1.00	0.40
	T_3(2.0kR)	250.00	2.00	0.80
	T_4(2.5kR)	250.00	2.00	0.80
	T_5(3.0kR)	250.00	1.00	0.40
	T_6(3.5kR)	250.00	1.00	0.40
	T_7(4.0kR)	250.00	1.00	0.40
	Mean	250.00	1.29	0.51
	Grand Mean	250.00	1.52	0.61

Table 28. Types of chlorophyll mutants of turmeric genotypes in vM_1 generation.

Genotypes	Treatments	Total number of chlorophyll mutants	Relative percent of chlorophyll mutant			
			Xantha	Albina	Chlorina	Deep green
G_1(CL144)	T_1(1.0kR)	1.00	_	_	1(100.00)	_
	T_2(1.5kR)	1.00	1(100.00)	_	_	_
	T_3(2.0kR)	3.00	1(33.33)	_	1(33.33)	1(33.33)
	T_4(2.5kR)	3.00	1(33.33)	1(33.33)	1(33.33)	_
	T_5(3.0kR)	2.00	_	_	1(50.00)	1(50.00)
	T_6(3.5kR)	1.00	1(100)	_	_	_
	T_7(4.0kR)	1.00	_	_	1(100)	_
	Mean	1.71	0.57(38.09)	0.14(4.76)	0.71(45.24)	0.29(11.90)
G_2(CL146)	T_1(1.0kR)	1.00	_	_	1(100)	_
	T_2(1.5kR)	1.00	_	_	_	1(100.00)
	T_3(2.0kR)	2.00	_	_	1(150)	1(50.00)
	T_4(2.5kR)	3.00	1(33.33)	_	1(33.33)	1(33.33)
	T_5(3.0kR)	2.00	1(50)	1(50)	_	1(100.00)
	T_6(3.5kR)	1.00	_	_	1(100)	_
	T_7(4.0kR)	1.00	_	_	_	_
	Mean	1.57	0.29(11.90)	0.14(7.14)	0.57(40.48)	0.57(40.48)
G_3(CL147)	T_1(1.0kR)	1.00	_	_	_	1(100.00)
	T_2(1.5kR)	1.00	_	_	-	1(100.00)
	T_3(2.0kR)	2.00	1(50.00)	_	1(50.00)	_
	T_4(2.5kR)	2.00	_	1(50.00)	1(50.00)	_
	T_5(3.0kR)	1.00	_	_	_	1(100.00)
	T_6(3.5kR)	1.00	_	_	_	1(100.00)
	T_7(4.0kR)	1.00	_	_	_	1(100.00)
	Mean	1.29	0.14 (7.14)	0.14(7.14)	0.29(14.29)	0.57(57.14)
	Grand Mean	1.52	0.33(19.04)	0.14(6.35)	0.52(3.34)	0.48(36.51)

Figures in the parenthesis indicate arc sine transformed values.

Table 29. Mutagenic effectiveness and efficiency of chlorophyll mutation (%) of turmeric genotypes in vM_1 generation.

Geno-types	Treat-ments	Survival percent (Lethality)(L)	Percent reduction in height (Injury) (I)	Mutants per 100 M_1 plants (per cent) (M)	Mutagenic effectiveness (%) $\frac{M \times 100}{Dose}$	Mutagenic efficiency (%)	
						$\frac{M \times 100}{L}$	$\frac{M \times 100}{I}$
G_1 (CL144)	T_1(1.0kR)	38.00	21.22	0.40	40.00	1.05	1.89
	T_2(1.5kR)	37.60	19.89	0.40	26.67	1.06	2.01
	T_3(2.0kR)	30.90	15.52	1.20	60.00	3.88	7.73
	T_4(2.5kR)	34.50	17.29	1.20	48.00	3.47	6.94
	T_5(3.0kR)	32.40	16.55	0.80	26.67	2.47	4.83
	T_6(3.5kR)	38.00	20.20	0.40	11.43	1.05	1.98
	T_7(4.0kR)	41.20	24.15	0.40	10.00	0.97	1.66
	Mean	36.09	19.26	0.69	31.82	1.51	2.90
G_2 (CL146)	T_1(1.0kR)	38.10	20.24	0.40	40.00	1.04	1.97
	T_2(1.5kR)	36.60	18.19	0.40	26.67	1.09	2.20
	T_3(2.0kR)	35.50	15.00	0.80	40.00	2.25	5.33
	T_4(2.5kR)	34.20	15.92	1.20	48.00	3.51	7.53
	T_5(3.0kR)	36.10	16.21	0.80	26.67	2.21	4.93
	T_6(3.5kR)	37.70	19.99	0.40	11.43	1.06	2.00
	T_7(4.0kR)	40.10	22.13	0.40	10.00	1.00	1.81
	Mean	36.90	18.24	0.63	28.97	1.50	3.19
G_3 (CL147)	T_1(1.0kR)	36.70	21.99	0.40	40.00	1.09	1.81
	T_2(1.5kR)	35.60	22.81	0.40	26.67	1.12	1.75
	T_3(2.0kR)	34.50	19.02	0.80	40.00	2.32	4.20
	T_4(2.5kR)	36.80	21.19	0.80	32.00	2.17	3.78
	T_5(3.0kR)	30.20	20.24	0.40	13.33	1.32	1.97
	T_6(3.5kR)	42.80	23.45	0.40	11.43	0.93	1.71
	T_7(4.0kR)	40.70	25.00	0.40	10.00	0.98	1.60
	Mean	36.76	21.96	0.51	24.78	1.13	1.92
	Grand Mean	36.58	19.82	0.61	28.52	1.38	2.67

Table 30. Frequency of viable mutants (%) of turmeric genotypes in vM_1 generation.

Genotypes	Treatments	Total M_1 plants studied	Total number of viable mutants	Mutation frequency (%)
G_1(CL144)	T_1(1.0kR)	250.00	3.00	1.20
	T_2(1.5kR)	250.00	3.00	1.20
	T_3(2.0kR)	250.00	6.00	2.40
	T_4(2.5kR)	250.00	5.00	2.00
	T_5(3.0kR)	250.00	4.00	1.60
	T_6(3.5kR)	250.00	3.00	1.20
	T_7(4.0kR)	250.00	2.00	0.80
	Mean	250.00	3.71	1.49
G_2(CL146)	T_1(1.0kR)	250.00	3.00	1.20
	T_2(1.5kR)	250.00	3.00	1.20
	T_3(2.0kR)	250.00	5.00	2.00
	T_4(2.5kR)	250.00	5.00	2.00
	T_5(3.0kR)	250.00	4.00	1.60
	T_6(3.5kR)	250.00	2.00	0.80
	T_7(4.0kR)	250.00	3.00	1.20
	Mean	250.00	3.57	1.43
G_3(CL147)	T_1(1.0kR)	250.00	3.00	1.20
	T_2(1.5kR)	250.00	3.00	1.20
	T_3(2.0kR)	250.00	5.00	2.00
	T_4(2.5kR)	250.00	5.00	2.00
	T_5(3.0kR)	250.00	4.00	1.60
	T_6(3.5kR)	250.00	3.00	1.20
	T_7(4.0kR)	250.00	2.00	0.80
	Mean	250.00	3.57	1.43
	Grand Mean	250.00	3.62	1.45

Table 32. Genetic parameters of turmeric genotypes in vM_0generation

Characters	Mean	PCV (per cent)	GCV (per cent)	Herita bility (h^2)	GA as percent of mean
Sprouting percent	58.94	12.43	10.61	0.73	18.65
Height of the plant (cm)	68.42	10.83	8.84	0.67	14.86
Number of tillers per plant	3.19	21.83	6.21	0.08	3.64
Days to maturity	249.30	9.34	7.31	0.61	11.78
Number of mother rhizomes	1.26	31.99	7.47	0.055	3.59
Weight of mother rhizomes (g)	34.69	37.56	11.96	0.10	7.84
Girth of mother rhizomes (cm)	9.35	23.95	13.92	0.34	16.67
Number of primary rhizomes	6.31	44.48	38.33	0.74	68.04
Weight of primary rhizomes (g)	15.69	28.74	12.30	0.18	10.84
Length of primary rhizomes (cm)	5.96	16.89	15.20	0.81	28.17
Girth of primary rhizomes (cm)	7.02	10.68	5.97	0.31	6.87
Rhizome to core diameter ratio	1.64	11.85	3.86	0.11	2.59
Number of secondary rhizomes	9.06	43.96	37.77	0.74	66.84
Weight of secondary rhizomes (g)	46.78	42.21	28.82	0.47	40.55
Length of secondary rhizomes (cm)	3.68	15.99	9.14	0.33	10.77
Girth of secondary rhizomes (cm)	5.45	16.63	7.67	0.21	7.30
Curing percent	24.37	5.06	3.28	0.42	4.38
Curcumin content (%)	12.39	8.83	8.03	0.83	15.04
Oleoresin content (%)	19.51	6.87	5.75	0.70	9.91
Essential oil content (%)	12.61	9.41	8.94	0.90	17.49
Yield per plant (g)	206.33	44.71	30.05	0.45	41.60

Table 33. Genetic parameters of turmeric genotypes in vM_1 generation

Characters	Mean	PCV (per cent)	GCV (per cent)	Hereta bility (h^2)	GA as percent of mean
Height of the plant (cm)	69.06	10.89	8.92	0.67	15.06
Number of tillers per plant	3.40	19.03	12.53	0.43	17.01
Number of mother rhizomes	1.48	37.51	11.71	0.10	7.53
Weight of mother rhizomes (g)	35.68	37.98	14.28	0.14	11.06
Number of primary rhizomes	6.41	42.74	33.16	0.60	53.00
Weight of primary rhizomes (g)	15.74	29.81	10.98	0.14	8.33
Length of primary rhizomes (cm)	5.99	19.55	12.31	0.40	15.98
Girth of primary rhizomes (cm)	6.92	11.94	7.03	0.35	8.53
Number of secondary rhizomes	9.23	42.45	30.43	0.51	44.94
Weight of secondary rhizomes (g)	47.88	41.33	31.61	0.59	49.82
Length of secondary rhizomes (cm)	3.75	15.24	3.73	0.06	1.88
Girth of secondary rhizomes (cm)	5.51	16.18	4.90	0.09	3.05
Curing percent	24.76	5.38	3.74	0.48	5.36
Oleoresin content (%)	20.44	22.00	7.56	0.19	5.35
Yield per plant (g)	225.90	41.91	18.86	0.20	17.49

Table 34. Simple correlation coefficient of turmeric genotypes in vM_0 generation.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	1	-0.078	-0.301	0.103	-0.054	-0.522	-0.210	0.077	-0.387	-0.125	-0.323	0.116	0.100	-0.244	-0.248	-0.362	-0.636	0.737**	0.803**	0.783**	-0.333
2		1	0.639**	0.247	0.272	0.325	0.206	0.176	0.249	0.089	0.209	-0.262	0.220	0.422	0.092	0.236	-0.172	0.080	0.163	0.155	0.260
3			1	0.065	0.457*	0.472*	0.057	0.359	0.397	0.203	0.444*	-0.470	0.300	0.535*	0.423*	0.313	-0.028	-0.125	-0.014	-0.019	0.545**
4				1	0.063	-0.101	-0.195	0.072	-0.008	-0.229	-0.050	-0.110	0.142	0.036	-0.137	0.081	-0.221	0.228	0.266	0.225	-0.032
5					1	0.016	-0.222	0.576**	0.092	0.252	0.197	-0.542	0.480*	0.611**	0.033	-0.262	-0.115	0.002	0.154	0.111	0.431*
6						1	0.305	-0.020	0.802**	0.093	0.436*	-0.271	0.020	0.449	0.374	0.639	0.224	-0.307	-0.301	-0.326	0.268
7							1	-0.090	0.502*	0.370	0.716**	0.087	-0.126	-0.024	0.240	0.652	0.190	-0.093	-0.131	-0.120	0.026
8								1	0.131	0.685	0.248	-0.590	0.913**	0.674**	0.372	-0.079	0.027	-0.146	0.099	0.059	0.526*
9									1	0.250	0.627**	-0.220	0.075	0.491*	0.190	0.643	0.226	-0.257	-0.135	-0.205	0.387
10										1	0.461*	-0.452	0.642**	0.462*	0.417	0.098	0.321	-0.335	-0.220	-0.243	0.393
11											1	-0.113	0.229	0.427*	0.303	0.640	0.113	-0.117	-0.035	-0.086	0.425
12												1	-0.502	-0.469	-0.375	-0.161	-0.005	0.220	0.075	0.028	-0.36
13													1	0.741**	0.450*	-0.015	-0.130	-0.009	0.150	0.149	0.454*
14														1	0.332	0.191	-0.094	-0.107	0.031	0.010	0.669**
15															1	0.474	0.017	-0.109	-0.224	-0.099	0.210
16																1	-0.024	-0.131	-0.157	-0.083	0.055
17																	1	-0.872	-0.810	-0.924	0.089
18																		1	0.906**	0.939**	-0.109
19																			1	0.954**	0.007
20																				1	-0.048
21																					1

*Significant at 5 per cent level (0.423) ** Significant at 1 per cent level (0.537)

1 Sprouting per cent
2 Height of the plant (cm)
3 Number of tillers per plant
4 Days to maturity
5 Number of mother rhizomes
6 Weight of mother rhizomes (g)
7 Girth of mother rhizomes (cm)
8 Number of primary rhizomes
9 Weight of primary rhizomes (g)
10 Length of primary rhizomes (cm)
11 Girth of primary rhizomes (cm)
12 Rhizome to core diameter ratio
13 Number of secondary rhizomes
14 Weight of secondary rhizomes (g)
15 Length of secondary rhizomes (cm)
16 Girth of secondary rhizomes (cm)
17 Curing per cent
18 Curcumin content (%)
19 Oleoresin content(%)
20 Essential oil content (%)
21 Yield per plant (g)

Table 35. Phenotypic correlation coefficient of turmeric genotypes in vM_0 generation.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
1	1	-0.056	-0.246	0.182	-0.039	-0.336	-0.171	0.079	-0.338	-0.113	-0.239	0.029	0.053	-0.173	-0.172	-0.301	-0.504*	0.652**	0.684**	0.789**	-0.208
2		1	0.595**	0.282	0.175	0.211	0.126	0.144	0.146	0.037	0.126	-0.113	0.152	0.344	0.040	0.131	-0.160	0.055	0.116	0.140	0.242
3			1	-0.028	0.303	0.289	0.039	0.263	0.142	0.150	0.290	-0.233	0.206	0.367	0.170	0.149	0.033	-0.057	0.030	-0.042	0.416
4				1	0.001	-0.060	-0.146	0.066	-0.095	-0.219	-0.036	-0.026	0.065	0.026	-0.069	0.003	-0.224	0.163	0.176	0.257	0.056
5					1	-0.083	-0.278	0.368	-0.036	0.213	0.149	-0.124	0.361	0.413	0.137	-0.101	0.012	0.048	0.164	0.085	0.180
6						1	0.232	0.011	0.617**	0.030	0.318	-0.094	0.011	0.460*	0.087	0.348	0.193	-0.166	-0.143	-0.218	0.181
7							1	0.003	0.385	0.266	0.677**	0.073	-0.020	-0.081	0.163	0.575**	0.123	-0.081	-0.104	-0.107	0.116
8								1	0.024	0.595**	0.224	-0.356	0.838**	0.500*	0.230	-0.089	-0.038	-0.162	0.044	0.065	0.514*
9									1	0.177	0.495*	-0.147	0.086	0.405	0.105	0.564**	0.255	-0.134	-0.022	-0.205	0.180
10										1	0.350	-0.343	0.578**	0.339	0.356	0.063	0.325	-0.267	-0.144	-0.226	0.304
11											1	-0.004	0.173	0.277	0.183	0.552**	0.122	-0.066	0.009	-0.066	0.318
12												1	-0.295	-0.204	-0.212	-0.092	-0.112	0.071	-0.041	-0.007	-0.219
13													1	0.556	0.327	0.045	-0.083	0.001	0.142	0.111	0.395
14														1	0.170	0.125	-0.019	-0.071	0.056	0.015	0.482*
15															1	0.356	0.076	-0.001	-0.122	-0.067	0.147
16																1	0.033	-0.068	-0.073	-0.095	0.070
17																	1	-0.545**	-0.422	-0.770**	-0.018
18																		1	0.912**	0.870**	-0.130
19																			1	0.850**	-0.049
20																				1	-0.007
21																					1

*Significant at 5 per cent level (0.423) ** Significant at 1 per cent level (0.537)

22 Sprouting per cent
23 Height of the plant (cm)
24 Number of tillers per plant
25 Days to maturity
26 Number of mother rhizomes
27 Weight of mother rhizomes (g)
28 Girth of mother rhizomes (cm)
29 Number of primary rhizomes
30 Weight of primary rhizomes (g)
31 Length of primary rhizomes (cm)
32 Girth of primary rhizomes (cm)
33 Rhizome to core diameter ratio
34 Number of secondary rhizomes
35 Weight of secondary rhizomes (g)
36 Length of secondary rhizomes (cm)
37 Girth of secondary rhizomes (cm)
38 Curing per cent
39 Curcumin content (%)
40 Oleoresin content(%)
41 Essential oil content (%)
42 Yield per plant (g)

Table 36. Genotypic correlation coefficient of turmeric genotypes in vM_0 generation.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	1	-0.110	-0.682**	-0.014	-0.173	-0.158	-0.301	0.074	-0.588**	-0.142	-0.521**	0.414	0.164	-0.369	-0.417	-0.565**	-0.892**	0.847**	0.971**	0.778**	-0.557**
2		1	0.130	0.192	0.970**	0.717**	0.382	0.221	0.585**	0.159	0.401	-0.778**	0.317	0.565**	0.209	0.542**	-0.198	0.114	0.231	0.174	0.296
3			1	0.511*	0.782*8	0.948**	0.174	0.938**	0.518**	0.523*	0.501*	-0.473*	0.839**	0.579**	0.069	0.597**	-0.365	-0.458*	-0.205	0.053	0.400
4				1	0.448*	-0.247	-0.309	0.081	-0.081	-0.246	-0.084	-0.415	0.257	0.053	-0.295	0.307	-0.218	0.321	0.403	0.184	-0.199
5					1	0.327	0.108	0.050	0.391	0.645**	0.636**	-0.281	0.440*	0.174	-0.735**	-0.807**	-0.013	-0.213	0.220	0.327	0.249
6						1	0.555**	-0.133	0.546**	0.307	0.878**	-0.438*	0.051	0.252	0.767**	0.175	0.290	-0.783**	-0.861**	-0.691**	0.584**
7							1	-0.274	0.990**	0.593**	0.837**	0.122	-0.344	0.120	0.473*	0.953**	0.366	-0.123	-0.193	-0.154	-0.207
8								1	0.444*	0.802**	0.313	-0.354	0.013	0.979**	0.679**	-0.064	0.143	-0.125	0.176	0.052	0.556**
9									1	0.489*	0.194	-0.567**	0.056	0.826**	0.544**	0.042	0.137	-0.625**	-0.471*	-0.252	0.136
10										1	0.718**	-0.792**	0.725**	0.672**	0.565**	0.198	0.326	-0.418	-0.322	-0.264	0.550**
11											1	-0.650**	0.362	0.825**	0.681**	0.993**	0.089	-0.226	-0.132	-0.133	0.716**
12												1	0.183	-0.499*	-0.055	-0.505*	0.504*	0.709**	0.491*	0.140	-0.886**
13													1	0.068	0.726**	-0.169	-0.219	-0.021	0.162	0.196	0.566**
14														1	0.752**	0.414	-0.264	-0.177	-0.012	0.002	0.075
15															1	0.929**	-0.143	-0.230	-0.446*	-0.167	0.377
16																1	-0.219	-0.303	-0.393	-0.072	0.008
17																	1	-0.458*	-0.544**	-0.220	0.335
18																		1	0.899**	0.020	-0.077
19																			1	0.088	0.108
20																				1	-0.114
21																					1

***Significant at 5 per cent level (0.423) ** Significant at 1 per cent level (0.537)**

1. Sprouting per cent
2. Height of the plant (cm)
3. Number of tillers per plant
4. Days to maturity
5. Number of mother rhizomes
6. Weight of mother rhizomes (g)
7. Girth of mother rhizomes (cm)
8. Number of primary rhizomes
9. Weight of primary rhizomes (g)
10. Length of primary rhizomes (cm)
11. Girth of primary rhizomes (cm)
12. Rhizome to core diameter ratio
13. Number of secondary rhizomes
14. Weight of secondary rhizomes (g)
15. Length of secondary rhizomes (cm)
16. Girth of secondary rhizomes (cm)
17. Curing per cent
18. Curcumin content (%)
19. Oleoresin content(%)
20. Essential oil content (%)
21. Yield per plant (g)

Table 37. Path coefficient analysis of turmeric genotypes in vM_0 generation.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	-0.307	-0.058	0.081	-0.151	0.099	0.039	-0.121	0.297	0.030	0.476	-0.131	0.148	0.014	-0.119	-0.307
2	-0.347	-0.051	0.232	-0.410	0.418	0.166	-0.398	0.111	0.079	0.332	-0.299	0.436	0.026	0.106	-0.051
3	-0.297	-0.142	0.084	-0.279	0.915	0.092	-0.491	0.471	0.136	0.834	0.462	-0.493	0.073	-0.113	0.084
4	-0.220	-0.099	0.110	0.211	-0.059	0.102	-0.234	0.650	0.005	0.213	-0.100	0.593	-0.021	0.443	0.211
5	-0.068	-0.048	0.171	0.028	0.446	0.029	-0.611	0.232	0.096	0.826	-0.427	-0.017	-0.010	-0.091	0.446
6	-0.179	-0.128	0.116	-0.326	0.198	0.066	-0.373	0.884	0.005	0.697	-0.342	0.284	-0.009	0.242	0.066
7	-0.049	-0.027	0.054	-0.065	0.358	0.032	-0.762	0.531	0.069	0.567	-0.355	0.054	-0.023	0.166	-0.762
8	-0.123	-0.077	0.053	-0.185	0.140	0.079	-0.547	0.740	0.034	0.696	-0.428	0.271	-0.006	0.068	0.740
9	-0.097	-0.043	0.120	-0.011	0.452	0.004	-0.552	0.268	0.094	0.901	-0.456	-0.046	0.016	-0.083	0.094
10	-0.173	-0.080	0.182	-0.053	0.437	0.055	-0.512	0.612	0.101	0.844	-0.472	0.113	0.019	0.006	0.844
11	-0.064	-0.105	-0.061	-0.372	0.303	0.036	-0.430	0.502	0.069	0.634	-0.628	0.253	0.010	0.230	-0.628
12	-0.166	-0.081	-0.151	-0.458	-0.029	0.069	-0.151	0.735	-0.016	0.349	-0.584	0.273	0.016	0.202	0.273
13	0.061	0.019	-0.085	-0.061	0.064	0.009	-0.248	0.066	-0.021	-0.223	0.090	-0.059	-0.072	0.795	-0.072
14	-0.071	0.011	0.018	0.181	0.078	-0.031	0.245	-0.097	0.015	-0.010	0.281	-0.107	0.111	-0.515	-0.515

Residual effect = 0.132

1 Height of the plant (cm)
2 Number of tillers per plant
3 Number of mother rhizomes
4 Weight of mother rhizomes (g)
5 Number of primary rhizomes
6 Weight of primary rhizomes (g)
7 Length of primary rhizomes (cm)
8 Girth of primary rhizomes (cm)
9 Number of secondary rhizomes
10 Weight of secondary rhizomes (g)
11 Length of secondary rhizomes (cm)
12 Girth of secondary rhizomes (cm)
13 Curing per cent
14 Oleoresin content (%)
15 Yield per plant (g)

Table 38. Simple correlation coefficient of turmeric genotypes in vM_1 generation.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	0.555**	0.207	0.091	0.041	-0.080	0.337	0.172	0.188	0.283	0.249	-0.144	-0.160	0.260	0.048
2		1	0.253	0.200	-0.276	0.300	0.070	0.290	-0.120	0.102	0.046	0.349	-0.354	0.110	-0.127
3			1	-0.108	0.052	0.083	0.186	0.298	0.056	0.177	0.057	0.095	-0.132	-0.030	0.118
4				1	-0.113	0.350	0.117	0.552**	0.051	0.201	0.290	0.599**	-0.033	0.210	-0.237
5					1	-0.120	0.638**	0.278	0.815**	0.535**	0.423*	-0.416	0.121	-0.076	0.524*
6						1	0.264	0.328	-0.125	0.025	0.222	0.683**	0.184	0.059	0.346
7							1	0.639**	0.595**	0.451*	0.340	-0.032	0.300	-0.032	0.529*
8								1	0.314	0.308	0.160	0.311	0.105	0.118	0.161
9									1	0.846**	0.477*	-0.401	-0.006	-0.167	0.489*
10										1	0.399	-0.159	-0.175	0.035	0.382
11											1	0.138	-0.043	0.163	0.266
12												1	-0.115	0.138	-0.221
13													1	-0.202	0.415
14														1	0.082
15															1

*Significant at 5 per cent level (0.423) ** Significant at 1 per cent level (0.537)

1 Height of the plant (cm)
2 Number of tillers per plant
3 Number of mother rhizomes
4 Weight of mother rhizomes (g)
5 Number of primary rhizomes
6 Weight of primary rhizomes (g)
7 Length of primary rhizomes (cm)
8 Girth of primary rhizomes (cm)
9 Number of secondary rhizomes
10 Weight of secondary rhizomes (g)
11 Length of secondary rhizomes (cm)
12 Girth of secondary rhizomes (cm)
13 Curing per cent
14 Oleoresin content (%)
15 Yield per plant (g)

Table 39. Phenotypic correlation coefficient of turmeric genotypes in vM_1 generation.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	0.528*	0.130	0.069	0.049	-0.094	0.333	0.099	0.147	0.254	0.178	-0.151	-0.145	0.142	0.010
2		1	0.271	0.170	-0.215	0.212	0.102	0.096	-0.123	0.082	0.106	0.181	-0.218	-0.039	0.018
3			1	0.010	-0.020	0.050	0.096	0.129	0.006	0.075	0.008	-0.041	-0.004	0.051	0.127
4				1	-0.118	0.333	0.106	0.475*	0.005	0.269	0.101	0.421	0.105	-0.139	-0.115
5					1	-0.108	0.486*	0.256	0.613**	0.378	0.341	-0.341	0.020	-0.108	0.410
6						1	0.087	0.293	-0.150	0.035	0.153	0.735**	0.053	-0.155	0.301
7							1	0.506*	0.530*	0.352	0.288	-0.107	0.256	-0.100	0.237
8								1	0.209	0.223	0.194	0.253	0.046	-0.057	0.044
9									1	0.626**	0.267	-0.356	0.041	-0.118	0.108
10										1	0.257	-0.053	-0.094	-0.080	0.218
11											1	0.142	-0.013	-0.063	0.238
12												1	-0.118	-0.119	-0.059
13													1	-0.144	0.279
14														1	0.041
15															1

*Significant at 5 per cent level (0.423) ** Significant at 1 per cent level (0.537)

1 Height of the plant (cm)
2 Number of tillers per plant
3 Number of mother rhizomes
4 Weight of mother rhizomes (g)
5 Number of primary rhizomes
6 Weight of primary rhizomes (g)
7 Length of primary rhizomes (cm)
8 Girth of primary rhizomes (cm)
9 Number of secondary rhizomes
10 Weight of secondary rhizomes (g)
11 Length of secondary rhizomes (cm)
12 Girth of secondary rhizomes (cm)
13 Curing per cent
14 Oleoresin content (%)
15 Yield per plant (g)

Table 40. Genotypic correlation coefficient of turmeric genotypes in vM_1 generation.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	0.615**	0.585**	0.185	0.028	-0.055	0.351	0.329	0.260	0.329	0.762**	-0.178	-0.188	0.758**	0.159
2		1	0.221	0.348	-0.400	0.705**	-0.007	0.790**	-0.113	0.141	-0.306	0.278	-0.653**	0.788**	-0.624**
3			1	-0.028	0.364	0.371	0.686**	0.269	0.296	0.662**	0.698**	0.527*	-0.592**	-0.780**	0.064
4				1	-0.119	0.470*	0.176	0.945**	0.228	0.006	0.377	0.181	-0.567**	0.915**	-0.966**
5					1	-0.191	0.956**	0.334	0.180	0.800**	0.105	-0.894**	0.310	0.021	0.906**
6						1	0.057	0.523*	-0.053	-0.005	0.009	0.223	0.730**	0.747**	0.624**
7							1	0.997**	0.743**	0.660**	0.815**	0.351	0.400	0.279	0.584**
8								1	0.568*	0.504*	-0.015	0.695**	0.248	0.007	0.609**
9									1	0.248	0.924**	-0.736**	-0.101	-0.402	0.710**
10										1	0.387	-0.678**	-0.327	0.482*	0.901**
11											1	0.097	-0.238	0.858**	0.558**
12												1	-0.136	0.611**	-0.427*
13													1	-0.483*	0.882**
14														1	0.349
15															1

*Significant at 5 per cent level (0.423) ** Significant at 1 per cent level (0.537)

1 Height of the plant (cm)
2 Number of tillers per plant
3 Number of mother rhizomes
4 Weight of mother rhizomes (g)
5 Number of primary rhizomes
6 Weight of primary rhizomes (g)
7 Length of primary rhizomes (cm)
8 Girth of primary rhizomes (cm)
9 Number of secondary rhizomes
10 Weight of secondary rhizomes (g)
11 Length of secondary rhizomes (cm)
12 Girth of secondary rhizomes (cm)
13 Curing per cent
14 Oleoresin content (%)
15 Yield per plant (g)

Table : 31. Spectrum of viable mutants (relative percent) of turmeric genotypes in vM_1generation.

Mutants	Type of mutants	CL144							CL146							CL147						
		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Plant stature	Tall	-	-	20.84	-	20.00	-	-	-	-	12.50	14.28	-	-	-	_	-	16.66	25.00	16.66	-	-
	Dwarf	40.00	-	-	-	-	33.33	-	20.00	26.67	-	-	-	-	33.33	33.33	20.00	-	-	-	-	-
Total		40.00	-	20.84	-	20.00	33.33	-	20.00	26.67	12.50	14.28	-	-	33.33	33.33	20.00	16.66	25.00	16.66	-	-
Tiller	More	-	-	16.67	37.51	40.00	-	-	-	-	16.66	14.30	16.66	-	-	_	-	16.66	12.00	12.50	-	-
	Less	20.00	50.00	-	-	-	20.00	33.33	20.00	-	-	-	-	-	-	33.33	20.00	-	-	-	33.33	-
Total		20.00	50.00	16.67	37.51	40.00	20.22	33.33	20.00	-	16.66	14.30	16.66	-	-	33.33	20.00	16.66	12.50	12.50	33.33	-
Maturity	Early	-	-	12.50	29.16	-	-	-	-	-	12.50	23.81	12.50	-	-	_	-	16.66	25.00	20.83	-	-
	Late	40.00	-	-	-	-	-	-	20.00	40.00	-	-	-	20.00	-	_	20.00	-	-	-	40.00	50.00
Total		40.00	-	12.50	29.16	-	-	-	20.00	40.00	12.50	23.81	12.50	20.00	-	-	20.00	16.66	25.00	20.83	40.00	50.00
Yield	High	-	-	20.83	12.50	-	-	-	-	-	20.83	14.28	20.83	-	-	-	-	16.66	12.50	12.50	-	-
	Low	-	50.00	-	-	-	16.67	40.00-	20.00	-	-	-	-	40.00	33.33	33.33	20.00	-	-	-	26.67	50.00
Total		-	50.00	20.83	12.50	-	16.67	40.00	20.00	-	20.83	14.28	20.83	40.00	33.33	33.33	20.00	16.66	12.50	12.50	26.67	50.00
Curcumin	High	-	-	29.16	20.83	40.00	-	-	-	-	16.67	19.05	-	-	-	_	-	16.66	12.50	16.66	-	-
	Low	-	-	-	-	-	30.00	-	20.00	16.66	-	-	-	40.00	33.33	-	20.00	-	-	-	-	-
Total		-	-	29.16	20.83	40.00	30.00	-	20.00	16.66	16.67	19.05	-	40.00	33.33	-	20.00	16.66	12.50	16.67	-	-
Oleoresin	High	-	-	-	-	-	-	-	-	-	20.84	14.28	50.01	-	-	-	-	16.66	12.50	20.84	-	-
	Low	-	-	-	-	-	-	26.67	-	16.66	-	-	-	-	-	-	-	-	-	-	-	-
Total		-	-	-	-	-	-	26.67	-	16.66	20.84	14.28	50.01	-	-	-	-	16.66	12.50	20.84	-	-
Total number of viable mutants		3	3	6	5	4	3	2	3	3	5	5	4	2	3	3	3	5	5	4	3	2

Annexure – I

LIST OF ABBREVIATIONS

kR	-	Kilo Rads
g	-	gramme
cm	-	centimetre
DAP	-	Days after planting
CV	-	Coefficient of variation
GCV	-	Genotypic coefficient of variation
PCV	-	Phenotypic coefficient of variation
GA	-	Genetic Advance
h^2	-	Heritability

Annexure – II

TYPES OF CHLOROPHYLL MUTANTS

Albina	:	Plants with white leaves, devoid of chlorophyll
Chlorina	:	Yellowish green leaves. Most of these types survived for 30 days, few having light yellowish green leaves survived till maturity.
Deep green	:	Leaves dark green with slightly broad leaves. Most of these persisted till maturity.
Xantha	:	Straw yellow plants with normal growth in the initial stage and later on failed to survive.

RESEARCH FINDINGS

INDUCED MUTATION IN TURMERIC (*Curcuma longa* L.) THROUGH GAMMA RAYS FOR VARIABILITY AND QUALITY IMPROVEMENT

Student :
H. Usha Nandhini Devi

Chairman :
Dr. N. Chezhiyan

The present investigation on induced mutation in turmeric through gamma rays for variability and quality improvement was carried out for vM_o and vM_1 generations. In both the generations, the morphological and biochemical traits such as sprouting per cent, height of the plant, number, length, breadth and area of the leaf, number of tillers per plant, days to maturity, number, weight, length and girth of mother, primary and secondary rhizomes, rhizome to core diameter ratio, yield per plant, curing per cent, curcumin, oleoresin and essential oil contents were improved at 2.0 kR followed by 2.5 kR whereas higher doses of gamma rays expressed an inhibitory effect on these parameters. In vM_1 generation, four different types of chlorophyll mutants *viz.*, xantha, albina, chlorina and deep green were recorded. A high percentage of deep green followed by xantha, albina and chlorina were accounted. The mutagenic effectiveness and efficiency in terms of lethality and injury were high at 2.0 kR in the genotype CL144. Similarly, the viable mutation frequency was higher at 2.0 kR in the genotype CL144. Six types of viable mutants *viz.*, plant stature (tall and dwarf), number of tillers (high and low), maturity (early and late), yield (high and low), curcumin content (high and low) and oleoresin content (high and low) were obtained. Number of primary rhizomes exhibited the highest PCV and GCV in both the generations. Heritability in broad sense was higher for essential oil content followed by curcumin content in vM_o generation whereas in vM_1 generation, greater heritability was obtained for height of the plant followed by number of primary rhizomes. GA as per cent of mean was more for number of secondary and primary rhizomes in vM_o and vM_1 generation respectively. The correlation study established that the weight of mother rhizomes, number, length and girth of primary rhizomes and number of secondary rhizomes expressed correlation with yield per plant in vM_o generation while the number, weight, length and girth of primary rhizomes, number, weight and length of secondary rhizomes and curing per cent were positively correlated with yield per plant in vM_1 generation. Path analysis in vM_o generation projected girth of primary rhizomes and weight and girth of secondary rhizomes as dominating contributors towards yield.

MINI ABSTRACT

INDUCED MUTATION IN TURMERIC (*Curcuma longa* L.) THROUGH GAMMA RAYS FOR VARIABILITY AND QUALITY IMPROVEMENT

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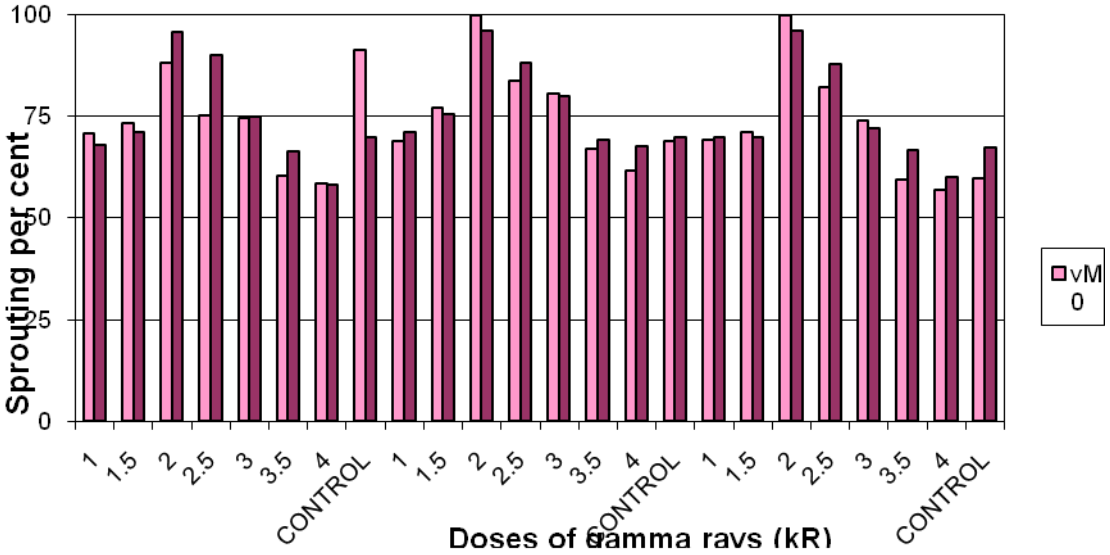
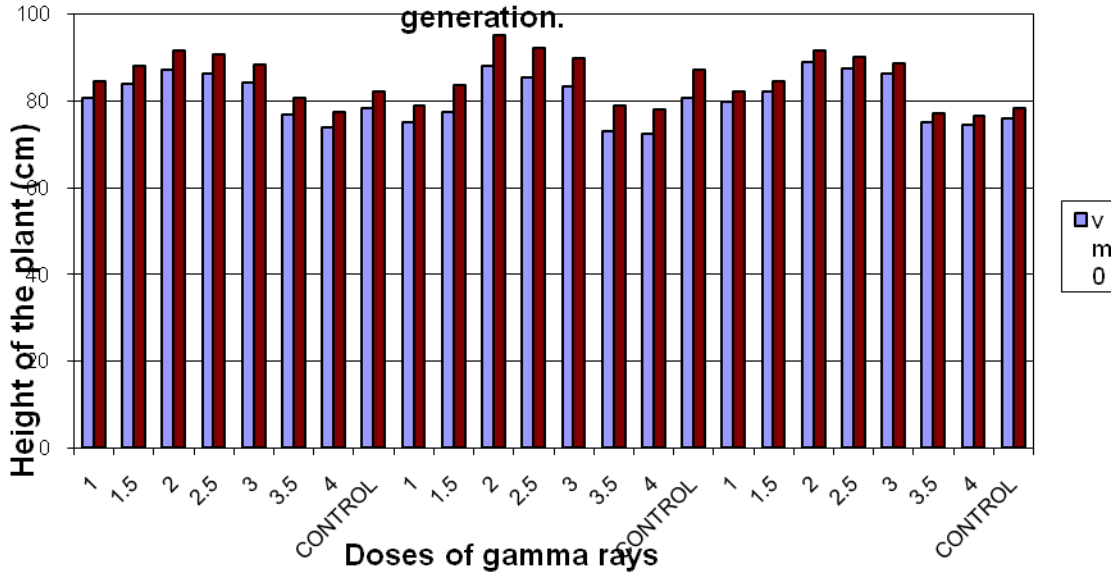
*** Originals not seen**

Figure.1.Effect of gamma irradiation in turmeric genotypes on sprouting per cent in $vM_0$and vM_1generation.



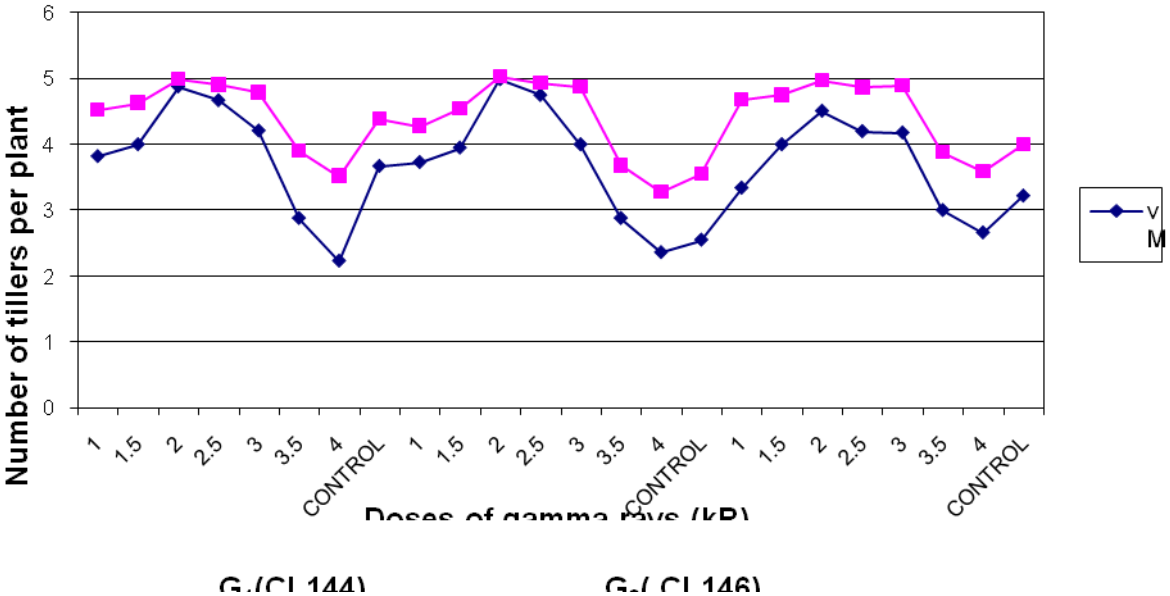
G_1(CL144) G_2(CL146) G_3(

Figure.2.Effect of gamma irradiation in turmeric genotypes on height of the plant(cm) at 225DAP in vM_0 and vM_1 generation.



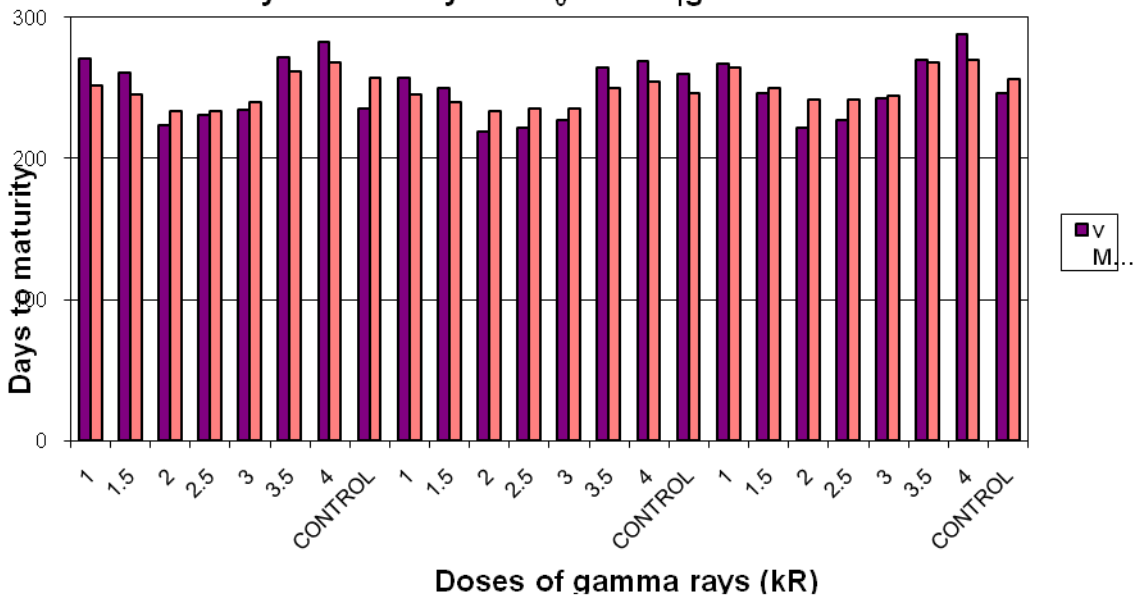
G_1(CL144) G_2(CL146)

Figure.3.Effect of gamma irradiation in turmeric genotypes on number of tillers per plant at 225DAP in vM_0 and vM_1 generation



G1(CL 144) G2(CL 146)

Figure.4.Effect of gamma irradiation in turmeric genotypes on days to maturity in $vM_0$and vM_1generation.



G1(CL 144) G2(CL 146)

Figure.5. Effect of gamma irradiation in turmeric genotypes on weight of mother rhizomes (g) in vM_0 and vM_1 generation.

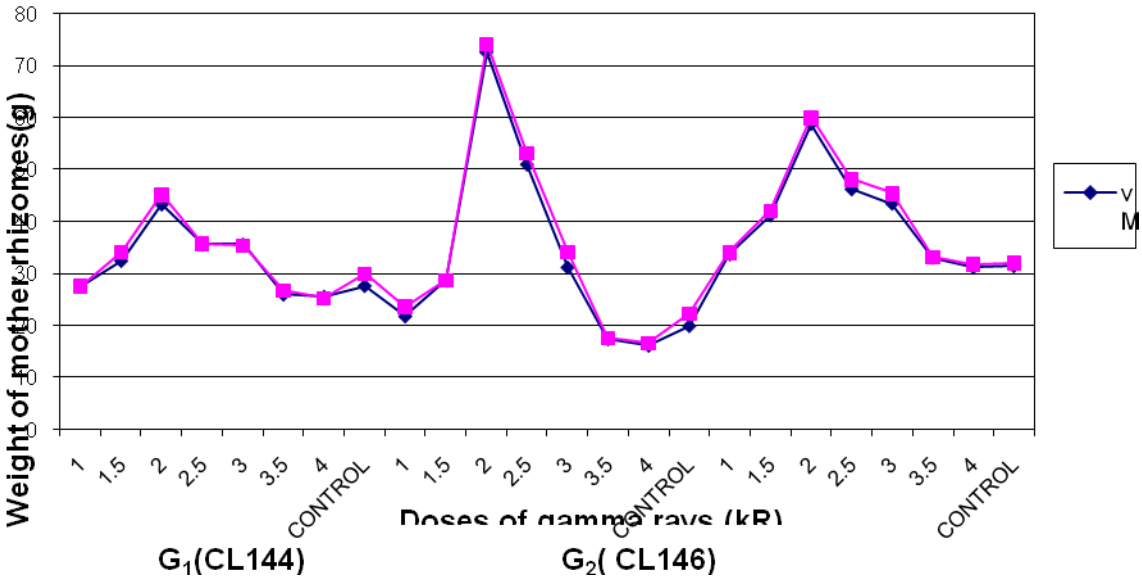


Figure.6. Effect of gamma irradiation in turmeric genotypes on number of primary rhizomes in vM_0 and vM_1 generation.

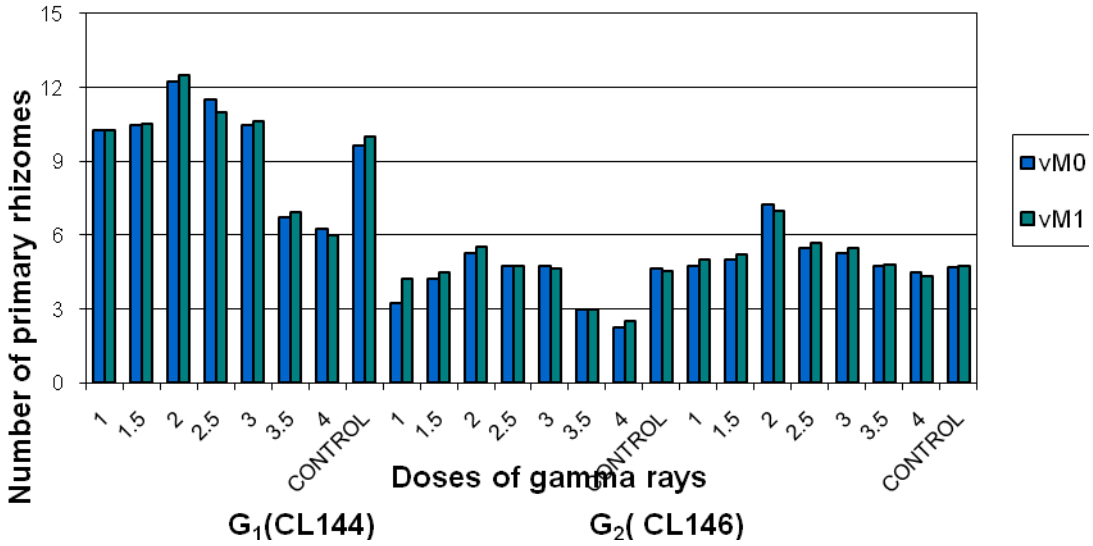


Figure.7. Effect of gamma irradiation in turmeric genotypes on number of secondary rhizomes in vM_0 and vM_1 generation.

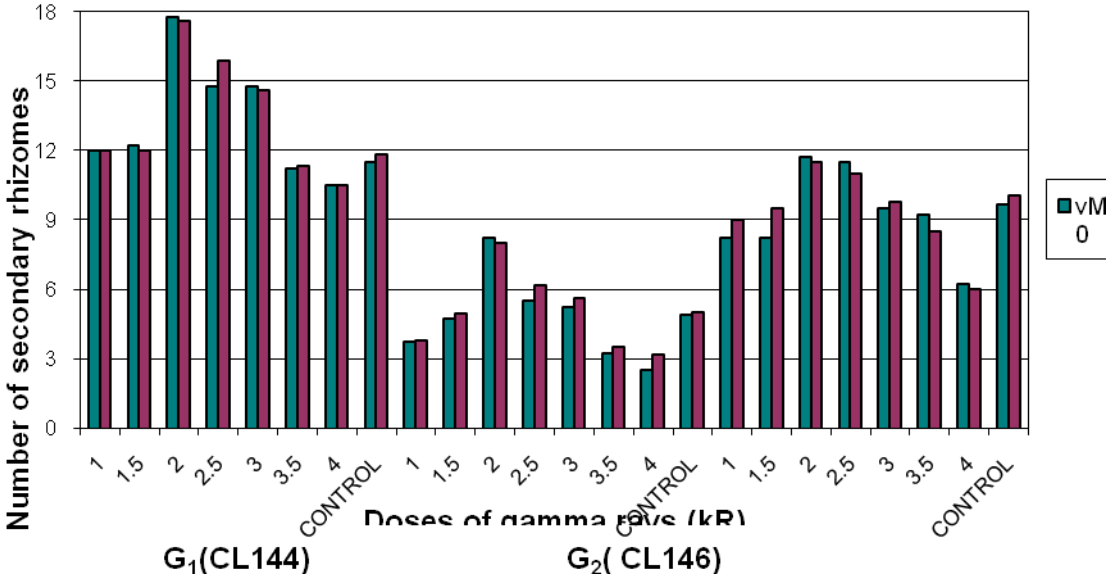


Figure.8. Effect of gamma irradiation in turmeric genotypes on yield per plant (g) in vM_0 and vM_1 generation.

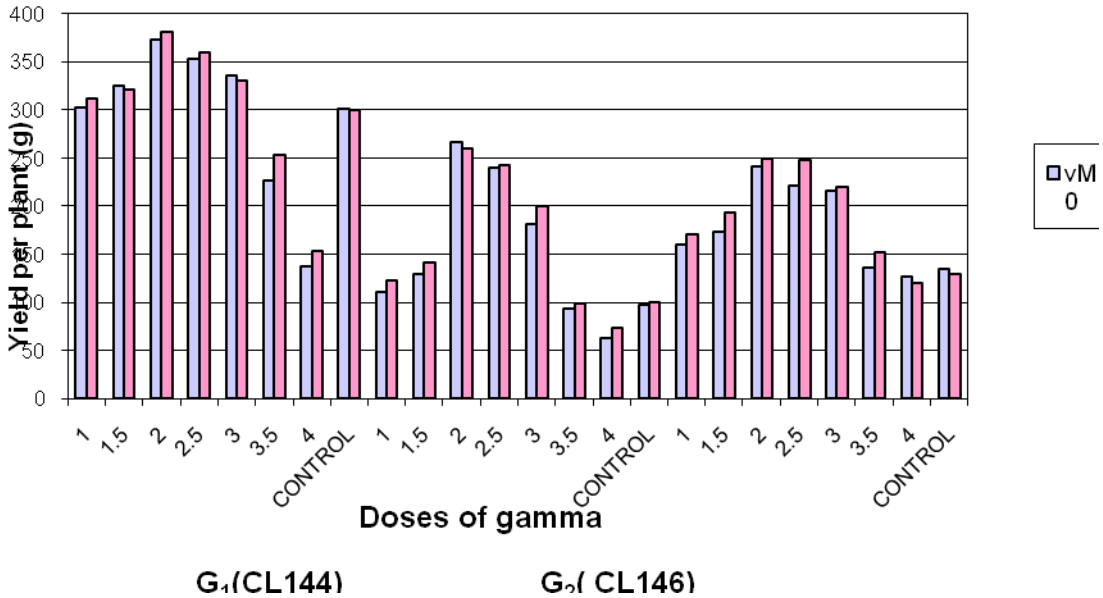
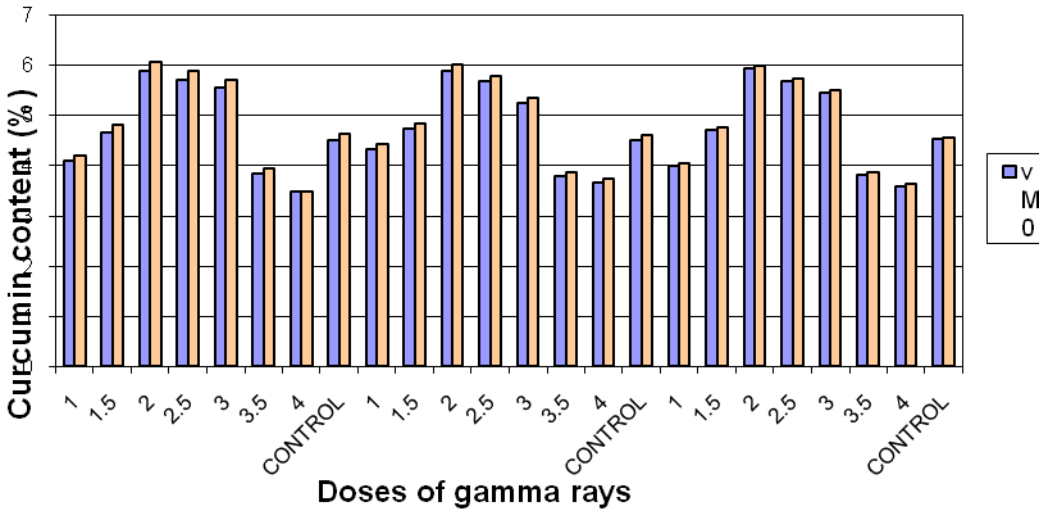
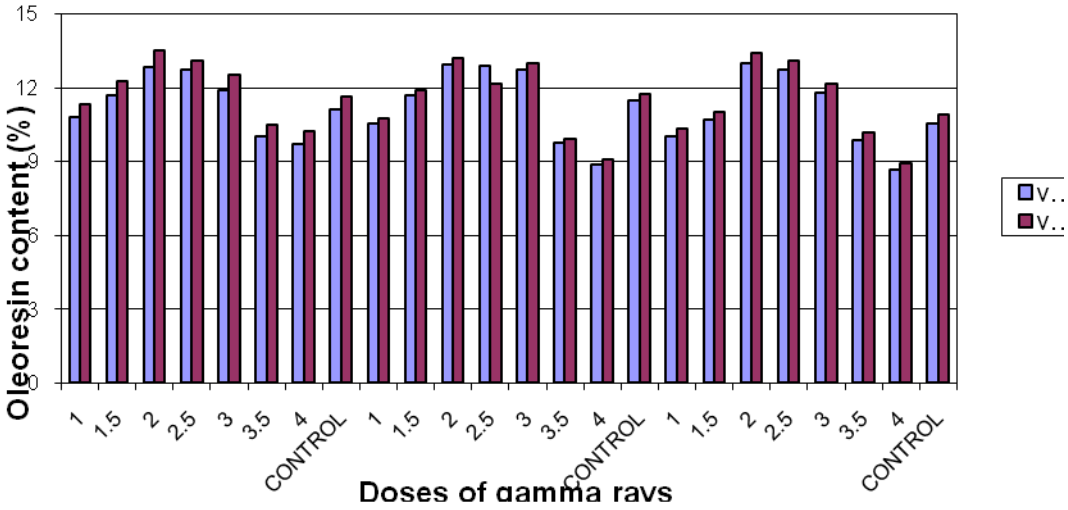


Figure.9.Effect of gamma irradiation in turmeric genotypes on curcumin content (%) in vM_0 and vM_1generation.



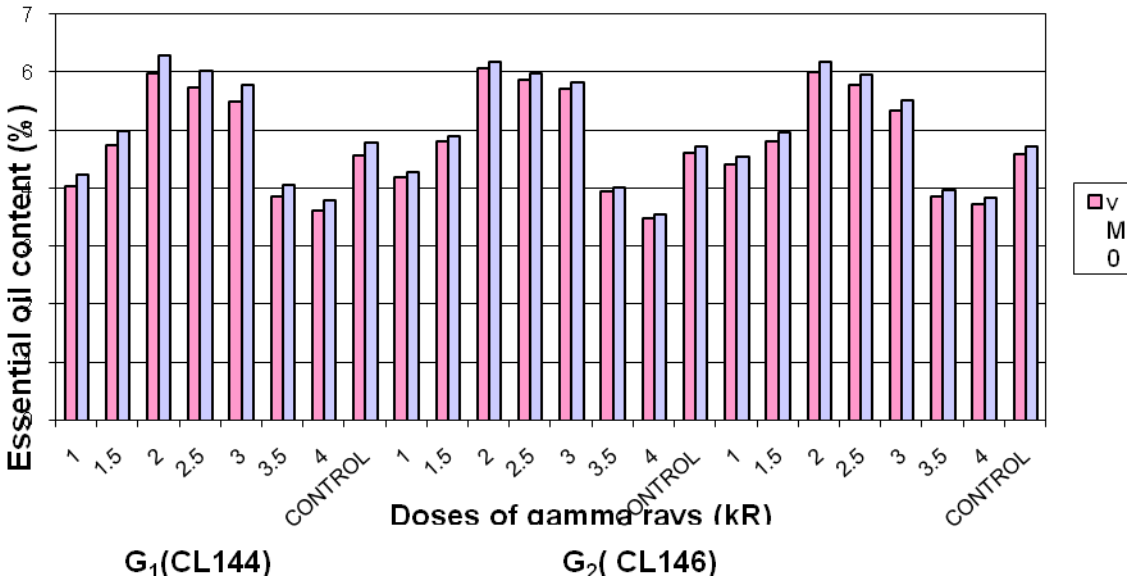
G_1(CL144) G_2(CL146)

Figure.10.Effect of gamma irradiation in turmeric genotypes on oleoresin content (%) in vM_0 and vM_1generation.



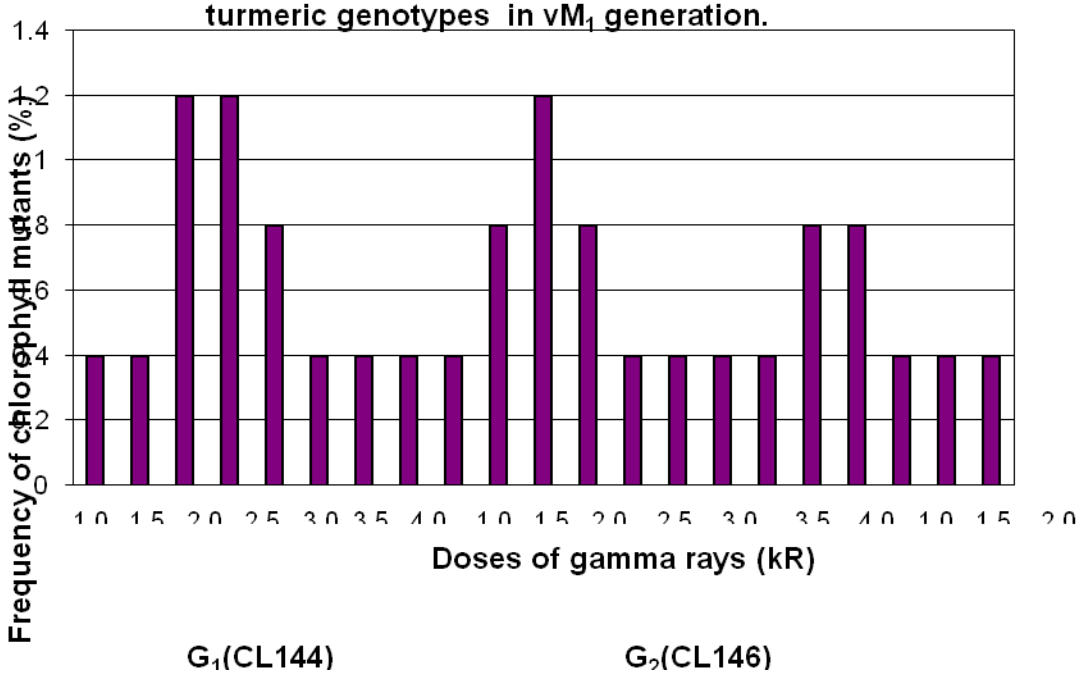
G_1(CL144) G_2(CL146)

Figure.11. Effect of gamma irradiation in turmeric genotypes on essential oil content (%) in vM_0 and vM_1 generation



G_1(CL144) G_2(CL146)

Figure.12. Frequency of chlorophyll mutants (%) of turmeric genotypes in vM_1 generation.



G_1(CL144) G_2(CL146)

Figure.13. Mutagenic effectiveness and efficiency of chlorophyll mutation(%) of turmeric genotypes in vM_1 generation.

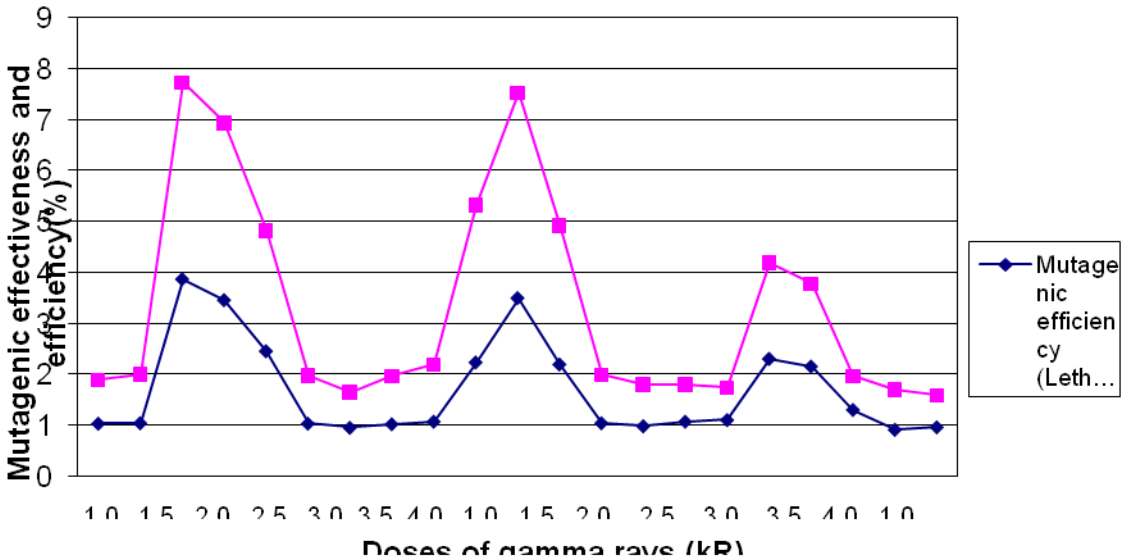


Figure.14. Frequency of viable mutants (%) of turmeric genotypes in vM_1 generation.

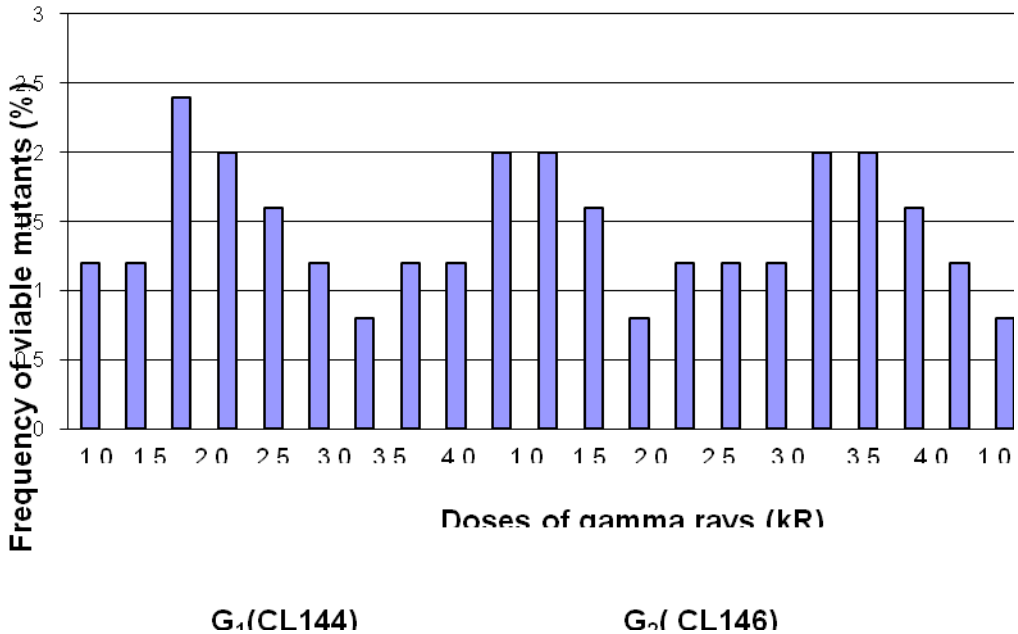


Figure.1. Effect of gamma irradiation in turmeric genotypes on sprouting per cent in vM0 and vM1generation.

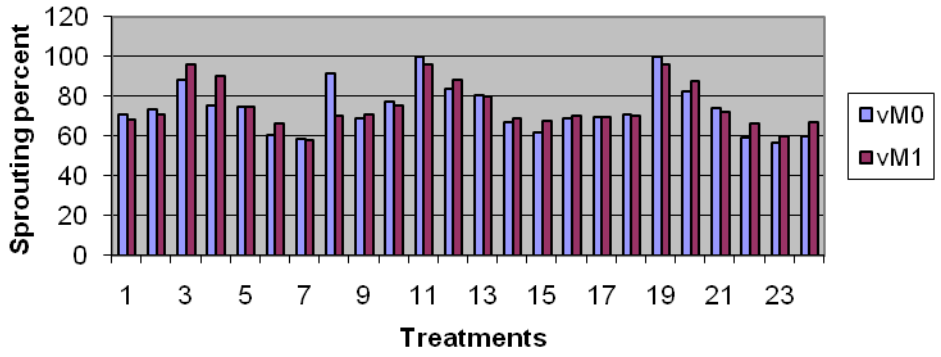
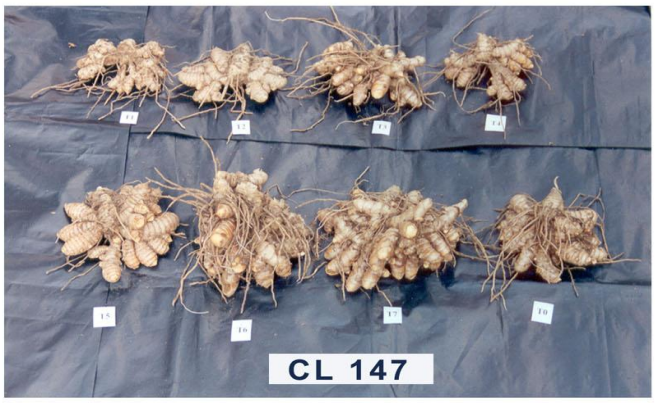


Plate 7. High yield mutant Vs control

Plate 8. Low yield mutant Vs Control



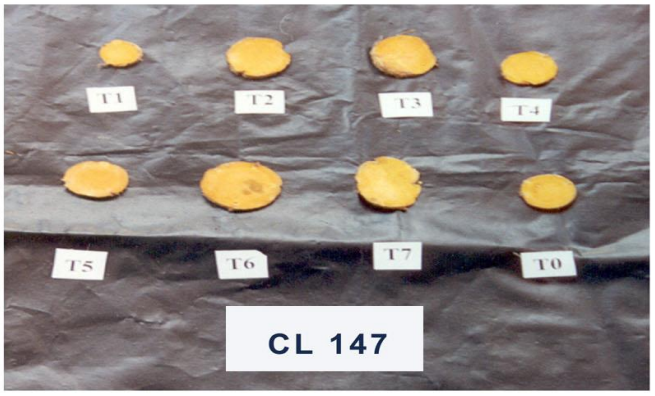


Plate 15. Variation in plant stature, rhizome and core diameter at different doses of gamma rays of CL 147

Plate 14. Variation in plant stature, rhizome and core diameter at different doses of gamma rays of CL 146

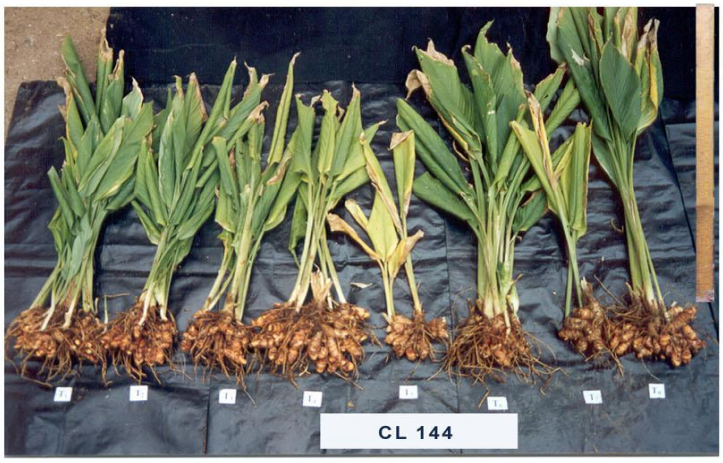


Plate13. Variation in plant stature, rhizhome and core diameter at different doses of gamma rays of CL 144

Plate 9. Chlorophyll mutant (Albina)

Plate 10. Chlorophyll mutant (Chlorina)

Plate 11. Chlorophyll mutant (Deep green)

Plate 12. Chlorophyll mutant (xantha)

Plate 3.Plant stature mutant(Tall)

Plate 4. Plant stature mutant(Dwarf)

Plate5. More tillering mutant

Plate6. Less tillering mutant

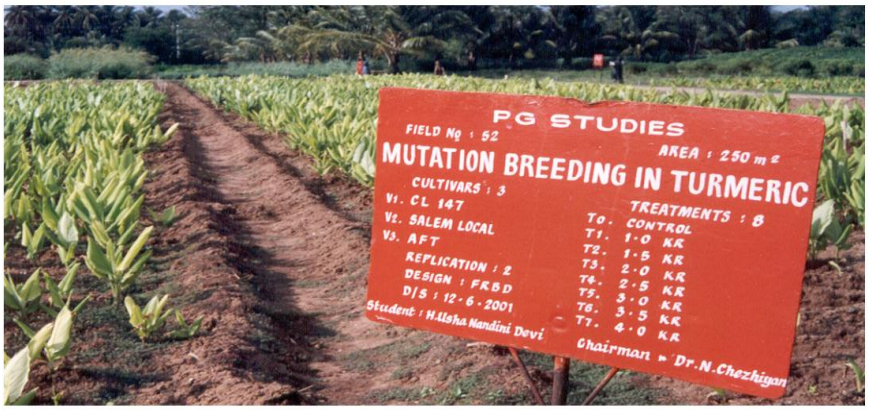


Plate 1.View of the experimental plot (vMo generation)

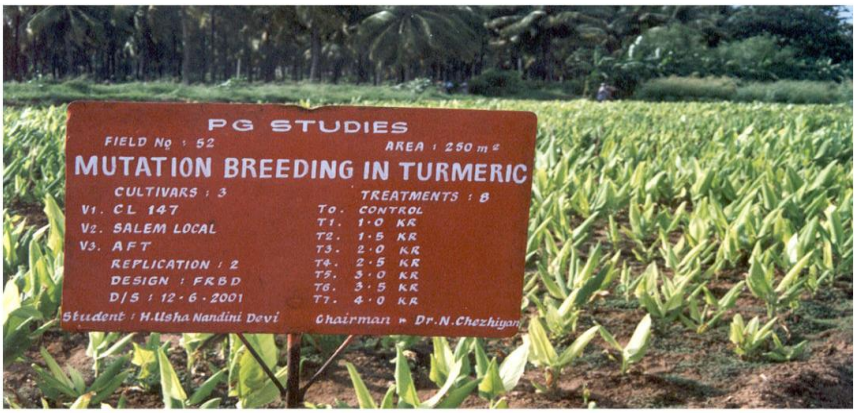


Plate 2.View of the experimental plot (vM1 generation)