EFFECT OF GAMMA IRRADIATION IN GINGER (*Zingiber officinale Rosc*)

BY

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THESIS

submitted in partial fulfilment of the
requirement for the degree

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DECLARATION

I hereby declare that this thesis entitled "Effect of gamma irradiation in ginger (Zingiber officinale Rosc.)" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellanikkara,
20-12-1984.

GIRIDHARAN, M.P.

CERTIFICATE

Certified that this thesis, entitled "Effect of gamma irradiation in ginger (*Zingiber officinale* Rosc.)" is a record of research work done independently by Sri. Giridharan, M.P. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to him.

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Introduction

INTRODUCTION

Ginger, Zingiber officinale Rosc., is an important spice belonging to the family Zingiberaceae. The dried underground rhizome of this spice has characteristic aroma, flavour and pungency and it is used mainly as a spice and medicine since 5000 B.C.

In India, its cultivation is distributed in the tropical and sub tropical regions. Besides Kerala; Meghalaya, Uttar Pradesh, West Bengal, Himachal Pradesh, Andhra Pradesh and Assam are the other states cultivating ginger in India.

India exports ginger mostly as dry ginger. Ginger oil and oleoresin are also exported to a lesser extent.

The major drawbacks of Indian ginger are its high fibre content, high cost of production and susceptibility to various diseases (Pruthi, 1976; Venkataraman, 1980). Hence, development of high yielding varieties possessing low fibre content, high volatile oil and oleoresin assumes importance from the point of view of export.

In spite of the fact that ginger is an important spice crop, research work done in this crop is rather limited.

Presently, crop improvement programme in ginger is mainly oriented towards collection of cultivars from different regions and evaluating them for their yield potential. Evolution of new varieties through hybridisation has not been successful so far because of the shy flowering nature of the plant and total absence of seed set.

In vegetatively propagated crops, ionising radiations play a significant role in inducing variations and for this purpose, gamma irradiation is widely used. The effect of gamma ray, in general, depends on the radio sensitivity of the species and in particular, on the plant part and the stage of development of the plants. Radio-sensitivity of a plant species is again associated with their nuclear volume, number of chromosomes and ploidy level. Further, the climate and other environmental conditions before and after the treatment of the plant parts also influence the radio sensitivity of a plant species. Within a plant species, the effects of gamma irradiation vary with the dosage used. Generally, a higher dosage induces mutagenic changes whereas lower dosage causes stimulatory effects.

Stimulatory effects of lower dose of gamma irradiation, which can be exploited commercially, has been reported in certain crops such as gladiolus, costus and mentha. But not much work in this line has been done in

ginger so far. Better rhizome growth and consequent increase in yield, and attainment of improved quality attributes such as high oleoresin, oil and dry ginger recovery are of significance in ginger both from economic and commercial points of view. Besides, induction of disease resistance is another aspect worthy of investigation. If profuse flowering in ginger that too ensuring good seed-set, high yield, dry ginger recovery and better oil production could be achieved, it will be a break-through in the ginger improvement programme.

With the aforesaid objectives, investigation was undertaken in ginger, at the College of Horticulture, Vellanikkara during 1983-84 to standardise the safe dose of gamma irradiation and to assess any stimulatory and/or mutagenic effects caused due to gamma irradiation on the vegetative and floral characters, rhizome yield and quality attributes and the incidence of soft rot disease.

Review of Literature

REVIEW OF LITERATURE

The morphology, flowering behaviour, yield and quality attributes of ginger have been reported by several workers. Literature is also available on the effects caused by low doses of gamma irradiation on other vegetatively propagated crops and related species of ginger. The work done so far on the above aspects is briefly reviewed.

2.1. Morphology

Ginger is an erect growing herbaceous perennial, attaining an average height of 50 to 75 cm and producing an average of 16 to 25 tillers (Nybe, 1978). Pillai (1973) found that the plant height and tiller production varied significantly in different cultivars and these characters could be correlated with the yield of rhizomes. Further, leaf production per plant significantly differed in different types. On an average, ginger plant produced 16 to 20 leaves in each tiller, with an average leaf size of 18 x 2 cm. The yield was found mostly influenced by the leaf area rather than the leaf numbers (Nybe, 1978). Thomas and Kannan (1969) reported that Rio-de-Janeiro variety of ginger was a vigorous growing type possessing large and well formed rhizomes.

2.2. Flowering and floral biology

In ginger, flowering rarely occurs and the same is highly influenced by the environment. Hooker (1894) described ginger as a species rarely flowering and never setting seed. Out of 35 cultivars of ginger maintained in the germplasm collection at the Central Plantation Crops Research Institute, Kasaragod, only six have so far flowered (Pillai et al., 1978). Nybe (1978) studied the flowering behaviour of some of the ginger cultivars under Vellanikkara conditions and observed flowering in 17 cultivars. They were Valluvanad (6.57%), Vengara (2.49%), Ernad Chernad (4.94%), Ernad Manjeri (1.11%). Wynad local (11.71%), Wynad Kunnamangalam (1.60%), Bajpai (7.43%), Karakal (6.03%), Thaiwan (0.53%), Tafingiva (0.63%), Sierra Leone (2.92%), Maran (1.19%), Rio-de-Janeiro (10.14%), Wynad Manantody (6.06%), Kuruppampady (5.30%), Jorhat (8.15%) and Assam (10.94%). Flowering was not observed in the cultivars such as Thodupuzha, Thingpuri and Himachal Pradesh. The shy flowering behaviour of ginger has also been reported by Nair et al. (1980). According to Ratnambal and Nair (1982), flowers were not produced in the majority of the Indian cultivars.

In the type collection of ginger maintained at the Regional Station, National Bureau of Plant Genetic Resources, Vellanikkara, flowering was observed only in

one accession introduced from North Kerala, that too when it was grown under shaded situation. It failed to produce any flower under open condition. When 134 types collected from South Kerala were planted in partially shaded situation, only 50 collections flowered (Velayudhan et al., 1983). According to them, North Indian conditions are more congeniel to cause flowering in ginger. Usha (1984) observed flowering only in two cultivators (Rio-de-Janeiro and Maran) in a collection of 25 cultivars maintained at the College of Horticulture, Vellanikkara.

Inflorescence in ginger is a scape, produced on a special scale leaf bearing shoot arising from the rhizome. Production of terminal inflorescence has been reported by Jayachandran et al. (1979) in the cultivar Rio-de-Janeiro. Velayudhan et al. (1983) found terminal inflorescence production in accession Nos. 11, 47 and 114. Similar observations have been recorded in cardamom also (Parameswar and Siddappaji, 1973).

Floral biology of ginger has been studied by many workers like Nybe (1978), Pillai et al. (1978) and Jayachandran et al. (1979). The inflorescence is a scape possessing prominent green bracts. One flower is produced in the axil of each bract, with a bracteole as long as the bract. Flowers are small, zygomorphic, bisexual, epigynous

and trimerous (Nybe, 1978). Calyx is tubular with three projections at the top. Corolla consists of three petals which unite to form a corolla tube at the base and separates at the top into three lobes. Androecioum consists of six stamens, of which five are modified into staminodes. They are arranged in two whorls of three each. The posterior one in the inner whorl is the only fertile stamen while the other two unite to form the conspicuous labellum possessing deep red colour. Anther is prolonged into a slender beak like appendage, which covers the funnel shaped stigma. Style is filiform and lies in a channel along the fertile stamen. Ovary is inferior, tricarpellary and syncarpous with three locules, each having many ovules in axile placentation (Purseglove et al., 1981, Anonymous, 1980).

In ginger, the flower opening occurs in acropetal succession and the blooming pattern is at the rate of a single flower per day in the initial phase and two or three flowers per day in the latter phases.

Pillai et al. (1978) reported that anthesis in ginger was between 1.30 to 3.30 PM, and anther dehiscence synchronised with flower opening. Stigma attained receptivity at the time of flower opening and continued to be receptive upto five hours after flower opening (Jayachandran et al., 1979).

2.3. Seed-set

Seed-set is not reported in ginger so far and many reasons have been attributed for the failure of seed-set. Ginger was considered as self incompatible species by East (1940) and Fryxell (1957). Jayachandran and Vijayagopal (1979) have also suggested self incompatibility as one of the reasons for the failure of seed-set in ginger.

Low pollen fertility and poor pollen germination have been quoted as reasons for the poor seed-set in ginger. Pillai et al. (1978) observed pollen fertility to a tune of 37 per cent in ginger. Ratnambal (1979) has reported the pollen fertility status of three species of Zingiber namely Zingiber officinale (8.6 to 45.6 per cent), Z. zerumbat (95.3%) and Z. cassumunar (91%). Usha (1984) found only pollen fertility to a tune of 16 per cent in cv. Rio-de-Janeiro under Vellanikkara conditions.

The pollen grains of ginger are heteromorphic and round in shape with a very thick exine acting as a barrier for successful pollen germination (Pillai et al., 1978). The pollen grains fail to germinate under ordinary conditions. Nair et al. (1975) obtained 1.6 per cent pollen germination in a media containing 15 per cent sucrose, 300 ppm calcium nitrate, 200 ppm potassium nitrate, 100 ppm boric acid, 100 ppm magnesium nitrate and one per cent agar. Pillai et al.

(1978) reported that addition of boric acid was helpful to cause breakage of the exine and thereby to achieve better germination of pollen grains. They observed 11.5 per cent pollen germination in a media containing eight per cent sucrose, three per cent gelatin and 60 ppm boric acid kept in a moist chamber at a temperature of 26.5°C.

Ratnambal and Pillai (1981) studied the ovule development and found that the development of the embryosac upto the tetrad stage was normal. But, the mature embryosacs were devoid of any nucleii. So, they suggested that abortion of nucleii took place after the tetrad stage making the fertilization impossible.

Darlington and Janaki Ammal (1945) observed the presence of two B chromosomes in ginger which led to unequal distribution of chromosomes, thus making the plant sterile. Ramachandran (1969) reported structural hybridity in ginger and suggested chromosonal aberration as the reason for the lack of seed-set. Ratnambal (1979) has also postulated that sterility in ginger was due to the chromosonal aberration during micro and mega sporogenesis. Her study revealed that, during meosis, multivalents were formed instead of bivalents in almost all the cultivars of ginger. So, in the pollen mother cell, there was an unequal distribution of chromosomes. Hence, microspores with deficient

or duplicate chromatin segments were produced. These microspores developed into unbalanced gamets and they were sterile leading to high pollen sterility. The formation of univalents due to early separation of bivalents, unequal breakages of the chromatin bridges and structural hybridity were also reported to be causes for sterility in ginger.

2.4. Rhizome yield

Khan (1959) reported cv. Burdwan as the maximum yielder producing thirteen times the quantity of seed used and cv. Rio-de-Janeiro as the best for the size of the rhizomes. According to Kannan and Nair (1965), the yield was 25 to 30 tons green ginger per hectare in the case of Rio-de-Janeiro and 18 to 20 tons per hectare in the case of China. Nair (1969) reported based on an experiment conducted at Ambalavayal that the type Maran gave an equally good yield as that of Rio-de-Janeiro. Thomas and Kannan (1969), Muralidharan (1972) and Nair (1975) have also found that the type Rio-de-Janeiro was significantly superior in respect of yield over the other types. In general, the yield of green ginger was 12000 to 23000 kg per hectare (Sankaranarayana, 1974). Pillai and Nambiar (1976) have accounted the yield of Maran cultivar as 9.73 kg/3m^2. Nybe et al. (1980) observed an average yield of 25210 kg green ginger per hectare in the cultivar Maran

and 17656 kg green ginger per hectare in the cultivar Rio-de-Janeiro when harvested on the 255th day after planting.

2.5. Quality evaluation

It has been reported that the drying percentage of Rio-de-Janeiro as 16 to 18 and the fibre content as 5.19 per cent (Kannan and Nair, 1965). Aiyadurai (1966) found that the recovery of dry ginger was low in the case of China and Rio-de-Janeiro. Nair (1969) placed Maran as a superior cultivar based on a higher recovery of dry ginger from green ginger.

The rhizomes of Zingiber elatum (wild ginger) contain 0.59 per cent essential oil on fresh weight basis. In Zingiber chrysanthum, the essential oil content is 0.17 per cent. Gulati (1969) and Krishnamurthy et al. (1970) reported that the peelings of ginger contained some amount of oil. The flavour quality of the oil obtained from green ginger was much superior than that obtained from dry ginger. They could get high oil content in Manantody and Mysore types (2.7%). According to Nair and Varma (1970), the optimum time for harvest of ginger was found to be 260 days after planting. A steady increase in the percentage of volatile oil occurred upto 260 days after planting. Further delay in the harvest caused reduction in the

percentage of oil but the fibre content increased. Natarajan et al. (1970) found that the volatile oil content in different cultivars varied from 1.25 to 2.81 per cent. They have stressed the importance for evolving and popularising proper varieties of ginger for specialised product development. Muralidharan (1972) has rated Rio-de-Janeiro as a variety yielding lowest recovery of dry ginger. In a study conducted to compare the recovery of the essential oil and oleoresin from green and dry gingers, Govindarajan (1972) found that the concentrates from green ginger were superior in odour. His work also showed that higher citral was a characteristic of green ginger odour and careful handling to preserve this component would lead to the production of a superior oil or oleoresin. Lewis et al. (1972 a) considered Jamaican ginger valuable because of its fine lemon-like odour. Indian ginger popularly known as cochin ginger was placed only next to Jamaican ginger in this regard. However, Indian ginger was considered superior to African ginger. In ginger, most of the constituents like volatile oil, acetone extracts and crude fibre content increased with maturity of the crop during the period September to December (Natarajan et al., 1972). Lewis et al. (1972 b) have recorded the essential oil content of Cochin, Sierra Leone and Jamaican gingers as 2.2 per cent, 1.6 per cent and 2.5 per cent respectively.

Mathai (1972) reported that the type Rio-de-Janeiro accounted for maximum yield of oleoresin followed by the type Manantody. According to Mathew et al. (1972), essential oil content of the type Rio-de-Janeiro was 2.5 per cent. Mathai (1973) studied the dry matter and oleoresin content of some ginger types. He observed 11.1 per cent dry matter in the type Rio-de-Janeiro and 16.1 per cent in the type Maran. The oleoresin content determined by acetone extraction worked out to 6.6 per cent and 5.5 per cent in the cultivars Rio-de-Janeiro and Maran respectively. Lewis (1973) stressed the importance of selecting proper variety for oil and oleoresin production. According to Muralidharan (1974), the yield of oleoresin in ginger was 200 kg per hectare for the cv. Rio-de-Janeiro.

In ginger, the oleoresin content is higher in the early growth phases of the plants. The same has been reported as 10.1 to 16.1 per cent in a crop of three months old and 4.8 to 9 per cent in a crop of seven months old (Mathai, 1974). Nair (1975) observed highest drying percentage in the types Sierra Leone and Maran and maximum oleoresin content in the type Rio-de-Janeiro. Nybe et al. (1980) have assessed the essential oil and oleoresin contents of some of the ginger types and reported that the essential oil and oleoresin content were 2.3 per cent and 10.5 per cent respectively in case of Rio-de-Janeiro,

and 19 per cent and 10 per cent respectively in case of Maran. The essential oil content of ginger varied from 0.8 to 4.0 per cent based on locations. In India, the range of essential oil has been reported as 0.5 to 2.5 per cent in different commercial cultivars (Sankarikutty et al., 1980).

The essential oil and oleoresin contents in the fresh and dry ginger samples were evaluated by Damayanthi et al. (1980). In their experiment, dry ginger contained volatile oil to an extent of 2.6 ml per 100 g which was equivalent to 0.2 to 0.25 per cent on fresh weight basis, whereas the yield of oleoresin from fresh ginger was 0.5 to 0.6 per cent compared to six to seven per cent in dry ginger.

Nair and Das (1980) studied the influence of nitrogen and planofix (NAA) on the oleoresin and crude fibre contents in five ginger cultivars. They found that the oleoresin content was significantly higher in samples harvested from the plots treated with urea alone and urea + planofix. In this experiment, the cultivar Rio-de-Janeiro recorded maximum oleoresin content closely followed by China and Maran. Application of urea or planofix did not have any effect on the crude fibre content of different ginger cultivars.

2.6. Pest and diseases

Many diseases occur in ginger crop which cause varying degrees of damage and thereby reduction in yield (Sharma and Jain, 1977). Kannan and Nair (1965) reported that yield loss due to incidence of rhizome-rot caused by Pythium aphanidermatum ranged from 80 to 90 per cent in different years. According to Joshi and Sharma (1980) soft-rot is a serious disease in most of the ginger growing tracts. Losses of more than 50 per cent of population have been reported due to this disease. By treating seed rhizomes and soil at the time of planting with cheshunt compound (28.35 g in 9 litre of water) or wettable Ceresan 0.1 per cent, the soft-rot disease could be controlled (Aiyadurai, 1966).

Many workers have reported the comparative resistance of different cultivars of ginger against rhizome rot disease. Nair (1969) found the cultivar Maran as comparatively tolerant to soft-rot disease while, Rio-de-Janeiro as very susceptible. Indrasenan and Paily (1974) screened 21 cultivars of ginger for their susceptibility to Pythium aphanidermatum and based on the results on the percentage of infection of rhizomes, they considered cv. Maran as tolerant. Sarma and Nambiar (1974) found the incidence of soft-rot to a tune of 22.78 per cent in plots

treated with aureofungin at 200 ppm, 28.34 per cent in plots treated with 0.1 per cent captafol as against 68.88 per cent in plots under control.

Balagopal et al. (1974) reported that the cultivars, Nadia and Narasapattam, as moderately resistant to soft-rot disease. According to Sarma et al. (1975) the incidence of soft-rot disease was least in cvs Jorhat and Sierra Leone (11.25 per cent) as against 82 per cent in the cv. Kuruppampady. Nair (1975) concluded that type Maran was significantly superior on its tolerance to rhizome-rot and cultivar China was most susceptible. Sarma et al. (1976) could reduce the incidence of soft-rot disease by application of methoxy ethyl mercuric chloride.

Several species of Pythium cause soft-rot disease of ginger. They are Pythium aphanidermatum (Edson) Fitzp, P. butleri Subr, P. gracile schenk, P. myriotylum Drech (Randhawa and Nandpuri, 1970), P. complectens Braan (Park, 1934), P. vexans de Barry (Ramakrishnan, 1949), P. deliense Meurs (Haware and Joshi, 1974).

Iyer et al. (1981) have reported that the adult insects of Mimegralla sp transmit the disease from infected clumps to healthy ones.

Yellow disease caused by Fusarium oxysporum f.sp. Zingiberi, bacterial wilt caused by Pseudomonas solanacearum

and phyllosticta leaf spot caused by Phyllosticta zingiberi are the other important diseases of ginger (Joshi and Sharma, 1980).

Nair (1980) reported the shoot borer (Dichocrocis punctiferalis Guen), the rhizome maggot (Chakidomyia atricornis Mall.) the leaf feeding caterpillar (Udaspes folus Cram.) the scale insect (Aspidiotus hortii Gr.) and the root-knot nematode (Meloidogyne incognite) as major pests of ginger.

2.7. Crop improvement

2.7.1. Screening for high yield

According to Muralidharan and Kamalam (1973), Rio-de-Janeiro was superior to other cultivars with respect to yield. In an yield trial of eleven cultivars conducted at Vellayani, Nair et al. (1976) found that the highest yield was given by the cultivar Nadia followed by Himachal Pradesh. In a comparative yield trial of 23 cultivars of ginger at Kasaragod, maximum yield was obtained from Rio-de-Janeiro followed by Burdwan and Jamaica (Anonymous, 1978).

2.7.2. Tissue culture

Hosoki and Sagawa (1977) found tissue culture as a successful technique in propagation of ginger. Buds from

storage rhizomes were grown in a media containing Murashige-skoog major elements, Ringe-Nitsch minor elements, vitamins, two per cent sucrose, and one ppm 6-benzyl aminopurine. They could produce numerous adventitious shoots with roots through repeated sub culturing of individual plantlets in one ppm-6 benzyl amino purine medium. The rooted plantlets could be successfully transferred to a mixture of 2 peat: 1 sponge rock : 1 vermiculate in the green house and exposed eventually to full sun in the nursery.

2.7.3. Growth regulator application

In ginger, a substantial increase in the shoot and root growth could be achieved by the application of Ethephon at dosage of 250 ppm (Islam et al., 1978). Jayachandran (1978) observed increased flower production in ginger by the application of Kinetin (10, 50 ppm). Nair and Das (1980) reported that in ginger the oleoresin content got increased by the application of urea (2 per cent) and planofix (200 ppm, 400 ppm).

2.7.4. Genetics and breeding

The hybridization programme in ginger is handicapped due to relatively very shy flowering nature of most of the cultivars and the total absence of seed-set. Mohanty and Sarma (1979) studied the genetic variability and heritability of 14 characters of 28 cultivars of ginger. The study

indicated that straight selection was useful to improve almost all the characters except in cases of number of tertiary fingeres and straw yield. Significant positive genotypic and phenotypic correlations with the number of tillers, number of leaves, plant height, leaf breadth and total number of fingers with rhizome yield were also obtained.

Ratnambal et al. (1980) studied the linear relationship between the morphological characters like height of the pseudostem, number of leaves and breadth and length of last fully opened leaf, and yield in 23 cultivars of ginger by multiple regression technique. Using this technique, they could predict fairly accurately the final yield with an R^2 of 73 per cent. They recorded the morphological characters 90 and 120 days after planting. Path coefficient analysis revealed that the phenotypic correlation between yield of rhizomes and height of the plant was quite high. The plant height also exhibited a high indirect effect in the establishment of correlation between yield and other morphological characters.

Ratnambal (1979) on conducting multivariate analysis found that the ginger cultivars showed differences with respect to rhizome characters such as number of nodes, length, breadth and internodal length of mother rhizomes, number of nodes, length and breadth at the base, middle and top and internodal distance of fingers.

2.8. Effect of ionising radiation on plant growth

2.8.1. Gamma ray

2.8.1.1. Germination

Many workers have reported the effects of gamma rays on germination of various vegetatively propagated crops. Vijayalakshmi and Rao (1960) irradiated the setts of sugarcane species, Saccharum officinarum, S. spontaneum, S. barberi, S. sinense and S. robustum with gamma rays at doses ranging from 50 to 10,000 rad and found that the upper limit of safe dosage for normal germination and growth of Saccharam sp was around 300 rad. According to Moh (1963) the LD_{50} i.e., the dose of gamma irradiation of which 50 per cent of the treated materials does not survive, for tapioca was approximately 3 k rad. Abraham (1970) observed maximum sproutings of buds of irradiated stem cuttings of tapioca at a dose lesser than 1.5 k rad.

Stotzky et al. (1964) treated the rhizomes of Musa sapienthm cv. Gros Michel with gamma rays and observed reduction in survival. Velez and Maldonado (1972) also studied the effect of gamma irradiation in banana. Suckers of the cultivar 'Gros Michel' were treated with 2.5 to 40 k rad of gamma rays, but sprouting occurred only upto 5 k rad.

According to Uzenbaev and Nazernko (1969) sprouting was delayed, when the corms of gladiolus were irradiated with gamma rays at 5, 10 and 15 k rad. Das (1970) reported the lethal dose of gamma irradiation as 10 k rad in the case of mulbery seedling. Mukherjee and Khoshoo (1970) treated rhizomes of canna with 1, 2 and 3 k rad of gamma rays and found that a dose of 3 k rad was lethal to the diploids, but not to the triploids.

According to Gonzalez et al. (1972) germination was completely inhibited by 5 k rad of gamma rays, in ginger. However Raju et al. (1980) observed 32 per cent germination by 2 k rad as against 96 per cent in control.

Gamma irradiation of bulbs of tuberose with a series of doses revealed the optimum dose to be around 2 k rad (Younis and Borham, 1975). Zhila (1975) suggested the optimum dose of gamma irradiation on garlic as below 1 k rad.

Gupta et al. (1982) observed that gamma rays induced variability in costus. Rhizome pieces were exposed to 1.5, 2, 2.5 and 3 k rad of gamma rays and planted. Lower doses had no effect on sprouting while marked decrease in sprouting was observed at 3 k rad. On the basis of survival LD_{50} dose was fixed as 3 k rad.

2.8.1.2. Vegetative growth

Stimulatory and inhibitory effects of gamma rays on plant growth have been reported by several scientists. In pineapple, irradiation of the plants of the varieties kew and Mauritus led to growth retardation, and in one plant to premature suckering (Anonymous, 1964). Irizary and Velez (1970) also studied the effect of gamma irradiation in pineapple crown. They observed that the doses 500 to 4000 rad did not influence either rooting efficiency or shoot growth. At higher doses above 4000 rad, reduced rooting and shoot growth were produced.

Koo and Ruiz (1964) irradiated the aerial tubers of dioscorea with 2 k rad of gamma rays and observed variation in the shoot growth during the second generation. Halevy and Shoub (1965) reported some non genetic effects of gamma irradiation on growth of iris plants. In crocus, some morphological changes were observed by Mitsukiri and Arai (1965), when the tubers of the cultivar 'Mammoth Yellow' irradiated with gamma rays.

Rhizomes of the young plants of canna were irradiated with gamma rays at 1, 1.5 and 2.7 k rad by Nakornthap (1965) and he observed stunted plant growth and variegated leaves. Desai and Abraham (1974) observed

growth stimulation in canna cv. 'Rosamund Coles' when exposed to gamma rays at 1 and 2 k rad. In lilly, plant height was increased by irradiating the bulbs with gamma rays at the rate of 10 rad/day for 35 days.

Gupta (1965) studied the effect of gamma irradiation in Cymbopogon martini, at 20, 30, 40 and 50 k rad. Compared with the control, the treated plants were taller and more vigorous. Banerjee (1967) irradiated zephyranthus bulbs with 1.2 and 5 k rad of gamma rays but he did not find growth stimulation. When the stem cuttings of portulaca were irradiated with gamma rays, the average number of branches decreased (Gupta, 1969).

Jauhar and Singh (1969) treated tubers of potato cultivar 'Kufri sindhuri', 'Kufri Red', 'Kufri Kuber' and 'Upto-date' with gamma rays alone and in combination with ultra violet rays, ^{35}S, ^{32}P and ^{45}Ca. A wide range of morphological and physiological variants could be produced in the M_1 generation, some of which were of potential breeding value. Nayar and Dayal (1969) used healthy dormant and uniform tubers of the variety 'Kufri Sindhuri' for gamma irradiation. The tubers were cut into two equal halves, one half exposed to gamma rays, and the other kept as control. They observed variation in growth of the plants in M_3 generation. Serebrenikov (1971)

observed growth stimulation in potato when tubers were irradiated with 500 rad of gamma rays.

Dryagina (1964) and Buiatti and Tesi (1968) reported that variation can be easily induced in gladiolus by irradiation. Uzenbaev and Nazernko (1969) observed reduced plant growth, and diminished leaves in gladiolus when the corms were irradiated with gamma rays at 5, 10 and 15 k rad.

Escober and Lopez (1970) treated sugarcane seed pieces with gamma rays to find out the effect of irradiation on growth of the plants. Growth stimulation was not observed even at the lowest dose (1.5 k rad). Abnormalities of the growing point, malformation of the leaves, stunting and reduction in the size of the stalk, were observed in the irradiated plants.

Rawkin (1970) observed that in strawberry, growth of the plant inhibited by gamma irradiation at 7 and 14 k rad. In chrysanthemum, growth stimulation was observed by Pavlova (1972), when the stem cuttings were irradiated with 200 and 1000 rad of gamma rays. Velez and Maldonado (1972) observed growth reduction and drastic leaf aberrations in banana, as a result of gamma irradiation.

Gupta et al. (1982) irradiated rhizomes of costus with 1.5, 2, 2.5 and 3 k rad of gamma rays. They observed growth stimulation at 1.5 k rad. At 2, 2.5 and 3 k rad, treatment, height of the plant, and number and size of leaves decreased.

2.8.1.3. Leaf and tuber colour

Hernandaz et al. (1959) observed variation in skin and flesh colour of sweet potato by gamma ray treatment at 10 and 15 k rad. Buiatti et al. (1965) studied the effect of gamma irradiation on the rooted cuttings of carnation and observed that the frequency of chlorophyll deficient sector per plant and branches were roughly proportional to the dose. Vasudevan et al. (1968) observed variation in the chlorophyll content of Colocassia esculenta as a result of gamma irradiation.

Ono (1971) compared the effect of gamma rays on developing buds, developing seeds and dormant seeds of mentha and found that irradiation of developing bud was most effective for the induction of chlorophyll mutants. Gupta et al. (1974), Abraham and Desai (1976), and Konzak (1984) observed yellow margined leaves in tuberose when the bulbs were irradiated with gamma rays. Laxmi et al. (1980) observed chimera formation in costus as a result of gamma irradiation.

2.8.1.4. Flowering

Gamma ray irradiation is found effective in modifying the flowering behaviour of crop plants. Treatment of stem cuttings of chrysanthemum with 2 to 4 k rad of gamma irradiation was an efficient method for inducing variation in the size and shape of individual florets (Bowen, 1965). Effect of gamma irradiation on flowering of iris had been reported by Halevy and Shoub (1965). Nakorthap (1965) observed changes in colour and forms of the flower petals of canna as a result of gamma irradiation.

Lantin and Decourtye (1970) irradiated, dormant tubers of dahlia with gamma rays and observed variations in the flower colour and form. Rawkin (1970) observed that in strawberry, flowering was inhibited by gamma irradiation at 7 and 14 k rad. According to Lata and Gupta (1971) size of the flower is reduced, by gamma irradiation in rose.

In gladiolus early flowering was observed by the combined treatment of gamma rays and nitrosomethyl urea (Dryagina and Kozarinov, 1972). Broertjes and Van Harten (1978) irradiated dormant corms of gladiolus cv 'Hawaii' with 2.5 to 15 k rad of gamma rays and observed variation in flower colour. When the normal colour of flower being red, irradiation helped to produce flowers of colour purple, crimson, scarlet, pink and white. Gupta et al. (1974)

observed delayed flowering in tuberose, when the bulbs were irradiated with gamma rays.

Nayar et al. (1979) reported radiation as a stimulant for early and uniform flowering in pineapple. Three month old, pineapple suckers were irradiated at 4 and 6 k rad and planted. Suckers exposed to 4 k rad produced cent per cent flowering after 16 months of planting while no flowering was observed in the control. Kukimura and Kouyama (1982) reported that gamma rays had effect on inducing flowering in sweet potato.

Decourtye (1970) observed reduced pollen germination in apple variety 'Golden Delicious', when the dormant scion wood was exposed to 5 k rad of rays before grafting. Singh and Khanna (1970) succeeded in producing male sterile plants in opium poppy following gamma irradiation.

2.8.1.5. Yield

Halevy and Shoub (1965) found that the bulb yield of iris was affected by gamma rays. In gladiolus, treating the corms with 15 k rad of gamma rays before planting resulted in increased production of new corms, (Sparrow, 1966). Banerjee (1967) irradiated zephyranthus bulbs with 1.5 and 5 k rad of gamma rays, but he did not find stimulation of growth and yield or mutation due to

Abraham (1970) reported increased yield in Amorphophallus companulatus and dioscorea by gamma irradiation of the corms and tubers before planting. According to Serebrenikov (1971) yield of potato increased at 500 rad of gamma irradiation. Mital et al. (1972) observed increased yield in Mentha arvensis, when the stolons were exposed before planting to gamma rays at 1, 2 and 3 k rad.

Raju et al. (1980) found formation of weaker and elongated underground rhizomes in ginger due to 2 k rad of gamma ray treatment. In Costus, Gupta et al.(1982) observed increased rhizome production in 1.5 k rad treatment. But the yield of rhizome decreased at 2, 2.5 and 3 k rad treatments. Gamma irradiation at 500 to 1500 rad increased the yield of strawberry cultivar, 'Frense' by 44 per cent (Sodowska, 1983). Kamala and Rao (1984) reported increase in the yield of yellow sarson when the cuttings were irradiated with 5 k rad of gamma rays.

2.8.1.6. Quality attributes

In, Cymbopogon martini, the essential oil content in the leaves and inflorescence was increased by gamma irradiation (Gupta, 1969). However the oil content was decreased in rose, when the buds were irradiated with gamma rays (Lata and Gupta, 1971).

Mital et al. (1972) observed that oil recovery was increased in Mentha arvensis, when the stolons were exposed before planting to gamma rays at 1.2 and 3 k rad. Kaul and Kak (1974) reported that in Mentha arvensis, the oil content increased by planting irradiated suckers. In costus, Gupta et al. (1982) observed increase in the diosgenin content in the treated plants at 1.5 and 2 k rad.

2.8.1.7. Disease resistance

Resistance to the disease caused by Phytophthora parasitica was induced through gamma irradiation in Abelmoschus manihot (Kuwada, 1967). Escober and Lopez (1970) treated sugarcane seed pieces with gamma rays to find out the effect of irradiation on disease resistance. But growth stimulation and disease resistance were not observed even at the lowest dose (1.5 k rad). According to Ono and Ikeda (1970) resistance to rust disease can be induced in Mentha arvensis by gamma irradiation. In Stenatophrum secundatum gamma irradiation of stem cuttings induced disease resistance against Pyricularia grisea, Sclerophthora sp. and Thanatephorus cucumeris (Toler and Grisham, 1983).

2.8.2. X-ray

2.8.2.1. Germination

Sparrow and Christenson (1950) observed that X-ray irradiation had an inhibitory effect on sprouting of potato tubers. De Mol (1953) assessed the optimum dose of X-ray irradiation as around 300 rad, in the case of hyacinthus. According to Haut and Subramanium (1973) an exposure level of 2 k rad of X-ray was the upper limit for survival of the dormant green buds of rubber clone RRIM-600.

Broertjes and Verboon (1974) stated that the best period for irradiating rhizomes of alstroemeria with X-ray was March-April, the optimum dose being between 350 and 500 rad for diploids and 500 to 700 rad for triploid cultivars. Broertjes (1977) has listed out the suitable irradiation doses to be used for some of the vegetatively propagated plants, which include, alstroemeria (rhizome 400 to 600 rad), Canna (rhizome, 1 to 3 k rad), Gladiolus (Corm, 4 k rad), banana (rhizome, 2.5 to 5 k rad), tulip (bulbs, 300 to 500 rad) hyacinthus (bulbs, 200 to 500 rad).

2.8.2.2. Vegetative growth

The vegetative growth of plants can be modified by X irradiation treatment. Ferwerda (1965) observed stunted growth and abnormalities in leaf colour and texture

in potato as a result of X-ray treatment. In peppermint, the leaf size was reduced, when the stolons irradiated with 500 to 6000 rad of X-rays (Murray, 1969). Zimar et al. (1974) reported that X-ray irradiation at 10, 40, 80, 150 and 600 rad increased the root growth in chrysanthemum. At 1200 rad root growth was decreased. A high yielding mutant of turmeric, viz., Co-1 has been developed by Shah et al. (1982). It is a vegetative mutant of type Erode, developed by X-ray irradiation at 5 k rad. The plants of Co-1 was found more robust, vigorous, and taller possessing more leaves and tillers.

Pavlovic et al. (1983) studied the effect of different doses of X-ray irradiation in Mentha piperita. Cuttings were exposed to X-rays at 500 to 4000 rad and planted. The lowest dosage stimulated the plant growth, whereas the highdst had an inhibiting effect.

2.8.2.3. Flowering

X-ray irradiation is also found effective in modifying the flowering behaviour of crop plants. Spencer (1955) noticed early flowering in zephyranthus, when the bulbs were irradiated with gamma rays. In hyacinthus, flower colour variations were observed as a result of X-ray irradiation (De Mol, 1953). X-ray treatment resulted in early flowering in Catheranthus roseus

(Bose et al., 1972). Irradiation of the dormant tubers of dahlia cv. 'Salmon Rays' at 1 to 4 k rad of X rays resulted in larger blooms and longer stem (Sigurbjornsson and Micke, 1973).

2.8.2.4. Yield

Johnson (1928) administered a low unspecified dose of X ray on the tubers of potato cv. Early Ohio and observed increased tuber formation. In cv. Irish Cobler, large sized tubers and high yield could be observed, as a result of irradiation of the seed tubers with 400 to 1200 rad of X rays (Sprauge and Lenz, 1929). In potato, Johnson (1937) again observed, increased tuber formation as well as better weight of tubers, after exposure to 1500 rad of X rays.

According to Cheng (1958) yield of sweet potato increased, when the tubers were irradiated with 1250 and 5000 rad of X rays. Shah et al. (1982) observed larger mother and finger rhizomes and high yield in turmeric as a result of X ray irradiation.

2.8.2.5. Quality

Pavlovic et al. (1983) observed a positive correlation between irradiation dose and essential oil content in Mentha piperita. Samantha and Sen (1983)

reported X ray induced variability in Solasodine content of Solanum khasianum. By 15 k rad X ray treatment, Solasodine content could be increased.

2.8.2.6. Disease resistance

In potato, Kishore et al. (1963) observed increased resistance to Phytophthora infestans by X ray irradiation. Murray (1969) irradiated the dormant stolons of peppermint with 500 to 6000 rad of X rays and observed resistance to verticillium wilt in the progenies.

Materials and Methods

MATERIALS AND METHODS

Investigation was undertaken in ginger during 1983-84 at the College of Horticulture, Vellanikkara with the objectives to find out the lethal dose of gamma irradiation for ginger rhizomes with reference to their germination, and the effects of gamma irradiation on the vegetative parameters, flowering behaviour including floral biology and seed-set, yield and quality attributes of rhizomes and the incidence of soft rot disease.

3.1. Determination of lethal dose of gamma irradiation

3.1.1. Selection of planting material

Healthy and viable rhizomes of cultivars, Rio-de-Janeiro and Maran were selected and were subjected to pre sowing treatment. The rhizomes were soaked in a solution containing 0.25 per cent Emisan and 0.05 per cent Ekalux for 30 minutes and were dried under shade.

The rhizomes were cut into pieces of 15 g, each possessing two or three viable buds. Fifty seed bits were then subjected to each dose of gamma irradiation.

3.1.2. Treatments

The following doses of gamma irradiation were selected for treating the seed bits.

T_1	-	0.7 k rad
T_2	-	1.0 k rad
T_3	-	1.5 k rad
T_4	-	2 k rad
T_5	-	4 k rad
T_6	-	6 k rad
T_7	-	8 k rad
T_8	-	10 k rad
T_9	-	20 k rad
T_{10}	-	30 k rad
T_{11}	-	40 k rad
T_{12}	-	Control (No irradiation).

The seed bits were exposed to the respective doses of ^{60}Co gamma rays at a dose rate of 0.316 MR per hour in the gamma chamber available at the Radio Tracer Laboratory, Kerala Agricultural University, Vellanikkara. For control, unirradiated seed bits were used.

3.1.3. Planting and after care

After irradiation, the seed bits were planted immediately in earthern pots, filled with potting mixture, consisting of soil, sand and farm yard manure in 1:1:1 proportion. The pots were irrigated once in two days.

3.1.4. Observations

The germination of seeds under each treatment was recorded daily and the germination percentage worked out to select suitable doses of gamma irradiation for undertaking further studies.

3.2. Stimulatory/mutagenic effects of gamma rays

3.2.1. Land preparation

A field trial was undertaken in loamy laterite soil having good drainage. The land was first ploughed to a depth of 30 cm and the clods broken to ~~bring~~ got a fine tilth. Levelling was done and raised beds of size 3 M x 1 M and ~~a~~ height 30 cm having drainage channels of width 50 cm all around each bed were made.

3.2.2. Design and layout

The experiment was laid out in Randomised Block Design with three replication.

The treatments were the following irradiation doses.

T_1	-	0.7 k rad
T_2	-	1 k rad
T_3	-	1.5 k rad
T_4	-	2 k rad
T_5	-	Control (No orradiation)

3.2.3. Cultivars

Two cultivars namely Rio-de-Janeiro and Maran were used for the study.

3.2.4. Selection of planting material

Viable and disease free rhizomes were selected and pre sowing treatment was given. The rhizomes were cut into pieces of weight 15 g each having two or three viable buds.

3.2.5. Treatments

The seed bits were exposed to the different doses of ^{60}Co gamma rays, as described under 3.1.2, in the gamma chamber of the Radio Tracer Laboratory, Kerala Agricultural University, Vellanikkara. Unirradiated seed bits were used as control.

3.2.6. Cultivation

The seed bits were irradiated as per treatments and planted on 21st June 1983, in the already prepared beds giving a spacing of 25 x 25 cm. Fortyeight seed bits could be accommodated in each bed.

Cultural and manurial practices recommended by the Kerala Agricultural University as per the Package of practices were adopted.

3.2.7. Observation on vegetative characters

3.2.7.1. Sprouting

The plot wise number of seed bits germinated was recorded. The number of days taken for the germination was also observed.

3.2.7.2. Height of the plant

Height of the plants was measured vertically from the base of the main pseudostem up to the tip of the top most leaf, at monthly intervals commencing from one month old stage to six months old stage.

3.2.7.3. Number of tillers per plant

The total number of tillers produced by the plants was counted and recorded at monthly intervals.

3.2.7.4. Number of leaves per tiller

From each plant, five tillers were selected and the number of leaves in each was counted to work out the average number of leaves per tiller.

3.2.7.5. Length and width of leaves

Length from the base to the tip of the last fully opened leaf was measured and recorded as the

length of the leaf. Width was measured at the base, middle, and the tip of the leaf and the mean was worked out. These observations were taken at monthly intervals.

3.2.7.6. Leaf area index

Leaf area was determined by multiplying the length and width of the leaves.

Leaf area index was calculated by multiplying the number of leaves per plant with the number of plants per one square metre and area of an individual leaf.

3.2.7.7. Leaf colour

Leaf colour and the extent of chlorosis in the leaves were observed.

3.2.8. Observation on flowering

3.2.8.1. Inflorescence

The number of plants flowered and the number of inflorescence produced per plant were counted. The time taken for the emergence of first and last inflorescence was recorded. The number of flowers produced per inflorescence and the time of flower opening were observed. Measurements on the length of the inflorescence and their stalks were also recorded.

3.2.8.2. Pollen fertility

Fresh pollen grains were collected immediately after flower opening, stained with acetocarmine and observed under the microscope. Properly stained pollen grains with proper round shape alone were counted as fertile pollens. Observations were taken from 10 microscopic fields and the mean found out to calculate the pollen fertility.

3.2.8.3. Pollen viability

Fresh pollen grains at the time of flower opening were collected and kept in a media containing eight per cent sucrose, three per cent gelatin and 60 ppm boric acid to count the pollen germination.

3.2.8.4. Anthesis

The time of anthesis was recorded.

3.2.8.5. Pollination and seed-set

Hand pollination with fresh pollens was done at different intervals namely, bud pollination one hour before flower opening, at the time of flower opening, one hour and two hours after the flower opening.

Pollinations were also undertaken using the mixture of pollen of Zingiber officinale, Costus speciosus, Alpinia galanga and Curcuma longa.

Observations on seed-set were recorded.

3.2.9. Yield

The crop was harvested when seven months old. The following observations were recorded.

3.2.9.1. Number of rhizomes per plant

The number of rhizomes produced per plant was counted and recorded.

3.2.9.2. Type of rhizome

The rhizomes produced directly from the seed rhizomes were counted as the primary rhizomes and those originated from primary rhizomes as the secondary rhizomes.

3.2.9.3. Yield of rhizomes per plant

Yield of rhizomes per plant was determined by taking the weight of the fresh rhizomes after the harvest.

3.2.9.4. Yield of rhizomes per hectare

Yield of rhizomes per hectare was calculated by multiplying the average yield per plant in a plot with the population per hectare.

3.2.9.5. Percentage recovery of dry rhizomes

From each plant, 100 g of fresh rhizomes were collected immediately after harvest and dried under Sun till a constant weight was obtained. From the values the percentage recovery of dry rhizomes was worked out.

3.2.9.6. Yield of dry ginger per hectare

Yield of dry ginger per hectare was calculated by multiplying the yield per hectare with the percentage recovery of dry ginger.

3.2.9.7. Extent of root formation

The total number of roots produced on the rhizomes was counted and recorded. From each rhizome five roots were selected and their length measured to find out the mean length of root produced.

3.2.10. Observation on quality factors

3.2.10.1. Essential oil content (green ginger)

The cleaned freshly harvested rhizomes were used to determine the essential oil content. Hundred grams of rhizomes were taken and crushed in a mortar. Then the essential oil was extracted adopting Clavenger Trapp water distillation method as per American Spice Trade

Association (1960). The essential oil content was expressed as ml per 100 g of green ginger.

3.2.10.2. Oleoresin content (green ginger)

Fresh and cleaned rhizomes (10 g) were taken and the oleoresin content was determined adopting the Soxhlet method of extraction with acetone as solvent which is the official Analytical method of American Spice Trade Association (1960).

3.2.10.3. Essential oil (dry ginger)

The dried rhizomes were ground in a grinding mill and 50 g of powder taken for analysis, adopting Clavenger Trap Method as per American Spice Trade Association (1960). The essential oil was expressed as ml per 100 g of dry ginger.

3.2.10.4. Oleoresin content (dry ginger)

Powdered dry ginger of five gram weight was taken and the oleoresin content determined adopting Soxhlet Method of extraction with acetone as the solvent.

3.2.10.5. Oleoresin content in the peel

Peel of the cleaned fresh rhizomes immediately after harvest was removed and the oleoresin content in the

peel determined adopting the Official Analytical Methods of ASTA (1960). The same was expressed as milli grams of oleoresin per 10 g of ginger peel.

3.2.11. Observations on incidence of soft rot disease

The number of plants infected by soft rot disease was counted and the percentage of infection worked out.

3.2.12. Statistical analysis

The data of the various aforesaid observations were analysed statistically using standard proceadures (Snedecor and Cochran, 1967).

Results

RESULTS

Investigation was undertaken to find out the lethal dose of gamma rays in respect of the germination of ginger rhizomes, and to investigate the effects of gamma irradiation on the vegetative characters, flowering, yield, quality attributes and the incidence of soft-rot disease in ginger. The results of the studies are presented in this chapter.

4.1. Determination of lethal dose of gamma rays

Observations on the number of germinated rhizomes, germination percentage and the period taken for germination are given in Table 1. Maximum germination in both the cultivars could be noticed in control. The cv. Rio-de-Janeiro accounted for 90 per cent germination whereas cv. Maran only 80 per cent. The germination percentage decreased gradually with the increase in the dose of irradiation. Germination was minimum at 1.5 k rad (4%) in the case of 'Maran' and at 2 k rad (8%) in case of Rio-de-Janeiro. Total failure in germination was observed in treatment 4 k rad and above in cv. Rio-de-Janeiro. In respect of 'Maran' total failure in germination of rhizomes subjected to irradiation dose of 2 k rad and above was noticed.

Table 1. Extent of germination of gamma irradiated rhizomes in pots

Treatment	Gamma irradiation doses (k rad)	cv. Rio-de-Janeiro			cv. Maran		
		Rhizomes germinated (Nos.)	Germination percentage	Days taken for germination	Rhizomes germinated (Nos.)	Germination percentage	Days taken for germination
1	2	3	4	5	6	7	8
T_1	0.7	42	84	25	38	76	27
T_2	1	41	82	26	24	48	30
T_3	1.5	18	36	26	2	4	30
T_4	2	4	8	31	-	-	-
T_5	4	-	-	-	-	-	-
T_6	6	-	-	-	-	-	-
T_7	8	-	-	-	-	-	-
T_8	10	-	-	-	-	-	-
T_9	20	-	-	-	-	-	-
T_{10}	30	-	-	-	-	-	-
T_{11}	40	-	-	-	-	-	-
T_{12}	0	45	90	22	40	80	25

Irradiation treatments delayed the germination process. In case of 'Rio-de-Janeiro', the rhizomes under control germinated 22 days after planting, whereas the rhizomes exposed to 2 k rad took 31 days for germination. In case of 'Maran', the rhizomes under control germinated 25 days after planting and those irradiated at 1.5 k rad germinated 30 days after planting. Completion of germination took place in 53 days after planting. The data revealed that only four dosages of gamma rays viz. 0.7 k rad, 1 k rad, 1.5 k rad and 2 k rad were beneficial to undertake further studies on the stimulatory and/or mutagenic effects of gamma irradiation in ginger.

4.2. Stimulatory and/or mutagenic effects of gamma rays

4.2.1. Vegetative characters

4.2.1.1. Germination

In general, a higher percentage of germination could be observed in the field trial compared to the pot culture. Observation recorded on the germination of rhizomes planted in the field after treatments using gamma rays, are presented in Table 2a and 2b and Fig.1-1 and 1-2. The treatments differed significantly in their germination capacities. Maximum germination was recorded by the treatment control. As the irradiation dosage increased

Table 2a. Extent of germination of gamma irradiated rhizomes in cv. Rio-de-Janeiro in field

Treatment	Gamma irradiation doses (k rad)	Rhizomes germinated (Nos.)	Germination percentage	Days taken for germination
1	2	3	4	5
T_1	0.7	40.00	83.33	15.33
T_2	1.0	41.00	85.41	14.67
T_3	1.5	37.67	78.47	20.00
T_4	2.0	16.00	33.33	25.33
T_5	0	45.33	94.43	13.33
F value		45.16**		29.62**
CD (0.05)		5.59		2.95
SEm ±		1.71		0.91

** Significant at 1% level

Table 2b. Extent of germination of gamma irradiated rhizomes in cv. Maran in field

Treatments	Gamma irradiation doses (k rad)	Rhizomes germinated (Nos.)	Germination percentage	Days taken for germination
1	2	3	4	5
T_1	0.7	45.67	95.14	13.33
T_2	1.0	43.67	90.97	13.33
T_3	1.5	33.00	68.75	17.33
T_4	2.0	9.00	18.75	24.67
T_5	0	47.67	99.31	11.33
F value	47.51**			16.71**
CD (0.05)	7.58			4.24
SEm ±	2.32			1.30

** Significant at 1% level

Scale 1 cm = 10%

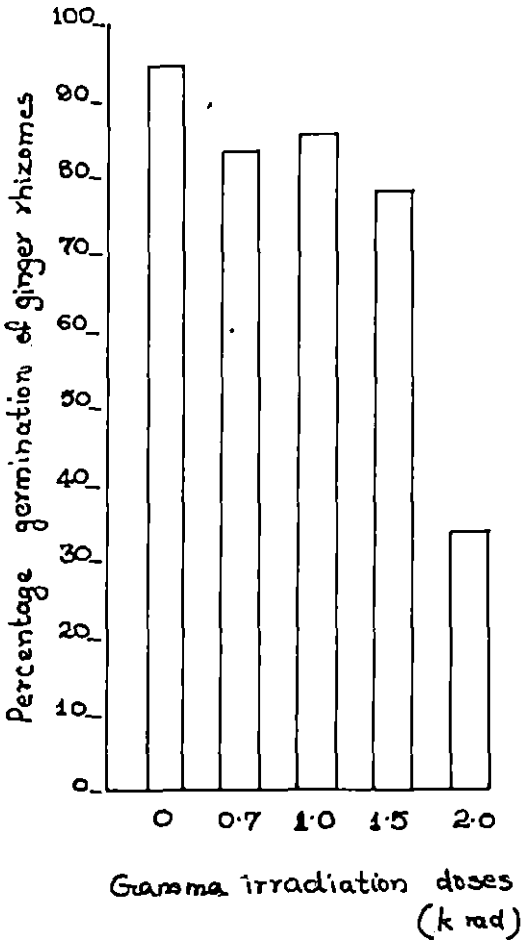

Fig.1-1 Effect of gamma irradiation on the germination of ginger rhizomes (cv. Rio -de- Janeiro).

Scale 1 cm = 10%

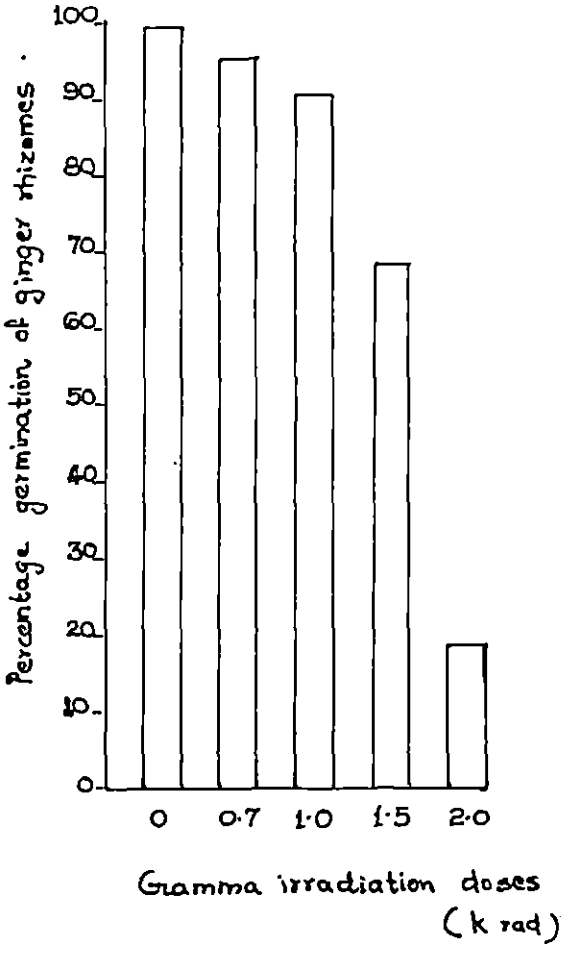

Fig.1-2 Effect of gamma irradiation on the germination of ginger rhizomes (cv. Maran).

graded decrease in the germination percentage was noticed irrespective of the cultivars tried. Minimum germination was recorded at 2 k rad, which worked out to 33.3 per cent in 'Rio-de-Janeiro' and 18.75 per cent in 'Maran'.

The treatments also exhibited difference in period taken for germination. Early germination occurred in control compared to all other treatments. In 'Rio-de-Janeiro' in control plot the number of days taken for germination was 13 days, whereas it was 25 days at 2 k rad. In 'Maran' the control plot took 11 days for starting germination whereas the rhizomes exposed to 2 k rad took 24 days. Treatments 0.7 k rad, and 1 k rad did not varyy from the control in respect of the number of days taken for germination.

4.2.1.2. Height of the plant

The data on the height of the plants under different treatments, recorded at monthly intervals are presented in Table 3a and 3b and Fig.2-1 and 2-2. The Anova presented in the Appendix II indicated that the irradiation doses had significant effect on plant height. The plant height was maximum for plants under control, throughout the growth phase of the crop. Graded decrease in the

Table 3a. Plant height in cm (cv. Rio-de-Janeiro)

Treatments	Gamma irradiation doses (k rad)	Growth periods (months)					
		One	Two	Three	Four	Five	Six
1	2	3	4	5	6	7	8
T_1	0.7	31.11	38.61	50.43	52.75	53.18	53.19
T_2	1.0	28.29	38.31	45.80	49.55	51.39	51.39
T_3	1.5	23.91	31.69	41.68	44.64	45.89	45.90
T_4	2.0	17.30	24.21	32.71	40.72	40.97	40.97
T_5	0 Control	39.80	46.26	55.92	57.90	59.18	59.19
F value		35.58**	57.46**	69.20**	51.18**	70.35**	70.13**
CD (0.05)		4.58	3.57	3.46	3.07	2.71	2.72
SEm ±		1.4	1.09	1.06	0.94	0.83	0.83

** Significant at 1% level

Table 3b. Plant height in cm (cv. Maran)

Treatments	Gamma irradiation doses (k rad)	Growth period (months)					
		One	Two	Three	Four	Five	Six
1	2	3	4	5	6	7	8
T_1	0.7	38.03	44.01	50.98	52.42	52.92	52.92
T_2	1.0	31.33	39.39	49.99	51.58	51.70	51.71
T_3	1.5	24.75	32.65	43.94	45.45	45.73	45.73
T_4	2.0	18.90	27.35	35.58	39.90	40.24	40.24
T_5	0 Control	39.99	45.01	53.74	56.05	56.91	56.91
F value		82.44**	64.45**	47.28**	26.85**	30.21**	30.21**
CD (0.05)		3.19	3.0	3.44	4.02	3.88	3.88
SEm ±		0.98	0.92	1.06	1.23	1.19	1.19

** Significant at 1% level

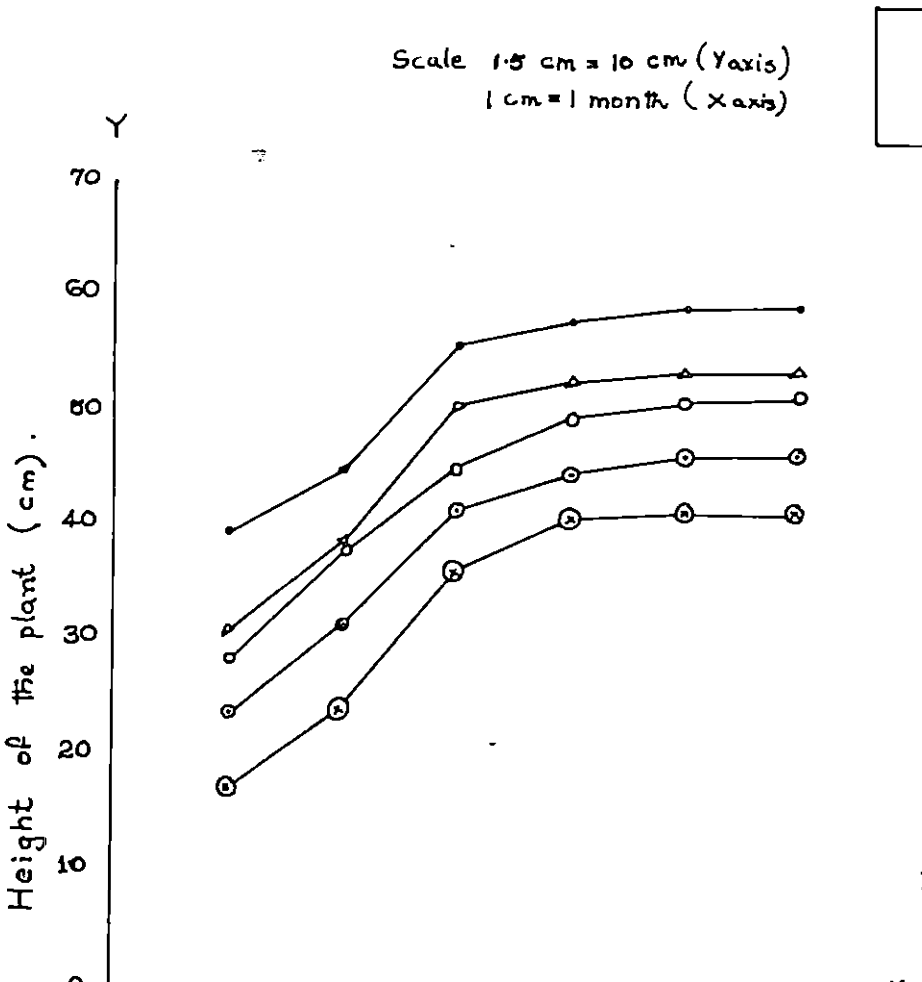

Fig. 2-1. Effect of gamma irradiation on plant height (cv. Rio -de - Janeiro).

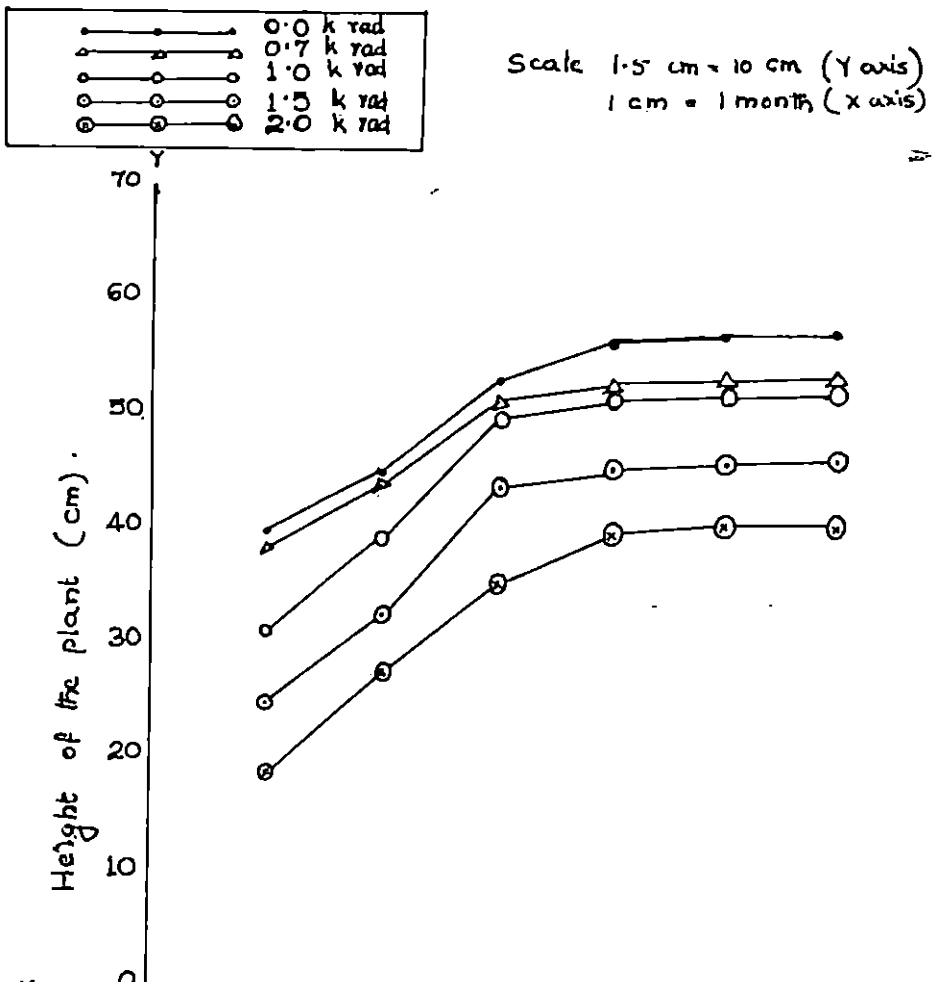

Fig. 2-2. Effect of gamma irradiation on plant height (cv. Muran).

plant height could be observed as the irradiation dosage increased. Plant height was minimum at 2 k rad. But with regard to plant height in both the cultivars, the treatments 0.7 k rad and 1 k rad did not differ significantly.

4.2.1.3. Number of tillers per plant

The data presented in Table 4a and 4b indicated that the treatments varied significantly with respect to tiller production, from the stage of 3 months onwards. In 'Rio-de-Janeiro', maximum tiller production was observed at 1 k rad (22.47) followed by 0.7 k rad (20.1) at six months old stage, whereas in 'Maran' it was maximum at 0.7 k rad (17.34) and then at 1 k rad (16.13) at the similar stage. In both the cultivars, tiller production was minimum at 2 k rad.

4.2.1.4. Number of leaves per tiller

The data on the number of leaves per tiller are given in Table 5a and 5b. The Anova (Appendix II) revealed that the treatments showed significant variation in leaf production. Leaf production was maximum in control and minimum at 2 k rad in both the cultivars.

Table 4a. Tiller production per plant (cv. Rio-de-Janeiro)

Treatments	Gamma irradiation doses (k rad)	Growth period (months)					
		One	Two	Three	Four	Five	Six
1	2	3	4	5	6	7	8
T_1	0.7	3.47	7.60	18.07	19.07	20.06	20.10
T_2	1.0	3.73	7.53	14.87	22.05	22.46	22.47
T_3	1.5	3.27	6.40	14.53	17.33	18.26	18.32
T_4	2.0	2.56	5.13	9.67	14.73	15.04	15.10
T_5	0 Control	3.90	5.80	15.20	17.25	18.47	18.48
F value		88.46**	74.76**	28.06**	15.64**	17.56**	17.49**
CD (0.05)		1.8	4.06	5.9	7.05	6.68	6.66
SEm ±		0.55	1.25	1.81	2.16	2.05	2.04

** Significant at 1% level

Table 4b. Tiller production per plant (cv. Maran)

Treatments	Gramma irradiation doses (k rad)	Growth period (months)					
		One	Two	Three	Four	Five.	Six
1	2	3	4	5	6	7	8
T_1	0.7	3.00	6.67	14.27	17.05	17.32	17.34
T_2	1.0	2.93	6.73	13.93	15.63	16.11	16.13
T_3	1.5	2.27	4.80	10.00	12.14	12.72	12.72
T_4	2.0	1.40	3.20	7.33	10.33	10.50	10.53
T_5	0 Control	3.33	5.20	12.10	14.50	15.50	15.54
F value		38.86**	72.17**	54.72**	26.34**	31.86**	32.56**
CD (0.05)		1.27	1.78	4.03	5.42	5.06	5.0
SEm ±		0.39	0.55	1.24	1.66	1.55	1.54

** Significant at 1% level

Table 5a. Leaf production per tiller (cv. Rio-de-Janeiro)

Treatments	Gamma irradiation doses (k rad)	Growth period (months)					
		One	Two	Three	Four	Five	Six
1	2	3	4	5	6	7	8
T_1	0.7	7.87	12.53	16.33	17.33	17.40	17.40
T_2	1.0	7.33	12.47	15.13	16.19	16.19	16.27
T_3	1.5	6.73	11.07	13.27	14.84	15.04	15.04
T_4	2.0	5.33	9.67	12.27	14.53	14.53	14.53
T_5	0 Control	9.70	14.50	17.60	19.83	19.93	19.93
F value		32.14**	10.07**	20.20**	10.13**	30.44**	30.19**
CD (0.05)		0.92	1.85	1.58	1.93	1.28	1.28
SEm ±		0.28	0.57	0.48	0.59	0.39	0.39

** Significant at 1% level

Table 5b. Leaf production per tiller (cv. Maran)

Treatments	Gamma irradiation doses (k rad)	Growth period (months)					
		One	Two	Three	Four	Five	Six
1	2	3	4	5	6	7	8
T_1	0.7	8.80	13.60	15.13	16.17	16.17	16.20
T_2	1.0	7.67	12.33	14.48	15.43	15.48	15.53
T_3	1.5	7.73	11.47	13.07	14.80	14.80	14.80
T_4	2.0	5.87	9.93	11.93	12.93	12.93	12.93
T_5	0 Control	10.13	13.93	15.77	18.11	18.43	18.60
F value		13.11**	7.95**	24.67**	25.85**	14.98**	18.30**
CD (0.05)		1.42	1.89	1.02	1.38	1.69	1.58
SEm ±		0.43	0.58	0.31	0.42	0.52	0.48

**Significant at 1% level

4.2.1.5. Length and width of the leaves

The data on the length and width of the leaves are presented in Table 6a and 6b.and 7a and 7b. The data revealed that the effect of the treatments on the length and width of the leaves was highly significant. Length and width of the leaves were maximum in the control plants, and minimum at 2 k rad, in both cultivars, during the entire growth period of the crop.

4.2.1.6. Leaf area index

Data regarding leaf area index are presented in Table 8a and 8b and Fig.3-1 and 3-2. Here again the treatments differed significantly with regard to the leaf area. In 'Rio-de-Janeiro' maximum leaf area index was 30.13 in control and minimum 8.8 at 2 k rad. In 'Maran' also the control plants yielded maximum leaf area index (25.7) and minimum (7.04) at 2 k rad.

4.2.1.7. Leaf colour

Leaf colour was normal in control (Plate I(a) and II(a), whereas chlorosis of varying intensities was observed in all the irradiation treatments. Chlorotic symptoms increased with the irradiation dosages. The extent of chlorosis was maximum in 2 k rad treatment (Plate I(b) and II(b).

Table 6a. Leaf length in cm (cv. Rio-de-Janeiro)

Treatments	Gamma irradiation doses (k rad)	Growth period (months)					
		One	Two	Three	Four	Five	Six
1	2	3	4	5	6	7	8
T_1	0.7	15.37	16.27	17.05	17.50	17.50	17.50
T_2	1.0	14.29	15.79	16.08	16.43	16.43	16.43
T_3	1.5	13.00	14.22	14.47	15.18	15.18	15.18
T_4	2.0	10.05	11.15	12.12	12.84	12.84	12.84
T_5	0 Control	17.79	19.28	19.32	19.36	19.56	19.56
F value		25.98**	28.12**	32.86**	39.45**	39.45**	39.45**
CD (0.05)		1.85	1.85	1.54	1.31	1.31	1.31
SEm ±		0.56	0.57	0.47	0.40	0.40	0.40

** Significant at 1% level

Table 6b. Leaf length in cm (cv. Maran)

Treatments	Gamma irradiation doses (k rad)	Growth period (months)					
		One	Two	Three	Four	Five	Six
1	2	3	4	5	6	7	8
T_1	0.7	19.19	20.93	21.04	21.04	21.04	21.04
T_2	1.0	16.37	17.68	18.11	18.14	18.14	18.14
T_3	1.5	13.37	14.95	15.61	16.08	16.08	16.08
T_4	2.0	11.58	13.77	14.59	14.65	14.65	14.65
T_5	0 (Control)	19.18	20.05	20.54	20.62	20.62	20.62
F value		30.14**	34.76**	41.55**	36.73**	36.72**	36.72**
CD (0.05)		2.04	1.72	1.45	1.5	1.5	1.5
SEm ±		0.63	0.53	0.45	0.46	0.46	0.46

** Significant at 1% level

Table 7a. Leaf width in cm (cv. Rio-de-Janeiro)

Treatments	Gamma irradiation doses (k rad)	Growth period (months)					
		One	Two	Three	Four	Five	Six
1	2	3	4	5	6	7	8
T_1	0.7	2.27	2.27	2.33	2.41	2.41	2.41
T_2	1.0	2.08	2.25	2.31	2.32	2.32	2.32
T_3	1.5	2.01	2.03	2.05	2.10	2.10	2.10
T_4	2.0	1.73	1.86	1.90	1.94	1.94	1.94
T_5	0 (Control)	2.42	2.44	2.51	2.58	2.58	2.58
F value		17.51**	13.0**	17.24**	9.89**	9.89**	9.89**
CD (0.05)		0.19	0.21	0.19	0.26	0.26	0.26
SEm ±		0.06	0.06	0.06	0.08	0.08	0.08

** Significant at 1% level

Table 7b. Leaf width in cm (cv. Maran)

Treatments	Gamma irradiation doses (k rad)	Growth period (months)					
		One	Two	Three	Four	Five	Six
1	2	3	4	5	6	7	8
T_1	0.7	2.58	2.58	2.58	2.60	2.60	2.60
T_2	1.0	2.34	2.35	2.39	2.41	2.41	2.41
T_3	1.5	1.99	2.05	2.07	2.09	2.14	2.14
T_4	2.0	2.15	2.19	2.19	2.19	2.19	2.19
T_5	0 (Control)	2.27	2.44	2.56	2.56	2.56	2.56
F value		13.11**	15.70**	21.51**	19.78**	16.54**	16.54**
CD (0.05)		0.19	0.17	0.16	0.16	0.17	0.17
SEm ±		0.06	0.05	0.05	0.05	0.05	0.05

** Significant at 1% level

Table 8a. Leaf area index (cv. Rio-de-Janeiro)

Treatments	Gamma irradiation doses (k rad)	Growth period (months)		
		Two	Four	Six
1	2	3	4	5
T_1	0.7	5.92	21.94	23.28
T_2	1.0	5.29	21.41	21.36
T_3	1.5	2.65	13.16	14.33
T_4	2.0	1.73	8.62	8.80
T_5	0 (Control)	6.70	27.68	30.13
F value		4.45**	9.96**	13.3**
CD (0.05)		3.34	7.84	7.38

** Significant at 1% level

Table 8b. Leaf area index (cv. Maran)

Treatments	Gamma irradiation doses (k rad)	Growth period (months)		
		Two	Four	Six
1	2	3	4	5
T_1	0.7	7.94	24.26	24.32
T_2	1.0	5.66	17.06	17.70
T_3	1.5	2.77	9.67	10.36
T_4	2.0	1.59	6.90	7.04
T_5	0 (Control)	5.92	24.69	25.70
F value		9.35**	11.28**	13.03**
CD (0.05)		2.67	7.93	7.47

** Significant at 1% level

Scale 1·5 cm = 5

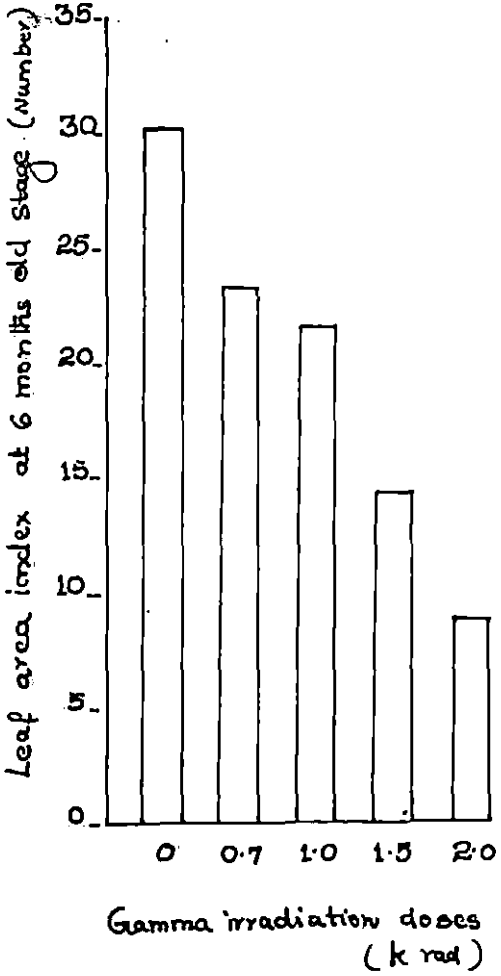

Fig. 3-1. Effect of gamma irradiation on leaf area index (cv. Rio-de-Janeiro)

Scale 1·5 cm = 5

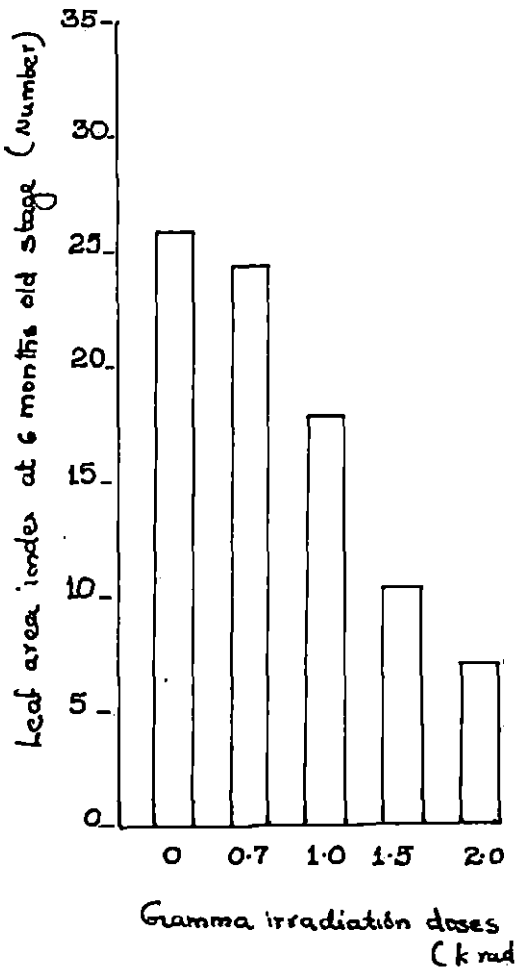

Fig. 3-2. Effect of gamma irradiation on leaf area index (cv. Maran)

PLATE-I (a) Plant (Two months old) from unirradiated ginger rhizome, cv. Rio-de-Janeiro.

Plate I (a)

PLATE-I (b) Plant (Two months old) from irradiated (2 k rad) ginger rhizomes, cv. Rio-de-Janeiro.

Plate I (b)

Plate II (a)

PLATE-II (b) Plant (Two months old) from irradiated (2 k rad) ginger rhizomes, cv. Maran

Plate II (b)

4.2.2. Flowering

4.2.2.1. Production of inflorescence

The data collected on various aspects of flowering and pollen fertility are presented in Table 9a and 9b.

It was observed that the number of plants flowered was meagre in all the treatments which varied from one to 2.6. However treatment 1 k rad was superior in this respect. In respect of inflorescence production per plant also the same trend was almost noticed. Only 1 to 1.3 inflorescences on an average was produced per plant.

The average number of flowers per inflorescence varied them five to nine. However maximum dose of irradiation (2 k rad) accounted for least values in this regard.

The time taken for first flowering was also not much variable in different treatments, although treatments 1.5 k rad in cv. Rio-de-Janeiro and 1 k rad in cv. Maran was early to flower, the days taken for flowering being 136 and 128 days respectively compared to 145 and 135 days in control. Almost the same trend was exhibited in respect of number of days taken for last flowering.

The length of inflorescence and inflorescence stalk were maximum in control plots and minimum in 2 k rad in both the cultivars.

Table 9a. Floral characters (cv. Rio-de-Janeiro)

Treatments	Gamma irradiation doses (k rad)	Number of plants flowered	Number of inflorescence per plant	Number of flowers per inflorescence	Days taken for first flowering	Days taken for last flowering	Length of the inflorescence (cm)	Length of inflorescence stalk (cm)	Percentage of pollen fertility
1	2	3	4	5	6	7	8	9	10
T_1	0.7	1.33	1.0	8.6	142.3	157	3.3	9.5	16.52
T_2	1.0	2.60	1.3	9.0	140.7	158	3.2	9.2	17.64
T_3	1.5	2.00	1.3	9.0	136.0	155	3.3	9.2	16.58
T_4	2.0	1.00	1.0	5.0	148.0	158	3.2	7.0	16.36
T_5	0 (Control)	1.33	1.0	7.5	145.0	160	3.5	10.0	16.11

Table 9b. Floral characters (cv. Maran)

Treatments	Gamma irradiation doses (k rad)	Number of plants flowered	Number of inflorescence per plant	Number of flowers per inflorescence	Days taken for first flowering	Days taken for last flowering	Length of inflorescence (cm)	Length of inflorescence stalk (cm)	Percentage of pollen fertility
1	2	3	4	5	6	7	8	9	10
T_1	0.7	1.0	1.0	10	128	140	3.2	8.5	17.04
T_2	1.0	2.0	1.0	8	135	150	3.2	8.5	17.08
T_3	1.5	1.0	1.0	6	138	152	3.1	8.0	16.96
T_4	2.0	1.0	1.0	6	138	150	3.1	6.0	16.97
T_5	0 (Control)	2.0	1.0	7	135	158	3.3	9.0	16.90

Thus it was evident that the treatments had played only very limited role in the flowering behaviour of plants.

4.2.2.2. Pollen fertility

The data on pollen fertility in Table 9a and 9b revealed that in general the pollen fertility was low in all the treatments. However the pollen fertility was comparatively better in treatment 1 k rad compared to all other treatments irrespective of the cultivars.

4.2.2.3. Pollen viability

No viable pollen was produced in any of the treatments.

4.2.2.4. Anthesis

The time of anthesis was observed as between 2.30 and 3.30 PM under Vellanikkara conditions.

4.2.2.5. Pollination and seed-set

Seed-set could not be obtained through hand pollination or bud pollination or using mixed pollen.

4.2.3. Yield

The data on yield attributes are presented in Table 10a and 10b. and Fig.4-1 and 4-2 which revealed that

Table 10a. Yield attributes (cv. Rio-de-Janeiro)

Treatments	Gamma irradiation doses (k rad)	Number of rhizomes per plant	Type of rhizomes		Yield of rhizome per plant (kg)	Yield per hectare (kg)	Percentage recovery of dry ginger	Yield of dry ginger per hectare (kg)	Extent of root formation	
			Primary rhizome	Secondary rhizome					No.of roots per plant	Length of root (cm)
1	2	3	4	5	6	7	8	9	10	11
T_1	0.7	2.0	2.0	9.3	0.208	10416.5	12.83	1336.38	32.65	19.95
T_2	1.0	2.0	2.0	7.4	0.188	9416.5	12.49	1176.12	27.76	15.59
T_3	1.5	2.0	2.0	6.9	0.168	8416.5	11.90	1001.56	31.80	20.12
T_4	2.0	1.6	1.6	6.2	0.132	6632.5	11.78	781.31	32.67	17.40
T_5	0 (Control)	2.00	2.00	9.6	0.211	10583.0	12.90	1365.20	32.80	23.05
F value		1.0	1.0	11.71**	12.2**		0.91		0.33	2.45
CD (0.05)		0.48	0.48	1.44	30.38		1.78		12.09	5.93
SEm ±		0.15	0.15	0.44	9.32		0.55		3.71	1.82

** Significant at 1% level

Table 10b. Yield attribute (cv. Maran)

Treatments	Gamma irradiation doses (k rad)	Number of rhizomes per plant	Type of rhizomes		Yield of rhizome per plant (kg)	Yield per hectare (kg)	Percentage recovery of dry ginger	Yield of dry ginger per hectare (kg)	Extent of root formation	
			Primary rhizome	Secondary rhizome					No. of roots per plant	Length of root (cm)
1	2	3	4	5	6	7	8	9	10	11
T_1	0.7	2	2	5.9	0.197	9886.5	15.39	1521.53	36.97	16.71
T_2	1.0	2	2	5.4	0.178	8934.5	14.71	1314.27	33.27	20.62
T_3	1.5	2	2	4.8	0.161	8061.0	14.45	1164.80	30.53	16.44
T_4	2.0	2	2	4.5	0.122	6100.0	14.50	884.50	40.30	17.54
T_5	0 (Control)	2	2	6.8	0.234	11727.5	15.17	1779.06	36.73	20.22
F value				3.6**	10.68**		1.09		0.98	1.81
CD (0.05)				1.56	41.74		1.29		12.34	4.79
SEm ±				0.44	12.8		0.55		3.79	1.47

** Significant at 1% level

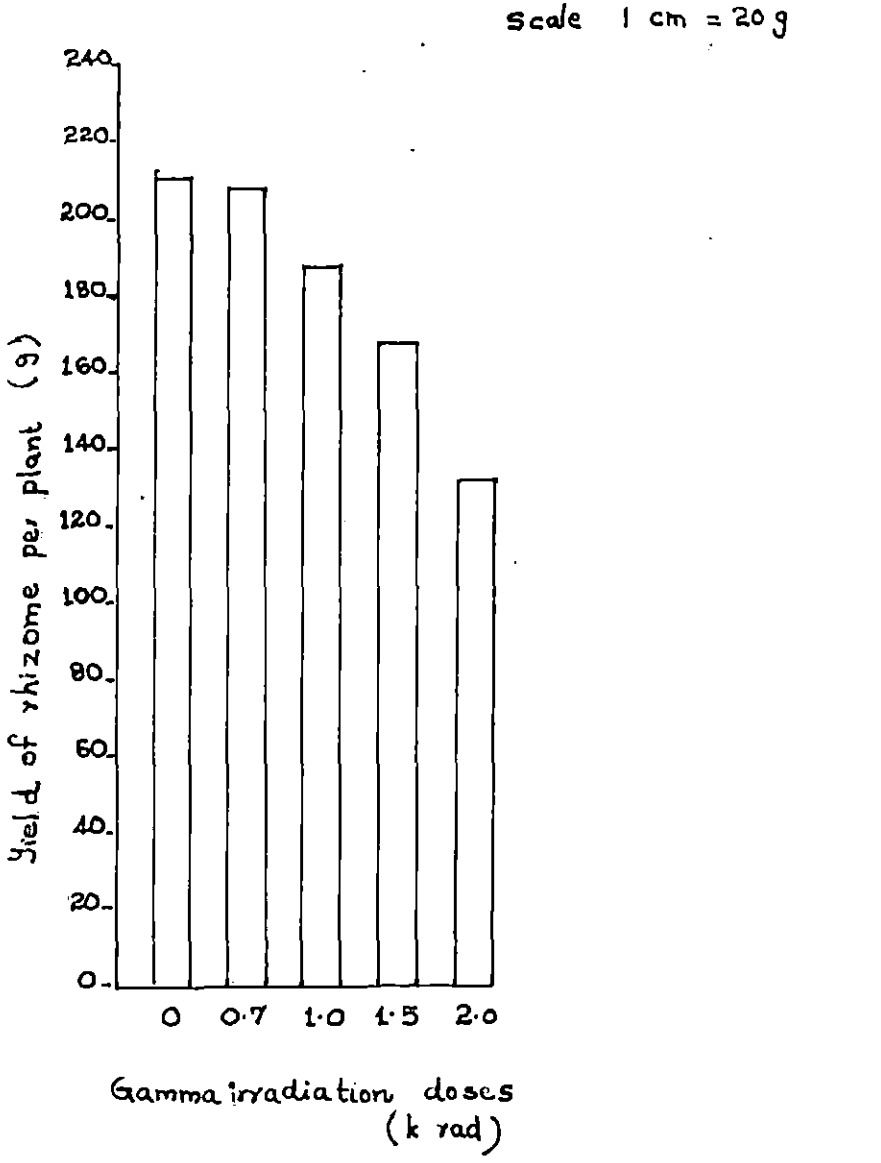

Fig. 4-1: Effect of gamma irradiation on the rhizome yield (cv. Rio-de-Janeiro)

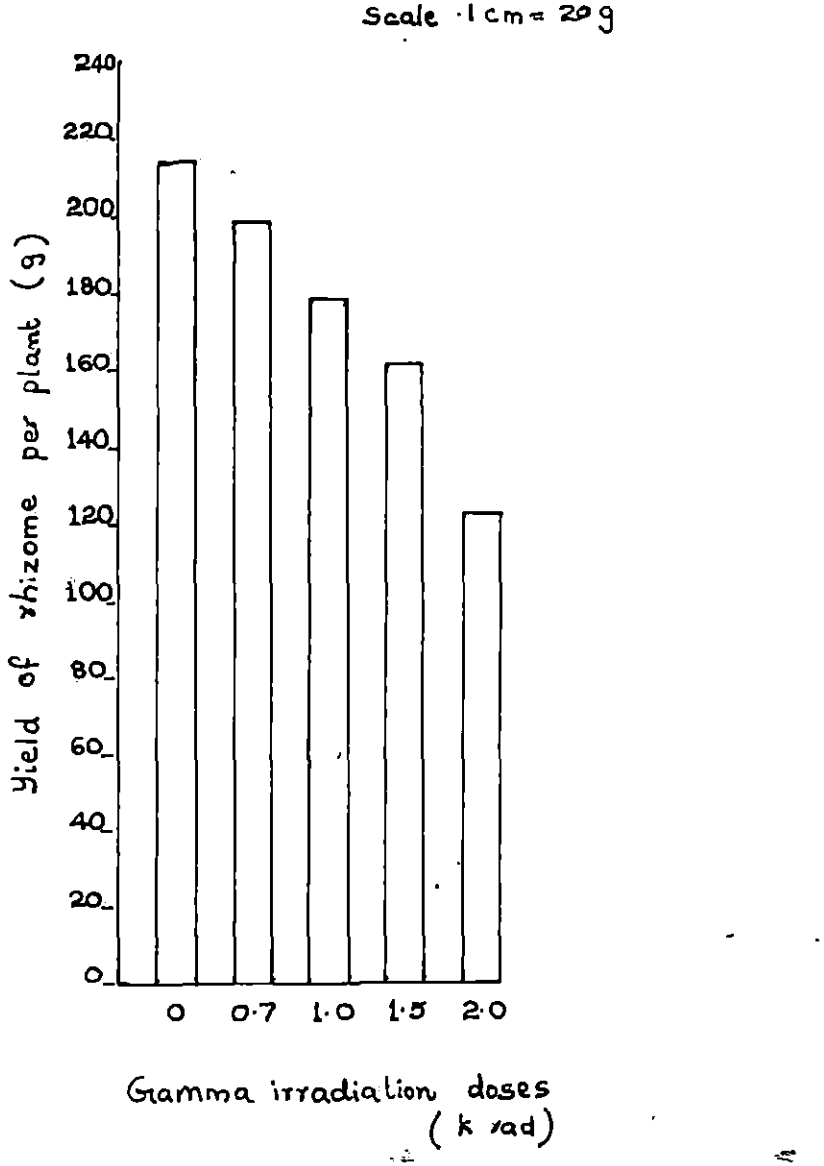

Fig. 4-2. Effect of gamma irradiation on the rhizome yield (cv. Maran)

the treatments differed significantly in respect of yield of rhizomes per plant and production of secondary rhizomes. Production of secondary rhizomes as well as plant yield were maximum in control. The number of primary rhizomes remained constant in all the treatments (two) except in the treatment 2 k rad in Rio-de-Janeiro (1.6). Yield of rhizomes per hectare was maximum in control, which decreased gradually with increase in the irradiation dosage. At 2 k rad, per hectare yield of rhizomes was minimum in both the cultivars. Regarding the percentage recovery of dry rhizomes, the treatments did not differ significantly. Root growth was almost similar in all the treatments.

4.2.4. Quality

The data on quality factors studied are presented in Table 11a and 11b which showed that the treatment effects were not significant on the essential oil and oleoresin contents of ginger as well as on the oleoresin of the ginger peel. However in both the cultivars, the oleoresin content was higher at 1 k rad, compared to other treatments. Oleoresin content in the ginger peel was maximum at 1 and 1.5 k rad in the case of cv. Rio-de-Janeiro and 2 k rad in case of cv. Maran.

Table 11a. Quality factors (cv. Rio-de-Janeiro)

Treatments	Gamma irradiation doses (k rad)	Essential oil in green ginger (ml/100 g)	Essential oil in dry ginger (ml/100 g)	Oleoresin in green ginger (mg/10g)	Oleoresin in dry ginger (mg/10g)	Skin recovery (Oleoresin in ginger peel) (mg/10 g)
1	2	3	4	5	6	7
T_1	0.7	0.53	3.74	174.3	973.32	310.33
T_2	1.0	0.53	3.86	179.0	976.66	311.33
T_3	1.5	0.53	3.80	175.66	961.32	311.33
T_4	2.0	0.57	3.86	176.66	970.00	310.00
T_5	0 (Control)	0.53	3.74	160.00	966.66	306.33
F value		0.76	0.62	2.26	0.50	1.18
CD (0.05)		0.17	0.14	16.34	8.55	6.51

Table 11b. Quality factors (cv. Maran)

Treatments	Gamma irradiation doses (k rad)	Essential oil in green ginger (ml/100 g)	Essential oil in dry ginger (ml/100 g)	Oleoresin in green ginger (mg/10g)	Oleoresin in dry ginger (mg/10g)	Skin recovery (Oleoresin in ginger peel) (mg/10g)
1	2	3	4	5	6	7
T_1	0.7	0.5	2.80	150.66	950.00	270.00
T_2	1.0	0.5	2.86	153.33	960.00	296.67
T_3	1.5	0.5	2.86	150.00	952.00	298.33
T_4	2.0	0.5	2.80	151.66	950.00	300.67
T_5	0 (Control)	0.47	2.80	146.66	943.32	292.33
F value		0.13	0.12	2.51	2.00	6.46
CD (0.05)		0.14	0.17	6.98	5.93	20.93

Table 12. Incidence of soft rot disease as influenced by gamma irradiation

Treatments	Gamma irradiation doses (k rad)	Percentage of soft rot infection	
		cv. Rio-de-Janeiro	cv. Maran
1	2	3	4
T_1	0.7	59.17	54.62
T_2	1.0	57.63	52.73
T_3	1.5	47.27	53.86
T_4	2.0	8.17	11.11
T_5	0 (Control)	72.00	56.82
F value		39.61**	168.9**
CD (0.05)		12.64	4.39

** Significant at 1% level

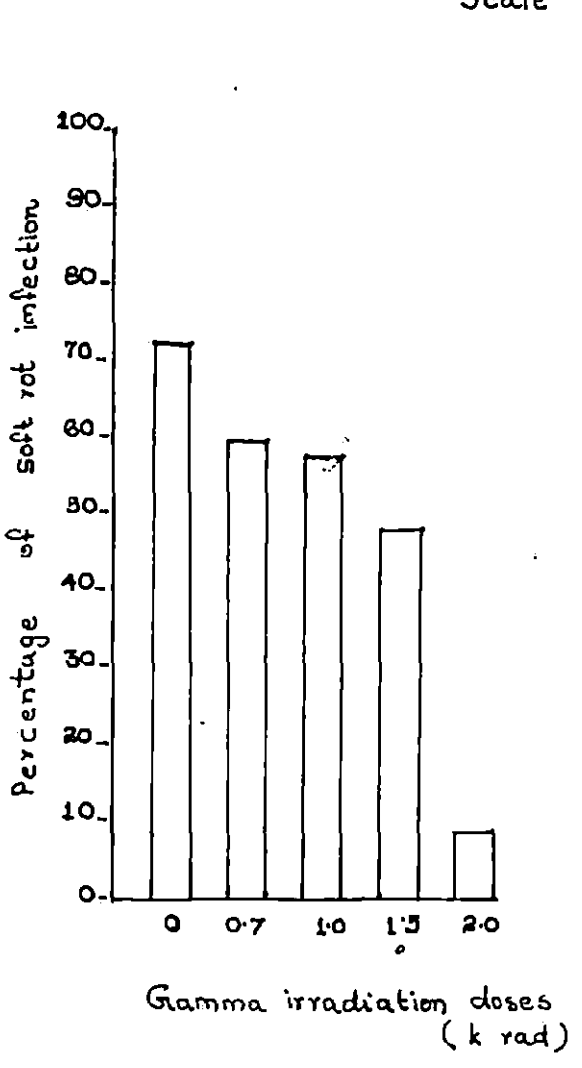

Fig. 5-1. Incidence of soft rot disease as influenced by gamma irradiation (cv. Rio-de-Janeiro).

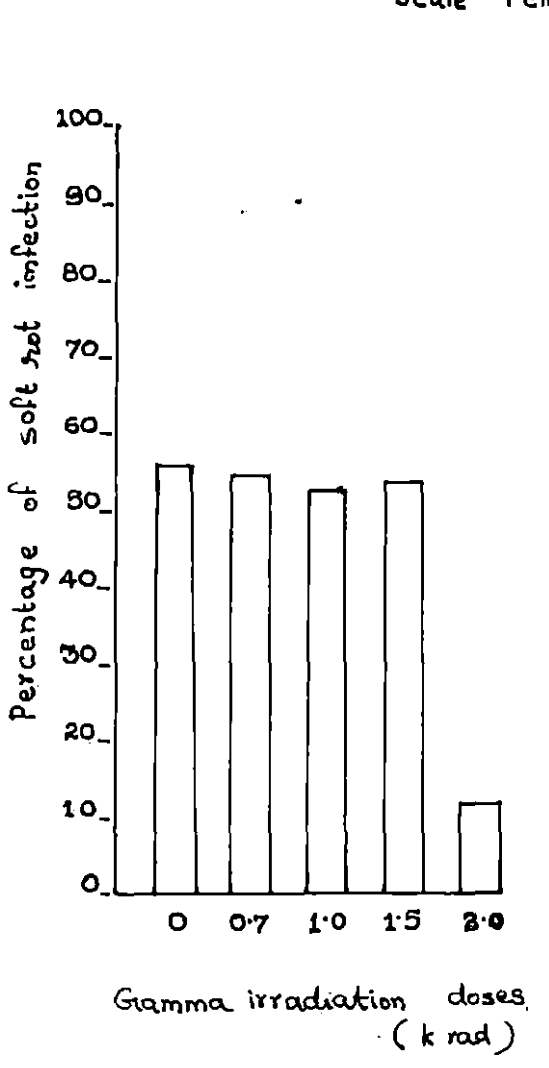

Fig. 5-2. Incidence of soft rot disease as influenced by gamma irradiation (cv. Maran).

4.2.5. Incidence of soft rot disease

The data on the extent of infection due to soft rot disease are presented in Table 12 and Fig.5-1 and 5-2. The data revealed that the treatments differed significantly with regard to soft-rot infection. Infection was maximum in control. The percentage of infection gradually decreased with increase in the dose of gamma rays and at 2 k rad the infection was the minimum.

Discussion

DISCUSSION

Ginger (*Zingiber officinale* Rosc.) is one of the ancient orient spices known to Europe and is still in large demand today. It is always propagated vegetatively and the number of clones at present available is rather limited. Hybridisation between clones and related species continued to be a difficult task in ginger as flowering rarely occurs and seeds are rarely produced. In this context gene mutation assumes considerable importance for further progress as they provide the raw material for evolution as well recombination and selection.

Therefore investigation was undertaken to find out the stimulatory and/or mutagenic effects of gamma radiation in ginger. The results of the studies are discussed here.

5.1. Rhizome germination

Irradiation treatments produced inhibitory effect on the germination of ginger rhizomes. Even the lowest dosage was not an exception. While the control plot of cv. Rio-de-Janeiro gave germination percentage as high as 94.4, the same was only 33.3 at 2 k rad level. In case

of cv. Maran the germination was still lower. No germination of rhizomes occurred in treatments 4 k rad and above. Further, in control plot earlier germination of rhizomes was noticed, which indicated that the irradiation treatments delayed germination. The aforesaid observations are in conformity with earlier works. Raju et al. (1980) could observe only germination to a tune of 32 per cent, by irradiating ginger rhizomes with 2 k rad gamma rays. Dosage of 5 k rad gamma rays prevented total germination in ginger according to Gonzalez et al. (1972). Higher germination observed in the field trial can be attributed to the variation in the climatic and soil factors.

Such inhibitory effects on the germination in vegetatively propagated crops have been reported by many workers. Vijayalakshmi and Rao (1960) found 300 rad of gamma rays as the upper limit of safe dosage for satisfactory germination and growth in sugarcane. Moh (1963) standardised the lethal dose of gamma irradiation at 3 k rad for cassava. Dosage of 3 k rad gamma rays was lethal for germination of canna rhizomes (Mukherjee and Khoshoo, 1970). Velez and Maldonado (1972) advocated the dosage of 5 k rad as upper limit for banana. In costus, 3 k rad treatment inhibited sprouting of rhizomes as reported by Gupta et al. (1982). Uzenbaev and

Nazernko (1969) observed delayed germination in gladiolus, in treatment using 5 k rad gamma rays.

Reduced sprouting of rhizomes of crops at higher doses of gamma irradiation was due to direct killing of the cells and higher rate of ionisation in the nucleii.

5.2. Vegetative characters

5.2.1. Height of plants

Significant difference in plant height was evident among treatments. Control accounted for maximum height during the entire growth phases of crop. The plant height decreased consistent with the increase in irradiation dosage. In both the cultivars, minimum plant height was recorded in treatment 2 k rad. Similar results have been reported in other crops by a few workers namely Uzenbaev and Nazernko (1969) in gladiolus, Escober and Lopez (1970) in sugarcane, Velez and Maldonado (1972) in banana and Gupta *et al.* (1982) in costus.

5.2.2. Tiller production per plant

Tiller production per plant differed significantly in different treatments and minimum tiller production was observed at 2 k rad. In cv. Rio-de-Janeiro maximum tillers per plant was produced at 1 k rad, whereas in cv. Maran, it was in 0.7 k rad. These observations were

in conformity with earlier works. Gupta (1962) had observed decreased production of branches in portulaca at higher doses of gamma rays. Again, Gupta et al. (1982) reported that in costus, the number of branches per plant increased at 1.5 k rad, but decreased at 3 k rad treatment.

5.2.3. Leaf production per tiller, length and width of leaves, leaf area index and colour of leaves

Gamma irradiation has been found to influence not only the leaf production, but also the length and width of individual leaves consequently the leaf area index. Maximum values for all the characters were obtained in control plot. With the increase in the dosages of irradiation proportionate reduction was caused in leaf production length and width of leaves and leaf area index. Again, the treatment 2 k rad contributed for minimum values for all the characters. Reduced plant height and tiller production might be contributory factors for reduction in the above characters.

The results obtained in the present investigation agree with the earlier workers. Uzenbaev and Nazernko (1969) observed production of smaller leaves in gladiolus when the corms were subjected to 5 k rad gamma rays. Gupta et al. (1974) working on tuberose found reduction in leaf production due to irradiation. In costus gamma

irradiation caused reduction in leaf production and leaf size (Gupta et al., 1982).

Another interesting feature noticed was that the leaves of irradiated plants possessed yellow streaks besides reduced leaf size. Production of chlorophyll mutant leaves with yellow or white streaks that too of abnormal size, through irradiation is a matter of interest in ornamental horticulture. Raju et al. (1980) have reported such a phenomenon in ginger. Variations in leaf shape and colour have been observed in costus by Gupta et al. (1982) when gamma irradiation was resorted to. Leaf variegations due to gamma irradiation have been reported in a few crops by many workers namely, Nakornthap (1965) in Canna, Vasudevan et al. (1963) in colocassia, Ono (1971) in mentha, Velez and Maldonado (1972) in banana, Gupta et al. (1974) and Konzak (1984) in tuberose and Escober and Lopez (1970) in sugarcane.

The leaf abnormalities consequent of irradiation might be due to chromosomal aberrations, change in the route of auxin synthesis, distribution or disruption of mineral metabolism or accumulation of free amino acids (Gupta et al., 1982). Laxmi et al. (1980) have contended that chimera formation in leaves due to gamma irradiation might be due to the multicellular nature of the tissues.

The present study, however, has not helped to achieve stimulatory effects on vegetative characters of ginger at the irradiation levels tried, although some workers have claimed varying degrees of success in certain other crops.

While Sparrow (1966), Serebrenikov (1971), Pavlova (1972); Desai and Abraham (1974), Gupta et al. (1982) and Pavlovic et al. (1983) have claimed growth stimulation due to gamma irradiation in gladiolus, lilly, potato, chrysanthemum, canna, costus and Mentha piperita respectively, Banerjee (1976) and Escober and Lepez (1970) failed to induce stimulatory effects through gamma irradiation in crops like zephyranthus and sugarcane.

The above facts indicate that different crops behave differently to gamma irradiation and its dosages, which again is influenced by environmental conditions as suggested by Raju et al. (1980).

The present study has indicated that there is scope for experimenting with gamma irradiation of doses below 0.7 k rad to induce growth stimulation in ginger. The levels tried in this investigation might have caused inhibition in mitosis or cell elongation as has already been reported by Gray (1954).

5.3. Flowering

In ginger flowering occurs very rarely, that too restricted to a very few cultivars. Favourable effects of gamma rays on flowering of some of the vegetatively propagated crops namely, zephyranthus, gladiolus, and dahlia have been reported by Spencer (1955), Dryagina and Kazarinov (1972) and Sigurbjornsson and Micke (1973) respectively. But in the investigation taken up, the range of 0.7 to 2 k rad of gamma irradiation did not help to contribute favourable effects on flowering. Rawkin (1970), Gupta et al. (1974) and Gupta et al. (1982) have reported inhibitory effects of flowering in strawberry, tuberose and costus respectively due to gamma irradiation.

The pollen fertility varied from 16.11 to 17.64 per cent in different gamma ray treatments, the variation between the treatments being negligible. However a slight increase in pollen fertility could be obtained at 1 k rad. The extent of pollen fertility obtained was almost similar to the values reported by Usha (1984). She had observed 16 per cent fertile pollen in ginger under Vellanikkara conditions. But Ratnambal (1979) has reported 8.6 to 45.6 per cent pollen fertility in ginger under Calicut conditions. Thus it was evident that the dosages of gamma irradiation tried did not improve the pollen fertility in ginger.

Pollen germination could not be obtained in any of the treatments. This phenomenon was similar to that observed by Decourtye (1970) in apple. In apple, the irradiation has an inhibitory effect on pollen germination.

In this study, gamma irradiation did not help in achieving seed-set in ginger. Pollination with mixed pollen was also not effective, indicating thereby that self incompatibility alone is not responsible for failure of seed-set in ginger as postulated by East (1940) and Fryxell (1957). Ramachandran (1969) and Ratnambal (1979) have reported that chromosonal aberration during micro and megasporogenesis might be the reason for lack of seed-set in ginger. The dosage range of 0.7 to 2 k rad gamma irradiation used in this experiment was not effective in overcoming the problems of flowering in ginger.

Not much is known about flowering behaviour of ginger. In-depth studies in ginger on the actual mechanism of flowering and factors controlling flowering and seed-set have not been conducted so far. The need for such studies is stressed.

5.4. Yield

Gamma irradiation is found to influence yield attributes in ginger. Highest yield was obtained from

control. There was reduction in yield as the irradiation dose increased. Consequently, the yield obtained from plots under treatment 2 k rad was the lowest. The low yield obtained in treatments could be attributed to the reduction caused by gamma irradiation on plant growth, leaf area index, size and growth of rhizomes particularly secondary rhizomes. Similar findings have been reported earlier by Raju et al. (1980), who found formation of weaker and elongated underground rhizomes in ginger due to 2 k rad treatment. In costus also, similar reduction in rhizome yield at 3 k rad treatment was found by Gupta et al. (1982).

The treatment effect on the recovery of dry ginger was also not significant in the study.

Thus the levels of gamma irradiation tried in this investigation have not helped to induce any stimulation in the yield attributes of ginger. The possible reason for the same have already been discussed in Section 5.2.3.

5.5. Quality attributes

Gamma irradiation at the levels tried did not influence either the essential oil or the oleoresin content of both green and dry gingers and also the oleoresin of ginger peel. But a slight increase in the oleoresin content

was perceptible in 1 k rad treatment in both the cultivars. The reports available on other crops on these aspects are also contradictory. Gupta (1969), Mital et al.(1972), Kaul and Kak (1974), and Pavlovic et al. (1983) have testified increased synthesis of essential oil due to gamma irradiation in certain aromatic plants such as Cymbopogon martini, Mentha arvensis and Mentha piperita. On the other hand, Lata and Gupta (1971) have reported that flowers of rose produced lesser oil when the buds were subjected to irradiation before budding. In costus, according to Gupta et al. (1982) diosgenin content increased at 2 k rad where as it decreased at 3 k rad.

Such variations in the synthesis of essential oil oleoresin and alkaloid might have been due to promotive or inhibitory influences exercised by gamma rays causing physiological and biochemical reactions leading to the synthesis of these compounds.

5.6. Incidence of soft rot disease

In the present study the incidence of soft rot disease was lower in all gamma irradiation treatments compared to control. With the increased dosages, the extent of incidence got reduced, the minimum incidence being obtained in 2 k rad treatment. It is inferred that the gamma rays had direct effect on the genes governing the same.

But this favourable result will be of significance if only it occurs together with high yield and quality of produces. However, a few workers have succeeded in using gamma irradiation as a tool for imparting disease resistance in a few crops like mentha, potato, Abelmoschus manihot and Stenatophorus secundatum (Ono and Ikeda, 1970; Kishore, 1963; Kuwada, 1967; Toler and Grisham, 1983).

Thus the present investigation has revealed that even though the dosages of 0.7 to 2 k rad were not very promising, scope exists for undertaking further studies adopting lower doses of gamma rays below 0.7 k rad with the objectives of obtaining higher productivity, quality and disease resistance in ginger.

Summary

SUMMARY

Investigation was carried out at the College of Horticulture, Vellanikkara, during 1983-84 on the effects of gamma irradiation on germination, vegetative growth, flowering, yield, quality attributes and incidence of soft rot disease in ginger. The results obtained are summarised below.

1. Irradiation treatments produced inhibitory effects on the germination of ginger rhizomes. The germination percentage decreased with increase in the irradiation dose and no germination was observed at 4 k rad and above.

2. Significant difference in plant height was evident among treatments. The plant height decreased consistent with the increase in irradiation dosage.

3. Tiller production per plant differed significantly in different treatments. Minimum tiller production was observed at 2 k rad, while maximum observed at 1 k rad in Rio-de-Janeiro and 0.7 k rad in Maran.

4. Gamma irradiation has been found to influence the leaf production as well as the leaf size. With the increase in the dose of gamma irradiation, proportionate reduction was caused in leaf production leaf size, and leaf area index. The leaves of irradiated plants possessed yellow streaks.

5. Flowering behaviour of ginger could not be altered by the levels of gamma irradiation tried. Anthesis took place between 2.30 and 3.00 PM. A slight increase in the pollen fertility could be obtained at 1 k rad. Pollen germination could not be obtained in any of the treatments. Gamma irradiation did not help in achieving seed-set in ginger. Pollination with mixed pollen was also not affective in inducing seed set.

6. Significant difference in yield was observed among treatments. Better rhizome growth and higher yield was obtained from control, and the yield reduced as the irradiation dose increased. The treatment effects on the recovery of dry ginger and root growth were also not significant.

7. Gamma irradiation at the levels tried, did not influence either the essential oil or the oleoresin content of both gree and dry ginger, and also the oleoresin of ginger peel.

8. Incidence of soft rot disease was lower in all gamma irradiation treatments compared to control. With the increased dosages, the extent of incidence got reduced.

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* Originals not seen

Appendices

Appendix I. Weather data during the period of plant growth - April to December, 1983.

Month	Temperature (°C)		Relative humidity			Total rainfall mm	Rainy days	Total sun shine hours
	Minimum	Maximum	0730 hours	1430 hours	Mean			
1	2	3	4	5	6	7	8	9
April	25.80	36.20	-	-	66.00	-	-	270.90
May	25.50	35.10	-	-	69.00	37.40	3.00	240.50
June	24.50	31.90	90.00	69.00	79.00	387.20	19.00	113.80
July	23.70	29.70	94.00	79.00	87.00	580.60	21.00	89.50
August	29.10	23.80	93.50	80.40	87.00	754.70	26.00	61.30
September	29.50	23.40	93.00	75.00	84.00	494.16	24.00	108.00
October	31.20	23.10	90.00	64.00	77.00	149.80	6.00	215.80
November	31.80	22.30	84.00	58.00	71.00	60.20	3.00	244.90
December	31.20	23.90	71.00	55.00	63.00	24.40	3.00	215.60

Source: Meterological Observatory, Vellanikkara

Appendix II - Analysis of variance - Mean sum of squre values

Character	cv. Rio-de-Janeiro		cv. Maran	
	Treatment	Error	Treatment	Error
1	2	3	4	5
Number of rhizomes germinated	398.17	8.82	769.60	16.19
Days taken for germination	73.07	2.46	84.66	5.07
Plant height	146.29	2.09	128.56	4.25
Number of tillers per plant	21.88	12.51	23.35	7.07
Number of leaves per tiller	13.92	0.46	12.83	0.70
Length of the leaf	19.01	0.48	23.26	0.63
Width of the leaf	0.19	0.02	0.13	0.01
Leaf area index	204.18	15.35	204.74	15.71
Number of secondary rhizome	6.82	0.58	2.48	0.68
Yield of rhizome per plant	3176.36	260.35	5251.36	491.66
Percentage recovery of dry rhizome	0.81	0.89	0.52	0.47
Number of roots per plant	13.85	41.28	42.26	42.99
Length of the root	24.38	9.93	11.72	6.48
Essential oil in green ginger	0.001	0.008	0.001	0.005
Essential oil in dry ginger	0.003	0.005	0.001	0.008
Oleoresin in green ginger	170.43	75.53	24.93	9.93
Oleoresin in dry ginger	10.43	20.68	27.50	18.75
Oleoresin in ginger peel	14.09	11.95	57.25	123.67
Percentage of soft rot infection	1782.66	45.00	1136.72	6.73

EFFECT OF GAMMA IRRADIATION IN GINGER (*Zingiber officinale Rosc*)

BY

GIRIDHARAN, M. P.

ABSTRACT OF THE THESIS

submitted in partial fulfilment of the
requirement for the degree

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture
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ABSTRACT

Investigation was carried out at the College of Horticulture, Vellanikkara, during 1983-84, to study the effect of gamma irradiation on germination, vegetative growth, flowering, yield, quality attributes and incidence of soft rot disease in ginger using four doses of gamma rays (0.7, 1, 1.5, 2 k rad). Irradiation treatments produced inhibitory effects on the germination of ginger rhizomes. The plant height, tiller production, leaf production, leaf size and leaf area index decreased with the increase in irradiation dosages.

Flowering behaviour of ginger could not be altered by the levels of gamma irradiation tried. Rhizome yield reduced as the irradiation dose increased. The treatments did not differ significantly with regard to essential oil and oleoresin content of both green and dry ginger; oleoresin of ginger peel and percentage recovery of dry rhizomes. However, the incidence of soft rot disease could be highly reduced by gamma irradiation.