GENIC MANIPULATIONS IN SWEET POTATO ADOPTING INDUCED MUTATIONS

BY

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DECLARATION

I hereby declare that this thesis entitled "Genic manipulations in sweet potato adopting induced mutations" 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.

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Certified that this thesis entitled "Genic manipulations in sweet potato adopting induced mutations" is a record of research work done independently by Smt. D.I. Suma Bai under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

INTRODUCTION

In the quest for food and the struggle for human survival, tuber crops have historically played an important role. Among such tuber yielding food crops sweet potato occupies a pre-eminent position. The crop belongs to the family Convolvulaceae under dicots (Genera - Ipomoea, Species - batatas).

Though sweet potato, believed to be a native of the American continent, is considered more as a crop of the tropics, it comes up well in the temperate regions also. Its cultivation is extensively distributed in the tropical humid parts of Asia and Africa, Latin America and in the temperate Zones of Japan, China, Korea and North America. In India it is cultivated in an area of 176.30 thousand hectares of which about 60 per cent is confined to Uttar Pradesh and Bihar. In Kerala its cultivation is reported to cover only 4635.00 hectares.

The crop is essentially suited to warm weather conditions. Growth is best at temperatures above 24°C. Below 10°C it is severely retarded. This sunshine loving crop performs in the best manner in areas where the light intensity is high. Day length affects both the flowering and tuberisation process. Tuber formation in sweet potato is promoted by short day conditions. Short days with low light intensity promote tuber formation while long days tend to favour vine development at the expense of root tubers. The crop comes up well on well drained sandy loam soil. It prefers a soil pH between 5.6 and 6.6. In alkaline and saline soils the crop seldom thrives (Onwueme, 1978). The high photosynthetic rate of this crop makes it a suitable subsidiary food crop for a highly food deficit State such as Kerala. Together with cassava it can contribute much to the food requirements of the State.

There is considerable scope for crop improvement in sweet potato. Cytogenetically sweet potato is identified as a hexaploid with a chromosome number 2n = 90. Most of the sweet potato cultivars are reported to be self-incompatible. It is a proven fact that in various crops mutagenic agents can be beneficially utilized for developing relatively superior varieties. The generally high degree of heterozygosity and frequent prevalence of polyploidy in sweet potato are advantageous in mutation breeding. Another advantage of mutation induction especially in vegetatively propagated crops like sweet potato is the ability to change desirably one or a few characters in an otherwise accomplished cultivar without altering the generalised economic desirability attribute (Broertjes and Harten, 1978).

There is a limitation for genetic variation with respect to yield per hectare in sweet potato. This limitation can to some extent be overcome by adopting certain genetic manipulations ie. induced mutagenesis by physical or chemical mutagens. However, many limiting factors for successful chemical mutagenesis exists in vegetatively propagated crops. Hence a physical mutagen like gamma rays appears to be the preferred choice for inducing variability by mutagenesis.

In Kerala, sweet potato is cultivated in lowlands during the summer fallows and in uplands during the South West and the North East monsoon periods. In both these periods sweet potato is mostly cultivated as an intercrop with coconut or other similar tree crops in the Northern regions and also with tapioca in the Southern districts. As a pure crop sweet potato can survive in Kerala only if the yield per hectare is much higher than what is currently obtained at present in view of high labour and material input cost in the cultivation. As a monocrop it has very low priority in land hungry Kerala. There is thus, a requirement of enhancing the yield output from sweet potato to enable its spread as an intercrop. For increasing the per hectare yield output of sweet potato the use of physical mutagens especially gamma rays appears to be the most suitable. To fulfil this overall requirement of developing high yielding varieties of the crop by mutation the following working objectives were set:

1. Radiosensitivity analysis.
2. Identification of low, medium and high radiation tolerant varieties.
3. Standardisation of the dose and choosing of plant organ to be irradiated for successful mutagenesis.
4. Utilization of low, medium and high radiation tolerant genotypes for induced mutagenesis.
5. Analysis on induced variability in both qualitative and quantitative characters.
6. Isolation of desirable variants having economic importance and
7. Maintenance and propagation of desirable mutants.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The term mutation was introduced by De Vries in 1900 and proposed the idea of inducing mutations and their utilization in breeding new forms (Clenand, 1962). In 1904, De Vries proposed the use of X-rays for artificial production of mutations (Blakeslee, 1936). X-irradiation was also tried in cells and chromosomes by Koernicke (1905) and Gager (1908). However, the conclusive proof that ionizing radiations induce mutations was presented by Muller (1927) in Drosophila. Following this, several workers proved experimentally that ionizing radiation can induce mutations in plants (Gager and Blakeslee, 1927 on _Datura stramonium_; Stadler, 1928 on Barley and Maize and Goodspeed, 1929 on _Nicotiana_). After the historically important findings of this period most of the observations in the following 25 years were from investigations of a purely theoretical nature. In spite of many investigations the maximum effectiveness and efficiency of radiations for inducing changes in plant characters, especially those of economic importance have not yet been realised (Nilan _et al_., 1965).

Early in this century chemical mutagenesis was tried by Schiemann (1912). The search for chemical mutagens started even before the discovery of the mutagenic effects of X-rays

(Auerbach, 1967). Induction of mutations by means of chemical treatments was amply demonstrated by Auerbach in England with mustard gas (Auerbach and Robson, 1942, 1947) and by Oehlkers (1943) in Germany by urethane. With this discovery workers all over the world started surveying different chemicals for their mutagenic activity.

Among the various chemical mutagens known, the alkylating agents have been found to be the most efficient in inducing mutations in a wide range of organisms from bacteria to mammals (Auerbach, 1961). Within this group, monofunctional agents in general, and Ethylmethane sulphonate in particular appear to be more efficient in producing mutations in several organisms including higher plants (Swaminathan et al., 1962). The mutagenic efficiency of ethyl methane sulphonate was first demonstrated in barley by Heslot et al. (1959).

The outstanding works of Gustafsson (1963); Yamaguchi and Mian (1964); Kawai and Sato (1965); Konzak (1966); Gaul et al (1966); Sato and Gaul (1967); Siddiq (1967); Soriano (1968); Kawai (1969) and Mikaelsen et al. (1971) gave a clear picture of the research work carried out to study the effectiveness and efficiency of chemical mutagens in various plant species. The effect of alkylating agents and their mechanism of action in the biological test system have been reviewed by Ross

(1962); Loveless (1966); Lawley (1973) and Sun and Singer (1975).

Nilan and Konzak (1961); Ehrenberg *et al.* (1961) and Gustafsson (1963) reported that the spectrum of chlorophyll deficient mutants may depend on the type of mutagens employed. Kamra and Brunner (1970) reported that in sexually propagated plants, seed treatment using chemical mutagens has yielded very high mutation frequencies and in most cases they are more efficient than ionizing radiations. A dose-dependent linear increase in frequency of chlorophyll mutations in both physical and chemical mutagens have also been reported by Siddiq (1967); Siddiq and Swaminathan (1968); Yamaguchi and Miah (1964); Singh (1970) and Nair (1981).

A large number of varieties developed by mutation breeding have arisen from materials irradiated with ionizing radiations (Sigurbjornsson and Micke, 1969). Both kinds of mutagens have their value, neutrons among radiations and ethyl methane sulphonate among chemicals are generally the mutagens of choice.

RADIOSENSITIVITY

Plants and animals differ in their responsiveness or sensitivity to a particular mutagen and the sensitivity differs even at the varietal level. The relevant factors that are known to alter the response of cells to mutagens include nuclear volume (including polyploidy), water content, atmosphere (oxygen, carbondioxide, hydrogen sulphide), stage of development and hydrogen ion concentration. Numerous other factors, appear to be of lesser importance, have been described in numerous reviews (Davidson, 1960; Konzak, 1957; Konzak et al., 1961 a, b; Nilan, 1956, 1964). The study of radiosensitivity of species or strains would be more desirable so that the optimum exposure of the mutagen can be used in each variety.

Oxygen is a major modifying factor of biological, including genetic damage caused by sparsely ionizing radiations in dry biological systems, such as dormant seeds. Its effect may be markedly influenced by various secondary factors such as temperature, seed water content, radiation energy and hydrogen ion concentration (Konzak et al., 1970).

The temperature of plant material before or after irradiation has a direct effect on the total amount of genetic damage induced by X- and gamma rays. It appears to be an important secondary factor which modifies the extent of oxygen radical or radical-radical interactions (Konzak et al., 1970).

Very low temperature ranging from -80 to -96°C may provide protection against radiation damage in plant seeds

(Konzak *et al.*, 1960; Nilan, 1954; Nybom *et al.*, 1953). "Heat shock" treatments applied immediately after seed irradiation has been found to reduce damage in terms of M_1 seedling height and chromosome aberration frequencies (Gaul, 1957 a, b; Konzak *et al.*, 1960) without decreasing mutation frequencies (Gaul, 1957 a, b; Khostova, 1956; Konzak *et al.*, 1961 a).

The role of nuclear and chromosome volume in determining the radiosensitivity of plant species has received a great deal of attention from Sparrow *et al.* (1968). It has been clearly demonstrated that there is an inverse relationship between radiosensitivity and "interphase" chromosome volume and to a lesser degree between radiosensitivity and DNA content (Konzak *et al.*, 1970; Capella and Conger, 1967)

Radiosensitivity in vegetatively propagated crops

Moh and Alan (1965) briefly outlined the behaviour of banana plants in a gamma field, as regards their radiosensitivity. At the Sugarcane Breeding Station, Coimbatore, several cultivars were irradiated around 1960 in an attempt to induce resistance to red rot caused by Physalospora tucumenensis (Anonymous, 1962). Jagathesan and Sreenivasan (1970) treated single buded sets of several Coimbatore cultivars with X- and r- rays. The material was studied upto VM_3

Radiosensitivity in tuber crops

Tubers and seeds of several varieties and species of Solanum were subjected to r-ray doses. Variants of Kufri Kumar with increased resistance to Late blight have been obtained (Kishore et al., 1963). Irradiation of cut tubers of five potato cultivars with subcritical doses of X-rays, r-rays and fast neutrons and treatment for 18 h with 0.1 per cent of ethylene imine and ethyl methane sulphonate retarded growth and development compared with the plants from untreated tubers. The effects on development depended mainly on the mutagen but the frequency of mitosis with chromosomal aberrations were also influenced by the cultivar, 7.50 - 10.47 per cent in X-ray, 2.65 - 6.18 per cent in r-ray, 4.41 - 60.90 per cent in fast neutrons, 3.14 - 5.23 per cent in ethylene imine and 1.85 - 4.60 per cent in ethyl methane sulphonate. Mutants for leaf, flower and tuber characters occurred in the first tuber generations (Tarasenko, 1963a). Three varieties of potato were exposed to different rates of r- irradiation. Unit 1 Porto Rico had the largest number of roots with one or more sectorial mutations in the flesh at all irradiation rates except 50 kR, when almost no plants developed. Heartagold had the highest mutation rate at 50 kR and Goldrush had a low mutation rate with all the irradiation treatments that produced plants. Most of the flesh mutations were from orange to white (Hernandez et al., 1964). Nayar et al. (1965) studied the M_2 generations of Kufri Kumar-Kufri Kuber and Kufri Safed which had been exposed to gamma irradiation. A general increase in mutation was associated with increased dosage, except that at the low rates of 500 r. There was no significant intervarietal differences in the mutation rates among the various characters studied. Persutina (1965) showed that the species with higher chromosome numbers proved more resistant to r-irradiation. Hybrid seeds of the cultivated varieties were more sensitive than seeds produced by self pollination. Solomko (1965 a) reported that in potato irradiation of the growing plant with X- and r-rays varying from 0.6 to 4 kR and of seeds with doses of 5-15 kR gave rise to a number of mutations in Rannjaya Rosa, Sedov and Epron. The proportions of undesirable mutants was only 3.7 - 7.7 per cent while 37.9 - 40.0 per cent were classed as useful. Gamma rays and high doses of X-rays produced the highest number of undesirable mutations. Irradiation of certain hybrids produced mutants with high yield and resistance to late blight.

The tubers of Epron, Early Rose and Sedov were exposed to X-rays at 400 to 8000 r, r-rays at 1500 to 3000 r and thermal neutrons at 1.10^{10} and 4.10^{10} neutron/sq. cm. Useful mutations included high yield, increased starch content, well formed tubers with small eyes and altered tuber colour. The widest spectrum of valuable mutants was induced by X-rays at 2-6 kR, r-ray doses of 3 kR or more induced less valuable forms. Gamma ray induced the greatest number of variants but the qualitative diversity of these was less than that of X-ray induced variants (Solomko, 1965 b). Up-to-date, Sebago and Sequoia were r-irradiated with 5000 r and Kennebec was treated with 1000 r. Sprouting was inhibited (Wills, 1965). Dry seeds of four hybrids and tubers of the varieties, Lorh, Peredovik and Barba were irradiated with r-rays. Only one type of mutation was obtained through tuber irradiation. The mutation spectrum was wider after seed irradiation but did not exceed the limits of natural mutation. Economically useful forms like early ripening with increased fertility were obtained (Jasina and Kirsanova, 1966 a). Jauhar and Swaminathan (1967) induced shallow eyes and an improved tuber skin colour in two important potato cultivars. Jauhar (1969 a) reported that in potato a hooded-eye and an eyeless mutant were induced in the varieties, up-to-date and Kufri Sindhuri by r-ray and ^{32}P treatments. The hooded-eye mutation was more frequently induced by r-rays and the eye-less mutation by ^{32}P. Jauhar (1969 b) reported the effects of r-rays and radioactive isotopes on the morphological and physiological characters of three potato varieties. The physiological variants included plants with fused leaves, simple leaves, many leaflets, bunchy type plants which are chlorophyll deficient and plants with aerial tubers. Fused and knobby tubers, rossetted and glossy-skinned tubers were noticed. Stimulatory effects of radioisotopes were observed on tuber sprouting, growth and yield.

Bancher and Washuttl (1970) studied the effect of r-rays on plant development and leaf form in two potato varieties, Bintje and Sieglinde, Bintje showed less reduction in height than Sieglinde following tuber irradiation with 500 to 5000 r. The two varieties showed similar leaf defects. Overchuk and Pika (1970) reported that by the action of r-rays the greatest frequency of mutation in the colour of tuber was shown by Nameshaev's Jubilee (13.6 per cent), a lower frequency by Tasty (2.1 per cent), Pearl (2.0 per cent) and no effect was observed with Priekuli Early. Kulakov (1971) reported that injections of potato tuber with dimethyl sulphate or soaking in different concentrations of mutagen induced mutations. Mezentsev and Yashina (1971) reported that irradiation of tubers of four cultivars with X-rays displayed various abnormalities. In Lorkh with white tubers there was no change in tuber colour whereas the other three having red tubers produced a certain number of tubers with reduced pigmentation. Mezentsev (1972) reported that the tubers of Lorkh and Volga were irradiated with electrons

(10-30 kR) and with X-rays and r-rays (3.5 kR). The frequency of recessive tuber colour mutations in volga with 18-20 kR electron irradiation was equal to the frequency of mutations after X- and r-irradiation. Raimkulov and Chervonnyi (1972) studied the action of ethyleneimine and dimethyl sulphate on the tubers of two potato varieties, Lorkh and Sedov. In the M_1 of both varieties, a high frequency of chlorophyll mutations was observed. As regards yield the control plants surpassed the M_1 population. Srinivasachar and Malik(1972) reported that non-waxy mutants were induced in the variety, Pusa sweti but not in PTW Globe. The mutants were resistant to Lipaphis pseudobrassicae.

Tuber treatment of Priekuli Early and Joy with 0.5 per cent N-Nitroso-N-ethyl urea, 0.03 per cent N-nitroso-N-methyl urea, 0.03 per cent ethyleneimine and 0.02 per cent dimethyl sulphate led to increases in leaf area, pollen fertility and content of starch and ascorbic acid (Volkov and Dan'ko, 1972). Irradiation of seeds of different varieties with 10 and 20 kR of X-rays at 50, 500 and 5000 R/min established the greater efficacy of the high intensity in increasing variability in starch content and yield (Mezentsev and Yashina, 1973). Surkova (1973) studied the effectiveness of 0.05 per cent solution of N-nitroso-N-ethyl urea on six potato varieties. The most sensitive variety was Augusta.

Treatment of its tubers for 20 minutes in a vacuum desiccator led to an increase in height of 91 per cent and in yield of 77 per cent.

The tubers of five potato varieties were irradiated with 1-7 kR dose in the autumn 2-3 weeks after harvesting. In plants grown from these tubers, the number of tubers per plant rose to different extent in the different varieties. With 1 kR dose, the number of tubers rose by 2-4 per plant in Loshitsa and Pavlinka but only by 0.2-0.5 in Tem (Dmitrieva and Mikhailov, 1977).

Dormant tubers of two potato varieties, Priekuli Early and Detskosel'skii were treated with various concentrations of dimethyl sulphate, ethylene imine, N-nitroso-N-methyl urea and N-nitroso-N-ethyl urea. In the M_1 generation starch content in clones of Priekul'skir rannii increased by 0.8 - 3.3 per cent compared with the initial variety, but no clones with an increased starch content were found in Detskoselskii (Kolesnikova and Maksimova, 1977). Tubers of twelve varieties and five promising seedlings were treated with 0.012, 0.025 and 0.05 per cent concentrations of dimethyl sulphate and 3000-3600 r doses of r-rays. The mutants obtained exceeded the Standard, Sulev by 20-89 per cent in tuber yield and by 28-72 per cent in starch yield. The best results were obtained with 0.05 per cent dimethyl sulphate and 3000 r r-rays (Maishchuk, 1978). Janave and Thomas (1979) studied the influence of post harvest storage temperature and gamma irradiation on potato carotenoids. Among the nine Indian varieties, total carotenoid content was positively correlated with yellow colouration of tuber flesh. Gamma irradiation reduced carotenoid levels in all varieties.

Excised eyes from haploids of Cherokee, Malakhovskii, Krassa and Flava were treated with N-nitroso-N-methyl urea. Judged by the percentage survival of plants from these eyes, haploids of Cherokee were the most resistant and those of Krassa the most sensitive to the mutagen. Treatment markedly increased the frequency of plants forming flower buds in many cases, but to a greater extent in the sensitive variety Krassa than the resistant Cherokee. Chlorophyll chimeras occurred after treatment in Malakhovskii (9.1, 66.7 and 75 per cent at 1, 2 and 3 mM/h respectively) than in Krassa (7.7, 9.1 and 42.9 per cent respectively). In Cherokee, chlorophyll chimeras occurred only at the concentrations of 3 and 5 mM, yield was always lower after treatment in Cherokee than in the untreated control but in Malakhovskii was sometimes higher after treatment (Broksh and Serova, 1980). True seeds and tuber eyes of 18 varieties and several F_1 hybrids were subjected to a range of X-ray doses. Immediate effects on the mode of development and the survival of the treated material varied according to variety, X-ray dose and either tuber age or the interval between seed irradiation and sowing. By the application of 3500 r dose to tubers, survival was particularly high in Apta, Gunosa and Bintje. Selection for yield was effective when begin in the M_2 generation. Selection for starch content and resistance to <u>Phytophthora infestans</u> occurred rarely and at random whereas it was possible to control the induction of field resistance through the choice of variety and dose (Groza, 1980). Norin 1, Tamayutaka and Okinawa 100 were treated with r-rays (20 kR - 120 R/h) and ethylene imine (0.5 per cent aqueous solution) for 1-3 clonal generations. Ethylene imine produced more deleterious effects than r-rays. Irradiation was more effective for improving tuber yield while ethylene imine was better for high dry matter and total sugar contents (Kukimura, 1981).

Vasudevan <u>et al</u>. (1967) have described the initiation of a mutation breeding programme in cassava using a wide range of mutagens. Morphological mutants were obtained after gamma irradiation of stem cuttings. One mutant showed an increase in starch content and a decrease in hydrogen cyanide content. A difference in the sprouting capacities of the two treated strains was observed after irradiation and advised a dose between 4 and 7.5 kR.

Stem cuttings and seeds of three cultivars of cassava were respectively exposed to 1-5 and 10-50 kR r-rays. Stem irradiation resulted in one mutant in each of the cultivars, M_4, H-165 and H-2304 while seed irradiation resulted in a mutant in H-2304. The mutants were characterised by light green leaves, short petioles and narrow leaf lobes, speckled leaves and yellow tuber flesh. The short-petiole mutant from 4-165 which can be closely planted gave a 20-25 per cent yield increase (Nayar and Rajendran, 1987).

Induced Mutagenesis

Mutations are the ultimate source of variability in organisms. Variability caused by induced mutations is not essentially different from variability caused by spontaneous mutation during evolution (Sigurbjornsson, 1970).

The direct use of mutations is a very valuable approach when it is desired to improve one or two easily identifiable characters in an otherwise well adapted variety. The main advantages are that the basic genotype of the variety is usually slightly altered, while the improved character is added and the time required to breed the improved variety can be much shorter than when hybridization is used to achieve the same result.

Several released mutant varieties derived from direct utilization of induced mutants in barley, wheat, oats, rice and soybeans have shown that short straw, earliness, resistance to certain diseases and certain improvements of grain quality can be introduced in otherwise well-adapted varieties without significantly altering their other attributes (Sigurbjornsson, 1970). There is some evidence that repeated mutagenic treatments can result with proper selection, in increased yield (Scholz, 1960; Gardner, 1969).

A desired mutation can be recovered in a homozygous stage already in M_2 or M_3 generation as compared with the F_6 or F_7 generation in the case of hybridization. Some workers have used mutagenic treatment in combination with hybridization in order to increase the variability to widen the basis for selection (Krull and Frey, 1961; Gregory 1956).

Vegetatively propagated crops are very suitable group of plants for the application of mutation breeding methods. The generally high degree of heterozygosity which causes a complex inheritance of genetic factors as well as the frequent polyploidy, both serious handicaps in conventional breeding are advantageous in mutation breeding as large variations can often be observed in the irradiated plants. Mutations are the only source of variability in sterile plants and in obligate apomicts (Nybom, 1961).

The main advantage of mutation induction in vegetatively propagated crops is the ability to change one or a few characters in an otherwise outstanding cultivar without altering the remaining and often unique part of the genotype (Broertjes and Harten, 1978). An example of radiation induced mutants of commercial value is that of *Chrysanthemum morifolium* cv Horim (Broertjes and Harten, 1978).

The main bottlenecks in mutation breeding of vegetatively propagated plants, where vegetative plant parts have to be irradiated, are chimera formation and diplontic selection both being complications caused by the multicellular nature of the bud apex. The result is a relatively low mutation frequency and probably limited mutation spectrum, while selection procedures cannot be applied before the stable periclinal chimera stage has been reached. These difficulties can be largely restricted or avoided by the use of *in vivo* or *in vitro* adventitious bud technique, by which large number of solid, non-chimeral mutants can be produced if detached leaves or explants, respectively, are irradiated before regeneration of the adventitious shoots (Broertjes and Harten, 1978).

For inducing mutations in vegetatively propagated plants, chemical mutagens are not usually considered, mainly because the number of cases in which they have been applied successfully has been small. This lack of success is probably a consequence of poor uptake and penetration of the chemical compound (Bowen, 1965; Moes, 1966; Nybom, 1961). Bulky materials like bulbs, scions are often difficult to treat with chemicals in a reproducible way.

The advantage of physical mutagens in vegetatively propagated plants is that ionizing radiation is easily applicable, clean with good penetration and reproducibility and high mutation frequency (Broertjes and Harten, 1978).

One of the advantages of breeding vegetatively propagated plants is that once a good genotype is obtained, it can be propagated and made use of directly (Broertjes and Harten, 1978).

Mutagenic effects observable in the M_1 generation

The three main effects of mutagens include physiological damage (primary injury), factor mutations (point mutations or gene mutations and chromosomal mutations (chromosomal aberrations) (Gaul, 1970). Primary injury is restricted to the M_1 generation whereas the latter two are transferred to the succeeding generations. Plant injury and lethality account for physiological damage and it can be chromosomal or extrachromosomal in origin. As reported by Gaul (1970) mutagenic treatments with low physiological effects and strong genetic effects are desirable.

Gaul (1959) reported that for a given mutagen treatment there is correlation between M_1 seedling height and survival on one hand and M_2 mutation frequency on the other hand. Hence a quantitative determination of M_1 injury should be a routine procedure in mutation breeding experiments.

Gaul (1970) listed the following criteria to measure plant injury in the M_1 generation.

(i) Seedling height after a particular period of growth
(ii) Root length
(iii) Emergence under field/laboratory conditions
(iv) Survival under field/laboratory conditions
(v) Number of spikes/inflorescence per plant
(vi) Number of seeds per spike
(vii) Fruits and/or seeds per plant

Gaul (1970) reported that with increasing dose the values obtained for each of these biological criteria decrease. As reported by Sparrow (1961) and Gaul (1963, 1970) the plant injury may vary depending on the genotype, type of mutagen, doses employed and various other modifying factors. Gaul (1959, 1964) reported a correlation between seedling height and survival and this correlation permits the prediction of the killing rate produced by a definite dose.

Cytological changes are also met with as a result of mutagenic treatments. A general survey of cellular changes due to mutagen treatment has been presented by Gatcheside (1945)., Darlington and La cour (1945)., Gustafsson and Von Wettstein (1958) and Sparrow (1961) and Evans (1962). Swanson (1957) and Sparrow (1961) reviewed the type of induced chromosomal mutations, their mitotic and meiotic behaviour and genetic consequences. Using X-rays and thermal neutrons, Caldecott et al. (1954) reported that the frequency of chromosomal aberrations is directly proportional to the doses.

Muller (1966) concluded that the achievements of increased mutation frequencies is limited by the increased sterility of the M_1 plants and not by the M_1 lethality.

Gaul (1970) is of the opinion that the mutagen induced sterility may be caused by

i) chromosome mutation
ii) factor mutation
iii) cytoplasmic mutation
iv) physiological effects.

Chromosome mutations are probably the major origin of all mutagen induced sterility. Gaul and Mittelstenscheid (1960) reported that in certain instances the radiation induced M_1 sterility is transferred into later generations. Most of the radiation induced sterility in M_1 and further generations is probably haplontic according to Muntzing (1930) and EMS induced sterility appears to have a diplontic nature (Sato and Gaul, 1967).

1. Germination

Germination has been reported to be little affected by radiations though damage occurred shortly afterwards (Myttenaere et al., 1965; Yamagata et al., 1965; Gaul et al., 1967; Gaul, 1967; Siddiq, 1967 and Ganeshan, 1970).

Sigurbjornsson and Fried (1966); Kawai and Sato (1965) and Siddiq (1967) reported that following seed irradiation there was greater reduction in growth of shoot than of primary roots.

Seed treatment of interspecific hybrids of potato with chemical mutagens gave a reduction in germination (Izotova, 1974). It was also reported by Budin et al. (1971) in potato with Nitroso ethyl urea. Jasina and Kirsanova (1966 b) reported that lower doses of gamma rays stimulated germination.

2. Survival

The survival of seedlings was generally found to decrease with increasing doses of radiations and chemical mutagens (Rao and Ayengar, 1964; Yamagata et al., 1965, Gaul 1966, Siddiq, 1967; Siddiq and Swaminathan, 1968 ; Swaminathan et al., 1970: and Ganeshan, 1970).

The survival of seedlings was significantly reduced with increasing doses of r-radiations in hexaploid triticale (Sapra and Constantin, 1978).

3. Plant growth

Treatment of tuber eyes of potato with X-rays caused a greater growth depression in the first and second tuber generations (Umaerus, 1966). Reduction in height has been more drastic in treatment with radiations than with chemicals (Siddiq, 1967 and Singh, 1970). As reported by Bancher and Wasnuttl (1970) a reduction in height was noticed with r-irradiation at a dose of 500-5000 r.

Budin et al. (1971) reported that seed treatment with Nitroso ethyl Urea will result in reduction in growth.

4. Fertility

A linear dependence of decreased pollen and seed fertility in rice on mutagen dose was reported by Yamaguchi (1964); Siddiq (1967) and Singh (1970).

Volkov and Dan'ko (1972) reported that in potato tuber treatment with physical and chemical mutagens lead to increase in fertility. Irradiation of cut tubers of potato with e_- produced 5.6-16 per cent higher proportion of fertile pollen.

5. Chimeras

Chlorophyll deficient sectors on the M_1 plants of rice following irradiation were observed by Siddiq (1967). Tanaka (1970) also observed diploid-like sectors on haploid plants subjected to chronic gamma irradiation.

Gamma irradiation of potato tubers resulted in different aberrant types. Light green type with several kinds of leaf deformity was obtained (Heiken, 1961).

Induced mutagenesis in vegetatively propagated crops

At the Sugarcane Breeding Institute, Coimbatore, the cv. Co 499 was treated with 500 r of r-rays and produced a plant with five stalks and a high degree of resistance to red rot strain D. The use of X-rays, r-rays and chemical mutagens resulted in further mutants that had no spines and profuse tillers (Anonymous, 1965 and Rao et al., 1966).

Several annual reports of the Sugarcane Breeding Station, Barbados also refer to morphological mutants that were obtained from irradiation or treatments with Ethyl methane sulphonate (Anonymous, 1966; Anonymous, 1970 a)

According to Hrishi and Marimuthammal (1968) and Hrishi _et al._, (1968) the treatment of buds and growing meristems with different chemical mutagens produced morphological mutants. Mee _et al._ (1969) also used various chemicals, such as 8-ethoxy caffeine, Methyl methane sulphonate and Ethyl methane sulphonate. For stem cuttings an acute dose of 2-6 kR r-rays were used (Siddiqi _et al._, 1976). Chronic irradiation was used by Sankaranarayan and Babu (1970).

In the 1969 annual report of the Hawaiian Sugar Planters Association (Anonymous, 1970b) it is stated that upper, middle and lower parts of young stalks were treated with up to 10 kR of r-rays. Stalks irradiated at the top showed great survival and varietal differences in resistance to radiation. A dose of 6 kR produced the highest rate of deviations, most of which were morphological. Jagathesan and Jalaja (1969) treated pollen grains with both ultra violet and X-rays.

Induction of the non flowering character has been reported by Walker and Sisodia (1969) and Rao (1974). The influence of mutagenic treatments on juice quality and grain weight was studied by Khan and Zakir (1970). Whole "thick-cane mutants were reported by Rao et al. (1977). Some preliminary work has been carried out by Anderez (1971) in Cuba.

Jagathesan and Sreenivasan (1970) treated single-budded sets of several Coimbatore cultivars with X- and r-rays. The material was observed up to vM_3 and some potentially useful mutants were described. Red rot resistant mutants of Co 449 and Co 997 were released (Rao et al., 1966).

Several other reports concerning the induction of resistance against red rot have appeared (Singh, 1970; Nair, 1973; Bari, 1974; Haq et al., 1970; 1974 a, b and Jagathesan et al., 1974). Resistance to the toxin from *Helminthosporium sacchari* in r-ray induced mutants was reported by Strobel et al. (1975). Several potentially useful mutants displaying disease resistance and high yield have been reported (Jagathesan, 1976, 1977; Darmodjo and Wirioatmodjo, 1976). Large scale mutation breeding has been prevented by the size of the plant and chimera problem.

Only a few irradiation experiments have been reported in pineapple. In Kerala, irradiation of plants of the cultivars Kew and Mauritius led to growth retardation and in one plant, to premature suckers (Anonymous, 1964). Marz (1964) reported the induction of self fertile mutants by X-irradiation of pollen during meiosis. Singh and Iyer (1974) described a suitable technique for applying chemical mutagens like ethyl imine (EI), N-nitroso-N-methyl urethane (NMU) and diethyl sulphate (DES) to detached slips of 1-1.5 months old. In this preliminary work, several morphological mutations were found, one of which produced spineless plants from cv. Queen and was economically significant.

In banana Panton and Menendez (1972) and Menendez (1973) applied ethyl methane sulphonate to seeds of a breeding line of Musa acuminata to obtain plants with decreased plant height. Soaking seeds in a 0.1 M EMS solution for 48 h at a temperature of 20°C reduced germination by 50 per cent.

In potato tuber halves of President were subjected to various r-ray doses. In vM_2 generation a light-green leaf type, a type with several kinds of leaf deformity including coalescent leaflets, two coarse-leaved dwarf forms, a plant with small leaflets and two flower colour mutants, one with white and the other with dark-purple corollas were found (Heiken, 1961). Tarasenko (1963b) reported that seed treatment of Kameraz 1 with a 0.1 per cent ethylene imine solution for 24 h or exposure to 15 kR of r-rays or 1000 r of fast neutrons resulted in increased variability of physiological characters including height, tuber weight and weight of aerial part of the plant. About 1 per cent of the radiation treated plants were mutants with changes in leaf colour, stem pigmentation, locule shape and other characters. Cytological analyses on rootlets indicated that the frequency of mitoses with chromosomal aberrations in control plants was 0.21 $\pm$ 0.22, while the corresponding proportions in treated material was 11.23 $\pm$ 0.31 in r-rays and 2.28 $\pm$ 0.45 in Ethylene imine. Rudorf and Wohrmann (1963) reported that sprouts of pregerminated tubers of Sieglinde were irradiated with 4000, 6000 and 8000 r r-rays. Alterations in leaf and stem characters and in chlorophyll formation were observed in the vM_2 and the somatic segregation in the vM_3 provided evidence of the chimerical nature of some of these characters. Several vM_3 plants were free from leafroll symptoms under conditions of several infection. Tarasenko (1964) reported that potato seeds were subjected to r-rays, fast neutrons and Ethyleneimine. Variation in morphological characters was studied in the M_1. The greatest mutagenicity was observed with fast neutrons. All mutagens caused mutations in tuber colour. Fast neutrons also gave mutations in tuber and leaf shape and duration of the vegetative period. All mutagens gave rise to variation in yield and in height of seedlings. Amirov and Babaev (1966) reported that irradiation of potato seeds with r-rays produced forms with divided leaves, pigmented stems and different colour and shape. Jasina and Kirsanova (1966b) reported that dry seeds of four hybrid seedlings were treated with 15 to 45 kR r-rays. The last proved the critical dose and the lower doses stimulated germination. A wide range of leaf abnormalities appeared in the progenies of the treated seeds all of which were absent in the untreated controls. In the tuber progeny of the mutant plants the abnormalities were more pronounced in the leaves than those in the upper part of the plant. Several forms of practical value were selected in the later tuber generations. One of them which had vestigeal flowers with enlarged corolla and tubers of good shape with shallow eyes matured early. It yielded 522 g of tubers per plant where the standard Priekuli Early yielded 240 g and the control gave a maximum of 300 g. Comparison of the cultivar Lorkh with various seedlings showed early forms to be more radiosensitive than late. Umacrus (1966) reported that treatment of tuber plugs containing single eye with X-rays and Ethyl methane sulphonate resulted in various aberrant forms. The X-ray treatment caused a greater growth depression in the first and second tuber generations but was easier to handle. The changes observed included Stolon length, greater tendency to tuber discoloration and to accumulate reducing sugars. Roer (1967) obtained best results when a dose of 3200 r was applied to unsprouted or slightly sprouted tubers. All the aberrants produced, mainly colour and leaf mutants, were inferior to the original clones. A mutant of Pimpernel had shorter stolons but this was correlated with a tendency to cracking of tubers. Nayar and Chauhan (1968) reported that healthy sprouts from disease free tubers of Craig's Defiance were subjected to serval Ethylmethane sulphonate treatments and in the second vegetative generation following the treatment a sectorial chimera was found. The parent tuber of the plant showing the chimera had produced two shoots from different eyes, both showing different characteristics from the original variety. In the same population a plant described as a systematic mutant and five others described as macromutants were found. As reported by Nayar (1969) methods for overcoming intrasomatic selection includes the use of chronic irradiation, neutron irradiation and chemical mutagenesis. Cuervo and Ramos (1970) reported that mutation experiments were initiated to alter the dormancy period and gametophytic incompatibility characters in <u>Solanum phureja</u>. Seeds and tubers of several clones were r-irradiated. One plant was selected in which the tubers did not sprout for seven months and another probable mutant had a fairly high seed set after pollination within the clone. Singh (1970) reported that hooded-eye mutants were obtained after irradiation of tubers with r-rays. As reported by Volkov and Dan'ko (1970) X-irradiation of seed tubers reduced the osmotic pressure of the cell sap and dry matter and starch contents of the tubers. The break down of starch caused accumulation of sugars and an increase in the protein content. In the following two crops there were increases in the contents of starch, ascorbic acid and protein indicating that genetic changes had been induced. Volkov and Dan'ko (1971) studied the effect of 0.025 and 0.05 per cent N-nitroso ethyl urea on the growth and development of potato plants from M_1-M_4. Promising forms possessing relative resistance to Phytophthora, high yield, high marketing quality and high starch content were selected in the M_3 and M_7. Budin et al. (1971) reported the influence of N-nitroso-N-ethyl urea and r-rays on potato species of different ploidy. There was reduction in germination and growth and the frequency of chlorophyll mutations in the M_1 were greater in some species than others. The frequency of chlorophyll mutants was highest in the tetraploid species, Solanum stoloniferum. Sergiyenko and Litovchenko (1971) reported that when seeds of hybrid origin or resulting from self pollination were treated with mutagens, variability in morphological and economically valuable characters increased considerably. Cherny and Vavrikova (1973) reported that treatment of the variety Jiskra with r-ray doses of 4.08 r to 1885.82 r during the growing period increased the variation in ploidy as shown by the number of chloroplasts per stoma in the M_2 generation. 2x, 3x and 6x forms were found in addition to the tetraploids. As reported by Harten and Bouter (1973) treatment with 3 kR of X-rays at a dose rate of 50 r/min proved very effective for producing relatively high frequencies of uniform mutations in dihaploid material of

Desiree. Dihaploids were not more radiosensitive than tetraploids. Treatment of hybrid seeds with 0.025 to 0.05 per cent N-nitroso ethyl urea (NEU) had no effect on seed variability or seedling survival, but there was variations in the colour of the flowers, staminal columnand tubers and there was a reduction in susceptibility to Phytophthora in first, second and third year seedlings. Average yield and commercial qualities of the tubers were reduced but individual families were obtained which gave higher yield. Harten et al. (1973) reported that dominant ivy-leaf genotype was obtained on treatment of tuber fragments each containing an eye with 2 kR r-rays.

Upadhya and Purohit (1973) reviewed the mutation breeding studies initiated at the Central Potato Research Institute. A genotype having a day neutral response with a low photorespiration rate and high photosynthetic efficiency would be suitable for warmer tropical and subtropical regions. As reported by Amirov (1974) a study was made of mutational changes in interspecific hybrids after treatment with Ethylene imine and N-nitroso-N-ethyl urea (NEU). A large number of changes was observed when NEU was used, but most of the mutant forms were deleterious. As reported by Izotova (1974) seeds of the BC_1 and BC_2 of hybrids between Solanum chacoense and Solanum curtilobum were treated with N-nitroso-N-ethyl urea

(NEU), N-nitroso-N-methyl urea (NMU) and 1, 4-bisdiazoacetyl-butane (DAB). The lowest number of germinated seeds and the highest yield of chlorophyll mutations were found after treatment with NMU. The largest number of tubers was found after treatment with DAB. After treatment with all the mutagens, an increase was observed in the number of high yielding forms. Kaneko (1975) reported that r-irradiation of tubers or Norin 1 produced many mutants which in the M_2 and M_3 had lower yields and starch content than the original variety. Some mutants were earlier and most mutations affected the leaves. Treatment of the eyes with N-nitroso-N-methyl urea considerably increased variation in the characters studied in the first vegetative generation of five dihaploids (Brcksh and Serova, 1976). As reported by Uzhovskaya (1976) the seeds of interspecific potato hybrids were treated with N-nitroso-N-ethyl urea (NEU) and 1,4-bisdiazoacetyl butane. A positive correlation occurred between starch content and yield which was high (r = 0.84) in plants obtained after treatment with 0.06 per cent N-nitroso-N-ethyl urea but much lower when the concentration was raised to 0.09 per cent. Similarly with 1,4-bisdiazoacetyl butane the coefficient of correlation between starch content and yield was higher after treatment with a lower concentration of the mutagen (0.2 per cent) as against 0.3 per cent. Tarasenko and Kharitonova (1976) induced wart-resistant potato mutants on treatment of the potato tubers with 3 kR X-ray dose. Dobias (1977) reported that it was difficult to establish morphological mutations in the M_1 following whole tuber, irradiation with 2,4 or 6 kR r-rays. But the majority of tuber-colour mutations could be determined in the M_2. Leaf, flesh colour and eye depth alterations could be detected from the M_3. A dose of 4 kR was the most effective. Groza (1977) induced mutants with increased yield potential by X-ray treatment of tuber eyes.

Treatment of potato seeds of different origin with ethyleneimine (EI) in concentrations of 0.01, 0.02 and 0.03 per cent, with N-nitroso-N-ethyl urea (NEU) in concentrations of 0.01 and 0.025 per cent and with r-ray doses of 15 and 20 kR increased variation in both qualitative and quantitative characters and resulted in the formation of mutant seedlings with better values for economically useful characters than seedlings from untreated seeds. The best results were obtained with 0.01 and 0.02 per cent EI, 0.025 per cent NEU and 20 kR r-rays (Maishchuk, 1977). Upadhya and Tiwari (1979) induced mutations by the treatment of seed, shoots, cut and whole tubers with physical and chemical mutagens. Tubers from two potato clones were treated with N-nitroso-N-methyl urea (0.015 per cent) and/or with r-irradiation (4 kR). Combined treatment with both mutagens procured the highest frequency of early ripening mutants. Some chlorophyll and tuber colour mutants were also found (Tellhelm _et al_., 1981).

Saulite (1983) induced mutants resistant to <u>Synchytrium endobioticum</u> with 6000 r r-rays and 0.6 per cent ethylene imine respectively. Tiits (1985) obtained chloroplast mutants on treatment of the seeds with 0.04 per cent N-nitroso-N-methyl urea.

Abraham (1970) reported that by treating tubers of yam with r-rays high yielding mutants were obtained. Koo and Cuevas Ruiz (1974), however, irradiated the aerial tubers of several varieties after 1-2 months storage at room temperature. The dose was 2 kR of r-rays given at a dose rate of 1 kR/min. The first shoots to appear were removed, forcing new shoots to develop, these latter shoots were allowed to grow and observed. The results showed that solid mutant shoots appeared as early as the second generation. Vasudevan <u>et al</u>. (1968) reported the effects of r-irradiation on <u>Colocasia esculenta</u>. A number of chlorophyll mutants were seen most of which were not of commercial interest.

Treatment of tubers of <u>Coleus parviflorus</u> with 1, 2, 3 or 4 kR r-rays gave 50 morphologically different mutants. Two early mutants were identified which are ready for harvesting 100 days after planting compared with 150-160 days normally. The early mutants formed tubers mainly near the base of the plant which makes for easier harvesting (Vasudevan and Jos, 1988).

Hernandez et al. (1959) reported that in sweet potato some flesh colour mutations had been induced with r-rays (10-50 kP). In every case the colour changed from dark (eg. orange) to light (white). In later publication the same authors compared mutation rates of three different cultivars treated with up to 50 kR of r-rays and observed considerable differences between cultivars. Most commonly mutated "sectors" with a colour change, again from orange to white, were obtained.

The effect of irradiation on the yield of sweet potato was studied by Poole (1959) and Poole and Tanaka (1963). Marumine and Sakai (1961) reported studies on X-ray induced mutants. Sakai (1966) studied the repeated application of ^{32}P to cuttings, leaves and tubers in order to obtain mutants with high starch content. Love (1969, 1972) noted mainly skin colour and flesh colour mutations after exposure of rooted cuttings to fast neutrons. Changes which darkened the skin were considerably less frequent than those resulting in lighter skin colours. Changes in flesh colour occurred more often than those in skin colour.

High yielding mutants with a high vitamin A content were obtained after irradiation by Miu et al. (1969). Kukimura (1971) achieved changes in tuber skin colour after using X-rays, r-rays and the chemical mutagen, ethylene imine

(EI). He claimed that (apparently) dominant mutations can be obtained at high frequencies. His results could be explained by the occurrence of chimeric structures being uncovered by irradiation.

Soriano (1971, 1972) treated terminal vines carrying between eight and ten axillary buds with 800-3200 r of r-rays and obtained a number of variants with aberrant leaf characters. He ascribed the change to chromosome aberrations. Miu (1973) and Miu et al. (1973) reported the induction of improved tolerance in the important native cultivar Red Flesh tall from Taiwan, after treatment with 5000 r of X-rays. Plants with darker leaves and higher yields were also obtained.

Kukimura and Takemata (1975) reported that mutants with increased as well as reduced sugar contents were obtained after treatment of shoots, dormant root tubers and seeds of sweet potato with cobalt-60 r-rays (10-15 kR) or EI at concentrations of 0.1 and 0.3 per cent and exposure for 3 h). Marumine (1983) reported that treatment with B-rays was carried out on cuttings, tubers and true seed. Tubers showed no damage at high doses. Heritability of tuber yield and dry matter percentage increased. Mutants for vine length and diameter and tuber colour were induced by ethyl imine treatment of cuttings. X-irradiation also induced mutants for vine length and diameter.

Thus it is gathered from a scanning through the review of literature that induced mutagenesis can be beneficially employed for varietal improvement in a wide range of crops.

MATERIALS AND METHODS

MATERIALS AND METHODS

PART I. RADIOSENSITIVITY ANALYSIS

A. MATERIALS

1. Planting material

Fifteen varieties of Sweet potato (Ipomoea batatas (L.) Lam.), the majority comprising of local types, were used for the present investigation (Table 1). The stem cuttings of these varieties were grown under uniform conditions, adopting the recommendations of the Package of Practices of Kerala Agricultural University, at the rate of 75 kg N, 50 kg P and 75 kg K per hectare. N was applied in two equal split doses, the first dose at the time of planting and the second 4-5 weeks after planting with whole amount of P and K given at planting time in a single dose. The crop was harvested and fully mature vines were selected for further studies. The vines were kept in shade for 3 days for leaf-shedding. Stem cuttings of 8-10 cm length bearing 2 nodes each of uniform maturity were taken from these well developed vines and kept sealed in polythene bags to maintain uniform moisture content. These cuttings were then exposed to gamma rays.

Gamma source

The irradiation of vines was done using a ^{60}Co gamma cell unit installed at the Radio Tracer Laboratory, Kerala Agricultural University, Vellanikkara, Trichur. The gamma source is stationary and irradiation is done by moving down a cylindrical gasket carrying the material.

B. METHODS

1. Gamma irradiation

One hundred and fifty cuttings of each variety were exposed to 2, 4, 6, 8 and 10 kR at a dose rate of 0.162 MR/h. Planting was done on the next day of irradiation.

2. Planting technique

The irradiated cuttings along with their controls were planted in raised beds at a spacing of 15 x 10 cm in three replications of 10 vines each. The soil was red loamy and the crop was raised in minimum fertilizer and manurial schedules, by applying half the recommended dose at the time of planting to check excessive vegetative growth of the vines.

Special care was taken to provide uniform field conditions for these plants till harvest. Irrigation was provided uniformly as and when required. All the field experiments relating to radiosensitivity analysis were conducted in the experimental area attached to the Department of Agricultural Botany, College of Agriculture, Vellayani. The experiment was conducted during the first half of 1987-'88.

3. Observations

The following observations were taken in vM_1 generation.

1. Days taken to start sprouting
2. Days taken to complete sprouting
3. Sprouting percentage
4. Chlorophyll deficient variants
5. Lethality on the 30th day of planting
6. Lethality at harvest
7. Length of vine
8. Number of branches per vine
9. Number of tubers per vine
10. Weight of tubers per vine

1. Days taken to start sprouting

Number of days taken to start sprouting was calculated from the date of planting to the date of first emergence of sprouts on each vine.

2. Days taken to complete sprouting

Number of days taken to complete sprouting was calculated from the date of planting to the day after which no further sprouting was observed.

3. Sprouting percentage

Sprouting counts were taken at 5 day intervals from the 5th to the 30th day of planting. Total sprouting percentage was estimated from the values taken on the day after which no further sprouting was observed.

4. Chlorophyll deficient variants

The vines were examined periodically in the early hours of the day for the presence of chlorophyll deficient sectors on the leaves.

5. Lethality on the 30th day of planting

Lethality of vines at seedling stage was determined on the 30th day of planting. The vines surviving in the field on that particular day were counted and the percentage value computed from the total sprouting percentage for each treatment.

6. Lethality at harvest

The number of vines surviving for each treatment at the time of harvest was counted. The percentage lethality at harvest was computed relating this value with that of the total percentage sprouting for each treatment.

7. Length of vine

The length of vine was taken from the soil level to the tip of shoots and expressed in cm.

Vine length was taken at 7 stages of growth at 15 day intervals starting from the 30th day of planting till harvest.

8. Number of branches per vine

Number of branches produced per vine was recorded at harvest. The branches produced per vine were counted separately and the average value per vine per treatment was estimated.

9. Number of tubers per vine

Number of tubers produced per vine was counted at harvest. Only fully developed tubers were considered.

10. Weight of tubers per vine

Tuber weight was determined from fresh tubers at the time of harvest. All the fully developed tubers per vine from each treatment were weighed and the mean weight calculated and recorded in g.

Radiosensitivity analysis was limited to vM_1 generation and based on the data collected for all the growth metrics and yield parameters, the varieties tested were grouped under three categories viz. sensitive, medium tolerant and tolerant varieties.

Statistical analysis

Statistical analysis was done following Snedecor and Cochran (1975). Analysis of covariance was done taking control as the concomitant variate and gamma ray exposure at 2000 r as the study variate. Since the 'F' value for the regression was found not significant, the analysis of variance was done for comparing the different varieties.

The percentage variation of different attributes over the control was computed varietywise using the expression.

Percentage variation $= \frac{Y - X}{X} \times 100$ where Y and X correspond to mean variable value for 2000 r and the control respectively.

PART II. INDUCED MUTAGENESIS

A. MATERIALS

The investigation to assess the created variability in Sweet potato due to ^{60}Co gamma rays was carried out in continuation with the radiosensitivity analysis.

Selection of varieties

Three varieties of sweet potato, viz. Muttavella (V_1), Kanhangad local (V_2) and Bhadrakalichuvala (V_3) were selected, one each from the low, medium and high mutagen tolerant groups. The above grouping of varieties was done by discriminant function analysis (Singh and Chaudhry, 1979).

Multiplication of selected varieties

Fifty stem cuttings/each of these three varieties were grown under uniform environmental conditions adopting the recommendation of the Package of Practices of the Kerala Agricultural University. The crop was harvested at full maturity and vines were selected for further studies.

Preparation of materials for irradiation

The three planting materials selected for gamma ray exposures were:

a. Fresh cuttings
b. Rooted cuttings
c. Rooted tubers

a. Fresh cuttings

Three hundred fresh cuttings of uniform maturity (50 each for 5 doses and control) having a length of 8-10 cm bearing 2 nodes each were collected from the well developed vines of the 3 selected varieties. These fresh cuttings were properly labelled and packed for irradiation.

b. Rooted cuttings

The harvested vines kept in shade for three days were allowed to root. Three hundred rooted stem cuttings of 8-10 cm length bearing 2 nodes each were taken, properly labelled and packed for irradiation.

c. Rooted tubers

Three hundred insectfree tubers of uniform size were chosen from each variety for the different treatments. The selected tubers were planted in sand and watered regularly for one week. The rooted tubers were uprooted, cleaned and packed in polythene bags for irradiation.

Gamma irradiation

The irradiation of planting materials was done by using a ^{60}Co gamma cell unit as mentioned earlier.

The exposures were selected on the basis of the radiosensitivity analysis as described in part 1 of this chapter. Consequently 500, 1000, 1500, 2000 and 2500 r were chosen with a dose rate of 0.162 MR/h.

B. METHODS

vM_1 generation

Fresh cuttings and rooted cuttings

The gamma irradiated and control vines were planted on the next day of exposure in two replications of 25 each. Planting was done in mounds of 75 cm diameter at the rate of 5 cuttings per mound. During planting special care was taken to have only one node above the soil. Uniform field conditions were provided for all the vines till harvest. The crop was raised by giving the minimum requirement of fertilizers. Irrigation was done uniformly as and when required. The experiment was conducted during the latter half of 1987-'88. During growth phase periodical observations were taken. On maturity the crop was harvested.

Rooted tubers

The gamma irradiated and control tubers were planted on the next day of exposure in 2 replications of 25 tubers each. The tubers were planted in mounds with 75 cm diameter at the rate of 5 tubers per mound. The soil was red loamy and uniform field conditions were provided for all the plants till harvest. The crop was raised by providing the minimum requirement of fertilizers. Irrigation was given uniformly as and when required. The experiment was conducted during the second half of 1987-'88. During the growth phase periodical observations were taken. On maturity the crop was harvested for observations.

The following observations were taken in vM_1 generation.

1. Days taken to start sprouting

Number of days taken to start sprouting was calculated from the date of planting to the date of first emergence of sprouts on each vine.

2. Days taken to complete sprouting

Number of days taken to complete sprouting was calculated from the date of planting to the day after which no further sprouting was observed.

3. Sprouting percentage

Sprouting counts were taken at 5 day intervals from the 5th day to the 30th day of planting. Total sprouting percentage was estimated from the values taken on the day after which no further sprouting was observed. The number of vines sprouted was expressed in percentage.

4. Lethality on the 30th day of planting

Lethality of vines at seedling stage was determined on the 30th day of planting. The vines surviving in the field on that particular day were counted and the percentage value computed from the total sprouting percentage for each treatment.

5. Lethality at harvest

The number of vines surviving in each treatment at the time of harvest was counted. The percentage lethality at harvest was computed by relating this value with that of the total percentage sprouting for each treatment.

6. Length of vine

Length of vine was taken at 7 stages of growth at intervals of 15 days from the 30th day after planting till harvest. The length of vine was taken from the soil level to the tip of shoots. The average length of vine for each treatment was calculated and expressed in cm.

7. Number of branches per vine

Number of branches produced per vine was studied at harvest. The branches produced per vine were counted separately and the average value per vine per treatment was determined.

8. Fresh weight of vine

Fresh weight of vine was observed immediately after harvest.

9. Number of tubers per vine

Number of fully developed tubers produced per vine was counted at harvest.

10. Weight of tuber

Tuber weight was determined from fresh tubers. All the fully developed tubers per variety from each treatment were weighed and the mean weight calculated and recorded in g.

11. Length of tuber

The length of tuber was measured as the distance from its point of attachment to the tip. The length of all the tubers in each treatment was measured to calculate the mean value.

12. Girth of tuber

Three tubers randomly selected from each vine per treatment were used to record the girth of tuber. The girth was measured uniformly from the widest part of the tuber and the mean value computed.

13. Volume of tuber

Volume of tuber was determined using a measuring cylinder. The tubers were individually immersed in the measuring cylinder filled with water and the quantity of water displaced was taken as the volume of the tuber which was expressed in cm^3.

14. Tuber yield per vine

Tuber yield per vine was found out by weighing all the tubers harvested from each vine per treatment.

15. Colour of tuber

At the time of harvest, the tubers from each cutting were observed to find out the colour variations created by the mutagen on the tuber skin.

16. Chlorophyll deficient variants

The vines were examined at frequent intervals in the early morning hours to assess the chlorophyll deficient variants.

17. Morphological variants

The vines were periodically examined to isolate morphological variants.

vM_2 generation

a. Selection of materials for vM_2 generation

vM_1 plants were uprooted and kept in shade for three days to facilitate rooting and representative 3-4 noded cuttings were taken from the basal, middle and top portions of each vine. These cuttings were suitably labelled and planting was done on the third day.

b. Raising vM_2 generation

All the cuttings from each plant were planted in mounds of 75 cm diameter taken 30 cm apart at the rate of 5 cuttings per mound. The crop was raised during 1988-'89. Fertilizer application was done according to recommendation of the Package of Practices of Kerala Agricultural University. Irrigation was done uniformly as and when required. Special care was taken to provide uniform field conditions for the entire crop till harvest.

c. Observations in vM_2 generation

1. Morphological variants

The vines were periodically examined to isolate morphological variants.

2. Length of vine

The length of vine was taken at harvest. It was measured from the soil level to the tip of shoots and expressed in cm.

3. Number of branches per vine

Number of branches produced per vine was studied at harvest. The branches produced per vine were counted separately and the average values per vine per treatment were computed.

4. Fresh weight of vine

Fresh weight of vine was observed immediately after harvest.

5. Number of tubers per vine

Number of fully developed tubers produced per vine was counted at harvest.

6. Weight of tuber

Tuber weight was determined from fresh tubers at the time of harvest. All the fully developed tubers per variety from each treatment were weighed and the mean weight calculated and recorded in g.

7. Length of tuber

The length of tuber was measured as the distance from its point of attachment to the tip. The length of all the tubers in each treatment was measured and the mean value computed.

8. Girth of tuber

Three tubers randomly selected from each vine per treatment were used to record the girth of tubers. The girth was measured uniformly from the widest part of the tuber and the mean value computed.

9. Volume of tuber

Volume of tuber was determined by using a measuring cylinder. Each tuber was immersed in the measuring cylinder filled with water and the quantity of water displaced was taken as the volume of the tuber which was expressed in cm^3.

10. Tuber yield per vine

Yield per vine was found out by weighing all the tubers harvested from each vine per treatment.

11. Colour of tuber

At the time of harvest tubers from each cutting were observed to find out the colour variations created by the mutagen on the tuber skin.

12. Classification of phenotypes and frequency analysis

vM_2 phenotypes were classified under three different classes namely positive variants, control group and negative variants.

The mean character expression for control population was taken as the middle value or control group. Those variants which exceeded these phenotypic measurements were grouped under positive variants and those that showed lower phenotypic measurements than the control group were included under the negative variants.

The frequency of each group per treatment was calculated in percentage and its significance tested using proper statistical procedures.

vM_3 generation

a. Selection of materials for vM_3 generation

vM_2 plants were harvested and all fully mature vines were selected to raise vM_3 generation. The harvested vines were kept in shade for leaf shedding. Stem cuttings of uniform maturity with a length of 20-25 cm, each bearing 3-4 nodes were taken from these well developed vines.

b. Raising vM_3 generation

Stem cuttings taken from vM_2 generation were carried forward to raise vM_3 generation. The planting and manuring were done as described earlier. The crop was raised during 1988-'89. Special care was taken to provide uniform field conditions for the entire crop till harvest. As the crop was raised during the rainy season adequate drainage was also provided.

c. Observations in vM_3 generation

1. Morphological variants
2. Length of vine
3. Number of branches per vine
4. Fresh weight of vine
5. Number of tubers per vine
6. Weight of tuber
7. Length of tuber
8. Girth of tuber
9. Volume of tuber
10. Tuber yield per vine
11. Colour of tuber
12. Classification of phenotypes and frequency analysis

vM_4 generation

a. Selection of materials for vM_4 generation

Five plants of uniform appearance were selected from each treatment which gave higher yield. The selected plants were kept in shade for 3 days for leaf shedding. Stem cuttings of 20-25 cm length, bearing 3-4 nodes each were taken from fully mature vines.

b. Raising vM_4 generation

The vM_4 generation was raised to carry out the performance analysis of the yield variants isolated out in vM_3 generation. Cultural practices used for raising the crop were the same as for vM_2 and vM_3 generations.

c. Observations in vM_4 generation

1. Morphological variants
2. Length of vine
3. Number of branches per vine
4. Fresh weight of vine
5. Number of tubers per vine
6. Weight of tuber
7. Length of tuber
8. Girth of tuber
9. Volume of tuber
10. Yield per vine
11. Colour of tuber

Statistical analysis

Analysis of variance of vM_1, vM_2 vM_3 and vM_4 data was done following Snedecor and Cochran (1975). Percentage values were transformed by the angular transformation. Analysis of mean values was done as a factorial in RBD with 3 varieties, 6 exposures and two replications. The outline of analysis of variance table showing the source of variations and corresponding degrees of freedom is given below.

Source	Degrees of freedom
Replication	1
Treatments	17
Between varieties (V)	2
Between exposures (E)	5
V x E	10
Error	17
Total	35

Analysis of vM_2 and vM_3 phenotypic classes was done in the form of factorial RBD. The frequencies with respect to negative variants, control group and positive variants were analysed by assigning values 0, 1 and 2, respectively for negative variants, control group and positive variants.

The outline of analysis of variance showing the source of variation and corresponding degrees of freedom is given below.

Source	Degrees of freedom
Replication	1
Treatments	17
Between varieties (V)	2
Between exposures (E)	5
V x E	10
Error	17
Total	35

Table 1. Varieties used for radiosensitivity analysis

Sl. No.	Varieties	Source
1	Kavivella (V_1)	Vellayani
2	Bhadrakalichuvala (V_2)	Vellayani
3	Kottaramchuvala (V_3)	Vellayani
4	H.4126 (V_4)	Vellayani
5	Muttavella (V_5)	Vellayani
6	Kanhangad local (V_6)	Central Tuber Crops Research Institute, Trivandrum.
7	H.268 (V_7)	"
8	Cross-4 (V_8)	"
9	S-5 (V_9)	"
10	76-OP-219 (V_{10})	"
11	S-30 (V_{11})	"
12	H-42 (V_{12})	"
13	OP-22 (V_{13})	"
14	76-OP-217 (V_{14})	"
15	OP-23 (V_{15})	"

RESULTS

RESULT

PART I : RADIOSENSITIVITY ANALYSIS

Fifteen varieties of sweet potato, majority of local types, were exposed to 2-10 kR gamma rays and the results emanated are presented below:

In majority of the varieties 4 kR and higher exposures showed cent per cent lethality and hence comparative analysis for radiosensitivity was done based on 2 kR with that of control population.

1. Days taken to start sprouting

The number of days taken to start sprouting in different varieties is depicted in Table 2 and Fig. 5. Statistical analysis of the data showed significant variation in gamma ray exposed population.

In the control population days taken to start sprouting varied from 2.00 (V_1, V_4 and V_{12}) to 2.45 (V_{14}). In treated population the mean values ranged from 2.00 in V_{12} to 2.83 in V_7 and V_8. Except two varieties (V_7 and V_8), in all the other varieties treated population showed almost similar values for days taken to start sprouting. The percentage variation gave positive values in most of the varieties. The mean values ranged from -3.70 in V_3 to 26.34 in

Table 2. Days taken to start sprouting

Varieties	Control	2000 r	Percentage variation over control
V_1	2.00	2.37	18.5
V_2	2.08	2.16	3.85
V_3	2.16	2.08	-3.70
V_4	2.00	2.38	19.00
V_5	2.16	2.38	10.19
V_6	2.31	2.58	11.69
V_7	2.38	2.83	18.91
V_8	2.24	2.83	26.34
V_9	2.24	2.24	0
V_{10}	2.24	2.24	0
V_{11}	2.16	2.31	6.94
V_{12}	2.00	2.00	0
V_{13}	2.30	2.31	0.43
V_{14}	2.45	2.58	5.30
V_{15}	2.08	2.24	7.69
F value	-	9.305**	4.271**
CD value	-	0.231	35.069

** Significant at 1% level

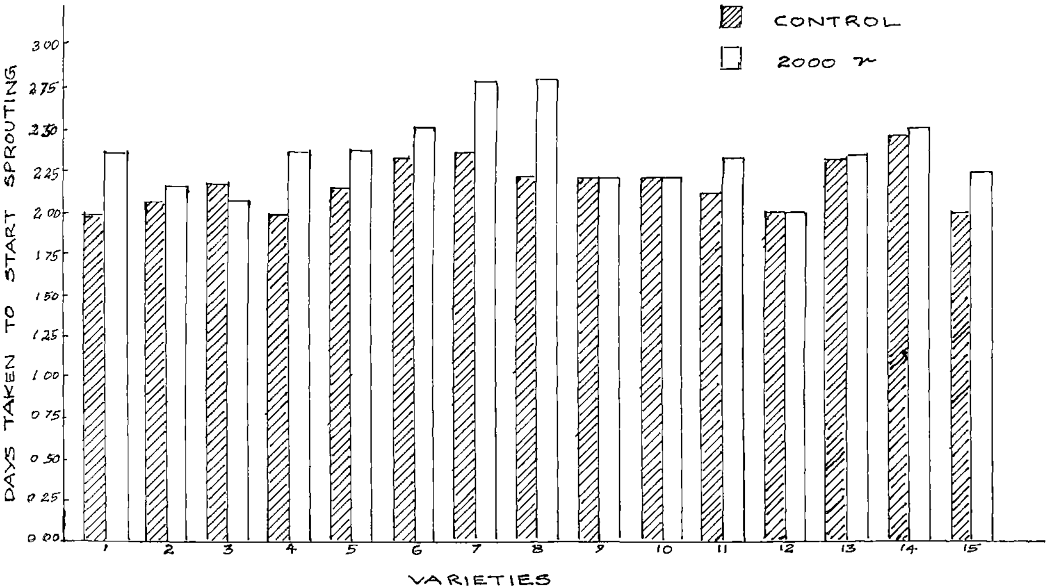

Fig: 5 DAYS TAKEN TO START SPROUTING

V_8. No variation in this regard was noticed in V_9, V_{10} and V_{12}.

2. Days taken to complete sprouting

Days taken to complete sprouting in different varieties is depicted in Table 3 and Fig. 6. Statistical analysis of the data showed significant variation by the influence of gamma ray exposure and also percentage variation over control.

In the control population the days taken to complete sprouting ranged from 2.83 in V_9 and V_{12} to 3.83 in V_7. In majority of the varieties tested, the days taken to complete sprouting was above 3.00. The gamma ray exposure showed variety-dependent variation for days to complete sprouting. In treated population the mean values ranged from 3.31 (V_9, V_{12} and V_{13}) to 4.24 (V_8). Higher values for days taken to complete sprouting compared to their respective controls were noted in V_7 and V_8. The percentage variation gave positive values in all the varieties. The mean values ranged from 6.23 in V_1 to 28.10 in V_8. Higher values for percentage variation were noted in V_3, V_8 and V_{15}, the maximum being in V_8 (28.10).

3. Sprouting percentage

The mean sprouting percentage at 15 days after planting

Table 3. Days taken to complete sprouting

Varieties	Control	2000 r	Percentage variation over control
V_1	3.21	3.41	6.23
V_2	3.16	3.56	12.66
V_3	2.89	3.64	25.95
V_4	3.11	3.74	20.25
V_5	3.26	4.00	22.70
V_6	3.27	3.65	11.62
V_7	3.83	4.20	9.66
V_8	3.31	4.24	28.10
V_9	2.83	3.31	16.96
V_{10}	2.94	3.41	15.99
V_{11}	3.05	3.74	22.62
V_{12}	2.83	3.31	16.96
V_{13}	3.11	3.31	6.43
V_{14}	3.26	3.65	11.96
V_{15}	2.89	3.69	27.68
F value	-	6.836**	2.578**
CD value	-	0.331	35.659

** Significant at 1% level

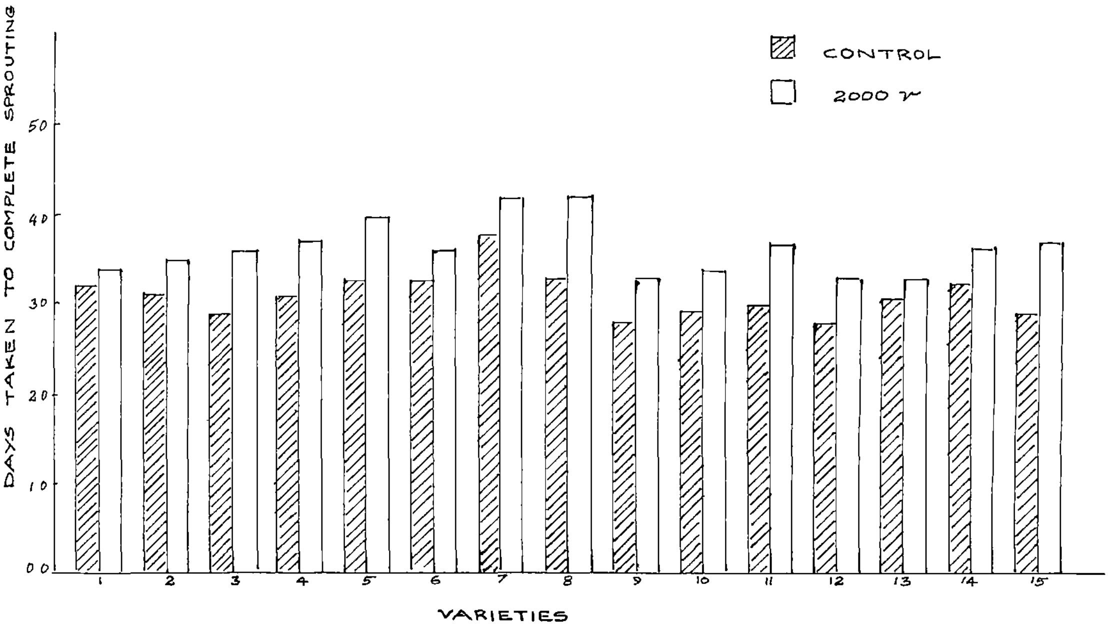

Fig 6 DAYS TAKEN TO COMPLETE SPROUTING

in different varieties is presented in Table 4.1 and Fig. 1. Statistical analysis of the data showed significant variation in gamma ray exposed population and also percentage variation over control.

In control population there was wide varietal variation for sprouting percentage and it varied from 37.21 in V_{14} to 77.69 in V_4. In majority of the varieties the mean sprouting was below 50 per cent. The percentage sprouting varied depending on the varieties. In almost all the varieties a reduction in percentage sprouting was noticed compared to their respective controls due to gamma ray exposure. Except three varieties ($V_{4,}$ V_9 and V_2), in all the other varieties the treated population gave a reduced sprouting percentage, below 50 per cent. In $V_{9,}$ V_{12} and V_{14} the treated population gave an increased sprouting percentage compared to their controls and it was maximum in $V_{9,}$ the percentage increase being 65.34 over the control.

The sprouting percentage at 20 days after planting in different varieties is presented in Table 4.2 and Fig. 2. Statistical analysis of the data showed significant variation in gamma ray exposed population and also percentage variation over the control.

In control population the mean values ranged from 39.22 per cent (V_{11} and V_{14}) to 83.85 per cent (V_4). In

Table 4.1. Sprouting percentage on the 15th day of planting

Varieties	Control	2000 r	Percentage variation over control
V_1	46.90	46.90	0
V_2	42.98	41.05	-4.47
V_3	48.91	41.14	-15.89
V_4	77.69	70.06	-9.82
V_5	61.20	41.14	-32.78
V_6	50.83	48.83	-3.95
V_7	41.14	35.00	-14.93
V_8	44.98	41.05	-8.73
V_9	46.99	77.69	65.34
V_{10}	41.14	39.22	-4.67
V_{11}	41.138	39.22	-4.67
V_{12}	50.83	51.12	0.57
V_{13}	51.12	46.90	-8.25
V_{14}	37.21	39.22	5.40
V_{15}	57.76	41.05	-28.93
F value	-	8.789**	2.685*
CD value	-	11.655	56.794

* Significant at 5% level

** Significant at 1% level

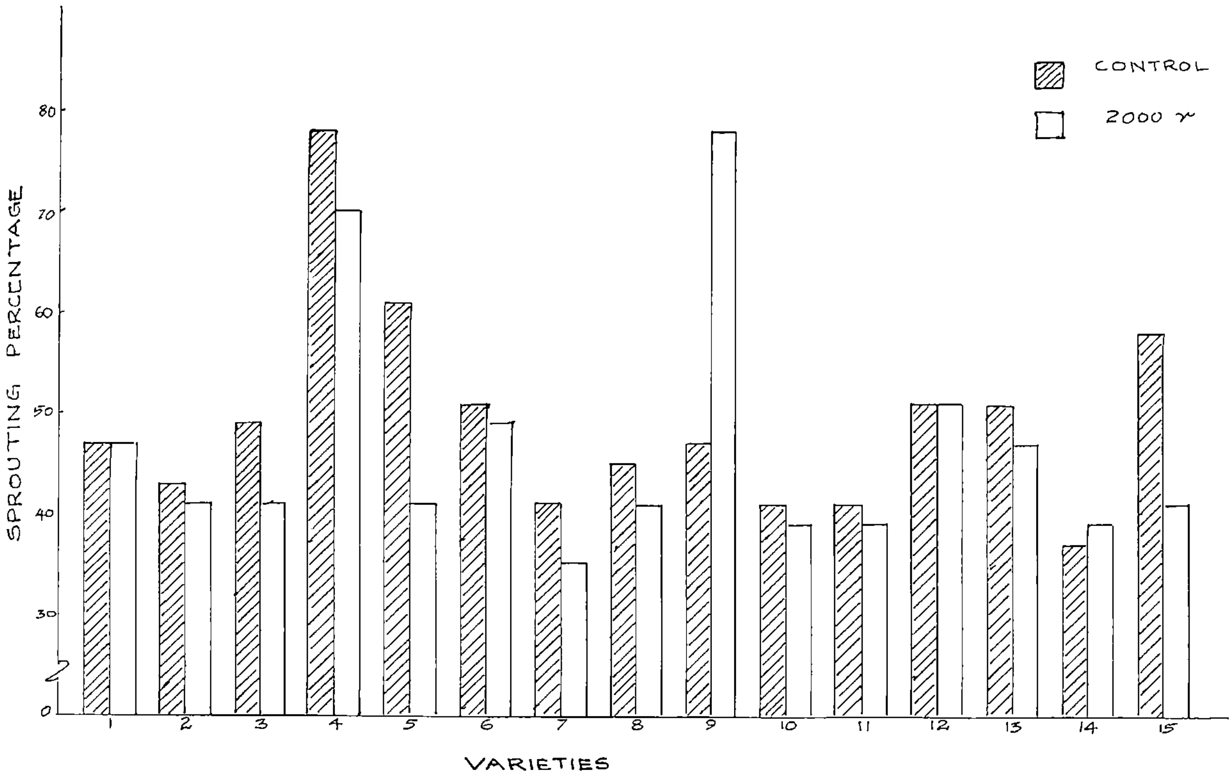

Fig 1 SPROUTING PERCENTAGE ON 15th DAY

Table 4.2. Sprouting percentage on the 20th day of planting

Varieties	Control	2000 r	Percentage variation over control
V_1	44.98	46.90	4.27
V_2	43.06	41.05	-4.66
V_3	43.06	41.14	-4.46
V_4	83.85	61.20	-27.01
V_5	61.20	41.14	-32.78
V_6	50.83	48.82	-3.95
V_7	41.14	39.13	-4.88
V_8	49.20	41.14	-16.39
V_9	46.99	71.54	52.24
V_{10}	41.14	39.22	-4.67
V_{11}	39.22	39.22	0
V_{12}	46.99	46.99	0
V_{13}	46.90	44.98	-4.10
V_{14}	39.22	39.22	0
V_{15}	53.83	43.06	-20.01
F value	-	12.339**	4.009**
CD value	-	7.574	36.922

** Significant at 1% level

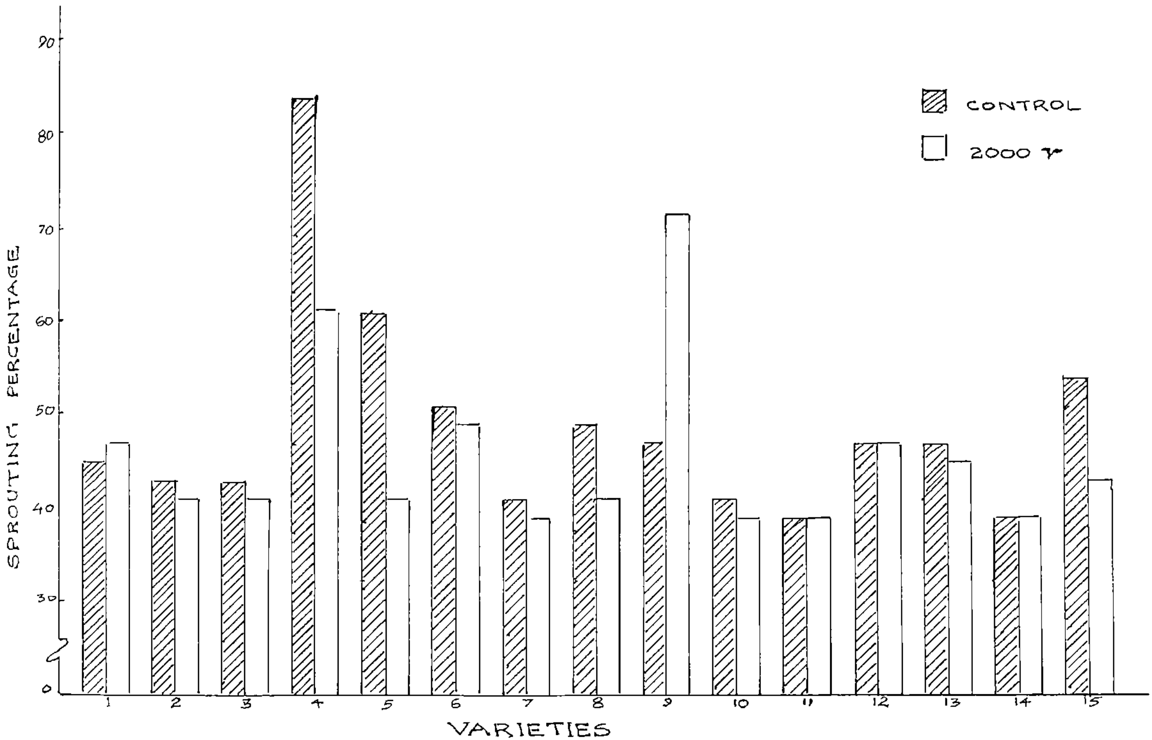

Fig 2 SPROUTING PERCENTAGE ON 20th DAY

majority of the varieties the mean sprouting was around 50 per cent. In treated population the mean values ranged from 39.13 per cent in V_7 to 71.54 per cent in V_9. Except two varieties (V_4 and V_9) in all the other varieties the treated population gave a reduced sprouting percentage. The percentage variation over control varied from -32.78 in V_5 to 52.24 in V_9. V_1 and V_9 gave positive values for the percentage variation, the maximum being 52.24 in V_9.

The sprouting percentage at 25 days after planting in different varieties due to gamma ray exposure is present d in Table 4.3 and Fig. 3. Statistical analysis of the data showed significant variation in gamma ray treated population and also percentage variation over control.

In the control population the mean values ranged from 39.22 per cent (V_{11} and V_{14}) to 83.85 per cent (V_4). In most of the varieties the sprouting was below 50 per cent. The gamma ray exposure caused variety-dependent effect for percentage sprouting. In majority of the varieties a reduction in this regard was seen as against their respective controls. The mean values ranged from 35.92 per cent in V_5 to 71.54 per cent in V_9. Except two varieties (V_4 and V_9) in all the other varieties treated population gave a reduced sprouting percentage, below 50 per cent. Among the different treated populations, V_9 and V_{11} gave an increased sprouting compared

Table 4.3. Sprouting percentage on the 25th day of planting

Varieties	Control	2000 r	Percentage variation over control
V_1	44.98	43.06	-4.28
V_2	41.05	41.05	0
V_3	43.06	39.13	-9.12
V_4	83.85	58.98	-29.66
V_5	61.20	36.92	-39.67
V_6	50.83	48.83	-3.95
V_7	44.98	41.14	-8.55
V_8	49.20	43.06	-12.49
V_9	46.99	71.54	52.24
V_{10}	41.14	39.22	-4.67
V_{11}	39.22	41.14	4.90
V_{12}	46.99	46.99	0
V_{13}	46.90	44.98	-4.10
V_{14}	39.22	39.22	0
V_{15}	53.83	43.06	-20.01
F value	-	9.501**	5.334**
CD value	-	8.652	33.771

** Significant at 1% level

to their controls and it was maximum in V_9 the percentage increase being 52.24. No variation in sprouting was noticed in V_2, V_{12} and V_{14}.

The sprouting percentage at 30 days after planting in different varieties is presented in Table 4.4 and Fig. 4. Statistical analysis of the data showed significant variation in gamma ray treated population.

In control population the mean values ranged from 39.22 per cent in V_{11} and V_{14} to 74.98 per cent in V_4. In almost all the varieties a reduction in sprouting percentage was noticed in the treated population compared to their respective controls. In gamma ray exposed population the mean values ranged from 36.92 per cent in V_5 to 58.98 per cent in V_4 and V_9. Except two varieties (V_4 and V_9), in all the other varieties treated population gave a reduced sprouting percentage. The percentage variation in gamma ray exposed population compared to their respective controls gave negative values in almost all the varieties. The mean values ranged from -30.00 in V_5 to 25.52 in V_9. No variation in sprouting was noticed in V_{11}, V_{12} and V_{14}. Positive values were recorded for the percentage variation in V_2 and V_9, the maximum being in V_9 (25.52).

4. Lethality on the 30th day of planting

The lethality on the 30th day of planting in different

Table 4.4. Sprouting percentage on the 30th day of planting

Varieties	Control	2000 r	Percentage variation over control
V_1	44.98	43.06	-4.27
V_2	41.05	42.98	4.70
V_3	43.06	39.13	-9.13
V_4	74.98	58.98	-21.33
V_5	52.75	36.92	-30.00
V_6	46.90	43.06	-8.54
V_7	44.98	41.14	-4.46
V_8	45.07	43.06	-4.46
V_9	46.99	58.98	25.52
V_{10}	41.14	39.22	-4.67
V_{11}	39.22	39.22	0
V_{12}	46.99	46.99	0
V_{13}	44.98	42.98	-4.45
V_{14}	39.22	39.22	0
V_{15}	46.99	41.14	-12.45
F value	-	3.052**	2.441*
CD value	-	9.219	32.589

* Significant at 5% level

** Significant at 1% level

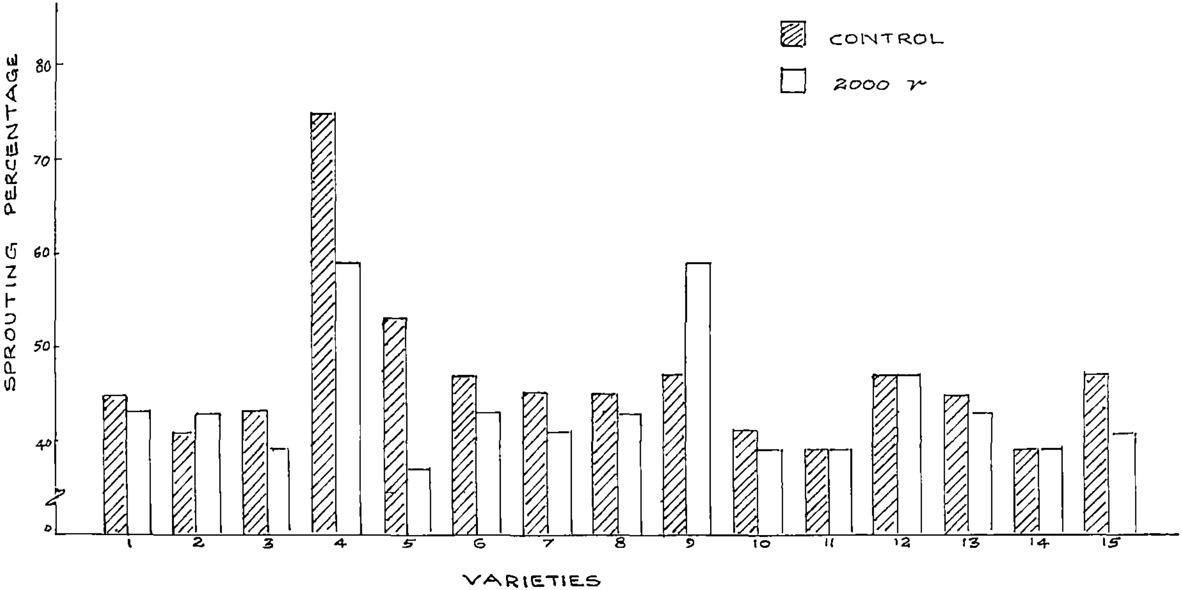

Fig. 4 SPROUTING PERCENTAGE ON 30th DAY

Table 5. Lethality on the 30th day of planting (per cent)

Varieties	Control	2000 r	Percentage variation over control
V_1	44.98	46.90	4.27
V_2	48.91	46.99	-3.93
V_3	46.90	50.83	8.37
V_4	14.99	30.98	106.64
V_5	34.99	53.05	51.58
V_6	43.06	46.90	8.93
V_7	44.98	48.83	8.55
V_8	44.90	46.90	4.47
V_9	42.98	30.98	-27.91
V_{10}	48.83	50.75	3.94
V_{11}	50.75	50.75	0
V_{12}	42.98	42.98	0
V_{13}	44.98	46.99	4.46
V_{14}	50.75	50.75	0
V_{15}	42.98	48.83	13.61
F value	-	4.301**	-
CD value	-	9.315	-

** Significant at 1% level

varieties is presented in Table 5. Statistical analysis of the data showed significant variation due to the influence of gamma ray exposure.

The mean lethality in control population ranged from 14.99 per cent in V_4 to 50.75 per cent in V_{11} and V_{14}. In most of the varieties the percentage lethality was above 40. In gamma ray exposed population the mean values ranged from 30.98 per cent (V_4 and V_9) to 53.05 per cent (V_5). Except two varieties (V_2 and V_9) all the other varieties in treated population gave higher values for lethality compared to their controls. The percentage variation over control ranged from -27.91 in V_9 to 106.64 in V_4. No variation in percentage lethality was noticed in V_{11}, V_{12} and V_{14}.

5. Lethality at harvest

The lethality at harvest due to the effect of gamma rays in different varieties is presented in Table 6 and Fig. 7. Statistical analysis of the data showed significant difference by gamma ray exposure and also percentage variation over control by the exposure.

In control population the mean percentage lethality at harvest ranged from 26.06 in V_4 to 51.12 in V_2. In most of the varieties the mean lethality was above 40 per cent. The gamma ray exposure showed variety-dependent variation for

Table 6. Lethality at harvest (per cent)

Varieties	Control	2000 r	Percentage variation over control
V_1	46.90	50.75	8.20
V_2	51.12	48.91	-4.32
V_3	48.83	54.97	12.57
V_4	26.06	37.13	42.48
V_5	39.13	55.76	42.50
V_6	46.90	50.75	8.20
V_7	44.98	48.83	8.56
V_8	46.90	48.83	4.12
V_9	44.98	32.99	-26.66
V_{10}	48.83	50.75	3.93
V_{11}	50.75	52.75	3.94
V_{12}	41.05	44.98	9.57
V_{13}	48.83	48.91	0.16
V_{14}	50.75	52.75	3.94
V_{15}	44.98	48.83	8.56
F value	-	3.120**	2.286*
CD value	-	10.097	69.621

* Significant at 5% level

** Significant at 1% level

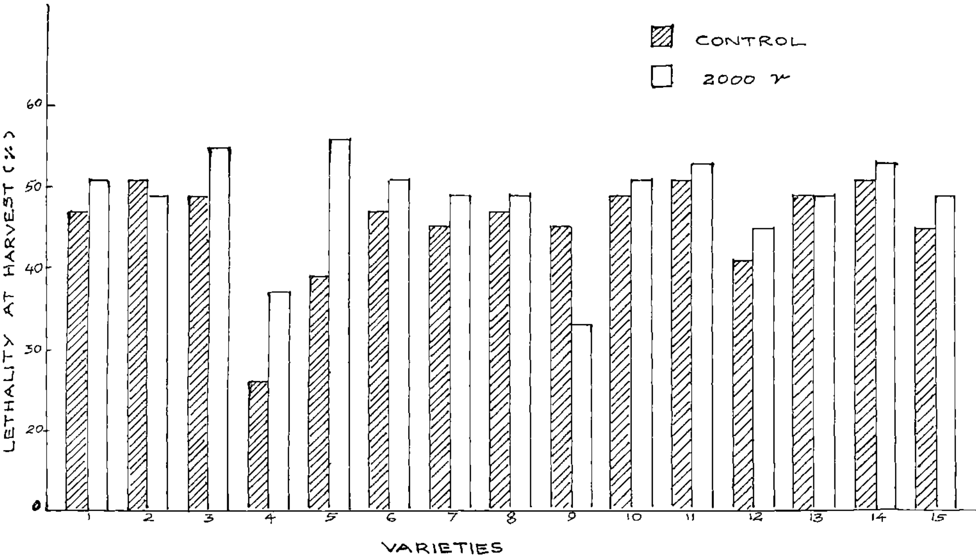

Fig. 7 LETHALITY AT HARVEST

lethality. In gamma ray exposed population the mean values ranged from 32.99 per cent in V_9 to 55.76 per cent in V_5. The percentage variation over control showed positive values in most of the varieties. The percentage variation ranged from -26.66 in V_9 to 42.50 in V_5.

6. Length of vine

The length of vine at 30 days after planting in different varieties due to gamma rays is depicted in Table 7.1 and Fig. 8. Statistical analysis of the data showed significant variation by the influence of gamma ray exposure.

In control population the mean vine length ranged from 12.00 cm in V_{11} to 38.57 cm in V_7. The gamma ray exposed population showed variety-dependent variation for vine length. In most of the varieties a reduction in this expression was noted compared to their respective controls. Among the treated population V_1 recorded the minimum value (10.00 cm) and the maximum value (27.83 cm) in V_8. Among the different varieties in the treated population, V_2 alone gave an increased vine length compared to its control. The percentage variation in treated population ranged from -60.00 in V_1 to 11.52 in V_2.

The length of vine at 45 days after planting is presented in Table 7.2 and Fig. 9. Statistical analysis of

Table 7.1. Vine length on the 30th day of planting (cm)

Varieties	Control	2000 r	Percentage variation over control
V_1	25.00	10.00	-60.00
V_2	22.30	24.87	11.52
V_3	12.67	10.17	-19.73
V_4	29.03	19.83	-31.69
V_5	28.70	13.67	-52.36
V_6	16.00	10.33	-35.44
V_7	38.57	22.67	-41.22
V_8	32.67	27.83	-14.81
V_9	22.37	14.67	-34.42
V_{10}	30.67	25.00	-18.49
V_{11}	12.00	10.33	-13.92
V_{12}	19.00	15.55	-18.16
V_{13}	23.83	18.33	-23.08
V_{14}	31.00	22.00	-29.03
V_{15}	35.33	24.67	-30.17
F value	-	4.355**	0.824
CD value	-	8.762	49.007

** Significant at 1% level

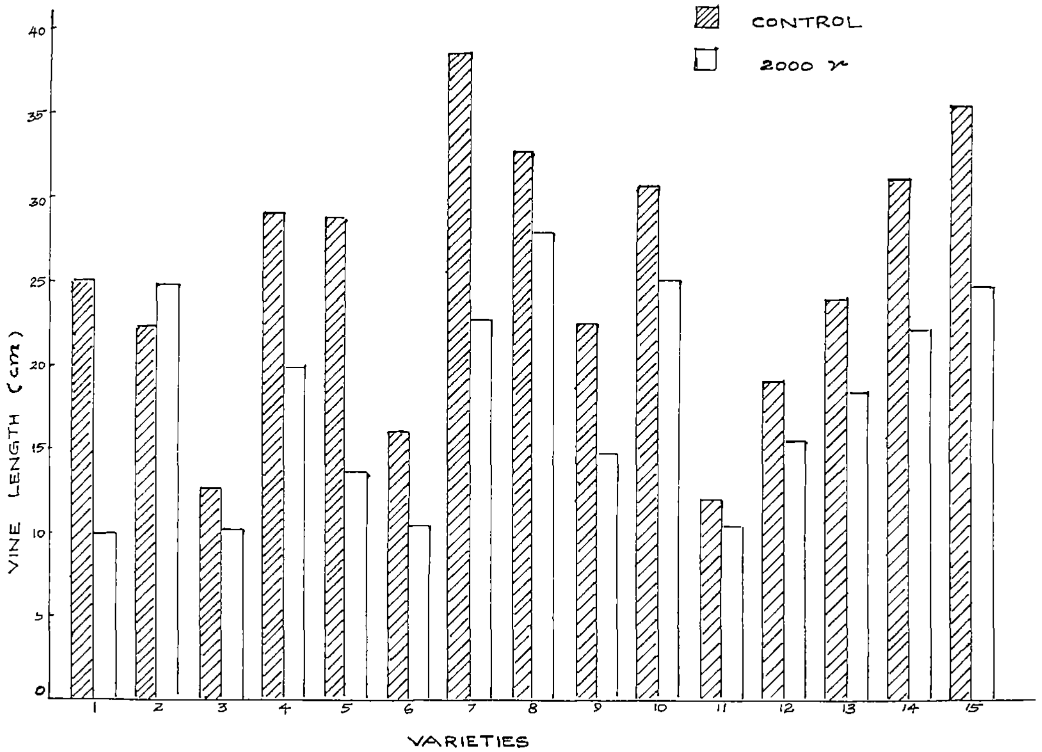

Fig 8 VINE LENGTH ON 30th DAY

the data showed significant difference by the influence of gamma ray exposure and also percentage variation over control.

The mean vine length in control population ranged from 17.83 cm in V_{11} to 66.93 cm in V_{15}. The gamma ray exposure showed variety-dependent variation for length of vine. In most of the varieties a decrease in this regard was noted compared to their controls. The mean values in treated population ranged from 13.67 cm in V_1 to 45.57 cm in V_8. The percentage variation in treated population compared to their respective controls gave negative values in majority of the varieties. The range was from -65.24 in V_1 to 6.30 in V_2. In the treated population, V_2 alone gave an increased vine length (33.73 cm) compared to its control (31.73 cm).

The vine length at 60 days after planting in different varieties is presented in Table 7.3 and Fig. 10. Statistical analysis of the data showed significant variation by the influence of gamma ray exposure and also percentage variation over control.

In control population the length of vine ranged from 24.17 cm in V_{11} to 116.17 cm in V_{15}. In the gamma ray exposed population the varieties showed a decrease in the length of

Table 7.2. Vine length on the 45th day of planting (cm)

Varieties	Control	2000 r	Percentage variation over control
V_1	39.33	13.67	-65.24
V_2	31.73	33.73	6.30
V_3	22.57	16.07	-28.80
V_4	38.27	25.93	-32.24
V_5	49.83	22.50	-54.85
V_6	20.57	13.90	-32.43
V_7	54.80	31.10	-43.25
V_8	58.83	45.57	-22.54
V_9	31.23	21.67	-30.61
V_{10}	34.22	31.17	-8.91
V_{11}	17.83	15.07	-15.48
V_{12}	25.37	21.50	-15.25
V_{13}	29.67	25.67	-13.48
V_{14}	41.50	28.00	-32.53
V_{15}	66.93	35.80	-46.51
F value	-	6.653**	2.746*
CD value	-	10.215	32.757

* Significant at 5% level

** Significant at 1% level

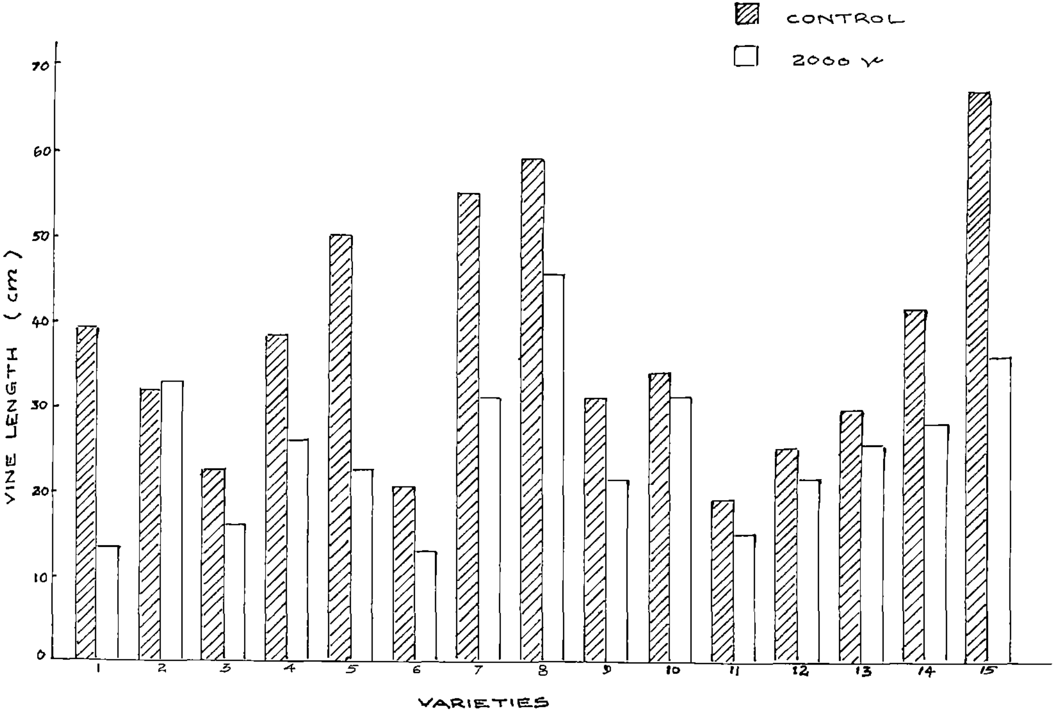

Fig. 9. VINE LENGTH ON 45th DAY

Table 7.3. Vine length on the 60th day of planting (cm)

Varieties	Control	2000 r	Percentage variation over control
V_1	62.00	20.83	-66.40
V_2	47.50	42.70	-10.11
V_3	38.60	30.17	-21.84
V_4	78.93	64.77	-17.94
V_5	75.93	37.50	-50.91
V_6	25.40	23.83	-6.18
V_7	66.03	51.00	-22.73
V_8	92.73	73.33	-20.92
V_9	39.90	31.13	-21.98
V_{10}	50.03	41.17	-17.71
V_{11}	24.17	20.00	-17.25
V_{12}	35.33	28.00	-20.75
V_{13}	39.00	34.50	-11.54
V_{14}	49.33	36.33	-26.35
V_{15}	116.17	48.67	-58.10
F value	-	11.042**	3.965**
CD value	-	13.493	27.191

** Significant at 1% level

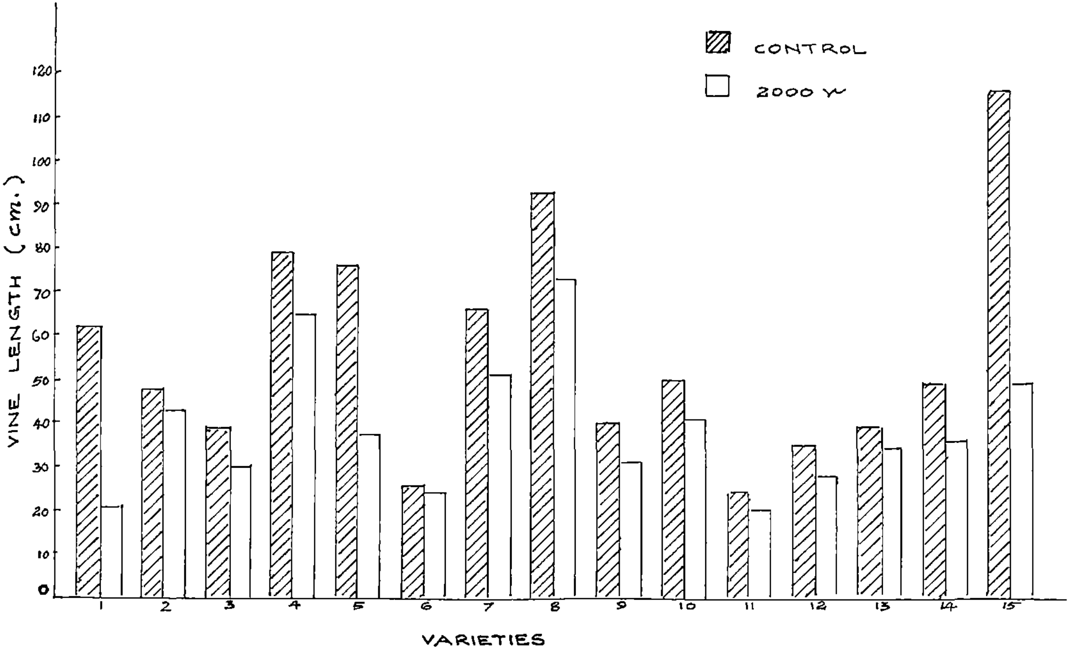

Fig 10 VINE LENGTH ON 60th DAY

vine compared to their respective controls. The mean values in treated population ranged from 20.00 cm in V_{11} to 73.33 cm in V_8. The percentage variation over control gave negative values in all the varieties, the range being -66.40 in V_1 to -6.18 in V_6.

The mean vine length on the 75th day of planting in different varieties is presented in Table 7.4 and Fig. 11. Statistical analysis of the data showed significant variation by the influence of gamma ray exposure and also percentage variation over control.

In control population the mean vine length ranged from 31.67 to 137.03 cm in V_{11} and V_{15} respectively. The gamma ray exposed population showed variety dependent variation for length of vine. A decrease in vine length was noticed in all the varieties compared to their respective controls. The mean values ranged from 21.43 cm in V_{11} to 96.20 cm in V_8. The percentage variation in treated population compared to their respective controls gave negative values in all the varieties and the range was from -52.00 in V_1 to -7.85 in V_6.

The mean vine length on 90th day of planting in different varieties is presented in Table 7.5 and Fig. 12. Statistical analysis of the data showed significant variation in

Table 7.4. Vine length on the 75th day of planting (cm)

Varieties	Control	2000 r	Percentage variation over control
V_1	83.33	40.00	-52.00
V_2	65.40	58.87	-9.98
V_3	55.33	39.17	-29.31
V_4	98.10	88.33	-9.96
V_5	91.33	55.67	-39.04
V_6	35.27	32.50	-7.85
V_7	85.43	66.67	-21.96
V_8	116.60	96.20	-17.50
V_9	48.87	39.23	-19.73
V_{10}	61.17	48.00	-21.53
V_{11}	31.67	21.43	-32.33
V_{12}	41.97	33.17	-20.97
V_{13}	46.50	40.67	-12.54
V_{14}	60.00	47.33	-21.12
V_{15}	137.03	69.50	-49.28
F value	-	16.267**	2.411*
CD value	-	15.066	24.909

* Significant at 5% level

** Significant at 1% level

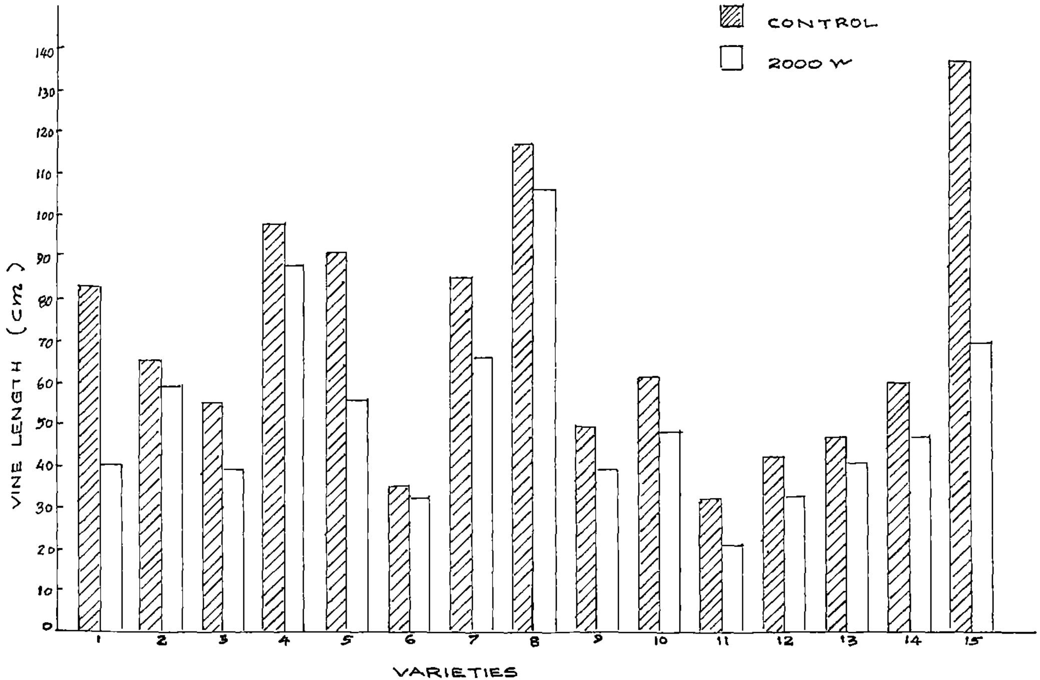

Fig: 11. VINE LENGTH ON 75th DAY

gamma ray exposed population and percentage variation over control.

The mean vine length in control population ranged from 37.67 cm in V_{11} to 161.50 cm in V_{15}. Variety-dependent variation for vine length was noticed in gamma ray treated population. In all the varieties a decrease in length of vine was noted compared to their respective controls. The mean values ranged from 24.67 cm in V_{11} to 111.07 cm in V_8. The percentage variation in treated population compared to their respective controls gave negative values in all the varieties. It ranged from -46.46 in V_{15} to -3.86 in V_4.

The length of vine on the 105th day of planting in different varieties is depicted in Table 7.6 and Fig. 13. Statistical analysis of the data showed significant variation by the influence of gamma ray exposure.

In control population the mean length of vine ranged from 43.67 to 204.50 cm in V_{11} and V_{15} respectively. A decrease in vine length was noticed in gamma ray exposed population. The mean values ranged from 28.67 cm in V_{11} to 127.73 cm in V_8. The percentage variation in treated population compared to their respective controls gave negative values in all the varieties. It ranged from -50.12 in V_{15} to -1.55 in V_4.

Table 7.5. Vine length on the 90th day of planting (cm)

Varieties	Control	2000 r	Percentage variation over control
V_1	94.33	53.33	-43.46
V_2	80.97	74.33	-7.66
V_3	64.33	51.83	-19.43
V_4	108.10	103.93	-3.86
V_5	108.77	91.90	-15.51
V_6	44.33	37.83	-14.66
V_7	94.87	76.33	-19.54
V_8	142.17	111.07	-21.88
V_9	57.43	48.33	-15.70
V_{10}	72.67	57.40	-20.88
V_{11}	37.67	24.67	-34.51
V_{12}	48.33	41.17	-14.81
V_{13}	54.00	48.10	-10.93
V_{14}	72.33	55.33	-23.50
V_{15}	161.50	86.47	-46.46
F value	-	25.521**	2.243*
CD value	-	14.529	22.613

* Significant at 5% level

** Significant at 1% level

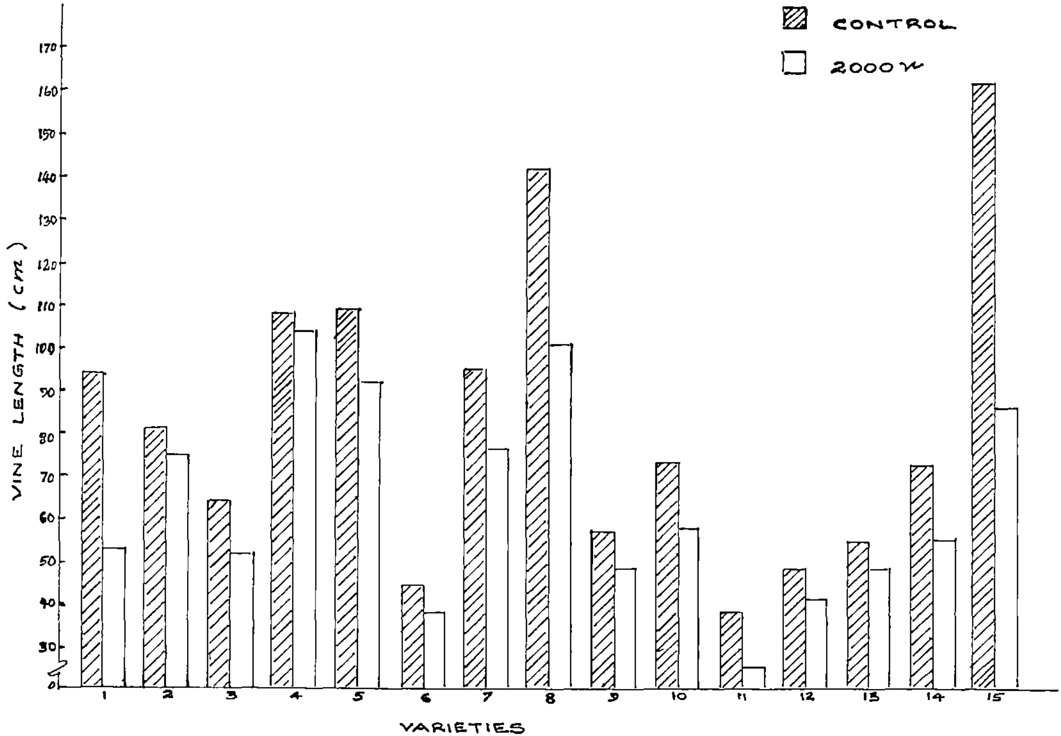

Fig. 12 VINE LENGTH ON 50% DAY

Table 7.6. Vine length on the 105th day of planting (cm)

Varieties	Control	2000 r	Percentage variation over control
V_1	108.67	64.67	-40.49
V_2	94.86	84.33	-11.10
V_3	83.00	65.67	-20.88
V_4	115.80	114.00	-1.55
V_5	127.17	111.00	-12.64
V_6	53.67	45.80	-14.66
V_7	110.10	87.33	-20.68
V_8	165.00	127.73	-22.59
V_9	67.87	57.17	-15.77
V_{10}	84.83	65.00	-23.38
V_{11}	43.67	28.67	-34.35
V_{12}	54.67	49.33	-9.77
V_{13}	60.77	53.43	-12.08
V_{14}	82.33	62.33	-24.29
V_{15}	204.50	102.00	-50.12
F value	-	21.919**	1.709
CD value	-	17.744	25.478

** Significant at 1% level

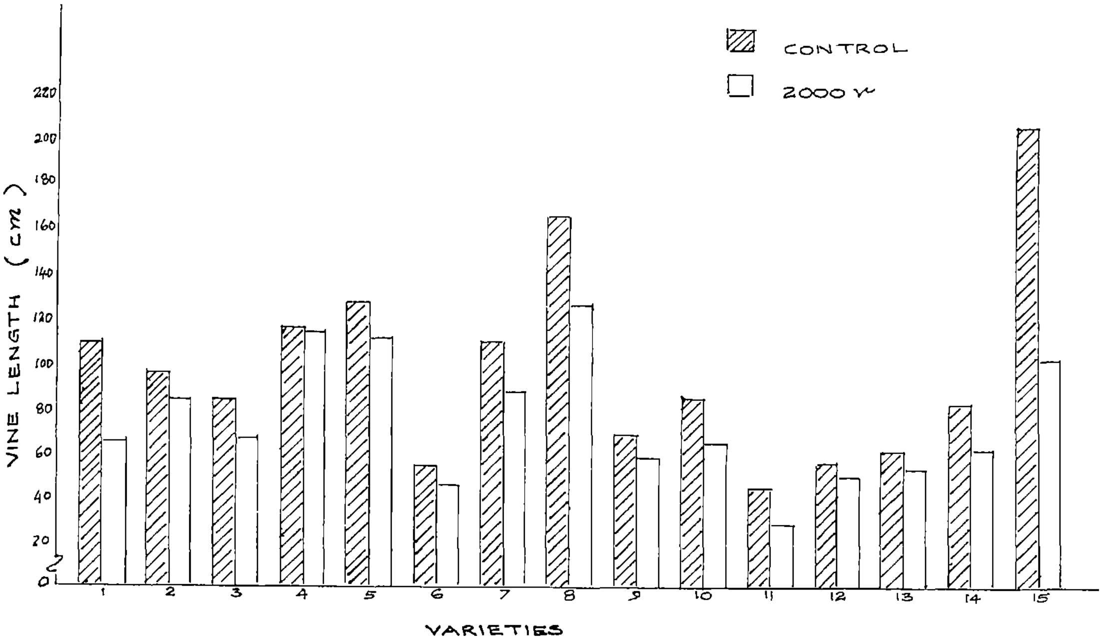

Fig: 13 VINE LENGTH ON 105th DAY

The vine length at harvest in different varieties is presented in Table 7.7 and Fig. 14. Statistical analysis of the data showed significant difference by the influence of gamma ray exposure and percentage variation over control.

The mean vine length in control population ranged from 52.87 cm in V_{11} to 224.17 cm in V_{15}. The gamma ray exposure showed variety-dependent variation for vine length. In all the varieties a reduction in length of vine was noted compared to their respective controls. The mean values ranged from 35.00 cm in V_{11} to 141.73 cm in V_8. Percentage variation over control gave negative values in all the varieties and the range was from -48.62 in V_{15} to -7.22 in V_{12}.

7. Number of branches per vine

The mean number of branches per vine in different varieties is presented in Table 8 and Fig. 17. Statistical analysis of the data showed significant variation by the influence of gamma ray exposure and also in percentage variation over control.

In control population the mean values ranged from 2.16 in V_8 to 3.31 in V_9. The gamma ray exposure showed variety-dependent variation for number of branches. In almost all the varieties a decrease in branch number was noted compared to their respective controls. The mean values

Table 7.7. Vine length at harvest (cm)

Varieties	Control	2000 r	Percentage variation over control
V_1	118.67	75.33	-36.52
V_2	101.60	93.00	-8.46
V_3	94.33	77.00	-18.37
V_4	139.67	126.00	-9.79
V_5	143.17	121.00	-15.49
V_6	63.00	51.00	-19.05
V_7	118.17	95.00	-19.61
V_8	191.17	141.73	-25.86
V_9	76.90	64.03	-16.74
V_{10}	96.67	72.67	-24.83
V_{11}	52.87	35.00	-33.80
V_{12}	60.00	55.67	-7.22
V_{13}	68.00	60.27	-11.37
V_{14}	89.00	69.33	-22.10
V_{15}	224.17	115.17	-48.62
F value	-	25.619**	2.097*
CD value	-	17.675	21.666

* Significant at 5% level

** Significant at 1% level

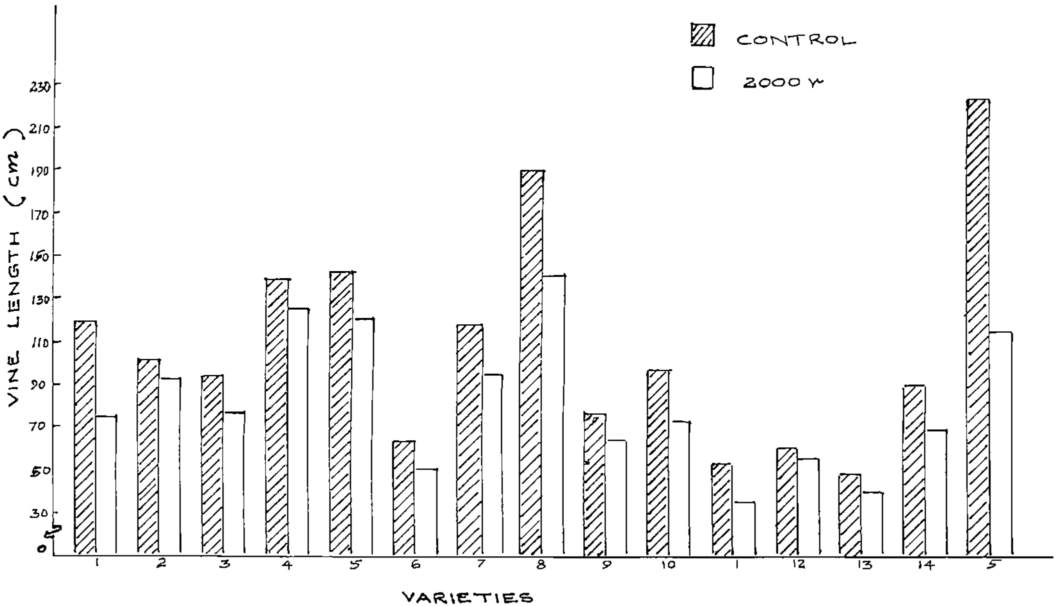

Fig 14 VINE LENGTH AT HARVEST

Table 8. Number of branches per vine

Varieties	Control	2000 r	Percentage variation over control
V_1	2.31	2.31	0
V_2	2.58	2.38	-7.76
V_3	2.38	2.24	-5.88
V_4	3.27	3.11	-4.89
V_5	2.52	2.45	-2.39
V_6	2.89	2.71	-6.23
V_7	2.38	2.24	-5.88
V_8	2.16	2.31	6.94
V_9	3.31	2.64	-20.24
V_{10}	2.76	2.52	-8.70
V_{11}	2.31	2.24	-3.03
V_{12}	2.89	2.71	-6.23
V_{13}	2.94	2.71	-7.82
V_{14}	2.71	2.38	-12.18
V_{15}	2.71	2.58	-4.80
F value	-	5.151**	4.754**
CD value	-	0.206	17.007

** Significant at 1% level

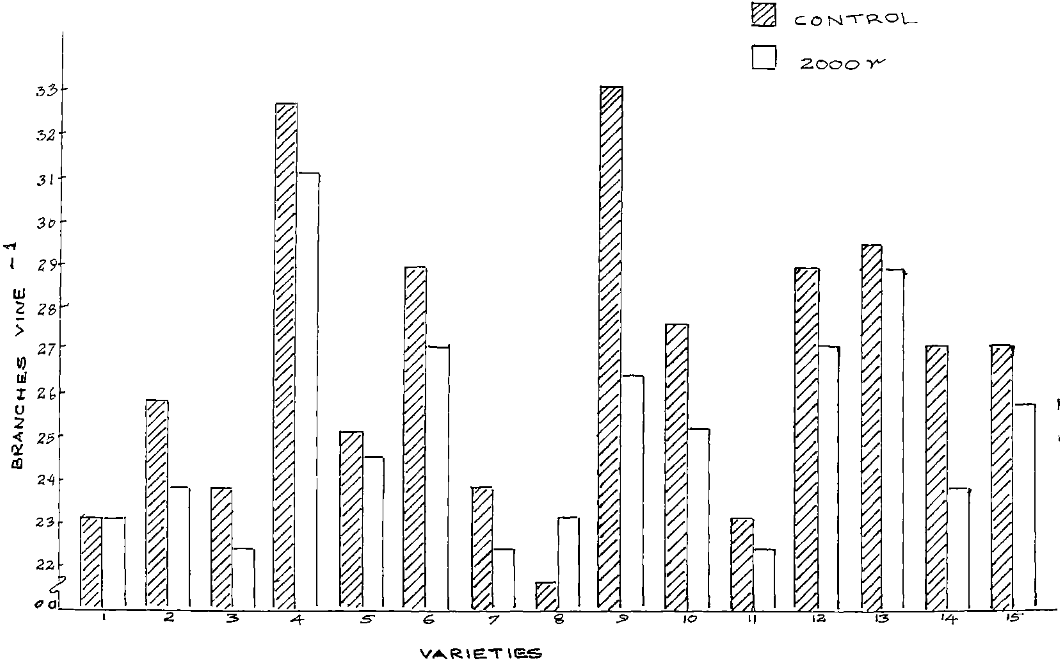

Fig. 17 NUMBER OF BRANCHES PER VINE

ranged from 2.24 (V_3, V_7 and V_{11}) to 3.11 (V_4). In gamma ray exposed population, V_8 alone showed an increase in branch number compared to its control. In most of the varieties the percentage variation over control gave negative values, the range was from -20.24 in V_9 to 6.94 in V_8. No variation in branch number was noticed in V_1.

8. Number of tubers per vine

The mean number of tubers per vine in different varieties is presented in Table 9 and Fig. 15. Statistical analysis of the data showed significant difference by the influence of gamma ray exposure and also in percentage variation over control.

The mean values in control population ranged from 1.41 in V_9 to 2.16 in V_6. In majority of the varieties the mean number was below 2.00 and it varied depending on the varieties. The gamma ray exposure showed variety-dependent variation for number of tubers. In majority of the varieties an increase in tuber number per vine was noted compared to their respective controls. The mean values ranged from 1.41 (V_4) to 2.31 (V_{11}, V_{12} and V_{15}). The percentage variation over control gave positive values in most of the varieties except in V_3, V_4, V_6 and V_7. The range was from -29.5 in V_4 to 47.52 in V_9.

Table 9. Number of tubers per vine

Varieties	Control	2000 r	Percentage variation over control
V_1	1.63	1.82	11.66
V_2	1.91	2.07	8.38
V_3	2.07	1.90	-8.21
V_4	2.00	1.41	-29.50
V_5	1.73	2.08	20.23
V_6	2.16	1.82	-15.74
V_7	1.91	1.73	-9.42
V_8	2.00	2.24	12.00
V_9	1.41	2.08	47.52
V_{10}	1.73	2.16	24.86
V_{11}	2.00	2.31	15.50
V_{12}	2.00	2.31	15.50
V_{13}	1.90	2.16	13.68
V_{14}	1.63	2.08	27.61
V_{15}	1.91	2.31	20.94
F value	-	9.60**	8.624**
CD value	-	0.235	70.287

** Significant at 1% level

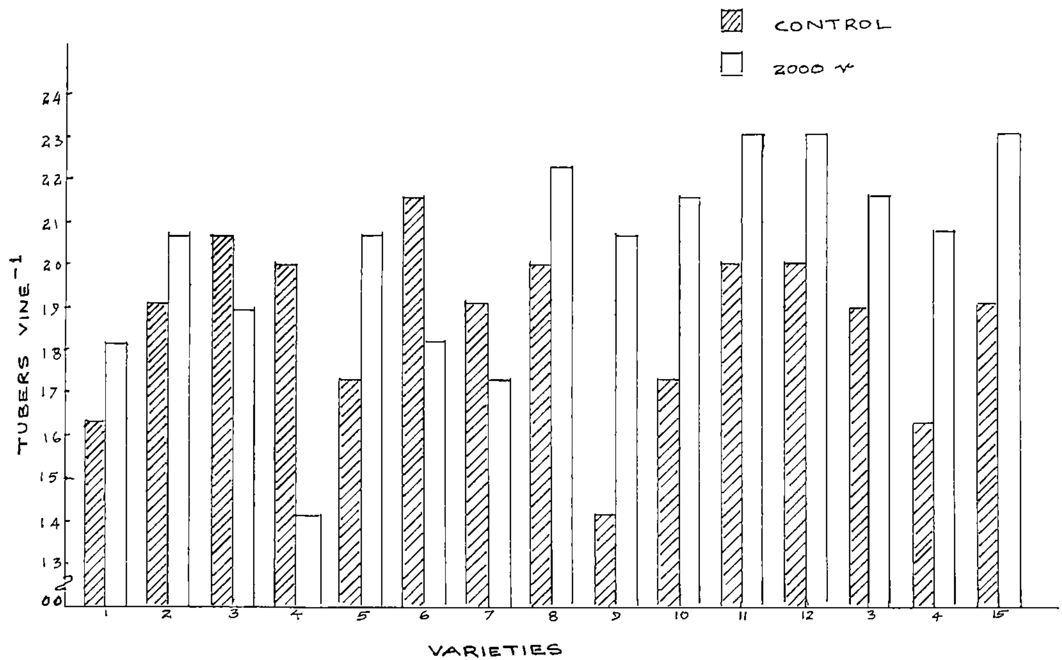

Fig: 15 NUMBER OF TUBERS PER VINE

9. Weight of tubers per vine

The mean weight of tubers per vine in different varieties is presented in Table 10 and Fig. 16. Statistical analysis of the data showed significant variation due to gamma ray exposure and also percentage variation over control.

In control population the mean values ranged from 63.33 g in V_9 to 263.33 g in V_5. The gamma ray exposure showed variety-dependent variation for weight of tuber. Except three varieties (V_1, V_2 and V_{14}) in all the other varieties, gamma ray exposure gave an increase in tuber weight. The mean values ranged from 108.33 g in V_1 to 350 g in V_4. An increase in tuber weight compared to their controls was noted in V_4 and V_9. The percentage variation over control ranged from -2.99 in V_1 to 389.50 in V_9.

Table 10. Weight of tubers per vine

Varieties	Control	2000 r	Percentage variation over control
V_1	111.67	108.33	-2.99
V_2	146.67	143.33	-2.27
V_3	173.33	175.00	0.96
V_4	236.67	350.00	47.89
V_5	263.33	333.67	27.85
V_6	248.33	288.33	16.11
V_7	191.67	216.67	13.04
V_8	196.67	211.67	7.62
V_9	63.33	310.00	389.50
V_{10}	250.00	290.00	16.00
V_{11}	171.67	186.67	8.74
V_{12}	256.67	290.00	12.99
V_{13}	240.00	280.00	16.67
V_{14}	170.00	165.00	-2.94
V_{15}	216.67	260.00	20.00
F value	-	3.345**	10.598**
CD value	-	116.974	91.716

** Significant at 1% level

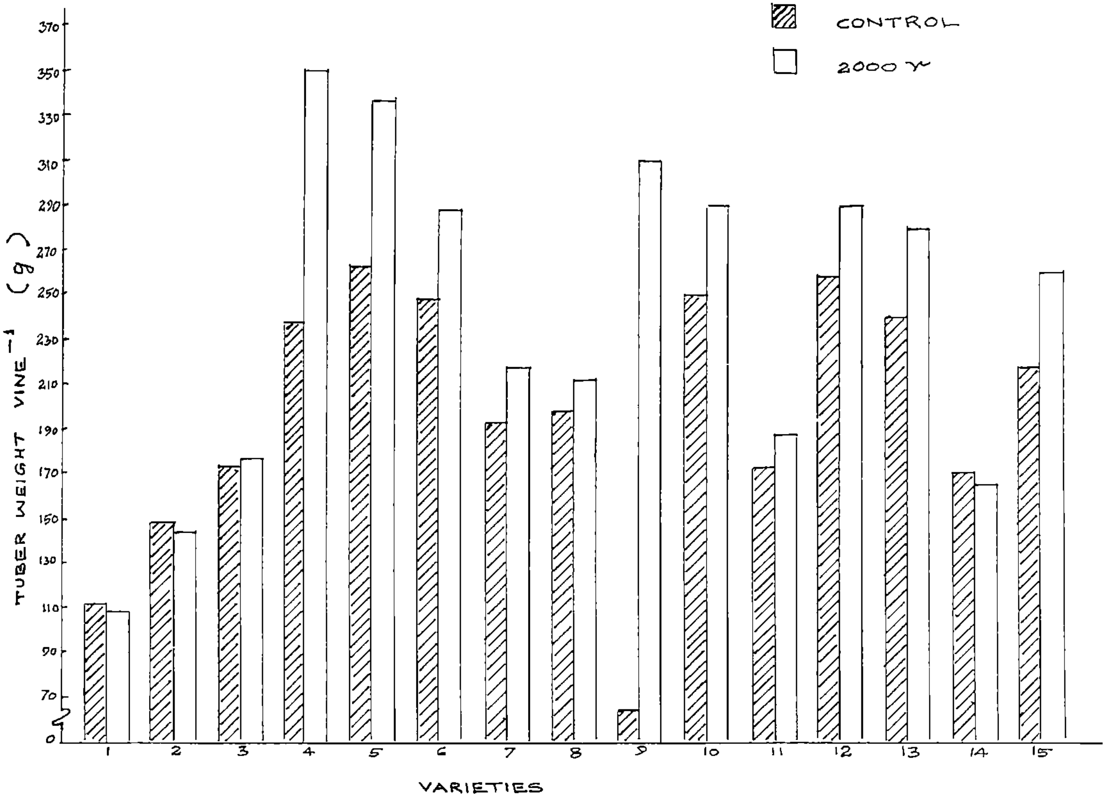

Fig: 16 WEIGHT OF TUBERS PER VINE

PART II - INDUCED MUTAGENESIS

A. vM_1 generation

The effect of five exposures of gamma rays (500 to 2500 r) in three different varieties on various growth and yield parameters in vM_1 generation is presented below:

Exposures below 4 kR were selected for induced mutagenesis, as doses above 4 kR were highly lethal in radiosensitivity analysis.

1. Days taken to start sprouting

Days taken to start sprouting in three sweet potato varieties as influenced by gamma rays is presented in Table 11 and Fig. 18. Statistical analysis of the data showed significant difference among treatments, varieties and exposures in all the three modes of treatment.

Days taken to start sprouting in V_1 control ranged from 2.00 in rooted tubers to 2.34 in rooted cuttings. In V_2 control the mean values ranged from 1.73 in rooted tubers to 2.34 in rooted cuttings. In V_3 the mean values in control ranged from 1.87 in fresh cuttings and rooted tubers and 2.12 in rooted cuttings.

In fresh cuttings days taken to start sprouting in V_1 ranged from 2.24 to 2.55 in control and 2500 r respectively.

In V_2 the values ranged from 2.00 (control and 500 r) to 2.45 (2500 r) while in V_3 it differed from 1.87 to 2.34 in control and 2500 r respectively.

In rooted cuttings the mean values in V_1 ranged from 2.34 (control, 500 and 1000 r) to 2.65 (2000 and 2500 r). In V_2 this ranged from 2.34 (control and 500 r) to 2.65 (2500 r). In V_3 it differed from 2.12 (control, 500, 1000 and 1500 r) to 2.45 (2500 r).

In rooted tubers the number of days taken to start sprouting in V_1 ranged from 2.00 in control to 2.34 in 2000 and 2500 r. In V_2 the values ranged from 1.73 to 2.34 in control and 2500 r respectively. The mean values in V_3 differed from 1.87 (control and 500 r) to 2.12 in 2500 r.

In gamma ray exposed population of V_1 the days taken to start sprouting ranged from 2.12 in 500 r of rooted tubers to 2.65 in 2000 and 2500 r of rooted cuttings. In V_2 the values ranged from 2.00 (500 r of fresh cuttings and rooted tubers) to 2.65 (2500 r of rooted cuttings). In V_3 it ranged from 1.87 in 500 r of rooted tubers to 2.45 in 2500 r of rooted cuttings.

2. Days taken to complete sprouting

The effect of gamma rays on days taken to complete sprouting in three sweet potato varieties is presented in

Table 11. Days taken to start sprouting

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	2.24	2.34	2.00
	500 r	2.34	2.34	2.12
	1000 r	2.34	2.34	2.24
	1500 r	2.45	2.55	2.24
	2000 r	2.45	2.65	2.34
	2500 r	2.55	2.65	2.34
V_2	Control	2.00	2.34	1.73
	500 r	2.00	2.34	2.00
	1000 r	2.12	2.45	2.12
	1500 r	2.24	2.45	2.12
	2000 r	2.34	2.45	2.24
	2500 r	2.45	2.65	2.34
V_3	Control	1.87	2.12	1.87
	500 r	2.00	2.12	1.87
	1000 r	2.00	2.12	2.00
	1500 r	2.12	2.12	2.00
	2000 r	2.24	2.34	2.00
	2500 r	2.34	2.45	2.12

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	6.736**	4.065**	8.333**	0.227	0.264	0.182
Varieties	24.349**	16.319**	22.740**	9.285	0.108	7.435
Exposures	12.253**	6.201**	16.592**	0.131	0.153	0.105
Inter-action	0.455	0.546	1.321	0.227	0.264	0.182

** Significant at 1% level

vM, GENERATION

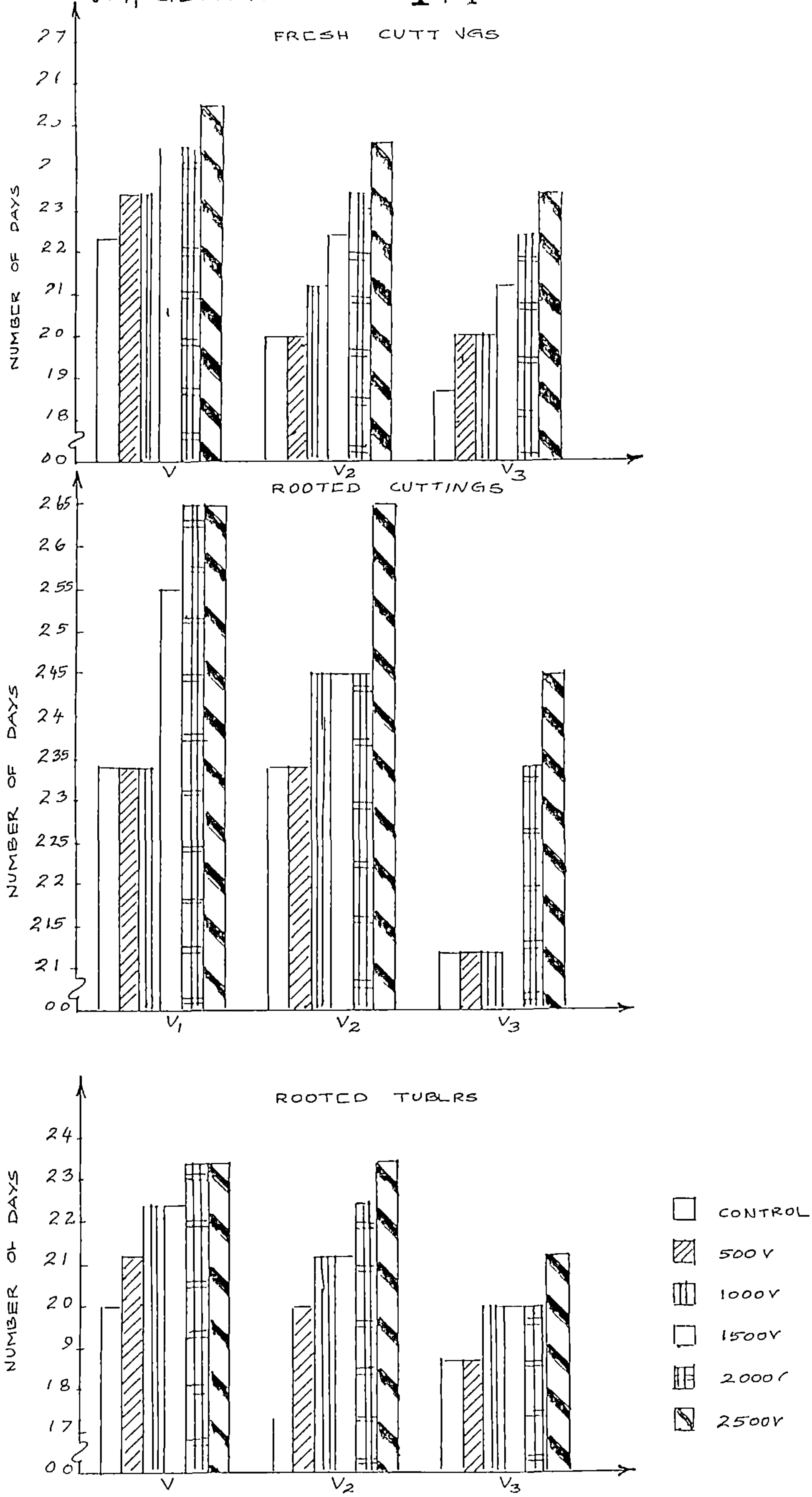

FIG 18 DAYS TAKEN TO START SPROUTING

Table 12 and Fig. 19. Statistical analysis of the data showed significant variation among treatments, varieties and exposures in all the three modes of treatment.

Days taken to complete sprouting in V_1 control ranged from 3.39 in fresh cuttings to 3.87 in rooted cuttings. In V_2 control the values ranged from 3.24 in fresh cuttings to 3.74 in rooted cuttings while in V_3 control it ranged from 3.08 in fresh cuttings to 3.46 in rooted cuttings.

In fresh cuttings the values in V_1 ranged from 3.39 in control to 4.58 in 2500 r. In V_2 it ranged from 3.24 to 4.47 in control and 2500 r respectively. In V_3 the mean values ranged from 3.08 in control to 4.30 in 2500 r.

In rooted cuttings the mean values in V_1 ranged from 3.87 to 5.10 in control and 2500 r respectively. In V_2 it ranged from 3.74 in control to 4.95 in 2500 r. In V_3 the range was from 3.46 in control to 4.69 in 2500 r.

In the case of rooted tubers the mean values ranged from 3.61 in control to 4.18 in 2500 r. In V_2 it ranged from 3.61 (control) to 4.12 (2000 and 2500 r). In V_3 this ranged from 3.24 to 3.67 in control and 2500 r respectively.

Among the treated population days to complete sprouting in V_1 showed the lowest value (3.67) in 500 and 1000 r

Table 12. Days taken to complete sprouting

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	3.39	3.87	3.61
	500 r	3.81	4.30	3.67
	1000 r	4.00	4.47	3.67
	1500 r	4.30	4.69	3.87
	2000 r	4.53	4.90	4.00
	2500 r	4.58	5.10	4.18
V_2	Control	3.24	3.74	3.61
	500 r	3.74	4.00	3.74
	1000 r	4.00	4.12	3.81
	1500 r	4.12	4.42	4.06
	2000 r	4.24	4.74	4.12
	2500 r	4.47	4.95	4.12
V_3	Control	3.08	3.46	3.24
	500 r	3.74	4.00	3.46
	1000 r	3.94	4.12	3.46
	1500 r	4.12	4.30	3.54
	2000 r	4.24	4.47	3.54
	2500 r	4.36	4.69	3.67

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	28.677**	25.985**	21.349**	0.241	0.261	0.173
Varieties	8.584**	28.754**	91.954**	0.098	0.107	0.071
Exposures	92.765**	75.581**	32.029**	0.139	0.151	0.099
Interaction	0.652	0.634	1.888	0.241	0.261	0.173

** Significant at 1% level

vM GENERATION

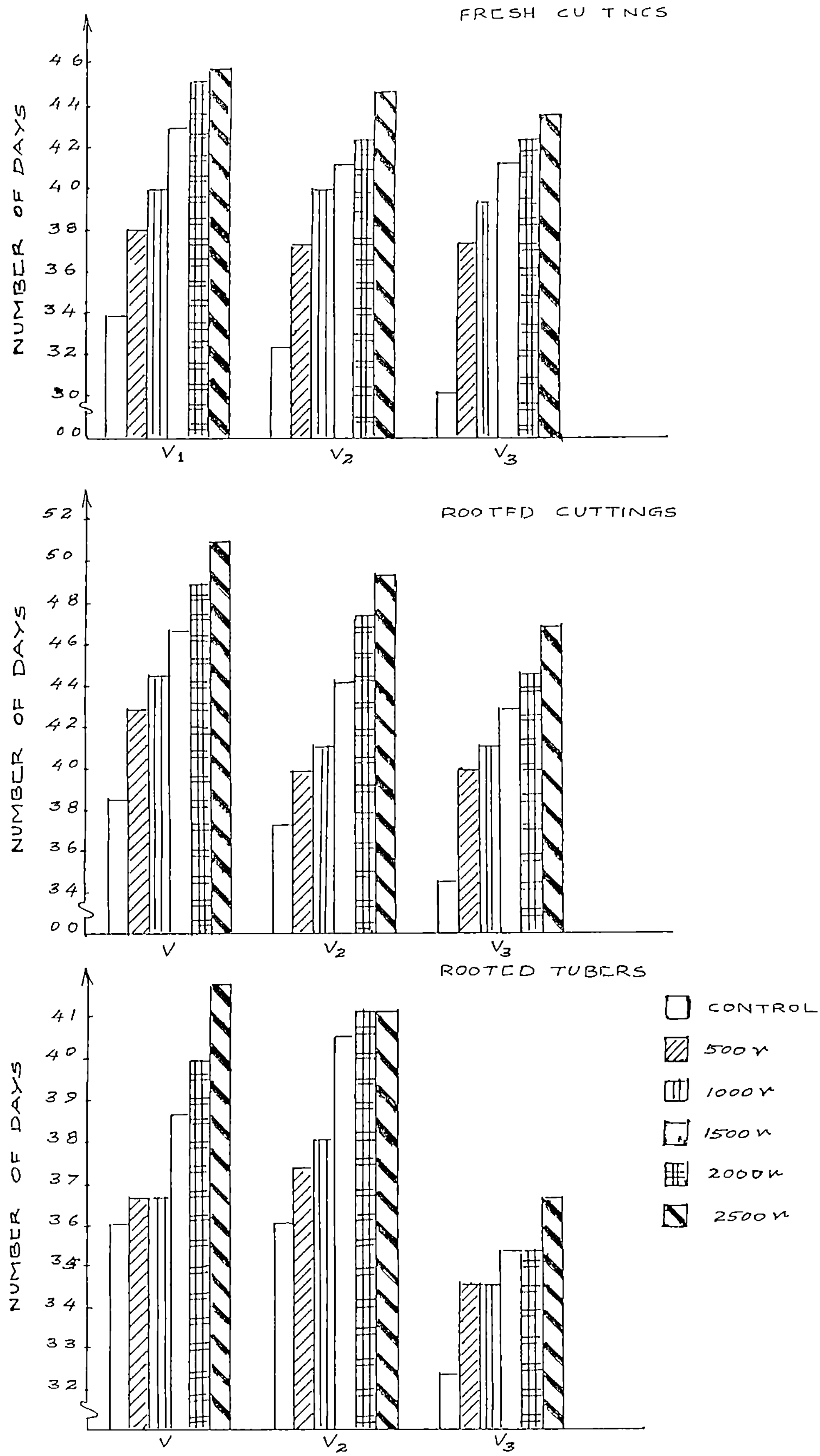

FIG 19 DAYS TAKEN TO COMPLETE SPROUT NG

of rooted tubers and the highest value (5.10) in 2500 r of rooted cuttings. In V_2 these values were 3.74 (500 r of fresh cuttings and rooted tubers) and 4.95 (2500 r of rooted cuttings). In V_3 it was minimum (3.46) in 500 and 1000 r of rooted tubers and maximum (4.69) in 2500 r of rooted cuttings.

3. Sprouting percentage

The effect of gamma rays on percentage sprouting in three sweet potato varieties, namely Muttavella, Kanhangad local and Bhadrakalichuvala is presented in Table 13 and Fig. 20. Statistical analysis of the data showed significant difference among varieties and exposures in fresh and rooted cuttings.

The mean sprouting in V_1 control ranged from 60.09 per cent in rooted cuttings to 82.50 per cent in rooted tubers. In V_2 control it ranged from 67.19 to 83.68 per cent in rooted cuttings and rooted tubers respectively. In V_3 control the mean values ranged from 71.54 per cent in rooted cuttings to 90.00 per cent in fresh cuttings.

In fresh cuttings, sprouting percentage in V_1 ranged from 55.36 to 65.30 in 2500 r and control respectively. The mean values in V_2 differed from 61.69 in 2500 r to 72.12 in control. In V_3 the values ranged from 67.19 to 90.00 in 2500 r and control respectively.

In rooted cuttings the mean sprouting in V_1 ranged from 44.98 to 60.09 per cent in 2500 r and control respectively. In V_2 the values ranged from 49.30 to 67.19 per cent in 2500 r and control respectively. The percentage value in V_3 ranged from 52.23 to 71.54 in 2500 r and control respectively.

In the case of rooted tubers, sprouting percentage in V_1 ranged from 62.35 to 82.50 in 2500 r and control respectively while in V_2 this ranged from 65.88 to 83.68 in 2500 r and control respectively. In V_3 the range was 68.58 in 2500 r to 83.17 in control.

Among the treated population the sprouting percentage of V_1 showed the lowest value (44.98) in 2500 r of rooted cuttings and the highest value (74.74) in 500 r of rooted tubers. In V_2 these values were 49.30 in 2500 r of rooted cuttings and 76.19 in 500 r of rooted tubers respectively. In V_3 the sprouting percentage was minimum (52.23) in 2500 r of rooted cuttings and maximum (77.05) in 500 r of fresh cuttings.

4. Lethality on the 30th day of planting

The effect of gamma rays on lethality at 30 days after planting in three sweet potato varieties is presented in Table 14. Statistical analysis of the data showed

Table 13. Sprouting percentage

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	65.30	60.09	82.50
	500 r	64.15	59.98	74.74
	1000 r	61.98	53.76	66.82
	1500 r	59.98	50.75	70.17
	2000 r	58.37	49.35	65.88
	2500 r	55.36	44.98	62.35
V_2	Control	72.12	67.19	83.68
	500 r	71.54	63.58	76.19
	1000 r	68.51	60.09	73.53
	1500 r	65.30	56.84	73.45
	2000 r	62.62	55.24	68.91
	2500 r	61.69	49.30	65.88
V_3	Control	90.00	71.54	83.17
	500 r	77.05	65.30	75.28
	1000 r	72.12	59.98	69.88
	1500 r	69.36	60.09	72.81
	2000 r	68.51	56.84	70.84
	2500 r	67.19	52.23	68.58

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	2.688*	8.464**	3.288**	14.353	7.056	10.046
Varieties	11.285**	17.465**	1.708	5.859	2.881	4.101
Exposures	3.709*	21.248**	10.079**	8.287	4.074	5.799
Inter-action	0.459	0.272	0.209	14.353	7.056	10.046

* Significant at 5% level

** Significant at 1% level

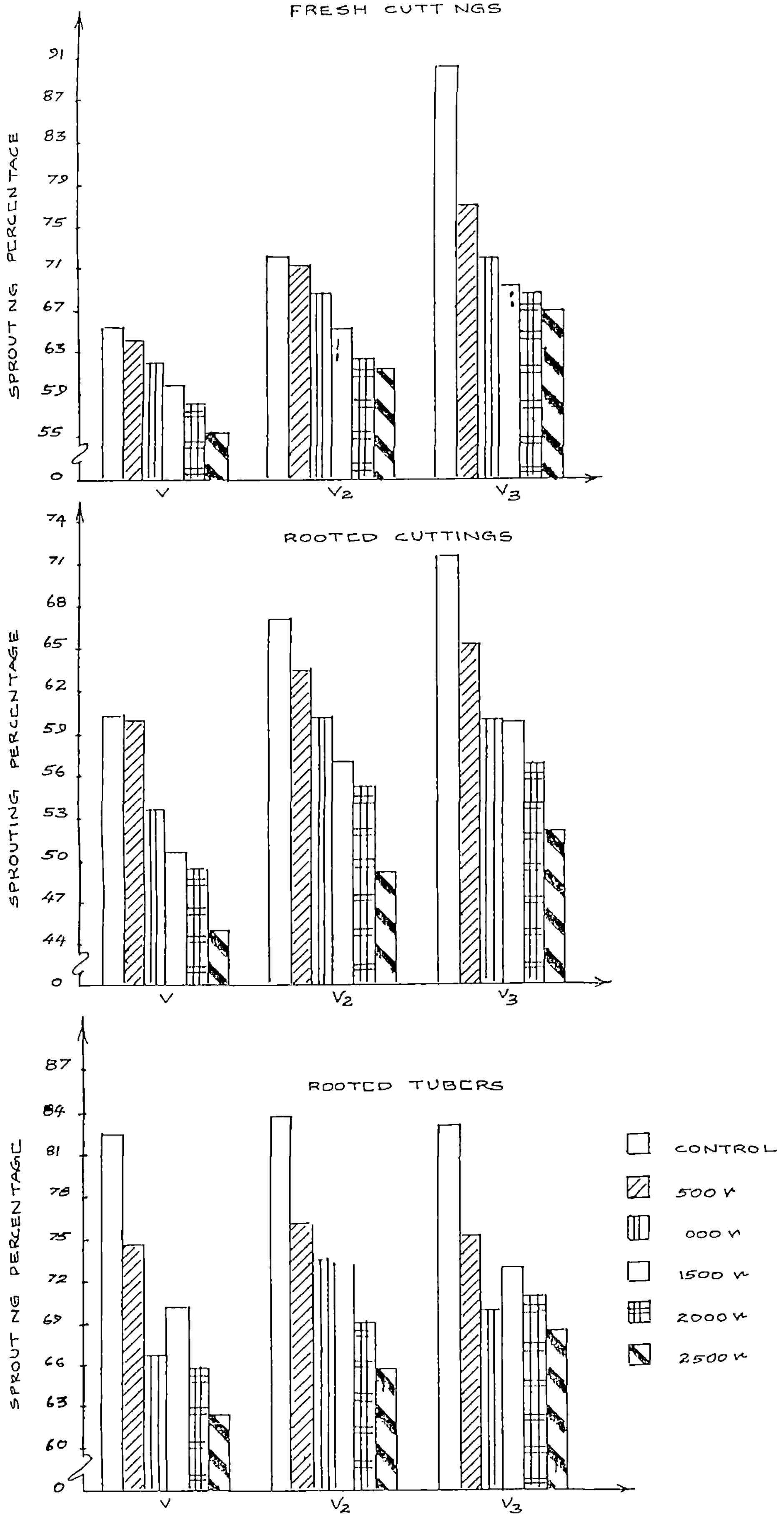

FIG 20 SPROUTING PERCENTAGE

significant variation among treatments, varieties and exposures in rooted cuttings and rooted tubers. But fresh cuttings showed significant difference only among varieties and exposures.

Lethality at 30 days after planting in V_1 control ranged from 14.96 per cent in rooted tubers to 31.59 per cent in rooted cuttings. In V_2 control it ranged from 12.60 to 22.78 per cent in rooted tubers and rooted cuttings respectively. In V_3 this range was from 13.12 per cent in rooted tubers to 20.60 per cent in fresh cuttings.

In the case of fresh cuttings the mean values in V_1 ranged from 28.27 per cent in control to 36.31 per cent in 2500 r. In V_2 it ranged from 17.85 per cent in control to 33.20 per cent in 2500 r. In V_3 this range was from 20.60 to 29.88 per cent in control and 2500 r respectively.

In rooted cuttings the lethality in V_1 ranged from 31.59 per cent in control and 500 r to 44.98 per cent in 2500 r. In V_2 the values ranged from 22.78 per cent in control to 42.11 per cent in 2500 r. In V_3 the range was from 18.43 per cent in control to 37.74 per cent in 2500 r.

In rooted tubers the mean values in V_1 ranged from 14.96 to 27.61 per cent in control and 2500 r respectively. In V_2 it ranged from 12.60 per cent in control to 24.09 per cent

Table 14. Lethality on the 30th day of planting (per cent)

Varieties	Treatments	Modes of treatment: Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	28.27	31.59	14.96
	500 r	29.88	31.59	15.98
	1000 r	31.41	36.21	23.15
	1500 r	33.20	40.67	21.78
	2000 r	33.20	42.10	25.85
	2500 r	36.31	44.98	27.61
V_2	Control	17.85	22.78	12.60
	500 r	20.60	26.38	14.96
	1000 r	27.99	31.59	16.82
	1500 r	26.38	34.73	19.12
	2000 r	31.41	36.26	21.05
	2500 r	33.20	42.11	24.09
V_3	Control	20.60	18.43	13.12
	500 r	22.49	24.67	14.68
	1000 r	26.55	29.99	20.08
	1500 r	28.27	29.88	17.15
	2000 r	27.99	34.73	19.12
	2500 r	29.88	37.74	22.96

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	2.141	15.706**	14.376**	10.211	5.393	3.519
Varieties	6.006*	35.061**	17.613**	4.169	2.202	1.437
Exposures	4.246*	37.958**	38.816**	5.895	3.113	2.032
Inter-action	0.316	0.708	1.508	10.211	5.393	3.519

* Significant at 5% level

** Significant at 1% level

in 2500 r while in V_3 the range was from 13.12 per cent in control to 22.96 per cent in 2500 r.

In gamma ray exposed population of V_1 the lethality ranged from 15.98 per cent in 500 r of rooted tubers to 44.98 per cent in 2500 r of rooted cuttings. In V_2 it ranged from 14.96 to 42.11 per cent in 500 r of rooted tubers and 2500 r of rooted cuttings respectively. In V_3 the range was from 14.68 per cent in 500 r of rooted tubers to 37.74 per cent in 2500 r of rooted cuttings.

5. Lethality at harvest

The influence of gamma rays on lethality at harvest in three sweet potato varieties is presented in Table 15 and Fig. 21. Statistical analysis of the data showed significant variation among treatments, varieties and exposures in all the three modes of treatment.

The mean lethality in V_1 control ranged from 20.08 per cent in rooted tubers to 36.26 per cent in rooted cuttings. In V_2 control the range was from 13.78 to 29.99 per cent in rooted tubers and rooted cuttings respectively. In V_3 control it ranged from 15.59 per cent in rooted tubers to 22.78 per cent in fresh cuttings.

In fresh cuttings the mean values in V_1 ranged from 33.12 in control to 43.55 per cent in 2500 r. In V_2 the percentage values ranged from 26.38 in control to 37.74 in 2500 r. In V_3 the percentage range was from 22.78 to 33.20 in control and 2500 r respectively.

In rooted cuttings the lethality in V_1 ranged from 36.26 per cent in control and 500 r to 49.30 per cent in 2500 r. In V_2 the percentage values ranged from 29.99 to 43.55 in control and 2500 r respectively while in V_3 it ranged from 22.49 in control to 37.74 in 2500 r.

In rooted tubers the percentage lethality in V_1 ranged from 19.88 to 31.59 in 500 and 2500 r respectively. In V_2 the mean values ranged from 13.78 in control to 25.85 per cent in 2500 r. In V_3 the percentage range was from 15.59 to 25.32 in control and 2500 r respectively.

In gamma ray exposed population of V_1 the percentage lethality ranged from 19.88 in 500 r of rooted tubers to 49.30 in 2500 r of rooted cuttings. In V_2 it ranged from 16.82 to 43.55 in 500 r of rooted tubers and 2500 r of rooted cuttings respectively. In V_3 the range was from 16.77 in 500 r of rooted tubers to 37.74 in 2500 r of rooted cuttings.

6. Length of vine

6.1. Length of vine on the 30th day of planting

The effect of gamma rays on the length of vine at

Table 15. Lethality at harvest (per cent)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	33.12	36.26	20.08
	500 r	34.73	36.26	19.88
	1000 r	36.21	39.22	23.15
	1500 r	37.74	42.11	26.73
	2000 r	40.67	44.98	28.23
	2500 r	43.55	49.30	31.59
V_2	Control	26.38	29.99	13.78
	500 r	26.55	31.59	16.82
	1000 r	33.12	36.26	21.05
	1500 r	33.12	37.74	22.39
	2000 r	36.05	39.22	24.09
	2500 r	37.74	43.55	25.85
V_3	Control	22.78	22.49	15.59
	500 r	24.21	28.27	16.77
	1000 r	28.27	31.59	21.45
	1500 r	29.88	32.89	20.08
	2000 r	31.41	34.73	23.32
	2500 r	33.20	37.74	25.32

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	3.164*	9.382**	12.153**	9.435	6.275	3.953
Varieties	13.331**	34.404**	22.117**	3.852	2.562	1.614
Exposures	5.236**	17.468**	30.973**	5.447	3.623	2.282
Interaction	0.095	0.334	0.751	9.435	6.275	3.953

* Significant at 5% level

** Significant at 1% level

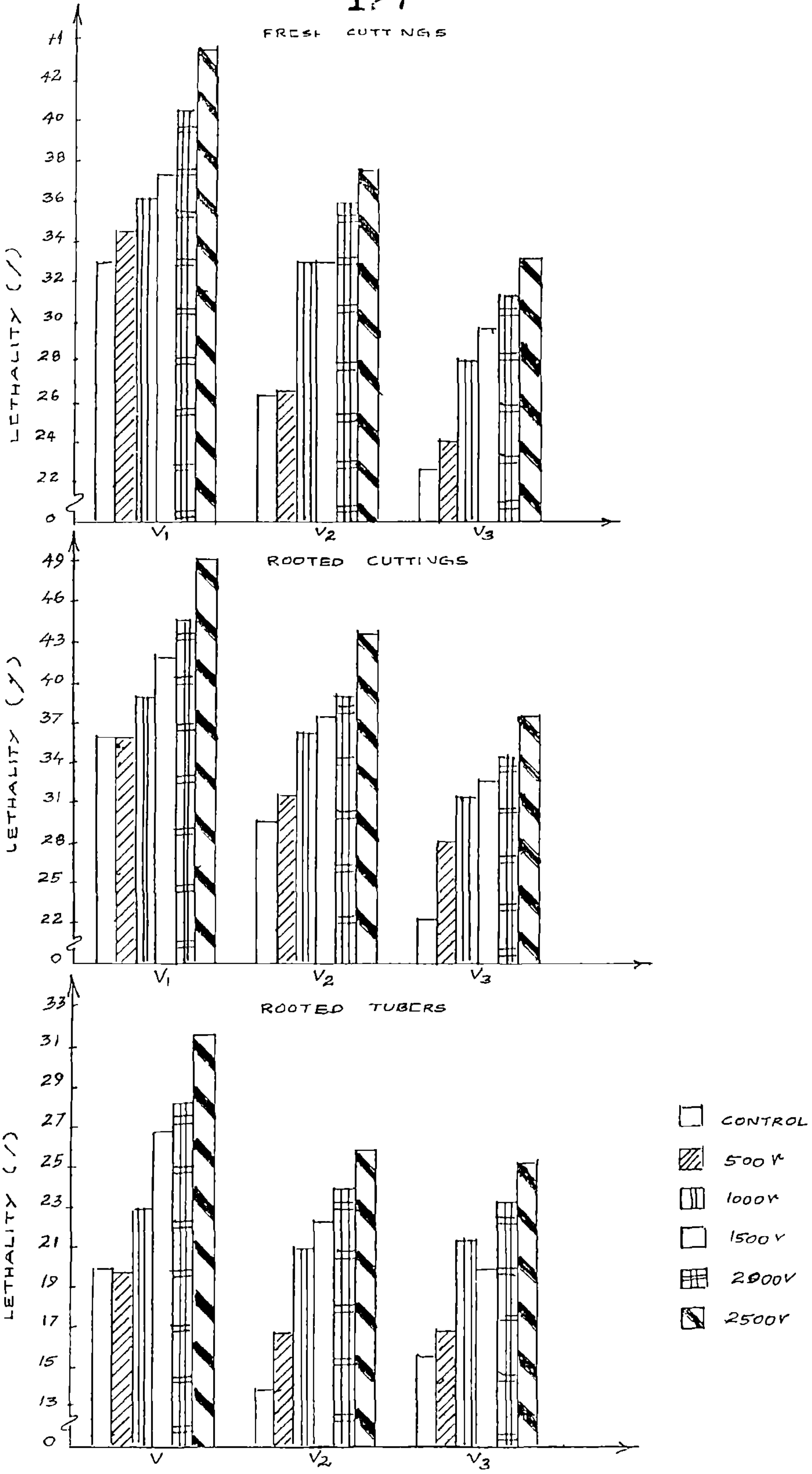

FIG 21 LETHALITY AT HARVEST (%)

30 days after planting in three sweet potato varieties is presented in Table 16.1. Statistical analysis of the data showed significant variation among treatments, varieties and exposures in the case of rooted tubers. No significant difference was noticed in the case of fresh cuttings. But in rooted cuttings, significant variation was noticed only among varieties.

Vine length on the 30th day of planting in V_1 control ranged from 18.10 cm in rooted cuttings to 38.95 cm in rooted tubers. In V_2 the mean values ranged from 14.79 to 28.95 cm in fresh cuttings and rooted tubers respectively. In V_3 it ranged from 10.09 cm in fresh cuttings to 34.60 cm in rooted tubers.

In fresh cuttings the mean values in V_1 ranged from 9.15 cm in 2500 r to 24.78 cm in control. In V_2 it ranged from 9.79 cm in 2500 r to 15.44 cm in 1000 r. Vine length in V_3 ranged from 10.09 cm in control to 16.34 cm in 1500 r.

In rooted cuttings the mean values in V_1 ranged from 6.75 to 18.10 cm in 500 r and control respectively. In V_2 it ranged from 12.80 cm in 2000 r to 22.10 cm in 1500 r while in V_3 it differed from 9.15 to 16.00 cm in 1500 and 1000 r respectively.

Table 16.1. Length of vine on the 30th day of planting (cm)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	24.78	18.10	38.95
	500 r	11.67	6.75	37.20
	1000 r	11.49	13.30	38.55
	1500 r	12.82	16.90	41.10
	2000 r	16.00	10.05	35.90
	2500 r	9.15	10.05	36.65
V_2	Control	14.79	19.80	28.95
	500 r	12.24	20.05	27.30
	1000 r	15.44	14.90	31.90
	1500 r	14.03	22.10	29.00
	2000 r	12.29	12.80	25.20
	2500 r	9.79	16.45	24.75
V_3	Control	10.09	13.55	34.60
	500 r	11.53	11.60	32.10
	1000 r	11.77	16.00	35.85
	1500 r	16.34	9.15	33.50
	2000 r	10.20	10.20	33.35
	2500 r	12.38	12.25	33.35

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	1.153	1.728	7.932**	8.478	9.605	4.991
Varieties	0.586	5.564*	56.378**	3.461	3.921	2.038
Exposures	1.226	1.511	3.057*	4.895	5.546	2.881
Inter-action	1.229	1.068	0.679	8.478	9.605	4.991

* Significant at 5% level

** Significant at 1% level

In rooted tubers the mean values in V_1 ranged from 35.90 cm in 2000 r to 41.10 cm in 1500 r. In V_2 the range was from 24.75 to 31.90 cm in 2500 and 1000 r respectively. In V_3 it differed from 32.10 cm in 500 r to 35.85 cm in 1000 r.

Among the treated population the vine length of V_1 showed the lowest value (6.75 cm) in 500 r of rooted cuttings and the highest (41.10 cm) in 1500 r of rooted tubers. In V_2 these values were 9.79 cm in 2500 r of fresh cuttings and 31.90 cm in 1000 r of rooted tubers. In V_3 it was minimum (9.15 cm) in 1500 r of rooted cuttings and maximum (35.85 cm) in 1000 r of rooted tubers.

6.2. Length of vine on the 45th day of planting

The influence of gamma rays on length of vine at 45 days after planting in three sweet potato varieties is depicted in Table 16.2. Statistical analysis of the data revealed that there was significant variation among treatments and varieties in rooted cuttings and rooted tubers. No significant difference was noticed among treatments, varieties, exposures and interaction in the case of fresh cuttings.

The vine length in V_1 control ranged from 29.99 cm in fresh cuttings to 49.00 cm in rooted tubers. In V_2

control the mean values ranged from 16.91 to 35.40 cm in fresh cuttings and rooted tubers respectively. The vine length in V_3 control differed from 13.87 cm in fresh cuttings to 41.85 cm in rooted tubers.

In fresh cuttings the mean values in V_1 ranged from 12.40 cm in 2500 r to 29.99 cm in control. In V_2 the range was from 16.55 cm in 2500 r to 19.91 cm in 1000 r. In V_3 it ranged from 13.87 to 17.82 cm in control and 1500 r respectively.

In the case of rooted cuttings the values in V_1 ranged from 31.25 cm in 500 r to 47.00 cm in control. In V_2 this ranged from 18.85 to 29.65 cm in 2000 and 1500 r respectively. In V_3 the range was from 12.45 cm in 2000 r to 19.25 cm in 1000 r.

In rooted tubers vine length in V_1 ranged from 45.50 cm in 1000 r to 49.00 cm in control. In V_2 the mean values ranged from 30.13 to 36.85 cm in 2500 and 1000 r respectively while in V_3 the range was from 41.45 cm in 1500 r to 47.75 cm in 2000 r.

Among the treated population vine length of V_1 showed the lowest value (12.40 cm) in 2500 r of fresh cuttings and the highest value (47.00 cm) in 1500 r of rooted tubers. In V_2 the minimum value (16.55 cm) was seen in 2500 r of fresh

Table 16.2. Length of vine on the 45th day of planting (cm)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	29.99	47.00	49.00
	500 r	17.58	31.25	46.25
	1000 r	14.09	40.00	45.50
	1500 r	19.00	42.50	47.00
	2000 r	22.50	37.00	46.00
	2500 r	12.40	32.00	45.90
V_2	Control	16.91	25.25	35.40
	500 r	19.35	27.00	35.05
	1000 r	19.91	22.90	36.85
	1500 r	19.29	29.65	34.50
	2000 r	17.85	18.65	31.50
	2500 r	16.55	20.50	30.13
V_3	Control	13.87	17.20	41.85
	500 r	16.30	15.50	41.95
	1000 r	16.92	19.25	42.35
	1500 r	17.82	12.95	41.45
	2000 r	14.53	12.45	47.75
	2500 r	17.34	16.95	42.25

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	1.382	5.487**	10.308**	9.844	13.356	5.438
Varieties	1.420	39.045**	77.216**	4.019	5.453	2.219
Exposures	0.735	1.278	0.797	5.684	7.711	3.140
Interaction	1.698	0.880	1.682	9.844	13.356	5.438

** Significant at 1% level

cuttings and the maximum (36.85 cm) in 1000 r of rooted tubers. In V_3 the range was from 12.45 to 47.75 cm in 2000 r of rooted cuttings and 2000 r of rooted tubers respectively.

6.3. Length of vine on the 60th day of planting

The effect of gamma rays on vine length at 60 days after planting in three sweet potato varieties is presented in Table 16.3. Statistical analysis of the data showed significant variation among treatments and varieties in all the three modes of treatment. No significant difference was noticed among exposures and interaction.

The vine length in V_1 control ranged from 74.00 cm in rooted tubers to 86.00 cm in rooted cuttings. In V_2 control the mean values ranged from 26.50 cm in fresh cuttings to 53.50 cm in rooted tubers. In V_3 control the range was from 31.50 cm in rooted cuttings to 60.00 cm in rooted tubers.

In fresh cuttings vine length of V_1 ranged from 72.50 cm in 2500 r to 85.50 cm in control. In V_2 it ranged from 26.50 cm (control and 2500 r) to 29.00 cm (500 r). In V_3 the range was from 30.50 cm in 2000 r to 36.50 cm in 500 r.

In rooted cuttings the mean values ranged from 70.50 cm to 86.00 cm in 2500 r and control respectively. In

V_2 the range was from 26.50 cm in 2000 r to 37.00 cm in 1500 r. In V_3 it differed from 24.00 to 31.50 cm in 2000 r and control respectively.

In rooted tubers the vine length in V_1 ranged from 67.00 cm in 2500 r to 74.00 cm in control. In V_2 it ranged from 42.00 cm in 2500 r to 53.50 cm in control while in V_3 the range was from 60.00 cm (2500 r and control) to 64.00 cm (500 r).

In gamma ray exposed population of V_1 the vine length ranged from 67.00 cm in 2500 r of rooted tubers to 79.50 cm in 1500 r of rooted cuttings. In V_2 the values were minimum (26.50 cm) in 2000 r of rooted cuttings and 2500 r of fresh cuttings and maximum (51.50 cm) in 1000 r of rooted tubers. In V_3 the range was from 24.00 to 64.00 cm in 2000 r of rooted cuttings and 500 r of rooted tubers respectively.

6.4. Length of vine on the 75th day of planting

The effect of gamma rays on vine length at 75 days after planting in three sweet potato varieties is presented in Table 16.4. Statistical analysis of the data showed significant variation among treatments and varieties in all the three modes of treatment. No significant difference was noticed among exposures.

Table 16.3. Length of vine on the 60th day of planting (cm)

Varieties	Treatments	Modes of treatment: Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	85.50	86.00	74.00
	500 r	79.00	71.00	71.00
	1000 r	75.00	77.50	69.00
	1500 r	75.50	79.50	70.00
	2000 r	76.50	76.00	71.00
	2500 r	72.50	70.50	67.00
V_2	Control	26.50	33.50	53.50
	500 r	29.00	35.50	48.00
	1000 r	28.50	30.50	51.50
	1500 r	28.00	37.00	46.50
	2000 r	27.50	26.50	45.50
	2500 r	26.50	28.00	42.00
V_3	Control	34.00	31.50	60.00
	500 r	36.50	28.50	64.00
	1000 r	36.00	31.00	62.00
	1500 r	32.50	25.50	62.00
	2000 r	30.50	24.00	63.50
	2500 r	32.00	24.50	60.00

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	27.707**	26.549**	8.068**	13.013	13.526	10.441
Varieties	231.879**	217.931**	63.338**	5.312	5.522	4.262
Exposures	0.606	1.769	1.060	7.513	7.809	6.028
Interaction	0.423	0.664	0.518	13.013	13.526	10.441

** Significant at 1% level

The vine length in V_1 control ranged from 153.50 cm in fresh cuttings to 220.00 cm in rooted tubers. In V_2 control it ranged from 45.00 cm in fresh cuttings to 76.50 cm in rooted tubers while in V_3 control it was from 71.50 to 104.00 cm in rooted cuttings and rooted tubers respectively.

In fresh cuttings the mean values in V_1 ranged from 127.50 cm in 1000 r to 153.50 cm in control. In V_2 the range was from 42.50 cm in 2500 r to 48.00 cm in 500 r. In V_3 it ranged from 65.00 to 78.50 cm in 1500 r and control respectively.

In rooted cuttings vine length in V_1 ranged from 140.00 cm in 500 r to 180.00 cm in 2500 r. In V_2 it ranged from 49.00 to 58.50 cm in 1000 and 1500 r respectively. The mean values in V_3 ranged from 60.50 cm in 2500 r to 72.50 cm in 1000 r.

In rooted tubers the mean values in V_1 ranged from 200.00 cm (2500 and 1000 r) to 220.00 cm (control). In V_2 it ranged from 56.50 cm in 2500 r to 76.50 cm in control. In V_3 the range was from 90.50 cm in 1500 r to 104.00 cm in control.

In the treated population the vine length of V_1 ranged from 127.50 cm in 1000 r of fresh cuttings to 217.50 cm in 1500 r of rooted tubers. In V_2 these values were (42.50 cm)

Table 16.4. Length of vine on the 75th day of planting (cm)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	153.50	157.50	220.00
	500 r	143.00	140.00	209.00
	1000 r	127.50	154.00	200.00
	1500 r	140.50	162.50	217.50
	2000 r	151.50	172.50	209.00
	2500 r	135.00	180.00	200.00
V_2	Control	45.00	51.50	76.50
	500 r	48.00	55.50	67.50
	1000 r	47.50	49.00	67.50
	1500 r	45.50	58.50	62.50
	2000 r	44.50	52.00	58.00
	2500 r	42.50	56.00	56.50
V_3	Control	78.50	71.50	104.00
	500 r	71.00	67.50	95.00
	1000 r	69.00	72.50	93.00
	1500 r	65.00	66.50	90.50
	2000 r	68.00	64.00	93.00
	2500 r	66.00	60.50	93.50

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	17.247**	18.096**	42.097**	30.576	34.961	29.615
Varieties	143.628**	149.588**	354.075**	12.483	14.273	12.090
Exposures	0.547	0.334	1.025	17.653	20.185	17.098
Interaction	0.320	0.679	0.237	30.576	34.961	29.615

** Significant at 1% level

in 2500 r of fresh cuttings and (67.50 cm) in 500 and 1000 r of rooted tubers. V_3 showed the lowest value (60.50 cm) in 2500 r of rooted cuttings and the highest value (95.00 cm) in 500 r of rooted tubers.

6.5. Length of vine on the 90th day of planting

The influence of gamma rays on the length of vine at 90 days after planting in three sweet potato varieties is depicted in Table 16.5. Statistical analysis of the data showed significant difference among treatments and varieties in all the three modes of treatment.

Vine length in V_1 control ranged from 195.00 cm in fresh cuttings to 260.00 cm in rooted tubers. In V_2 control the range was from 72.50 to 93.50 cm in rooted cuttings and rooted tubers respectively. In V_3 mean values ranged from 91.50 cm in fresh cuttings to 122.00 cm in rooted tubers.

In fresh cuttings the mean values in V_1 ranged from 155.00 cm in 2500 r to 196.00 cm in 500 r. In V_2 it ranged from 66.50 to 82.50 cm in 2500 and 2000 r respectively. In V_3 the range was from 85.00 cm in 1500 r to 94.50 cm in 2500 r.

In rooted cuttings vine length in V_1 ranged from 182.00 cm in 500 r to 242.50 cm in 2500 r. In V_2 it ranged from 66.00 cm in 1000 and 1500 r to 91.00 cm in 500 r. In V_3 the values differed from 85.00 cm in 2500 r to 105.00 cm in 1000 r.

In rooted tubers the vine length in V_1 ranged from 221.00 cm in 2500 r to 260.00 cm in control. In V_2 the range was from 74.50 cm in 2500 r to 93.50 cm in control. In V_3 the values ranged from 99.00 to 122.00 cm in 2500 r and control respectively.

In gamma ray exposed population the vine length of V_1 ranged from 155.00 cm in 2500 r of fresh cuttings to 245.00 cm in 500 r of rooted tubers. In V_2 the range was from 66.00 cm (1000 and 1500 r of rooted cuttings) to 91.00 cm (500 r of rooted cuttings). In V_3 the mean values differed from 85.00 cm (2500 r of rooted cuttings and 1500 r of fresh cuttings) to 114.50 cm (500 r of rooted tubers).

6.6. Length of vine on the 105th day of planting

Data regarding the effect of gamma rays on length of vine at 105 days after planting in three sweet potato varieties is presented in Table 16.6. Statistical analysis of the data showed significant variation among treatments and varieties in all the three modes of treatment. No significant difference was noticed among exposures.

Table 16.5. Length of vine on the 90th day of planting (cm)

Varieties	Treatments	Modes of treatment: Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	195.00	205.00	260.00
	500 r	196.00	182.00	245.00
	1000 r	185.00	218.00	240.50
	1500 r	183.00	216.50	244.00
	2000 r	195.00	236.00	242.50
	2500 r	155.00	242.50	221.00
V_2	Control	80.50	72.50	93.50
	500 r	76.00	91.00	83.50
	1000 r	78.00	66.00	87.50
	1500 r	77.50	66.00	80.50
	2000 r	82.50	75.00	77.50
	2500 r	66.50	71.00	74.50
V_3	Control	91.50	100.00	122.00
	500 r	89.00	96.50	114.50
	1000 r	87.50	105.00	107.00
	1500 r	85.00	91.00	103.00
	2000 r	90.50	94.00	107.00
	2500 r	94.50	85.00	99.00

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	14.497**	31.618**	58.549**	39.509	35.112	28.230
Varieties	119.134**	257.727**	490.022	16.129	14.334	11.525
Exposures	0.722	0.494	2.574	22.811	20.272	16.299
Interaction	0.457	1.958	0.235	39.509	35.112	28.230

** Significant at 1% level

The length of vine in V_1 control ranged from 223.00 cm in fresh cuttings to 293.00 cm in rooted tubers. The mean values in V_2 control ranged from 84.50 cm in rooted cuttings to 106.50 cm in rooted tubers. In V_3 control the range was from 112.50 to 132.50 cm in fresh cuttings and rooted tubers respectively.

In the case of fresh cuttings the mean values in V_1 ranged from 176.50 cm in 2500 r to 239.00 cm in 2000 r. In V_2 the range was from 88.50 to 101.50 cm in 2500 and 1000 r respectively. The vine length in V_3 ranged from 101.50 cm in 1500 r to 112.50 cm in control.

In rooted cuttings the mean values in V_1 ranged from 201.50 cm in 500 r to 270.00 cm in 2500 r. In V_2 the range was from 76.50 to 107.00 cm in 1000 and 500 r respectively. In V_3 it differed from 97.00 cm in 2500 r to 120.00 cm in 1000 r.

In rooted tubers vine length in V_1 ranged from 251.50 cm in 2500 r to 293.00 cm in control. In V_2 the mean values differed from 90.00 to 107.00 cm in 2500 and 1000 r respectively. In V_3 the range was from 112.00 cm in 2500 r to 132.50 cm in control.

Among the treated population the vine length of V_1 showed the lowest value (176.50 cm) in 2500 r of fresh

Table 16.6. Length of vine on the 105th day of planting (cm)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	223.00	230.50	293.00
	500 r	238.00	201.50	283.00
	1000 r	222.50	245.50	267.50
	1500 r	208.50	247.00	281.00
	2000 r	239.00	263.00	274.00
	2500 r	176.50	270.00	251.50
V_2	Control	99.00	84.50	106.50
	500 r	99.00	107.00	106.50
	1000 r	101.50	76.50	107.00
	1500 r	95.00	79.00	97.50
	2000 r	93.50	91.00	93.00
	2500 r	88.50	92.50	90.00
V_3	Control	112.50	115.00	132.50
	500 r	111.00	118.00	123.00
	1000 r	109.00	120.00	120.50
	1500 r	101.50	108.00	124.00
	2000 r	107.50	116.50	117.00
	2500 r	111.00	97.00	112.00

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	15.343**	24.194**	45.807**	43.991	43.391	35.593
Varieties	123.764**	196.154**	383.869**	17.959	17.714	14.531
Exposures	1.136	0.488	1.668	25.398	25.051	20.549
Interaction	0.762	1.654	0.264	43.991	43.391	35.593

** Significant at 1% level

cuttings and the highest value (283.00 cm) in 500 r of rooted tubers. In V_2 these values were 76.50 cm in 1000 r of rooted cuttings and 107.00 cm in 1000 r of rooted tubers and 500 r of rooted cuttings respectively. In V_3 the length was minimum (97.00 cm) in 2500 r of rooted cuttings and maximum (124.00 cm) in 1500 r of rooted tubers.

6.7. Length of vine at harvest

The influence of gamma rays on length of vine at harvest is depicted in Table 16.7. Statistical analysis of the data showed significant variation among treatments and varieties in all the three modes of treatment.

The mean vine length in V_1 control ranged from 236.00 cm in fresh cuttings to 312.00 cm in rooted tubers. In V_2 control the range was from 92.75 cm in rooted cuttings to 114.00 cm in rooted tubers. In V_3 control the mean values ranged from 122.00 to 139.50 cm in fresh cuttings and rooted tubers respectively.

In fresh cuttings vine length in V_1 ranged from 186.50 cm in 2500 r to 261.50 cm in 2000 r. In V_2 the values ranged from 100.00 cm in 2500 r to 111.00 cm in 1000 r. In V_3 the range was from 110.50 to 124.00 cm in 1500 and 500 r respectively.

In the case of rooted cuttings the mean values in V_1 ranged from 219.00 cm in 500 r to 291.00 cm in 2500 r. In V_2 the range was from 83.50 to 116.00 cm in 1000 and 500 r respectively. In V_3 it ranged from 113.00 cm in 2500 r to 135.00 cm in 1000 r.

In rooted tubers the vine length in V_1 ranged from 264.00 cm in 2500 r to 312.00 cm in control. In V_2 the range was from 96.50 to 118.00 cm in 2500 and 500 r respectively. In V_3 it ranged from 120.00 cm in 2500 r to 139.50 cm in control.

Among the treated population the vine length of V_1 showed the lowest value (186.50 cm) in 2500 r of fresh cuttings and the highest value (308.00 cm) in 500 r of rooted tubers. In V_2 these values were 83.50 cm in 1000 r of rooted cuttings and 118.00 cm in 500 r of rooted tubers. In V_3 vine length was minimum (110.50 cm) in 1500 r of fresh cuttings and maximum (135.00 cm) in 1000 r of rooted cuttings and 1500 r of rooted tubers.

7. Number of branches per vine

The effect of gamma rays on the number of branches per vine in three sweet potato varieties is presented in Table 17. Statistical analysis of the data showed significant variation among varieties in the case of rooted cuttings.

Table 16.7. Length of vine at harvest (cm)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	236.00	247.00	312.00
	500 r	254.50	219.00	308.00
	1000 r	248.25	270.00	284.50
	1500 r	228.50	284.50	296.50
	2000 r	261.50	285.00	291.50
	2500 r	186.50	291.00	264.00
V_2	Control	107.50	92.75	114.00
	500 r	110.85	116.00	118.00
	1000 r	111.00	83.50	112.00
	1500 r	108.20	89.50	105.00
	2000 r	100.50	99.00	101.00
	2500 r	100.00	103.00	96.50
V_3	Control	122.00	127.00	139.50
	500 r	124.00	133.00	128.50
	1000 r	118.00	135.00	127.50
	1500 r	110.50	120.00	135.00
	2000 r	116.50	128.00	122.50
	2500 r	122.50	113.00	120.00

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	16.394**	20.792**	43.172**	45.615	50.885	38.968
Varieties	131.016**	168.290**	360.741**	18.622	20.774	15.909
Exposures	1.224	0.416	1.806	26.336	29.379	22.498
Interaction	1.055	1.481	0.348	45.615	50.885	38.968

** Significant at 1% level

No significant variation was seen among treatments, exposures and interaction in all the three modes of treatment.

The mean values in V_1 control ranged from 2.58 in rooted cuttings to 2.74 in fresh cuttings. In V_2 the range was from 2.22 in rooted cuttings to 3.11 in fresh cuttings. In V_3 control the values ranged from 2.51 (rooted cuttings) to 2.78 (fresh cuttings and rooted tubers).

In fresh cuttings the mean number of branches in V_1 ranged from 2.64 in 2500 r to 2.99 in 500 r. In V_2 the range was from 2.41 to 3.19 in 2500 and 1000 r respectively. In V_3 the mean values ranged from 2.58 in 1500 r to 2.92 in 500 r.

In the case of rooted cuttings the mean values in V_1 ranged from 2.53 in 500 r to 2.75 in 1500 r. In V_2 the range was from 2.20 to 2.91 in 1000 and 500 r respectively. The mean values in V_3 ranged from 2.03 in 1500 r to 2.58 in 500 r.

In rooted tubers the values in V_1 ranged from 2.63 to 2.87 in control and 1000 r respectively. In V_2 the range was from 2.60 (control and 1000 r) to 2.71 (500 r). In V_3 it ranged from 2.74 in 500 r to 2.81 in 2500 r.

In gamma ray exposed population of V_1 the mean branch number ranged from 2.53 in 500 r of rooted cuttings to 2.99

Table 17. Number of branches per vine

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	2.74	2.58	2.63
	500 r	2.99	2.53	2.66
	1000 r	2.76	2.65	2.87
	1500 r	2.93	2.75	2.71
	2000 r	2.88	2.59	2.79
	2500 r	2.64	2.69	2.70
V_2	Control	3.11	2.22	2.60
	500 r	3.12	2.91	2.71
	1000 r	3.19	2.20	2.60
	1500 r	3.15	2.63	2.61
	2000 r	2.73	2.59	2.68
	2500 r	2.41	2.49	2.61
V_3	Control	2.78	2.51	2.78
	500 r	2.92	2.58	2.74
	1000 r	2.75	2.40	2.79
	1500 r	2.58	2.03	2.75
	2000 r	2.71	2.22	2.80
	2500 r	2.67	2.16	2.81

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	1.226	1.582	0.274	3.278	2.686	2.609
Varieties	2.088	4.154*	1.209	1.338	1.097	1.065
Exposures	1.641	0.873	0.146	1.892	1.551	1.507
Interaction	0.846	1.422	0.152	3.278	2.686	2.609

* Significant at 5% level

in 500 r of fresh cuttings. In V_2 the range was from 2.20 to 3.19 in 1000 r of rooted cuttings and 1000 r of fresh cuttings respectively. The mean values in V_3 ranged from 2.03 in 1500 r of rooted cuttings to 2.92 in 500 r of fresh cuttings.

8. Fresh weight of vine

Data regarding the effect of gamma rays on fresh weight of vine in three sweet potato varieties is presented in Table 18 and Fig. 22. Statistical analysis of the data showed significant variation among treatments and varieties in fresh cuttings and rooted cuttings. But in rooted tubers significant difference was noticed among varieties only.

The mean values in V_1 control ranged from 442.00 g in rooted tubers to 855.50 g in fresh cuttings. In V_2 control the range was from 329.00 to 825.50 g in rooted cuttings and fresh cuttings respectively. The fresh weight in V_3 control ranged from 412.50 g in rooted cuttings to 607.50 g in fresh cuttings.

In fresh cuttings the values in V_1 ranged from 833.00 g in 2500 r to 1485.00 g in 500 r. In V_2 it ranged from 540.00 to 966.00 g in 2500 and 1500 r respectively. In V_3 the range was from 545.50 g in 1500 r to 657.50 g in 1000 r.

In rooted cuttings the mean values in V_1 ranged from 539.50 g in control to 658.00 g in 1500 r. In V_2 it ranged from 282.50 to 608.50 g in 1000 and 500 r respectively. In V_3 this range was from 256.50 g in 1500 r to 412.50 g in control.

In rooted tubers the fresh weight of V_1 ranged from 394.00 g in 1500 r to 442.00 g in control. In V_2 the range was from 347.00 g in 2500 r to 462.50 g in 500 r. The fresh weight in V_3 ranged from 371.50 to 433.00 g in 500 r and control respectively.

In gamma ray exposed population of V_1 the fresh weight ranged from 394.00 g in 1500 r of rooted tubers to 1485.00 g in 500 r of fresh cuttings. In V_2 the mean values ranged from 282.50 to 966.00 g in 1000 r of rooted cuttings and 1500 r of fresh cuttings respectively. In V_3 the range was from 256.50 g in 1500 r of rooted cuttings to 657.50 g in 1000 r of fresh cuttings.

9. Number of tubers per vine

The influence of gamma rays on the number of tubers per vine in three sweet potato varieties is presented in Table 19. Statistical analysis of the data showed significant difference among treatments, varieties and exposures in rooted tubers. Rooted cuttings gave significant variation

Table 18. Fresh weight of vine (g)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	855.50	539.50	442.00
	500 r	1485.00	572.00	432.17
	1000 r	1158.50	565.50	412.17
	1500 r	1149.00	658.00	394.00
	2000 r	1223.00	574.50	415.33
	2500 r	833.00	604.00	400.67
V_2	Control	825.50	329.00	404.50
	500 r	755.00	608.50	462.50
	1000 r	911.00	282.50	393.50
	1500 r	966.00	383.00	367.50
	2000 r	633.50	477.50	399.50
	2500 r	540.00	400.00	347.00
V_3	Control	607.50	412.50	433.00
	500 r	603.00	357.00	371.50
	1000 r	657.50	379.00	385.50
	1500 r	545.50	256.50	385.00
	2000 r	575.50	296.50	378.50
	2500 r	634.00	285.50	405.00

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	3.453**	2.732*	0.841	437.528	238.329	134.514
Varieties	19.130**	15.837**	4.153*	178.620	97.297	54.915
Exposures	1.510	0.615	0.494	252.607	137.599	77.662
Interaction	1.289	1.169	0.353	437.528	238.329	134.514

* Significant at 5% level

** Significant at 1% level

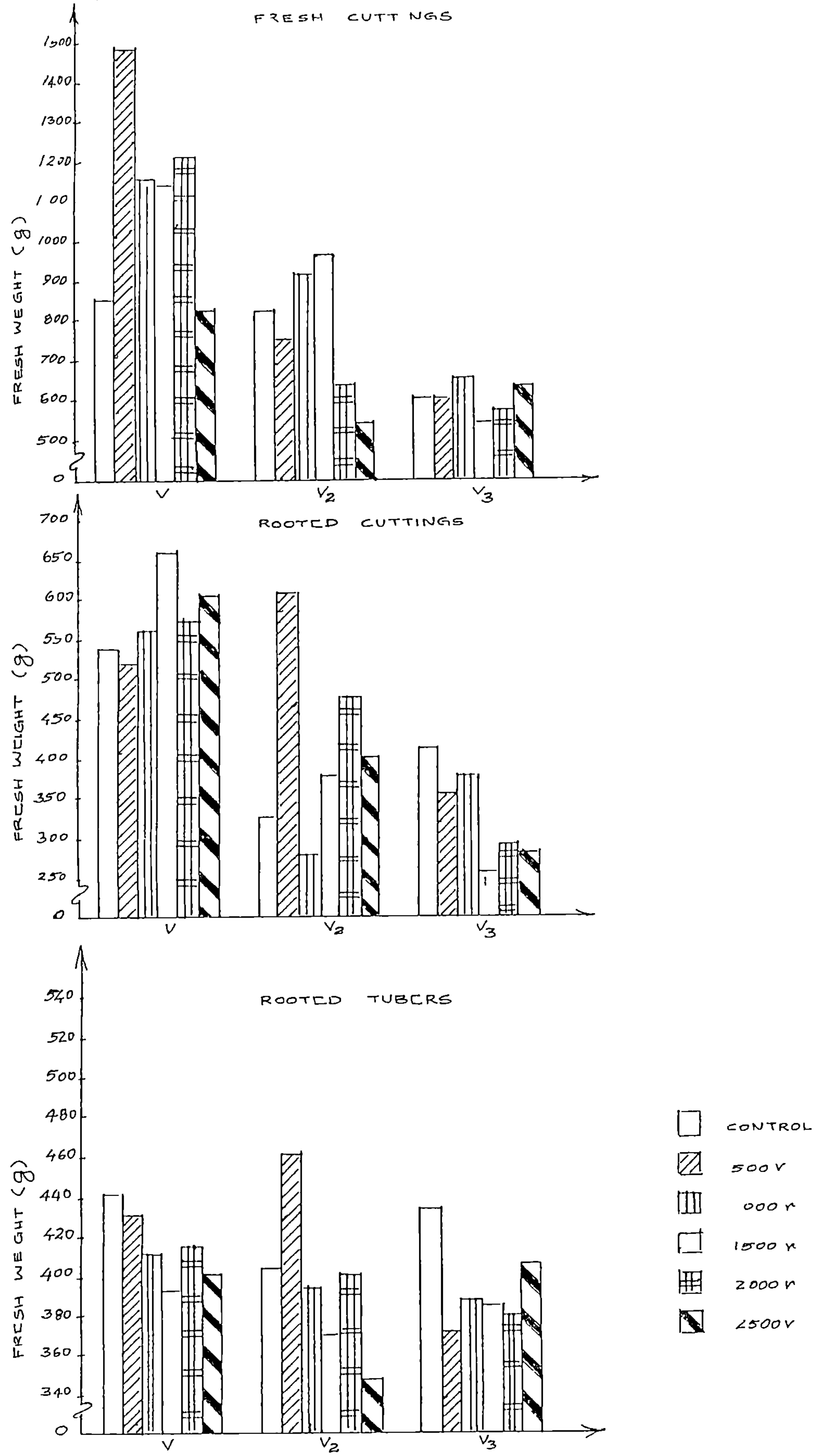

FIG 22 FRESH WEIGHT OF VINE

among exposures only. In the case of fresh cuttings no significant difference was noticed.

The mean values in V_1 control ranged from 0.25 in rooted tubers to 1.50 in rooted cuttings. In V_2 control the range was from 0.38 in rooted tubers to 1.00 in fresh cuttings and rooted cuttings. In V_3 control tuber number ranged from 0.25 in rooted tubers to 1.75 in fresh cuttings.

In fresh cuttings the mean values in V_1 ranged from 1.10 in control to 1.75 in 2500 r. In V_2 the range was from 1.00 to 2.00 in control and 1500 r respectively. The values in V_3 ranged from 1.43 (1500 r) to 1.75 (control, 500, 2000 and 2500 r).

In rooted cuttings tuber number in V_1 ranged from 1.50 (control, 1000 and 1500 r) to 1.98 (2500 r). In V_2 it ranged from 1.00 in control to 1.88 in 2500 r. In V_3 the range was from 1.38 to 2.38 in control and 2500 r respectively.

In rooted tubers the mean values in V_1 ranged from 0.25 in control to 1.88 in 2500 r. In V_2 it ranged from 0.38 to 1.25 in control and 2500 r respectively while in V_3 the range was from 0.25 in control to 1.50 in 2000 and 2500 r.

Table 19. Number of tubers per vine

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	1.10	1.50	0.25
	500 r	1.38	1.75	0.76
	1000 r	1.45	1.50	1.38
	1500 r	1.53	1.50	1.38
	2000 r	1.65	1.75	1.68
	2500 r	1.75	1.98	1.88
V_2	Control	1.00	1.00	0.38
	500 r	1.13	1.63	0.88
	1000 r	1.59	1.63	1.00
	1500 r	2.00	1.50	1.00
	2000 r	1.50	1.63	1.00
	2500 r	1.63	1.88	1.25
V_3	Control	1.75	1.38	0.25
	500 r	1.75	1.63	0.50
	1000 r	1.68	1.63	1.25
	1500 r	1.43	1.63	1.25
	2000 r	1.75	1.88	1.50
	2500 r	1.75	2.38	1.50

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	1.348	1.836	6.509**	0.677	0.594	0.565
Varieties	1.707	1.701	3.821*	0.276	0.242	0.231
Exposures	1.528	3.928*	18.381**	0.390	0.343	0.326
Interaction	1.186	0.817	1.112	0.677	0.594	0.565

* Significant at 5% level

** Significant at 1% level

Among the treated population, the tuber number of V_1 showed the lowest value (0.76) in 500 r of rooted tubers and the highest value (1.98) in 2500 r of rooted cuttings. In V_2 these values were 0.88 in 500 r of rooted tubers and 2.00 in 1500 r of fresh cuttings respectively. In V_3 tuber number was minimum (0.50) in 500 r of rooted tubers and maximum (2.38) in 2500 r of rooted cuttings.

10. Weight of tuber

The effect of gamma rays on weight of tuber in three sweet potato varieties is depicted in Table 20. Statistical analysis of the data showed significant variation among varieties in fresh cuttings and rooted tubers.

The mean weight of tuber in V_1 control ranged from 58.00 g in rooted tuber to 185.50 g in fresh cuttings. In V_2 control the mean values ranged from 27.50 g in fresh cuttings to 90.00 g in rooted cuttings. In V_3 control the range was from 75.00 g in fresh cuttings to 80.50 g in rooted cuttings.

In the case of fresh cuttings the mean values in V_1 ranged from 77.00 g in 500 r to 185.50 g in control and 2500 r. In V_2 the range was from 27.50 to 145.00 g in control and 500 r respectively. In V_3 it ranged from 66.00 g in 2000 r to 115.00 g in 2500 r.

In rooted cuttings the mean tuber weight in V_1 ranged from 82.00 g in 500 r to 154.00 g in 2500 r. In V_2 the mean values ranged from 73.50 to 115.00 g in 1500 and 2500 r respectively. The tuber weight in V_3 was 75.00 g in 1500 r and 100.00 g in 2500 r.

In rooted tubers the mean values in V_1 ranged from 58.00 to 75.00 g in control and 1500 r respectively. In V_2 the range was from 77.50 g in 1500 r to 105.00 g in 500 r. In V_3 the values ranged from 77.50 g in control to 127.50 g in 2000 r.

In gamma ray exposed population of V_1 the mean tuber weight ranged from 61.50 g in 500 r of rooted tubers to 185.50 g in 2500 r of fresh cuttings. In V_2 the range was from 68.50 to 145.00 g in 2000 r of fresh cuttings and 500 r of fresh cuttings respectively. In V_3 the mean values ranged from 66.00 g in 2000 r of fresh cuttings to 127.50 g in 2000 r of rooted tubers.

11. Length of tuber

The effect of gamma rays on mean length of tuber in three sweet potato varieties is depicted in Table 21. Statistical analysis of the data showed significant variation among treatments in fresh cuttings and rooted tubers. Significant difference was noticed among varieties in all the

Table 20. Weight of tuber (g)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	185.50	96.50	58.00
	500 r	77.00	82.00	61.50
	1000 r	127.50	87.50	72.50
	1500 r	147.50	125.00	75.00
	2000 r	135.00	110.00	72.50
	2500 r	185.50	154.00	72.50
V_2	Control	27.50	90.00	80.00
	500 r	145.00	104.00	105.00
	1000 r	71.00	74.50	97.50
	1500 r	77.50	73.50	77.50
	2000 r	68.50	94.00	95.00
	2500 r	97.50	115.00	92.50
V_3	Control	75.00	80.50	77.50
	500 r	77.50	90.00	107.50
	1000 r	80.00	77.50	95.00
	1500 r	69.50	75.00	107.50
	2000 r	66.00	86.00	127.50
	2500 r	115.00	100.00	115.50

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	0.991	1.397	0.746	131.702	52.204	66.777
Varieties	3.968*	3.076	4.049*	53.767	21.312	27.262
Exposures	0.878	2.109	0.492	76.038	30.140	38.554
Interaction	0.702	0.705	0.212	131.702	52.204	66.777

* Significant at 5% level

three modes of treatment.

The mean tuber length in V_1 control ranged from 18.75 cm in rooted tubers to 19.70 cm in fresh cuttings. The mean values in V_2 control ranged from 14.25 to 15.25 cm in rooted tubers and fresh cuttings respectively. In V_3 the range was from 14.55 cm in rooted cuttings to 18.50 cm in fresh cuttings.

In fresh cuttings the mean values in V_1 ranged from 19.70 cm in control to 21.30 cm in 1000 r. In V_2 the range was from 15.25 to 18.00 cm in control and 2500 r respectively. The tuber length in V_3 ranged from 16.75 cm in 1000 r to 19.35 cm in 2000 r.

In the case of rooted cuttings the mean values in V_1 ranged from 19.10 cm in control to 23.50 cm in 1500 r. In V_2 the range was from 14.65 cm (control) to 17.75 cm (2000 and 2500 r). In V_3 it ranged from 14.55 to 17.60 cm in control and 2000 r respectively.

In rooted tubers length in V_1 ranged from 18.75 cm in control to 20.90 cm in 2000 r. In V_2 the mean values ranged from 14.25 to 17.00 cm in control and 2500 r respectively. In V_3 the range was from 16.00 cm in control to 18.55 cm in 2500 r.

Table 21. Length of tuber (cm)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	19.70	19.10	18.75
	500 r	20.90	19.60	19.35
	1000 r	21.30	19.25	19.65
	1500 r	21.20	23.50	20.60
	2000 r	20.25	21.55	20.90
	2500 r	21.05	20.60	20.75
V_2	Control	15.25	14.65	14.25
	500 r	16.10	17.00	14.95
	1000 r	16.40	16.95	15.40
	1500 r	15.95	17.50	15.00
	2000 r	17.75	17.75	16.75
	2500 r	18.00	17.75	17.00
V_3	Control	18.50	14.55	16.00
	500 r	17.85	14.90	16.90
	1000 r	16.75	16.65	17.30
	1500 r	18.35	15.45	17.85
	2000 r	19.35	17.60	18.00
	2500 r	18.70	14.75	18.55

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	4.209**	2.127	4.198**	2.823	5.223	3.029
Varieties	29.369**	13.026**	28.958**	1.153	2.132	1.236
Exposures	1.031	1.031	2.444	1.630	3.015	1.749
Interaction	0.765	0.495	0.123	2.823	5.223	3.029

** Significant at 1% level

Among the treated population the tuber length of V_1 showed the lowest value (19.25 cm) in 1000 r of rooted cuttings and the highest value (23.50 cm) in 1500 r of rooted cuttings. In V_2 these values were 14.95 cm in 500 r of rooted tubers and 18.00 cm in 2500 r of fresh cuttings respectively. In V_3 length of tuber was minimum (14.75 cm) in 2500 r of rooted cuttings and maximum (19.35 cm) in 2000 r of fresh cuttings.

12. Girth of tuber

The influence of gamma rays on girth of tuber in three sweet potato varieties is presented in Table 22. Statistical analysis of the data showed significant variation among treatments and varieties in all the three modes of treatment. Significant difference among exposures was noted only in rooted tubers.

The mean values in V_1 control ranged from 10.00 cm in fresh cuttings to 17.00 cm in rooted cuttings. In V_2 control the range was from 13.50 in rooted tubers to 14.00 cm in fresh cuttings and rooted cuttings. The tuber girth in V_3 control ranged from 10.00 to 12.00 cm in fresh cuttings and rooted cuttings respectively.

In the case of fresh cuttings the mean values in V_1 ranged from 10.00 cm in control to 12.80 cm in 1500 r. In

V_2 the range was from 14.00 to 15.65 cm in control and 2000 r respectively. The tuber girth in V_3 ranged from 10.00 cm in control to 11.85 cm in 500 r.

In rooted cuttings the mean values in V_1 ranged from 17.00 to 18.70 cm in control and 2000 r respectively. In V_2 the range was from 14.00 cm (control and 2500 r) to 15.45 cm (1500 r). In V_3 it ranged from 12.20 cm in control to 14.20 cm in 1500 r.

In rooted tubers the girth of tuber in V_1 ranged from 16.50 cm (control) to 18.00 cm (1000, 1500 and 2000 r). In V_2 the values ranged from 13.50 to 16.60 cm in control and 2000 r respectively. In V_3 the range was from 11.75 cm in control to 14.20 cm in 1500 r.

In gamma ray exposed population the tuber girth of V_1 showed the lowest value (10.20 cm) in 500 r of fresh cuttings and the highest value (18.70 cm) in 2000 r of rooted cuttings. In V_2 these values were 14.00 cm in 2500 r of rooted cuttings and 16.60 cm in 2000 r of rooted tubers respectively. In V_3 girth of tuber was minimum (10.90 cm) in 2500 r of fresh cuttings and maximum (14.20 cm) in 1500 r of rooted cuttings and rooted tubers.

13. Volume of tuber

Data regarding the effect of gamma rays on volume of

Table 22. Girth of tuber (cm)

Varieties	Treatments	Modes of treatment Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	10.00	17.00	16.50
	500 r	10.20	17.30	17.65
	1000 r	11.15	17.90	18.00
	1500 r	12.80	18.50	18.00
	2000 r	12.00	18.70	18.00
	2500 r	11.85	17.95	17.55
V_2	Control	14.00	14.00	13.50
	500 r	15.10	14.95	14.30
	1000 r	15.40	15.30	15.50
	1500 r	15.60	15.45	16.25
	2000 r	15.65	14.75	16.60
	2500 r	15.20	14.00	16.50
V_3	Control	10.00	12.20	11.75
	500 r	11.85	13.25	12.00
	1000 r	11.65	13.75	13.15
	1500 r	11.45	14.20	14.20
	2000 r	11.00	13.65	12.55
	2500 r	10.90	13.65	12.20

	F value Fresh cuttings	Rooted cuttings	Rooted tubers	CD value Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	3.619**	4.834**	9.473**	3.221	2.758	2.195
Varieties	26.436**	37.330**	69.924**	1.315	1.126	0.896
Exposures	1.133	1.194	2.817*	1.859	1.593	1.267
Interaction	0.295	0.154	0.711	3.221	2.758	2.195

* Significant at 5% level

** Significant at 1% level

tuber in three sweet potato varieties is depicted in Table 23. Statistical analysis of the data showed significant variation among varieties in all the three modes of treatment.

The volume of tuber in V_1 control ranged from 57.50 cm^3 in rooted tubers to 177.50 cm^3 in fresh cuttings. In V_2 control the range was from 27.50 to 82.50 cm^3 in fresh cuttings and rooted cuttings respectively. In V_3 control mean values ranged from 67.50 cm^3 in fresh cuttings to 77.50 cm^3 in rooted cuttings.

In fresh cuttings volume of tuber in V_1 ranged from 76.50 cm^3 in 500 r to 177.50 cm^3 in control. In V_2 it ranged from 27.50 to 130.00 cm^3 in control and 500 r respectively. In V_3 mean values ranged from 60.00 cm^3 in 2000 r to 107.50 cm^3 in 2500 r.

In rooted cuttings the mean values in V_1 ranged from 77.50 cm^3 in 500 r to 135.00 cm^3 in 2500 r. In V_2 the range was from 70.00 to 102.50 cm^3 in 1500 and 2500 r respectively. In V_3 it ranged from 72.50 cm^3 (1000 and 1500 r) to 92.50 cm^3 (2500 r).

In the case of rooted tubers, the tuber volume in V_1 ranged from 57.50 cm^3 (control and 500 r) to 72.50 cm^3 (2000 r). In V_2 the mean values ranged from 71.00 cm^3 in control to 96.00 cm^3 in 500 r. The mean values in V_3 ranged

Table 23. Volume of tuber (cm^3)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	177.50	89.00	57.50
	500 r	76.50	77.50	57.50
	1000 r	115.00	82.50	65.00
	1500 r	135.00	114.00	70.00
	2000 r	130.00	102.50	72.50
	2500 r	170.00	135.00	65.00
V_2	Control	27.50	82.50	71.00
	500 r	130.00	95.00	96.00
	1000 r	67.50	74.00	92.50
	1500 r	73.50	70.00	72.50
	2000 r	62.50	88.00	86.50
	2500 r	95.00	102.50	87.50
V_3	Control	67.50	77.50	72.50
	500 r	67.50	82.50	95.50
	1000 r	75.00	72.50	90.00
	1500 r	65.00	72.50	97.50
	2000 r	60.00	78.50	110.00
	2500 r	107.50	92.50	115.00

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	1.086	1.486	0.851	116.727	41.026	55.639
Varieties	4.574*	3.619*	4.542*	47.653	16.749	22.712
Exposures	0.429	2.104	0.587	67.392	23.686	32.120
Interaction	0.716	0.751	0.245	116.727	41.026	55.634

* Significant at 5% level

from 72.50 to 115.00 cm^3 in control and 2500 r respectively.

Among the treated population the volume of tuber in V_1 ranged from 57.50 cm^3 in 500 r of rooted tubers to 170.00 cm^3 in 2500 r of fresh cuttings. In V_2 the mean values ranged from 62.50 to 130.00 cm^3 in 2000 of fresh cuttings and 500 r of fresh cuttings respectively. In V_3 the range was from 60.00 cm^3 in 2000 r of fresh cuttings to 115.00 cm^3 in 2500 r of rooted tubers.

14. Tuber yield per vine

The influence of gamma rays on tuber yield per vine in three sweet potato varieties is presented in Table 24. Statistical analysis of the data showed significant difference among exposures in rooted cuttings and rooted tubers.

The mean tuber yield per vine in V_1 control ranged from 37.50 g in rooted tubers to 195.50 g in fresh cuttings. In V_2 control the range was from 42.50 g (fresh cuttings and rooted tubers) to 105.00 g in rooted cuttings. In V_3 control the mean values ranged from 31.00 to 144.00 g in rooted tubers and fresh cuttings respectively.

In fresh cuttings the mean tuber yield in V_1 ranged from 106.00 g in 500 r to 373.00 g in 2500 r. In V_2 the range was from 42.50 to 165.50 g in control and 500 r respectively. The mean values in V_3 ranged from 96.50 g in 1500 r to 194.00 g in 2500 r.

In the case of rooted cuttings the mean values in V_1 ranged from 133.50 g in 1000 r to 262.50 g in 2500 r. The mean values in V_2 ranged from 98.50 to 212.50 g in 1500 and 2500 r respectively. In V_3 the range was from 108.00 g in control to 238.50 g in 2500 r.

In rooted tubers the tuber yield in V_1 ranged from 37.50 to 132.50 g in control and 2500 r respectively. In V_2 it ranged from 42.50 g in control to 114.00 g in 1000 and 2500 r. The mean values in V_3 ranged from 31.00 to 189.50 g in control and 2000 r respectively.

In gamma ray exposed population the tuber yield of V_1 showed the lowest value (42.50 g) in 500 r of rooted tubers and the highest value (373.00 g) in 2500 r of fresh cuttings. In V_2 these values were 55.00 g in 1500 r of fresh cuttings and 212.50 g in 2500 r of rooted cuttings respectively. In V_3 tuber yield was minimum (54.00 g) in 500 r of rooted tubers and maximum (238.50 g) in 2500 r of rooted cuttings.

B. vM_2 generation

In vM_2 generation only the main yield attributing characters were analysed in detail and the observations made

Table 24. Tuber yield per vine (g)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	195.50	154.00	37.50
	500 r	106.00	141.50	42.50
	1000 r	177.00	133.50	98.00
	1500 r	247.00	193.00	107.00
	2000 r	249.00	190.00	122.00
	2500 r	373.00	262.50	132.50
V_2	Control	42.50	105.00	42.50
	500 r	165.50	171.50	94.50
	1000 r	111.00	119.50	114.00
	1500 r	55.00	98.50	89.00
	2000 r	81.00	152.00	108.00
	2500 r	144.50	212.50	114.00
V_3	Control	144.00	108.00	31.00
	500 r	140.00	147.50	54.00
	1000 r	134.50	127.00	111.50
	1500 r	96.50	122.50	134.50
	2000 r	115.50	163.00	189.50
	2500 r	194.00	238.50	173.50

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	0.856	1.943	1.689	242.979	99.064	103.166
Varieties	2.97	1.939	0.971	99.196	40.443	42.117
Exposures	0.731	4.983**	4.337*	140.284	57.194	59.563
Interaction	0.496	0.434	0.509	242.979	99.064	103.166

* Significant at 5% level

** Significant at 1% level

are detailed below.

1. Length of vine at harvest

The effect of gamma rays on mean length of vine at harvest in three sweet potato varieties is presented in Table 25. Statistical analysis of the data showed significant variation among treatments, varieties and exposures in rooted cuttings. But in fresh cuttings and rooted tubers significant difference was noticed among treatments and exposures only.

The mean vine length in V_1 control ranged from 212.50 cm in rooted cuttings to 222.50 cm in rooted tubers. The mean values in V_2 differed from 105.00 cm in rooted tubers to 117.00 cm in fresh cuttings and rooted cuttings. In V_3 the mean values in control ranged from 118.00 to 124.00 cm in rooted cuttings and rooted tubers respectively.

In the case of fresh cuttings the vine length in V_1 ranged from 155.50 cm in 1000 r to 217.00 cm in control. The mean values in V_2 ranged from 107.50 to 126.00 cm in 2500 and 500 r respectively. In V_3 the range was from 117.50 cm in 2000 r to 139.50 cm in 500 r.

In rooted cuttings the mean values in V_1 differed from 177.50 cm in 2500 r to 212.50 cm in control. The vine length in V_2 ranged from 104.00 cm (2000 and 2500 r) to 117.00 cm

Table 25. Length of vine at harvest (cm)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	217.00	212.50	222.50
	500 r	176.50	202.50	210.00
	1000 r	155.50	195.00	204.00
	1500 r	182.50	192.50	197.00
	2000 r	180.00	182.50	180.00
	2500 r	172.50	177.50	177.00
V_2	Control	117.00	117.00	105.00
	500 r	126.00	110.50	99.00
	1000 r	125.50	109.50	99.50
	1500 r	115.00	106.50	95.00
	2000 r	114.50	104.00	95.00
	2500 r	107.50	104.00	91.50
V_3	Control	123.00	118.00	124.00
	500 r	139.50	110.00	120.00
	1000 r	121.00	106.00	116.00
	1500 r	122.50	107.50	109.00
	2000 r	117.50	97.50	116.00
	2500 r	119.00	96.50	113.00

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	10.149**	24.548**	16.669**	31.204	25.809	33.783
Varieties	77.797**	200.179**	134.709**	12.739	10.537	13.792
Exposures	1.346	2.914*	1.751	18.015	14.901	19.504
Interaction	1.021	0.239	0.521	31.204	25.809	33.783

* Significant at 5% level

** Significant at 1% level

(control). In V_3 it ranged from 96.50 to 118.00 cm in 2500 r and control respectively.

In rooted tubers the values in V_1 differed from 177.00 to 222.50 cm in 2500 r and control respectively. In V_2 it ranged from 91.50 cm in 2500 r to 105.00 cm in control. In V_3 it was 113.00 cm in 2500 r and 124.00 cm in control.

Among the treated population vine length of V_1 showed the lowest value (155.50 cm) in 1000 r of fresh cuttings and the highest value (210.00 cm) in 500 r of rooted tubers. In V_2 these values were 91.50 cm in 2500 r of rooted tubers and 126.00 cm in 500 r of fresh cuttings. In V_3 vine length was minimum (96.50 cm) in 2500 r of rooted cuttings and maximum (139.50 cm) in 500 r of fresh cuttings.

2. Number of branches per vine

The mean number of branches per vine as influenced by gamma rays in three sweet potato varieties is depicted in Table 26 and Fig. 23. Statistical analysis of the data showed significant difference among treatments, varieties, exposures and interaction in rooted tubers. In fresh cuttings and rooted cuttings there was significant variation only among varieties.

The mean number of branches in V_1 control ranged from 6.35 in fresh cuttings to 7.90 in rooted tubers. The mean values in V_2 control ranged from 6.45 to 7.65 in rooted cuttings and rooted tubers respectively. In V_3 the mean values in control ranged from 6.95 in rooted cuttings to 8.80 in rooted tubers.

In fresh cuttings branch number in V_1 ranged from 5.40 in 500 r to 6.35 in control and 2500 r. In V_2 the values ranged from 5.95 in 500 and 2500 r to 6.95 in control. In V_3 the range was from 7.30 to 7.75 in 1500 r and control respectively.

In the case of rooted cuttings mean values in V_1 differed from 5.90 in 2500 r to 6.43 in control. The mean values in V_2 ranged from 5.95 (500 and 2500 r) to 6.45 (control). In V_3 it ranged from 6.50 to 7.00 in 2500 and 500 r respectively.

In rooted tubers the mean values in V_1 ranged from 7.90 in control to 9.70 in 1500 r. In V_2 it differed from 6.70 in 1500 r to 8.80 in 500 r. In V_3 the range was from 6.48 in 1000 r to 9.04 in 500 r.

Among the treated population, branch number of V_1 showed the lowest value (5.40) in 500 r of fresh cuttings and the highest value (9.70) in 1500 r of rooted tubers. In V_2 these values were 5.95 (500 and 2000 r of fresh cuttings and 500 and 2500 r of rooted cuttings) and 8.80 (500 r of

Table 26. Number of branches per vine

Varieties	Treatments	Modes of treatment: Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	6.35	6.43	7.90
	500 r	5.40	6.15	8.74
	1000 r	5.65	6.10	8.84
	1500 r	5.50	6.12	9.70
	2000 r	5.60	6.05	8.05
	2500 r	6.35	5.90	7.97
V_2	Control	6.95	6.45	7.65
	500 r	5.95	5.95	8.80
	1000 r	6.75	6.20	7.45
	1500 r	6.40	6.15	6.70
	2000 r	5.95	6.10	7.05
	2500 r	6.80	5.95	7.25
V_3	Control	7.75	6.95	8.80
	500 r	7.35	7.00	9.04
	1000 r	7.45	6.70	6.48
	1500 r	7.30	6.70	6.75
	2000 r	7.45	6.60	6.58
	2500 r	7.50	6.50	6.74

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	3.149**	1.605	4.914**	1.313	1.305	1.341
Varieties	21.593**	12.075**	11.858**	0.536	0.533	0.547
Exposures	1.541	0.478	5.431**	0.758	0.754	0.774
Inter-action	0.264	0.074	3.266*	1.313	1.305	1.341

* Significant at 5% level

** Significant at 1% level

rooted tubers) respectively. In V_3 the branch number was minimum (6.48) in 1000 r of rooted tubers and maximum (9.04) in 500 r of rooted tubers.

3. Fresh weight of vine

The influence of gamma rays on mean fresh weight of vine in three sweet potato varieties is presented in Table 27. Statistical analysis of the data showed significant variation among treatments and varieties in rooted tubers.

The mean fresh weight of vine in V_1 control ranged from 380.00 g in rooted cuttings to 600.00 g in rooted tubers. The mean values in V_2 control ranged from 245.00 g in rooted tubers to 351.00 g in rooted cuttings. In V_3 the mean values in control population ranged from 270.00 g in rooted tubers to 365.00 g in rooted cuttings.

In fresh cuttings the mean values in V_1 ranged from 343.50 g in 500 r to 416.00 g in 1000 r while in V_2 it ranged from 295.00 to 360.50 g in 2000 and 2500 r respectively. In V_3 the range was from 343.00 g in 1500 r to 390.00 g in 2000 r.

In rooted cuttings the mean fresh weight in V_1 ranged from 312.50 g in 2500 r to 380.00 g in control. In V_2 the range was from 330.00 to 351.00 g in 2500 r and control respectively. The mean values in V_3 ranged from 315.00 g (2000 and 2500 r) to 365.00 g (control).

In the case of rooted tubers the mean values in V_1 differed from 505.00 g in 2500 r to 600.00 g in control. In V_2 it ranged from 215.00 g (1500 and 2000 r) to 245.00 g (control). In V_3 it ranged from 212.50 to 270.00 g in 2500 r and control respectively.

Among the treated population the mean fresh weight of V_1 showed the lowest value (312.50 g) in 2500 r of rooted cuttings and the highest value (580.00 g) in 500 r of rooted tubers. In V_2 these values were 215.00 g in 1500 and 2000 r of rooted tubers and 360.50 g in 2500 r of fresh cuttings respectively. In V_3 it was minimum (212.50 g) in 2500 r of rooted tubers and maximum (390.00 g) in 2000 r of fresh cuttings.

4. Number of tubers per vine

The mean number of tubers per vine as influenced by gamma rays is presented in Table 28 and Fig. 24. Statistical analysis of the data showed significant variation among treatments, varieties and exposures in fresh cuttings and rooted tubers. Rooted cuttings gave significant difference only among the exposures.

The mean value in V_1 control ranged from 1.43 in rooted tubers to 2.10 in fresh cuttings. In V_2 the mean

Table 27. Fresh weight of vine (g)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	405.00	380.00	600.00
	500 r	343.50	370.00	580.00
	1000 r	416.00	355.00	561.00
	1500 r	382.50	350.00	523.50
	2000 r	368.00	325.00	532.50
	2500 r	372.00	312.50	505.00
V_2	Control	303.50	351.00	245.00
	500 r	340.00	340.00	230.00
	1000 r	359.50	340.00	240.00
	1500 r	335.50	337.00	215.00
	2000 r	295.00	334.00	215.00
	2500 r	360.50	330.00	225.00
V_3	Control	360.00	365.00	270.00
	500 r	387.50	353.00	249.00
	1000 r	351.00	340.00	232.50
	1500 r	343.00	332.00	222.50
	2000 r	390.00	315.00	219.00
	2500 r	361.00	315.00	212.50

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	0.374	0.213	16.401**	152.563	122.977	115.391
Varieties	1.431	0.145	136.173**	62.283	50.205	47.108
Exposures	0.092	0.543	1.015	88.082	71.001	66.621
Interaction	0.304	0.061	0.140	152.563	122.977	115.391

** Significant at 1% level

values in control population differed from 1.25 to 1.75 in rooted cuttings and fresh cuttings respectively. In V_3 control it ranged from 1.63 in rooted tubers to 2.00 in fresh cuttings.

In fresh cuttings the mean tuber number in V_1 ranged from 2.10 (control) to 2.55 (1000, 1500 and 2000 r). In V_2 the mean values ranged from 1.75 in control to 2.50 in 2500 r while in V_3 the range was from 2.00 (control and 500 r) to 2.65 (2000 and 2500 r).

In rooted cuttings the mean values in V_1 ranged from 2.05 to 2.30 in control and 2500 r respectively. In V_2 it ranged from 1.25 in control to 2.40 in 2500 r. The mean values in V_3 differed from 1.90 in control to 2.40 in 2500 r.

In rooted tubers the mean tuber number in V_1 ranged from 1.43 to 1.82 in control and 1000 r respectively. In V_2 the range was from 1.47 (control) to 1.64 (500 and 2000 r). In V_3 it differed from 1.63 in control to 1.79 in 1500 r.

In gamma ray exposed population the mean tuber number in V_1 ranged from 1.67 (1500 and 2500 r) of rooted tubers) to 2.55 (1000, 1500 and 2000 r of fresh cuttings). In V_2 the mean values ranged from 1.53 in 1500 r of rooted tubers to 2.50 in 2500 r of fresh cuttings. The mean values in V_3 ranged from 1.72 in 2500 r of rooted tubers to 2.65 in 2000

Table 28. Number of tubers per vine

Varieties	Treatments	Modes of treatment: Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	2.10	2.05	1.43
	500 r	2.40	2.25	1.73
	1000 r	2.55	2.10	1.82
	1500 r	2.55	2.15	1.67
	2000 r	2.55	2.20	1.71
	2500 r	2.45	2.30	1.67
V_2	Control	1.75	1.25	1.47
	500 r	1.95	1.90	1.64
	1000 r	2.00	2.00	1.62
	1500 r	2.05	2.10	1.53
	2000 r	2.30	2.30	1.64
	2500 r	2.50	2.40	1.62
V_3	Control	2.00	1.90	1.63
	500 r	2.00	2.30	1.78
	1000 r	2.40	2.15	1.56
	1500 r	2.30	2.25	1.79
	2000 r	2.65	2.35	1.77
	2500 r	2.65	2.40	1.72

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	2.745*	2.272	6.826**	0.491	0.531	0.131
Varieties	8.779**	2.865	21.551**	0.200	0.217	0.054
Exposures	4.757**	4.570**	12.223**	0.283	0.306	0.076
Interaction	0.532	1.003	1.183	0.491	0.531	0.131

* Significant at 5% level

** Significant at 1% level

and 2500 r of fresh cuttings.

5. Weight of tuber

The effect of gamma rays on mean weight of tuber in three sweet potato varieties is presented in Table 29 and Fig. 25. Statistical analysis of the data showed significant difference among treatments, varieties and exposures in rooted tubers. Fresh cuttings gave significant variation only among the varieties.

The mean tuber weight in V_1 control differed from 70.00 g in rooted tubers to 150.00 g in fresh cuttings. In V_2 the mean values in control ranged from 90.00 g in fresh cuttings to 125.00 g in rooted cuttings. The mean values in V_3 control ranged from 95.00 to 149.00 g in rooted tubers and rooted cuttings respectively.

In fresh cuttings the mean values in V_1 ranged from 150.00 g in control to 167.00 g in 2500 r. In V_2 it ranged from 90.00 g in control to 140.00 g in 2500 r. In V_3 the range was from 105.00 to 145.00 g in control and 2500 r respectively.

In the case of rooted cuttings the mean tuber weight in V_1 differed from 127.50 g in control to 165.00 g in 2500 r. In V_2 it ranged from 125.00 g in control to 157.50 g in 2000 r. The mean values in V_3 ranged from 149.00 g (control) to 166.50 g (2500 r).

In rooted tubers the mean values in V_1 ranged from 70.00 g in control to 104.00 g in 2000 r. In V_2 it ranged from 97.50 to 155.00 g in control and 2500 r respectively. The mean values in V_3 ranged from 95.00 g in control to 141.00 g in 2500 r.

Among the treated population the tuber weight of V_1 showed the lowest value (90.00 g) in 500 r of rooted tubers and the highest value (167.00 g) in 2500 r of fresh cuttings. In V_2 these values were 99.50 g in 500 r of fresh cuttings and 157.50 g in 2000 r of rooted cuttings respectively. In V_3 it was minimum (122.50 g) in 500 r of fresh cuttings and maximum (166.50 g) in 2500 r of rooted cuttings.

6. Length of tuber

The influence of gamma rays on mean length of tuber in three sweet potato varieties is depicted in Table 30. Statistical analysis of the data showed significant variation among treatments and varieties in all the three modes of treatment. Rooted tubers alone showed significant difference among the exposures.

The mean tuber length in V_1 control ranged from 17.30 cm in rooted tubers to 20.25 in rooted cuttings. In

Table 29. Weight of tuber (g)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	150.00	127.50	70.00
	500 r	154.00	142.50	90.00
	1000 r	155.50	147.50	92.50
	1500 r	162.50	150.00	95.00
	2000 r	160.00	160.00	104.00
	2500 r	167.00	165.00	97.00
V_2	Control	90.00	125.00	97.50
	500 r	99.50	140.00	132.50
	1000 r	105.00	147.50	141.50
	1500 r	125.00	152.50	140.00
	2000 r	132.50	157.50	150.00
	2500 r	140.00	155.00	155.00
V_3	Control	105.00	149.00	95.00
	500 r	122.50	157.00	125.00
	1000 r	128.50	160.50	132.50
	1500 r	135.00	166.00	140.00
	2000 r	130.00	160.00	140.00
	2500 r	145.00	166.50	141.00

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Pooted tubers
Treatments	1.165	1.091	16.929**	63.329	34.329	18.628
Varieties	6.476**	2.369	88.247**	25.854	14.015	7.605
Exposures	1.099	2.409	20.758**	36.564	19.619	10.755
Inter-action	0.136	0.176	0.752	63.329	34.329	18.628

** Significant at 1% level

V_2 it ranged from 13.05 cm in rooted cuttings to 16.15 cm in rooted tubers. The mean values in V_3 ranged from 14.05 to 17.25 cm in fresh cuttings and rooted cuttings respectively.

In the case of fresh cuttings the mean values in V_1 ranged from 19.40 cm in 2500 r to 20.20 cm in 1500 r. In V_2 the range was from 15.70 to 18.30 cm in control and 1500 r respectively. In V_3 it ranged from 14.05 cm in control to 16.75 cm in 2500 r.

In rooted cuttings the mean tuber length in V_1 ranged from 20.25 cm in control to 22.00 cm in 1500 r. In V_2 it ranged from 13.05 to 15.40 cm in control and 2500 r respectively. The mean values in V_3 ranged from 17.25 cm in control to 18.65 cm in 1500 r.

In rooted tubers the mean tuber length in V_1 differed from 17.30 to 19.20 cm in control and 2500 r respectively. In V_2 it ranged from 16.15 cm in control to 18.00 cm in 2500 r. The mean values in V_3 ranged from 17.10 cm in control to 18.60 cm in 2500 r.

In gamma ray exposed population the mean tuber length in V_1 ranged from 17.42 cm in 500 r of rooted tubers to 22.00 cm in 1500 r of rooted cuttings. In V_2 it ranged from 14.15 cm in 500 r of rooted cuttings to 18.30 cm in 1500 r

Table 30. Length of tuber (cm)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	19.55	20.25	17.30
	500 r	19.50	21.35	17.42
	1000 r	20.00	21.50	17.67
	1500 r	20.20	22.00	18.57
	2000 r	19.55	21.35	18.80
	2500 r	19.40	21.25	19.20
V_2	Control	15.70	13.05	16.15
	500 r	17.50	14.15	16.25
	1000 r	17.60	14.60	16.35
	1500 r	18.30	14.75	17.45
	2000 r	17.35	15.10	17.80
	2500 r	17.75	15.40	18.00
V_3	Control	14.05	17.25	17.10
	500 r	14.85	17.60	17.25
	1000 r	16.00	18.00	17.50
	1500 r	16.20	18.65	18.40
	2000 r	16.50	18.35	18.55
	2500 r	16.75	18.25	18.60

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	3.129*	14.425**	3.916**	3.110	2.288	2.041
Varieties	21.946**	117.142**	22.622**	1.269	0.934	0.833
Exposures	1.214	1.804	4.092*	1.796	1.321	1.179
Inter-action	0.322	0.192	0.086	3.110	2.288	2.041

* Significant at 5% level

** Significant at 1% level

of fresh cuttings. The mean values in V_3 ranged from 14.85 cm in 500 r of fresh cuttings to 18.65 cm in 1500 r of rooted cuttings.

7. Girth of tuber

The effect of gamma rays on mean girth of tuber in three sweet potato varieties is presented in Table 31. Statistical analysis of the data showed significant variation among treatments, varieties and exposures in all the three modes of treatment.

The mean values in V_1 control ranged from 10.55 cm in rooted tubers to 16.50 cm in fresh cuttings. In V_2 it differed from 12.80 to 14.10 cm in rooted cuttings and fresh cuttings respectively while in V_3 it ranged from 9.25 cm in rooted tubers to 12.75 cm in fresh cuttings.

In fresh cuttings the mean values in V_1 differed from 16.50 cm (control) to 17.30 cm (1500 and 2000 r). In V_2 the range was from 14.10 to 16.00 cm in control and 2500 r respectively. The mean tuber girth in V_3 ranged from 12.75 cm in control to 14.00 cm in 1500 r.

In the case of rooted cuttings the mean values in V_1 ranged from 13.50 cm in control to 15.10 cm in 1500 r. In V_2 it ranged from 12.80 to 14.50 cm in control and 2000 r respectively. The mean values in V_3 ranged from 11.30 cm in control to 13.20 cm in 2000 r.

In rooted tubers the mean values in V_1 ranged from 10.55 to 11.85 cm in control and 1500 r respectively. In V_2 the range was from 13.60 cm in control to 17.00 cm in 1500 r while in V_3 it differed from 9.25 cm in control to 10.60 cm in 1500 r.

Among the treated population tuber girth of V_1 showed the lowest value (11.00 cm) in 500 r of rooted tubers and the highest value (17.30 cm) in 1500 and 2000 r of fresh cuttings. In V_2 these values were 13.50 cm in 500 r of rooted cuttings and 17.00 cm in 1500 r of rooted tubers respectively. In V_3 it was minimum (9.40 cm) in 2500 r of rooted tubers and maximum (14.00 cm) in 1500 r of fresh cuttings.

8. Volume of tuber

The mean volume of tuber as influenced by gamma rays is depicted in Table 32. Statistical analysis of the data showed significant variation among treatments, varieties and exposures in rooted tubers. Fresh cuttings gave significant difference among the varieties only.

The mean volume in V_1 control population ranged from 67.50 cm^3 in rooted tubers to 144.00 cm^3 in fresh cuttings. In V_2 the mean values in control ranged from 84.00 to

Table 31. Girth of tuber (cm)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	16.50	13.50	10.55
	500 r	16.65	14.75	11.00
	1000 r	16.65	15.05	11.45
	1500 r	17.30	15.10	11.85
	2000 r	17.30	14.75	11.75
	2500 r	17.25	14.50	11.75
V_2	Control	14.10	12.80	13.60
	500 r	14.65	13.50	16.45
	1000 r	15.25	13.75	16.85
	1500 r	15.35	14.20	17.00
	2000 r	15.95	14.50	16.65
	2500 r	16.00	14.25	15.40
V_3	Control	12.75	11.30	9.25
	500 r	13.05	12.10	9.80
	1000 r	13.05	12.20	10.40
	1500 r	14.00	12.90	10.60
	2000 r	13.75	13.20	9.80
	2500 r	13.20	12.75	9.40

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	18.614**	9.289**	19.644**	1.118	1.087	1.883
Varieties	141.882**	56.315**	152.875**	0.456	0.444	0.768
Exposures	5.089**	7.859**	3.877*	0.645	0.628	1.087
Inter-action	0.722	0.599	0.881	1.118	1.087	1.883

* Significant at 5% level

** Significant at 1% level

119.00 cm^3 in fresh cuttings and rooted cuttings respectively. In V_3 control it was 90.00 cm^3 in rooted tubers and 143.00 cm^3 in rooted cuttings.

In fresh cuttings the mean values in V_1 differed from 144.00 to 180.00 cm^3 in control and 2500 r respectively. In V_2 it ranged from 84.00 cm^3 in control and 131.50 cm^3 in 2500 r. In V_3 it differed from 98.00 cm^3 in control to 133.50 cm^3 in 2500 r.

In the case of rooted cuttings the mean tuber volume in V_1 ranged from 124.00 cm^3 in control to 155.00 cm^3 in 2500 r while in V_2 the range was from 119.00 to 145.00 cm^3 in control and 2500 r respectively. The mean values in V_3 differed from 143.00 cm^3 in control to 156.00 cm^3 in 2500 r.

In rooted tubers the mean values in V_1 ranged from 67.50 cm^3 in control to 94.00 cm^3 in 2000 r. In V_2 the range was from 90.00 to 138.00 cm^3 in control and 2500 r respectively. The mean values in V_3 ranged from 90.00 cm^3 in control to 133.00 cm^3 in 2000 and 2500 r.

In gamma ray exposed population the mean tuber volume in V_1 ranged from 84.00 cm^3 in 500 r of rooted tubers to 180.00 cm^3 in 2500 r of fresh cuttings. The mean values in V_2 differed from 93.50 cm^3 in 500 r of fresh cuttings to 145.00 cm^3 in 2500 r of rooted cuttings. In V_3 the range

Table 32. Volume of tuber (cm^3)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	144.00	124.00	67.50
	500 r	148.00	134.00	84.00
	1000 r	152.50	137.00	90.00
	1500 r	155.00	142.50	90.00
	2000 r	157.50	148.00	94.00
	2500 r	180.00	155.00	88.50
V_2	Control	84.00	119.00	90.00
	500 r	93.50	129.50	120.00
	1000 r	98.00	137.50	129.50
	1500 r	115.00	141.50	130.00
	2000 r	124.50	134.00	135.00
	2500 r	131.50	145.00	138.00
V_3	Control	98.00	143.00	90.00
	500 r	113.00	146.00	114.00
	1000 r	120.50	148.50	122.50
	1500 r	126.50	151.00	129.00
	2000 r	127.50	153.00	133.00
	2500 r	133.50	156.00	133.00

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	1.501	0.636	21.811**	56.924	39.009	14.438
Varieties	8.979**	2.062	113.558**	23.239	15.925	5.894
Exposures	1.248	1.139	26.622**	32.865	22.521	8.336
Interaction	0.132	0.098	1.056	56.924	39.009	14.438

** Significant at 1% level

was from 113.00 to 156.00 cm^3 in 500 r of fresh cuttings and 2500 r of rooted cuttings respectively.

9. Tuber yield per vine

The effect of gamma rays on mean tuber yield per vine in three sweet potato varieties is presented in Table 33 and Fig. 26. Statistical analysis of the data showed significant variation among treatments, varieties and exposures in all the three modes of treatment.

The mean tuber yield in V_1 control ranged from 74.00 g in rooted tubers to 330.00 g in fresh cuttings. In V_2 the mean values in control population differed from 112.00 g in rooted tubers to 180.00 g in fresh cuttings. In V_3 control the range was from 207.50 to 282.00 g in rooted tubers and rooted cuttings respectively.

In fresh cuttings the mean values in V_1 ranged from 330.00 g in control to 432.00 g in 1500 r. In V_2 the range was from 180.00 to 321.50 g in control and 2500 r respectively while in V_3 it ranged from 210.00 g in control to 382.00 g in 2500 r.

In rooted cuttings the mean tuber yield in V_1 ranged from 265.00 g in 500 r to 450.00 g in 2500 r. In V_2 it ranged from 162.50 g in control to 381.00 g in 2500 r. The

Table 33. Tuber yield per vine (g)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	330.00	267.00	74.00
	500 r	371.00	265.00	180.50
	1000 r	403.00	367.00	216.00
	1500 r	432.00	375.50	171.00
	2000 r	403.00	440.00	201.50
	2500 r	410.00	450.00	177.00
V_2	Control	180.00	162.50	112.00
	500 r	200.00	268.00	225.00
	1000 r	207.00	293.50	233.50
	1500 r	254.00	320.00	187.50
	2000 r	305.00	362.50	255.50
	2500 r	321.50	381.00	255.00
V_3	Control	210.00	282.00	207.50
	500 r	245.00	358.00	272.50
	1000 r	314.50	384.00	323.00
	1500 r	325.00	378.50	306.50
	2000 r	344.00	408.00	295.50
	2500 r	382.00	416.50	279.00

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	2.382*	3.082*	11.211**	155.413	126.301	58.430
Varieties	12.094**	5.295*	48.923**	63.447	51.562	23.854
Exposures	2.745	7.547**	16.545**	89.728	72.920	33.735
Interaction	0.258	0.415	11.001	155.413	126.301	58.430

* Significant at 5% level

** Significant at 1% level

mean values in V_3 ranged from 282.00 to 416.50 g in control and 2500 r respectively.

In the case of rooted tubers the mean values in V_1 ranged from 74.00 g in control to 216.00 g in 1000 r. In V_2 it ranged from 112.00 g (control) to 255.50 g (2000 r). In V_3 the range was from 207.50 to 323.00 g in control and 1000 r respectively.

Among the treated population the mean tuber yield in V_1 ranged from 171.00 g in 1500 r of rooted tubers to 450.00 g in 2500 r of rooted cuttings. In V_2 the range was from 187.50 to 381.00 g in 1500 r of rooted tubers and 2500 r of rooted cuttings respectively. V_3 showed the lowest value (245.00 g) in 500 r of fresh cuttings and the highest value (416.50 g) in 2500 r of rooted cuttings.

10. Frequency distribution of variants in vM_2 generation

Exposure to gamma rays induced both negative and positive variants compared to control values in all the growth parameters in the three varieties tested irrespective of the three types of materials used viz. fresh cuttings, rooted cuttings and rooted tubers. Statistical analysis of the data showed no significant variation either in the frequency of negative variants or positive variants in any of the characters. (Tables 34 - 42).

1. Length of vine at harvest

The frequency of negative variants in V_1 for fresh cuttings ranged from 27.50 per cent in 1500 r to 38.50 per cent in 500 r. In rooted cuttings it ranged from 41.80 per cent in 1500 r to 54.00 per cent in 500 r. In rooted tubers the range was from 42.00 per cent in 500 r to 57.75 per cent in 2500 r. In V_2, for fresh cuttings the frequency ranged from 33.30 per cent in 1500 r to 49.20 per cent in 2500 r. In rooted cuttings it ranged from 32.25 per cent in 500 r to 62.50 per cent in 2500 r. In rooted tubers the range was from 39.90 per cent in 1000 r to 47.85 per cent in 500 r. In V_3 the frequency of negative variants for fresh cuttings ranged from 43.40 per cent in 1500 r to 54.30 per cent in 2500 r. In rooted cuttings it ranged from 27.80 per cent in 2000 r to 46.75 per cent in 2500 r. The frequency of negative variants in rooted tubers ranged from 36.50 per cent in 2500 r to 46.10 per cent in 500 r.

The frequency of positive variants in V_1 for fresh cuttings ranged from 17.95 per cent in 2500 r to 27.85 per cent in 1000 r. In rooted cuttings the range was from 6.75 to 18.10 per cent in 2000 and 1500 r respectively. In rooted tubers the frequency of positive variants ranged from 34.00 per cent in 2000 r to 41.80 per cent in 1000 r. In V_2 the frequency of positive variants for fresh cuttings ranged

Table 34. Frequency distribution of vine length variants in vM_2 generation (per cent)

Varieties	Treatments	Fresh cuttings			Rooted cuttings			Rooted tubers		
		Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants
V_1	500 r	38.50	34.00	27.50	54.00	35.00	11.00	42.00	19.60	38.40
	1000 r	37.05	35.10	27.85	47.30	41.40	11.30	45.05	13.15	41.80
	1500 r	27.50	49.15	23.35	41.80	40.10	18.10	50.00	10.00	40.00
	2000 r	30.95	47.65	21.40	48.25	45.00	6.75	55.00	11.00	34.00
	2500 r	36.15	45.90	17.95	47.00	37.25	15.75	57.75	5.50	36.75
V_2	500 r	38.35	24.15	37.50	32.25	45.90	21.85	47.85	39.50	20.65
	1000 r	34.90	30.75	34.35	37.50	40.80	21.70	39.90	29.60	30.50
	1500 r	33.30	38.40	28.30	34.80	47.95	17.25	46.85	28.05	25.10
	2000 r	44.10	36.70	19.20	50.25	37.75	12.00	43.95	43.95	16.10
	2500 r	49.20	34.75	16.05	62.50	31.00	6.50	43.00	37.00	20.00
V_3	500 r	51.05	33.65	15.30	33.50	35.55	30.95	46.10	34.65	19.25
	1000 r	45.70	40.20	14.10	28.35	41.80	29.85	43.10	34.50	22.40
	1500 r	43.40	38.95	17.65	35.60	47.35	17.05	41.20	34.75	24.05
	2000 r	50.20	38.00	11.80	27.80	61.30	10.90	43.80	28.25	27.95
	2500 r	54.30	31.05	14.65	46.75	41.65	11.60	36.50	35.75	27.75

	F value		
	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	0.032	0.049	0.043
Varieties	0.140	0.105	0.241
Exposures	0.028	0.062	0.022
Interaction	0.008	0.029	0.004

from 16.05 per cent in 2500 r to 37.50 per cent in 500 r. In rooted cuttings the range was from 6.50 to 21.85 per cent in 2500 and 500 r respectively. The frequency of positive variants in rooted tubers ranged from 16.10 per cent in 2000 r to 30.50 per cent in 1000 r. The frequency of positive variants in V_3 for fresh cuttings ranged from 11.80 per cent in 2000 r to 17.65 per cent in 1500 r. In rooted cuttings it ranged from 10.90 to 30.95 per cent in 2000 and 500 r respectively. In rooted tubers the range was from 19.25 per cent in 500 r to 27.95 per cent in 2000 r.

2. Number of branches per vine

The frequency of negative variants in V_1 for fresh cuttings ranged from 10.00 per cent (1000 and 1500 r) to 19.00 per cent (500 r). In rooted cuttings it ranged from 20.50 per cent (1500 r) to 27.50 per cent (500 r). In rooted tubers it ranged from 17.50 per cent in 2500 r to 28.00 per cent in 500 r. In V_2 the frequency of negative variants for fresh cuttings ranged from 12.00 per cent in 2500 r to 15.50 per cent in 500 r. In rooted cuttings the range was from 17.00 per cent in 2000 r to 25.00 per cent in 500 r. In rooted tubers the range was from 15.50 to 20.00 per cent in 500 and 2500 r respectively. The frequency of negative variants in V_3 for fresh cuttings ranged from 15.00 per cent in 1000 r to 22.50 per cent in 2000 r. In rooted cuttings it ranged from 21.00 per cent in 2500 r to 31.00 per cent in 2000 r. In rooted tubers it ranged from 16.00 per cent in 500 r to 20.50 per cent in 2500 r.

The frequency of positive variants in V_1 for fresh cuttings ranged from 7.50 per cent (1500 and 2000 r) to 13.00 per cent (500 r). In rooted cuttings it ranged from 10.00 per cent in 2500 r to 17.50 per cent in 500 r. In rooted tubers it ranged from 6.50 to 13.50 per cent in 2500 and 500 r respectively. In V_2 for fresh cuttings it ranged from 10.00 per cent in 2500 r to 20.50 per cent in 500 r. In rooted cuttings it ranged from 29.00 per cent in 2000 r to 44.50 per cent in 1500 r. In rooted tubers the range was from 19.50 to 25.00 per cent in 2000 and 500 r respectively. In V_3 the frequency of positive variants for fresh cuttings ranged from 13.00 per cent in 500 r to 21.00 per cent in 1000 r. In rooted cuttings the range was from 30.00 per cent in 2000 r to 35.50 per cent in 1000 r. In rooted tubers the frequency of positive variants ranged from 10.50 per cent in 1500 r to 15.00 per cent in 2000 r.

3. Fresh weight of vine

The frequency of negative variants in V_1 for fresh cuttings ranged from 38.50 per cent (1500 r) to 42.50 per cent (1000 and 2500 r). In rooted cuttings it ranged from 8.50 per cent in 1500 r to 16.00 per cent in 2000 r. In rooted

Table 35. Frequency distribution of branch number variants in vM_2 generation (per cent)

Varieties	Treatments	Fresh cuttings			Rooted cuttings			Rooted tubers		
		Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants
V_1	500 r	19.00	68.00	13.00	27.50	55.00	17.50	28.00	58.50	13.50
	1000 r	10.00	84.00	6.00	21.00	65.50	13.50	26.00	62.50	11.50
	1500 r	10.00	82.50	7.50	20.50	63.50	16.00	24.50	64.00	10.50
	2000 r	18.50	74.00	7.50	24.00	65.00	11.00	20.00	69.50	10.50
	2500 r	15.50	74.00	10.50	22.50	67.50	10.00	17.50	76.00	6.50
V_2	500 r	15.50	64.00	20.50	25.00	34.50	40.50	15.50	59.50	25.00
	1000 r	14.00	69.50	16.50	20.00	42.50	37.50	19.50	57.00	23.50
	1500 r	15.00	65.00	20.00	23.00	32.50	44.50	19.50	60.00	20.50
	2000 r	15.00	69.00	16.00	17.00	54.00	29.00	17.00	63.50	19.50
	2500 r	12.00	78.00	10.00	22.00	45.00	33.00	20.00	57.50	22.50
V_3	500 r	17.00	70.00	13.00	24.50	44.50	31.00	16.00	70.50	13.50
	1000 r	15.00	64.00	21.00	23.50	41.00	35.50	16.50	70.00	13.50
	1500 r	16.50	68.50	15.00	25.00	42.50	32.50	18.50	71.00	10.50
	2000 r	22.50	61.50	16.00	31.00	39.00	30.00	17.00	68.00	15.00
	2500 r	19.50	65.00	15.50	21.00	47.50	31.50	20.50	67.00	12.50

	F value		
	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	0.007	0.039	0.018
Varieties	0.023	0.225	0.105
Exposures	0.007	0.002	0.004
Interaction	0.003	0.011	0.003

tubers the range was from 14.00 to 31.00 per cent in 1000 and 2500 r respectively. In V_2 for fresh cuttings it ranged from 10.00 per cent in 2000 r to 19.00 per cent in 1500 r. In rooted cuttings the frequency of negative variants ranged from 23.50 per cent in 1500 r to 30.00 per cent in 2000 r. In rooted tubers the range was from 28.00 to 35.00 per cent in 500 and 2000 r respectively. The frequency of negative variants in V_3 for fresh cuttings ranged from 13.50 per cent in 1500 r to 29.00 per cent in 2500 r. In rooted cuttings the range was from 10.50 per cent in 2500 r to 18.00 per cent in 1500 r. In rooted tubers it ranged from 30.50 per cent in 500 r to 37.00 per cent in 1500 r.

The frequency of positive variants in V_1 for fresh cuttings ranged from 17.50 per cent (2000 r) to 22.00 per cent (500 and 1000 r). In rooted cuttings it ranged from 25.00 per cent (2500 r) to 30.00 per cent (500 and 1000 r). In rooted tubers the frequency ranged from 13.50 per cent in 2000 r to 21.00 per cent in 1000 r. In V_2 the frequency of positive variants for fresh cuttings ranged from 19.00 per cent in 1500 r to 28.50 per cent in 500 r. In rooted cuttings it ranged from 8.50 per cent in 2500 r to 11.50 per cent in 500 r. In rooted tubers the range was from 5.50 per cent in 2500 r to 10.00 per cent in 1500 r. In V_3 the frequency of positive variants for fresh cuttings ranged from 16.00 per cent

Table 36. Frequency distribution of fresh weight variants in vM_2 generation (per cent)

Varieties	Treatments	Fresh cuttings			Rooted cuttings			Rooted tubers		
		Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants
V_1	500 r	39.0	39.0	22.0	12.0	58.0	30.0	18.0	66.0	16.0
	1000 r	42.5	36.5	22.0	11.5	58.5	30.0	14.0	65.0	21.0
	1500 r	38.5	42.5	19.0	8.5	64.5	27.0	22.0	64.0	14.0
	2000 r	39.0	43.5	17.5	16.0	56.5	27.5	26.0	60.5	13.5
	2500 r	42.5	39.5	18.0	10.0	65.0	25.0	31.0	51.0	18.0
V_2	500 r	13.0	58.5	28.5	29.0	59.5	11.5	28.0	63.0	9.0
	1000 r	10.5	64.5	25.0	25.0	66.0	9.0	30.5	60.5	9.0
	1500 r	19.0	62.0	19.0	23.5	66.5	10.0	33.0	57.0	10.0
	2000 r	10.0	62.5	27.5	30.0	59.5	10.5	35.0	57.0	8.0
	2500 r	11.5	55.0	25.0	28.0	63.5	8.5	34.0	60.5	5.5
V_3	500 r	23.0	60.0	17.0	11.0	69.0	20.0	30.5	60.5	9.0
	1000 r	18.5	62.0	24.5	13.5	68.0	18.5	33.5	56.5	10.0
	1500 r	13.5	65.5	21.0	18.0	66.0	16.0	37.0	55.0	8.0
	2000 r	17.0	64.0	19.0	11.0	72.0	17.0	34.0	58.5	7.5
	2500 r	29.0	55.0	16.0	10.5	76.5	13.0	35.0	59.0	6.0

	F value		
	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	0.050	0.060	0.031
Varieties	0.297	0.402	0.166
Exposures	0.006	0.003	0.019
Interaction	0.011	0.003	0.003

in 2500 r to 24.50 per cent in 1000 r. In rooted cuttings the range was from 13.00 to 20.00 per cent in 2500 and 500 r respectively. In rooted tubers it ranged from 6.00 per cent in 2500 r to 10.00 per cent in 1000 r.

4. Number of tubers per vine

The frequency of negative variants in V_1 for fresh cuttings ranged from 8.50 per cent in 2500 r to 23.30 per cent in 500 r. In rooted cuttings it ranged from 9.50 per cent in 2500 r to 24.25 per cent in 1000 r. In rooted tubers it ranged from 21.00 per cent in 2000 r to 29.50 per cent in 500 r. In V_2 for fresh cuttings the frequency of negative variants ranged from 11.30 to 24.80 per cent in 2500 and 500 r respectively. In rooted cuttings it ranged from 12.55 per cent in 2500 r to 26.80 per cent in 1500 r. In rooted tubers the range was from 31.25 per cent in 500 r to 37.10 per cent in 1000 r. The frequency of negative variants in V_3 for fresh cuttings ranged from 16.60 per cent in 2000 r to 28.00 per cent in 500 r. In rooted cuttings it ranged from 6.50 per cent in 2000 r to 24.90 per cent in 500 r. In rooted tubers the frequency of negative variants ranged from 30.54 to 36.20 per cent in 500 and 2500 r respectively.

The frequency of positive variants in V_1 for fresh cuttings ranged from 44.65 per cent in 500 r to 62.90 per cent

in 2500 r. In rooted cuttings it ranged from 26.40 per cent in 1000 r to 50.00 per cent in 2000 r. In rooted tubers the range was from 16.70 to 23.75 per cent in 500 and 2500 r respectively. In V_2 the frequency of positive variants for fresh cuttings ranged from 27.90 per cent in 500 r to 50.40 per cent in 2000 r. In rooted cuttings the range was from 25.35 to 34.90 per cent in 1000 and 2500 r respectively. In rooted tubers it ranged from 19.50 per cent in 500 r to 23.00 per cent in 2500 r. The frequency of positive variants in V_3 for fresh cuttings ranged from 41.30 per cent in 500 r to 48.25 per cent in 2000 r. In rooted cuttings it ranged from 39.90 per cent in 1500 r to 49.90 per cent in 2000 r. In rooted tubers the range was from 28.00 to 37.00 per cent in 500 and 2500 r respectively.

5. Weight of tuber

The frequency of negative variants in V_1 for fresh cuttings ranged from 21.00 per cent in 2000 r to 35.50 per cent in 1000 r. In rooted cuttings it ranged from 20.00 per cent (2000 and 2500 r) to 29.50 per cent (1000 r). In rooted tubers the range was from 25.50 per cent in 500 r to 33.00 per cent in 1500 and 2000 r. In V_2 the frequency of negative variants for fresh cuttings ranged from 7.00 per cent in 2500 r to 15.00 per cent in 500 and 1000 r. In rooted cuttings the range was from 11.00 to 23.00 per cent in 2000 and 1000 r

Table 37. Frequency distribution of tuber number variants in vM_2 generation (per cent)

Varieties	Treatments	Fresh cuttings			Rooted cuttings			Rooted tubers		
		Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants
V_1	500 r	23.30	32.05	44.65	16.20	38.60	45.20	29.50	53.80	16.70
	1000 r	19.25	31.65	49.10	24.25	49.35	26.40	27.30	54.55	18.15
	1500 r	15.70	39.25	45.05	18.65	52.60	28.75	27.40	54.55	18.05
	2000 r	10.90	35.90	53.20	13.70	36.30	50.00	21.00	57.50	21.50
	2500 r	8.50	28.60	62.90	9.50	43.90	46.60	22.50	54.25	23.75
V_2	500 r	24.30	47.30	27.90	16.75	56.95	26.30	31.25	49.25	19.50
	1000 r	19.10	42.40	38.50	15.00	59.65	25.35	37.10	42.20	20.70
	1500 r	18.65	45.50	35.85	26.80	42.25	30.95	35.40	42.25	22.35
	2000 r	11.35	38.25	50.40	13.00	55.20	31.80	33.80	44.10	22.10
	2500 r	11.30	39.80	48.90	12.55	52.55	34.90	31.40	45.60	23.00
V_3	500 r	28.00	30.70	41.30	24.90	32.25	42.85	30.54	41.15	28.00
	1000 r	19.60	37.30	43.10	15.00	41.00	44.00	31.90	36.90	31.20
	1500 r	21.85	33.75	44.40	19.15	40.95	39.90	32.00	33.00	35.00
	2000 r	16.60	35.15	48.25	6.50	43.60	49.90	31.50	32.50	36.00
	2500 r	19.85	32.30	47.35	7.80	46.75	45.45	36.20	26.80	37.00

	F value		
	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	0.028	0.035	0.008
Varieties	0.041	0.068	0.035
Exposures	0.066	0.065	0.005
Interaction	0.005	0.012	0.002

respectively. In rooted tubers it ranged from 9.00 per cent in 2500 r to 18.00 per cent in 500 r. In V_3 the frequency of negative variants for fresh cuttings ranged from 14.00 per cent in 2500 r to 25.00 per cent in 500 r. In rooted cuttings it ranged from 20.00 to 31.00 per cent in 2500 and 500 r respectively. In rooted tubers the range was from 13.00 per cent in 2500 r to 24.00 per cent in 500 r.

The frequency of positive variants in V_1 for fresh cuttings ranged from 10.00 per cent in 500 r to 14.00 per cent in 2500 r. In rooted cuttings it ranged from 16.50 per cent in 1000 r to 20.50 per cent in 1500 r. In rooted tubers the range was from 7.50 to 12.50 per cent in 1500 and 2500 r respectively. In V_2 the frequency of positive variants for fresh cuttings ranged from 14.00 per cent in 500 r to 17.50 per cent in 2000 r. In rooted cuttings the range was from 18.50 to 25.00 per cent in 1000 and 2500 r respectively. In rooted tubers it ranged from 12.50 per cent in 500 r to 17.00 per cent in 2000 r. In V_3 for fresh cuttings the frequency of positive variants ranged from 4.50 per cent in 500 r to 12.00 per cent in 2500 r. In rooted cuttings the range was from 9.00 per cent in 500 r to 14.00 per cent in 2500 r. In rooted tubers it ranged from 7.50 per cent in 500 r to 12.50 per cent in 2500 r.

Table 38. Frequency distribution of tuber weight variants in vM_2 generation (per cent)

Varieties	Treatments	Fresh cuttings			Rooted cuttings			Rooted tubers		
		Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants
V_1	500 r	33.5	56.5	10.0	28.0	55.0	17.0	25.5	66.5	8.0
	1000 r	35.5	53.5	11.0	29.5	54.0	16.5	23.5	63.5	8.0
	1500 r	27.0	61.0	12.0	24.5	55.0	20.5	33.0	59.5	7.5
	2000 r	21.0	67.0	12.0	20.0	62.5	17.5	33.0	56.0	11.0
	2500 r	21.5	64.5	14.0	20.0	60.5	19.5	27.0	60.5	12.5
V_2	500 r	15.0	71.0	14.0	21.0	60.0	19.0	18.0	69.5	12.5
	1000 r	15.0	70.0	15.0	23.0	58.5	18.5	15.5	70.0	14.5
	1500 r	11.0	72.5	16.5	20.0	59.0	21.0	13.0	73.0	14.0
	2000 r	9.0	73.5	17.5	11.0	65.0	24.0	12.5	73.5	17.0
	2500 r	7.0	76.5	16.5	13.5	61.5	25.0	9.0	75.5	15.5
V_3	500 r	25.0	70.5	4.5	31.0	65.0	9.0	24.0	68.5	7.5
	1000 r	22.0	71.0	7.0	26.5	64.0	9.5	23.0	68.0	9.0
	1500 r	17.0	76.0	7.0	25.0	64.0	11.0	20.0	71.0	9.0
	2000 r	15.0	73.5	11.5	22.0	67.0	11.0	16.0	72.0	12.0
	2500 r	14.0	74.0	12.0	20.0	66.0	14.0	13.0	74.5	12.5

	F value		
	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	0.039	0.024	0.032
Varieties	0.171	0.096	0.172
Exposures	0.048	0.032	0.017
Interaction	0.002	0.001	0.005

6. Length of tuber

The frequency of negative variants in V_1 for fresh cuttings ranged from 18.50 per cent in 1500 r to 23.50 per cent in 1000 r. In rooted cuttings the range was from 10.00 per cent in 2500 r to 16.50 per cent in 500 r. In rooted tubers the range was from 15.00 per cent (2000 and 2500 r) to 25.00 per cent (1000 r). In V_2 the frequency of negative variants for fresh cuttings ranged from 16.00 to 25.00 per cent in 1000 and 2500 r respectively. In rooted cuttings the range was from 6.50 per cent in 2500 r to 18.00 per cent in 1000 r. In rooted tubers the range was from 6.00 per cent (2000 and 2500 r) to 16.00 per cent (1000 r). In V_3, for fresh cuttings the negative variants ranged from 21.50 per cent to 38.00 per cent in 2500 and 500 r respectively. In rooted cuttings the range was from 10.00 per cent in 1500 r to 20.00 per cent in 500 r. In rooted tubers it ranged from 9.00 per cent in 1500 r to 19.00 per cent in 2500 r.

The frequency of positive variants in V_1 for fresh cuttings ranged from 7.50 per cent in 1000 r to 15.00 per cent in 2000 r. In rooted cuttings the range was from 12.00 per cent in 2500 r to 21.00 per cent in 1500 r. In rooted tubers it ranged from 12.00 per cent in 500 r to 22.00 per cent in 2000 r. In V_2 for fresh cuttings the frequency of positive variants ranged from 10.00 per cent in 1000 r to 20.00 per cent

Table 39. Frequency distribution of tuber length variants in vM_2 generation (per cent)

Varieties	Treatments	Fresh cuttings			Rooted cuttings			Rooted tubers		
		Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants
V_1	500 r	23.00	65.00	12.00	16.50	71.50	12.50	23.00	65.00	12.00
	1000 r	23.50	69.00	7.50	13.00	70.00	17.00	25.00	60.50	14.50
	1500 r	18.50	72.00	9.50	15.00	64.00	21.00	21.00	60.50	18.50
	2000 r	22.50	62.50	15.00	12.50	73.50	14.00	15.00	63.00	22.00
	2500 r	20.50	65.50	14.00	10.00	78.00	12.00	15.00	68.00	17.00
V_2	500 r	18.00	68.00	14.00	13.00	76.50	10.50	15.50	71.50	13.00
	1000 r	16.00	74.00	10.00	18.00	70.50	11.50	16.00	68.00	16.00
	1500 r	20.00	60.00	20.00	9.50	75.00	15.50	12.00	68.00	20.00
	2000 r	21.50	63.50	15.00	13.00	70.00	17.00	6.00	73.00	23.00
	2500 r	25.00	59.00	16.00	6.50	79.00	14.50	6.00	76.00	18.00
V_3	500 r	38.00	51.00	11.00	20.00	69.00	11.00	15.00	76.00	9.00
	1000 r	33.00	58.00	9.00	19.00	62.50	18.50	16.00	73.00	11.00
	1500 r	30.00	56.00	14.00	10.00	70.00	20.00	9.00	80.00	11.00
	2000 r	26.00	62.00	12.00	13.00	70.00	17.00	13.00	72.00	15.00
	2500 r	21.50	68.50	10.00	11.00	74.00	15.00	19.00	70.00	11.00

	F value		
	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	0.019	0.019	0.026
Varieties	0.100	0.092	0.043
Exposures	0.002	0.016	0.056
Interaction	0.008	0.003	0.006

in 1500 r. In rooted cuttings the range was from 10.50 per cent in 500 r to 17.00 per cent in 2000 r. In rooted tubers it ranged from 13.00 per cent in 500 r to 23.00 per cent in 2000 r. In V_3 for fresh cuttings the frequency of positive variants ranged from 9.00 per cent in 1000 r to 14.00 per cent in 1500 r. In rooted cuttings the range was from 11.00 per cent in 500 r to 20.00 per cent in 1500 r. In rooted tubers the range was from 9.00 per cent in 500 r to 15.00 per cent in 2000 r.

7. Girth of tuber

The frequency of negative variants in V_1 for fresh cuttings ranged from 5.00 per cent in 1500 r to 9.50 per cent in 1000 r. In rooted cuttings it ranged from 6.00 per cent in 2000 r to 23.00 per cent in 500 r. In rooted tubers the range was from 8.00 per cent (1000 and 2500 r) to 11.50 per cent (2000 r). In V_2 the frequency of negative variants in fresh cuttings ranged from 4.00 per cent in 1500 r to 11.50 per cent in 500 r. In rooted cuttings it ranged from 5.50 per cent in 2500 r to 14.00 per cent in 500 r. In rooted tubers the range was from 6.00 per cent (500 and 2000 r) to 8.50 per cent (1000 r). In V_3 the frequency of negative variants for fresh cuttings ranged from 2.50 per cent (2500 r) to 8.50 per cent (1000 r). In rooted cuttings it ranged from 25.00 per cent in 500 r to 32.50 per cent in 2500 r. In rooted tubers the range was from 5.50 to 17.50 per cent in 1000 and 2000 r respectively.

The frequency of positive variants in V_1 for fresh cuttings ranged from 11.00 per cent (500 and 2000 r) to 14.00 per cent (2500 r). In rooted cuttings it ranged from 23.00 per cent in 1000 r to 30.00 per cent in 2000 r. In rooted tubers the range was from 12.00 per cent in 500 r to 16.00 per cent in 1000 and 2000 r. In V_2 the frequency of positive variants for fresh cuttings ranged from 12.00 to 16.00 per cent in 500 and 1500 r respectively. In rooted cuttings the range was from 14.00 per cent in 1000 r to 20.00 per cent in 2000 r. In rooted tubers it ranged from 7.00 per cent in 500 r to 15.00 per cent in 1500 r. In V_3 the frequency of positive variants for fresh cuttings ranged from 8.50 per cent in 500 r to 13.00 per cent in 2000 r. In rooted cuttings the range was from 12.50 per cent in 2500 r to 18.00 per cent in 1500 r. In rooted tubers it ranged from 11.00 to 18.50 per cent in 2500 and 1500 r respectively.

8. Volume of tuber

The frequency of negative variants in V_1 for fresh cuttings ranged from 18.50 per cent in 1000 r to 24.00 per cent in 1500 r. In rooted cuttings it ranged from 31.00 per cent in 2500 r to 38.00 per cent in 500 r. In rooted tubers

Table 40. Frequency distribution of tuber girth variants in vM_2 generation (per cent)

Varieties	Treatments	Fresh cuttings			Rooted cuttings			Rooted tubers		
		Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants
V_1	500 r	6.00	83.00	11.00	23.00	52.50	24.50	10.00	78.00	12.00
	1000 r	9.50	78.00	12.50	16.50	60.50	23.00	8.00	76.00	16.00
	1500 r	5.00	83.00	12.00	7.00	64.00	27.00	10.00	76.00	14.00
	2000 r	8.00	81.00	11.00	6.00	64.00	30.00	11.50	72.50	16.00
	2500 r	8.00	78.00	14.00	10.00	63.50	26.50	8.00	76.50	15.50
V_2	500 r	11.50	76.50	12.00	14.00	68.00	18.00	6.00	87.00	7.00
	1000 r	10.00	75.00	15.00	13.50	72.50	14.00	8.50	82.00	9.50
	1500 r	4.00	80.00	16.00	7.00	75.00	18.00	8.00	77.00	15.00
	2000 r	9.00	77.50	13.50	10.00	70.00	20.00	6.00	84.00	10.00
	2500 r	5.00	81.00	14.00	5.50	73.00	19.00	8.00	79.00	13.00
V_3	500 r	7.50	84.00	8.50	25.00	60.00	15.00	12.00	75.00	13.00
	1000 r	8.50	82.50	9.00	30.00	53.50	16.50	5.50	77.50	17.00
	1500 r	5.00	83.00	12.00	31.50	50.50	18.00	7.50	74.00	18.50
	2000 r	7.50	79.50	13.00	28.00	58.00	14.00	17.50	70.50	12.00
	2500 r	2.50	86.00	11.50	32.50	55.00	12.50	11.00	78.00	11.00

	F value		
	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	0.011	0.055	0.057
Varieties	0.012	0.282	0.123
Exposures	0.021	0.024	0.112
Interaction	0.005	0.013	0.013

the range was from 36.50 per cent (1500 and 2500 r) to 40.00 per cent (1000 r). In V_2 the frequency of negative variants for fresh cuttings ranged from 18.00 per cent in 500 r to 22.50 per cent in 2000 r. In rooted cuttings it ranged from 36.00 to 41.00 per cent in 2500 and 1000 r respectively. In rooted tubers the range was from 29.00 per cent in 1000 r to 43.50 per cent in 1500 r. In V_3 the frequency of negative variants for fresh cuttings ranged from 34.00 per cent in 2000 r to 39.50 per cent in 1000 r. In rooted cuttings the range was from 32.50 per cent (500 and 2000 r) to 34.50 per cent (1500 and 2500 r). The frequency of negative variants in rooted tubers ranged from 28.00 per cent in 2500 r to 34.00 per cent in 500 r.

The frequency of positive variants in V_1 for fresh cuttings ranged from 34.25 per cent in 500 r to 39.00 per cent in 1000 r. In rooted cuttings the range was from 20.50 per cent in 1500 r to 30.00 per cent in 2500 r. In rooted tubers it ranged from 16.00 per cent (500 r) to 22.50 per cent (1500, 2000 and 2500 r). In V_2 the frequency of positive variants for fresh cuttings ranged from 45.50 per cent in 2500 r to 50.00 per cent in 1500 r. In rooted cuttings it ranged from 25.50 per cent in 2000 r to 32.00 per cent in 1000 r. In rooted tubers the range was from 17.50 to 25.50 per cent in 500 and 2000 r respectively. In V_3 the frequency of positive variants for fresh cuttings ranged from 29.50

Table 41. Frequency distribution of tuber volume variants in vM_2 generation (per cent)

Varieties	Treatments	Fresh cuttings			Rooted cuttings			Rooted tubers		
		Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants
V_1	500 r	21.50	44.25	34.25	38.00	41.00	21.00	39.00	45.00	16.00
	1000 r	18.50	42.50	39.00	35.00	42.00	23.00	40.00	40.00	20.00
	1500 r	24.00	38.50	37.50	37.50	37.00	20.50	36.50	41.00	22.50
	2000 r	20.50	42.50	37.00	33.00	38.50	28.50	37.50	40.00	22.50
	2500 r	22.00	43.00	35.00	31.00	39.00	30.00	36.50	41.00	22.50
V_2	500 r	18.00	35.00	47.00	38.00	33.25	28.75	34.00	48.50	17.50
	1000 r	21.00	32.00	47.00	41.00	27.00	32.00	29.00	50.00	21.00
	1500 r	21.00	29.00	50.00	38.50	32.00	29.50	43.50	34.00	22.50
	2000 r	22.50	30.00	47.50	40.00	34.50	25.50	40.50	34.00	25.50
	2500 r	20.50	34.00	45.50	36.00	36.50	27.50	43.00	33.00	24.00
V_3	500 r	35.00	35.50	29.50	32.50	52.50	15.00	34.00	47.00	19.00
	1000 r	39.50	31.00	29.50	33.00	50.50	16.50	31.00	46.00	23.00
	1500 r	36.00	29.00	35.00	34.50	48.00	17.50	31.00	48.50	20.50
	2000 r	34.00	36.50	29.50	32.50	47.50	20.00	30.00	45.00	25.00
	2500 r	36.00	32.50	31.50	34.50	47.00	18.50	28.00	47.00	25.00

	F value		
	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	0.027	0.005	0.006
Varieties	0.176	0.009	0.020
Exposures	0.002	0.003	0.003
Interaction	0.003	0.004	0.004

per cent (500, 1000 and 2000 r) to 35.00 per cent (1500 r). In rooted cuttings the range was from 15.00 per cent in 500 r to 20.00 per cent in 2000 r. In rooted tubers the range was from 19.00 per cent in 500 r to 25.00 per cent in 2000 and 2500 r.

9. Tuber yield per vine

The frequency of negative variants in V_1 for fresh cuttings ranged from 5.00 per cent in 2000 r to 11.00 per cent in 500 r. In rooted cuttings it ranged from 10.00 per cent in 2500 r to 19.00 per cent in 500 r. In rooted tubers the range was from 15.00 per cent (2000 and 2500 r) to 26.00 per cent (1000 r). In V_2 the frequency of negative variants in fresh cuttings ranged from 8.00 per cent (2000 and 2500 r) to 15.50 per cent (500 r). In rooted cuttings the range was from 10.00 per cent in 2500 r to 20.00 per cent in 500 r. In rooted tubers the range was from 14.00 to 22.00 per cent in 2500 and 500 r respectively. In V_3 the frequency of negative variants for fresh cuttings ranged from 8.50 per cent in 2500 r to 16.00 per cent in 500 r. In rooted cuttings the range was from 21.00 to 31.00 per cent in 2500 and 500 r respectively. In rooted tubers it ranged from 17.00 per cent (2000 and 2500 r) to 29.00 per cent (500 r).

The frequency of positive variants in V_1 for fresh cuttings ranged from 12.50 per cent in 500 r to 19.00 per cent

Table 42. Frequency distribution of tuber yield variants in vM_2 generation (per cent)

Varieties	Treatments	Fresh cuttings			Rooted cuttings			Rooted tubers		
		Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants
V_1	500 r	11.00	76.50	12.50	19.00	55.00	26.00	24.00	66.50	9.50
	1000 r	10.50	75.50	14.00	16.00	60.00	24.00	26.00	65.00	9.00
	1500 r	10.00	73.00	17.00	14.50	58.00	27.50	17.50	70.50	12.00
	2000 r	5.00	80.00	15.00	12.50	56.50	31.00	15.00	73.00	12.00
	2500 r	6.00	75.00	19.00	10.00	57.00	33.00	15.00	72.50	12.50
V_2	500 r	15.50	66.50	18.00	20.00	60.00	20.00	22.00	67.50	10.50
	1000 r	12.50	68.50	19.00	17.00	63.50	19.50	20.00	68.50	11.50
	1500 r	11.50	64.50	24.00	18.50	62.00	19.50	17.50	69.00	13.50
	2000 r	8.00	69.00	23.00	12.00	65.00	23.00	20.00	65.00	15.00
	2500 r	8.00	70.00	22.00	10.00	70.00	20.00	14.00	72.00	14.00
V_3	500 r	16.00	65.50	18.50	31.00	50.00	19.00	29.00	59.00	12.00
	1000 r	15.00	64.00	21.00	26.00	54.00	20.00	25.00	65.00	10.00
	1500 r	13.00	69.00	18.00	23.00	54.00	23.00	20.00	65.00	15.00
	2000 r	12.50	65.00	22.50	25.00	45.50	29.50	17.00	70.00	13.00
	2500 r	8.50	67.50	24.00	21.00	51.00	28.00	17.00	68.00	15.00

	F value		
	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	0.020	0.028	0.028
Varieties	0.005	0.078	0.018
Exposures	0.057	0.052	0.082
Interaction	0.005	0.003	0.004

in 2500 r. In rooted cuttings it ranged from 24.00 per cent in 1000 r to 33.00 per cent in 2500 r. In rooted tubers it ranged from 9.00 to 12.50 per cent in 1000 and 2500 r respectively. In V_2 the frequency of positive variants in fresh cuttings ranged from 18.00 per cent in 500 r to 24.00 per cent in 1500 r. In rooted cuttings it ranged from 19.50 per cent (1000 and 1500 r) to 23.00 per cent (2000 r). In rooted tubers the range was from 10.50 per cent in 500 r to 15.00 per cent in 2000 r. In V_3 the frequency of positive variants for fresh cuttings ranged from 18.00 per cent in 1500 r to 24.00 per cent in 2500 r. In rooted cuttings it ranged from 19.00 per cent in 500 r to 29.50 per cent in 2000 r. In rooted tubers the range was from 10.00 per cent (1000 r) to 15.00 per cent (1500 and 2500 r).

C. vM_3 generation

This generation represents only a repetition of the crop performance in vM_2 generation, as the crop is propagated vegetatively. The main characters analysed are presented below.

1. Length of vine at harvest

The mean length of vine at harvest as influenced by gamma rays in three sweet potato varieties is presented in Table 43. Statistical analysis of the data showed significant variation among treatments and varieties in all the three modes of treatments. Among exposures significant difference was noticed in rooted cuttings and rooted tubers.

The mean vine length in V_1 control ranged from 161.00 cm in rooted cuttings to 316.00 cm in rooted tubers. In V_2 the mean values ranged from 74.00 cm in rooted cuttings to 130.50 cm in rooted tubers. In V_3 the range was from 89.00 to 117.50 cm in rooted cuttings and rooted tubers respectively.

In fresh cuttings length of vine in V_1 ranged from 166.00 cm in 2500 r to 182.50 cm in control. In V_2 the mean values ranged from 75.00 cm (1000 and 2500 r) to 88.00 cm in control. In V_3 the range was from 87.50 cm (2000 and 2500 r) to 98.00 cm in control.

In rooted cuttings the mean values in V_1 ranged from 142.00 cm in 2000 r to 161.00 cm in control. The mean values in V_2 ranged from 66.50 to 74.00 cm in 2500 r and control respectively. In V_3 it ranged from 81.00 cm (2000 and 2500 r) to 89.00 cm in control.

In the case of rooted tubers vine length in V_1 ranged from 283.50 cm in 2000 r to 354.00 cm in 1500 r. In V_2 the range was from 129.00 to 149.50 cm in 2500 and 500 r respectively. In V_3 the mean values ranged from 117.50 cm in

Table 43. Length of vine at harvest (cm)

Varieties	Treatments	Modes of treatment: Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	182.50	161.00	316.00
	500 r	177.00	152.50	326.00
	1000 r	173.00	146.00	340.50
	1500 r	169.00	147.00	354.00
	2000 r	168.00	142.00	283.50
	2500 r	166.00	145.00	289.00
V_2	Control	88.00	74.00	130.50
	500 r	77.50	73.00	149.50
	1000 r	75.00	72.50	143.50
	1500 r	78.00	67.50	142.50
	2000 r	77.50	68.50	134.50
	2500 r	75.00	66.50	129.00
V_3	Control	98.00	89.00	117.50
	500 r	95.00	85.50	120.00
	1000 r	90.00	85.50	133.50
	1500 r	90.00	83.50	141.50
	2000 r	87.50	81.00	135.00
	2500 r	87.50	81.00	122.50

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	97.058**	69.933**	56.772**	13.138	12.670	35.438
Varieties	816.762**	585.199**	458.817**	5.364	5.173	14.467
Exposures	2.678	2.855*	5.535**	7.585	7.315	20.460
Interaction	0.307	0.419	1.981	13.138	12.670	35.438

* Significant at 5% level

** Significant at 1% level

control to 141.50 cm in 1500 r.

In gamma ray exposed population the mean vine length in V_1 showed the lowest value (142.00 cm) in 2000 r of rooted cuttings and the highest value (354.00 cm) in 1500 r of rooted tubers. In V_2 these values were 66.50 cm in 2500 r of rooted cuttings and 149.50 cm in 500 r of rooted tubers. In V_3 the length of vine was minimum (81.00 cm) in 2000 and 2500 r of rooted cuttings and maximum (141.50 cm) in 1500 r of rooted tubers.

2. Number of branches per vine

The influence of gamma rays on mean number of branches per vine in three sweet potato varieties is depicted in Table 44 and Fig. 23. Statistical analysis of the data showed significant variation among treatments, varieties, exposures and interaction in the case of rooted tubers. Significant difference among varieties and exposures was noted in fresh cuttings.

The mean number of branches in V_1 control ranged from 4.25 in fresh cuttings to 8.50 in rooted tubers. In V_2 control the mean values ranged from 3.75 in fresh cuttings to 7.75 in rooted tubers. In V_3 control the range was from 4.25 to 5.50 in fresh cuttings and rooted tubers respectively.

In fresh cuttings the mean values in V_1 ranged from 3.25 (2000 and 2500 r) to 4.25 (control). In V_2 it ranged from 3.25 (2000 and 2500 r) to 3.75 (control). In V_3 the range was from 3.75 (2000 and 2500 r) to 4.25 (control and 500 r).

In the case of rooted cuttings mean branch number in V_1 ranged from 4.50 in 2000 and 2500 r to 5.50 in control. In V_2 the values ranged from 4.60 (2500 r) to 5.50 (control). The mean values in V_3 ranged from 4.60 to 5.25 in 2500 r and control respectively.

In rooted tubers the number of branches in V_1 ranged from 7.70 to 10.20 in 2500 and 1500 r respectively. In V_2 the range was from 6.70 in 2000 r to 8.80 in 500 r. The mean values in V_3 ranged from 5.15 in 2000 r to 6.80 in 500 r.

Among the treated population the mean number of branches in V_1 showed the lowest value (3.25) in 2000 and 2500 r of fresh cuttings and the highest value (10.20) in 1500 r of rooted tubers. In V_2 these values were 3.25 in 2000 and 2500 r of fresh cuttings and 8.80 in 500 r of rooted tubers. In V_3 it was minimum (3.75) in 2000 and 2500 r of fresh cuttings and maximum (6.80) in 500 r of rooted tubers.

3. Fresh weight of vine

The effect of gamma rays on mean fresh weight of vine

Table 44. Number of branches per vine

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	4.25	5.50	8.50
	500 r	4.00	5.25	7.75
	1000 r	3.75	4.85	7.80
	1500 r	3.50	4.85	10.20
	2000 r	3.25	4.50	7.80
	2500 r	3.25	4.50	7.70
V_2	Control	3.75	5.50	7.75
	500 r	3.65	5.25	8.80
	1000 r	3.45	5.00	7.60
	1500 r	3.40	4.80	6.90
	2000 r	3.25	4.70	6.70
	2500 r	3.25	4.60	7.00
V_3	Control	4.25	5.25	5.50
	500 r	4.25	5.15	6.80
	1000 r	4.10	5.00	5.30
	1500 r	3.80	4.70	5.25
	2000 r	3.75	4.65	5.15
	2500 r	3.75	4.60	6.00

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	1.744	0.813	17.404**	0.810	1.082	0.972
Varieties	5.697*	0.089	101.710**	0.330	0.442	0.397
Exposures	3.267*	2.607	5.570**	0.467	0.625	0.561
Interaction	0.192	0.061	6.460**	0.810	1.082	0.972

* Significant at 5% level

** Significant at 1% level

in three sweet potato varieties is presented in Table 45. Statistical analysis of the data showed significant difference among treatments and varieties in all the three modes of treatment. Among exposures fresh cuttings and rooted cuttings showed significant variation.

The mean fresh weight of vine in V_1 control ranged from 131.20 g in rooted cuttings to 350.00 g in rooted tubers. In V_2 control the mean values ranged from 98.50 to 255.00 g in rooted cuttings and rooted tubers respectively. In V_3 control the range was from 90.00 g in rooted cuttings to 212.50 g in rooted tubers.

In fresh cuttings the mean values in V_1 ranged from 125.00 g in 2500 r to 140.00 g in control. In V_2 the mean values ranged from 125.00 g (2000 and 2500 r) to 137.50 g (control). In V_3 the fresh weight ranged from 90.00 to 112.50 g in 2500 r and control respectively.

In the case of rooted cuttings the mean values in V_1 ranged from 97.00 g in 2500 r to 131.20 g in control while in V_2 it ranged from 85.00 to 98.50 g in 2500 r and control respectively. In V_3 it ranged from 72.50 g in 2500 r to 90.00 g in control.

In rooted tubers the fresh weight in V_1 ranged from 295.00 g in 2500 r to 350.00 g in control. In V_2 the range

Table 45. Fresh weight of vine (g)

Varieties	Treatments	Modes of treatment: Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	140.00	131.20	350.00
	500 r	134.00	120.00	330.00
	1000 r	130.00	115.00	315.00
	1500 r	135.00	105.00	315.00
	2000 r	130.00	100.00	305.00
	2500 r	125.00	97.00	295.00
V_2	Control	137.50	98.50	255.00
	500 r	130.00	98.00	244.50
	1000 r	130.00	92.00	222.50
	1500 r	128.00	87.00	215.00
	2000 r	125.00	87.00	210.00
	2500 r	125.00	85.00	205.00
V_3	Control	112.50	90.00	212.50
	500 r	107.50	88.00	200.00
	1000 r	100.00	87.50	190.00
	1500 r	95.00	79.50	185.00
	2000 r	95.00	75.00	175.00
	2500 r	90.00	72.50	175.00

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	9.903**	18.885**	2.391*	15.296	10.516	112.707
Varieties	72.705**	108.797**	18.578**	6.245	4.293	46.013
Exposures	3.860*	17.889**	0.674	8.831	6.071	65.072
Interaction	0.364	1.401	0.011	15.296	10.516	112.707

* Significant at 5% level

** Significant at 1% level

was from 205.00 to 255.00 g in 2500 r and control respectively. In V_3 it ranged from 175.00 g (2000 and 2500 r) to 212.50 g (control).

Among the treated population the fresh weight of V_1 ranged from 97.00 g in 2500 r of rooted cuttings to 330.00 g in 500 r of rooted tubers. The mean values in V_2 ranged from 85.00 to 244.50 g in 2500 r of rooted cuttings and 500 r of rooted tubers respectively. In V_3 the range was from 72.50 g in 2500 r of rooted cuttings to 200.00 g in 500 r of rooted tubers.

4. Number of tubers per vine

The influence of gamma rays on mean number of tubers per vine in three sweet potato varieties is depicted in Table 46 and Fig. 24. Statistical analysis of the data showed significant variation among treatments and varieties in fresh cuttings and rooted cuttings. Significant difference was noticed among exposures in all the three modes of treatment.

The mean number of tubers in V_1 control ranged from 1.36 in rooted tubers to 1.58 in rooted cuttings. The values in V_2 control ranged from 1.18 to 1.41 in rooted tubers and fresh cuttings respectively. In V_3 the mean values in control population ranged from 1.32 in rooted tubers to 1.48 in fresh cuttings.

In fresh cuttings the mean values in V_1 ranged from 1.41 in control to 1.67 in 2500 r. In V_2 it ranged from 1.41 (control) to 1.66 (2000 and 2500 r). In V_3 the range was from 1.48 in control to 1.73 in 2000 and 2500 r.

In rooted cuttings the mean tuber number in V_1 ranged from 1.58 in control to 1.76 in 2000 and 2500 r. In V_2 the mean values ranged from 1.34 to 1.58 in control and 2000 r respectively. In V_3 the range was from 1.47 in control to 1.76 in 2500 r.

In the case of rooted tubers the mean tuber number in V_1 ranged from 1.36 to 1.58 in control and 2500 r respectively. In V_2 it was 1.18 in control and 1.50 in 2500 r. The mean values in V_3 ranged from 1.32 in control to 1.55 in 2000 and 2500 r.

In gamma ray exposed population the mean tuber number of V_1 showed the lowest value of 1.45 (500 r of fresh cuttings and 1000 r of rooted tubers) and the highest value of 1.76 (2000 and 2500 r of rooted cuttings). In V_2 these values were 1.41 (500 r of rooted cuttings and rooted tubers) and 1.66 (2000 and 2500 r of fresh cuttings). In V_3 it was minimum (1.41) in 500 and 1000 r of rooted tubers and maximum (1.76) in 2500 r of rooted cuttings.

Table 46. Number of tubers per vine

Varieties	Treatments	Modes of treatment: Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	1.41	1.58	1.36
	500 r	1.45	1.61	1.46
	1000 r	1.55	1.61	1.45
	1500 r	1.61	1.69	1.50
	2000 r	1.61	1.76	1.57
	2500 r	1.67	1.76	1.58
V_2	Control	1.41	1.34	1.18
	500 r	1.47	1.41	1.41
	1000 r	1.50	1.45	1.48
	1500 r	1.63	1.55	1.48
	2000 r	1.66	1.58	1.46
	2500 r	1.66	1.54	1.50
V_3	Control	1.48	1.47	1.32
	500 r	1.58	1.52	1.41
	1000 r	1.64	1.55	1.41
	1500 r	1.70	1.57	1.48
	2000 r	1.73	1.69	1.55
	2500 r	1.73	1.76	1.55

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	5.807**	3.358**	1.359	0.132	0.195	0.248
Varieties	8.758**	12.601**	0.939	0.053	0.079	0.101
Exposures	15.765**	5.841**	3.731*	0.076	0.113	0.143
Interaction	0.238	0.269	0.258	0.132	0.195	0.248

* Significant at 5% level

** Significant at 1% level

5. Weight of tuber

The effect of gamma rays on mean weight of tuber in three sweet potato varieties is presented in Table 47 and Fig. 25. Statistical analysis of the data showed significant difference among treatments, varieties and exposures in rooted tubers. In fresh cuttings and rooted cuttings significant variation was noticed among varieties only.

The mean weight of tuber in V_1 control ranged from 85.00 g in rooted cuttings to 88.00 g in fresh cuttings. In V_2 control it was 72.50 g for fresh cuttings and 130.50 g for rooted tubers. In V_3 the values in control population ranged from 66.00 to 105.00 g in fresh cuttings and rooted tubers respectively.

In fresh cuttings the mean values in V_1 ranged from 88.00 g in control to 98.00 g in 1500 r. In V_2 it ranged from 72.50 to 95.00 g in control and 2500 r respectively. The mean values in V_3 differed from 66.00 g in control to 80.00 g in 2000 and 2500 r.

In the case of rooted cuttings mean tuber weight in V_1 ranged from 85.00 to 98.00 g in control and 2500 r respectively. In V_2 the mean values ranged from 95.00 g in control and 500 r to 105.00 g in 2000 r while in V_3 it was 77.00 g in control and 90.00 g in 2500 r.

In rooted tubers the mean values in V_1 differed from 87.50 g in control to 108.00 g in 2500 r. In V_2 the values ranged from 130.50 to 156.50 g in control and 2500 r respectively. The mean values in V_3 ranged from 105.00 g (control) to 137.50 g (2000 and 2500 r).

Among the treated population the mean tuber weight of V_1 showed the lowest value (89.00 g) in 500 r of fresh cuttings and rooted cuttings and the highest value (108.00 g) in 2500 r of rooted tubers. In V_2 these values were 77.00 g in 500 r of fresh cuttings and 156.50 g in 2500 r of rooted tubers respectively. In V_3 the weight of tuber was minimum (71.50 g) in 500 r of fresh cuttings and maximum (137.50 g) in 2000 and 2500 r of rooted tubers.

6. Length of tuber

The mean length of tuber as influenced by gamma rays in three sweet potato varieties is depicted in Table 48. Statistical analysis of the data showed significant variation among treatments and varieties in all the three modes of treatment. Rooted cuttings and rooted tubers gave significant variation among exposures.

The mean length of tuber in V_1 control ranged from 16.10 cm in fresh cuttings to 19.23 cm in rooted tubers. In V_2 the mean values ranged from 12.05 cm in rooted cuttings

Table 47. Weight of tuber (g)

Varieties	Treatments	Modes of treatment: Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	88.00	85.00	87.50
	500 r	89.00	89.00	92.50
	1000 r	94.00	90.50	98.00
	1500 r	98.00	92.00	99.50
	2000 r	97.00	95.00	102.00
	2500 r	90.00	98.00	108.00
V_2	Control	72.50	95.00	130.50
	500 r	77.00	95.00	143.00
	1000 r	83.00	100.00	144.00
	1500 r	90.00	101.00	149.50
	2000 r	93.00	105.00	155.00
	2500 r	95.00	100.00	156.50
V_3	Control	66.00	77.00	105.00
	500 r	71.50	80.00	112.50
	1000 r	76.00	83.00	127.00
	1500 r	78.00	85.00	133.50
	2000 r	80.00	85.00	137.50
	2500 r	80.00	90.00	137.50

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	1.647	1.074	12.133**	22.365	22.599	19.446
Varieties	8.145**	6.697**	83.609**	9.131	9.226	7.939
Exposures	1.833	0.839	7.024**	12.913	13.048	11.227
Interaction	0.254	0.067	0.392	22.365	22.599	19.446

** Significant at 1% level

to 15.65 cm in rooted tubers. The mean values in V_3 control ranged from 12.75 cm in fresh cuttings to 16.55 cm in rooted tubers.

In fresh cuttings the mean values in V_1 ranged from 16.10 cm in control to 17.70 cm in 2500 r. In V_2 the values ranged from 13.65 cm (control) to 15.30 cm (2000 and 2500 r). In V_3 the mean values ranged from 12.75 to 13.75 cm in control and 1500 r respectively.

In rooted cuttings the mean values in V_1 ranged from 17.00 to 18.50 cm in control and 2500 r respectively. The values in V_2 ranged from 12.05 cm in control to 13.10 cm in 2000 and 2500 r. In V_3 the range was from 13.00 to 14.20 in control and 2500 r respectively.

In rooted tubers the mean length of tuber in V_1 ranged from 19.23 to 21.20 cm in control and 1500 r respectively. In V_2 the values ranged from 15.65 cm in control to 19.25 cm in 2500 r. The tuber length in V_3 was 16.55 cm in control and 18.95 cm in 2000 r.

In gamma ray exposed population the tuber length of V_1 ranged from 16.30 cm in 500 r of fresh cuttings to 21.20 cm in 1500 r of rooted tubers. In V_2 the range was from 12.20 cm in 500 r of rooted cuttings to 19.25 cm in 2500 r of rooted tubers. The mean values in V_3 ranged from 13.25 cm in 1000 r

Table 48. Length of tuber (cm)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	16.10	17.00	19.23
	500 r	16.30	17.80	19.80
	1000 r	16.80	17.90	20.15
	1500 r	17.30	18.30	21.20
	2000 r	17.50	18.30	20.90
	2500 r	17.70	18.50	19.25
V_2	Control	13.65	12.05	15.65
	500 r	14.50	12.20	16.45
	1000 r	14.90	12.75	17.55
	1500 r	15.10	13.00	18.25
	2000 r	15.30	13.10	18.90
	2500 r	15.30	13.10	19.25
V_3	Control	12.75	13.00	16.55
	500 r	13.40	13.60	16.60
	1000 r	13.25	13.80	17.50
	1500 r	13.75	14.00	18.75
	2000 r	13.50	14.10	18.95
	2500 r	13.25	14.20	18.75

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	9.231**	51.702**	4.637**	1.594	0.988	2.159
Varieties	70.185**	423.389**	20.747**	0.651	0.403	0.882
Exposures	2.673	6.160**	5.667**	0.920	0.570	1.247
Interaction	0.319	0.136	0.901	1.594	0.988	2.159

** Significant at 1% level

of fresh cuttings to 18.95 cm in 2000 r of rooted tubers.

7. Girth of tuber

The influence of gamma rays on mean girth of tuber in three sweet potato varieties is presented in Table 49. Statistical analysis of the data showed significant variation among treatments and varieties in all the three modes of treatment. Rooted cuttings along gave significant difference among the exposures.

The mean girth of tuber in V_1 control ranged from 10.75 cm in rooted cuttings to 15.00 cm in fresh cuttings. In V_2 the mean values in control population ranged from 12.50 to 14.40 cm in fresh cuttings and rooted tubers respectively while in V_3 control it ranged from 10.50 cm in rooted cuttings to 11.80 cm in fresh cuttings.

In fresh cuttings the mean values in V_1 ranged from 15.00 cm in control to 16.75 cm in 2000 r. In V_2 the values ranged from 12.50 to 14.30 cm in control and 2000 r respectively. The mean values in V_3 ranged from 11.80 cm (control) to 13.75 cm (2000 and 2500 r).

In the case of rooted cuttings the tuber girth in V_1 ranged from 10.75 to 12.80 cm in control and 2000 r respectively. In V_2 it ranged from 13.75 cm in control to

15.15 cm in 2000 r. In V_3 the range was from 10.50 cm in control to 12.60 cm in 2000 r.

In rooted tubers the mean values in V_1 ranged from 12.90 cm in control to 15.20 cm in 1500 r. In V_2 it ranged from 14.40 to 16.60 cm in control and 1500 r respectively. In V_3 the range was from 11.00 cm (control) to 12.00 cm (1000 r).

Among the treated population the tuber girth of V_1 showed the lowest value (11.50 cm) in 500 r of rooted cuttings and the highest value (16.75 cm) in 2000 r of fresh cuttings. In V_2 these values were 13.60 cm in 500 r of fresh cuttings and 16.60 cm in 1500 r of rooted tubers respectively. In V_3 the tuber girth was minimum (11.40 cm) in 500 r of rooted tubers and maximum (13.75 cm) in 2000 and 2500 r of fresh cuttings.

8. Volume of tuber (cm^3)

The effect of gamma rays on mean volume of tuber in three sweet potato varieties is depicted in Table 50. Statistical analysis of the data showed significant difference among varieties in all the three modes of treatment. Rooted tubers alone showed significant variation among treatments and exposures.

Table 49. Girth of tuber (cm)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	15.00	10.75	12.90
	500 r	15.35	11.50	14.00
	1000 r	15.70	12.00	14.85
	1500 r	16.25	12.35	15.20
	2000 r	16.75	12.80	14.10
	2500 r	16.25	12.75	14.10
V_2	Control	12.50	13.75	14.40
	500 r	13.60	14.50	16.00
	1000 r	13.80	14.70	16.45
	1500 r	14.20	15.20	16.60
	2000 r	14.30	15.75	16.20
	2500 r	14.25	15.30	16.05
V_3	Control	11.80	10.50	11.00
	500 r	12.75	11.75	11.40
	1000 r	12.75	12.25	12.00
	1500 r	13.50	12.50	11.80
	2000 r	13.75	12.60	11.80
	2500 r	13.75	12.50	11.60

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	2.971*	4.975**	5.961**	2.423	2.084	2.379
Varieties	19.710**	33.212*	45.190**	0.969	0.851	0.971
Exposures	2.137	3.505*	1.884	1.399	1.203	1.374
Inter-action	0.051	0.063	0.153	2.423	2.084	2.379

* Significant at 5% level

** Significant at 1% level

The mean volume of tuber in V_1 control ranged from 79.00 cm^3 in rooted cuttings to 86.00 cm^3 in rooted tubers. In V_2 control the mean values ranged from 70.00 cm^3 in fresh cuttings to 125.50 cm^3 in rooted tubers. In V_3 control it ranged from 68.00 to 100.50 cm^3 in fresh cuttings and rooted tubers respectively.

In fresh cuttings the mean tuber volume in V_1 ranged from 82.00 cm^3 in control to 94.00 cm^3 in 1500 r. In V_2 it ranged from 70.00 cm^3 in control to 85.50 cm^3 in 2000 r while in V_3 it ranged from 64.50 cm^3 in 500 r to 73.50 cm^3 in 2500 r.

In rooted cuttings the mean values in V_1 ranged from 79.00 cm^3 in control to 88.00 cm^3 in 2000 and 2500 r. In V_2 the range was from 85.00 to 98.00 cm^3 in control and 2000 r respectively. In V_3 it ranged from 68.50 cm^3 in control to 82.00 cm^3 in 2500 r.

In rooted tubers the mean volume in V_1 differed from 86.00 cm^3 in control to 101.50 cm^3 in 2500 r. In V_2 the values ranged from 125.50 cm^3 in control to 152.50 cm^3 in 2500 r. The tuber volume in V_3 was 100.50 cm^3 in control and 134.00 cm^3 in 2000 r.

In gamma ray exposed population of V_1 the mean values ranged from 81.00 cm^3 in 500 r of rooted cuttings to 101.50 cm^3

Table 50. Volume of tuber (cm^3)

Varieties	Treatments	Modes of treatment: Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	82.00	79.00	86.00
	500 r	83.50	81.00	87.00
	1000 r	88.00	84.00	91.00
	1500 r	94.00	85.00	95.00
	2000 r	87.50	88.00	98.00
	2500 r	87.50	88.00	101.50
V_2	Control	70.00	85.00	125.50
	500 r	76.00	87.50	137.50
	1000 r	79.00	90.00	139.50
	1500 r	84.50	94.00	144.00
	2000 r	85.50	98.00	150.50
	2500 r	84.50	92.50	152.50
V_3	Control	68.00	68.50	100.50
	500 r	64.50	75.00	108.50
	1000 r	69.50	79.00	121.00
	1500 r	70.00	80.00	125.50
	2000 r	72.50	81.00	134.00
	2500 r	73.50	82.00	132.50

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	1.315	0.869	11.612**	7.469	22.745	19.767
Varieties	8.242**	4.765*	80.816**	3.049	9.286	8.069
Exposures	0.878	0.955	6.356**	4.312	13.132	11.413
Interaction	0.149	0.046	0.399	7.469	22.745	19.767

* Significant at 5% level

** Significant at 1% level

in 2500 r of rooted tubers. In V_2 the values differed from 76.00 cm^3 in 500 r of fresh cuttings to 152.50 cm^3 in 2500 r of rooted tubers. In V_3 the values ranged from 64.50 to 134.00 cm^3 in 500 r of fresh cuttings and 2000 r of rooted tubers respectively.

9. Tuber yield per vine

The influence of gamma rays on mean tuber yield per vine in three sweet potato varieties is presented in Table 51 and Fig. 26. Statistical analysis of the data showed significant variation among treatments, varieties and exposures in rooted cuttings and rooted tubers. Significant difference among treatments and exposures was noted in the case of fresh cuttings.

The mean tuber yield in V_1 control ranged from 161.50 g in rooted tubers to 212.00 g in rooted cuttings. The mean values in V_2 control ranged from 144.50 g in fresh cuttings to 183.50 g in rooted tubers. In V_3 control it ranged from 146.50 to 182.50 g in fresh cuttings and rooted tubers respectively.

In fresh cuttings the mean values in V_1 ranged from 176.00 g in control to 272.00 g in 2000 r. In V_2 it ranged from 144.50 g in control to 261.00 g in 2500 r. In V_3 the range was from 146.50 to 245.00 g in control and 2000 r

Table 51. Tuber yield per vine (g)

Varieties	Treatments	Modes of treatment: Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	176.00	212.00	161.50
	500 r	188.00	233.50	198.00
	1000 r	226.50	235.00	205.00
	1500 r	256.00	263.00	224.00
	2000 r	272.00	294.00	252.50
	2500 r	252.00	303.50	270.50
V_2	Control	144.50	171.00	183.50
	500 r	165.00	190.00	286.00
	1000 r	187.50	209.50	317.00
	1500 r	239.50	240.00	334.50
	2000 r	255.00	262.50	334.50
	2500 r	261.00	251.50	349.50
V_3	Control	146.50	164.50	182.50
	500 r	178.50	183.50	226.50
	1000 r	205.00	199.00	254.00
	1500 r	227.50	211.50	294.50
	2000 r	245.00	244.50	330.00
	2500 r	240.00	274.00	330.00

	F value: Fresh cuttings	F value: Rooted cuttings	F value: Rooted tubers	CD value: Fresh cuttings	CD value: Rooted cuttings	CD value: Rooted tubers
Treatments	2.486*	2.753*	3.729**	78.202	72.943	95.492
Varieties	1.230	5.524*	10.099**	31.926	29.779	38.984
Exposures	7.680**	6.872**	7.884**	45.150	42.114	55.132
Interaction	0.141	0.140	0.377	78.202	72.943	95.492

* Significant at 5% level

** Significant at 1% level

respectively.

In the case of rooted cuttings the mean tuber yield in V_1 ranged from 212.00 g in control to 303.50 g in 2500 r. In V_2 the mean values differed from 171.00 g in control to 262.50 g in 2000 r while in V_3 it ranged from 164.50 to 274.00 g in control and 2500 r respectively.

In rooted tubers the mean values in V_1 differed from 161.50 g in control to 270.50 g in 2500 r. In V_2 it ranged from 183.50 to 349.50 g in control and 2500 r respectively. The mean tuber yield in V_3 was 182.50 g in control to 330.00 g in 2000 and 2500 r.

Among the treated population the mean tuber yield of V_1 showed the lowest value (188.00 g) in 500 r of fresh cuttings and the highest value (303.50 g) in 2500 r of rooted cuttings. In V_2 these values were 165.00 g in 500 r of fresh cuttings and 349.50 g in 2500 r of rooted tubers respectively. In V_3 the tuber yield was minimum (178.50 g) in 500 r of fresh cuttings and maximum (330.00 g) in 2000 and 2500 r of rooted tubers.

10. Frequency distribution of variants in vM_3 generation

Frequency distribution of variants for various polygenic characters is presented in Tables 52 - 60.

1. Length of vine at harvest

The frequency of negative variants in V_1 for fresh cuttings ranged from 22.00 per cent in 1500 r to 29.00 per cent in 2000 r. In rooted cuttings it ranged from 41.00 per cent in 1500 r to 48.00 per cent in 1000 r. In rooted tubers the range was from 30.00 per cent in 500 r to 44.00 per cent in 2000 r. In V_2 for fresh cuttings the frequency of negative variants ranged from 28.00 per cent in 1500 r to 36.00 per cent in 2500 r. In rooted cuttings it ranged from 35.00 per cent in 500 r to 40.50 per cent in 2000 r. In rooted tubers the range was from 33.00 per cent in 2500 r to 39.00 per cent in 500 r. In V_3 for fresh cuttings it ranged from 42.50 per cent in 1000 r to 51.00 per cent in 1500 r. In rooted cuttings the range was from 35.00 to 47.50 per cent in 1500 and 2500 r respectively. In rooted tubers it ranged from 36.50 per cent (500 and 1500 r) to 40.50 per cent in 2500 r.

The frequency of positive variants in V_1 for fresh cuttings ranged from 24.50 per cent in 2000 r to 35.50 per cent in 1500 r. In rooted cuttings it ranged from 16.50 per cent in 2500 r to 33.00 per cent in 1500 r. In rooted tubers it ranged from 25.00 per cent (2000 and 2500 r) to 35.50 per cent in 1000 r. In V_2 for fresh cuttings it ranged from 30.00 per cent in 2500 r to 39.00 per cent in 1500 r. In rooted cuttings the range was from 13.00 per cent in 2000 r to 24.00 per cent in 1000 r. In rooted tubers the frequency

Table 52. Frequency distribution of vine length variants in vM_3 generation (per cent)

Varieties	Treatments	Fresh cuttings			Rooted cuttings			Rooted tubers		
		Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants
V_1	500 r	25.00	44.00	31.00	45.00	30.60	25.00	30.00	35.00	35.00
	1000 r	27.50	38.00	34.50	48.00	32.00	20.00	39.50	25.00	35.50
	1500 r	22.00	42.50	35.50	41.00	26.00	33.00	34.00	37.50	28.50
	2000 r	29.00	46.50	24.50	46.50	34.00	19.50	44.00	30.50	25.00
	2500 r	27.50	45.00	27.50	46.50	37.00	16.50	35.00	40.00	25.00
V_2	500 r	30.00	35.00	35.00	35.00	44.00	21.00	39.00	41.00	20.00
	1000 r	30.00	35.00	35.00	40.00	36.00	24.00	36.00	37.00	27.00
	1500 r	28.00	33.00	39.00	37.00	45.00	18.00	35.00	42.00	23.00
	2000 r	29.00	40.00	31.00	40.50	46.50	13.00	38.50	40.00	21.50
	2500 r	36.00	34.00	30.00	37.50	45.00	17.50	33.00	46.00	21.00
V_3	500 r	47.50	32.50	20.00	41.00	28.00	31.00	36.50	31.00	32.50
	1000 r	42.50	33.50	24.00	38.50	30.50	31.00	37.00	34.00	29.00
	1500 r	51.00	38.50	10.50	35.00	35.00	30.00	36.50	30.00	33.50
	2000 r	44.00	36.00	20.00	38.00	31.50	30.50	37.00	33.00	30.00
	2500 r	48.00	34.00	18.00	47.50	26.00	26.50	40.50	32.00	27.50

	F value		
	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	0.046	0.013	0.007
Varieties	0.281	0.013	0.019
Exposures	0.001	0.005	0.007
Interaction	0.009	0.005	0.004

of positive variants ranged from 21.00 to 27.00 per cent in 2500 and 1000 r respectively. In V_3 for fresh cuttings it ranged from 10.50 per cent in 1500 r to 24.00 per cent in 1000 r. In rooted cuttings it ranged from 26.50 per cent (2500 r) to 31.00 per cent (500 and 1000 r). In V_3 for rooted tubers it ranged from 27.50 per cent in 2500 r to 33.50 per cent in 1500 r.

2. Number of branches per vine

The frequency of negative variants in V_1 for fresh cuttings ranged from 18.00 per cent in 2000 r to 27.50 per cent in 1000 r. In rooted cuttings it ranged from 25.00 per cent in 500 r to 34.00 per cent in 2500 r. In rooted tubers it ranged from 21.00 per cent in 2500 r to 30.00 per cent in 2000 r. In V_2 the frequency of negative variants for fresh cuttings ranged from 26.00 per cent in 500 r to 41.00 per cent in 2500 r. In rooted cuttings it ranged from 19.50 per cent in 500 r to 30.00 per cent in 1500 r. In rooted tubers the range was from 23.00 per cent in 1000 r to 37.00 per cent in 1500 r. In V_3 the frequency of negative variants for fresh cuttings ranged from 9.00 per cent in 2500 r to 26.00 per cent in 1000 r. In rooted cuttings it ranged from 24.00 per cent (1000 and 2000 r) to 35.50 per cent (2500 r). The frequency of negative variants in rooted tubers ranged from 19.00 per cent in 2000 r to 25.00 per cent in 500 r.

The frequency of positive variants in V_1 for fresh cuttings ranged from 7.00 per cent in 1500 r to 17.00 per cent in 500 r. In rooted cuttings it ranged from 7.00 per cent in 2000 r to 13.00 per cent in 500 r. In rooted tubers the range was from 15.50 per cent in 2000 r to 23.50 per cent in 500 r. In V_2 for fresh cuttings the frequency of positive ranged from 12.10 per cent in 500 r to 45.00 per cent in 2500 r. In rooted cuttings the range was from 25.00 to 30.50 per cent in 500 and 2000 r respectively. In rooted tubers it ranged from 50.50 per cent in 2000 r to 55.00 per cent in 2500 r. In V_3 the frequency of positive variants for fresh cuttings ranged from 11.00 per cent (500 and 1500 r) to 17.00 per cent (2500 r). In rooted cuttings the range was from 11.00 per cent in 2000 r to 17.00 per cent in 500 r. In rooted tubers it ranged from 11.00 per cent in 1000 r to 17.00 per cent in 2000 r.

3. Fresh weight of vine

In fresh cuttings the frequency of negative variants in V_1 ranged from 27.50 per cent in 1000 r to 39.00 per cent in 500 r. In rooted cuttings it ranged from 51.80 per cent in 2000 r to 60.50 per cent in 500 r. In rooted tubers the range was from 40.50 per cent in 500 r to 47.50 per cent in 2000 r. In V_2 the frequency of negative variants for fresh cuttings ranged from 31.50 per cent in 500 r to 39.00 per cent

Table 53. Frequency distribution of branch number variants in vM_3 generation (per cent)

Varieties	Treatments	Fresh cuttings			Rooted cuttings			Rooted tubers		
		Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants
V_1	500 r	25.00	58.00	17.00	25.00	49.50	25.50	26.50	53.50	20.00
	1000 r	27.50	63.50	9.00	30.00	46.00	24.00	26.00	60.00	14.00
	1500 r	24.50	68.50	7.00	33.00	56.50	10.50	29.00	58.50	12.50
	2000 r	18.00	72.50	9.50	27.50	59.50	13.00	30.00	55.00	15.00
	2500 r	21.00	71.50	7.50	34.00	53.00	13.00	21.00	65.00	14.00
V_2	500 r	26.00	48.50	25.50	19.50	67.50	13.00	35.00	41.50	23.50
	1000 r	31.00	55.00	19.00	27.00	62.50	10.50	23.00	56.00	21.00
	1500 r	30.00	56.50	13.50	30.00	62.00	8.00	37.00	45.00	18.00
	2000 r	33.00	53.00	14.00	23.50	69.50	7.00	36.00	48.50	15.50
	2500 r	41.00	49.50	9.50	25.50	64.50	10.00	27.00	53.00	20.00
V_3	500 r	24.00	65.00	11.00	29.00	54.00	17.00	25.00	60.00	15.00
	1000 r	26.00	61.00	13.00	24.00	63.00	15.00	21.50	67.50	11.00
	1500 r	18.00	71.00	11.00	31.50	56.50	12.00	21.00	66.00	15.00
	2000 r	15.50	72.50	12.00	24.00	65.00	11.00	19.00	64.00	17.00
	2500 r	9.00	74.00	17.00	35.50	51.00	13.50	22.00	64.00	14.00

	F value		
	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	0.022	0.011	0.013
Varieties	0.036	0.003	0.014
Exposures	0.007	0.029	0.004
Interaction	0.027	0.005	0.017

in 2000 r. In rooted cuttings it ranged from 34.30 per cent in 500 r to 52.70 per cent in 2500 r. In rooted tubers the range was from 37.50 per cent in 500 r to 56.00 per cent in 2500 r. In V_3 the frequency of negative variants for fresh cuttings ranged from 27.00 per cent in 2000 r to 34.00 per cent in 2500 r. In rooted cuttings it ranged from 42.60 per cent in 2000 r to 57.60 per cent in 1000 r. In rooted tubers it ranged from 31.50 per cent in 500 r to 50.00 per cent in 2500 r.

The frequency of positive variants in V_1 for fresh cuttings ranged from 28.50 per cent in 1500 r to 42.50 per cent in 1000 r. In rooted cuttings it ranged from 12.70 per cent in 2500 r to 22.30 per cent in 1000 r. In rooted tubers the range was from 14.50 per cent in 2000 r to 19.50 per cent in 500 r. In V_2 for fresh cuttings the frequency of positive variants ranged from 25.50 per cent in 1000 r to 29.50 per cent in 500 r. In rooted cuttings it ranged from 11.00 per cent in 2500 r to 23.80 per cent in 500 r. In rooted tubers the range was from 22.00 per cent in 2500 r to 27.00 per cent in 1000 r. The frequency of positive variants in V_3 for fresh cuttings ranged from 20.00 per cent in 2500 r to 24.00 per cent in 1500 r. In rooted cuttings it ranged from 14.00 per cent in 2500 r to 25.00 per cent in 500 r. In rooted tubers the range was from 11.50 per cent in 2500 r to

Table 54. Frequency distribution of fresh weight variants in vM_3 generation (per cent)

Varieties	Treatments	Fresh cuttings			Rooted cuttings			Rooted tubers		
		Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants
V_1	500 r	39.00	22.00	39.00	60.50	21.80	17.70	40.50	40.00	19.50
	1000 r	27.50	30.00	42.50	52.00	25.70	22.30	41.00	42.50	16.50
	1500 r	38.50	33.00	28.50	59.60	27.80	17.70	45.50	37.50	17.00
	2000 r	37.50	31.50	31.00	51.80	31.40	16.90	47.50	38.00	14.50
	2500 r	33.00	29.00	38.00	53.60	33.90	12.70	43.00	41.00	16.00
V_2	500 r	31.50	39.00	29.50	34.30	41.90	23.80	37.50	39.00	23.50
	1000 r	35.50	39.00	25.50	38.90	43.00	18.10	38.00	35.00	27.00
	1500 r	36.50	35.00	28.50	46.00	31.60	22.50	41.00	32.50	26.50
	2000 r	39.00	35.00	26.00	42.20	40.20	17.70	48.50	28.00	23.50
	2500 r	34.00	40.00	26.00	52.70	36.40	11.00	56.00	22.00	22.00
V_3	500 r	32.00	45.00	23.00	44.00	31.00	25.00	31.50	39.00	29.50
	1000 r	32.50	45.00	22.50	57.60	23.70	20.70	38.50	41.00	20.50
	1500 r	30.50	45.50	24.00	43.50	36.20	20.30	41.00	37.00	22.00
	2000 r	27.00	51.00	22.00	42.60	34.20	23.20	38.50	45.00	16.50
	2500 r	34.00	46.00	20.00	56.00	30.00	14.00	50.00	38.50	11.50

	F value		
	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	0.009	0.018	0.014
Varieties	0.022	0.039	0.034
Exposures	0.004	0.022	0.026
Interaction	0.008	0.010	0.025

29.50 per cent in 500 r.

4. Number of tubers per vine

The frequency of negative variants in V_1 for fresh cuttings ranged from 8.50 per cent in 2000 r to 18.00 per cent in 500 r. In rooted cuttings the range was from 14.00 per cent in 2000 r to 23.00 per cent in 500 r. In rooted tubers the range was from 15.00 per cent in 1500 r to 25.00 per cent in 1000 r. The frequency of negative variants in V_2 for fresh cuttings ranged from 12.00 per cent in 2500 r to 18.50 per cent in 500 r. In rooted cuttings it ranged from 17.50 per cent (1500 and 2000 r) to 25.00 per cent (500 r). In rooted tubers the range was from 10.00 to 15.50 per cent in 2500 and 500 r respectively. The frequency of negative variants in V_3 for fresh cuttings ranged from 9.00 per cent (1500 and 2500 r) to 13.00 per cent (1000 r). In rooted cuttings it ranged from 10.00 per cent in 2500 r to 17.00 per cent in 1000 r. In rooted tubers the negative variants ranged from 12.00 per cent in 2500 r to 26.00 per cent in 500 r.

In the case of fresh cuttings the frequency of positive variants in V_1 ranged from 5.00 per cent in 1000 r to 31.00 per cent in 2000 r. In rooted cuttings the range was from 6.50 per cent in 500 r to 31.00 per cent in 2000 r. In rooted tubers the frequency of positive variants ranged from 13.50 per cent in 500 r to 26.50 per cent in 2000 r.

The frequency of positive variants in V_2 for fresh cuttings ranged from 16.00 per cent in 500 r to 30.00 per cent in 2000 and 2500 r. In rooted cuttings the range was from 18.50 per cent in 500 r to 35.00 per cent in 2000 r. The frequency of positive variants in rooted tubers ranged from 6.50 to 15.50 per cent in 500 r and 2000 r respectively. The frequency of positive variants in V_3 for fresh cuttings ranged from 4.50 per cent in 500 r to 28.50 per cent in 2500 r. In rooted cuttings it ranged from 6.00 per cent in 500 r to 18.50 per cent in 2000 r. In rooted tubers the range was from 13.00 per cent in 1000 r to 25.00 per cent in 2500 r.

5. Weight of tuber

The frequency of negative variants in V_1 for fresh cuttings ranged from 12.00 per cent in 2500 r to 23.00 per cent in 500 r. In rooted cuttings it ranged from 21.00 per cent in 2500 r to 32.50 per cent in 500 r. In rooted tubers the range was from 12.00 to 20.00 per cent in 2000 and 500 r respectively. In V_2 the frequency of negative variants for fresh cuttings ranged from 9.00 per cent in 2500 r to 15.00 per cent in 1000 r. In rooted cuttings it ranged from 26.00 per cent in 2500 r to 33.00 per cent in 500 r. In rooted

Table 55. Frequency distribution of tuber number variants in vM_3 generation (per cent)

Varieties	Treatments	Fresh cuttings			Rooted cuttings			Rooted tubers		
		Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants
V_1	500 r	18.00	76.00	6.00	23.00	70.50	6.50	21.50	65.00	13.50
	1000 r	12.50	82.50	5.00	20.50	67.50	12.00	25.00	59.00	16.00
	1500 r	10.50	68.50	21.00	16.00	61.00	23.00	15.00	65.00	20.00
	2000 r	8.50	60.50	31.00	14.00	55.00	31.00	18.00	55.50	26.50
	2500 r	9.50	60.50	30.00	17.50	65.00	17.50	16.00	60.00	24.00
V_2	500 r	18.50	65.50	16.00	25.00	56.50	18.50	15.50	78.00	6.50
	1000 r	15.00	64.50	20.50	21.00	57.50	21.50	13.00	77.00	10.00
	1500 r	17.50	56.00	26.50	17.50	54.00	26.50	13.00	75.00	12.00
	2000 r	13.00	57.00	30.00	17.50	47.50	35.00	14.00	70.50	15.50
	2500 r	12.00	58.00	30.00	19.00	50.00	31.00	10.00	78.00	12.00
V_3	500 r	10.50	85.00	4.50	16.00	78.00	6.00	26.00	60.00	14.00
	1000 r	13.00	78.50	8.50	17.00	75.00	8.00	23.00	64.00	13.00
	1500 r	9.00	67.50	23.50	13.00	75.00	12.00	19.00	60.00	21.00
	2000 r	11.50	61.50	27.00	11.50	70.00	18.50	16.00	60.00	24.00
	2500 r	9.00	62.50	28.50	10.00	72.00	18.00	12.00	63.00	25.00

	F value		
	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	0.044	0.032	0.032
Varieties	0.002	0.018	0.002
Exposures	0.136	0.093	0.099
Interaction	0.008	0.005	0.005

tubers the range was from 16.50 per cent in 2000 r to 24.00 per cent in 500 r. In V_3 the frequency of negative variants for fresh cuttings ranged from 15.00 per cent in 2500 r to 26.00 per cent in 500 r. In rooted cuttings it ranged from 12.50 per cent in 1500 r to 33.00 per cent in 500 r. In rooted tubers it ranged from 15.50 per cent in 500 r to 21.50 per cent in 1000 r.

The frequency of positive variants in V_1 for fresh cuttings ranged from 11.00 per cent in 500 r to 33.00 per cent in 2500 r. In rooted cuttings it ranged from 15.00 to 30.00 per cent in 500 and 2500 r respectively. In rooted tubers the range was from 16.00 per cent in 500 r to 37.50 per cent in 2000 and 2500 r. In V_2 the frequency of positive variants for fresh cuttings ranged from 10.00 to 22.50 per cent in 500 and 2500 r respectively. In rooted cuttings it ranged from 29.00 per cent (500 r) to 41.00 per cent (1500 and 2500 r). In rooted tubers the range was from 15.00 per cent in 500 r to 32.50 per cent in 2500 r. The frequency of positive variants in V_3 for fresh cuttings ranged from 12.50 per cent in 500 r to 28.00 per cent in 2500 r. In rooted cuttings the frequency ranged from 14.00 per cent in 500 r to 25.00 per cent in 2000 r. In rooted tubers the frequency of positive variants ranged from 13.00 per cent in 500 r to 20.00 per cent in 2500 r.

Table 56. Frequency distribution of tuber weight variants in vM_3 generation (per cent)

Varieties	Treatments	Fresh cuttings			Rooted cuttings			Rooted tubers		
		Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants
V_1	500 r	23.00	66.00	11.00	32.50	52.50	15.00	20.00	64.00	16.00
	1000 r	17.00	62.00	21.00	30.00	48.00	22.00	15.50	59.00	25.50
	1500 r	17.00	61.50	21.50	28.00	48.00	24.00	15.00	62.50	22.50
	2000 r	13.00	57.50	29.50	23.00	50.00	27.00	12.00	50.50	37.50
	2500 r	12.00	55.00	33.00	21.00	49.00	30.00	13.50	49.00	37.50
V_2	500 r	11.00	79.00	10.00	33.00	38.00	29.00	24.00	61.00	15.00
	1000 r	15.00	74.00	11.00	29.00	36.00	35.00	22.00	59.00	19.00
	1500 r	13.00	73.50	13.50	29.00	30.00	41.00	17.50	56.00	26.50
	2000 r	11.00	71.50	17.50	27.50	38.00	34.50	16.50	55.00	23.50
	2500 r	9.00	68.50	22.50	26.00	33.00	41.00	19.00	48.50	32.50
V_3	500 r	26.00	61.50	12.50	33.00	53.00	14.00	15.50	71.50	13.00
	1000 r	23.00	61.00	16.00	23.50	58.50	18.00	21.50	64.00	14.50
	1500 r	21.00	60.00	19.00	12.50	64.50	23.00	18.50	65.00	16.50
	2000 r	16.00	64.00	20.00	17.50	57.50	25.00	16.50	64.00	19.50
	2500 r	15.00	57.00	28.00	17.00	60.00	23.00	17.00	63.00	20.00

	F value		
	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	0.028	0.019	0.026
Varieties	0.021	0.024	0.052
Exposures	0.077	0.048	0.051
Interaction	0.005	0.004	0.007

6. Length of tuber

The frequency of negative variants in V_1 for fresh cuttings ranged from 8.50 per cent in 2500 r to 23.30 per cent in 500 r. In rooted cuttings it ranged from 9.50 per cent in 2500 r to 24.35 per cent in 1000 r. In rooted tubers the range was from 21.00 per cent in 2000 r to 29.50 per cent in 500 r. In V_2 the frequency of negative variants for fresh cuttings ranged from 11.30 per cent in 2500 r to 24.80 per cent in 500 r. In rooted cuttings it ranged from 12.55 per cent in 2500 r to 26.80 per cent in 1500 r. In rooted tubers the range was from 15.70 to 19.50 per cent in 1000 and 500 r respectively. The frequency of negative variants in V_3 for fresh cuttings ranged from 16.60 per cent in 2000 r to 28.00 per cent in 500 r. In rooted cuttings the range was from 6.50 per cent in 2000 r to 24.90 per cent in 500 r. In rooted tubers it ranged from 25.85 per cent in 2500 r to 32.00 per cent in 1500 r.

The frequency of positive variants in V_1 for fresh cuttings ranged from 44.65 per cent in 500 r to 62.90 per cent in 2500 r. In rooted cuttings it ranged from 26.30 per cent in 1000 r to 50.00 per cent in 2000 r. In rooted tubers it ranged from 16.70 per cent in 500 r to 26.25 per cent in 2500 r. In V_2 the frequency of positive variants for fresh cuttings ranged from 27.90 per cent in 500 r to 50.40 per cent

Table 57. Frequency distribution of tuber length variants in vM_3 generation (per cent)

Varieties	Treatments	Fresh cuttings			Rooted cuttings			Rooted tubers		
		Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants
V_1	500 r	23.30	32.05	44.65	16.20	38.60	45.20	29.50	53.80	16.70
	1000 r	19.25	31.65	49.10	24.35	49.35	26.30	27.30	52.55	20.15
	1500 r	15.70	39.25	45.05	18.65	52.60	28.75	27.40	55.55	17.05
	2000 r	10.90	35.90	53.20	13.70	36.30	50.00	21.00	55.50	23.50
	2500 r	8.50	28.60	62.90	9.50	43.90	46.60	22.50	51.25	26.25
V_2	500 r	24.80	47.30	27.90	16.75	50.95	32.30	19.50	49.25	31.25
	1000 r	19.10	42.40	38.50	15.00	59.65	25.35	15.70	42.20	42.10
	1500 r	18.65	45.50	35.85	26.80	42.25	30.95	19.35	42.25	38.40
	2000 r	11.35	58.25	50.40	13.00	55.20	31.80	16.10	44.10	39.80
	2500 r	11.30	39.80	48.90	12.55	52.55	34.90	18.30	45.60	36.10
V_3	500 r	28.00	30.70	41.30	24.90	32.25	42.85	26.80	41.20	32.00
	1000 r	19.60	37.30	43.10	15.00	41.00	44.00	28.50	27.50	45.00
	1500 r	21.85	33.75	44.40	19.15	40.95	39.90	32.00	33.00	35.00
	2000 r	16.60	35.15	48.25	6.50	43.60	49.90	29.40	36.90	33.70
	2500 r	17.85	32.30	49.85	7.75	41.75	50.50	25.85	41.15	33.00

	F value		
	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	0.028	0.035	0.027
Varieties	0.039	0.067	0.132
Exposures	0.071	0.064	0.020
Interaction	0.004	0.012	0.005

in 2000 r. In rooted cuttings it ranged from 25.35 per cent in 1000 r to 34.90 per cent in 2500 r. In rooted tubers the range was from 31.25 to 42.10 per cent in 500 and 1000 r respectively. In V_3 the frequency of positive variants for fresh cuttings ranged from 41.30 per cent in 500 r to 49.85 per cent in 2500 r. In rooted cuttings it ranged from 39.90 per cent in 1500 r to 50.50 per cent in 2500 r. In rooted tubers the range was from 32.00 per cent in 500 r to 45.00 per cent in 1000 r.

7. Girth of tuber

The frequency of negative variants in V_1 for fresh cuttings ranged from 17.00 per cent in 2500 r to 22.00 per cent in 500 r. In rooted cuttings it ranged from 31.00 per cent in 2500 r to 48.00 per cent in 500 r. In rooted tubers the range was from 39.00 per cent in 2500 r to 41.50 per cent in 1500 r. The frequency of negative variants in V_2 for fresh cuttings ranged from 28.00 to 34.00 per cent in 2500 and 500 r respectively. In rooted cuttings it ranged from 24.50 per cent in 2000 r to 39.00 per cent in 1000 r. In rooted tubers it ranged from 29.00 per cent in 2500 r to 35.00 per cent in 500 r. In V_3 the frequency of negative variants for fresh cuttings ranged from 17.50 per cent in 2500 r to 27.50 per cent in 500 and 1000 r. In rooted cuttings it ranged from 20.50 per cent in 1500 r to 27.00 per cent in 1000 r. In rooted tubers the range was from 18.00 per cent in 2500 r to 32.50 per cent in 500 r.

The frequency of positive variants in V_1 for fresh cuttings ranged from 39.00 per cent in 500 r to 44.50 per cent in 1500 r. In rooted cuttings the range was from 27.00 per cent in 500 r to 32.50 per cent in 1500 r. In rooted tubers it ranged from 17.00 to 22.00 per cent in 500 and 2500 r respectively. The frequency of positive variants in V_2 for fresh cuttings ranged from 29.00 per cent in 500 r to 35.00 per cent in 2500 r. In rooted cuttings it ranged from 17.00 per cent (500 r) to 24.00 per cent (2000 and 2500 r). In rooted tubers the range was from 28.00 to 34.00 per cent in 500 and 2500 r respectively. In V_3 the frequency of positive variants for fresh cuttings ranged from 33.50 per cent in 500 r to 39.00 per cent in 2000 r. In rooted cuttings it ranged from 24.00 per cent in 500 r to 34.00 per cent in 2000 r. In rooted tubers the range was from 27.50 per cent (500 and 1000 r) to 35.50 per cent (2000 r).

8. Volume of tuber

The frequency of negative variants in V_1 for fresh cuttings ranged from 15.90 per cent in 2000 r to 42.25 per cent in 500 r. In rooted cuttings it ranged from 30.00 per cent (500, 1500 and 2500 r) to 33.50 per cent in 2000 r. In

Table 58 Frequency distribution of tuber girth variants in VM_3 generation (per cent)

Varieties	Treatments	Fresh cuttings			Rooted cuttings			Rooted tubers		
		Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants
V_1	500 r	22.00	39.00	39.00	48.00	25.00	27.00	41.00	42.00	17.00
	1000 r	20.00	40.00	40.00	47.50	21.50	31.00	39.50	40.00	20.50
	1500 r	20.50	35.00	44.50	38.50	29.00	32.50	41.50	38.00	20.50
	2000 r	20.50	40.00	39.50	36.00	34.50	29.50	40.00	40.00	20.00
	2500 r	17.00	42.00	41.00	31.00	38.50	30.50	39.00	39.00	22.00
V_2	500 r	34.00	37.00	29.00	35.50	47.50	17.00	35.00	37.00	28.00
	1000 r	31.00	36.00	33.00	39.00	41.00	20.00	33.00	37.00	30.00
	1500 r	31.00	38.50	30.50	27.00	50.50	22.50	30.50	38.50	31.00
	2000 r	30.00	37.00	33.00	24.50	51.50	24.00	33.00	36.00	31.00
	2500 r	28.00	37.00	35.00	29.50	46.50	24.00	29.00	37.00	34.00
V_3	500 r	27.50	39.00	33.50	26.00	50.00	24.00	32.50	40.00	27.50
	1000 r	27.50	38.50	34.00	27.00	45.00	28.00	24.00	48.50	27.50
	1500 r	24.00	39.00	37.00	20.50	48.50	31.00	27.50	39.00	33.50
	2000 r	21.00	40.00	39.00	23.00	43.00	34.00	25.00	39.50	35.50
	2500 r	17.50	48.50	34.00	23.00	47.00	30.00	18.00	48.50	33.50

	F value		
	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	0.013	0.019	0.024
Varieties	0.071	0.067	0.127
Exposures	0.006	0.031	0.013
Interaction	0.000	0.001	0.003

rooted tubers the range was from 19.00 per cent in 1000 r to 22.50 per cent in 1500 r. The frequency of negative variants in V_2 for fresh cuttings ranged from 7.25 per cent in 2500 r to 20.40 per cent in 500 r. In rooted cuttings it ranged from 27.00 per cent in 2500 r to 36.50 per cent in 1000 r. In rooted tubers the range was from 17.00 per cent in 500 r to 24.50 per cent in 2000 r. In V_3 the frequency of negative variants for fresh cuttings ranged from 11.50 per cent in 2000 r to 16.35 per cent in 500 r. In rooted cuttings it ranged from 32.00 per cent in 2500 r to 38.00 per cent in 2000 r. In rooted tubers the range was from 15.00 per cent (1000, 1500 and 2500 r) to 19.00 per cent (500 r).

The frequency of positive variants in V_1 for fresh cuttings ranged from 20.25 per cent in 500 r to 35.90 per cent in 2000 r. In rooted cuttings the range was from 25.00 per cent in 500 r to 32.50 per cent in 2000 r. In rooted tubers it ranged from 35.50 per cent in 500 r to 44.00 per cent in 2500 r. In V_2 the frequency of positive variants for fresh cuttings ranged from 12.10 per cent in 500 r to 45.00 per cent in 2500 r. In rooted cuttings it ranged from 25.00 to 30.50 per cent in 500 and 2000 r respectively. In rooted tubers the range was from 50.50 per cent in 2000 r to 55.00 per cent in 2500 r. In V_3 the frequency of positive variants for fresh cuttings ranged from 15.10 per cent in 500 r to 31.35 per cent in 1500 r. In rooted cuttings it ranged from

Table 59. Frequency distribution of tuber volume variants in vM_3 generation (per cent)

Varieties	Treatments	Fresh cuttings			Rooted cuttings			Rooted tubers		
		Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants
V_1	500 r	42.25	37.50	20.25	30.00	45.00	25.00	22.25	42.25	35.50
	1000 r	20.75	47.50	31.75	32.00	40.50	27.50	19.00	42.75	38.25
	1500 r	22.50	45.50	32.00	30.00	44.00	26.00	22.50	38.50	39.00
	2000 r	15.90	48.20	35.90	33.50	34.00	32.50	19.50	38.00	42.50
	2500 r	21.00	45.00	34.00	30.00	40.00	30.00	21.00	35.00	44.00
V_2	500 r	20.40	67.50	12.10	35.00	40.00	25.00	17.00	30.00	53.00
	1000 r	12.65	59.20	28.15	36.50	38.00	25.50	21.00	27.50	51.50
	1500 r	11.25	62.25	26.50	33.50	36.50	30.00	18.00	22.50	54.50
	2000 r	8 90	54.90	36.20	28.50	41.00	30.50	24.50	25.00	50.50
	2500 r	7.25	47.75	45.00	27.00	43.00	30.00	20.00	25.00	55.00
V_3	500 r	16.35	68.55	15.10	34.00	42.00	24.00	19.00	35.00	46.00
	1000 r	13.85	62.45	23.70	33.00	49.50	17.50	15.00	38.00	47.00
	1500 r	12.25	56.40	31.35	32.50	41.50	26.00	15.00	35.00	50.00
	2000 r	11.50	65.50	23.00	38.00	39.00	23.00	17.50	34.00	48.50
	2500 r	13.00	58.25	28.75	32.00	41.00	27.00	15.00	38.00	47.00

	F value		
	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	0.045	0.004	0.011
Varieties	0.035	0.007	0.062
Exposures	0.113	0.004	0.002
Interaction	0.013	0.003	0.002

17.50 per cent in 1000 r to 27.00 per cent in 2500 r. In rooted tubers the range was from 46.00 per cent in 500 r to 50.00 per cent in 1500 r.

9. Tuber yield per vine

The frequency of negative variants in V_1 for fresh cuttings ranged from 6.00 per cent in 2500 r to 12.50 per cent in 500 and 1000 r. In rooted cuttings it ranged from 6.00 per cent in 2500 r to 16.00 per cent in 500 r. In rooted tubers the frequency of negative variants ranged from 4.00 per cent in 1000 r to 16.00 per cent in 500 r. The frequency of negative variants in V_2 for fresh cuttings ranged from 5.00 per cent in 2500 r to 15.00 per cent in 500 r. In rooted cuttings it ranged from 4.00 to 11.00 per cent in 2500 and 500 r respectively. In rooted tubers the range was from 15.00 per cent in 2500 r to 31.50 per cent in 500 r. In V_3 the frequency of negative variants for fresh cuttings ranged from 8.00 per cent in 2500 r to 18.00 per cent in 500 r. In rooted cuttings it ranged from 11.00 per cent in 2500 r to 25.00 per cent in 500 r. The frequency of negative variants in rooted tubers ranged from 11.00 per cent in 2500 r to 22.00 per cent in 500 r.

The frequency of positive variants in V_1 for fresh cuttings ranged from 6.50 per cent in 500 r to 20.00 per cent

Table 60. Frequency distribution of tuber yield variants in vM_3 generation (per cent)

Varieties	Treatments	Fresh cuttings			Rooted cuttings			Rooted tubers		
		Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants
V_1	500 r	12.50	81.00	6.50	16.00	78.00	6.00	16.00	71.50	12.50
	1000 r	12.50	76.50	11.00	14.00	78.00	8.00	4.00	73.00	13.00
	1500 r	10.00	80.00	10.00	13.50	76.00	10.50	14.00	69.00	17.00
	2000 r	9.00	73.00	18.00	9.00	82.00	9.00	12.00	65.00	23.00
	2500 r	6.00	74.00	20.00	6.00	81.50	12.50	7.00	67.00	26.00
V_2	500 r	15.00	74.00	11.00	11.00	76.00	13.00	31.50	49.50	19.00
	1000 r	13.00	73.50	13.50	8.50	77.50	14.00	26.00	51.50	22.50
	1500 r	11.00	74.00	15.00	7.00	77.00	16.00	25.00	54.00	21.00
	2000 r	7.00	75.00	18.00	6.00	79.00	15.00	20.00	55.00	25.00
	2500 r	5.00	75.00	20.00	4.00	78.50	17.50	15.00	62.00	23.00
V_3	500 r	18.00	78.50	3.50	25.00	71.00	4.00	22.00	64.00	14.00
	1000 r	14.00	82.00	4.00	22.00	71.50	6.50	18.00	64.50	17.50
	1500 r	12 00	80.00	8.00	16.00	77.00	7.00	18.00	64.50	17.50
	2000 r	10.00	78.50	11.50	14.00	76.00	10.00	14.00	64.50	21.50
	2500 r	8.00	78.50	13.50	11.00	75.50	13.50	11.00	63.00	26.00

	F value		
	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	0.030	0.040	0.019
Varieties	0.053	0.158	0.016
Exposures	0.079	0.055	0.057
Interaction	0.000	0.003	0.000

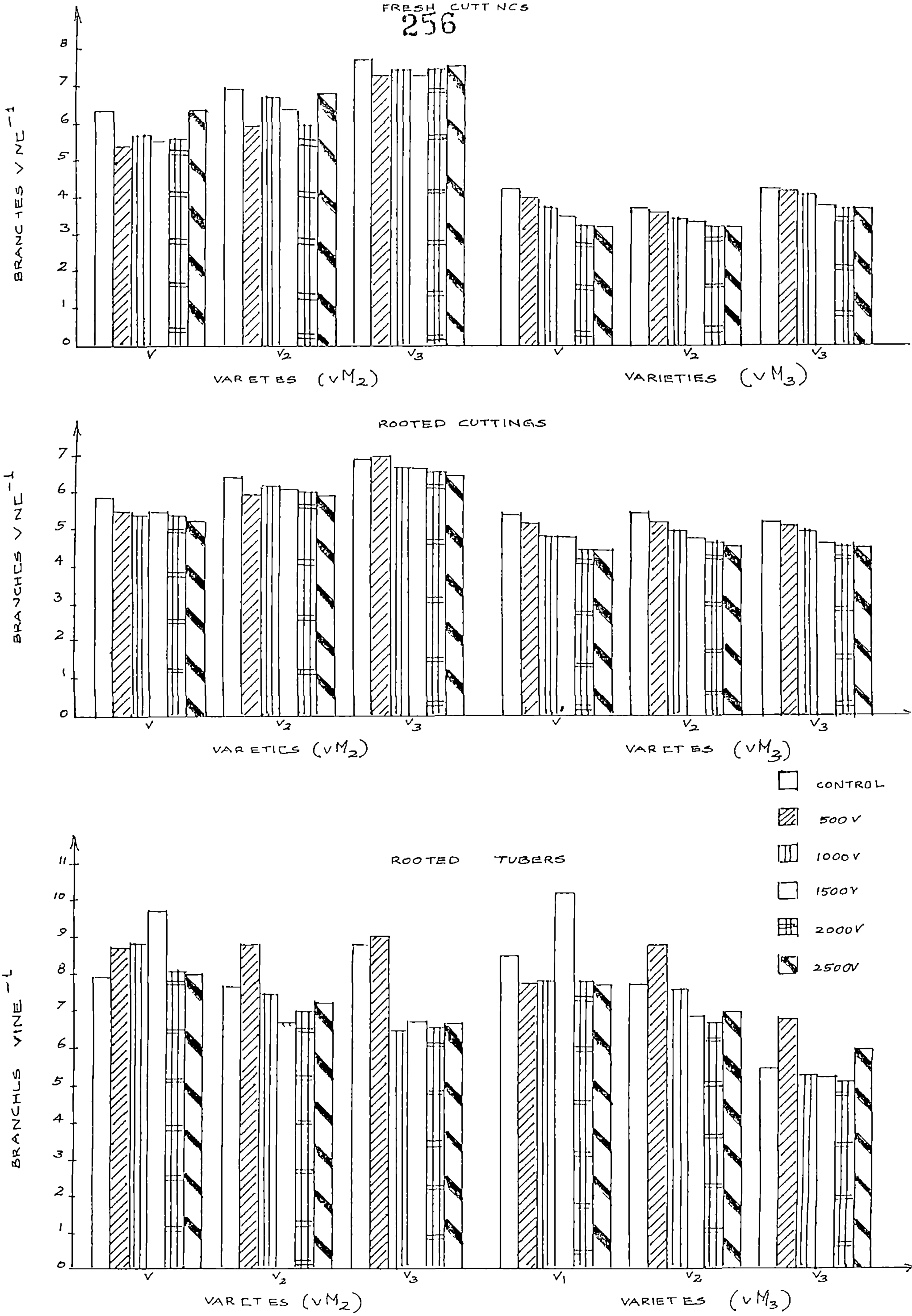

FIG 23 NUMBER OF BRANCHES PER VINE

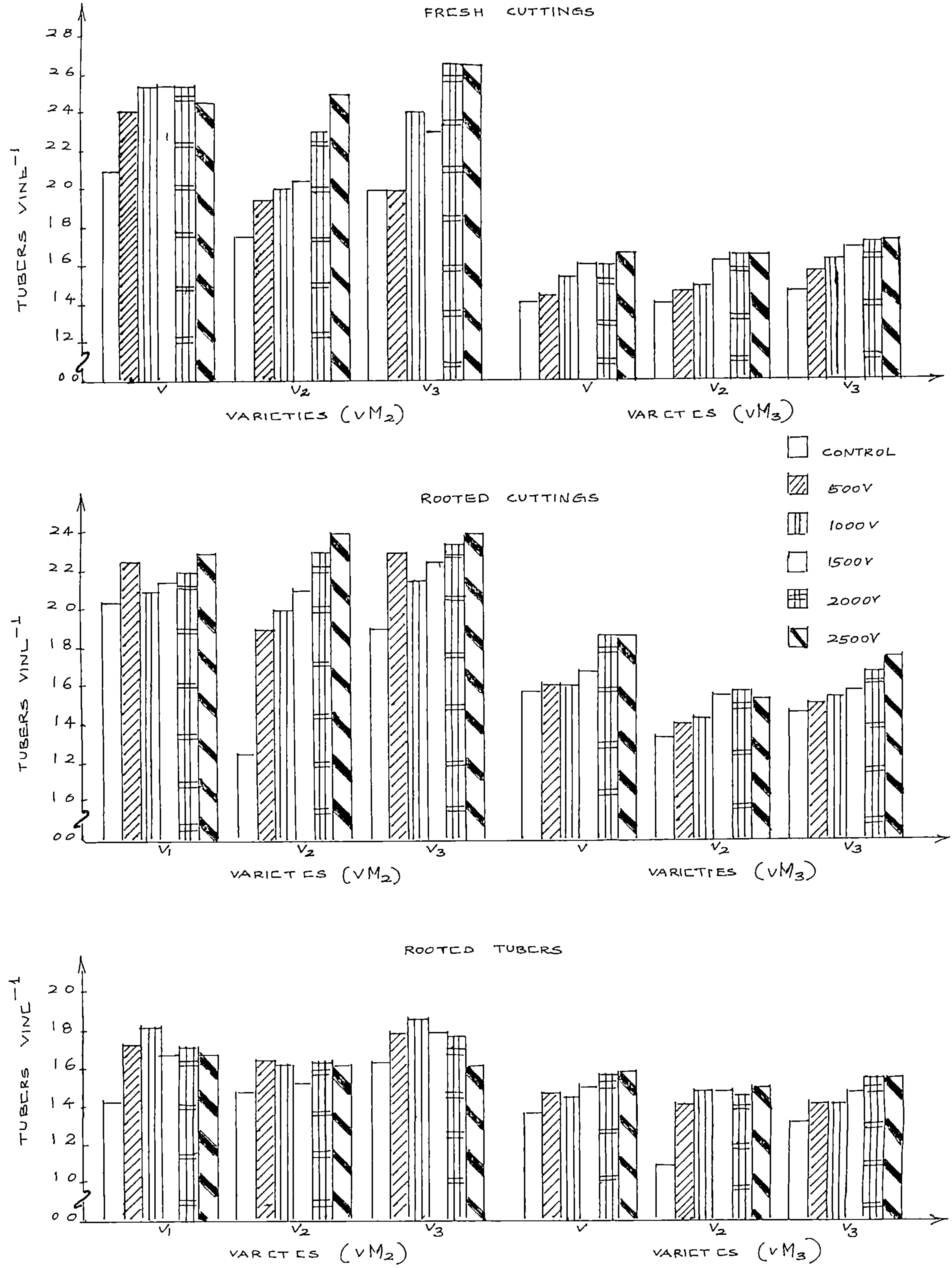

FIG 24 NUMBER OF TUBERS PER VINE

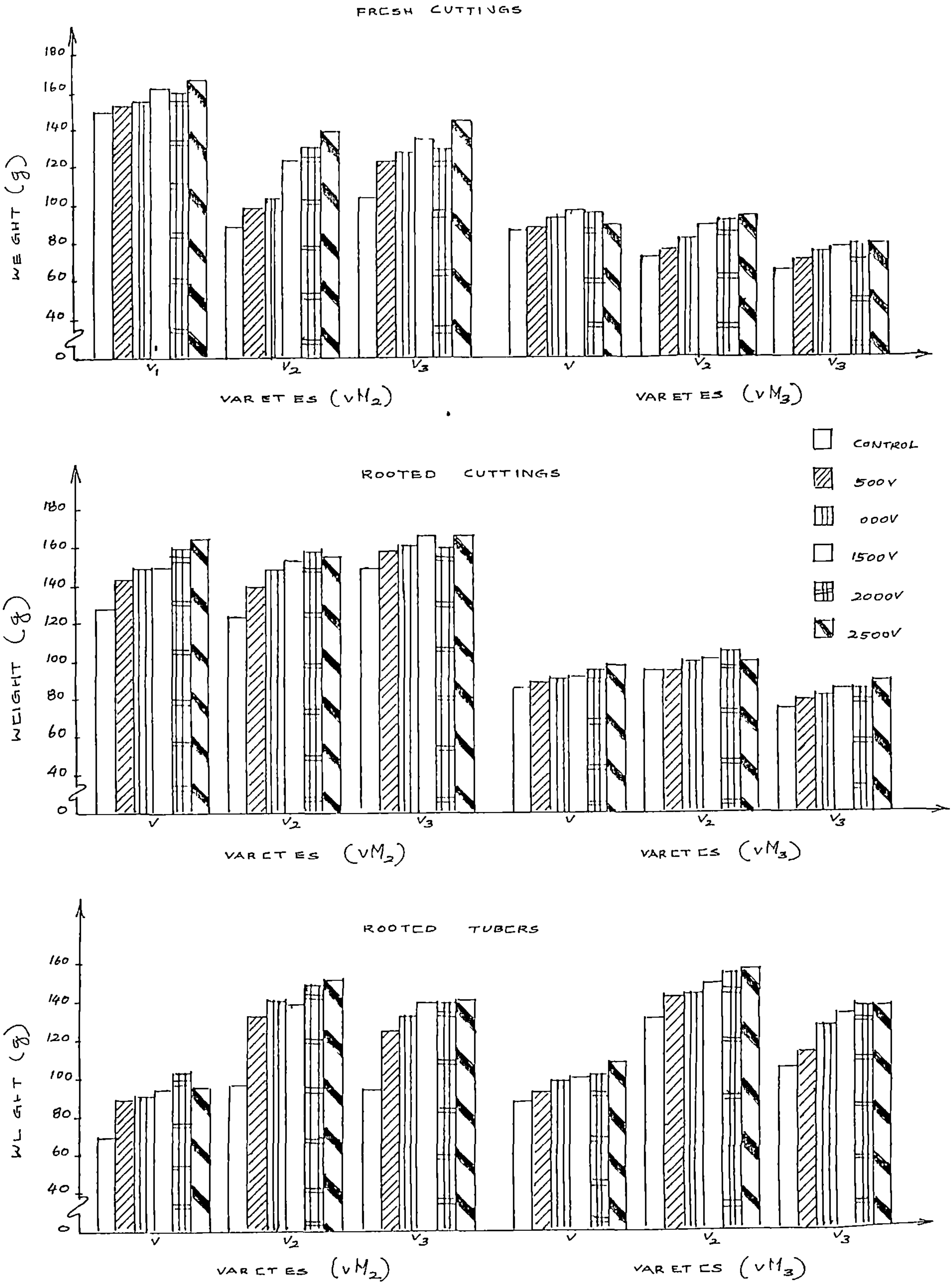

FIG 25 WEIGHT OF TUBER

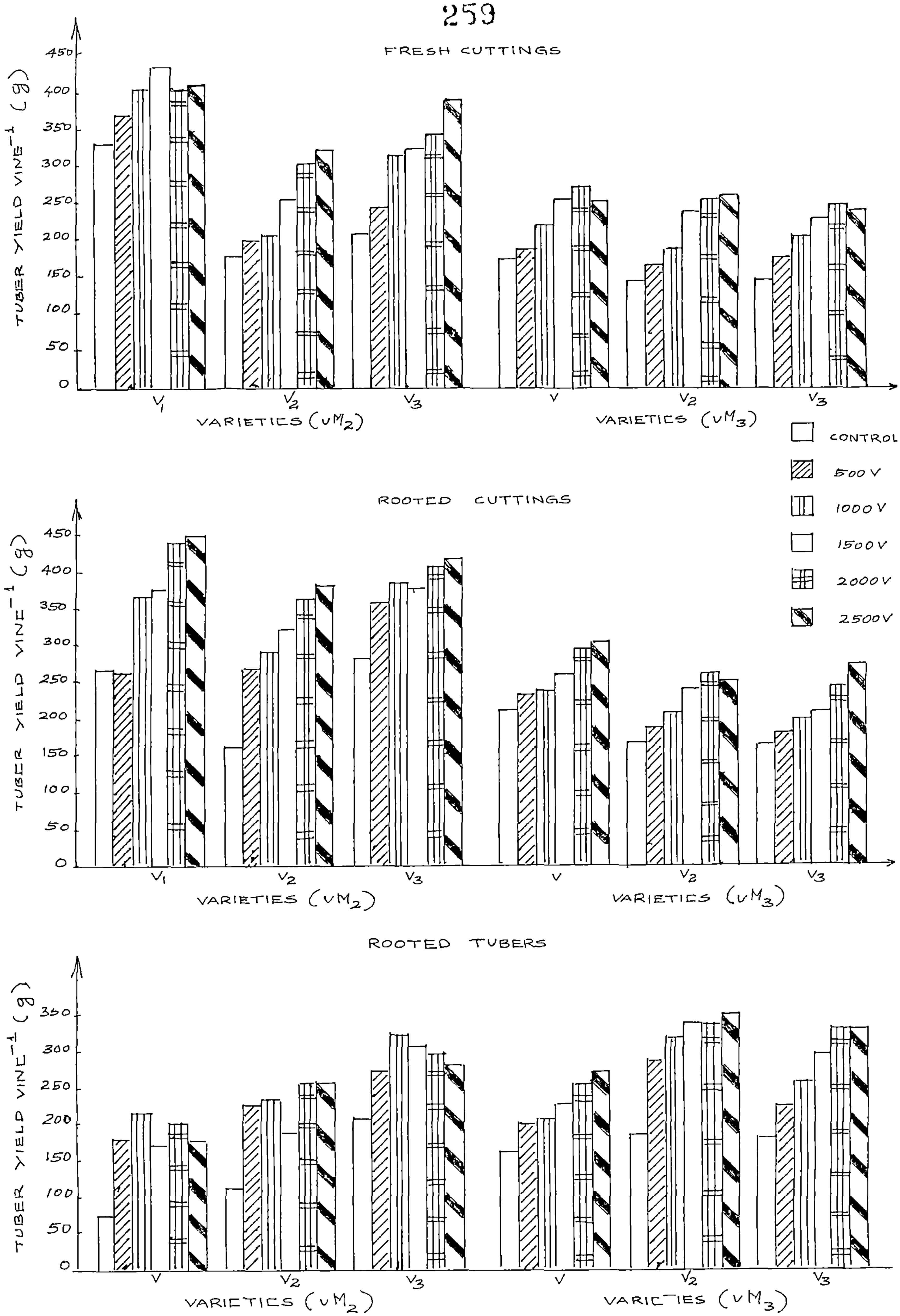

FIG 26 TUBER YIELD PER VINE

in 2500 r. In rooted cuttings the frequency of positive variants ranged from 6.00 per cent in 500 r to 12.50 per cent in 2500 r. In rooted tubers the range was from 12.50 per cent in 500 r to 26.00 per cent in 2500 r. In V_2 the frequency of positive variants for fresh cuttings ranged from 11.00 per cent in 500 r to 20.00 per cent in 2500 r. In rooted cuttings it ranged from 13.00 per cent in 500 r to 17.50 per cent in 2500 r. In rooted tubers it ranged from 19.00 per cent in 500 r to 25.00 per cent in 2000 r. The frequency of positive variants in V_3 for fresh cuttings ranged from 3.50 per cent in 500 r to 13.50 per cent in 2500 r. In rooted cuttings it ranged from 4.00 to 13.50 per cent in 500 and 2500 r respectively. In rooted tubers the range was from 14.00 per cent in 500 r to 26.00 per cent in 2500 r.

D. vM_4 generation

The fourth vegetatively propagated generation was raised to test further the performance of the selected entries from vM_3 generation. The results emanated are presented below.

1. Length of vine at harvest

The mean vine length as influenced by gamma rays is presented in Table 61. Statistical analysis of the data showed significant variation among treatments, varieties and exposures in all the three modes of treatment. Significant interaction was noticed in fresh cuttings.

The mean length of vine in V_1 control ranged from 189.00 cm in rooted tubers to 214.00 cm in rooted cuttings. In V_2 the mean values in control differed from 90.00 cm in fresh cuttings to 106.00 cm in rooted tubers. The mean values in V_3 control ranged from 80.00 to 110.00 cm in fresh cuttings and rooted cuttings respectively.

In fresh cuttings the mean values in V_1 ranged from 160.00 cm in 2500 r to 222.50 cm in 500 r. In V_2 it ranged from 63.50 cm in 2500 r to 90.00 cm in control. In V_3 the range was from 62.00 to 80.00 cm in 2500 r and control respectively.

In rooted cuttings the vine length in V_1 ranged from 157.50 cm in 2500 r to 214.00 cm in control. In V_2 the range was from 62.50 (2500 r) to 95.00 cm (control). In V_3 it ranged from 80.00 to 110.00 cm in 2500 r and control respectively.

In rooted tubers the mean values in V_1 differed from 152.50 cm in 2500 r to 189.00 cm in control. In V_2 it ranged from 75.00 to 106.00 cm in 2500 r and control respectively. In V_3 the range was from 67.50 cm in 2500 r to 90.00 cm in control.

Table 61. Length of vine at harvest (cm)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	210.00	214.00	189.00
	500 r	222.50	190.00	185.00
	1000 r	185.00	177.50	175.00
	1500 r	175.00	168.00	171.50
	2000 r	170.00	166.00	158.00
	2500 r	160.00	157.50	152.50
V_2	Control	90.00	95.00	106.00
	500 r	80.00	83.50	100.00
	1000 r	71.50	82.50	87.50
	1500 r	72.00	74.00	85.00
	2000 r	67.00	71.00	80.00
	2500 r	63.50	62.50	75.00
V_3	Control	80.00	110.00	90.00
	500 r	76.50	100.50	87.50
	1000 r	74.00	90.50	82.50
	1500 r	67.00	95.00	75.00
	2000 r	70.00	83.00	75.00
	2500 r	62.00	80.00	67.50

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	94.890**	56.095**	51.779**	17.566	19.035	18.287
Varieties	754.150**	435.408**	411.950**	7.171	7.771	7.466
Exposures	14.667**	14.592**	10.529**	10.142	10.990	10.558
Interaction	3.150*	0.985	0.370	17.566	19.035	18.287

* Significant at 5% level

** Significant at 1% level

In gamma ray exposed population the mean values in V_1 ranged from 152.50 cm in 2500 r of rooted tubers to 222.50 cm in 500 r of fresh cuttings. In V_2 it ranged from 62.50 cm in 2500 r of rooted cuttings to 100.00 cm in 500 r of rooted tubers. In V_3 the range was from 62.00 cm in 2500 r of fresh cuttings to 100.50 cm in 500 r of rooted cuttings.

2. Number of branches per vine

The mean number of branches as influenced by gamma rays is depicted in Table 62. Statistical analysis of the data showed significant variation among treatments, varieties and exposures in all the three modes of treatment.

The mean number of branches per vine in V_1 control ranged from 7.50 in rooted cuttings to 8.70 in rooted tubers. In V_2 it ranged from 5.95 in fresh cuttings to 8.10 in rooted tubers. In V_3 control the range was from 6.50 to 7.75 in rooted tubers and fresh cuttings respectively.

In fresh cuttings the mean number of branches in V_1 differed from 6.20 in 2500 r to 8.00 in control. In V_2 it ranged from 4.95 in 500 r to 5.95 in control. In V_3 the range was from 5.85 to 7.75 in 2500 r and control respectively.

In rooted cuttings the mean values in V_1 ranged from 6.50 (2000 and 2500 r) to 7.50 (control). In V_2 it ranged from 5.30 (2500 r) to 6.50 (control and 1000 r). The mean values in V_3 ranged from 6.25 to 7.25 in 2000 r and control respectively.

In rooted tubers the mean branch number in V_1 differed from 7.15 in 2500 r to 8.70 in control. In V_2 the range was from 7.00 in 2500 r to 8.10 in control. The mean values in V_3 ranged from 5.60 (1000 and 2500 r) to 6.50 (control).

Among the treated population the mean values in V_1 showed the lowest value (6.20) in 2500 r of fresh cuttings and the highest value (8.40) in 500 r of rooted tubers. In V_2 these values were 4.95 in 500 r of fresh cuttings and 7.50 in 500 r of rooted tubers. In V_3 it was minimum (5.60) in 1000 and 2500 r of rooted tubers and maximum (7.20) in 500 r of fresh cuttings and rooted cuttings.

3. Fresh weight of vine

The effect of gamma rays on mean fresh weight of vine in three sweet potato varieties is presented in Table 63. Statistical analysis of the data showed significant variation among treatments, varieties and exposures in all the three modes of treatment.

Table 62. Number of branches per vine

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	8.00	7.50	8.70
	500 r	7.60	7.00	8.40
	1000 r	7.95	6.75	8.05
	1500 r	7.40	6.65	7.80
	2000 r	7.10	6.50	7.40
	2500 r	6.20	6.50	7.15
V_2	Control	5.95	6.50	8.10
	500 r	4.95	5.75	7.50
	1000 r	5.40	6.50	7.40
	1500 r	5.35	6.00	7.30
	2000 r	5.10	5.65	7.40
	2500 r	5.20	5.30	7.00
V_3	Control	7.75	7.25	6.50
	500 r	7.20	7.20	6.40
	1000 r	6.55	6.55	5.60
	1500 r	6.60	6.80	5.90
	2000 r	6.00	6.25	6.00
	2500 r	5.85	6.30	5.60

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	6.613**	3.111**	11.201**	1.217	0.967	0.841
Varieties	39.062**	12.944**	75.506**	0.497	0.395	0.343
Exposures	4.699**	4.141**	6.532**	0.702	0.558	0.485
Interaction	0.911	0.629	0.675	1.217	0.967	0.841

** Significant at 1% level

The mean values for V_1 control ranged from 270.00 g in rooted cuttings to 308.00 g in rooted tubers. In V_2 control the range was from 160.00 g in rooted cuttings to 168.00 g in fresh cuttings. In V_3 the mean values in control population differed from 128.00 to 138.00 g in fresh cuttings and rooted cuttings respectively.

In the case of fresh cuttings the mean values in V_1 ranged from 235.00 g in 2500 r to 287.50 g in control. In V_2 it ranged from 122.50 to 168.00 g in 2500 r and control respectively. The mean values in V_3 differed from 100.00 g in 2500 r to 140.00 g in 500 r.

In rooted cuttings the mean fresh weight in V_1 differed from 210.00 g in 2500 r to 270.00 g in control. In V_2 the range was from 135.00 to 160.00 g in 2500 r and control respectively. In V_3 it ranged from 110.00 g in 2500 r to 138.00 g in control.

In rooted tubers the mean values in V_1 ranged from 230.00 g in 2500 r to 308.00 g in control. In V_2 it ranged from 125.00 to 165.00 g in 2500 r and control respectively. In V_3 the range was from 94.00 g in 2500 r to 132.50 g in control.

In gamma ray exposed population the fresh weight of V_1 showed the lowest value (210.00 g) in 2500 r of rooted

Table 63. Fresh weight of vine (g)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	267.50	270.00	308.00
	500 r	260.00	260.00	300.00
	1000 r	275.00	235.00	290.50
	1500 r	250.00	240.00	272.50
	2000 r	265.00	230.00	242.50
	2500 r	235.00	210.00	230.00
V_2	Control	168.00	160.00	165.00
	500 r	162.50	150.00	145.50
	1000 r	155.00	145.00	150.00
	1500 r	145.00	155.00	140.00
	2000 r	135.00	145.00	130.00
	2500 r	122.50	135.00	125.00
V_3	Control	128.00	138.00	132.50
	500 r	140.00	122.50	130.00
	1000 r	137.50	117.50	123.00
	1500 r	127.50	122.50	118.00
	2000 r	110.00	115.00	102.50
	2500 r	100.00	110.00	94.00

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	18.784**	22.486**	64.176**	44.135	34.312	27.466
Varieties	149.534**	179.155**	502.570**	18.018	14.008	11.213
Exposures	3.336*	3.785*	14.630**	25.481	19.810	15.857
Interaction	0.358	0.502	1.272	44.135	34.312	27.466

* Significant at 5% level

** Significant at 1% level

cuttings and the highest value (300.00 g) in 500 r of rooted tubers. In V_2 these values were 122.50 g in 2500 r of fresh cuttings and 162.50 g in 500 r of fresh cuttings respectively. In V_3 it was minimum (94.00 g) in 2500 r of rooted tubers and maximum (140.00 g) in 500 r of fresh cuttings.

4. Number of tubers per vine

The influence of gamma rays on mean number of tubers per vine in three sweet potato varieties is depicted in Table 64. Statistical analysis of the data showed significant variation among treatments, varieties and exposures in all the three modes of treatment.

The mean tuber number in V_1 control ranged from 1.80 (fresh cuttings) to 2.50 (rooted cuttings and rooted tubers). In V_2 the mean values in control ranged from 1.75 in rooted tubers to 2.05 in fresh cuttings. In V_3 control it ranged from 1.90 in fresh cuttings to 2.10 in rooted cuttings.

In fresh cuttings the mean values in V_1 ranged from 1.80 (control) to 2.25 (2000 and 2500 r). In V_2 it differed from 2.05 in control to 3.00 in 2500 r. In V_3 the range was from 1.90 to 2.80 in control and 2500 r respectively.

In rooted cuttings the mean values in V_1 differed from 2.50 (control) to 3.10 (2000 and 2500 r). In V_2 the mean values ranged from 2.00 in control to 2.40 in 2000 r. In V_3 the range was from 2.10 in control to 3.10 in 2000 r.

In rooted tubers the mean tuber number in V_1 ranged from 2.50 in control to 3.25 in 2500 r. In V_2 it differed from 1.75 in control to 2.75 in 2500 r. The mean values in V_3 ranged from 2.00 (control) to 2.60 (2000 and 2500 r).

Among the treated population the mean tuber number showed the lowest value (2.00) in 500 r of fresh cuttings and the highest value (3.25) in 2500 r of rooted tubers. In V_2 these values were 2.05 in 1500 r of rooted cuttings and 3.00 in 2500 r of fresh cuttings respectively. In V_3 it was minimum (2.10) in 500 r of fresh cuttings and maximum (3.10) in 2000 r of rooted cuttings.

5. Weight of tuber

The mean weight of tuber as influenced by gamma rays is presented in Table 65. Statistical analysis of the data showed significant difference among treatments, varieties and exposures in fresh cuttings and rooted cuttings. In rooted tubers there was significant variation only among treatments and varieties.

The mean weight of tuber in V_1 control ranged from 90.00 g in rooted cuttings to 137.50 g in rooted tubers. In V_2 the mean values in control differed from 112.50 g in

Table 64. Number of tubers per vine

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	1.80	2.50	2.50
	500 r	2.00	2.75	2.70
	1000 r	2.10	2.75	2.70
	1500 r	2.10	2.75	2.90
	2000 r	2.25	3.10	3.15
	2500 r	2.25	3.10	3.25
V_2	Control	2.05	2.00	1.75
	500 r	2.10	2.10	2.15
	1000 r	2.50	2.10	2.40
	1500 r	2.50	2.05	2.65
	2000 r	2.90	2.40	2.70
	2500 r	3.00	2.20	2.75
V_3	Control	1.90	2.10	2.00
	500 r	2.10	2.70	2.20
	1000 r	2.40	2.65	2.30
	1500 r	2.50	3.00	2.25
	2000 r	2.70	3.10	2.60
	2500 r	2.80	3.05	2.60

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	4.840**	3.058*	2.522*	0.477	0.693	0.719
Varieties	11.463**	15.949**	8.898**	0.195	0.283	0.294
Exposures	10.542**	3.098*	4.507**	0.275	0.400	0.415
Interaction	0.665	0.459	0.255	0.477	0.693	0.719

* Significant at 5% level

** Significant at 1% level

Table 65. Weight of tuber (g)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	135.00	90.00	137.50
	500 r	147.50	100.00	145.00
	1000 r	162.50	101.00	150.00
	1500 r	166.00	110.00	154.50
	2000 r	158.00	117.50	157.50
	2500 r	150.00	112.50	155.00
V_2	Control	133.00	113.00	112.50
	500 r	140.50	115.00	112.50
	1000 r	146.50	130.00	118.00
	1500 r	155.00	132.00	120.00
	2000 r	160.00	142.50	124.00
	2500 r	167.50	150.00	127.50
V_3	Control	120.00	85.00	130.00
	500 r	130.00	100.00	135.00
	1000 r	132.50	97.50	139.00
	1500 r	135.00	105.00	142.50
	2000 r	140.00	110.00	150.00
	2500 r	135.00	105.00	150.00

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	2.787*	6.369**	3.049*	24.813	20.433	25.608
Varieties	11.399**	33.273**	20.540**	10.130	8.342	10.455
Exposures	3.677*	7.209**	2.021	14.326	11.797	14.785
Interaction	0.619	0.569	0.064	24.813	20.433	25.608

* Significant at 5% level

** Significant at 1% level

(1000 r of rooted cuttings) to 150.00 g (2000 and 2500 r of rooted tubers).

6. Length of tuber

The effect of gamma rays on mean length of tuber in three sweet potato varieties is depicted in Table 66. Statistical analysis of the data showed significant variation among treatments and varieties in all the three modes of treatment. Rooted cuttings alone showed significant difference among the exposures.

The mean values in V_1 control ranged from 19.00 cm in rooted tubers to 19.25 cm in rooted cuttings. In V_2 the mean values in control population differed from 15.50 cm (fresh cuttings and rooted cuttings) to 16.00 cm (rooted tubers). In V_3 control the range was from 14.00 cm in rooted tubers to 16.00 in fresh cuttings.

In fresh cuttings the mean tuber length in V_1 ranged from 19.05 cm in control to 20.35 cm in 2500 r. In V_2 it ranged from 15.50 cm in control to 17.65 cm in 2500 r. The mean values in V_3 differed from 16.00 cm in control to 18.55 cm in 2500 r.

In rooted cuttings the mean values in V_1 ranged from 19.25 cm in control to 20.75 cm in 2500 r. In V_2 the range was from 15.50 cm in control to 18.00 cm in 1500 r. In V_3 it ranged from 15.20 cm in control to 16.60 cm in 2500 r.

In rooted tubers the mean values in V_1 differed from 19.00 cm in control to 21.50 cm in 1500 r. In V_2 it ranged from 16.00 cm in control to 17.15 cm in 2000 r. The mean values in V_3 differed from 14.00 cm (control) to 15.50 cm (1500, 2000 and 2500 r).

Among the treated population the mean tuber length in V_1 showed the lowest value of 19.50 cm (500 r of fresh cuttings, 500 r of rooted tubers, 500 and 1000 r of rooted cuttings) and the highest value of 21.50 cm (1500 r of rooted tubers). In V_2 these values were 15.75 cm in 1000 r of rooted tubers and 18.00 cm in 1500 r of rooted cuttings respectively. In V_3 it was minimum (14.75 cm) in 500 and 1000 r of rooted tubers and maximum (18.55 cm) in 2500 r of fresh cuttings.

7. Girth of tuber

The mean girth of tuber as influenced by gamma rays is presented in Table 67. Statistical analysis of the data showed significant variation among treatments, varieties and exposures in rooted cuttings. But fresh cuttings showed significant difference only among the varieties.

Table 66. Length of tuber (cm)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	19.05	19.25	19.00
	500 r	19.50	19.50	19.50
	1000 r	20.50	19.50	20.00
	1500 r	20.75	20.00	21.50
	2000 r	20.10	20.25	21.00
	2500 r	20.35	20.75	21.00
V_2	Control	15.50	15.50	16.00
	500 r	16.55	16.85	16.50
	1000 r	17.25	16.75	15.75
	1500 r	16.90	18.00	16.75
	2000 r	17.20	17.90	17.15
	2500 r	17.65	17.80	17.00
V_3	Control	16.00	15.20	14.00
	500 r	17.85	15.50	14.75
	1000 r	15.90	15.80	14.75
	1500 r	18.00	16.25	15.50
	2000 r	18.00	16.50	15.50
	2500 r	18.55	16.60	15.50

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	2.886*	9.914**	6.293**	2.908	1.726	2.868
Varieties	18.536**	72.288**	49.022**	1.187	0.705	1.171
Exposures	1.581	4.170*	1.496	1.679	0.996	1.656
Interaction	0.408	0.312	0.145	2.908	1.726	2.868

* Significant at 5% level

** Significant at 1% level

The mean tuber girth in V_1 control ranged from 15.00 cm in rooted tubers to 15.50 cm in fresh cuttings. In V_2 the mean values in control differed from 13.50 cm in rooted cuttings and rooted tubers to 14.65 cm in fresh cuttings. In V_3 it differed from 12.85 cm (fresh cuttings) to 13.00 cm (rooted cuttings and rooted tubers).

In fresh cuttings the mean values in V_1 differed from 15.50 cm in control to 16.70 cm in 2000 r. In V_2 it ranged from 14.65 cm in control to 16.00 cm in 2500 r. In V_3 the range was from 12.85 to 14.75 cm in control and 2500 r respectively.

In rooted cuttings the mean tuber girth in V_1 differed from 15.10 cm in control to 16.40 cm in 1500 r. In V_2 it ranged from 13.50 cm (control) to 15.00 cm (1000 and 2500 r). The mean values in V_3 differed from 13.00 cm in control to 15.00 cm in 2000 r.

In rooted tubers the mean values in V_1 ranged from 15.00 cm in control to 15.75 cm in 2000 r. In V_2 it ranged from 13.50 to 14.30 cm in control and 2500 r respectively. In V_3 the range was from 13.00 cm in control to 15.10 cm in 2500 r.

In gamma ray exposed population the mean values in V_1 showed the lowest value (15.25 cm) in 2500 r of rooted

Table 67. Girth of tuber (cm)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	15.50	15.10	15.00
	500 r	15.85	15.50	15.50
	1000 r	16.00	15.75	15.60
	1500 r	16.25	16.40	15.50
	2000 r	16.70	16.05	15.75
	2500 r	16.00	15.90	15.25
V_2	Control	14.65	13.50	13.50
	500 r	15.50	14.05	13.60
	1000 r	15.50	15.00	13.90
	1500 r	15.80	14.75	13.70
	2000 r	15.90	14.50	14.15
	2500 r	16.00	15.00	14.30
V_3	Control	12.85	13.00	13.00
	500 r	13.55	14.00	14.00
	1000 r	13.60	13.80	14.30
	1500 r	14.00	14.60	14.30
	2000 r	14.40	15.00	14.75
	2500 r	14.75	14.50	15.10

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	2.268	3.020*	2.521	2.158	1.574	1.550
Varieties	15.171**	16.175**	15.009**	0.881	0.643	0.633
Exposures	1.387	3.049*	1.703	1.246	0.909	0.895
Interaction	0.129	0.375	0.433	2.158	1.574	1.550

* Significant at 5% level

** Significant at 1% level

tubers and the highest value (16.70 cm) in 2000 r of fresh cuttings. In V_2 these values were 13.60 cm in 500 r of rooted tubers and 16.00 cm in 2500 r of fresh cuttings respectively. In V_3 it was minimum (13.55 cm) in 500 r of fresh cuttings and maximum (15.10 cm) in 2500 r of rooted tubers.

8. Volume of tuber

The influence of gamma rays on mean volume of tuber in three sweet potato varieties is presented in Table 68. Statistical analysis of the data showed significant variation among treatments, varieties and exposures in all the three modes of treatment.

The mean volume of tuber in V_1 control ranged from 85.00 cm^3 in rooted cuttings to 130.00 cm^3 in rooted tubers. In V_2 the mean values in control population ranged from 100.00 cm^3 in rooted tubers to 127.50 cm^3 in fresh cuttings. In V_3 the range was from 82.50 cm^3 in rooted cuttings to 125.00 cm^3 in rooted tubers.

In fresh cuttings the mean tuber volume in V_1 ranged from 125.00 cm^3 in control to 158.00 cm^3 in 1500 r. In V_2 it differed from 127.50 cm^3 in control to 157.50 cm^3 in 2500 r. The mean values in V_3 ranged from 112.50 cm^3 in control to 133.00 cm^3 in 2000 r.

In rooted cuttings the mean values in V_1 ranged from 85.00 cm^3 in control to 108.00 cm^3 in 2000 r. In V_2 it differed from 105.00 cm^3 in 500 r to 140.00 cm^3 in 2500 r. In V_3 the range was from 82.50 to 103.00 cm^3 in control and 2000 r respectively.

In rooted tubers the mean values in V_1 ranged from 130.00 cm^3 in control to 150.00 cm^3 in 2000 r. In V_2 the mean values differed from 100.00 cm^3 in control to 116.00 cm^3 in 2000 r while in V_3 it ranged from 125.00 cm^3 in control to 143.00 cm^3 in 2500 r.

Among the treated population the mean tuber volume in V_1 showed the lowest value (93.00 cm^3) in 1000 r of rooted cuttings and the highest value (158.00 cm^3) in 1500 r of fresh cuttings. In V_2 these values were 105.00 cm^3 (500 r of rooted cuttings and 500 r of rooted tubers) and 157.50 cm^3 (2500 r of fresh cuttings) respectively. In V_3 it was minimum (90.00 cm^3) in 500 r of rooted cuttings and maximum (143.00 cm^3) in 2500 r of rooted tubers.

9. Tuber yield per vine

The effect of gamma rays on mean tuber yield per vine in three sweet potato varieties is depicted in Table 69. Statistical analysis of the data showed significant variation among treatments, varieties and exposures in rooted

Table 68. Volume of tuber (cm^3)

Varieties	Treatments	Modes of treatment: Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	125.00	85.00	130.00
	500 r	136.00	96.00	138.00
	1000 r	150.00	93.00	145.00
	1500 r	158.00	102.50	145.00
	2000 r	151.00	108.00	150.00
	2500 r	145.00	107.50	147.50
V_2	Control	127.50	106.00	100.00
	500 r	134.00	105.00	105.00
	1000 r	141.50	122.50	108.00
	1500 r	150.00	123.00	114.00
	2000 r	152.00	135.00	116.00
	2500 r	157.50	140.00	115.00
V_3	Control	112.50	82.50	125.00
	500 r	120.00	90.00	127.50
	1000 r	123.50	92.50	130.00
	1500 r	127.50	97.00	129.00
	2000 r	133.00	103.00	141.00
	2500 r	130.00	99.00	143.00

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	3.475**	9.039**	5.419**	21.917	15.957	20.088
Varieties	14.222**	46.919**	37.704**	8.947	6.514	8.201
Exposures	5.282**	10.155**	2.982*	12.654	9.213	11.598
Inter-action	0.422	0.904	0.181	21.917	15.957	20.088

* Significant at 5% level

** Significant at 1% level

tubers. In rooted cuttings there was significant difference among treatments and exposures. In fresh cuttings significant variation was noticed among the exposures only.

The mean values in V_1 control ranged from 226.00 g in rooted cuttings to 345.00 g in rooted tubers. In V_2 the mean values in control ranged from 196.50 g in rooted tubers to 231.00 g in fresh cuttings. In V_3 control it ranged from 178.00 g in rooted cuttings to 328.00 g in fresh cuttings.

In fresh cuttings the mean values in V_1 differed from 243.00 g in control to 356.00 g in 2000 r. In V_2 it ranged from 231.00 g in control to 375.00 g in 2500 r. The mean values in V_3 ranged from 206.00 g in 500 r to 381.00 g in 2000 r.

In rooted cuttings the mean tuber yield in V_1 ranged from 226.00 g in control to 356.50 g in 2000 r while in V_2 it differed from 226.00 g to 342.00 g in control and 2000 r respectively. In V_3 it ranged from 178.00 g in control to 344.00 g in 2000 r.

In rooted tubers the mean values in V_1 ranged from 345.00 g in control to 503.50 g in 2500 r. In V_2 it differed from 196.50 g in control to 344.00 g in 2500 r. In V_3 the range was from 260.00 g in control to 392.00 g in 2000 r.

Table 69. Tuber yield per vine (g)

Varieties	Treatments	Modes of treatment		
		Fresh cuttings	Rooted cuttings	Rooted tubers
V_1	Control	243.00	226.00	345.00
	500 r	295.50	271.00	393.50
	1000 r	340.50	275.00	400.00
	1500 r	248.50	303.50	435.00
	2000 r	356.00	356.50	496.00
	2500 r	337.50	348.00	503.50
V_2	Control	231.00	226.00	196.50
	500 r	234.50	239.50	244.50
	1000 r	295.00	271.00	282.50
	1500 r	299.00	311.00	323.50
	2000 r	359.00	342.00	333.50
	2500 r	375.00	330.00	344.00
V_3	Control	328.00	178.00	260.00
	500 r	206.00	269.50	299.00
	1000 r	315.50	252.00	317.50
	1500 r	337.50	314.00	320.00
	2000 r	381.00	344.00	392.00
	2500 r	374.00	320.50	390.00

	F value			CD value		
	Fresh cuttings	Rooted cuttings	Rooted tubers	Fresh cuttings	Rooted cuttings	Rooted tubers
Treatments	2.081	2.981*	3.172*	114.658	87.052	136.468
Varieties	0.705	0.515	15.113**	46.809	35.539	55.713
Exposures	4.897**	9.421**	4.536**	66.198	50.260	78.790
Interaction	0.948	0.254	0.101	114.658	87.052	136.468

* Significant at 5% level

** Significant at 1% level

In gamma ray exposed population the mean tuber yield in V_1 showed the lowest value (271.00 g) in 500 r of rooted cuttings and the highest value (503.50 g) in 2500 r of rooted tubers. In V_2 these values were 234.50 g in 500 r of fresh cuttings and 375.00 g in 2500 r of fresh cuttings respectively. In V_3 it was minimum (206.00 g) in 500 r of fresh cuttings and maximum (397.00 g) in 2000 r of rooted tubers.

Plate 1. A chlorophyll deficient chimera in vM_1 generation

Plate 1

Plate 2. Variety S_5 (V_9) - Control plant

Plate 3. Variety S_5 (V_9) - Broad leaved mutant

Plate 2

Plate 3

Plate 4. H-42 (V_{12}) - Control plant

Plate 5. Chlorophyll deficient chimera in H-42 (V_{12})

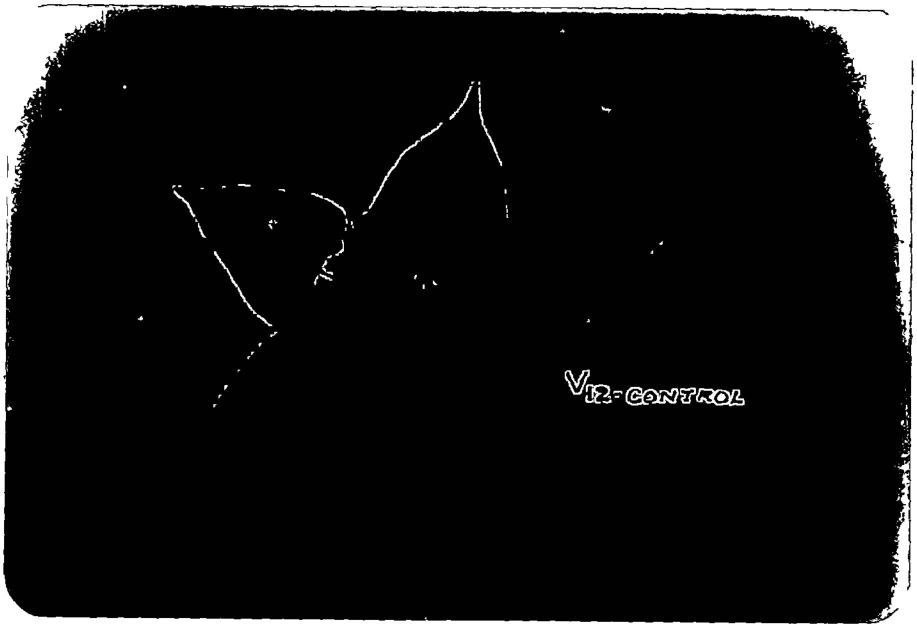

Plate 4

Plate 5

Plate 6. Chlorina type chimera in H-42 (V_{12})

Plate 7. An abnormal plant development in H-42 (V_{12})

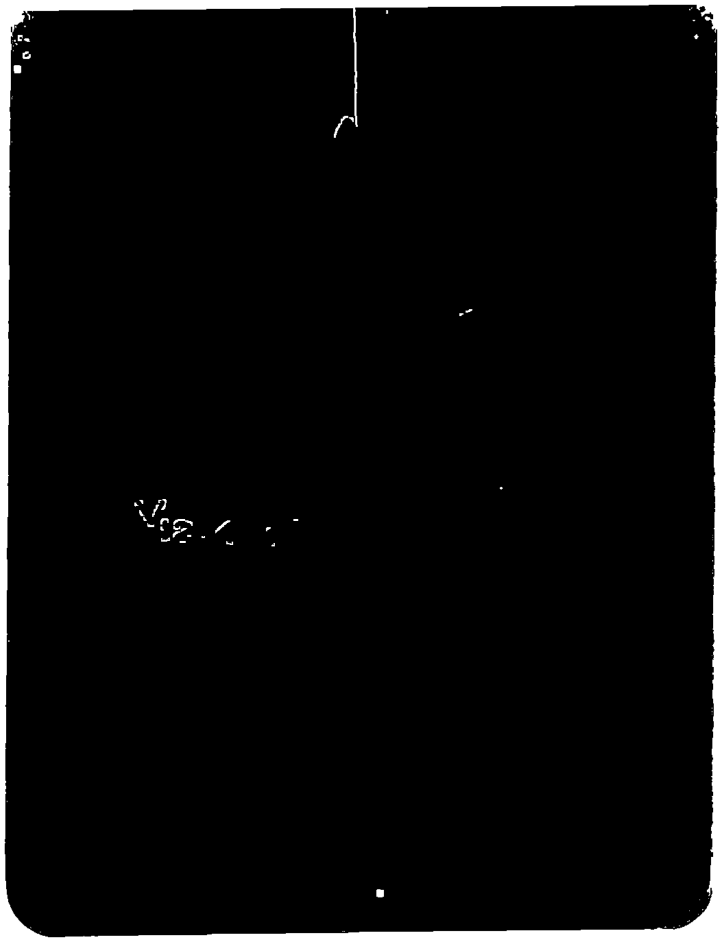

Plate 6

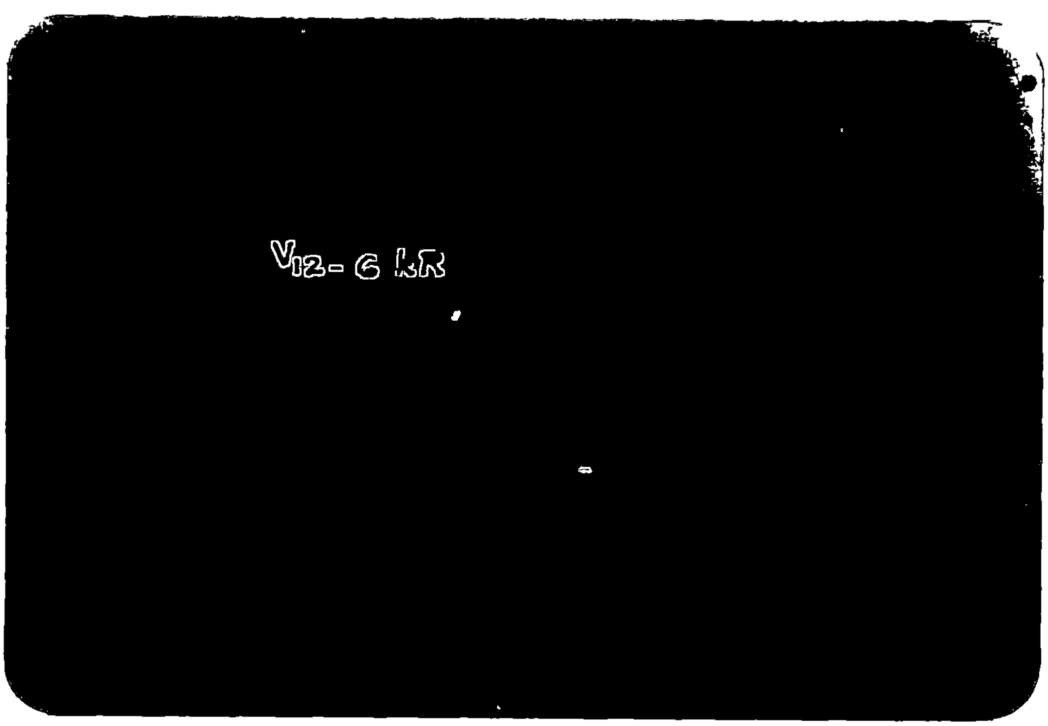

Plate 7

Plate 8. S_5 Tuber yield variant - vM_2 generation

Plate 9. S_5 Leaf shape variant - vM_2 generation

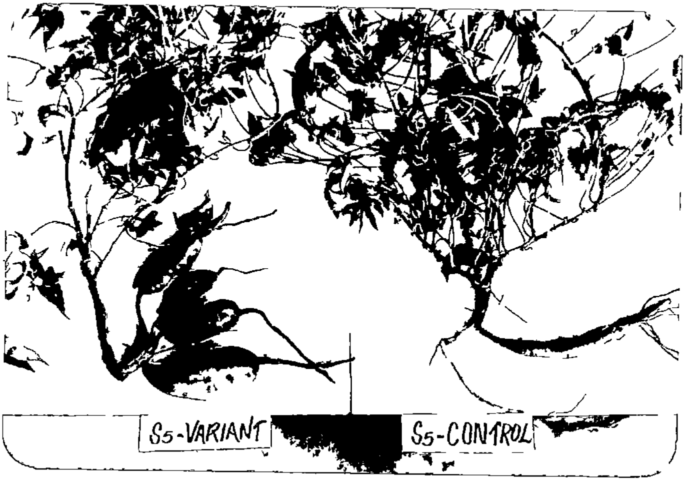

Plate 8

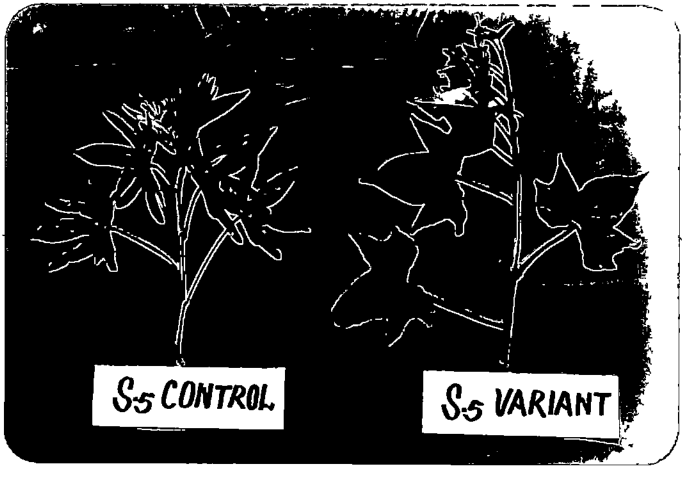

Plate 9

Plate 10. Leaf size variants induced in vM_1 generation (Fresh cuttings)

Plate 11. Leaf size variants induced in vM_1 generation (Rooted cuttings)

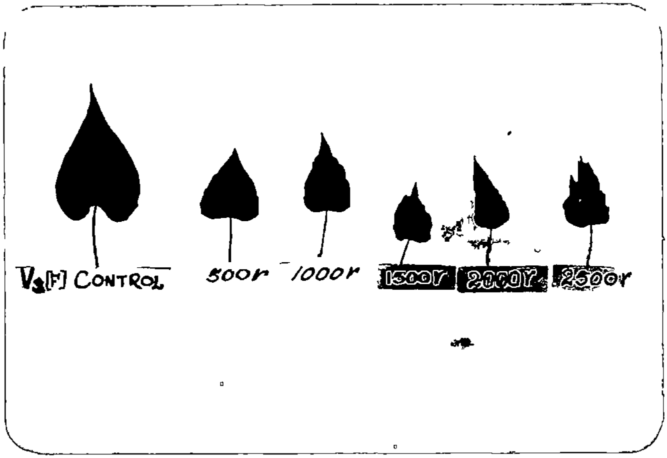

Plate 10

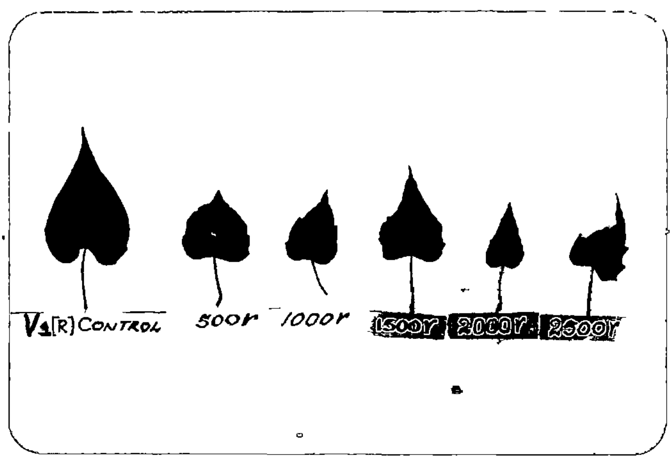

Plate 11

Plate 12. Leaf size variant in Bhadrakalichuvala (V_3) - Rooted cuttings in vM_1 generation

Plate 13. Tuber yield variant in Bhadrakalichuvala (V_3) - Rooted cuttings in vM_1 generation

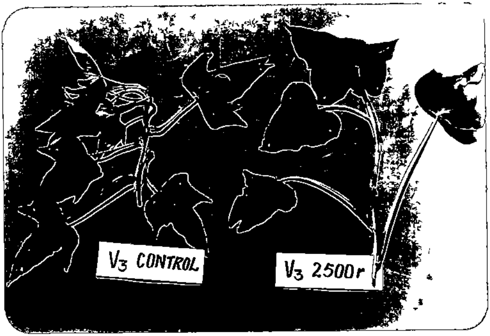

Plate 12

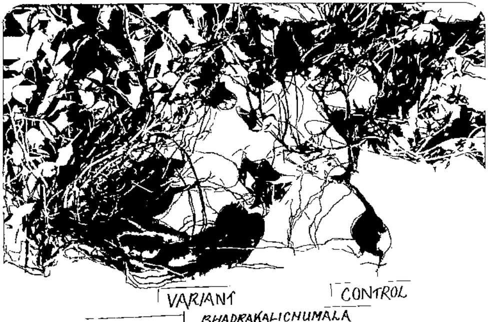

Plate 13

Plate 14. Tuber colour variant in Kanhangad local (V_2) - Rooted cuttings

Plate 15. Tuber size variant in Kanhangad local (V_2) - Rooted cuttings

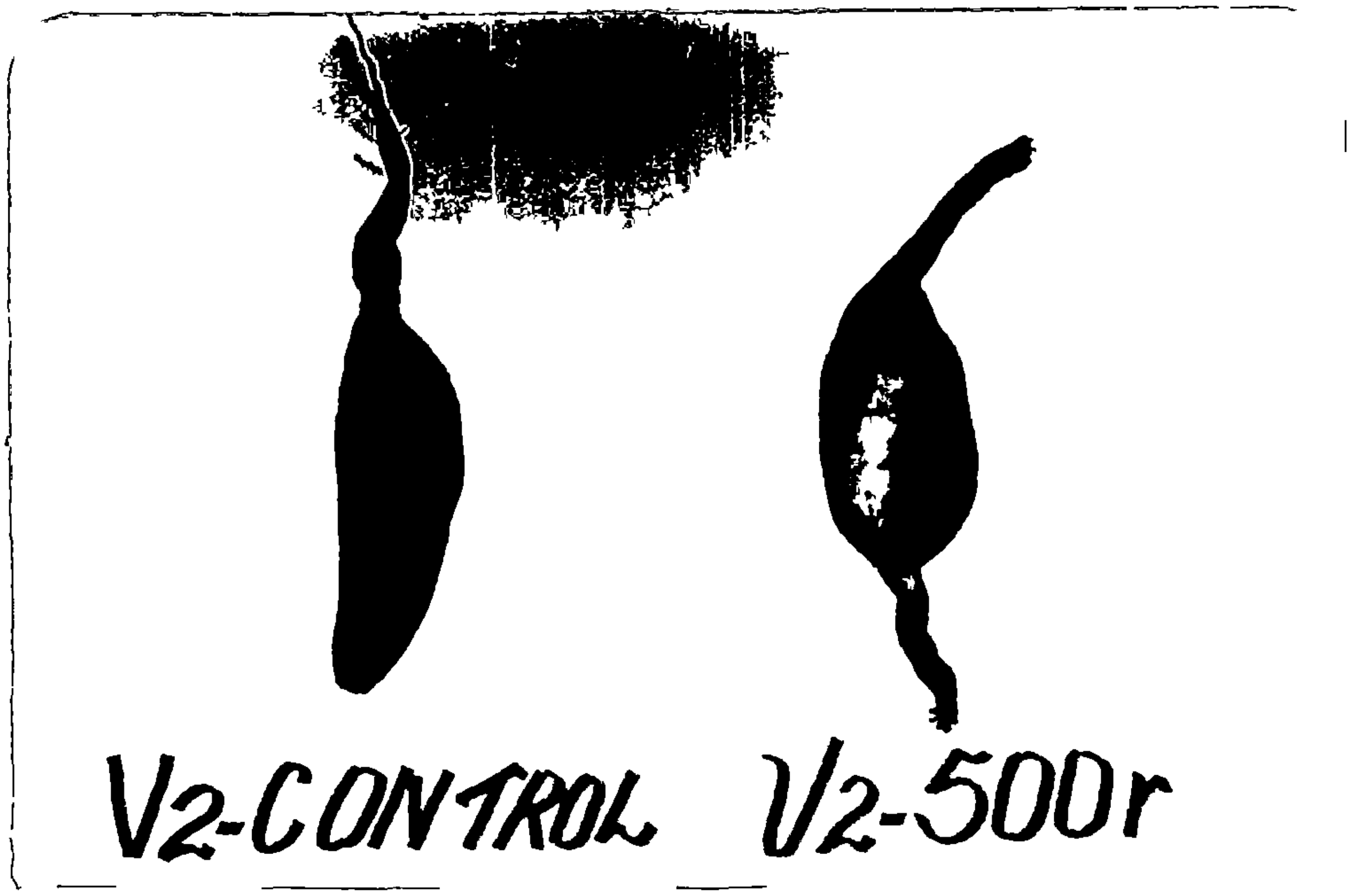

Plate 14

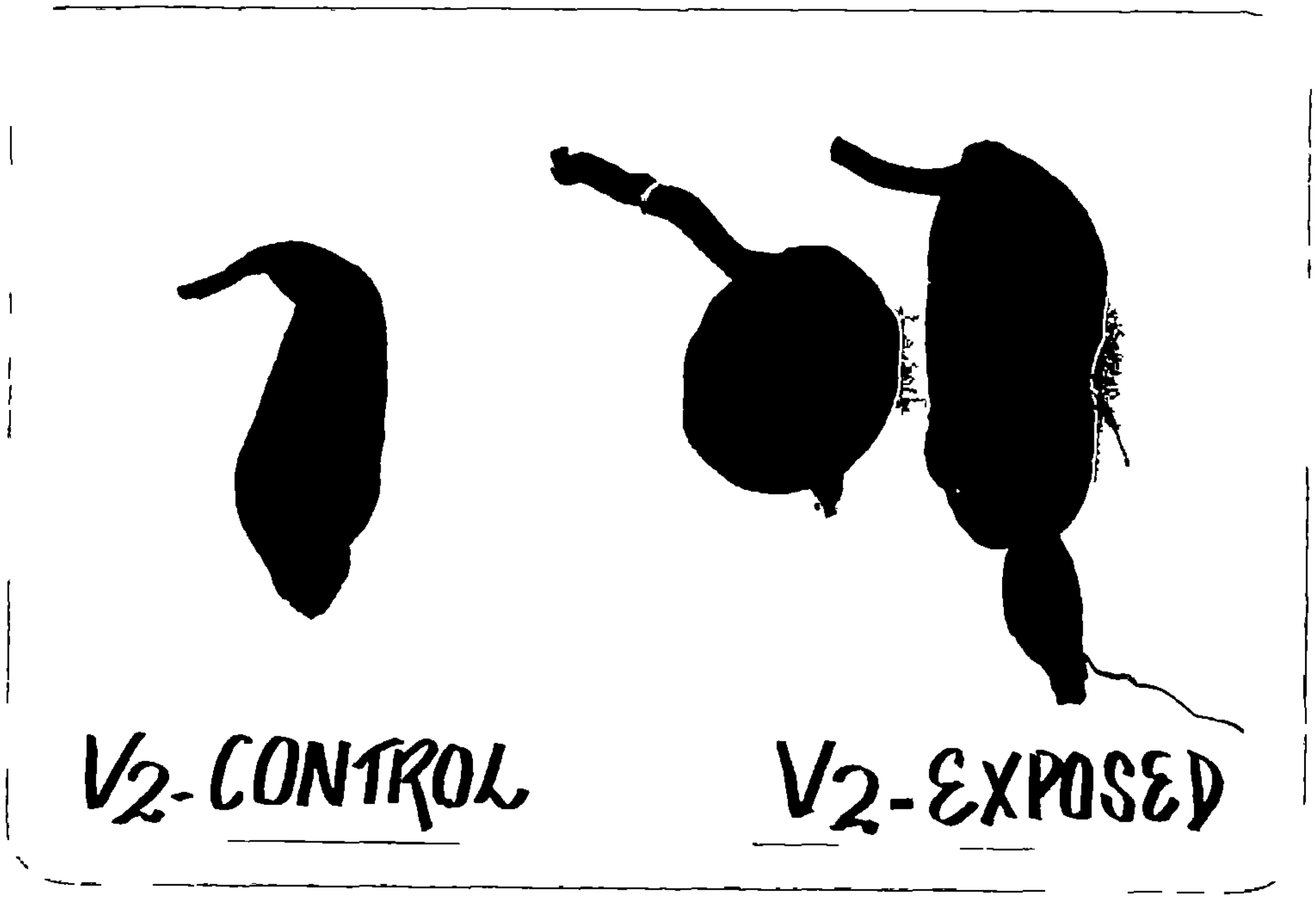

Plate 15

DISCUSSION

DISCUSSION

Part I - Radiosensitivity analysis

The study of radiosensitivity of species or strains would be more desirable so that the optimum exposure of mutagen can be used in each variety. According to Sparrow (1961) the nuclear and chromosomal variables are the main factors influencing the sensitivity to radiation.

Information regarding the radiosensitivity of sweet potato varieties to gamma rays is very limited. The study was undertaken to compare the response of fifteen varieties of sweet potato to gamma rays. These sweet potato varieties exhibited marked differences in sensitivity as expressed by differences in days taken to start sprouting, days taken to complete sprouting, sprouting percentage, length of vine, branch number, tuber number and tuber weight per vine in the vM_1 generation. Thus the magnitude of differences in sensitivity between varieties depend on the criteria adopted to measure the radiation effects.

The results obtained from the present study are discussed in the following sections.

The vines treated with different exposures of gamma rays took more time to start sprouting than the control. The delay in sprout initiation may be due to the influence of gamma rays on plant hormones and plant growth regulators as reported by Casarett (1968) in higher plants. Goud (1967) reported considerable delay in germination of seeds at high doses of radiation. The gamma ray exposure tested showed a variety-dependent variation for days taken to start sprouting.

In the present investigation the days taken to complete sprouting also showed a variety-dependent variation. In almost all the varieties a longer period to complete sprouting was noted or in other words gamma ray exposure delayed sprouting in most of the varieties. Similar results were reported by Wills (1965) on potato.

The sprouting percentage varied depending on the varieties in the present study. In most of the varieties there was no sprouting in 6, 8 and 10 kR. So also there was significant difference in sprouting in 2 kR exposure. The decrease in sprouting may be mainly attributed to chromosomal aberrations and the related physiological disorders. Similar reduction in sprouting percentage was reported by Izotova (1974) in potato and also bv Budin _et al_. (1971) in potato. Jasina and Kirsanova (1966 b) reported that lower doses of gamma rays stimulated germination.

The percentage lethality was more in gamma exposed population in most of the varieties when compared to the respective control. The lower survival rate may be due to the inactivation of auxin level in the plant with increasing exposures as reported by Skoog (1935). In addition mutagenic treatments also caused chromosomal aberrations which affected adversely the cell division (Read, 1959; Sparrow, 1961) and inhibition of DNA synthesis (Mikaelsen, 1968). The reduction in survival is an index of post germination mortality in the treated material as a result of radiation effect. Sato and Gaul (1967) suggested that the reduction in survival may be due to physiological disturbances. The increase in percentage lethality was maximum till the 30th day beyond which only gradual increase was observed.

Vine length was measured in seven different growth stages. In the treated population of most of the varieties a reduction in vine length was noted compared to their control. Similar results were obtained by Tarasenko (1963 a) and Umaerus (1966) in potato. The reduction in vine length may be due to high radiosensitivity of the vines. Surkova (1973) reported height increase in potato as a result of mutagen treatment. According to Sinha and Goward (1972) the stimulation in height at low doses may be due to an increase in the rate of cell division or increase in the size of cells.

There was genotype-dependent variation in the number of branches in the case of r-ray exposed population when compared to control. A decrease in branch number per vine was noted in the treated population. This may be due to the retarded growth and development of the plant by r-ray exposure. Tarasenko (1963 a) and Umaerus (1966) in potato reported retarded growth and development by the action of physical and chemical mutagens.

Gamma irradiation was effective in increasing the yield attributes like number of tubers per vine and the weight of tubers per vine. A comparatively higher number of tubers was recorded in the treated population. Due to high lethality of vines the number of vines per unit area is less in the treated population. So there is the chance of utilizing the nutrients, space, water and light in an efficient manner for getting more number of sizable tubers per vine and thereby increasing the yield. Reduction in vine length which reduced the excessive vegetative growth may also be a favourable attribute in sweet potato to increase tuber yield per plant. Increased tuber number as a result of gamma irradiation was reported by Dmitrieva and Mikhailov (1977) and Saulite (1983) in potato. Nayar and Rajendran (1987) in tapioca reported 20-25 per cent yield increase as a result of gamma irradiation. Saulite (1981) obtained mutants for higher yield in potato by chemical mutagens. Mikhailov (1980) reported that varietal differences were found in the optimum dose to give the highest increase in yield.

Chlorophyll deficient sectors appeared on vM_1 plants in the radiosensitivity analysis depending on the varieties. Gaul (1963) reported that the type of chimerism varied with the dose of the mutagen. Chlorophyll deficient streaks or spots as a result of mutagen treatment could be related to gene mutations and used to estimate mutagenic effects in the M_1 generation (Kaplan, 1954; Blixt, 1972). Chlorophyll chimeras were reported to be associated with plastid mutations (Goud, 1967). Batikyan et al. (1975) suggested that the formation of leaf spots or streaks in pepper by the action of alkylating agents were accompanied by extensive structural disturbances on the grana part of the leaf. In the present study plants with chlorophyll deficient patches on the leaves have been produced by destruction of chlorophyll as reported by Batikyan et al. (1975). A vine with one chimeric branch and the rest being normal was observed in the treated population of V_4. This may be due to the fact that only a part of the tissue was affected by r-rays resulting in chimeric regions in certain branches. Similar chlorophyll chimeras were observed by Pitirimova (1985) in barley, Heiken (1961) in potato and Rudorf and Lohrmann (1963) in potato. Hernandez et al. (1964) reported that in sweet potato r-irradiation resulted in sectorial mutation.

In potato also a sectorial chimera was reported (Nayar and Chauhan, 1968). Chlorophyll deficient sectors on the M_1 plants of rice following irradiation were observed by Siddiq (1967) and also by Tanaka (1970). The types of morphological variations in the M_1 plants depend upon the duration of exposure, age and condition of the plant and the environment during and after exposure. The morphological variations in the present study included vines with variation in leaf size and shape. Morphological variations were reported by Chopde (1970) in Cajanus cajan and Jauhar (1969 b) in potato after gamma ray exposures.

Part II - Induced mutagenesis

A. Direct effect of the mutagen (vM_1 generation)

Fresh cuttings, rooted cuttings and rooted tubers treated with different exposures of gamma rays took more time for sprout initiation compared to the control. Of the three modes of treatment, rooted cuttings gave higher values for days to start sprouting when compared to fresh cuttings and rooted tubers. Rooted tubers gave only lower values for sprout initiation. Whatever be the mode of treatmen and varieties, there was a delay in sprout initiation with increase in gamma ray exposures. The delay in sprout initiation observed in the present study may be due to the influence of gamma rays on plant hormones and plant growth regulators as reported by Casarett (1968) in higher plants.

Rooted cuttings gave higher values for days taken to complete sprouting compared to fresh cuttings and rooted tubers. Whatever be the mode of treatment and varieties, there was a dose-dependent variation in days taken to complete sprouting.

In the present investigation the sprouting percentage was found to decrease with increase in gamma ray exposures. Among the three modes of treatment, rooted tubers gave higher values for sprouting percentage compared to fresh cuttings and rooted cuttings. Rooted cuttings recorded lower values for percentage sprouting. Here also a dose-dependent variation in sprouting percentage was noticed in all the three varieties. Sprouting inhibition in potato was reported by Wills (1965). Similar decrease in sprouting percentage was reported by Izotova (1974) and Budin _et al_. (1971) in potato. It was also found that the lower doses of gamma rays stimulated sprouting in all the three varieties and also in three modes of treatment. Jasina and Kirsanova (1966 b) reported that in potato the lower doses stimulated sprouting.

The percentage lethality was found to increase with increase in gamma ray exposures. Eventhough the increase in lethality was not linear the highest exposure (2500 r) recorded the maximum value for lethality percentage in all the three varieties and also in all the three modes of treatment. A reduction in survival consequent to irradiation was observed by Fautrier (1976) in lucerne, Krishnaswamy et al. (1977) in green gram and Reddy et al. (1977) in groundnut. Sapra and Constantin (1978) reported that the survival was significantly reduced by increasing doses of r-rays in hexaploid triticale. The reduction in survival is an index of post-germination mortality in the treated material as a result of radiation effect. Sato and Gaul (1967) suggested that the reduction in survival may be due to physiological disturbances.

Mc Crory and Grun (1969) in potato reported that the mutagen treatment was lethal at the highest rate but was progressively less effective at lower rates probably due to the operation of chromosomal repair mechanisms.

The increase in percentage lethality was maximum till the 30th day of planting beyond which only gradual increase was noticed.

There was a decrease in vine length with increase in gamma ray exposures in all the three modes of treatment and also in the three varieties. The maximum decrease was noticed in the two higher exposures (2000 and 2500 r). The reduction in vine length was maximum during the seedling stage.

Tarasenko (1963 a) and Umaerus (1966) reported similar results in potato. The decrease in vine length may be due to the retarded growth and development of the plant by r-ray exposure. In the present study the lower exposures (500 and 1000 r) showed increase in vine length in certain growth stages. The increase in plant growth due to gamma irradiation may be due to the destruction of inhibitory substances and increase in the physiologically active substances like auxin and gibberellin which stimulate elongation as reported by Surkova (1973) in potato due to mutagen treatment.

A decrease in branch number was noticed with increase in gamma ray exposures in all the three modes of treatment. This may be due to the retarded growth and development of the plant as a result of gamma irradiation. Tarasenko (1963 a) and Umaerus (1966) reported retarded growth and development in potato by the action of physical and chemical mutagens.

A decrease in fresh weight of vine was noticed in the present investigation as a result of higher exposures (2000 and 2500 r) of gamma rays. The same trend was noticed in all the three modes of treatment. The reduction in fresh weight may be attributed to retarded growth and development due to gamma ray exposure.

An increase in tuber number per vine was noticed in the vM_1 generation as a result of higher exposures (1500, 2000 and 2500 r) of gamma irradiation. Dmitrieva and Mikhailov (1977) and Saulite (1983) reported increased tuber number in potato by higher exposures of gamma irradiation.

Gamma irradiation was effective in increasing the tuber yield per vine in all the three modes of treatment. Due to higher percentage lethality in higher exposures the vine number per unit area was less. Lesser number of vines might have utilized the available nutrients, water, space and light in an effective manner by producing more number of sizable tubers per vine and thereby increasing the tuber yield. Saulite (1981) obtained mutants for higher yield in potato by chemical mutagens. Nayar and Rajendran (1987) reported 20-25 per cent yield increase in tapioca by using gamma irradiation. Similar results in potato were obtained by Anikiev (1973), Izotova (1974), Dańko (1975), Jasina and Kirsanova (1966 b), Maishchuk (1978) and Mikhailov (1980). In the present study it was also found that the higher exposures (2000 and 2500 r) produced the maximum tuber yield. Solomko (1969) reported similar result in potato. In sweet potato Miu (1973) and Miu et al. (1973) obtained higher tuber yield by using gamma irradiation at 5000 r.

B. Induced mutagenesis in polygenic characters (vM_2, vM_3 and vM_4 generations)

Genetic variability created in quantitative or polygenic characters using physical and chemical agents has become the most potent line of approach to tailor better varieties of crop plants to suit almost all stress conditions. Many dedicated research workers including Gregory (1955) in groundnut, Oka *et al.* (1958) in rice and Rawlings *et al.* (1958) in soybean have analysed the effect of mutagen on polygenic systems. A general conclusion drawn from earlier studies clearly demonstrates that mutagens can create genetic variation in quantitative characters in any direction. But still, it is a matter of debate whether irradiation induced mutations in polygenes occur towards negative and positive directions or towards either of the two. The problem is of great importance from the stand point of practical utilization of radiation energy for the improvement of economically important characters of crop plants. The results emanated during the course of study are discussed below:

1. Mean character expressions and frequency of variants

A comparison of vine length in the three segregating generations showed that it was maximum for the control and the lower exposures (500 and 1000 r) and minimum for higher exposures of gamma irradiation (2000 and 2500 r) in all the three modes of treatment. In vM_2 and vM_3 generations, gamma rays induced a negative shift in vine length in all the three modes of treatment. But a positive shift in mean vine length was observed in 500, 1000, 1500 and 2000 r in rooted tubers of vM_3 generation.

A reduction in mean plant height as a result of mutagen treatment has been reported by several workers. Mutants showing dwarfness with short stems were reported by Tarasenko (1963 a) and Umaerus (1966) in potato and Shasthry and Nandhachary (1965) in M_4 of irradiated rice. Sakai and Suzuki (1964) after X-irradiation in rice, reported that mutation of polygenes responsible for quantitative characters like plant height occurs in most cases unidirectionally in minus direction. Sreerangasamy et al. (1973) observed that green gram plants treated with gamma rays were shorter than the parents. Nayar (1976) found significant reduction in mean values in M_2 and M_3 generations for six polygenic characters including plant height in rice following EMS and gamma ray treatments.

An increase in mean vine length as a result of gamma ray exposure, as noted in certain cases in the present study has also been reported by several workers. A positive shift in plant height was observed by Goud et al. (1971) in ragi. Increased plant height in M_2 and later generations in comparison to the unirradiated plants was observed by Kumar and Das (1977) in Brassica. They suggested that this may be related to the effect of selection applied in M_2 and later generations. Increased plant height after mutagen treatment was also reported by Kamannavar (1985) in chilli.

Whatever be the mode of treatment and varieties the two higher exposures were effective in decreasing the vine length in vM_2, vM_3 and vM_4 generations. The range in frequency of variants varied widely with respect to the genotype and the generations. In the vM_2 generation, V_1 recorded a higher range of negative plant height variants compared to V_2 and V_3 in all the 3 modes of treatment. The range of positive variants was higher in 500 and 1000 r in all the three modes of treatment and in the three generations. This may be the reason why the mean vine length showed a negative shift in all the three generations.

In vM_2 generation a positive shift in mean number of branches was noted in the lower exposures of r-rays. In vM_2 generation at higher exposures a positive shift in mean branch number was observed in fresh cuttings and a negative shift was observed in rooted cuttings. A complete negative shift in the mean value was noted in vM_4 generation. In vM_3 generation the higher exposures of rooted tubers showed both negative and positive shift. The negative shift in branch number may be due to higher frequency of negative variants or lower frequency of positive variants. The positive shift in some exposures may be due to higher frequency of positive variants and lower frequency of negative variants.

Sakai and Suzuki (1964) noted decreased number of tillers in rice and suggested that X-irradiation resulted in a decrease in polygenic characters like number of tillers. Similar result was reported by Ehrenberg et al. (1964) in rice in the M_4 generation. Gamma ray and EMS treatments in rice have led to a significant reduction in mean number of tillers in M_2 and M_3 generations (Nayar, 1976). Bateman (1959) observed that the mean value of tillers per plant in rice increased after irradiation and suggested that the over-all effect of polygenic mutation in rice was unidirectional. The mean number of branches in M_2 and later generations was found to be increased due to treatment with gamma rays and thermal neutrons as was reported by Kumar and Das (1977) in *Brassica*.

The mean value for fresh weight of vine exhibited both negative and positive shift. In vM_2 the negative variants were at a higher frequency compared to positive variants. In vM_3 and vM_4 generations the two higher exposures exhibited very low values for fresh weight in all the three varieties and in the three modes of treatment. In the fresh cuttings of vM_2 generation the two lower exposures exhibited a positive shift. This may be due to the occurrence of a higher frequency of positive variants. On the contrary the higher exposures of fresh cuttings exhibited a positive shift in fresh weight in the vM_2 generation.

The mean tuber number exhibited a positive shift in vM_2, vM_3 and vM_4 generations. The increase in positive shift was more in vM_4 generation compared to vM_2 and vM_3 generations. This may be due to more number of positive variants. In general, irradiation of rooted cuttings was found to be more effective in increasing the tuber number rather than irradiation of fresh cuttings and rooted tubers.

Berezoskii et al. (1981) obtained increased fruit number per plant in the third generation by chemical mutagen treatment in tomato. Similar result was reported by Kamannavar (1985) in chilli by gamma irradiation. Increased tuber number as a result of gamma irradiation was reported by Dmitrieva and Mikhailov (1977) and Saulite (1983) in potato. Several workers including Miah and Yamaguchi (1965) are of opinion that mutations for majority of polygenic traits occurred symmetrically in positive and negative directions following gamma irradiation.

The positive shift in the mean value observed in the vM_2, vM_3 and vM_4 generations was due to the production of more number of positive variants compared to negative variants. Comparatively higher positive variants produced was responsible for positive shift in mean value in all the exposures.

The range of positive variants was wider in the vM_3 generation compared to vM_2. Irrespective of modes of treatment and varieties in all the three generations the higher exposures exhibited the maximum number of positive variants compared to negative variants.

Gamma irradiation led to a general increase in mean weight of tuber in all the three modes of treatment. In vM_2 generation the positive variants were at a lower frequency compared to vM_3 generation. But in all the three generations, a positive shift in mean tuber weight was exhibited by the three modes of treatment. Compared to vM_2 and vM_3 generations, a wider range of positive variants was observed in the vM_4 generation ie. the variability created in the vM_4 is higher than that in the vM_2 and vM_3 generations. This is in agreement with the result obtained by Sakai and Suzuki (1964) in X-irradiated rice. Patel and Swaminathan (1961) reported range of variability in M_2, M_3 and M_4 generations of irradiated tobacco. Rao and Siddiq (1977) after analysing induced variation for yield and its components in rice, suggested that the changes in the mean value and skewness of the frequency distribution in mutagen treated population varied with the variety, character, mutagen and the generation.

The mean value for tuber length exhibited positive and negative shift. In the lowest dose of fresh cuttings in vM_2 a negative shift was noticed. In vM_4 generation only positive shift was noticed in the mean value. In general, positive shift in tuber length was exhibited in the irradiated population compared to control. This may be due to a higher production of gamma ray induced positive variants in the r-ray exposed population. Significant difference in the mean values on panicle length among treated and between treated and controls were observed by Matsuo et al. (1964) in M_6 generation of rice. A negative shift in mean panicle length following X-irradiation has been reported in rice by Sakai and Suzuki (1964). Nayar (1976) has also reported similar reduction in mean panicle length in rice. On the contrary increased frequency of mutants in M_3 with respect to panicle length was reported by Siddiq and Swaminathan (1968) in EMS treated rice.

The range of negative variants in vM_3 was lower compared to that in vM_2. The positive shift in the mean value seen in the exposed population may be due to the production of lesser number of negative variants and a higher frequency of positive variants. Hence selection for longer tubers will be more effective from the vM_3 generation.

The mean value for tuber girth exhibited positive shift in vM_2, vM_3 and vM_4 generations. There was an increase in tuber girth with increase in gamma ray exposures in all the three generations and in the three modes of treatment. The maximum value for tuber girth was shown by higher exposures of gamma rays. The effects noticed in vM_2 are comparable to that of vM_3. The positive shift in tuber girth in the treated population may be due to a higher production of gamma ray induced positive variants.

The mean value for tuber volume exhibited positive shift in vM_2, vM_3 and vM_4 generations. In vM_2 generation the range of positive variants was wider in fresh cuttings compared to rooted cuttings and rooted tubers. Whatever be the mode of treatment and varieties in all the three generations the higher exposures gave higher values for tuber volume compared to the control. This may be due to the production of higher frequency of positive variants and lower frequency of negative variants. In vM_3 generation a wider range of positive variants was exhibited in the V_3 of rooted tubers. But in vM_4 generation, the range was maximum in V_2 of rooted cuttings.

A positive shift for mean tuber yield per vine was noticed in the three generations and in the three modes of treatment. There was an increase in tuber yield with increase in gamma ray exposures. The maximum was recorded in the two higher exposures in the three generations. The lower exposures also gave comparatively higher frequency of positive variants in the three generations.

Significant positive shift in the mean tuber yield may be due to higher frequency of positive variants created by the effect of gamma rays. Higher yield is contributed by increased length, girth, volume and mean number and weight of tubers. In the irradiated population a wider variability is created in vM_4 compared to vM_2 and vM_3 generations. The range of positive variants in vM_4 was higher than that in vM_2 and vM_3.

Increase in yield as a result of irradiation was reported by many workers including Saulite (1981), Mikhailov (1980), Maisnchuk (1978), Dańko (1975) and Groza (1977) in vM_3 and Jasina and Kirsanova (1966 b) in vM_2 of potato. In sweet potato Miu (1973) and Miu et al. (1973) reported higher yield by 5000 r of gamma rays in vM_2 generation. Vasudevan et al. (1984) studied the yield performance in M_3 and M_4 generations of Vigna unguiculata and reported the same trend.

Mutants showing lower yield than control were also observed by some workers; Johnston (1961) in M_4 and M_5 of oats, Sakai and Suzuki (1964) in M_4 of rice and Kotvics (1981) in M_3 and M_4 of soybean.

2. Frequency distribution of variants in vM_2 and vM_3 generations

Gamma rays induced negative and positive variants in all the three modes of treatment in vM_2 and vM_3 generations. There was no significant difference in frequency distribution in any of the characters.

In vM_2 generation for vine length the positive variants were at a higher frequency in rooted tubers and fresh cuttings when compared to rooted cuttings. In fresh cuttings, rooted cuttings and rooted tubers the negative variants were at a higher frequency when compared to positive variants. In vM_3 generation, for fresh cuttings negative variants and positive variants were almost equal in V_1 and V_2. But in V_3 the positive variants were at a lower frequency compared to negative variants. But in rooted cuttings and rooted tubers the positive variants were at a lower frequency compared to negative variants in all the three varieties. In vM_2 and vM_3 the two higher exposures gave a lower frequency of positive variants compared to negative variants in all the three modes of treatment. The reduction in vine length at the two higher levels may be due to higher frequency of negative variants and lower frequency of positive variants.

In the case of branch number per vine no general trend in frequency distribution was noted in the three modes of treatment. But in fresh cuttings of V_1 the positive variants were at a lower frequency compared to negative variants. But 2500 r of fresh cuttings gave a lower frequency of positive variants compared to negative variants in all the three varieties. In rooted cuttings for V_2 and V_3 positive variants were at a higher frequency compared to negative variants. The higher branch number in the lower exposure and also at higher exposures may be due to the production of higher frequency of positive variants compared to negative variants in all the three modes of treatment. In vM_3 generation the positive variants were at a lower frequency compared to negative variants in all the modes of treatment. The higher exposures of gamma rays showed both positive and negative shift. The positive shift may be due to production of higher frequency of positive variants and lower frequency of negative variants. The negative shift exhibited by the higher exposures may be due to the higher frequency of negative variants and lower frequency of positive variants.

In the case of fresh weight of vine no general trend in the frequency distribution of variants was noticed in vM_2. For fresh cuttings V_1 and V_3 gave higher frequency of negative variants and a lower frequency of positive variants. V_2 showed higher frequency of positive variants in fresh cuttings and lower frequency of positive variants in rooted cuttings and rooted tubers. But the two higher exposures gave lower frequency of positive variants in rooted tubers. In vM_3 generation a lower frequency of positive variants was noted compared to negative variants in the three modes of treatment. The maximum decrease in fresh weight was exhibited in the two higher exposures. This negative shift in fresh weight may be due to the production of higher frequency of negative variants or lower frequency of positive variants in vM_2 and vM_3. The positive shift in fresh weight shown by the two higher exposures may be due to the production of higher frequency of positive variants and lower frequency of negative variants.

In the case of tuber number per vine, the increase in tuber number shown by the higher exposures may be due to the production of higher frequency of positive variants and lower frequency of negative variants in vM_2 and vM_3. In vM_2 the rooted tubers of V_2 showed an exception to this general trend, ie. the negative variants were at a higher frequency compared to positive variants in the two higher exposures.

In the case of mean tuber weight the positive variants were at a lower frequency in V_1 and V_3 in the vM_2 generation. But in V_2 the positive variants were at a higher frequency in the higher exposures in the three modes of treatment. In

vM_3 also, a higher frequency of positive variants was noted in all the higher exposures. The increase in mean tuber weight by the higher exposures may be due to the production of higher frequency of positive variants and lower frequency of negative variants.

In tuber length, a higher frequency of negative variants was noted in the lower exposures of all modes of treatment. The higher exposures showed comparatively higher frequency of positive variants in vM_2 and vM_3 generations. The increase in tuber length at higher exposures may be due to the production of higher frequency of positive variants and lower frequency of negative variants. The negative shift in the lower exposures may be due to the production of higher frequency of negative variants compared to positive variants.

Tuber girth showed positive shift in mean value in the three modes of treatment in vM_2. This positive shift may be due to higher frequency of positive variants and lower frequency of negative variants. But in vM_3 the fresh cuttings and rooted cuttings showed a higher frequency of negative variants compared to positive variants.

In the case of tuber volume, the negative variants were at a higher frequency in rooted cuttings and rooted tubers in vM_2. In fresh cuttings the positive variants were at a higher frequency compared to negative variants. In vM_3 for tuber volume, no general trend was noticed. But the positive variants were at a higher frequency in the higher exposures in all the three modes of treatment.

In tuber yield per vine no general trend was noticed regarding the frequency distribution of variants. But in the two generations, the higher exposures gave higher values for tuber yield per vine. This may be due to the production of higher frequency of positive variants and lower frequency of negative variants. The lower exposures showed higher frequency of negative variants compared to positive variants in all the three modes of treatment.

SUMMARY

SUMMARY

Crop improvement in sweet potato to suit the various agroecological requirements of the State was attempted by mutagenesis with gamma rays. Various studies including radiosensitive analysis, standardisation of dose and plant organ to be irradiated, identification of varietal tolerance to irradiation etc. were conducted in an attempt to isolate desirable variants with economic importance at the Department of Agricultural Botany, College of Agriculture, Vellayani during 1987-1989. The gamma irradiation was done by a ^{60}Co gamma cell unit installed at Radio Tracer Laboratory, Trichur. Stem cuttings of fifteen varieties were exposed to 2-10 kR with 2 kR intervals at a dose rate of 0.162 MR/h. The direct effect of the doses used was assessed based on various growth and yield parameters. The characters selected include days taken to start sprouting, days taken to complete sprouting, sprouting percentage on the 15th to 30th day of planting recorded at intervals of 5 days, lethality as on the 30th day of planting and at harvest, vine length at 7 different growth stages from the 30th day of planting till harvest at 15 day intervals, branch and tuber number and weight of tubers per vine.

The exposures above 4 kR were found to cause lethality in most of the varieties and hence comparative analysis for

radiosensitivity against control was assessed at 2000 r. The results of these studies are presented below:

1. The gamma ray exposed population took more number of days for sprout initiation and for completion of sprouting in all the genotypes.

2. Exposure of gamma rays reduced sprouting percentage in all the genotypes.

3. The percentage lethality varied depending on genotypes and was more in gamma ray exposed population than in control population.

4. The vine length and branch number per vine also varied depending on genotypes and found to be comparatively less in treated population.

5. The tuber number and weight of tubers per vine were found to be significantly increased by gamma ray exposure at 2000 r.

Based on the above observations the fifteen varieties were grouped into three, viz. low, medium and high radiation sensitive varieties as indicated by discriminant function analysis.

Induced mutagenesis was done in continuation with radiosensitivity analysis. Three varieties, viz. Muttavella

(V_1), Kanhangad local (V_2) and Bharakalichuvala (V_3) were selected one each from the low, medium and high radiation tolerant groups respectively. The three planting materials selected for gamma irradiation were fresh cuttings, rooted cuttings and rooted tubers. The gamma irradiation was done by a gamma cell unit and the exposures were 500 to 2500 r at 500 r intervals with a dose rate of 0.162 MR/h. The irradiated materials along with control were planted on the next day of exposure.

In vM_1 generation the direct effect of ^{60}Co gamma rays was assessed based on days taken to start sprouting, days taken to complete sprouting, sprouting percentage, lethality on the 30th day of planting and at harvest, vine length, branch number per vine, fresh weight of vine, number of tubers per vine, weight, length, girth and volume of tuber and tuber yield per vine. At the time of harvest the tubers from each cutting were observed to find out the colour variations created by the mutagen on the tuber skin.

vM_1 plants were uprooted and kept in shade for three days and representative 3-4 noded cuttings were taken from the basal, middle and top portions of each vine for planting.

In vM_2, vM_3 and vM_4 generations the yield parameters were analysed in detail. Classification of phenotypes and frequency analysis were also done. The salient results are presented below:

1. The gamma ray exposed population took more number of days for sprout initiation and for completion of sprouting.

2. A decrease in sprouting percentage and an increase in lethality were noticed with increase in exposures.

3. A reduction in vine length and branch number per vine were found in higher exposures of gamma rays.

4. The fresh weight of vine was reduced by higher exposures.

5. There was an increase in tuber number per vine with increase in gamma ray exposures.

6. The mean tuber weight, length, girth and volume were also increased by higher exposures.

7. Gamma irradiation was effective in increasing the tuber yield per vine and the maximum yield was recorded in 2 higher exposures.

8. All the exposures and the different modes of treatment induced phenotypic variants both in negative and positive directions.

9. Positive variants were in higher frequency in later generations compared to early segregating generation.

10. Irradiation of rooted cuttings was found to be more economical or beneficial compared to fresh cuttings and rooted tubers.

The study enabled to isolate out 2 distinct types, one each from S_5 and Bhadrakalichuvala, which outyielded all the three control varieties. These variants are being multiplied by vine cuttings for farm trials in different agro-ecological milieus of the State.

REFERENCE

REFERENCES

Abraham, A. (1970). Breeding work on tapioca (cassava) and few other tropical tuber crops. Tropical Root and Tuber Crops Tomorrow, Vol. I, Univ. Hawaii, pp. 76-78.

*Amirov, Z.S. (1974). Chemical mutagenesis in interspecific hybrids of potato. Eksperim mutagenez. rast. Z. Baku Azer baijan SSR, pp. 115-117.

*Amirov, Z.S. and Babaev, M.S. (1966). Obtaining artificial mutations in interspecific potato hybrids by means of irradiation. Sci. Mem. Azerb. Univ. Ser. biol. Sci., 3: 3-5.

*Anderez, M. (1971). Preliminary report of studies on inducing mutations in sugarcane in Cuba with a ^{60}Co γ-source. Rev. Agric. Cuba, 4 (2): 1-4.

*Anikiev, A. (1973). Results of experiments on producing heritable changes in potato by induced mutagenesis. Sekektsiya i Semenovodstov. polevykh kul'tur. Riga, Latvian SSR, Zinatne, pp. 106-109.

*Anonymous. (1962). Hawaii Sugar Plant Assoc. Exp. Stn. Annu. Rep., 1961 p. 70.

Anonymous. (1964). Banana Research Station, Kannara, Kerala Agric. Res. Indian Counc. Agric. Res., 4: 141-142.

*Anonymous. (1965). Sugarcane breeding at Coimbatore. Int. Sugar J., 68: 355-356.

Anonymous. (1966). Sugarcane Breed. Inst. Coimbatore, India. Annu. Rep., 1966-'67. p. 117.

*Anonymous. (1970 a). Cent. Sugarcane Breed. Stn. Barbados, 37th Annu. Rep., 37: 1-70.

Anonymous. (1970 b). Hawaii Sugar Plant. Assoc. Exp. Stn. Annu. Rep. 1969, pp. 3-7.

Auerbach, C. (1961). Chemicals and their effects. Mutat. Plant Breed. NAS-NRC 891: 120-144.

Auerbach, C. (1967). The chemical production of mutations. Science, 158: 1141-1147.

*Auerbach, C. and Robson, J.M. (1942). Experiments on the action of mustard gas in Drosophila. Rep. Minist. Supply, W.3979 W.11831.

*Auerbach, C. and Robson, J.M. (1947). The production of mutations by chemical substances. Proc. R. Soc. Edinb. (Sect. B), 62: 271-283.

*Bancher, E. and Washuttl, J. (1970). Studies on the effect of r-rays on plant development and leaf form in two potato varieties. Osterreichische Botanische Zeitschrift, 118 (3): 216-225.

Bari, G. (1974). Induction of somatic mutations for disease resistance in sugarcane. Induced Mutations for Disease Resistance in crop plants. Proc. Meet. FAO/IAEA/SIDA, Novisad, IAEA, Vienna, p. 149.

Bateman, A.J. (1959). Induction of polygenic mutations in rice. Int. J. Radiat. Biol., 1: 425-427.

*Batikyan, G.G., Gukasyan, L.A., Sarkisyan, S.A. and Abramyan, L.Kh. (1975). Ultra structure of chloroplasts of pepper leaves with chlorophyll changes under the effect of NEU. Biol. Zh. Arnu. 28 (5): 14-16.

*Berezoskii, S., Perchikhin, G.N. and Yu, A. (1981). Results of N-nitroso-N-dimethyl urea treatment in successive generations of an experiment. Primenenie Khim. mutagenov V Zashchite Sredy ot Zagrazneniya Vs-kh prakt. Moscow, USSR, pp. 205-208.

*Blakeslee, A.F. (1936). Twenty five years of genetics, 1910-1935. Brooklyn Botanic Garden Memoirs, 4: 29-40.

Blixt, S. (1972). Mutation genetics in Pisum. Agric. Hort. Genet., 24: 62-74.

Bowen, H.J.M. (1965). Mutations in horticultural chrysanthemus. Radiation Bot., 5: 695-700.

Broertjes, C. and Harten, A.M.V. (1978). Application of mutation breeding methods in the improvement of vegetatively propagated crops. Elsevier Scientific Publishing Co. Amsterdam - Oxford - New York, pp. 1-16.

*Broksh, V.L. and Serova, R. (1976). A study of the effect of N-nitroso-N-methyl urea on dihaploids of potato. Effektivn. khim. mutagenov. V Selektsii, Moscow, USSR, Nauka, pp. 256-261.

*Broksh, V.L. and Serova, R. (1980). Nature of variation in potato haploids after treatment with N-nitroso-N-methyl urea. Bulleten' Vsesoyuznogo Ordena Lenina i Ordena Druzhby Narodov Instituta Rastenievodstva Imeni N.1. Vavilova, 99: 48-54.

*Budin, K.Z., Surkova, L.I. and Sharova, L.D. (1971). Influence of mutagens on potato species of different ploidy. Trudy po Prikladnoi Botanike, Genetike i Selektsii, 48 (2): 153-157.

Caldecott, R.S., Beard, H.H. and Gardner, C.O. (1954). Cytogenetic effects of X-ray and thermal neutron irradiation on seeds of barley. Genetics, 39: 240-259.

Capella, J.A. and Conger, A.D. (1967). Radiosensitivity and interphase chromosome volume in gymnosperms. Radiat. Bot., 7: 137-149.

*Casarett, A.P. (1968). Radiation Biology, Prentice Hall, Engelwood Cliffs, New Jersey.

*Catcheside, D.G. (1945). Effects of ionizing radiation on chromosomes. Biol. Rev. Camb., 20: 14-28.

*Cherny, J. and Vavrikova, M. (1973). The influence of chronic irradiation of potato plants (Solanum tuberosum) on the level of ploidy in the seed progeny. Sbornik. Vysoke. Zemedelske. V Praze. Fakulta. Agronomicka, 2: 269-279.

*Chopde, P.R. (1970). Mutagenic effects of X-rays on Cajanus cajan. (L.). Proc. Symp. Radiations and Radiomimetic substances in Mutation Breeding. Dept. Atomic Energy, India, pp. 394-403.

*Clenand, R.E. (1962). The cytogenetics of Oenothera. Adv. Genet., 11, 147-237.

*Cuervo, P.L.G. and Ramos, N.E. (1970). Artificial induction of mutants in the criolla potato (Solanum phureja Juz. et. Buk). Proc. study group on induced mutations and plant improvement. Buenos Aires, IAEA, Vienna, pp. 457-468.

*Danko, G.V. (1975). The use of potato mutants to obtain breeding material. Khim. supermutageny V Selek.sii. Moscow, USSR, Nauka, pp. 308-312.

Darlington, C.D. and La Cour, L.F. (1945). Chromosome breakage and the nucleic acid cycle. J. Genet., 46: 180-267.

*Darmodjo, S. and Wiriatmodjo, B. (1976). Resistance mutation of sugarcane species from top borer (Scirpophaga nivella) as the effect of irradiation with gamma rays. Lokakarya Pemberantassan Hama Dengan Radiasi (I). Jakarta, p. 10.

*Davidson, D. (1960). "Protection and recovery from ionizing radiation. Mechanism in seeds and roots". Radiat. Prot. Recovery, Pergamon Press, New York, pp. 337-359.

*Dmitrieva, Z.A. and Mikhailov, V.A. (1977). Increasing tuber number. Kartofel' i Ovoshchi, 10: 12-13.

*Dobias, K. (1977). Occurrence of somatic mutations of morphologic signs of potatoes in VM_1 to VM_3 generation of irradiation by r-rays. Res. Inst. Potato Growing Breed., Havlickuv Brod, Czechoslovakia, p. 198.

Ehrenberg, L., Ekman, G., Gustafsson, A., Janson, G. and Lundqvist, V. (1964). Variation in quantitative and biochemical characters in barley after mutagenic treatments. Radiat. Bot. Suppl., 5: 477-490.

Ehrenberg, L., Gustafsson, A. and Lundqvist, U. (1961). Viable mutants induced in barley by ionizing radiations and chemicals. Hereditas, 47: 243-282.

*Evans, H.J. (1962). Chromosome aberrations induced by ionizing radiations. Int. Rev. Cytol., 13: 221-222.

Fautrier, A.G. (1976). The influence of gamma irradiation on dry seeds of lucerne, cv. Wairu-1. Observations on the M_1 generation. Environ. Exp. Bot., 16: 77-81.

*Gager, C.S. (1908). Effects of radium rays on mitosis. Science, N.S. 27: 336.

*Gager, C.S. and Blakeslee, A.F. (1927). Chromosome and gene mutations in Datura following exposure to radium rays. Proc. Nat. Acad. Sci. U.S.A. 13: 75-79.

Ganeshan, P. (1970). Induced mutation studies with Brachiaria brizantha Stapf and some indica rice varieties from Ceylon. Rice Breeding with Induced Mutations II. (Tech. Rep. Ser. No. 102), IAEA, Vienna, pp. 7-12.

*Gardner, C.O. (1969). Genetic variation in irradiated and control populations of corn after ten cycles of mass selection for high grain yield. Induced Mutations in plants (Proc. Symp. Pullman, 1969), IAEA, Vienna, pp. 469-477.

*Gaul, H. (1957 a). Die Wirkung von Rontgenstrahen in Verbindung mit CO_2, Colchicin und Hitze auf Gerste. Z. Pflzucht., 38: 397-429.

*Gaul, H. (1957 b). Zur trage der ontogenetischen Elimination mutierter Zellen nach Rontg bestrahlung von Samen, Naturwissenschaften, 44: 566.

*Gaul, H. (1959). Determination of the suitable radiation dose in mutation experiments, Proc. 2nd Congr. Eur. Assoc. Res. Plant Breed. Cologne, pp. 65-69.

*Gaul, H. (1963). Mutationen in der pflanzenznchtung. Z. pflzucht., 50: 194-307.

Gaul, H. (1964). Mutations in plant breeding. Radiat. Bot., 4 (3): 155-232.

*Gaul, H. (1966). Zuchterische Bedeutung von Kleinmutationen. Z. Pflzücht., 55: 1-20.

*Gaul, H. (1967). Studies on the population of micromutants in barley and wheat without and with selection. Induced mutations and their utilization, Proc. Symp. Erwin Bauer Gedachtnisverlesungen. IV. Gatersleben, Academic-Verlag, Berlin, pp. 269-281.

Gaul, H. (1970). Mutagen effects observable in the first generation. 1. Plant injury and lethality 2. Sterility. Manual Mutat. Breed. (Tech. Rep. Ser. No. 119), IAEA, Vienna, pp. 85-95.

*Gaul, H., Bender, K., Ulonska, E. and Sato, M. (1966). EMS induced genetic variability in barley, the problem of EMS induced sterility and a method to increase the efficiency of EMS treatment. Mutat. Plant Breed. (Proc. Panel, Vienna), IAEA, Vienna, pp. 64-84.

*Gaul, H., Grunewaldt, J., Heseman, C.U. (1967). Variation of character expression of barley mutants in a changed genetic background. Mutat. Plant Breed. II (Proc. Panel, Vienna, 1967), IAEA, Vienna, p. 77.

*Gaul, H. and Mittelstenscheid, L. (1960). Hinweise Zur Herstellung Von Mutationen durch ionisierende Strahlen in der Pflanzenzuchtung. Z. Pflzucht., 43: 404-422.

Goodspeed, T.H. (1929). The effects of X-rays and radium on species of the genus Nicotiana. J. Hered., 20: 243-259

Goud, J.V. (1967). Induced polygenic mutations in hexaploid wheats. Radiat. Bot., 7: 321-331.

Goud, J.V., Nair, K.M.D. and Rao, N.C. (1971). Induced polygenic mutations in ragi. Indian J. Genet. Plant Breed., 31 (2): 202-208.

Gregory, W.C. (1955). X-ray breeding of peanut (Arachis hypogaea L). Agron. J., 47: 396-399.

*Gregory, W.C. (1956). The comparative effect of radiation and hybridisation in plant breeding. Peaceful Uses of Atomic Energy, (Proc. 1st U.N Int. Conf.) 12: 48-51.

*Groza, H. (1977). Use of mutagenesis in breeding new potato varieties with increased yield potential. Cartoful, 8: 21-36.

*Groza, H. (1980). The usefulness of mutagenesis in potato breeding. Probleme de Genetica Teoretica Si Aplicata, 12 (5): 413-426.

Gustafsson, A. (1963). Productive mutations induced in barley by ionizing radiations and chemical mutagens. Hereditas, 50: 211-263.

*Gustafsson, A. and Von Wettstein, D. (1958). "Mutationen und Mutations Zuchtung". Handbuch der Pflenzenzuchtung. IV. (Roemer - Rudorf) Varlag Paul Parey Hamburg-Berlin, pp. 612-699.

*Haq, M.S., Manicuzzaman, A.F.M. and Ali, S.M. (1970). Evolution of high yielding disease resistant strains of sugarcane through gamma radiation. Proc. 21st-22nd Pak. Sci. Conf. Rajshatic Atomic Energy Centre.

*Haq, M.S., Rahman, M.M., Mia, M.M. and Ahmed, H.U. (1974 a). Disease resistance of some mutants induced by gamma rays. Induced Mutations for Disease Resistance in crop plants. Proc. Meet. FAO/IAEA/SIDA/Novi Sad, p. 150.

*Haq, M.S., Tin, N.M. and Myint, T. (1974 b). The prospect of breeding red-rot resistant sugarcane varieties through induced mutations in Burma. Induced Mutations for Disease Resistance in crop plants. Proc. Meet. FAO/IADA/SIDA, Novi Sad, pp. 150-155.

Harten, A.M.V. and Bouter, H. (1973). Dihaploid potatoes in mutation breeding: Some preliminary results. Euphytica, 22 (1): 1-7.

Harten, A.M.V., Bouter, H. and Schut, B. (1973). Ivy leaf of potato (Solanum tuberosum), a radiation-induced dominant mutation for leaf shape. Radiat. Bot., 13 (5): 287-292.

Heiken, A. (1961). Induction of somatic changes in Solanum tuberosum by acute gamma irradiation. Hereditas, 47: 606-614.

Hernandez, T.P., Hernandez, T. and Miller, J.C. (1959). Effects of different rates of irradiation on sweet potato roots and tomato seeds. Proc. Am. Conv. Assoc. South Agric. Work., 56: 157-158.

Hernandez, T.P., Hernandez, T. and Miller, J.C. (1964). Frequency of somatic mutations in several sweet potato varieties. Proc. Amer. Soc. Hort. Sci., 85: 430-433.

Heslot, H., Ferrary, R., Levy, R. and Monard, C. (1959). Recherches Sur les substances mutagenes esters sulphoniques et sulphuriques. Compt. rend., 248: 729-732.

Hrishi, N. and Marimuthammal, S. (1968). Studies in mutagenesis in sugarcane. 1. Effect of chemical mutagens. Proc. Indian Acad. Sci. Sect. B, 68: 131-142.

Hrishi, N., Krishnamurthy, T.N. and Marimuthammal, S. (1968). I. Studies in mutagenesis in sugarcane. II. Induction of visible and micromutations in sugarcane by chemical mutagens. Proc. Indian Acad. Sci., Sect. B, 68: 181-189.

*Izotova, G.N. (1974). Effect of chemical mutagens on germination rate of seeds and variability in interspecific hybrids of potato. Nauch. tr. NII Kartof. kh-va., 18: 84-89.

Jagathesan, D. (1976). Induction and isolation of mutants in sugarcane. Improvement of vegetatively propagated plants and Tree Crops through Induced Mutations, Wageningen, IAEA, Vienna, pp. 69-82.

Jagathesan, D. (1977). Induction and isolation of mutants in sugarcane. Mutat. Breed. Newsl., 9 (1): 5-6.

Jagathesan, D. and Jalaja, N.C. (1969). Effect of Uv and X-rays on the pollengrains of Saccharum and Erianthus. Proc. Symp. Radiat. Radiomimetic Subst. Mutat. Breed. Bombay, pp. 103-111.

Jagathesan, D. and Sreenivasan, T.V. (1970). Induced mutations in sugarcane. Indian J. Agric. Sci., 40: 165-172.

Jagathesan, D., Balasundaram, N. and Alexander, K.C. (1974). Induced mutations for disease resistance in sugarcane. Induced Mutations for Disease Resistance in crop plants. Proc. Meet. FAO/IAEA/SIDA, Novi Sad, V, p. 151.

Janave, M.T. and Thomas, P. (1979). Influence of post harvest storage temperature and gamma irradiation on potato carotenoids, Potato Res., 22 (4): 365-369.

Jasina, I.M. and Kirsanova, E.V. (1966 a). Induction of heritable variations in potato by means of r-rays. Trans. Moscow Soc. Nat. Biol. Sect., 23: 229-234.

Jasina, I.M. and Kirsanova, E.V. (1966 b). Production of hereditary changes in potato by means of r-rays. Genetics, 1: 53-58.

Jauhar, P.P. (1969 a). Induction of some rare somatic mutations in Solanum tuberosum L. by ionizing radiations and radio phosphorus. Eur. Potato J., 12 (1): 8-12.

Jauhar, P.P. (1969 b). Morphological and physiological effects of radiations and radioisotopes on potato, Solanum tuberosum L. Indian J. Agric. Sci., 39: 88-100.

Jauhar, P.P. and Swaminathan, M.S. (1967). Mutational rectification of specific defects in some potato varieties. Curr. Sci., 36: 340-342.

Johnston, T.D. (1961). Studies on the use of radiation in out breeding. Ann. Appl. Biol., 49: 370-373.

Kamannavar, P.Y. (1985). Studies on mutagenesis in chilli (Capsicum annuum L.). Thesis abstracts, Directorate of Publications, Haryana Agric. Univ., 9 (1): 50-51.

Kamra, O.P. and Brunner, H. (1970). Chemical mutagenesis, methods of treatment. Manual Mutat. Breed. (Tech. Rep. Ser. No. 119) IAEA, Vienna, pp. 64-66.

*Kaneko, I. (1975). Mutations induced in potato by radiation. 1. Mutations induced by r-rays. Bull. Hokkaido Prefectural Agric. Exp. Stn., 31: 28-33.

*Kaplan, R.W. (1954). Beinflussung der durch Rontgenstrahlen induzierten mutativen Pleckenmossiks auf den Blattem der sojebohne durch Zusatzbehandlung, Strahlentherapic, 94: 106-118.

Kawai, T. (1969). Relative effectiveness of physical and chemical mutagens. (Proc. Symp. Pullman, 1969), IAEA, Vienna, pp. 137-152.

Kawai, T. and Sato, H. (1965). Studies on artificial induction of mutations in rice by chemicals. 1. Chlorophyll mutations by ethyleneimine and ethyline oxide treatments. Bull. Natn. Inst. Agric. Sci., (Japan), 13: 133-162.

*Khan, A.M. and Zakir, A. (1970). Improvement of sugarcane through radiation. West Pak. J. Agric. Res., 81: 1-6.

*Khostova, V.V. (1966). Mutagenic treatment of agricultural plants. (Abst.). Induced Mutations and Their Utilization, Proc. Symp. Erwin-Bauer Gedachtnisvorlesungen IV, Gatersleben, 1966, Alcademie-Verlag, Berlin.

Kishore, H., Pushkarnath and Singh, G. (1963). The effect of gamma radiation on potato tubers. Indian Potato J., 5: 86-92.

*Koernicke, M. (1905). Uber die Wirkung von Runtgen und Radiumstrahlen auf pflanzliche Gewebe und Zellen. Ber. dt. bot. Ges., 23: 404.

Kolesnikova, L.G. and Maksimova, A.D. (1977). Effect of chemical mutagens on content of dry matter and starch in potato tubers. Genetika, 13 (10): 1742-1753.

Konzak, C.F. (1957). Genetic effects of radiation on higher plants. Q. Rev. Biol., 32: 27-45.

Konzak, C.F. (1966). Qualitative mutations and plant breeding. Int. Rice Commn. Newsl., 15 (1): 20-21.

Konzak, C.F., Conger, B.V. and Nilan, R.A. (1970). Radiation sensitivity and modifying factors. Manual Mutat. Breed. (Tech. Rep. Ser. No. 119), IAEA, Vienna, pp. 44-48.

Konzak, C.F., Curtis, H.J., Delihas, N. and Nilan, R.A. (1960). Modification of radiation-induced damage in barley seeds by thermal energy, Can. J. Genet. Cytol., 2: 129-141.

Konzak, C.F., Nilan, R.A., Harle, J.R. and Heiner, R.E. (1961 a). Control of factors affecting the response of plants to mutagens. Brookhaven Symp. Biol., 14: 128-157.

Konzak, C.F., Nilan, R.A., Legault, R.R. and Heiner, R.E. (1961 b). Modification of induced genetic damage in seeds. Proc. Symp. on the effects of ionizing radiations on seeds. IAEA, Vienna, pp. 155-169.

Koo, F.K.S. and Cuevas-Ruiz, J. (1974). Exploratory induction of solid mutations in yam by r-irradiation. Genes, Enzymes and populations. Plenum Publishing Co., New York, N.Y. pp. 331-336.

Kotvics, G. (1981). Selection for high yield in early maturing mutants of soybean. Mutat. Breed. Newsl., 18: 12-16.

Krishnaswamy, S., Rathnaswamy, R. and Veeraswamy, R. (1977). Studies on induction of mutations in greengram (Phaseolus aureus Roxb.) through physical mutagens. Madras Agric. J., 64 (2): 48-50.

Krull, C.F. and Frey, K.J. (1961). Genetic variability in oats following hybridization and radiation. Crop Sci., 1: 141-146.

Kukimura, H. (1971). On the artificial induction of skin colour mutants in sweet potato tubers. Tech. News, Inst. Radiat. Breed., 8: 2.

Kukimura, H. (1981). Mutant clones of sweet potato in quantitative characters induced by r-rays and ethyleneimine. Tech. News, Inst. Radiat. Breed., 24: 2.

Kukimura, N. and Takemata, T. (1975). Induced quantitative variation by gamma rays and ethylene imine in tuber bearing plants. Gamma Field Symp., 14: 25-38.

*Kulakov, N.P. (1971). Effect of dimethyl sulphate on potato tubers. Tr. Gor'kov. S.-kh. in-ta., 46: 167-172.

Kumar, P.R. and Das, K. (1977). Induced quantitative variation in self-incompatible forms in Brassica. Indian J. Genet., 37: 5-11.

Lawley, F.D. (1973). Reaction of MNUA with ^{32}p labelled DNA, evidence for formation of phosphotriesters. Chem. Biol. Interactions, 7: 127-130.

Love, J.E. (1969). Mutation induction in the sweet potato by means of fast neutron irradiation. Induced mutations in plants. Proc. Symp. Pullman, Wash., IAEA, pp. 331-336.

Love, J.E. (1972). Somatic mutation in Poinsettia and sweet potato. M.J. Constantin (Editor), Mutat. Breed. Workshop, Knoxville, Univ. Tenn.

Loveless, A. (1966). Genetic and allied effects of alkylating agents. Betterworths, London, p. 270.

*Maishchuk, Z.N. (1977). Effect of mutagens on characters in potato seedlings. Kartoplyarstvo Resp. mizhvid. temat nauk, zb., 8: 12-17.

*Maishchuk, Z.N. (1978). Use of mutagens dimethyl sulphate and r-rays in potato breeding. 3-ii s'ezd. Vses. Ob-va genetikov i selektsionerov im. N.I. Vavilov. Leningrad, USSR, p. 318.

*Marumine, S. (1983). Use of artificial mutants in sweet potato breeding. 1. Artificial mutants induced by ^{32}p, ethyleneimine and X-rays. Bull. Kyushu Natl. Agric. Exp. Stn., 23 (1): 21-62.

Marumine, S. and Sakai, K. (1961). Studies on the induction of artificial mutation in sweet potato. 1. X-ray induced mutations. Proc. Kyushu Crop Sci. Soc. Japan, 16: 4-6.

Marz, C.S. (1964). Study of self-incompatibility in the pineapple. Agric. Res. Pretoria, 2-6: 561-562.

Matsuo, T., Onozawa, Y. and Shiomi, M. (1964). Studies on the induction of mutations by radiation and chemicals III. Changes in quantitative characters in M_6 generation. Jpn. J. Breed., 14: 173-176.

*Mc Crory, G.J. and Crun, P. (1969). Relationship between radiation dose rate and lethality of diploid clones of Solanum. Radiat. Bot., 9 (1): 27-32.

Mee, G.W.P., Nickel, L.G. and Heinz, D.J. (1969). Chemical mutagens - their effects on cells in suspension culture. Hawaii. Sugar Plant. Assoc. Exp. Stn. Annu. Rep., pp. 7-8.

Menendez, T. (1973). Application of mutation methods to banana breeding. Induced mutations in vegetatively propagated plants, IAEA, Vienna, pp. 75-83.

*Mezentsev, A.V. (1972). Production of somatic mutations of the potato (Solanum tuberosum L.) by means of electrons, X-rays and r-rays. Tsitologiya i Genetika, 6 (4): 309-312.

*Mezentsev, A.V. and Yashina, I.M. (1971). The effect of r-ray dose rate on the frequency of somatic mutations affecting tuber colour in potato (Solanum tuberosum L.). Genetika, 7 (4): 5-12.

*Mezentsev, A.V. and Yashina, I.M. (1973). The effect of r-ray dose rate on the variability of quantitative characters in potato in vM_2 and M_1 progeny. Genetika, 9 (1): 39-45.

Miah, A.J. and Yamaguchi, H. (1965). The variation of quantitative characters in the irradiated progenies of two rice varieties and their hybrids. Radiat. Bot., 5: 187-196.

Mikaelsen, K. (1968). Comparison between chromosome aberrations induced by ionizing radiations and alkylating agents at different stages of mitosis in barley seed. Mutat. Plant Breed. (Proc. Panel Vienna, 1967), IAEA, Vienna, pp. 287-290.

Mikaelsen, K., Karunakaran, K. and Kiss, I.S. (1971). Mutagenic effectiveness and efficiency of gamma rays, fast neutrons and ethylmethane sulphonate on rice. Tech. Rep. Ser. No. 131, IAEA, Vienna, pp. 91-96.

*Mikhailov, V.A. (1980). Effect of r-irradiation of the tubers on yield in some potato varieties. Sb. nauch. tr. Belorus. NII kartofelevod. i plodoovoshchevod., 4: 35-40.

Miu, T.S. (1973). An enquiry into indicators of cold tolerance among radiation induced lines of sweet potato. Genetics, 74: 183.

Miu, T.S., Yu, C.Y. and Chang, C.S. (1973). An enquiry into assessment of cold resistance in groups of irradiation-induced lines of sweet potato. Taiwan Agric. Q., 9 (1): 28-40.

Miu, T.S., Lin, Y.T., Hsin, C.F. and Chang, C.S. (1969). The course of breeding new mutant sweet potato lines R_8 and R_{19} resulting from irradiation treatment. Taiwan Agric. Q., 5 (1): 78-83.

Moes, A. (1966). Mutations induites chez le glaieul. Bull. Rech. Agron. Gembloux, 1: 76-95.

Moh, C.C. and Alan, J.J. (1965). Radiosensitivity of tropical plants. Application Nucl. Energy Annu. Rep., Turrialba, Costa Rica, pp. 33-36.

Muller, H.J. (1927). Artificial transmutation of the gene. Science, 66: 84-87.

*Muller, A.J. (1966). Die Induktion von rezessiven Lethal mutationen durch Athylmethan sulfonat bei Arabidopsis. 1. Dosis - Effekt - Beziehungen und deren Beinflussung durch die Behandlungs bedingungen, Zuchter, 36: 201-220.

Muntzing, A. (1930). Outlines to a genetic monograph of the genus Galeopsis with special reference to the nature and inheritance of partial sterility, Hereditas, 13: 185-341.

Myttenaere, C., Bourdeau, P., Heleke, G. and Masse, T.M. (1965). Radiosensitivity of rice seed in relation to water content and free radicals. Radiat. Bot., 5: 443-451.

Nair, M.K. (1973). Note on an induced red-rot resistant mutant of 'Co 997' variety of sugarcane. Indian J. Agric. Sci., 43 (3): 323-324.

Nair, V.G. (1981). The relative mutagenic effects of ionizing radiations and alkylating chemicals in rice. Agric. Res. J. Kerala, 19 (1): 32-40.

Nayar, N.K. (1976). Studies on induced mutations in rice var. Jaya. Ph.D. Thesis, Kerala Univ.

Nayar, N.M. (1969). Considerations on overcoming intra-somatic selection during mutation breeding of vegetatively propagated plants. Theor. Appl. Genet., 39: 99-103.

Nayar, N.M. and Chauhan, H.S.A. (1968). Chemically induced systematic mutation in the potato (Solanum tuberosum L.) produced as a sectorial chimera. Jpn. J. Genet., 43: 389-392.

Nayar, G.G. and Rajendran, P.G. (1987). Radiation induced mutations in cassava (Manihot esculenta Crantz). Mutat. Breed. Newsl., 30: 18.

Nayar, N.M., Pushkarnath and Hakim, K.L. (1965). Frequencies of certain types of gamma ray induced mutations in potato. Indian Potato J., 7: 76-80.

Nilan, R.A. (1954). Relation of carbondioxide, oxygen and low temperature to the injury and cytogenetic effects of X-rays in barley. Genetics, 39: 943-953.

*Nilan, R.A. (1956). Factors governing plant radiosensitivity. Conf. Radioactive Isotopes in Agriculture. USAEC, Michigan State Univ. East Lansing, pp. 151-162.

Nilan, R.A. (1964). The cytology and genetics of barley 1951-52. Monogr. Suppl. No. 3, Wash. State Univ., p. 276.

Nilan, R.A. and Konzak, C.F. (1961). Increasing the efficiency of mutation induction. Mutat. Plant Breed. NAS-NRC, 891: 431-460.

Nilan, R.A., Konzak, C.F., Wagner, J. and Legault, R.R. (1965). Effectiveness and efficiency of radiations for inducing genetic and cytogenetic changes. Radiat. Bot. Suppl., 5: 71.

Nybom, N. (1961). The use of induced mutations for the improvement of vegetatively propagated plants. Mutat. Plant Breed. NAS/NRC 891: 252-294.

Nybom, N., Lundqvist, U., Gustafsson, A. and Ehrenberg, L. (1953). Biological effects of X-irradiation at low temperatures. Hereditas, 39: 445-457.

Oehlkers, F. (1943). Die Auslosungvon Chromosomenmutationen in der Meiosis durch Einwirkung von Chemikalien, Z. indukt. Abstamm. -u. VererbLehre, 81: 313-341.

Oka, H.I., Hayashi, J. and Shiojiri, I. (1958). Induced mutation of polygenes for quantitative characters in rice. J. Hered., 49: 11-14.

Onwueme, I.C. (1978). The tropical tuber crops. John Wiley & Sons, New York, pp. 167-175.

*Overchuk, V.I. and Pika, M.A. (1970). Induction of heritable changes through the action of r-rays on potato tubers. Visnilk Sil'skogospod. nauki, 7: 50-54.

Panton, C.A. and Menendez, T. (1972). Possibilities and implications of mutation breeding in Jamaica. Induced Mutations and Plant Improvement, IAEA, Vienna, pp. 61-66.

Patel, K.A. and Swaminathan, M.S. (1961). Mutation breeding in tobacco. Tobacco Sci., 5: 67-69.

Persutina, O.A. (1965). Alteration of certain characteristics in the seed and vegetative progeny of potato during irradiation. Trans. Sci. res. Inst. Pot. Industr., 4: 55-66.

*Pitirimova, M.A. (1985). Variation in barley after repeated treatment of 2 successive generations with mutagenic factors. 1. Treatment of r-irradiated plants with ethyleneimine. Genetika, 21 (7): 1222-1224.

Poole, C.F. (1959). Improvement in yield of sweet potato clones. Proc. Am. Soc. Hortic. Sci., 73: 445-452.

Poole, C.F. and Tanaka, J.S. (1963). Transmission of yield variation in irradiated sweet potato clones. Proc. Am. Soc. Hortic. Sci., 80: 488-496.

*Raimkulov, K.R. and Chervonnyi, G.I. (1972). Variation in the potato produced by the action of mutagens on the tubers. Tr. Kirg. un-ta. Ser. biol. n., 12: 16-18.

Rao, P.S. (1974). Mutation breeding for non-flowering in sugarcane. Mutat. Breed. Newsl., 3: 9.

Rao, N.S. and Ayengar, A.R.G. (1964). Combined effects of thermal neutrons and diethyl sulphate on mutation frequency and spectrum in rice. Biological Effects of Neutron and Proton Irradiations 1. IAEA, Vienna, pp. 383-391.

Rao, G.M. and Siddiq, E.A. (1977). Induced variation for yield and its components in rice. Indian J. Genet. Plant Breed., 37 (1): 12-21.

Rao, H.K.S., Sachan, R. and Singh, M. (1977). Gamma ray induced mutations in sugarcane. Mutat. Breed. Newsl., 9 (1): 5.

Rao, J.T., Sreenivasan, K.V. and Alexander, K.O. (1966). A red rot resistant mutant of sugarcane induced by gamma irradiation. Proc. Indian Acad. Sci. Sect. B, 4: 224-230.

Rawlings, J.O., Hanway, D.G. and Gardner, C.O. (1958). Variation in quantitative characters of soybeans after seed irradiation. Agron. J., 40: 524-528.

Read, J. (1959). Radiation on biology of Vicia faba in relation to the general problem. Oxford Buckwell Scientific Publications.

Reddy, P.S., Reddy, M.V., Raju, B.T. and Ali, S.M. (1977). Creation of genetic variability by recourse to irradiation in groundnut (Arachis hypogea L.). Oleagineus, 32 (2): 59-63.

Roer, L. (1967). Mutations in potatoes induced by gamma irradiation. Euphytica, 16: 283-292.

Ross, W.C.J. (1962). Biological alkylating agents, Butterworths, London.

*Rudorf, W. and Wohrmann, K. (1963). Experiments on the induction of mutations by means of ^{60}Co irradiation of pregerminated eye sprouts of potato. Z. Pflanzenz., 49: 397-414.

Sakai, K. (1966). Induction of mutants in sweet potato by absorption of ^{32}P. Mutations induced by RI and chemicals. Gamma Field Symp., 5: 25-34.

Sakai, K.I. and Suzuki, A. (1964). Induced mutation and pleiotropy of genes responsible for quantitative characters in rice. Radiat. Bot., 4: 141-151.

Sankaranarayan, P. and Babu, C.N. (1970). Effects of chronic gamma irradiation in sugarcane varieties. Indian J. Hered., 2(2): 97-102.

Sapra, V.T. and Constantin, M.J. (1978). Seed radiosensitivity of a hexaploid triticale. Environ. Exp. Bot., 18: 77-79.

Sato, M. and Gaul, H. (1967). Effect of ethyl methane sulphonate on the fertility of barley. Radiat. Bot., 7: 7-15.

Saulite, A. (1981). Practical results of using chemical mutagen in potato breeding. Primenenie khim. mutagenov v zashchite sredy ot zagrya zneniya iv s. kh. prakt., pp. 203-204.

Saulite, S. (1983). Induced mutant of potato variety "Early Rose" resistant to Synchytrium endobioticum. Mutat. Breed. Newsl., 23: 9.

*Schiemann, E. (1912). Mutation bei Aspergillus niger. Z. indukt. Abstammange. Vererbungel, 8: 1.

*Scholz, F. (1960). Qualitats probleme in der Futtergerstenzuchtung dargestellt an Ergebnissen Von Mutations - Versuchen. Z. Pflzucht., 44: 105-128.

*Sergiyenko, V.M. and Litovchenko, N.S. (1971). The effect of chemical mutagens in improving economical useful characters in potato. Kartoplyarstov. Resp. mizhvid. temat. nauk. Zb., 2: 7-10.

Shastry, S.V.S. and Nandhachary (1965). X-ray induced mutations in cultivated rice-MP-130. Curr. Sci., 34: 55-56.

Siddiq, E.A. (1967). Induced mutations in relation to the breeding and phylogenetic differentiation of Oryza sativa. Ph.D. Thesis, Indian Agric. Res. Inst., New Delhi.

Siddiq, E.A. and Swaminathan, M.S. (1968). Induced mutations in relation to the breeding and phylogenetic differentiation of Oryza sativa. Rice Breed. Induced Mutat. (Tech. Rep. Ser. No. 86), IAEA, Vienna, pp. 25-51.

Siddiqi, S.H., Mujeeb, K.A. and Keerio, G.R. (1976). Gamma irradiation effects on sugarcane (Saccharum sp) clone Co-547. Environ. Exp. Bot., 16 (1): 65-68.

Sigurbjornsson, B. (1970). Mutations in plant breeding programs. Manual Mutat. Breed. (Tech. Rep. Ser. No. 119) IAEA, Vienna, pp. 1-8.

Sigurbjornsson, B. and Fried, M. (1966). Report on the FAO/IAEA Co-ordinated programme of Research on the use of Induced Mutations in Rice Breeding 1965/66.

Sigurbjornsson, B. and Micke, A. (1969). Progress in mutation breeding. Proc. Symp. Induced Mutations in plants. IAEA, Vienna, pp. 673-697.

Singh, C.B. (1970). Studies on subspecific differentiation of Oryza sativa. Ph.D. Thesis, Division of Genetics, Indian Agric. Res. Inst., New Delhi.

Singh, S. (1970). Chronic gamma irradiation induced resistance to red rot disease in sugarcane var. Co.997. Sugarcane Pathol. News., 5: 24.

Singh, U. (1970). Radiation-induced hooded eye mutants in potato. Sci. Cult., 36: 609-610.

Singh, R.K. and Chaudhary, B.D. (1979). Biometrical methods in quantitative genetic analysis, Kalyani Publishers, New Delhi, pp. 267-273.

Singh, R. and Iyer, C.P.A. (1974). Chemical mutagenesis in pineapple (Ananas comosus). Proc. Int. Hortic. Congr., 19 (1A): 108.

Sinha, S.S.N. and Goward, M.B. (1972). Radiation studies in Lens culinaris Meiosis - Abnormalities induced due to gamma radiation and its consequences. Cytologia, 37: 685-695.

Skoog, F. (1935). The effect of X-irradiation of auxin and plant growth. J. Cell. Comp. Physiol., 7: 227-270.

Snedecor, G.W. and Cochran, W.G. (1975). Statistical Methods. Oxford and IBH Publishing Co., Sixth Edn., pp. 325-327, 339-377, 419-443.

*Solomko, E.A. (1965 a). Induced mutations of practical value in potatoes. Genetika, 1: 179-184.

*Solomko, E.A. (1965 b). Potato mutations caused by the action of ionizing radiations on the vegetative plant parts. Radiobiol. Inform. Bull., 5 (4): 547-51.

*Solomko, E.A. (1969). The use of radiation in potato breeding. Sel'skohoz. Biol., 4 (1): 17-23.

Soriano, J.D. (1968). Modifying the effects of fast neutrons in rice seeds by post-treatment with chemical mutagens. Neutron Irradiation of Seeds, II, (Tech. Rep. Ser. No. 92), IAEA, Vienna, pp. 55-62.

Soriano, J.D. (1971). Induction of leaf mutations in irradiated vines of sweet potato. Sabrc. Newsl., 3 (2): 113-116.

Soriano, J.D. (1972). Effect of gamma radiation on buds of sweet potato (Ipomoea batatas (L.). Nat. Appl. Sci. Bull., 24 (1-2): 41-53.

Sparrow, A.M. (1961). Types of ionizing radiation and their cytogenetic effects. Mutat. Plant Breed. NAS-NRC, 891: 55-119.

Sparrow, A.H., Furuya, M. and Schwemmer, S. (1968). Effects of X- and gamma radiation on anthocyanin content in leaves of Rumex and other plant genera., Radiat. Bot., 8: 7-16.

Sreerangasamy, S.R., Oblisami, G. and Krishnaswami, S. (1973). Nodulation and productivity in the induced mutants of greengram by gamma rays. Madras Agric. J., 60 (6): 359-361.

Srinivasachar, D. and Malik, R.S. (1972). An induced aphid-resistant, non-waxy mutant in turnip, Brassica rapa. Curr. Sci., 41 (22): 820-821.

Stadler, L.J. (1928). Mutation in barley induced by X-rays and radium. Science, 68: 186-187.

Strobel, G.A., Steiner, G.W. and Byther, R. (1975). Deficiency of toxin-binding protein activity in mutants of sugarcane clone H54-775 as it relates to disease resistance. Biochem. Genet., 13 (9/10): 557-565.

Sun, L. and Singer, B. (1975). The specificity of different classes of ethylating agents towards various sites of Hela Cell DNA in vitro and in vivo. Biochem., 14 (8): 1795-1802.

*Surkova, L.I. (1973). The effectiveness of the action of N-nitroso-N-ethyl urea on potato varieties. Byulleten' Vsesoyuznogo Ordena Lenia Instituta Rastenievodstva Imeni N.I. Vavilova, 36: 49-50.

Swaminathan, M.S., Chopra, V.L. and Bhaskaran, S. (1962). Chromosome aberrations, frequency and spectrum of mutations induced by ethylmethane sulphonate in barley and wheat. Indian J. Genet., 22: 192-207.

Swaminathan, M.S., Siddiq, E.A., Singh, C.B. and Pai, R. . (1970). Mutation Breeding in rice in India. Rice Breeding with Induced mutations II. (Tech. Rep. Ser. No. 102). IAEA, Vienna, pp. 25-43.

Swanson, C.P. (1957). Cytology and Cytogenetics. Englewood cliffs (N.J.), Prentice Hall, Inc. USA.

Tanaka, S. (1970). Haploid rice plants in mutation studies. Rice Breeding with Induced mutations II (Tech. Rep. Ser. No. 102), IAEA, Vienna, pp. 45-46.

*Tarasenko, N.D. (1963 a). The effect of ionizing radiation and chemical compounds on growth processes and hereditary variability in potato. News Siber. Sect. USSR Acad. Sci. Ser. biol. med. Sci., 1 (4): 35-40.

*Tarasenko, N.D. (1963 b). The effect of γ-rays fast neutrons and chromosome aberrations in potato seedlings. Radiobiology, 3: 427-430.

*Tarasenko, N.D. (1964). Variability in first generation potato seedlings under the action of r-rays, fast neutrons and ethylene imine. Radiobiology, 4 (5): 770-774.

*Tarasenko, N.D. and Kharitonova, Z.T. (1976). A study of wart-resistant potato mutants of the variety Lorkh. Tesisy, dokl. Simpoz. po Si-kh. radiobiol. Kishinev, pp. 160-161.

*Tolhelm, E., Effmert, W. and Effmert, B. (1981). Induction and investigation of vegetative mutants of tetraploid potato. Archiv. fur Zuchtungsforschung, 11 (2): 105-114.

*Tiits, A. (1985). Chloroplast mutants of potato. Eesti NSV Teaduste Akadeemia Toimetised, Biologia, 34 (4): 307-310.

*Umaerus, M. (1966). Somatic aberrations in Solanum tuberosum induced by ethyl methane sulphonate and Y-irradiation. Zh. Pflanzenz., 55: 238-240.

Upadhya, M.D. and Purohit, A.N. (1973). Mutation induction and screening procedure for physiological efficiency in potato. Induced Mutations in Vegetatively Propagated Plants. Proc. Meeting FAO/IAEA, pp. 61-66.

Upadhya, M.D. and Tiwari, S.P. (1979). Induced mutations for potato improvement in India. Symp. on the role of induced mutations in crop improvement, Hyderabad September 1979.

*Uzlovskaya, G.N. (1976). The effect of chemical mutagens on the correlation between yield and starch content in hybrid progeny. Nauch. tr. NII kartof. Kh-va, 25: 42-44.

Vasudevan, K. and Jos, J.S. (1988). Gamma ray induced mutants in Coleus. Mutat. Breed. Newsl., 32: 5.

Vasudevan, K., Shanker, K. and Dua, R.P. (1984). Gamma ray induced erect and semierect mutants in Vigna unguiculata L. Walp.) Mutat. Breed. Newsl., 24: 4.

Vasudevan, K.N., Nair, S.C., Jos, J.S. and Magoon, M.L. (1967). Radiation induced mutations in cassava. Indian J. Hort., 24 (1-2): 95-98.

Vasudevan, K.N., Nair, S.G., Jos, J.S. and Magoon, M.L. (1968). Radiation induced mutations in Colocasia esculenta (L.). Indian J. Hort., 25: 66-69.

Volkov, V.D. and Danko, G.V. (1970). The influence of physical and chemical mutagens on the growth and development of potato plants. Kartoplyarstvo. Resp. mizhvid. temat. nauk. Zb., 1: 51-56.

*Volkov, V.D. and Danko, C.V. (1971). Effect of N-nitroso ethyl urea on the growth and development of potato plants. Praktika khim mutageneza. Moscow, Nauka. pp. 177-179.

*Volkov, V.D. and Danko, G.V. (1972). The use of chemical mutagens to obtain initial material for potato breeding. Khim. mutagenez i sozdanie, selekts. materiala. Moscow, USSR, Nauka, pp. 277-280.

Walker, D.I.T. and Sisodia, N.S. (1969). Induction of non-flowering mutant in sugarcane (Saccharum sp.). Crop Sci., 9: 551-552.

Wills, P.A. (1965). Some effect of gamma radiation on several varieties of Tasmanian potatoes. 1. Storage problems. Aust. J. Exp. Agric. Anim. Husband., 5: 282-288.

Yamagata, H., Syakudo, K, and Furukawa, T. (1965). Studies on the usefulness of artificially induced mutations in breeding. V. On the mutagenic effects of treating rice grains with chemicals. Jpn. J. Breed., 15: 263-270.

Yamaguchi, H. (1964). Genetic effects of pile radiations in rice. Biological effects of Neutron and Proton Irradiations, IAEA, Vienna, pp. 371-382.

*Yamaguchi, H. and Miah, M.A.J. (1964). Mutational mosaicism induced by X-, gamma rays and ethyleneimine in rice. Radioisotopes, 13: 471-476.

* Originals not seen

GENIC MANIPULATIONS IN SWEET POTATO ADOPTING INDUCED MUTATIONS

BY

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ABSTRACT OF THE THESIS
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ABSTRACT

An experiment was conducted at the Department of Agricultural Botany, College of Agriculture, Vellayani during 1987-1989 for genetic manipulations in sweet potato through gamma ray induced mutagenesis for increased variability and to isolate out genotypes having wider adaptability and better performance.

Stem cuttings of 8 to 10 cm length bearing two nodes each, taken from fifteen sweet potato varieties were used for radiosensitivity analysis. Gamma irradiation was done by a ^{60}Co gamma cell unit installed in the Radio Tracer Laboratory of Kerala Agricultural University, Trichur. The material was subjected to exposures of 2-10 kR at intervals of 2 kR. The chosen dose rate was 0.162 MR/h.

The direct effect of doses on the material was assessed on the basis of days to start sprouting, days to complete sprouting, sprouting percentage, vine length, branch and tuber number and weight of tubers per vine. The exposures above 4 kR caused lethality in the majority of the varieties and hence comparative analysis for radiosensitivity was assessed at the 2 kR level.

The gamma ray exposed population started sprouting late. The days taken for completion of sprouting were also

more in all the varieties. Gamma rays, in addition, reduced the sprouting percentage. The percentage lethality varied depending on variety. The vine length and number of branches per vine also varied from variety to variety. They were found to be comparatively less in treated population. The tuber number and weight of tubers per vine were found to be significantly increased by gamma irradiation at 2 kR. Based on the above observations the fifteen varieties were classified into three, viz. low, medium and high radiation sensitive categories.

Induced mutagenesis was done in continuation with the radiosensitivity analysis using three varieties, each selected from the low, medium and high radiation tolerant groups. The planting materials selected for gamma irradiation included fresh cuttings, rooted cuttings and rooted tubers which were exposed to radiation at a range of 500-2500 r, at 500 r intervals. The dose rate was 0.162 MR/h. The irradiated materials along with the control were planted on the subsequent day.

In vM_1 generation the direct effect of gamma rays was assessed based on days taken to start sprouting, days taken to complete sprouting, sprouting percentage, lethality on the 30th day of planting and at harvest, vine length, branch number per vine, fresh weight of vine, tuber number per vine, weight, length, girth and volume of tuber and tuber yield per vine. From vM_1 plants 3-4 noded cuttings were taken from the basal, middle and top portions for raising vM_2 generation. vM_3 and vM_4 generations were also raised in the same manner. In vM_2, vM_3 and vM_4 generations the yield parameters were analysed in detail. Classification of the phenotypes and frequency analysis were also done. The salient findings of the experiment are the following:

There was a delay in sprout initiation and for completion of sprouting caused by gamma ray exposure. A decrease in sprouting percentage and an increase in lethality were noticed under higher levels of exposures. Similarly a reduction in vine length and branch number per vine were found at higher exposures. The fresh weight of vine was reduced and the tuber number increased at higher exposures. There was an increase in mean tuber weight, length, girth, volume and tuber yield per vine at higher exposures. All the exposures and the different modes of treatment induced phenotypic variants both in negative and positive directions. Positive variants were in higher frequency in later generations. Irradiation of rooted cuttings was found to be more economical or beneficial compared to fresh cuttings and rooted tubers.

The study enabled to isolate out two promising types, one each from S_5 and Bhadrakalichuvala. These mutants outyielded the control and are being multiplied by vine cuttings for farm trials in different agroecological milieus of the State.