INDUCED MUTAGENESIS FOR DELAYED FLOWERING AND HIGH TILLERING IN GUINEA GRASS (*Panicum maximum* Jacq.)

by

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(2014-21-123)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"INDUCED MUTAGENESIS FOR DELAYED FLOWERING AND HIGH TILLERING IN GUINEA GRASS (*Panicum maximum* Jacq.)"** is a bonafide record of research work done by me during the course of research and 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 **"INDUCED MUTAGENESIS FOR DELAYED FLOWERING AND HIGH TILLERING IN GUINEA GRASS (*Panicum maximum* Jacq.)"** is a record of research work done independently by Mr. Sudrik Bibhishan Popat under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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Place : Vellayani

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(Sudrik Bibhishan)

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LIST OF ABBREVIATIONS

%	-	Per cent
&	-	And
:	-	Ratio
μ	-	Micro
^{0}C	-	Degree Celsius
$^{-1}$	-	Per
Ac/Ds	-	Activator / Dissociation
AICRP	-	All India Coordinated Research Project
ANOVA	-	Analysis of Variance
bp	-	Base pairs
CD	-	Critical Difference
Cm	-	Centimeter
Co^{60}	-	Cobalt 60
CV	-	Coefficient of Variation
cv.	-	cultivar
d.f.	-	Degree of freedom
DAP	-	Days After Planting
e.g.	-	For example
ECV	-	Environmental Coefficient of Variation
EMS	-	Ethyl methane sulphonate
et al.	-	Et alia, and others
etc.	-	Et cetera
Fig.	-	Figure
g	-	Gram
GA	-	Genetic Advance or Gibberellic Acid
GCV	-	Genotypic Coefficient of Variation
Gy	-	Gray
h^2	-	Heredity
hr	-	Hour

i.e.	-	Id est and that is
KAU	-	Kerala Agricultural University
kb	-	Kilobase
krad/kR	-	Kilo radiation
LA	-	Leaf Area
LAI	-	Leaf Area Index
LD	-	Lethal Dose
m^2	-	Square meter
mM	-	Millimolar
No.	-	Numbers
PCV	-	Phenotypic Coefficient of Variation
Ph.D.	-	Doctorate in Philosophy
SE	-	Standard Error
t/ha	-	Tonnes per hectare
T-DNA	-	Transfer Deoxyribo Nucleic Acid
viz.	-	Namely
Wt.	-	Weight

Introduction

1. INTRODUCTION

Guinea grass (*Panicum maximum* Jacq.) is a tall vigorous perennial grass with stem height up to 3.5 m, high yielding, fast growing, nutritious, drought tolerant with wide variation in growth habit. As a perennial crop, it is suitable for cultivation in humid, tropical and subtropical areas with more than 900 mm of rainfall on a wide range of soils. The deep, dense and fibrous root system and hardy nature allows guinea grass to survive long drought periods; but it performs best on well drained soils of good fertility in high rainfall regions (Humphreys and Partridge, 1995). Guinea grass is tolerant to shade and fire, but not to water logging or severe drought. It produces high yields of palatable fodder and responds well to manuring, but rapidly declines in nutritive value with age. It dies if continually grazed close to the ground and needs rest late in the growing season (FAO, 2003).

Guinea grass (*Panicum maximum* Jacq.) is generally recognized as one of the best forage grasses of the tropics with good yield potential and produces good quality fodder when properly managed (Sukhchain and Sidhu, 1992a). It is much valued for its productivity, palatability and good persistence (Javier, 1970). It responds well to cutting and grazing management and is fairly pest-tolerant (Gerardo and Olivia, 1977). It is considered as a suitable plant to stop soil erosion as it has well developed root system. It is primarily raised as a pasture in tropical and sub-tropical areas of the world and is also cultivated as a summer fodder for stall-feeding (Sukhchain and Sidhu, 1991). In India, Guinea grass was introduced as a pasture grass as early as 1793 but it did not become popular as a cultivated crop since pasture strains had low production potential per unit area and time (Sukhchain and Sidhu, 1992c). For this purpose, annual, vigorous, multicut varieties responsive to fertilizer and irrigation were bred and are being cultivated for stall-feeding in India.

Guinea grass has profuse thin tillers, quick regeneration and high leaf-stem ratio (Sukhchain and Sidhu, 1991). It has high digestibility, crude protein and minerals (Bogdan, 1977). Crude protein was found to vary by 4 to 14 % of dry matter (Chauhan *et al.*, 1980). In vitro dry matter digestibility (IVDMD) of the complete culm at the full head stage ranged from 41 to 72 % with most ecotypes having IVDMD values more than 60 % (Burton *et al.*, 1973). It tolerates shade and can be grown under tree plantations. Being a perennial grass, green fodder yield ranges from 80 to 100 t/ha/year and dry matter productivity 25-35 t/ha. Due to its multicut nature and high green fodder yield, its adoption is good among farmers both as cultivated crop and pasture crop.

Guinea grass (*Panicum maximum*) belongs to the grass family Gramineae or Poaceae, with chromosomal number $2n$ = 18, 32, 36, 48. It is a facultative apomict in which both apospory and pseudogamy occurs. The amount of sexual reproduction is generally 15 per cent depending on the variety, although sexual lines have been identified. Guinea grass apparently has good seed production potential, but actual seed yields are low because of seed shattering and small seed size and its establishment is poor due to low percentage of germination (Sidhu *et al.*, 1989). Although Guinea grass is primarily an aposporous apomict (Warmke, 1954), some sexual genotypes have been reported by various workers (Combes and Pernes, 1970; Smith, 1972; Hanna *et al.*, 1973; Savidan, 1981; Sidhu *et al.*, 1987)

The forage crops are grown in 4.8 % of the total cultivated land in India to feed 15% of the world's livestock population. At present situation the country is facing a net deficit of 35.6% green fodder, 10.95% dry fodder and 44% concentrate feed mixture. Hence, there is a need for over production of quality fodder especially the range grasses which could rejuvenate the fast degrading grasslands. In order to improve the productivity, adaptability and quality of Guinea grass, it is important to understand the genetic diversity that exists in the population which also helps in their conservation and germplasm management (Tiwari and Chandra, 2010). Genetic diversity is an important factor and is also a pre-requisite in any breeding programme. Inclusion of diverse genotypes in breeding programme serves the purpose of producing desirable genotypes.

Many scientists have reported the superior adaptability of guinea grass over other fodder grasses under coconut garden environment (Boonklinkajorn and Duryadrapan, 1977; Reynolds, 1978). But under Kerala conditions the green fodder yielding ability of this grass in the partial shade of coconut gardens was found to decrease with ratooning. The ratoon crop flowers immediately without tillering. This is a serious problem faced by the dairy farmers, since the green fodder yield and nutritive value has been decreased with flowering, as most of dry matter is diverted to panicle formation. Suppression of flowering has many advantages in forage crops; non flowering types remain green and fresh in the field compared to flowering types.

In nature, plants need to adapt to changes in their environment in order to successfully propagate. Such adaptation coincides with some advantageous mutations that spontaneously occur in their genomes over a long period of time, leading to the evolution of different species each endowed with a specific set of characteristics. Today, this diversity is seen as an important tool for plant breeding as specific plants can be used as donors of agronomically important traits such as those relating to yield, nutrient value, drought tolerance, lodging resistance, pest and disease resistance, and others. In conventional breeding, such donors are sexually crossed with other varieties to produce segregating populations which are systematically screened to ensure that only the progenies with favorable traits are advanced to succeeding generations. It also involves back-crossing the progenies with any of the parents to produce near isogenic lines (NILs). The entire process runs for several years until a stable line or variety is produced. However, with the advent of artificial mutation induction techniques, modern plant breeders have not only become able to address the slow process of producing new varieties, they also found an alternative method of broadening a crop's natural genetic diversity.

Mutation induction employs three categories of mutagens: physical (*e.g.*, gamma rays or heavy ion beam) (Bhaskara Rao and Reddi, 1975), chemical (*e.g.*, ethyl methane sulphonate (EMS), nitrosomethylurea (NMU) and diethyl sulfate (DES) (Komorisono *et al.*, 2005; Saito *et al.*, 2011; Rao *et al.*, 2012), and insertional elements (*e.g.*, tissue culture-induced Tos17 retrotransposon, and transgenic Ac/Ds and T-DNA techniques) (Hirochika, 2001; Miyao *et al.*, 2007; Lo *et al.*, 2008; Qu *et al.*, 2009). Of these, physical and chemical agents afford the advantage of stable mutations suitable for crop varietal development. For instance, gamma rays are reported to produce direct mutant varieties that do not go through the otherwise lengthy and laborious process of conventional breeding. It is also known to generate both mild and severe phenotypes, depending on the extent of damage incurred by the plant genome, which usually come in the form of DNA deletions ranging from 1 bp up to more than 10 kb in length (Henner *et al.*, 1982 and Ordonio *et al.*, 2014). Given the random nature of gamma rays deleterious effect on individual genes in the genetic repertoire, the resulting mutant population can provide a library of mutants that can be used for gene isolation, functional analysis, or molecular plant breeding (Van Harten, 1998; Henikoff and Comai, 2003; Till *et al.*, 2003; Ahloowalia *et al.*, 2004; Henikoff *et al.*, 2004).

In these circumstances, the current study was performed with the objective to develop high yielding guinea grass types with delayed flowering and high tillering through induced mutagenesis.

Review of Literature

2. REVIEW OF LITERATURE

Several research workers evaluated guinea grass genotypes as collected from different sources, which exhibited immense range of variation in morphology, yield and quality traits. Keeping in view of the objectives of the problem, the available review of literature is presented under the following sub-headings based on experiment I, II, III and IV.

2.1 COLLECTION AND EVALUATION OF GERMPLASM

Reviews relating to the experiment are presented under the following headings.

2.1.1 Genetic parameters

Two basic requirements for any trait improvement are variation and selection. For effective selection, information on the nature and magnitude of variation with regard to component characters contributing to yield and the part played by the environment in the expression of these characters is essential. The magnitude of variability is measured in terms of genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) and environmental coefficient of variation (ECV). Burton (1952) suggested that genetic variability with heritability should be considered for assessing the maximum and accurate effect of selection. This is of prime importance to estimate genotypic coefficient of variation, heritability and genetic advance for a successful breeding programme. The range of genetic variability for a character is measured with the help of genotypic coefficient of variation and this also provides a measure to compare the genetic variability present in various characters. It has been suggested by many workers that the heritable variation cannot be measured with the help of genotypic coefficient of variation alone. To the plant breeders, heritability is important, primarily as a measure of the value of selection for a particular character in various progenies and as an index of transmissibility as given by Hayes *et al.*

(1955). Heritability is important to evaluate the relative magnitude of the effect of genes and environments on total phenotypic variability.

The concept of heritability was given by Lush (1940). Heritability is the ratio of variance due to hereditary difference (genotypic variance) to the total observed variance (phenotypic variance). Robinson *et al.* (1949) defined heritability as the additive genetic variance as per cent of the total variance. The concept of heritability is based on relative magnitude of the effect of environment on total phenotypic variance *i.e.* in broadsense; heritability is the portion of total phenotypic variance that occurs due to genetic reason. Genetic advance is the improvement in mean genotypic performance of selected lines over the original base population. Johnson *et al.* (1955) suggested that heritability estimate with genetic advance could be more reliable than heritability alone for predicting the effect of selection. According to Comstock and Robinson (1952) genetic advance or genetic gain depends on the amount of genetic variability, the magnitude of masking effect of the genetic diversity and the intensity of selection. Heritability and genetic gain are complementary to each other and heritability estimate in broadsense accompanied by high genetic advance is a reliable combination for a rewarding selection (Ramanujam and Tirumalachar, 1967). Below is given a brief review of earlier works done in these aspects in guinea grass and related crops.

2.1.1.1 Genetic variability

Kandasamy and Ramamoorthy (1990) investigated one hundred and eighty eight germplasm of Kodo millet *(Paspalum scrobiculatum* L.*)* to assess genetic variability, heritability and genetic advance for eight yield component traits and found that high genotypic coefficient variation (GCV) and phenotypic coefficient of variation were observed for dry fodder yield, grain yield plant^{-1} and plant height. In Sudan grass PCV were higher than the corresponding GCV for all the characters. High GCV was observed for leaf area, green and dry fodder yields. Leaf stem ratio, crude protein, plant height and numbers of tillers plant^{-1} exhibited low GCV (Anup and Vijayakumar, 2000). In grasspea for all traits, phenotypic coefficient of variation was higher than the genotypic coefficient. The differences between genotypic and phenotypic variability for all traits, except pods plant^{-1}, seeds plant^{-1} and yield plant^{-1}, was small indicating that these traits were less influenced by environment. A wide range of phenotypic variation was observed for pods plant^{-1}, seeds plant^{-1} and yield plant^{-1}. Coefficients of genotypic and phenotypic variation suggest that there is good scope for yield improvement through selection for pods plant^{-1}, seeds plant^{-1} and yield plant^{-1} (Kumar and Dubey, 2001). Bendale *et al.* (2002) found higher phenotypic coefficient of variation than genotypic coefficient of variation in finger millet. Phenotypic coefficient of variance and genotypic coefficient of variance were high for number of effective tillers, grain yield plant^{-1}, straw yield plant^{-1}, number of tillers and weight of grains of main ear head. Kebere *et al.* (2006) concluded that the mean squares of genotypes were highly significant for all characters. The genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) estimates ranged from 3.25 (Days to 50% flowering) to 47.78 (stem weight) and 3.54 (days to 50% flowering) to 48.18 (stem weight), respectively in finger millet. Except days to 50% flowering, plant height and stem diameter, all other characters showed high PCV and GCV estimates in pearl millet (Shanmuganathan *et al.*, 2006). Fourteen advanced hybrids of pearl millet were studied for twelve quantitative traits. Significant differences were observed for all the characters, indicating the diverse genetic nature of the hybrids. High PCV and GCV for grain yield, tiller number, fodder yield and number of leaves indicate the possibilities of improving these characters through phenotypic selection for the development of dual purpose hybrids in pearl millet (Vidyadhar *et al.*, 2007). Highest PCV and GCV values were observed for dry fodder yield plant^{-1} followed by earhead breadth and length, grain yield plant^{-1}, stem girth and 1000 seed weight in sorghum (Warkad *et al.*, 2008).

Godbharle *et al.* (2010) observed variability in sorghum and found that genotypic variance was lower than the phenotypic variance for all the characters. High genotypic and phenotypic variance were observed for the characters panicle length, fodder yield, primary branches panicle^{-1}, grains primary branches^{-1}, harvest index, grain yield and plant height indicating that additive gene effects were operating for these traits. Sumathi *et al.* (2010) evaluated 47 genotypes of Pearl millet. The phenotypic coefficient of variation (PCV) was greater than genotypic coefficient of variation (GCV) for all the characters studied; this shows the influence of the environment on the characters. The traits, number of tillers plant^{-1}, ear head length, root shoot ratio and seed yield showed moderate PCV and GCV while the traits, days to 50% flowering, plant height, ear head breadth, root length and shoot length showed low PCV and GCV. Shet *et al.* (2010) reported high PCV and GCV values for grain yield plant^{-1} and finger width and low for plant height and days to 50% flowering, and it was low to moderate for all other characters. Ganapathy *et al.* (2011) revealed that the coefficient of variation at phenotypic and genotypic levels were high for productive tillers plant^{-1} and moderate for the traits *viz.*, days to 50 per cent flowering, plant height, and grain yield plant^{-1}. Low PCV and GCV were observed for the trait days to maturity. Wide genetic variability was observed among wheat genotypes for days to 50% flowering, plant height (cm.), length of ear (cm), number of spikelets ear^{-1}, days to maturity, number of seed ear^{-1}, test weight (g) and grain yield plant^{-1}. Phenotypic variances were higher than the genotypic variances (Rajpoot *et al.*, 2013). Nukasani *et al.* (2013) evaluated hundred and fourteen prebreeding lines of wheat for variability. High values of GCV and PCV were recorded for tillers per meter and grain yield per meter, whereas moderate values were reported for rest of the traits. Maximum phenotypic coefficient of variance (PCV) and genotypic coefficient of variance (GCV) was observed for grain yield ha^{-1}, number of effective tillers plant^{-1}, grain yield plant^{-1} and number of grain spike^{-1} and minimum for initiation of spike and days to maturity (Singh and Upadhyay, 2013). Estimated highest GCV and PCV values were in rice recorded for grain yield plot^{-1} followed by fertile grains panicle^{-1} and grains panicle^{-1} (Aditya and Bhartiya, 2013). Guinea grass genotypes were screened for fodder yield and its component traits and quality parameters. The traits, green fodder yield plant^{-1} and crude protein content showed moderate PCV and GCV while the trait, crude fibre content showed low PCV and GCV (Ramakrishnan *et al.*, 2013). Two hundred and seven accessions and eighteen released varieties of barley were studied. Analysis of variance showed highly significant differences among the tested genotypes for all traits indicating the presence of genetic variability in the traits. Phenotypic coefficient of variation ranged from 8.77 for days to maturity to 63.49 for susceptibility to lodging, while genotypic coefficient of variation ranged from 7.98 to 60.03, for the same traits (Derbew *et al.*, 2013). Kumar *et al.* (2014b) studied ninety seven pearl millet genotypes. Reported significant differences were observed among the genotypes for all the characters studied. The characters, namely, grain yield, panicle diameter, panicle length and plant height showed high phenotypic (PCV), genotypic (GCV) coefficient of variation. Kumar *et al.* (2014a) estimated high genotypic variance and phenotypic variance in maize for grain yield, plant height, ear height, 100-kernel weight and number of kernels row^{-1}; thus, indicating the presence of sufficient inherent genetic variance over which selection can be effective. High to moderate PCV and GCV were recorded for grain yield, ear height, 100-kernel weight, number of kernels row^{-1}, plant height, ear length and ear girth. Suggesting sufficient variability offers scope for selection. Mishra *et al.* (2014) found that PCV were higher than GCV for all the characters. Phenotypic and genotypic coefficient variations were highest for number of spikes plant^{-1} (35.76 and 36.25 respectively) and lowest for days to opening of first florets (8.77 and 9.31 respectively) in gladiolus. In Napier grass observed genotypic coefficient of variation and phenotypic coefficient of variation was highest for green forage yield (72.17, 72.98) and lowest for oxalic acid content (4.76, 6.52). High estimates of GCV and PCV were observed for green forage yield (72.17, 72.98) followed by dry matter yield (69.47, 0.89) and number of tillers (45.60, 46.57) (Mali *et al.*, 2014).

The characters dry matter yield, leaf stem ratio, green fodder yield, leaf area, spike length and number of tillers per meter row length showed high GCV and PCV in pearl millet (Kanwar *et al.*, 2015). Dhedhi *et al.* (2015) studied 23 genotypes of fodder pearl millet for genetic variability; it indicated presence of sufficient variability and scope for further selection for breeding superior and desirable genotypes. Estimated of phenotypic and genotypic variances were high for green fodder yield (3376.7, 2116.7), dry fodder yield (913.7, 591.1) and plant height (643.7, 357.6). The phenotypic and genotypic variances were moderate for days to 50 per cent flowering (52.1, 32.1) and days to maturity (36.7, 30.3); while, they were low for the remaining characters. Twelve maize genotypes were evaluated for character association. The phenotypic coefficients of variation (PCV) estimates were invariably higher than their corresponding genotypic coefficient of variation (GCV) values thereby suggesting the environmental influence. High estimates of GCV and PCV were observed for plant height, leaf length, stem girth, number of cobs, number of seeds, dry matter yield and green fodder yield, suggesting that selection based on these characters would facilitate successful isolation of desirable types (Kapoor and Batra, 2015). Yadav *et al.* (2015) reported significant variation in the entire gene pool of barley. The genotypic and phenotypic coefficient of variation was high for tillers plant^{-1}, spike plant^{-1}, grain yield plant^{-1}, flag leaf area, harvest index, 1000 grain weight, grain weight spike^{-1}, upper leaf area and husk content. In forage maize estimated higher phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) was obtained for per day productivity of dry matter yield (Chakrovorty and Neog, 2015). Rahman *et al.* (2015) revealed that the phenotypic coefficients of variation were higher than the genotypic coefficient of variation for all the characters studied. The magnitude of phenotypic and genotypic variability was high for ear height, 1000 grain weight and number of grain per cob in maize. In pearl millet observed GCV and PCV values were low for biomass, days to 50% flowering, plant height and 1000 grain weight; medium for number of panicle, leaf dry weight and stem weight; high for root weight. The panicle weight and plant height were recorded with low GCV and moderate PCV (Konate *et al.*, 2016). Jyothsna *et al.* (2016) observed that the genotypic coefficients of variation for all the characters studied were lesser than the phenotypic coefficients of variation indicating the interaction of genotypes with environment studied in foxtail millet. Rana *et al.* (2016) studied forty diverse genotypes in forage sorghum and magnitude of genetic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) recorded were high for various characters like leaf stem ratio, number of leaves plant^{-1}, green fodder yield plant^{-1}, stem girth and dry matter yield plant^{-1}. Geethanjali and Jegadeeswaran (2016) reported that in foxtail millet grain yield plant^{-1} exhibited the maximum variation with a CV of 22.5%, while days to fifty per cent flowering and plant height exhibited the least variation with a CV 7.2% and 9.3% respectively. Kour and Pradhan (2016) investigated 40 diverse genotypes of forage sorghum, found high genetic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) as percentage of mean for characters like leaf stem ratio, number of leaves plant^{-1}, green fodder yield plant^{-1}, stem girth and dry matter yield plant^{-1}.

In marvel grass estimates of genotypic as well as phenotypic coefficients of variances were higher for leaf stem ratio, stem thickness, green forage yield and number of tillers tussock^{-1} (Gore *et al.*, 2016). Sabit *et al.* (2017) investigated nineteen genotypes of wheat found that maximum genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) was observed for biological yield plant^{-1}, followed by seed yield plant^{-1}, grain filling period, thousand grains weight, number of grain spike^{-1}, peduncle length, number of productive tiller plant^{-1}, plant height, and flag leaf width. Ranjith *et al.* (2017) evaluated sorghum for yield and yield components and observed high genotypic coefficient of variation and phenotypic coefficient of variation for the character fodder yield plant^{-1} followed by 1000 seed weight whereas moderate for plant height and grain yield plant^{-1} and low for the character 50 per cent flowering. Evaluated fifty four accessions of pearl millet for genetic variability and found that PCV was slightly higher than GCV indicating little influence of environment on the expression of characters. High PCV and GCV were recorded for all the characters except dry matter per cent, crude protein and crude fibre content (Kumar *et al.*, 2017). Investigation was carried out in foxtail millet to measure the variability, coefficients of variation which indicated that the estimates of PCV were slightly higher than the corresponding GCV estimates for all the characters, indicating that the characters were less influenced by the environment (Kavya *et al.*, 2017). Meena *et al.* (2017) revealed that sufficient genetic variation was observed in field pea. Phenotypic coefficients of variation were higher than genotypic coefficients of variation for all the characters under study indicating environmental influence on the traits.

2.1.1.2 Heritability and genetic advance

Suthamathi and Dorairaj (1997) evaluated 40 genotypes of Napier grass of diverse origin to estimate genetic variability for sixteen characters. Leaf weight, green fodder yield plant^{-1}, stem weight, crude fat content, number of leaves, tillers plant^{-1}, plant height, crude protein content and stem diameter recorded high heritability and genetic advance. Anup and Vijayakumar (2000) estimated high heritability for plant height, leaf area, green and dry fodder yields, and moderate for days to 50 percent flowering and crude protein. The character number of nodes, number of leaves and leaf stem ratio had low heritability. Broad sense heritability was highest (74.4%) for plant height which was followed by 100 seed weight (68.8%). Days to flowering, seeds pod^{-1}, seeds plant^{-1}, yield plant^{-1} and number of primary branches showed moderate heritability values ranging from 45.8% to 54.6%. Lowest heritability value of 45.3% was recorded for pods plant^{-1} in grasspea (Kumar and Dubey, 2001). Kebere *et al.* (2006) had concluded that the heritability estimates ranged from 20% for grain-filling duration to 84% for days to heading. Values of expected genetic advance varied from 6.67-44.14% for grain filling duration and finger width, respectively. High heritability coupled with high genetic advance of percentage of mean was observed for all characters except days to 50% flowering suggesting that these traits are governed by additive gene action and possibility of improving these characters through selection in pearl millet (Shanmuganathan *et al.*, 2006). In pearl millet Vidyadhar *et al.* (2007) reported high heritability coupled with high genetic advance as percentage of mean for days to flowering, grain yield, plant height, fodder yield, tiller number, days to maturity and leaf length suggesting that these traits are governed by additive gene effects and that is possibility of improving these characters through selection. Deepalakshmi and Ganesamurthy (2007) observed high heritability accompanied with high GA as per cent of mean was observed for the characters days to fifty per cent flowering, plant height, leaves plant^{-1}, leaf length, earhead weight, number of primaries panicle^{-1}, 100 grain weight and single plant yield thus suggesting that these characters are under additive gene action and thus gives better scope for selection.

Warkad *et al.* (2008) reported high heritability accompanied with high genetic advance over mean for the characters grain and dry fodder yield, stem girth, earhead length and breadth, suggesting the influence of additive genes and provides scope for selection. High value of heritability alongwith low genetic advance over mean were observed for the characters days to maturity and number of leaves plant^{-1} indicating that variability due to the non-additive gene effects in sorghum. Hasan *et al.* (2010) studied twenty four hybrid rice varieties of diverse origin. High values of heritability along with moderate genetic advance were observed for panicle per m^2, days to 50% flowering and plant height. Forty seven pearl millet genotypes recorded high heritability for all the traits. High heritability combined with high genetic advance was observed for ear head length and seed yield and these characters were controlled by additive gene effects (Sumathi *et al.*, 2010). Salini *et al.* (2010) observed high variability for grain yield plant^{-1} and total number of productive tillers showed highest heritability. High genetic advance as per cent of mean was recorded for all characters except days to fifty per cent flowering and plant height. High heritability coupled with high genetic advance was observed for grain yield, number of productive tillers and total number of tillers. Godbharle *et al.* (2010) reported high heritability coupled with high genetic advance for the characters plant height (90.73 % & 31.45), threshed grade score (87.14% & 44.60), panicle length (83.42 % & 29.12), primary branches panicle^{-1} (95.11 % & 68.98), fodder yield (93.06 % & 71.58), total biomass (91.52 % & 55.79), harvest index (95.48 % & 72.86) and grain yield plant^{-1} (97.80 % & 78.92) in sorghum. Shet *et al.* (2010) reported high genetic advance for plant height, test weight and grain yield plant^{-1}. Sasamala *et al.* (2011)

observed moderate to high estimates of heritability along with moderate to high genetic advance (GA) and genotypic coefficient of variation (GCV) for grain yield and all the component traits except plant height and panicle number. Ganapathy *et al.* (2011) revealed that high heritability coupled with high genetic advance was observed for days to 50 percent flowering, plant height, productive tillers plant^{-1}, and seed yield plant^{-1}. Jain and Patel (2012) observed high heritability accompanied with high GA as per cent of mean for days to 50% flowering, plant height, number of leaves plant^{-1}, leaf length and fodder yield plant^{-1} suggesting that these characters are under additive gene action and gives better scope for selection in forage sorghum. Seventy three rice varieties were evaluated for their variability with regards to yield and yield components, high variability, heritability and genetic advance as per cent of mean for grain yield while panicle bearing tillers and 1000 grain weight had recorded high heritability coupled with low genetic advance as per cent of mean (Kishore *et al.*, 2013). In wheat Rajpoot *et al.* (2013) reported high heritability with low genetic advance as percent of mean for days to maturity which indicated the involvement of non-additive gene action for the expression of this character and selection for such trait might not be rewarding. High heritability coupled with high genetic advance as percent of mean was observed for days to 50% flowering, indicating that these traits were under additive gene control and selection for genetic improvement for these traits would be effective. Singh and Upadhyay (2013) studied twenty seven wheat genotypes and reported high heritability coupled with high genetic advance as per cent over mean for grain yield ha^{-1}, plant height at maturity, number of grain spike^{-1} and days to maturity suggesting selection for these traits would give good responses. Nukasani *et al.* (2013) reported high heritability coupled with high genetic advance for traits plant height, tillers m^{-1}, grain yield m^{-1}, grain wt spike^{-1} and spike length indicating that these characters are governed by additive gene effects and directional selection for these traits would be more effective. High heritability coupled with high genetic advance as per cent of mean was observed for number of leaves plant^{-1}, leaf weight and crude protein content and these characters were controlled by additive gene effects, hence selection of genotypes based on these traits would be effective in the improvement of both fodder yield and quality in Guinea grass (Ramakrishnan *et al.*, 2013). Lal *et al.* (2013) screened forty genetic stocks of vetiver (*Vetiveria zizanioides* L. Nash) for high oil yield and observed that heritability and corresponding genetic advance (GA), both were high for plant height (h^2 = 98.48 and GA = 64.83). Derbew *et al.* (2013) observed high heritability and high genetic advance as the percent of the mean for susceptibility to lodging, flag leaf width, spikelets spike^{-1} and grain yield plant^{-1}. Relatively rapid progress can be achieved in these traits through selection in barley. Fifteen genotypes of pearl millet (*Pennisetum glaucum* L. R. Br.) were evaluated for heritability. High estimates of heritability and genetic advance were scored for days to 50% flowering and days to maturity indicating that these characters were under the control of additive genetic effects (Subi and Idris, 2013). In rice broad sense heritability was highest for plant height and fertile grains panicle^{-1} (98.14%) followed by grains panicle^{-1} (97.74%), days to 50 per cent flowering (95.18) and days to maturity (94.71). Estimated genetic advance was found highest for grains panicle^{-1} and fertile grains panicle^{-1} (Aditya and Bhartiya, 2013).

High heritability coupled with high genetic advance as per cent of mean was observed for days to 50 per cent flowering, plant height, panicle length, panicle diameter and grain yield indicating the importance of these traits in selection and crop improvement in pearl millet (Kumar *et al.*, 2014b). High heritability with moderate estimates of genetic advance was observed for number of kernels row^{-1} and 100-kernel weight. High to moderate heritability along with low estimates of genetic advance were observed for days to 50 per cent tasseling, days to 50 per cent silking, shelling percentage, ear length, days to maturity, ear girth and number of kernel rows ear^{-1} in maize (Kumar *et al.*, 2014a). High heritability estimates accompanied by high genetic advance as percentage of mean was reported for characters *viz.*, number of tillers, dry matter yield and green forage yield, indicating presence of additive gene action thereby, suggesting these traits for selection and scope for Napier improvement (Mali *et al.*, 2014). Mishra *et al.* (2014) reported high genetic advance in percentage of mean coupled with high for the characters number of sprouts, number of spikes plant^{-1}, length of spike, vase life, weight of corms plant^{-1}, weight of cormels plant^{-1}, number of corms plant^{-1} and number of cormels plant^{-1} in gladiolus. Singh *et al.* (2014) recorded observations on twelve yield and yield contributing traits in pearl millet. Wide range of heritability and genetic advance as per cent of mean were recorded for grain yield plant^{-1}, dry fodder weight plant^{-1}, fresh fodder weight plant^{-1}, productive tillers plant^{-1}, plant height and number of nodes plant^{-1}. In pearl millet high heritability estimate was observed for dry fodder yield (64.70%), green fodder yield (62.70%), days to 50 per cent flowering (61.70%) and plant height (55.60%). High heritability may be due to additive gene effects hence, these traits are likely to respond to direct selection (Dhedhi *et al.*, 2015). Kanwar *et al.* (2015) reported that high estimates of heritability along with high genetic advance were observed for number of tillers meter^{-1} row length, leaf stem ratio, spike length, green fodder yield, dry matter yield and leaf area in pearl millet. Parnaliya *et al.* (2015) high estimates of heritability were observed for grain weight per main spike, ear length, plant height, number of grains per main spike, days to maturity, days to 50 per cent flowering, 100 grain weight, grain filling period, number of productive tillers plant^{-1}, grain yield plant^{-1} and biological yield plant^{-1}. Values of genetic advance expressed as percentage of mean were found high for number of productive tillers plant^{-1}, grain yield plant^{-1} and biological yield plant^{-1} in bread wheat. Yahaya (2015) reported high heritability for 1000-seed weight and grain yield, whereas the number of productive tillers had low heritability in pearl millet. Chakrovorty and Neog (2015) reported high heritability coupled with high genetic advance for per day productivity of green forage yield and per day productivity of dry matter yield in forage maize. This indicated that these characters were under the control of additive gene action. High heritability along with high genetic advance were recorded for plant height, leaf length, leaf width, stem girth, number of leaves, crude protein, acid detergent fibre, dry matter yield and green fodder yield indicating the predominance of additive effects in the inheritance of these characters in maize (Kapoor and Batra, 2015). In barley Yadav *et al.* (2015)

reported that high heritability coupled with high genetic advance was recorded for tillers plant^{-1}, spikes plant^{-1}, grain yield plant^{-1}, flag leaf area, harvest index, grain weight spike^{-1}, upper leaf area, husk content, grain size and plant height suggesting that these traits are highly heritable and governed by additive gene action. Moderate heritability coupled with high genetic advance was observed for 1000 grain weight, biological yield plant^{-1}, spike length, protein content, grains spike^{-1} and spike weight; however, days to 50% flowering and days to maturity had moderate heritability coupled with low genetic advance suggesting preponderance on non-additive gene action in the inheritance of these traits. Konate *et al.* (2016) observed that leaf dry weight and root weight had high heritability and high genetic advance, whereas biomass, day to 50% flowering, leaf area, number of panicle and yield plant^{-1} had high heritability but moderate genetic advance. Panicle weight and stem weight had both moderates heritability and genetic advance percentage of mean in pearl millet. High heritability coupled with high genetic advance was observed for grain yield plot^{-1} indicating the importance of additive gene action in governing the inheritance of these traits (Jyothsna *et al.*, 2016). Heritability and genetic advance as percentage of mean were recorded high for various characters like leaf stem ratio, number of leaves plant^{-1}, green fodder yield plant^{-1}, stem girth and dry matter yield plant^{-1} in forage sorghum (Rana *et al.*, 2016). Maximum heritability was observed for leaf stem ratio (97.10%) and minimum for dry matter (61.90%). High estimates of heritability accompanied by high estimates of genetic advance as percentage of mean were observed for characters like number of tillers tussock^{-1}, stem thickness, leaf stem ratio, number of leaves tiller^{-1}, leaf length, leaf breadth, crude protein (%) and green forage yield indicating that these traits are predominately governed by additive gene action and selection for these characters will be effective in marvel grass (Gore *et al.*, 2016). In forage sorghum high heritability and genetic advance were recorded for characters like number of leaves plant^{-1}, leaf stem ratio, green fodder yield plant^{-1}, stem girth and dry matter yield plant^{-1}. Therefore, more emphasis should be laid on these component traits during selection for further improvement of green forage yield (Kour and Pradhan, 2016). In wheat high heritability was recorded for no of grains spike^{-1}, plant height, thousand grains weight, biological yield, grain filling periods, days to 50% heading, days to 50% flowering, peduncle length, spike length and seed yield plant^{-1}. High genetic advance was recorded for plant height (Sabit *et al.*, 2017). High heritability in broad sense was recorded for fodder yield plant^{-1} (96%), 1000-seed weight (89.4), grain yield plant^{-1} (83.6) and plant height (77.9), while moderate heritability was recorded for days to 50 per cent flowering (52.9%) and panicle breadth (50.9%). The highest genetic advance percentage over mean was observed for the character fodder yield plant^{-1} (55.14%) followed by 1000-seed weight (49.35%), grain yield plant^{-1} (26.25%), plant height (26.10%) and panicle breadth (22.32%) while for days to 50 per cent flowering the expected genetic advance was moderate (11.93%) (Ranjith *et al.*, 2017). High heritability with high genetic advance as per cent of mean for plant height, number of nodes in main culm, number of tillers plant^{-1}, number of leaves tiller^{-1}, leaf width, leaf weight, stem weight, leaf stem ratio, dry matter per cent, crude protein and crude fat suggested the prevalence of additive gene action in their inheritance indicating that selection based on these traits will be quite effective in pearl millet (Kumar *et al.*, 2017). In foxtail millet observed high heritability coupled with high genetic advance as percent of mean was observed for number of basal tillers, number of culm branches, panicle exertion, ear length, ear width, 1000 seed weight, seed yield plant^{-1}, straw yield plant^{-1}, protein content. Thus, these traits are predominantly under the control of additive gene action and hence these characters can be improved by selection. Moderate heritability with moderate genetic advance was recorded for plant height, flag leaf length, flag leaf width, days to 50% flowering, carbohydrate content. These traits appear to be under the control of both additive and non-additive gene actions (Kavya *et al.*, 2017).

2.1.2 Correlation studies

Correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for improvement in yield. The magnitude and direction of association is measured by correlation coefficients. Correlation studies provide information so that selection for one character results in progress for all positively correlated characters. Simple correlations are of three types *viz.*, phenotypic, genotypic and environmental. Phenotypic correlation is the observable correlation between variables, measures the environmental deviation together with non-additive gene action. Genotypic correlation on the other hand is the inherent association between two variables. Estimation of phenotypic and genotypic correlations between different characters is helpful in a breeding programme as it supplies different information regarding the characters, which may be used as the criteria for selection. The intensity and direction of association among characters may be measured by phenotypic and genotypic coefficient of correlation depending on the type of material under study and experimental design used (Mode and Robinson, 1959). Studies on correlation coefficient merely provide a picture of relative importance of direct and indirect influence of each components character towards dependent variable. Therefore, the knowledge of direct and indirect of component on yield is of prime importance to select high yielding genotypes. A brief review of previous works on correlation studies in guinea grass and related crops is described beneath.

Seed yield plant^{-1} showed significant positive correlation coefficient with branch number panicle^{-1}, panicle number plant^{-1}, panicle length, branch length, 100 seed weight and days to flower. Path coefficients analysis revealed that panicle number plant^{-1} had highest direct effect on seed yield plant^{-1}, followed by branch number panicle^{-1}, days to flower and 100 seed weight (Sukhchain and Sidhu, 1992b). Ramasamy *et al.* (1994) found that genotypic correlation coefficient was generally higher than phenotypic correlation coefficients. Devarathinam and Dorairaj (1994) derived information on yield correlations from data on twelve yield components in fifty three genotypes of Napier grass. Green fodder yield was significantly and positively correlated with plant height, leaves tiller^{-1}, leaf weight, stem weight, dry matter and crude protein yield. Kandasamy and Manoharan (1996) reported positive association of grain yield plant^{-1} with number of productive tillers, but significant and negative association with plant height and days to maturity. Rao (2000) found that tillers plant^{-1} and ear length had positive significant correlation with fodder yield and all the three had positive association with yield. Days to flower, days to maturity and plant height had negative correlation with yield. Path analysis indicated highest direct effects of ear length followed by fodder yield and days to flower on grain yield, whereas tillers plant^{-1} had highest direct effects on fodder yield followed by days to maturity and plant height. Considering the genetic parameters, association and path analysis, ear length and fodder yield had a great influence on grain yield. Anup and Vijayakumar (2000) reported that green fodder yield had positive correlation with leaf area, plant height, number of leaves plant^{-1}, number of nodes plant^{-1}, crude protein and dry fodder yield.

Seed yield was positively and significantly correlated with days to maturity, number of leaves plant^{-1}, earhead weight and number of primaries panicle^{-1} but there was negative significant correlation with grain mould score. The characters number of leaves plant^{-1}, earhead length, earhead weight, number of primaries panicle^{-1} and grain mould score showed positive direct effect on seed yield (Deepalakshmi and Ganesamurthy, 2007). Grain yield had positive and significant correlation with most of the characters under study except leaf length, panicle width and tiller number. It is suggested that selection should be based on days to flowering, days to maturity, plant height, leaf length, panicle length, panicle width and fodder yields towards the development of dual purpose hybrids in pearl millet (Vidyadhar *et al.*, 2007). Misra *et al.* (2008) found the component traits *viz.*, days to flowering, tillers plant^{-1}, spike length, 1000 grain weight and harvest index showed significant positive phenotypic and genotypic correlation with grain yield. Path coefficient analysis showed high positive direct and indirect effects of tillers plant^{-1}, 1,000 grain weight and fingers spike^{-1} on grain yield. John (2008) studied thirty seven Napier grass genotypes and showed that green fodder yield had significant and positive association at both genotypic and phenotypic levels for plant height and leaf width but number of tillers plant^{-1} and crude fibre content showed significant association at genotypic level only. Godbharle *et al.* (2010) reported positive and significant correlation between grain yield and harvest index, total biomass, fodder yield and leaf area index both at phenotypic and genotypic level, while the characters field grade score, threshed grade score and days to 50% flowering exhibited negative correlation with grain yield in sorghum. Rana *et al.* (2016) reported green forage yield plant^{-1} was highly significant and positively correlated with stem girth, leaf length, leaf width and dry matter yield plant^{-1} at both genotypic and phenotypic level. These characters may be considered as important yield components in sorghum. Grain yield showed positive significant association with number of effective tillers hill^{-1}, panicle per m^2, spikelet fertility and thousand grain weight at both genotypic and phenotypic levels. Same traits had highest significant positive effect on yield was observed as hybrid rice (Hasan *et al.*, 2010). Sasamala *et al.* (2011) observed significant positive association of grain yield with plant height, flag leaf length, flag leaf area, panicle length, panicle weight, panicle yield, biological yield, harvest index and 1000 grain weight. Fodder yield was positively and significantly correlated with number of leaves plant^{-1}, leaf length, leaf width and panicle length. The characters leaf width, number of leaves plant^{-1}, days to 50% flowering and panicle length showed positive direct effect on fodder yield. Leaf length showed positive significant association with fodder yield but the direct effect of leaf length was negative with fodder yield (Jain and Patel, 2012).

Nukasani *et al.* (2013) revealed that characters *viz.*, tiller number meter^{-1}, grain weight spike^{-1}, number of grains spike^{-1} exhibited positive and strong association and maximum positive direct effects on grain yield in wheat. In rice, yield was observed to be positively associated with panicle bearing tillers and number of filled grains panicle^{-1} and these characters were noticed to exert high direct effects on grain yield plant^{-1}. High indirect effects of most of the traits were noticed mostly through panicle bearing tillers hill^{-1} indicating importance of the trait as selection criteria in crop yield improvement programmes (Kishore *et al.*, 2013). Aditya and Bhartiya (2013) observed phenotypic correlation coefficient among fifteen traits showed that grain yield was significantly and positively correlated with plant height, days to 50 per cent flowering, days to maturity, flag leaf length, flag leaf width, panicle length, grains panicle^{-1}, fertile grains panicle^{-1}, kernel length and length breadth ratio. Grain yield ha^{-1} showed significant positive genotypic and phenotypic correlation with grain yield plant^{-1} (rg=0.454, rp= 0.442) and spike length (rg=0.536). Grain yield ha^{-1} (0.938, 0.502) had highest positive direct effect on grain yield plant^{-1} followed by 1000 grain weight (0.490, 0.336). It is suggested that these characters can be considered as selection criteria in improving the grain yield (Singh and Upadhyay, 2013). Yield plant^{-1} had high positive and significant correlation with number of tillers plant^{-1}, number of seeds ear^{-1} and test weight (g). Path coefficient analysis revealed maximum direct contribution towards yield plant^{-1} with length of ear followed by test weight (g). Hence, emphasis should be given to select these traits to increase the production and productivity of wheat (Rajpoot *et al.*, 2013). Dhamdhere *et al.* (2013) reported that straw weight and total biomass showed highly significant positive correlation with yield. Grain yield was found positively associated with days to 50% flowering, days to maturity, thousand grain weight, ear weight and harvest index. Days to 50% flowering showed highly significant positive correlation with days to maturity, ear weight, straw weight and total biomass. Genetic and phenotypic associations coefficients among the seven traits indicated that plant height was highly and significantly correlated with tillers plant^{-1}, fresh root with dry root yield and oil content with oil yield at both genotypic and phenotypic level. The plant height with root length was also positively correlated with each other at both genetic and phenotypic levels in vetiver (Lal *et al.*, 2013). Green fodder yield plant^{-1} was highly significant and positively associated with number of tillers and leaves plant^{-1}, leaf weight and dry matter content and suggested that these characters may be considered for improvement of fodder yield (Ramakrishnan *et al.*, 2013). Kumar *et al.* (2014b) observed that grain yield had significant and positive correlation with plant height and panicle diameter at phenotypic level. The genotypic correlation estimates showed significant positive association of grain yield with panicle length, panicle diameter, number of nodes and internode length. Panicle length and plant height exhibited highest positive and significant direct effect on grain yield. Hence, these traits could be considered as suitable selection criteria for the development of high yielding pearl millet genotypes. Singh *et al.* (2014) observed grain yield to be positively and highly significantly correlated with all the traits under study. Path analysis revealed that productive tillers plant^{-1} had highest positive direct effect followed by plant height, spike length and nodes plant^{-1}. These desirable correlations showed that productive tillers plant^{-1}, plant height, spike length, nodes plant^{-1} and fresh fodder weight were the major yield components in pearl millet and therefore can be used as selection criteria for yield improvement of pearl millet.

Dhedhi *et al.* (2015) studied that green fodder yield exhibited significant positive correlation with days to 50 per cent flowering (0.839, 0.479), days to maturity (0.658, 0.512) and dry fodder yield (0.976, 0.959), while non-significant and positive correlation was observed with plant height (0.071, 0.227) at both genotypic and phenotypic levels. Negative and significant association of green fodder yield was observed with grain yield (- 0.770, -0.568) and harvest index (-0.972, -0.799) at both genotypic and phenotypic levels in pearl millet. Parnaliya *et al.* (2015) estimated that genotypic correlation was higher than the corresponding phenotypic correlation. The grain yield plant^{-1} showed significant and positive correlation with biological yield plant^{-1}, number of productive tillers plant^{-1}, harvest index, number of grains main spike^{-1}, grain filling period, grain weight main spike^{-1} and days to maturity at genotypic and phenotypic levels in bread wheat. Yahaya (2015) reported that grain yield was positively and significantly correlated with the number of productive tillers, panicle width, panicle length and 1000 seed weight. Significant negative correlation was observed between the number of productive tillers and panicle width. There was a positive association between the number of productive tillers, panicle length and 1000-seed weight and grain yield High significant association also existed between panicle width and panicle length in pearl millet. In maize the correlation analysis showed that in most cases the genotypic correlation between traits was greater than phenotypic correlation. The highest coefficient of correlations was found between grain yield plant^{-1} and 1000 GW, but the relationship was negative (Rahman *et al.*, 2015). Kapoor and Batra (2015) observed that plant height, leaf length, leaf width, stem girth, number of leaves plant^{-1} and dry matter yield had positive and significant correlation at genotypic as well as phenotypic level with green fodder yield and the selection based on these traits will result in improving the green fodder yield in maize. Jyothsna *et al.* (2016) revealed that, four out of five characters exhibited highly significant positive correlation with grain yield plot^{-1} both at phenotypic and genotypic levels. However, the traits plant height, number of productive tillers plant^{-1}, days to 50% flowering and days to maturity were found to possess significant association in desirable direction with grain yield plot^{-1} at both genotypic and phenotypic levels. In marvel grass characters like days to 50 per cent flowering, plant height, stem thickness, number of internodes tiller^{-1}, number of leaves tiller^{-1}, leaf length and leaf breadth, showed significant positive genotypic correlations with green forage yield. Plant height and leaf breadth exhibited high positive direct and indirect effect and significant positive genotypic correlation with green forage yield (Gore *et al.*, 2016). Grain yield plant^{-1} recorded positive and significant correlation with stem weight (r=0.5262) and biomass (r=0.9291). This result indicates that selection based on these two characters will be highly effective for yield improvement in rice (Konate *et al.*, 2016). Sabit *et al.* (2017) evaluated nineteen genotypes of wheat and reported that seed yield exhibited positive significant correlation with biological yield, main spike weight, spikelets spike^{-1} at genotypic level, while biological yield plant^{-1} showed positive significant association at both genotypic and phenotypic level. Plant height, days to 50% flowering, spike length, peduncle length, biological yield, harvest index and main spike weight displayed positive direct effects on grain yield plant^{-1} at both genotypic and phenotypic level. Kumar *et al.* (2017) studied that plant height, number of tillers plant^{-1}, number of leaves tiller^{-1} and leaf stem ratio showed positive association with green fodder yield for which indirect selection can be made in future breeding programme to enhance green fodder yield in pearl millet. Meena *et al.* (2017) reported positive relationship of seed yield with all the attributing traits except pod length and hundred seed weight, where it was inconsistent in both the crosses in field pea. Days to flowering, plant height, clusters plant^{-1}, seed setting per cent and pods cluster^{-1} had significant positive association with seed yield, indicating that major emphasis should be given on these component characters for improving seed yield in the populations of pea, under improvement.

2.1.3 Path coefficient analysis

Path coefficient analysis devised by Wright (1921) is a standardized partial regression coefficient and as such measures the direct influence of one variable upon another and permits the separation of correlation coefficients into components of direct and indirect effects. Working on Crested weed grass Dewey and Lu (1959) demonstrated the method of path coefficient on the analysis of correlation in a system of correlated variables which was widely employed by animal breeders but only rarely by plant breeders. The path coefficient technique is more useful than stepwise multiple regression in establishing the direct and indirect relationships among different variables (Ogunbodede, 1989). High yield depends on those yield components which are highly heritable and strongly correlated with yield and show positive correlations with their yield components. A brief review of previous works on path analysis was described beneath.

Path coefficient analysis revealed that panicle number plant^{-1} had highest direct effect on seed yield plant^{-1}, followed by branch number panicle^{-1}, days to flower and 100 seed weight in guinea grass (Sukhchain and Sidhu, 1992b). The path analysis revealed that leaf area was the single major character which exhibited the highest positive direct effect on green fodder yield and crude protein; in addition all other independent character had maximum indirect contribution through leaf area in sudan grass (Anup and Vijayakumar, 2000). The characters number of leaves plant^{-1}, earhead length, earhead weight, number of primaries panicle^{-1} and grain mould score showed positive direct effect on seed yield. The direct and indirect effects among the component *viz.*, panicle weight and number of primaries panicle^{-1} were positive and improvement of any of these traits will simultaneously improve the seed yield in sorghum (Deepalakshmi and Ganesamurthy, 2007). Six characters showed a positive direct effect on green fodder yield. Leaf width recorded the highest direct effect followed by plant height, panicle length, crude protein content and crude fibre content in Napier grass (John, 2008). Path analysis revealed that characters *viz.*, dry matter yield exhibited the highest positive direct effect on green forage yield followed by crude protein content, stem girth at IInd internode and plant height in bajra napier hybrid (Shinde *et al.*, 2010). The characters leaf width, number of leaves plant^{-1}, days to 50% flowering and panicle length showed positive direct effect on fodder yield. Leaf length showed positive significant association with fodder yield but the direct effect of leaf length was negative with fodder yield, which may be a result of the indirect effect of this trait via other traits in forage sorghum (Jain and Patel, 2012). Aditya and Bhartiya (2013) estimated direct and indirect effect revealed that length breadth ratio had the highest positive direct effect on grain yield followed by kernel width, grains panicle^{-1}, and tillers plant^{-1} in rice. In maize the yield contributing traits like plant height, leaf width, stem girth and dry matter yield as well as the quality trait neutral detergent fibre exhibited positive direct effect on green fodder yield (Kapoor and Batra, 2014). Yield was observed to be positively associated with panicle bearing tillers and number of filled grains panicle^{-1} and these characters were noticed to exert high direct effects on grain yield plant^{-1}. High indirect effects of most of the traits were noticed mostly through panicle bearing tillers hill^{-1} indicating importance of the trait as selection criteria in crop yield improvement programmes in rice (Kishore *et al.*, 2015). Gore *et al.*, 2016 reported Plant height and leaf breadth exhibited high positive direct and indirect effect and significant positive genotypic correlation with green forage yield. The characters *viz.*, number of internodes, stem thickness, leaf length and number of tillers tussock^{-1} also exhibited high indirect effects in marvel grass.

Path analysis studies revealed that plant height, number of productive tillers plant^{-1} showed true relationship by establishing significant positive association and direct effect on grain yield plant^{-1} both at genotypic and phenotypic levels and days to maturity at phenotypic level in foxtail millet (Jyothsna *et al.*, 2016). Path coefficient analysis revealed high positive direct effect of dry matter yield plant^{-1}, stem girth and days to fifty per cent flowering. These traits had high magnitude of genotypic correlation with green forage yield plant^{-1} in forage sorghum (Rana *et al.*, 2016). The traits, plant height, number of tillers plant^{-1}, number of leaves tiller^{-1} and leaf stem ratio showed positive association with green fodder yield for which indirect selection can be made in future breeding programme to enhance green fodder yield in pearl millet (Kumar *et al.*, 2017). Plant height, days to 50% flowering, spike length, peduncle length, biological yield, harvest index and main spike weight displayed positive direct effects on grain yield plant^{-1} at both genotypic and phenotypic level in wheat (Sabit *et al.*, 2017).

2.2 INDUCED MUTAGENESIS

Plant breeding essentially involves improvement of crop to suit the needs of man. The extent of improvement depends upon the variability available (or generated) and the efficiency of selection schemes. An induced mutation has come in as a very effective method of generating variability. The concept of induced mutation was developed by Hugo de Vries (1910) and its significance was subsequently demonstrated by Muller (1927) in Drosophila with X-rays. Several types of ionizing radiations namely, gamma rays, alpha and beta particles, protons and neutrons, we used as physical mutagens Cobalt^{60} and Caesium^{17} are the main sources of gamma rays. The discovery of chemical mutagens during Second World War was another milestone in the history of induced mutations. Auerbach (1943) and Rapoport (1946) were the first, who clearly induced the existence of powerful chemical mutagens. Subsequently, many chemical mutagens such as ethyl-methane sulphonate, methyl methane sulphonate, ethylene-imines, nitroso compounds, base analogs, several antibiotics *etc.* have been used in mutation studies. Generally the high degree of heterozygosity which cause complex inheritance of genetic factors as well as frequent polyploidy both serous 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). Irradiation has been more useful than chemical mutagen in producing mutations in asexually propagated crops. The main advantage of inducing mutations in vegetatively propogated crops is the ability to change one or a few characters in otherwise outstanding cultivars without altering the remaining and often unique part of genotype (Broetjes and Vanharten, 1978). According to Fehr (1987), artificial and induced mutation can be a practical and efficient genetic breeding technique to be used with cultivated plants. Artificial induced mutation is carried out using physical and chemical mutagens which can increase the mutation frequency when compared to its spontaneous occurrence. It is used mainly to obtain mutants for quantitative genes and on a smaller scale, for quantitative genes. However, the breeding process for quantitative genes has been successful in detriment of the genetic variability found in the populations used. High efficiency of mutant production is essential for its extensive use in plant breeding. Thus the use of any mutagenic agent depends not only on its mutagenic effectiveness but also on its efficiency. Mutagenic efficiency is the production of desirable changes free of association with unwanted genetic alterations.

Gamma rays are effective and efficient physical mutagen. They have shorter wave length and therefore posses more energy per photon than X-rays. These rays penetrate up to many cms, which are generally produced in a wide range of energies like X-rays. CO^{60} has half life of 5.3 year with energy = 133 Mev (μ_1) or 1.17 Mev (μ_2) with specific activity 1.400 ci/g it penetrates up to 5 cmpb. When gamma rays impinge on matter, certain physical process (photoelectric absorption, Compton scattering, and ion pair formation) occur by which energy is absorbed in the atoms of the target material and released in the form of fast charged particles. Gamma rays are having high energy photons, which penetrate the surface and induce ionization. Physical mutagen used in the present investigations was gamma rays. A brief description of the mutagens used is given below.

Nayar *et al.* (1979) treated *Eleusine coracana* variety 'Hamsa' with 20 krad gamma rays. The frequency of early M_2 mutants with ears more open than in Hamsa was 2.09-6.87 %. The mutants with open ears were taller than Hamsa, with more inflorescences per plant. Krishna *et al.* (1984) determined the sensitivity of Rhodes grass *(Chloris gayana* Kunth.) by exposing to nine doses of gamma rays ranging from 10 to 90 krad. The chlorophyll mutant spectrum included albino, xantha, chlorina, viridis, tigrina, striata, albo-xantha and albo-viridis. The frequency of these mutants varied with treatments. A dose rate of 60 krad was found to be effective as well as efficient for inducing chlorophyll mutations in M_1 and M_2 plants. Pathak and Patel (1988) studied the effect of irradiation treatment on three genotypes of upland rice. Seeds were treated with 5 krad, 10 krad, 15 krad and 20 krad doses of gamma rays. Germination percentage was not appreciably reduced by gamma radiation. Root lengths were progressively reduced from 0 krad (7.14 cm) to 20 krad (3.82 cm). Gamma radiation did not reduce shoot lengths except in Culture 102-105. Shivashankar *et al.* (1988) subjected seeds of green panic grass to gamma ray treatment with doses of 40, 50 and 60 krad. From the large spectrum of variation observed for flowering habit quite a few nonflowering plants were isolated and of these the one from 40 krad treatment was prominent. Hayat *et al.* (1990) studied effects of 15 krad, 25 krad, 35 krad and 45 krad gamma irradiation treatments. Highly significant differences in the mean values due to radiation doses was noticed for days to 50% flowering, plant height and grain yield. Banerji *et al.* (1994) irradiated dormant corms of gladiolus cv. White Friendship with 250, 500, 750, 1000 and 1250 Gy gamma rays. They observed reduction in survival, plant height, number of leaves and florets, spike length and corm size and delayed flowering after irradiation. Morphological abnormalities in foliage and chromosomal aberrations during root tip mitosis increased with increase in dose. Bretaudeau (1995) irradiated several sorghum cultivars of Mali with different doses of gamma rays and compared with the Caudatum types. Radiation-induced variation was observed in several characters such as plant height, resistance to lodging, plant architecture, drought tolerance, panicle length and compactness, seed size and color, seed quality and protein content, glume color and structure, flowering date (early and late maturity), and tillering capacity. One mutant was drought tolerant. Singh *et al.* (1998) studied the effect of gamma ray seed treatment (10 krad, 20 krad and 30 krad doses) on two cultivars of rice. Chlorophyll and morphological mutations having wider spectrum were also observed in M_2 generation. Kumar *et al.* (1995) irradiated the varieties A404 and HR374 of finger millet with gamma rays, EMS and their combinations. In M_1 generation dwarf plants, dwarf plants with leaning growth habit, grassy non-flowering type, tall with elongated internodes, panicle with gappy rachis, panicle with extra-large glumes, panicle with extra distal thumb, sterile panicle with twisted fingers, panicle profusely branched were obtained. In M_2 generation chlorophyll mutants albino, xantha, viridis, striata and tigrina were obtained. Amnueysit (1999) studied genetic variation of forage sorghum induced by gamma irradiation at 0, 15, 30, 45, 60, 75 and 90 krad. Genetic variation was obtained for four agronomic characters *i.e.* plant height, number of leaves plant^{-1}, shoot fresh weight and number of days to flowering in M_1 and M_2 generation. Banerji and Datta (2001) exposed the rooted cuttings of *chrysanthemum morifolium* cv. 'Surekha' to 150, 200 and 250 Gy doses of gamma rays and observed significant reduction in plant height, number of branches, leaves and flower heads as well as leaf size and flower head size. The foliage and floral abnormalities as well as chromosomal aberrations increased in the treated plants as compared to control.

Sakin and Sencar (2002) subjected wheat cultivars seeds to irradiation with 50 Gy, 100 Gy, 150 Gy and 200 Gy gamma rays or treated with 0.1 %, 0.2 %, 0.3 % and 0.4 % EMS. The spectrum and frequency of mutations were varied with treatments of mutagen and cultivars. The effect of mutagens markedly increased with high doses. The highest mutagenic efficiency was obtained from 0.4 % EMS dose in Gediz-75 cultivar and from 100 Gy gamma ray dose in Sofu cultivar. Talukdar *et al.* (2002) irradiated seeds of grass pea with different doses (5, 10, 15, 20, 25, 30, 35, 40 kR) of gamma rays screened M_2 plants individually. Out of the 49 plants, 3 violet flower colour mutant plants were isolated in the samples treated with 15 kR gamma ray and these were distinguished from the control plants having blue coloured petals. Cheema and Atta, 2003 examined varietal differences in three Basmati rice cultivars exposed to 150 Gy, 200 Gy, 250 Gy and 300 Gy of gamma rays. With the increase in radiation dose, a decrease in germination, seedling height, root length and emergence under field conditions was observed in M_1 generation. Plant height and seed fertility decreased with increase in gamma radiation dose in an approximately linear fashion. Dilta *et al.* (2003) treated rooted cuttings of various cultivars of chrysanthemum with gamma rays at 0 and 20 Gy. Changes were observed after gamma ray treatment in different vegetative and floral characters. Plant survival, plant height, number of branches, plant spread and number of flowers decreased after treatment. An increase in the magnitude of plant abnormalities was recorded. Delay in number of days to bud formation and days to harvest were recorded in treated plants as compared to control. Hussin (2003) irradiated *Brachiaria decumbens* seeds with doses of 100, 200, 300, 400, 500, 600, 700, 800 and 900 Gy. Results showed that, *B. decumbens* seeds were less sensitive to gamma ray than most other species and the LD_{50} was found to be between 800 to 900 Gy. Gamma radiation at 900 Gy increased variability in morphological characteristics and nutrient content and an obvious phenotypic mutant was detected. Pradit *et al.* (2005) found that ten clones of grass with good morphological properties were selected and subsequently grown in the salt stress environment. Under salt stress condition, seven out of ten selected clones showed salt tolerant trait. Boersen *et al.* (2006) studied the effect of various rates of gamma radiation (0, 10.0, 12.5, 15.0, 17.5, 20.0 and 30.0 Gy) on the frequency of mutations in inflorescence colour and type of chimeras in non-rooted cuttings of chrysanthemum. A linear decrease in plant height and a quadratic tendency in survival percentage were observed as the rate of the mutagen increased. Salahbiah and Rusli (2006) observed that dormant axillary bud explants in roses subjected to increasing doses of gamma rays showed a decrease in regeneration capacity, which was completely suppressed at 100 Gy. The lethal dose for 50% of the regenerating explants (LD_{50}) for both cut and miniature roses were observed to be between 20 and 40 Gy. Human *et al.* (2007) studied induced mutation was made by Gamma irradiation on sorghum. The optimal radiation dose was to be around 300-500 Gy. Through selection processes and direct screening for drought tolerance, a number of ten putative mutant lines were obtained. An investigation was carried out by Nirmalakumari *et al.* (2007) to study the nature and amount of gamma ray to induced genetic variability. Maximum variability was observed for plant height and total number of tillers in M_2 generation. Mutants in 500 Gy and 600 Gy also exhibited maximum variability, heritability and genetic advance for plant height, total number of tillers, number of nodes, inter-nodal length, culm thickness and grain yield. Muduli and Misra (2007) studied the effect of three doses, each of gamma rays, ethyl methane sulphonate and nitroso guanidine coupled with combination treatments. High frequency of positive mutations was observed for 1000-grain weight, finger length and fingers ear^{-1} in case of VR 708 and fingers ear^{-1} and finger length in case of GPU 26. Dwivedi and Banerji (2008) irradiated dahlia cultivar 'Pinki' with 0, 2.5, 5, 10 and 15 Gy gamma rays. Reduction in survival, plant height, leaf number and size, length of peduncle, flower size and floret number and size was observed after irradiation and with increase in dosage of gamma rays. Mutation appeared in foliage in the form of chlorophyll variegation and in the flower head in the form of white sectors in ray florets in M_1V_1 generation. Kiong *et al.* (2008) studied effect of gamma irradiation on *O. stamineus* using different doses raging from 0, 10, 20, 30, 40, 50, 60 and 70 Gray (Gy). Biochemical studies on *O. stamineus* revealed that the total soluble protein and total chlorophyll content decreased notably as the gamma dosage increases. Singh and Balyan (2009) reported the effect of gamma rays on bread wheat (*Triticum aestivum* L.) *Cv.* Kharchia. 65 mutants characterized by reduced plant height, square head, awnless ear, amber seed colour, bold seeds and storage capacities were induced. Out of the thirteen reduced plant height homozygous mutant progenies, only three progenies namely 398, 446-7 and 621 showed superiority over control population for several traits. Sutarto *et al.* (2009) exposed bud woods of two Indonesian local commercial mandarins to Gamma-ray doses of 20, 40 and 60 Gy, and irradiated bud woods were then budded onto rootstocks cv. Japanche citroen. Selected promising mutant lines were found in terms of seedlessness in cvs SoE mandarin and Nambangan pummelo, and nearly seedless cultivars were found in cultivars Soe, Garut and Nambangan when bud woods were irradiated at 20 and 40 Gy. Tan *et al.* (2009) isolated seven dwarf mutants of *Stylosanthes guianensis* from seedlings germinated following gamma ray irradiation of seeds. Shoot dry weight of line 4.2-3 was significantly greater than for CIAT 184. All mutant lines had increased drought tolerance over that of the parent, and the lines 4.2-4, 4.2-6 and 4.2-11 had increased chilling resistance. Kahrizi *et al.* (2010) studied the effect of different doses of gamma-rays on axillary buds of two rose cultivars. The LD_{50} was determined on survival rate and calculated at 67 and 66 Gy in ‘Mourossia’ and ‘Apollo’ respectively. The doses that caused 50 % reduction in height in ‘Apollo’ and ‘Maroussia’ were 70 and 68 Gy respectively. Li *et al.* (2010) mutagenesis by gamma ray irradiation employed to treat *St. Augustinegrass* node cuttings and calli. Most mutants were semi-dwarf type with reduced internode length and leaf blade length. One mutant had much less and shorter stolons and displayed an upright and tufty growth pattern. Mahure *et al.* (2010) irradiated unrooted cuttings of chrysanthemum cultivar ‘Red Gold’ with 10, 20 and 30 Gy gamma rays to induce favorable variation. It was found that lower doses of gamma irradiation and induced encouraging novelties while the higher doses often induced high degree of abnormalities and consequent mortality. The colour novelties induced by the mutagens were isolated and purified in M_2 generation. Premnath *et al.* (2010) Seeds of Hedge lucerne (*Desmanthus virgatus*) was exposed to different doses (50 to 500 Gys, with an interval of 50 Gys) of gamma rays. About thirty five mutants were identified. High biomass yielding dwarf statured plants were identified from the treatments of 350 and 500 Gys irradiation. Similarly high fodder yielding superior plants as a result of increased number of branches ranging from 22-34 were observed in 400 and 450 Gys population when compared to the control (12-16 branches). Sasikala and Kalaiyarasi (2010) studied the effect of gamma irradiation on seed germination and the root and shoot length variation in six promising rice varieties. The seedling height was decreased in decreasing manner with the increase of irradiation dose in the varieties such as CO 47. The root development in seedlings was inhibited higher in the dose of 300 Gy in all the six varieties. Plant height and seed fertility percentage were decreased with increase of gamma radiation dose in linear fashion.

Golubinova and Gecheff (2011) studied effects in the first generation (M_1) of gamma-irradiated dry seeds of Sudan grass using doses (100, 200, 300 and 400 Gy). With increasing dose the values obtained for each of these biological parameters decrease. Rahimi and Bahrani (2011) reported that 1000-grain weight, grain yield, grain protein content and harvest index were affected with different levels of irradiation. Grain yield increased in response to application of gamma irradiation. Sherif *et al.* (2011) reported in *Hibiscus sabdariffa* L. the enhancement in fresh weight of roots as well as leaves, when treatmed with gamma radiation. Furthermore, a significant increase in dry weight of the whole plant irradiated with 25 and 50 Gy was observed. Tiwari and Kumar (2011) studied gamma ray induced morphological changes in *Calendula officinalis* and observed higher percentage of survival at lower doses and poor survival at higher doses in all generations of *Calendula officinalis*. However, reduced survival upto the second generation (M_2) and no survival after that were exhibited by the plant treated with 5 kR gamma rays. Amir and Khavar (2012) studied amaranth seeds which were subjected to different gamma irradiation doses (*i.e.* 0, 100, 150, 200 and 250 Gy). Reported that seed germination percentages, seedling shoot and root length decreased with increasing dose of gamma-ray. Harding *et al.* (2012) reported the radio-sensitivity of thirteen rice varieties were exposed to gamma radiation ranging from 50 Gy to 800 Gy. Percentage survival of germinated seedlings from the 8th to 14th day under laboratory conditions decreased significantly with increase in radiation dose up to 600 Gy. With increase in radiation above 300 Gy a reduction in seedling height and percentage survival under field conditions was observed in irradiated plants of M_1 generation. Jain *et* *al.* (2013) fresh seeds of isabgol variety RI-87 were subjected to 15, 30, 45, 60, 75, 90, 105,120 and 135 Kr doses at Co^{60} gamma-rays. Reduction of germination, seeding height, seedling dry weight and pollen fertility in the M_1 generation was observed with increases doses of gamma-rays. The spectrum of chlorophyll mutants included albino, xantha, chlorina, viridis, tigrina and others. Occurrence of major viable mutants from seedling to adult growth stages were varied *viz.*, broad and narrow leaves, paired spikes, coxcomb spikes, ball mutants, gappy spikes, partial and complete sterile. Jain *et al.* (2012) fresh seeds of isabgol variety RI-87 were subjected to 15, 30, 45, 60, 75, 90, 105,120 and 135 Kr doses at Co^{60} gamma-rays. Reduction of germination, seeding height, seedling dry weight and pollen fertility in the M_1 generation was observed with increases doses of gamma-rays. The spectrum of chlorophyll mutants included albina, xantha, chlorina, viridis, tigrina and others. Occurrence of major viable mutants from seedling to adult growth stages were varied *viz.*, broad and narrow leaves, paired spikes, coxcomb spikes, ball mutants, gappy spikes, partial and complete sterile. Laghari *et al.*, 2012 develop twelve mutant lines of wheat through intraspecific crosses cum radiation-induced. Two mutants matured earlier than other entries including check varieties. Mutant produced higher grain yield. Higher grain yield produced by mutant MASR-64 and MASR-6. Talebi and Talebi (2012) studied the effects of gamma ray on seed germination, seedling height and root length of rice variety. The seedling height and root length decreased with the increase in gamma dose and an abnormal decrease in germination was observed. Akshatha *et al.* (2013) seeds of *Terminalia arjuna* were irradiated with 25, 50, 100, and 200 Gy. Increase in the number of leaves was clearly evident and the maximum increase was 43 % at 200 Gy. Dry weights of the plants were found to be significantly higher at 25 and 50 Gy. Chakravarti *et al.*, 2013 studied mutagenic effect on aromatic rice cultivars. Variability induced for quantitative characters were assessed on individual plant basis in M_1 generation. The maximum frequency of chlorophyll mutations per 100 M_2 plants obtain in M_2 generation. The different types of chlorophyll mutations observed in M_2 generation were albino, xantha, striata and viridis. Emrani *et al.* (2013) studied the dose of gamma radiation on seed germination of two cultivars of maize. The root and shoot of both cultivars at doses of 400 and 600 Gy was highest in the third and fourth days. Traits also showed significant reduction in the dose of 800. Lee *et al.* (2013) reported that *Brachypodium* was acutely or chronically irradiated at doses of 50, 100, 150, 200, and 250 Gy. A dose-dependent negative effect in plant height, tiller number, floral spikelet, and total seed number was observed, with a positive effect in days to heading. The phenotype of 1,773 M_1 plants was evaluated, with 417 plants being selected to construct the M_2 population. Lee *et al.* (2013) observed distinctly different phenotype of *B. decumbens.* Mutant had an erect growth habit, short internodes and profuse tillers. The leaves were dark green and they had fine hairs as compared to the control plants. The mutant leaves were also wider and shorter than the control plants. The leaf to stem ratio was also greater in the mutant. The nutritive characteristics between the mutant and control plants were similar with the exception that the mutant had a significantly greater crude protein concentration (20.07 %) as compared to control (18.86 %). Ambavane *et al.* (2014) irradiated seeds of two finger millet cultivar *viz.*, Dapoli-1 and Dapoli Safed with four doses of gammarays *viz.,* 400 Gy, 500 Gy, 600 Gy and 700 Gy. Root and shoot lengths of seedlings were decreased with increase in dose of gamma rays. Similarly, germination percentage and survival rate of seedlings were decreased with increase in dose of gamma irradiation during field study. In M_1 generation, three types of chlorophyll mutations *viz.,* albino, xantha and viridis were observed. Albino and xantha were observed in all treatments, whereas, viridis observed only in lower doses *viz.,* 400 Gy and 500 Gy. Animasaun *et al.* (2014) *Digitaria exilis* seeds exposed to gamma irradiation (20 Gy, 40 Gy, 80 Gy, and 100 Gy) from Co^{60} source. Plant height, tillering and number of leaves were significantly affected by gamma irradiation and early maturity was achieved among irradiated plants and 100-grain weight was highest at 80Gy. Bhave *et al.* (2014) irradiated seeds of proso millet with six doses of gamma rays *viz.*, 20 krad, 30 krad, 40 krad, 50 krad, 60 krad and 70 krad. In M_2 generation, two early maturing mutants were isolated from 40 krad and 50 krad doses as well as two high yielding mutants were isolated from 20 krad and 60 krad doses. Chakraborty and Kole (2014) reported in two advanced breeding lines of aromatic non-basmati rice, irradiated with 250Gy, 350Gy and 450Gy of gamma ray wide variation for polygenic characters in M_2 and M_3 generations. Increase in values of GCV and PCV in M_3 over M_2 generation for flag leaf length and spikelet number was due to release of additional variability. Ramezani and More (2014) Variety Pusa -24 were treated with Gamma rays, EMS and Combination treatment of Gamma rays with EMS to obtain the spectrum and frequency of chlorophyll mutations in M_2 generation. Three different types of chlorophyll mutants, such as, Albino, Xantha and Viridis were induced with effect of mutagens. The highest frequency of chlorophyll mutations were observed in the combination of EMS and gamma Rays. Silveira *et al.* (2014) observed that gamma irradiation did not to increase seed yield in black oats, but it was effective in generating variability for the other traits. Tiller number and plant height are important selection traits to increase dry matter yield.

Htun *et al.* (2015) studied M_2 generation and reported that chlorophyll mutations (albino, viridis, striata); leaf mutations (narrow, broad); morphological mutations (early, dwarf, tall, twin stem) and panicle mutations (twin panicle, compact, spread). High yielding mutant that was observed at 400 Gy produced double the yield plant^{-1} as compared to control. Kham *et al.* (2015) irradiated seeds of local cultivar Sorghum (Shweni-15) with doses (0Gy - 800Gy) from Gamma ray Co^{60} source. The traits like plant height, stem width and seed yield plant^{-1} exhibited high heritability accompanied with high genetic advance in the treatment with 300Gy. The treatment with 300 Gy also showed moderate heritability with low genetic advance for number of leaves plant^{-1}, brix % and 100 seed weight. Mutlu *et al.* (2015) determined variations in morphology and turfgrass characteristics of a native drought resistant bermudagrass germplasm irradiated with 70, 90 or 110 Gy using a Co^{60} source. A total of four mutant lines showed a distinct dwarfed growth habit. Three of these lines were originated from 70 Gy and one from 110 Gy. Poonguzhali and Gomathinayagam (2015) irradiated seeds of sweet sorghum variety SSV 84 with different concentration of

Gamma rays and Ethyl methane sulphonate. Five different types of chlorophyll mutants *viz.,* albino, chlorina, xantha, alboviridis and xanthaviridis were identified in the treated population. Cisse and Khouma (2016) studied influence of a mutation to improve the undesirable traits of wild rice (*O. longistaminata*) radiation Gamma rays of 20Kr from Co^{60} was studied. Irradiation followed by crossing with an interspecific genotype generated a large genetic variability, in the subsequent generations, *viz*., plant height, maturity, non-shattering grain, kernel colour, spikelets fertility, panicle length, and grain size. Kumar *et al*. (2016) noted the effectiveness and efficiency of different doses of gamma rays in pea variety (Arkel) by studying the spectrum of macro mutants *i.e*., plant stature (tall, dwarf, small dwarf), maturity (early, late), pod shape (bold, long, short), seed colour (brown, light white, light green) and seed shape (small, bold, wrinkled) were observed in M_2 generation. Rani *et al*. (2016) studied two rice genotypes exposed to gamma and X-ray irradiations to compare their sensitivity and to determine the effective radiation dose for mutation induction. It was found that germination percentage, seedling height and plant survival percentage decreased with the gradual increase of dose rate both in gamma and X-ray irradiation. Yadav (2016) studied seeds of *C. decurrens* exposed to gamma radiation at doses (5, 10, 15, 20, 25, 30, 35, 40, 45 and 50kR). Gradual reduction was observed in number of plant survived with increased doses. Similarly earlier germination and shoot induction were recorded at lower doses. Various morphological variants like stem thickening, more number of nodes with shorter internodes, increase in leaf size and area were also observed.

2.2.1 Effectiveness and efficiency of different doses of gamma rays

Konzak *et al.* (1965) reported that, the mutagenic efficiency was defined as the ratio mutation to biological damage factor that mutagens need not always causes damage. Low doses of gamma rays stimulate seedling growth. In this situation a negative value for damage is obtained with a negative mutagenic efficiency rate. The higher efficiency was observed at lower concentration of the mutagen concentration than the actual mutations. Gupta and Yashvir (1975) reported viable mutation for each character in two cultures of foxtail millet (*Setaria italic* Beauv.) induced by individual and combination treatments of gamma rays, EMS and dES (diethyl sulphate). The mutation frequencies were recorded as mutants per 100 M_2 plants and these were found to be higher in MU-1 than MU-2 in all treatment except dES (diethyl sulphate). The frequencies also increase in dose or duration of treatments and found to be much higher in combination treatments than individual treatments. Aradhya and Menon (1977) studied the effect of gamma-rays and EMS, each in 5 doses, *viz.*, 10-50 krad and 0.5-2.5 % on the finger millet variety CO-1. The chlorophyll mutation rate was characterized by linearity at low to medium doses and saturation as well as erratic behavior at high doses. As per mutation rate, estimated on the basis of M_2 plants, EMS induced a high frequency. The spectrum consisted of albino, chlorina, xantha, albo-viridis, tigrina (3 types) and striata (2 types), with tigrina being predominant. The treatments varied in their spectrum, with 2.0% yielding the widest spectrum of mutants. Kumar *et al.* (1995) reported that, the varieties A404 and HR374 of finger millet, treated with gamma rays, EMS, and their combinations gave mutant types of agronomic and academic interests. Higher doses of all mutagenic treatments affected pollen fertility adversely and produced morphological deformities. The efficiency and effectiveness were high at the lower doses of mutagens in both the varieties.

Cheema and Atta (2003) examined varietal differences in three Basmati rice varieties (Basmati 370, Basmati Pak and Super Basmati) in relation to gamma rays mutation. The effectiveness of the dose in inducing genetical changes was estimated by counting the number of chlorophyll mutants in the M_2 generation. The frequency of chlorophyll mutations increased with the radiation dosage upto 250 Gy which sharply decreased thereafter. Ichitani *et al.* (2003) studied effects of irradiation conditions on mutation rate induced by gamma-ray irradiation in foxtail millet (*Setaria italica* Beauv). The growth of M_1 plants, and the frequency and kind of chlorophyll mutants in the M_2 generation were examined. Difference in irradiation conditions influence the growth of M_1 plants, but it greatly influenced the rate of chlorophyll mutation. Ganapathy *et al.* (2008) reported the mutagenic effectiveness and efficiency of different doses of gamma rays in two little millet cultivars. The mutagenic effectiveness decreased with the increase in dose of mutagen in both genotypes, indicating that negative relationship between effectiveness and dose of mutagen. Mutagenic efficiency in both varieties, were highest at the lowest dose and it decreased with the increase in dose. Muduli and Misra (2008) reported induced mutation in finger millet varieties. The seed of varieties VR 708 and GPU 26 were treated with three doses each of gamma rays (15 krad, 30 krad and 45 krad) and the varieties showed differential response to mutagenic treatments. The frequency of macromutations increased with increase in dose of mutagen. Horn *et al.* (2010) reported that two pearl millet varieties were exposed to different doses (0, 100, 150, 200, 300, 400, 500 and 600) of gamma radiation (Gy) to determine the lethal doses (LD). Pearl millet Okashana2 variety responded to gamma rays with a decreasing percentage survival rate when the gamma ray doses were increased. Kumar and Ratnam (2010) reported that mutagenic effectiveness decreased with an increased dose or concentration of gamma-rays and sodium azide in both varieties. Mutagenic efficiency decreased gradually with an increased dose in both varieties. Makeen and Babu (2010) studied mutagenic effectiveness and efficiency of gamma rays, sodium azide and their combination treatments in the genotype of urdben variety T9. The frequency of mutagenic efficiency and effectiveness was found to be highest at lower doses.

Subramanian *et al.* (2011) studied mutagenic effectiveness and efficiency of gamma ray in two genotypes of Kodo millet (*Paspalum scrobiculatum* L.). The mortality percentage, lethality and injury in M_1 seedlings were found to have linear relationship with the dose of gamma rays. Both mutagenic effectiveness and efficiency reduced with the increase in dose of irradiation. 500 Gy dose was found to be effective dose in Kodo millet. Dai *et al.* (2012) observed various variations including characteristics of leaves (shape, size, hairs), stems (shape, internode length, branching), flowers (color, size, and structure), and plant stature in Buddleia. Ambavane *et al.* (2014) observed the chlorophyll mutation frequency on M_1 plants and mutagenic effectiveness and efficiency were computed. In M_2 generation, the mutagenic treatments were effective in inducing various types of chlorophyll and morphological macro mutants. Few of those showed significant change in flowering, maturity and plant height characters and few of them have good breeding value. Bharathi *et al.* (2014) observed the mutagenic effectiveness and efficiency increased with the decreased in dose or concentration in sesame. Mangaiyarkarasi *et al.* (2014) studied the mutagenic effectiveness and efficiency of gamma rays and EMS in the genotype of *Catharanthus roseus*. The frequency of mutation was more in EMS than gamma rays. Mutagenic effectiveness and efficiency increased with decrease in dose or concentration. Mullainathan and Suthakar, 2015 studied effectiveness and efficiency of chlorophyll mutants in treated material of Sorghum with gamma rays and EMS. EMS treatment were found highly effective than the gamma rays. Mutagened effectiveness and efficiency decreased with increased in mutagenic treatments and the mutation frequency was high in M_1 plants than M_2. Ambli *et al.*, 2016, treated the seeds of *Pennisetum typhoides* with 10, 20,30,40,50 and 60 kR of gamma rays and 10,20,30,40 and 50 mM of EMS along with control. In M_1 and M_2 mutagenic effectiveness and efficiency decreased with increase in mutagenic treatments. The seedling injury and pollen sterility increased with an increase in concentration of mutagenic treatments of both EMS and gamma rays.

Materials and Methods

3. MATERIALS AND METHODS

The study entitled 'Induced mutagenesis for delayed flowering and high tillering in guinea grass (*Panicum maximum* Jacq.)' was carried out at College of Agriculture, Vellayani during the period 2014-2017. The materials used and the methodologies adopted in this study are described below.

3.1 EXPERIMENT–I: EVALUATION AND CHARACTERIZATION OF GERMPLASM

3.1.1 Experimental materials

In the present study, thirty seven accessions maintained by AICRP (Forage Crops) Vellayani were screened for yield attributes and flowering characters. These thirty seven accessions were then grouped into three classes based on days to flowering and gibberellic acid content *i.e.* early flowering, mid flowering and late flowering. These accessions were planted using rooted slips, adopting a spacing of 60 cm x 30 cm and plot size of 3 x 3 m^2 in a Randomized Block Design with two replications. The genotypes used for evaluation are listed in Table 1.

3.1.2 Observations recorded

Observations belonging to the following characters were recorded on the basis of average of five plants per replication in each treatment. Five competitive plants were taken at random from each row of accessions.

3.1.2.1 Morphological observations

Observations were taken for first cutting 75 days after planting (DAP) and second cutting 120 DAP and then average of the same was computed for further analysis.

3.1.2.1.1 Plant height

Height of guinea grass was measured from base to the tip of the longest leaf of the plant. Mean height was worked out and presented in centimeter.

Table 1. List of Guinea grass accessions

Sl. No	Name of the accession	Source of collection	Sl. No	Name of the accession	Source of collection
1	PM-1188	IGFRI Jhansi	20	PGG-202	Ludhiana
2	PGG-293	Ludhiana	21	PM-4728	IGFRI Jhansi
3	FP-553	JGFRI Jhansi	22	MS-4687	Dapoli
4	MS-4688	Dapoli	23	MS-4691	Dapoli
5	PGG-316	Ludhiana	24	PGG-205	Ludhiana
6	MS-4681	Dapoli	25	PGG-14	Ludhiana
7	MS-4600	Dapoli	26	MS-4733	Dapoli
8	PGG-200	Ludhiana	27	FR-600	IGFRI Jhansi
9	PGG-208	Ludhiana	28	PM-FR-600	IGFRI Jhansi
10	FR-428	Pantnagar	29	MC-16	IGFRI Jhansi
11	PGG-251	Ludhiana	30	PGG-195	Ludhiana
12	MC-14	IGFRI Jhansi	31	MS-4685	Dapoli
13	PGG-9	Ludhiana	32	MS-4690	Dapoli
14	PGG-277	Ludhiana	33	FR-426	Pantnagar
15	MS-4675	IGFRI Jhansi	34	PR-553	Pantnagar
16	PGG-327	Ludhiana	35	Haritharee	Vellayani
17	MS-4732	Dapoli	36	Marathakam	Vellayani
18	PGG-227	Ludhiana	37	Vellayani local	Vellayani
19	PGG-192	Ludhiana			

3.1.2.1.2 Number of tillers hill^{-1}

It was recorded by counting all the tillers present in one hill at the time of harvesting.

3.1.2.1.3 Number of leaves hill^{-1}

It was recorded by counting all the leaves present on the plant at the time of harvesting and the mean was calculated.

3.1.2.1.4 Leaf stem ratio

For calculating this, dry weight of leaf and stem was recorded. The mean leaf stem ratio was calculated by using following formula…

$$\text{Leaf stem ratio} = \frac{\text{Dry weight of leaf}}{\text{Dry weight of stem}}$$

3.1.2.1.5 Length of internode

Length of each internode was measured in centimeter with scale and the average of the same was calculated for recording the length of internode of every single plant.

3.1.2.1.6 Leaf area index

For recording this, central tiller in the hill was identified and length (l) and breadth (b) of all the leaves in the tiller was measured. Leaf area of all leaves was worked out. It was computed by using the length and width multiplication method.

$$LA = l \times b \times k$$

Where, k is constant and k = 0.67at seedling

k = 0.75 at all other stages

The leaf area of all leaves in the central tiller

$LA_1 = a_1$; $LA_2 = a_2$; $LA_3 = a_3$; $LA_4 = a_4$

The sum of all the leaves in the central tiller

Leaf area of middle tiller = $a_1+a_2+a_3+a_4$

Leaf area of particular hill = Leaf area of middle tiller x number of tillers

$$L.A.I = \frac{\text{Leaf area of the hill}}{\text{Land area}}$$; Spacing is the land area

3.1.2.1.7 Leaf length

Leaf length was measured from ligule to the tip of longest leaf with the help of measuring tape and then average was calculated and expressed as centimeter.

3.1.2.1.8 Leaf breadth

Leaf width of the longest leaf at widest point was recorded with measuring scale and then mean of the same was computed for further calculations and expressed as centimeter.

3.1.2.1.9 Days to flowering

Number of days from planting to first flowering was recorded for each plant for first cutting and for second cutting, days for emergence of inflorescence after cutting was observed.

3.1.2.1.10 Length of panicle

Panicle length was measured from the initiation of branching on the main rachis to the tip of the panicle.

3.1.2.1.11 Number of panicles hill^{-1}

It was recorded by counting all the panicles present in each hill at the time of harvesting.

3.1.2.1.12 Weight of seeds hill^{-1}

The panicles from hill were harvested from each row to obtain seed yield and expressed in grams.

3.1.2.1.13 Green fodder yield

Grass was harvested at its optimum growth stage and fresh weight of the plant was recorded. Green fodder yield was computed with the help of following formula.

$$\text{Green fodder yield} = \text{Fresh weight of plant} \times \text{number of plants ha}^{-1}$$

3.1.2.1.14 Dry fodder yield

After recording the fresh weight the plants were oven dried to a constant weight at 70°C and recorded dry weight of the plants. Dry fodder yield of the plants was computed by using the given formula.

$$\text{Dry fodder yield} = \frac{\text{Dry wt. of fodder plant}}{\text{Fresh wt. of plant}} \times \text{Green fodder yield}$$

3.1.2.2 Biochemical observations

3.1.2.2.1 Crude protein content

Crude protein content was calculated by multiplying the nitrogen content of the plant by the factor 6.25 (Simpson *et al.* 1965) and expressed in percentage.

3.1.2.2.2 Crude fibre content

Crude fibre content was determined by A.O.A.C. method (A.O.A.C., 1975) and expressed in percentage.

3.1.2.2.3 Gibberellic acid content

Gibberellic acid content from the plant tissue was determined by using the spectrophotometric method. (Sunderberg, 1990 and Kojima, 1995) and expressed in microgram per gram.

3.2 EXPERIMENT–II: M_1 AND M_1V_1 GENERATION

3.2.1 Experimental material

LD_{50} is a common parameter to decide the effective doses of mutagens. Thus, LD_{50} is a dose which results in 50 per cent mortality of treated cuttings. LD_{50} statistic value was determined for each variety. Based on this, four doses including control was fixed separately for seeds and slips of each variety and was administered to the genotypes.

For determination of LD_{50} observations on germination were recorded on tenth day from the date of sowing. Effect on seedling height and survival were recorded thirty days after sowing. Dry seeds of four genotypes were irradiated with five doses of gamma rays along with control 0 Gy (control), 60 Gy, 80 Gy, 100 Gy, 120 Gy and 140 Gy from ^{60}Co with a rate of approximately 80 Gy/hr, at the Centre for Plant Breeding and Genetics, Coimbatore. The experiments to determine effect of gamma ray on germination, survival and height of seedling were conducted in nursery. Each treatment was replicated three times and for each replication one hundred seeds were sown and tested for their germination, survival and seedling height.

The slips were cut into single node cuttings. Shoots and roots were trimmed to 9-10 cm in length so that the cuttings had similar size in irradiation treatment. The cuttings were sealed in brown paper bags and irradiated with five dosages of gamma ray 20 Gy, 40 Gy, 60 Gy, 80 Gy and 100 Gy from ^{60}Co with a rate of approximately 80 Gy/hr, at the Centre for Plant Breeding and Genetics, Coimbatore to determine the dosages for LD_{50}. The control cutting was not irradiated, but kept in brown paper bag and sprayed with water to maintain moisture. The cuttings were then planted in nursery bags for recovery in three replications. Each replicate had 100 cuttings. Survival of cuttings and plant height was scored thirty days later. Survival rate was calculated as the percentage of the number of total cuttings with re-growth divided by the number of total cuttings treated. In field study, ten seedlings were selected randomly for taking observations.

3.2.2 Observations recorded

Observations belonging to the following characters were recorded from ten plants per replication in each treatment.

3.2.2.1 Nursery observations

3.2.2.1.1 Seeds

3.2.2.1.1.1 Germination of seeds

Seedling emergence was recorded on day tenth.

Germination percentage = (Number of germinated seeds after 10 days / Total number of seeds sown) X 100

3.2.2.1.1.2 Survival of seedlings

Seedling survival was based on the number of viable seedlings thirty days after sowing and was expressed in percentage.

3.2.2.1.1.3 Height of seedlings

The seedling height was measured from the soil surface to the tip of fully opened leaf from ten randomly selected plants per treatment per variety in each replication and expressed in centimeter.

3.2.2.1.2 Slips

3.2.2.1.2.1 Regeneration of shoots from slips

Regeneration of shoots from slips was recorded on tenth day.

3.2.2.1.2.2 Survival of shoots

Survival rate was calculated as the percentage of the number of total cuttings with re-growth divided by the number of total treated cuttings planted.

3.2.2.1.2.3 Height of plants

The plant height was measured from the soil surface to the tip of fully opened leaf by taking random samples of ten plants in each replication and expressed in centimeter.

3.2.2.2 Morphological observations

For assessing the variation created in quantitative characters in M_1 (for seeds), M_1V_1 (for slips) generation, 10 plants were randomly selected from each treatment including control, and observations were recorded on the following quantitative and qualitative characters with two cuttings *i.e.* at 75 DAP and 120 DAP.

3.2.2.2.1 Plant height,
3.2.2.2.2 Number of tillers hill^{-1},
3.2.2.2.3 Number of leaves hill^{-1},
3.2.2.2.4 Leaf stem ratio,
3.2.2.2.5 Leaf area index,
3.2.2.2.6 Length of internode,
3.2.2.2.7 Leaf length,
3.2.2.2.8 Leaf breadth,
3.2.2.2.9 Days to flowering,
3.2.2.2.10 Green fodder yield,
3.2.2.2.11 Dry fodder yield

Observations 1 to 11 were recorded by using the same methodology as in experiment-I for first as well as second cutting and observation 12 to 15 were documented in second cutting as follows,

3.2.2.2.12 Root length

Root length was measured from the base of plant (collar region) to the tip of longest root expressed in centimeter.

3.2.2.2.13 Root spread

Root spread was measured from widest point of root with measuring scale in centimeter.

3.2.2.2.14 Root dry weight

The roots of sample plants were washed free of adhering soil with low jet of water. The roots were oven dried and dry weight was recorded and expressed in grams.

3.2.2.2.15 Root shoot ratio

This was computed by dividing the root dry weight of a sample plant by its shoot dry weight.

For first as well as second cutting above mentioned observations were taken and then average of the same was computed for further analysis.

3.3 EXPERIMENT III: M_2 AND M_2V_2 GENERATION

3.3.1 Nursery

Chlorophyll mutation frequency was estimated as follows.

500 seeds and 50 slips selected from M_1 and M_1V_1 generation from each dose of mutagen were scored for chlorophyll mutants from 5^{th} to 15^{th} day of sowing to estimate chlorophyll mutation frequency and spectrum (Gustafson, 1940). On the basis of this mutagenic efficiency, effectiveness was calculated (Konzak *et al.*, 1965).

Mutagenic effectiveness = M/kR

Mutagenic efficiency = M/L or M/S

Where,

M- number of mutants per 100 M_2 plants

kR- dose of mutagen

L- percentage survival reduction on 30^{th} day of sowing

S- percentage pollen sterility

3.3.2 Chlorophyll mutations

The chlorophyll mutations were carefully scored based in M_2 and M_2V_2 on single plant basis. Such mutations were counted and recorded upto 15^{th} day after sowing. They were classified according to the method suggested by Gustafsson (1940) and are presented as indicated below:

***3.3.2.1 Albino*:** Seedling with no chlorophyll or carotenoid pigments; white; non-viable seedlings.

***3.3.2.2 Xantha*:** Corotenoid pigment predominantly found but chlorophylls are not formed; they are yellow and non-viable.

3.3.3 Viable mutations

The viable mutations deviating from the control plants were recorded upto harvest day. The viable mutations such as abnormal leaves, more number of tillers, more number of leaves, dwarf plants, tall plant, early flowering and late flowering plants were recorded.

3.3.4 Morphological parameters

Hundred seeds from each selected mutant in M_1 and M_1V_1 generation were advanced to M_2 and M_1V_2 generation and sown in three replications. Variation created in quantitative characters were accessed in M_2 and M_1V_2 generation, 10 plants were randomly selected from each treatment including control, and observations were recorded on the following quantitative and qualitative characters, plant height, number of tillers hill^{-1}, number of leaves hill^{-1}, leaf stem ratio, leaf area index, length of internode, leaf length, leaf breadth, days to flowering, green fodder yield, dry fodder yield, root length, root spread, root dry weight, root shoot ratio, crude protein content, crude fibre content and gibberellic acid content

For first as well as second cutting, all the above observations were recorded by using the similar methodology as in experiment-II.

3.4 EXPERIMENT IV: M_3 AND M_1V_3 GENERATION

Selected mutants from M_2 and M_1V_2 were forwarded to M_3 and M_1V_3 generation and evaluated in two seasons for yield and delayed flowering habit in three replications using RBD design. Following morphological observations for first as well as second cutting *i.e.* 75 DAP and 120 DAP were recorded with similar methodology as used in experiment III and ten plants were randomly selected used for the study.

3.4.1 Plant height

3.4.2 Number of tillers hill^{-1}

3.4.3 Number of leaves hill^{-1}

3.4.4 Leaf stem ratio

3.4.5 Green fodder yield

3.4.6 Dry fodder yield

3.5 STATISTICAL ANALYSIS

The data were processed with the help of various standard statistical procedures as mentioned below.

3.5.1 Analysis of variance

The biometric observations recorded from the field evaluation were subjected to analysis of variance for the comparison among various accessions and to estimate variance components. The significance of mean sum of squares for each character was tested against the corresponding error degrees of freedom using F test (Fisher and Yates, 1967).

3.5.2 Estimation of genetic parameters

3.5.2.1 Genetic components of variance

The phenotypic and genotypic variances were calculated by utilizing the respective mean square values (Johnson *et al*., 1955).

i. Genotypic variance (VG)

$$\mathrm{VG} = \frac{MST - MSE}{r}$$

ii. Environmental variance (VE)

VE =MSE

iii. Phenotypic variance (VP)

VP= VG+ VE

3.5.2.2 Coefficient of variation

The genotypic and phenotypic variations were calculated by following methodology suggested by Burton (1952).

i) Phenotypic coefficient of variation (PCV)

$$PCV = \frac{\sqrt{VP}}{\overline{X}} \times 100$$

ii) Genotypic coefficient of variation (GCV)

$$GCV = \frac{\sqrt{VG}}{\overline{X}} \times 100$$

$\overline{X}$= mean of characters

Categorization of the range of variation was effected as proposed by Sivasubramanian and Menon (1973).

Category	Range
Low	< 10%
Moderate	10-20%
High	>20%

3.5.2.3 Heritability

Heritability percentage in broad sense was estimated for various characters as per the formulae suggested by Johnson *et al.* (1955).

Heritability, $H^2 = \frac{VG}{VP} \times 100$

VG = Genotypic variance

VP = Phenotypic variance

As suggested by Johnson *et al.* (1955) heritability in broad sense estimates were categorized as,

Category	Range
Low	0-30%
Moderate	30-60%
High	>60

3.5.2.4 Genetic advance

Genetic advance is the measure of genetic gain under selection which depends upon standardized selection differential, heritability and phenotypic standard deviation (Allard, 1960). The genetic advance was calculated in per cent by formulae (Johnson *et al*., 1955).

Genetic advance $(GA) = K \times H^2 \sqrt{v_p}$

GA as percentage of mean $= \frac{GA}{\overline{X}} \times 100$

Where K = standardized selection differential (2.06 at 5% selection intensity)

H^2 = heritability

The range of genetic advance as per cent of mean was classified as suggested by Johnson *et al*. (1955).

Category	Range
Low	<10%
Moderate	10-20%
High	>20%

3.5.3 Correlation analysis

Phenotypic, genotypic and environmental correlation coefficients were calculated using the respective variance and covariance of the characters which showed significant variation in the ANOVA.

Phenotypic correlation coefficients, $r_{PXY} = \frac{C_0V_P(X,Y)}{\sqrt{V_P(X) \times V_P(Y)}}$

Genotypic correlation coefficients, $r_{GXY} = \frac{C_0V_G(X,Y)}{\sqrt{V_G(X) \times V_G(Y)}}$

Where,

CoV_P (X, Y) - phenotypic covariance between two traits X and Y

CoV_G (X, Y) - genotypic covariance between two traits X and Y

Vp (X) and Vp (Y) - phenotypic variance for X and Y, respectively

V_G (X) and V_G (Y) - genotypic variance for X and Y, respectively

3.5.4 Path coefficient analysis

To study the cause and effect relationship of yield and its component characters, direct and indirect effects were analysed using path coefficient analysis as suggested by Wright (1954).

The genotypic correlation between yield and selected component characters were subjected to path analysis and the direct effect of the character on yield as well as the indirect effect through other characters were estimated.

3.5.5 LD_{50} value

The LD_{50} dose of irradiation was calculated by Probit analysis method using observations on mortality percentage as described by Sharma (1998).

Results

4. RESULTS

The present investigation entitled "Induced mutagenesis for delayed flowering and high tillering in guinea grass (*Panicum maximum* Jacq.)" was carried out at College of Agriculture, Vellayani during the period 2014-2017. The objective of the study was to analyze the genetic diversity among different guinea grass genotypes using morphological characters and to analyze the effectiveness of gamma rays on inducing variability in guinea grass seeds and slips. The salient findings as revealed from the investigation are presented here.

4.1 EVALUATION AND CHARACTERIZATION OF GERMPLASM

Under this experiment, thirty seven varieties were evaluated separately for morphological characters. The population was evaluated in RBD design with three replications.

4.1.1 Analysis of variance

The mean performance for seventeen quantitative characters in thirty seven genotypes of guinea grass is presented in Table 3. Highly significant differences were observed among the genotypes for all the characters indicating the presence of considerable genetic variability.

4.1.2 Mean performance of guinea grass genotypes

The mean performances of all guinea grass genotypes for various quantitative characters are given below. The range in mean values are presented in Table 2.

Plant height ranged between 122.15 and 163.75 cm. Among thirty seven genotypes, highest plant height was observed in PGG-200 (163.75 cm) followed by MS-4600 (161.85 cm) and MS-4681 (159.65 cm). Lowest height was recorded in Marthakam (122.15 cm) followed by MS-4690 (129.75 cm) and MS-4691

Table 2. Mean performance for seventeen characters in 37 genotypes of guinea grass

Characters	PM-1188	PGG-293	FP-553	MS-4688	PGG-316	MS-4681	MS-4600	PGG-200	PGG-208	FR-428
Days to flowering	32.70	40.20	30.45	36.60	36.20	39.40	40.10	38.75	40.50	34.90
Plant height (cm)	137.70	148.00	141.75	155.95	157.05	159.65	161.85	163.75	154.10	150.50
Leaf length (cm)	67.60	56.85	56.60	62.65	67.80	63.30	64.65	61.90	75.30	58.90
Leaf breadth (cm)	2.28	2.27	2.29	2.49	2.25	2.42	2.44	2.26	2.36	2.38
Leaf area index	3.50	3.35	3.72	5.46	5.40	4.61	7.42	4.79	5.86	4.57
Length of internode (cm)	24.58	29.28	25.21	26.33	28.51	27.19	27.86	25.39	26.99	24.98
Length of panicle (cm)	50.45	38.85	38.05	50.70	39.90	42.35	46.55	46.50	44.60	46.00
No. of tillers hill^{-1}	17.80	19.45	22.45	26.40	26.65	23.65	38.85	28.20	25.00	25.80
No. leaves hill^{-1}	96.55	105.25	126.60	134.70	133.25	128.10	191.45	140.85	113.10	120.95
No. of panicles hill^{-1}	13.65	14.50	16.35	15.00	20.00	17.00	25.80	21.25	18.70	18.75
Green fodder yield (t/ha)	74.21	54.68	82.02	85.93	60.93	62.02	125.62	84.37	82.81	103.59
Leaf-stem ratio	0.71	0.70	0.72	0.80	0.68	0.77	0.86	0.59	0.52	0.62
Wt. of seeds hill^{-1}(g)	8.10	10.80	11.85	8.00	9.10	9.75	11.20	10.50	12.80	12.15
Dry fodder yield (t/ha)	17.34	15.34	20.49	21.15	16.65	13.12	30.23	22.59	21.59	19.31
Crude protein content (%)	10.10	8.90	11.40	10.75	13.15	10.30	13.40	9.60	12.20	11.10
Crude fibre content (%)	29.00	25.00	27.00	29.00	27.50	30.00	32.50	27.50	33.50	31.00
Gibberellic acid content (µg/g)	81.18	41.37	84.78	57.25	56.52	47.15	41.12	43.87	38.95	57.80

Characters	PGG-251	MC-14	PGG-109	PGG-277	MS-4675	PGG-327	MS-4732	PGG-227	PGG-192	PGG-202
Days to flowering	40.30	37.85	43.30	39.85	36.10	33.70	36.10	34.30	37.80	35.10
Plant height (cm)	154.10	149.40	138.30	146.20	146.70	146.20	143.50	141.45	140.90	145.40
Leaf length (cm)	63.60	62.05	63.65	66.35	56.80	71.50	71.45	58.80	59.50	64.85
Leaf breadth (cm)	2.20	2.19	2.28	2.23	2.27	2.24	2.17	2.13	2.09	2.14
Leaf area index	3.80	4.33	4.51	5.55	5.22	5.53	5.53	4.41	3.45	6.75
Length of internode (cm)	25.98	24.78	24.56	23.73	24.15	27.77	25.11	29.06	24.78	24.32
Length of panicle (cm)	42.15	39.20	41.70	39.05	36.40	39.65	40.95	41.15	38.90	41.40
No. of tillers $hill^{-1}$	23.80	26.15	25.70	31.95	30.15	29.65	29.00	30.30	22.75	38.10
No. leaves $hill^{-1}$	115.35	122.90	117.95	159.80	151.65	134.05	125.60	141.45	108.80	172.30
No. of panicles $hill^{-1}$	16.90	18.85	20.25	21.15	23.50	25.00	21.20	19.55	18.35	27.75
Green fodder yield (t/ha)	64.06	64.84	57.02	46.87	63.27	70.31	67.18	79.68	53.90	77.03
Leaf-stem ratio	0.57	0.71	0.80	0.58	0.79	0.54	0.77	0.57	0.62	0.61
Wt. of seeds $hill^{-1}$ (g)	9.95	9.85	8.10	8.30	9.35	11.20	8.15	7.45	8.80	9.80
Dry fodder yield (t/ha)	14.43	15.15	14.09	20.37	16.18	21.68	14.90	17.03	12.78	23.18
Crude protein content (%)	9.80	10.70	8.90	11.75	10.00	7.90	9.95	10.45	12.70	10.05
Crude fibre content (%)	30.50	29.50	26.50	22.00	33.50	32.00	28.50	33.00	31.50	35.00
Gibberellic acid content (µg/g)	42.25	50.60	47.57	50.00	56.27	65.17	55.00	57.25	60.60	56.72

Characters	PM-4728	MS-4687	MS-4691	PGG-205	PGG-14	MS-4733	FR-600	PM-FR-600	MC-16	PGG-195
Days to flowering	37.30	35.10	35.00	34.80	32.40	30.55	32.35	33.50	33.45	33.65
Plant height (cm)	146.80	142.05	132.1	134.55	147.25	136.85	144.25	148.80	152.65	148.70
Leaf length (cm)	56.75	56.50	59.30	59.70	63.05	67.45	62.40	54.80	62.30	59.65
Leaf breadth (cm)	2.17	2.20	2.19	2.02	2.07	2.29	2.19	2.10	2.17	2.23
Leaf area index	3.24	4.26	5.28	5.29	5.53	7.16	4.85	3.59	4.45	4.07
Length of internode (cm)	24.12	26.05	27.14	23.87	23.86	24.76	23.64	21.84	27.93	23.78
Length of panicle (cm)	36.35	39.10	37.40	38.50	38.85	33.75	34.60	37.70	34.35	38.80
No. of tillers hill^{-1}	22.15	30.45	34.00	35.50	33.20	37.05	27.00	24.30	26.15	24.45
No. leaves hill^{-1}	103.40	132.90	219.00	182.50	182.75	184.65	121.95	113.05	136.55	118.60
No. of panicles hill^{-1}	16.70	23.40	20.70	23.90	22.75	24.35	19.30	19.40	18.00	17.70
Green fodder yield (t/ha)	100.00	81.24	53.12	61.71	59.37	53.90	60.62	61.71	64.53	59.68
Leaf-stem ratio	0.74	0.81	0.76	0.76	0.96	0.80	0.63	0.55	0.56	0.58
Wt. of seeds hill^{-1} (g)	9.25	8.95	8.95	8.10	6.40	6.70	8.55	7.30	5.45	6.80
Dry fodder yield (t/ha)	24.34	18.49	22.40	15.34	15.15	14.71	20.12	17.78	17.53	13.90
Crude protein content (%)	13.35	9.80	10.60	11.95	10.75	10.90	12.50	11.15	11.80	10.35
Crude fibre content (%)	26.50	34.00	31.00	26.50	25.50	31.50	27.00	26.50	34.00	32.50
Gibberellic acid content (µg/g)	55.25	57.75	57.25	57.15	82.75	85.50	82.80	65.50	65.20	60.26

Characters	MS-4685	MS-4690	FR-426	PR-553	Haritha	Marathakam	Blue guinea	**Mean**	**C.D @ 5%**	**C.D @ 1%**
Days to flowering	33.65	31.05	32.75	33.70	29.90	29.90	32.85	35.27	4.36	5.86
Plant height (cm)	142.80	129.75	148.70	141.30	140.25	122.15	148.75	145.68	17.01	22.88
Leaf length (cm)	65.35	64.30	56.50	59.60	61.10	59.00	63.05	62.29	7.94	10.68
Leaf breadth (cm)	2.07	2.23	2.09	2.22	2.12	2.12	2.53	2.22	0.24	0.32
Leaf area index	4.36	5.37	3.84	4.17	3.40	4.38	3.89	4.73	1.89	2.55
Length of internode (cm)	24.78	26.51	23.49	26.08	22.94	23.49	20.80	25.59	-	-
Length of panicle (cm)	37.00	37.80	36.10	38.70	34.65	35.60	43.15	39.92	4.55	6.12
No. of tillers hill^{-1}	26.25	30.30	26.40	26.15	22.75	30.80	19.55	27.52	7.19	9.60
No. leaves hill^{-1}	120.85	150.40	120.75	118.35	108.70	164.30	88.80	133.35	52.45	70.54
No. of panicles hill^{-1}	18.35	21.70	15.70	16.75	17.30	16.90	13.20	19.45	5.32	7.16
Green fodder yield (t/ha)	59.37	57.03	57.81	37.49	41.40	43.74	43.74	66.40	29.74	40.00
Leaf-stem ratio	0.76	0.89	0.82	0.76	0.87	0.98	1.46	0.74	0.22	0.30
Wt. of seeds hill^{-1} (g)	9.90	8.10	6.30	6.25	6.95	6.60	4.70	8.66	2.19	2.94
Dry fodder yield (t/ha)	12.87	14.90	13.72	10.03	10.46	11.53	12.34	17.12	6.26	8.42
Crude protein content (%)	9.55	12.05	12.20	10.35	12.90	13.20	13.35	11.07	0.34	0.45
Crude fibre content (%)	32.00	24.50	24.00	28.00	35.50	30.50	22.50	29.35	2.86	3.84
Gibberellic acid content (µg/g)	64.50	85.45	77.40	60.60	99.75	95.10	70.70	62.44	0.98	1.32

Table 3. Analysis of variance of 37 genotypes for 17 characters in guinea grass

Source of variation	DF	Days to flowering	Plant height (cm)	Leaf length (cm)	Leaf breadth (cm)	Leaf area index	Length of internode (cm)	Length of panicle (cm)	No. of tillers hill^{-1}	No. leaves hill^{-1}
MSS Treatment	36	22.33**	152.14*	43.93**	0.027*	2.14**	1.94	34.60**	51.82**	1716.03**
MSS Replications	1	0.85	240.07	90.42	0.020	4.43	0.87	34.64	38.12	117.33
MSS Error	36	4.61	70.24	15.31	0.014	0.87	2.12	5.03	12.36	667.72

Source of variation	DF	No. of panicles hill^{-1}	Green fodder yield (t/ha)	Leaf-stem ratio	Wt. of seeds hill^{-1} (g)	Dry fodder yield (t/ha)	Crude protein content (%)	Crude fibre content (%)	Gibberellic acid content (μg /g)
MSS Treatment	36	23.98**	658.83**	0.058**	7.27**	38.04**	4.01**	25.13**	502.19**
MSS Replications	1	69.67	2634.85	0.006	5.03	3.80	0.114	6.53	0.451
MSS Error	36	6.88	214.77	0.012	1.16	9.51	0.0283	1.98	0.235

***Significant at 5 % level** ****Significant at 1 % level**

(132.10 cm). The genotypes differed significantly with respect to number of tillers hill^{-1} which ranged from 17.80 to 38.85. The highest number of tillers hill^{-1} was recorded in the genotype MS-4600 (38.85) followed by PGG-202 (38.10) and MS-4733 (37.15). Lowest number of tillers hill^{-1} was recorded in PM-1188 (17.80) followed by Blue guinea (19.55) and PGG-293 (19.45). Significant variation was observed for number of leaves hill^{-1} as evidenced by the large differences in their mean values ranging from 88.80 to 219.00. The highest number of leaves hill^{-1} was recorded in the genotype MS-4691 (219.00) followed by MS-4600 (191.45) and MS-4733 (184.65). Lowest number of leaves hill^{-1} was recorded in Blue guinea (88.8) followed by PM-1188 (96.55) and Harithasree (108.70). Leaf stem ratio ranged from 0.52 to 1.46. Among the 37 genotypes, highest leaf stem ratio was seen in Blue guinea (1.46) followed by Marthakam (0.98) and MS-4690 (0.89) whereas lowest leaf stem ratio was recorded in PGG-208 (0.52) followed by PGG-327 (0.54) and PM-FR-600 (0.55).

Leaf area index exhibited a wide range of variation from 3.25 to 7.42 in guinea grass. The genotype PM-4728 (3.25) had the lowest leaf area index followed by PGG-293 (3.35) and Harithasree (3.40). The highest leaf area index was found in MS-4600 (7.42) followed by MS-4733 (7.16) and PGG-202 (6.75). Considerable amount of variation existed among the genotypes for length of internode as shown by mean values ranging from 20.80 cm to 29.28 cm. Length of internode was the highest in the genotype PGG-293 (29.28 cm) followed by PGG-227 (29.06 cm) and PGG-316 (28.51cm) whereas the genotypes Blue guinea (20.80 cm), PM-FR-600 (21.84 cm) and Harithasree (22.94 cm) recorded shorter internode length. Leaf length ranged between 54.8 and 75.30 cm. Leaf length was the highest in the genotype PGG-208 (75.30 cm) followed by PGG-327 (71.50 cm) and MS-4732 (71.45 cm), whereas the genotypes PM-FR-600 (54.80 cm), MS-4687 (56.50 cm) and FP-553 (56.60 cm) recorded shorter leaf length. Considerable amount of variation existed among the genotypes for leaf with mean values ranging from 2.02 to 2.53 cm. Leaf breadth was the highest in the genotype Blue guinea (2.53 cm) followed by PM-4688 (2.49 cm) and MS-4600 (2.44 cm) whereas the genotypes PGG-205 (2.02 cm), PGG-14 (2.07 cm), MS-4685 (2.07 cm) and PGG-192 (2.09 cm) recorded low leaf breadth.

Days to flowering taken by plants to initiate flowering in the thirty seven genotypes varied from 29.90 to 43.30 days. The early flowering genotypes were *viz.*, Harithasree, Marthakam and FP-553 with 29.90, 29.90 and 30.45 days respectively to flower. The late flowering genotypes were PGG-109, PGG-251 and PGG-293 which took 43.30, 40.30 and 40.20 days respectively to flower. Length of panicle ranged from 33.75 to 50.70 cm. Among the 37genotypes, higher length of panicle was seen in MS-4688 (50.70 cm) followed by PM-1188 (50.45 cm) and MS-4600 (46.55 cm) whereas lower length of panicle was recorded in MS-4733 (33.75 cm) followed by MC-16 (34.35 cm) and FR-600 (34.60 cm). Number of panicles hill^{-1} among all the 37 genotypes ranged between 13.20 and 27.75 and genotypes PGG-202 (27.75), MS-4600 (25.80) and MS-4733 (24.35) recorded higher number of panicles hill^{-1}. On the other hand Blue guinea (13.20) followed by PM-1188 (13.65) and PGG-293 (14.50) have recorded lower number of panicles hill^{-1}. Weight of seeds hill^{-1} ranged from 4.70 to 12.80 g. Among the 37 genotypes, weight of seeds hill^{-1} was low in Vellayani local (4.70 g) followed by MC-16 (5.45 g) and FR-426 (6.30 g). Weight of seeds hill^{-1} was high in PGG-208 (12.80 g), FR-428 (12.15 g) and FP-553 (11.85 g). Significant variation was observed for green fodder yield as is evidenced by the large differences in their mean values ranging from 37.49 to 125.62 t/ha. The highest green fodder yield was recorded in the genotype MS-4600 (125.62 t/ha) followed by FR-428 (103.59 t/ha) and PM-4728 (100.00 t/ha). Lowest green fodder yield was recorded in PR-553 (37.49 t/ha) followed by Harithasree (41.40 t/ha) and Marthakam (43.74 t/ha). Significant variation was observed for dry fodder yield as is evidenced by the large differences in their mean values ranging from 10.03 to 30.23 t/ha. The highest dry fodder yield was recorded in the genotype MS-4600 (30.23 t/ha) followed by PM-4728 (24.34 t/ha) and PGG-202 (23.18 t/ha). Lowest dry fodder yield was recorded in PR-553 (10.03 t/ha) followed by Harithasree (10.46 t/ha) and PGG-192 (12.78 t/ha). Among the 37 genotype studied, crude protein content ranged from 7.90 to 13.40 %. Higher crude protein content was observed in MS-4600 (13.40 %), PM-4728 (13.35 %), Vellayani local (13.35 %) and PGG-316 (13.15 %). Lower crude protein content was recorded in PGG-327 (7.90 %), followed by PGG-293 (8.90 %) and PGG-109 (8.90 %). Crude fibre content ranged from 22.00 to 35.50 %. Among the 37 genotypes crude fibre content was low in PGG-227 (22.00 %) followed by Vellayani local (22.50 %) and FR-426 (24.00 %). Crude fibre content was high in Harithasree (35.50 %), PGG-202 (35.00 %), MC-16 (34.00 %) and MS-4687 (34.00 %). Significant variation was observed for gibberellic acid content and their mean values ranged from 35.15 to 99.75 μg/g. The highest gibberellic acid was recorded in the genotype Harithasree (99.75 μg/g) followed by Marthakam (95.10 μg/g) and MS-4733 (85.50 μg/g). Lowest gibberellic acid was recorded in PGG-208 (38.95 μg/g) followed by MS-4600 (41.12 μg/g) and PGG-293 (41.37 μg/g).

4.1.3 Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV)

To know the extent of genetic variability existing in the diverse genotypes, the data on phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) are presented in Table 4.

The estimates of phenotypic coefficient of variation (PCV) were higher than the estimates of genotypic coefficient of variation (GCV) for all the traits under study indicating the environmental influence over the traits. High PCV and GCV were observed for green fodder yield (31.47, 22.43), leaf stem ratio (25.47, 20.48), weight of seeds hill^{-1} (23.72, 20.18), dry fodder yield (28.48, 22.06) and gibberellic acid content (25.38, 25.36) respectively. High magnitude of PCV and GCV indicated the presence of wide genetic variability for these traits and hence chances for improvement of these characters were fairly high. The high and moderate estimates of PCV and GCV were observed for leaf area index (25.98, 16.88), number of leaves hill^{-1} (25.50, 16.91), number of tillers hill^{-1} (20.58, 16.13) and number of panicles hill^{-1} (20.19, 15.03). Moderate PCV and GCV were

Table 4. Mean, Range and estimates of genetic parameters for sixteen characters in guinea grass (*Panicum maximum* Jacq.)

Sr. No.	Characters	General Mean	Range	PV	GV	P.C.V	G.C.V	h^2 (%)	GA as% of mean
1	Days to flowering	35.27	29.9 - 43.30	13.47	8.86	10.40	8.43	65.76	14.09
2	Plant height (cm)	145.68	122.15 -163.75	111.19	14.09	7.23	4.39	36.83	5.49
3	Leaf length (cm)	62.29	54.8 - 75.30	29.62	14.30	8.73	6.07	48.29	8.69
4	Leaf breadth (cm)	2.22	2.02 - 2.53	0.02	0.006	6.52	3.68	31.87	4.28
5	Leaf area index	4.73	3.25 - 7.42	1.51	0.63	25.98	16.88	42.23	22.60
6	Length of panicle (cm)	39.92	33.75 - 50.70	19.81	14.78	11.15	9.63	74.59	17.13
7	No. of tillers $hill^{-1}$	27.52	17.80 - 38.85	32.09	19.72	20.58	16.13	61.46	26.06
8	No. leaves $hill^{-1}$	135.35	88.80 – 219.00	1191.87	524.15	25.50	16.91	43.98	23.10
9	No. of panicles $hill^{-1}$	19.45	13.20 - 27.75	15.43	8.54	20.19	15.03	55.40	23.05
10	Green fodder yield (t/ha)	66.40	37.49 - 125.62	436.80	222.03	31.47	22.43	50.83	32.95
11	Leaf-stem ratio	0.74	0.52 - 1.46	0.03	0.02	25.47	20.48	64.64	33.92
12	Wt. of seeds $hill^{-1}$ (g)	8.66	4.70 - 12.80	4.22	3.05	23.72	20.18	72.39	35.38
13	Dry fodder yield (t/ha)	17.12	10.03 - 30.23	23.78	14.26	28.48	22.06	59.97	35.19
14	Crude protein content (%)	11.07	7.90- 13.40	2.02	1.99	12.83	12.74	98.60	26.07
15	Crude fibre content (%)	29.35	22.00 - 35.50	13.56	11.57	12.54	11.59	85.36	22.06
16	Gibberellic acid content (µg/g)	62.44	35.15 - 99.75	251.21	250.97	25.38	25.36	99.91	52.23

observed for crude protein content (12.83, 12.74) and crude fibre content (12.54, 11.59). The moderate and low estimates of PCV and GCV were observed for length of panicle (11.15, 9.63) and days to flower (10.40, 8.43) respectively. Selection will be effective based on the heritable nature of these traits. Low PCV and GCV were observed for leaf length (8.73, 6.07), plant height (7.23, 4.39), leaf breadth (6.52, 3.68) and length of internode (5.81, 0.00) which are highly influenced by the environment and hence selection would be ineffective

4.1.4 Heritability and genetic advance as per cent of mean

To know the extent of genetic variability existing in the diverse genotypes the data on heritability and genetic advance are presented in Table 4.

High heritability coupled with high genetic advance was observed for number of tillers hill^{-1} (61.46, 26.06), leaf stem ratio (64.64, 33.92), weight of seeds hill^{-1} (72.39, 35.38), crude protein content (98.60, 26.07), crude fibre content (85.36, 22.06) and GA (99.91, 52.23). High heritability coupled with moderate genetic advance as per cent of mean was observed for days to flowering (65.76, 14.09) and length of panicle (74.59, 17.13). High heritability may be due to additive gene effects hence, these traits are likely to respond to direct selection. Moderate heritability coupled with high genetic advance as per cent of mean was recorded for leaf area index (42.23, 22.60), number of leaves hill^{-1} (43.98, 23.10), number of panicles hill^{-1} (55.40, 23.05), green fodder yield (50.83, 32.95) and dry fodder yield (59.97, 35.19). Moderate heritability coupled with low genetic advance as per cent of mean was recorded for plant height (36.83, 5.19), leaf length (48.29, 8.69) and leaf breadth (31.87, 4.28). This character is affected by environment and is controlled by non-additive gene action. This character will have poor response for selection. Low heritability coupled with low genetic advance as per cent of mean was recorded for length of internode.

Table 5. Phenotypic correlation coefficient for green fodder yield and yield components

Character	X1	X2	X3	X4	X5	X6	X7	X8
X1	1.00							
X2	0.4750**	1.00						
X3	0.1983	0.2915	1.00					
X4	0.2945	0.4843**	0.3221*	1.00				
X5	0.0721	0.1841	0.6028**	0.2830	1.00			
X6	0.4451**	0.4794**	0.3008	0.5852**	0.1333	1.00		
X7	-0.1042	-0.1779	0.1419	-0.1869	0.7798**	-0.1671	1.00	
X8	-0.0990	-0.1632	0.892**	-0.1107	0.6904**	-0.1580	0.8688**	1.00
X9	-0.0178	-0.0553	0.2358	-0.2280	0.6957**	-0.1666	0.8483**	0.6815**
X10	0.2479	0.4496**	0.1225	0.3533*	0.2913	0.5329**	0.1400	0.0878
X11	-0.2758	-0.2139	-0.1303	0.2261	-0.0487	-0.0351	-0.0233	0.0417
X12	0.4155**	0.3105	0.1976	0.2147	0.1622	0.3483*	0.0129	0.0052
X13	0.2507	0.3851*	0.2120	0.2818	0.4421**	0.3720*	0.2957	0.2942
X14	-0.2315	-0.0331	-0.081	0.0256	-0.0044	-0.1721	-0.0095	0.0164
X15	-0.0563	0.0513	0.0967	-0.0813	0.1782	-0.0313	0.2227	0.1602
X16	-0.8215**	-0.4862**	-0.1291	-0.2305	-0.1374	-0.4132**	-0.0251	0.0269

Character	X9	X10	X11	X12	X13	X14	X15	X16
X9	1.00							
X10	0.1986	1.00						
X11	-0.1885	-0.2364	1.00					
X12	0.2119	0.5810**	-0.4018	1.00				
X13	0.3635*	0.7987**	-0.3026	0.5210**	1.00			
X14	-0.1718	0.0322	0.3061	-0.2294	0.0493	1.00		
X15	0.3069	0.1791	-0.2925	0.2055	0.0646	-0.1678	1.00	
X16	-0.1236	-0.3402*	0.3478	-0.4712**	-0.3364*	0.3115	-0.0589	1.00

X1 – Days to flowering, **X2** - Plant height (cm), **X3** - Leaf length (cm), **X4** - Leaf breadth (cm), **X5** - Leaf area index, **X6** - Length of panicle (cm), **X7** - No. of tillers $hill^{-1}$, **X8** - No. leaves $hill^{-1}$, **X9** - No. of panicles $hill^{-1}$, **X10** - Green fodder yield (t/ha), **X11** - Leaf-stem ratio, **X12** - Wt. of seeds $hill^{-1}$ (g), **X13** - Dry fodder yield (t/ha), **X14** - Crude protein content (%), **X15** - Crude fibre content (%), **X16** – Gibberellic acid content (µg/g)

4.1.5 Correlation studies

The phenotypic and genotypic correlation coefficients were worked out for seventeen characters in thirty seven genotypes. It was evident from the table that, the values of genotypic correlation coefficient were greater than the values of phenotypic correlation coefficient for most of the characters.

4.1.5.1 *Phenotypic correlation coefficient*

Phenotypic correlation coefficients between green fodder yield and its 16 contributing traits are presented in Table 5.

Green fodder yield showed significant positive correlation with dry fodder yield (0.7987) and weight of seeds hill^{-1} (0.5810). It exhibited significant negative correlation with gibberellic acid content (-0.3402). Days to flowering showed significant positive correlation with plant height (0.4750), length of panicle (0.4451) and weight of seeds hill^{-1} (0.4155). It also exhibited significant negative correlation with gibberellic acid content (-0.8215). Plant height showed significant positive correlation with leaf breadth (0.4843), length of panicle (0.4794), green fodder yield (0.4496) and dry fodder yield (0.3851). It also exhibited significant negative correlation with gibberellic acid content (-0.4862). Leaf length showed significant positive correlation with number of leaves hill^{-1} (0.8920), leaf area index (0.6028) and leaf breadth (0.3221). Leaf breadth showed significant positive correlation with length of panicle (0.5852) and green fodder yield (0.3533). Leaf area index showed significant positive correlation with number of panicles hill^{-1} (0.6957), number of leaves hill^{-1} (0.6904) and dry fodder yield (0.4421).

Length of panicle showed significant positive correlation with green fodder yield (0.5329), dry fodder yield (0.3720) and weight of seeds hill^{-1} (0.3483). It also exhibited significant negative correlation with gibberellic acid content (-0.4132). Number of tillers hill^{-1} showed significant positive correlation with number of leaves hill^{-1} (0.8688) and number of panicles hill^{-1} (0.8483).

Table 6. Genotypic correlation coefficient for green fodder yield and yield components

Character	X1	X2	X3	X4	X5	X6	X7	X8
X1	1.00							
X2	0.5936**	1.00						
X3	0.1597	-0.1653	1.00					
X4	0.2782	0.3411*	0.0721	1.00				
X5	0.0907	-0.0528	0.4304**	0.0471	1.00			
X6	0.3935*	0.4217**	0.3407*	0.6898**	0.1558	1.00		
X7	-0.0436	-0.1212	0.1729	-0.2346	0.9463**	-0.1214	1.00	
X8	-0.1413	-0.3686*	-0.0502	-0.3015	0.8079**	-0.1460	0.9788**	1.00
X9	0.1543	0.002	0.2448	-0.2042	0.8922**	-0.0926	0.8876**	0.7140**
X10	0.3163	0.5354**	-0.1225	0.2863	0.2410	0.5372**	0.2096	0.0587
X11	-0.3442*	-0.2989	-0.0457	0.4243**	0.3470*	0.0080	-0.0273	0.0151
X12	0.5358**	0.3959*	0.2217	0.1373	0.2145	0.3472*	0.0030	-0.0252
X13	0.3102	0.3797*	0.0017	0.2540	0.4964**	0.3389*	0.4603**	0.4393**
X14	-0.2905	-0.0737	-0.1311	0.0174	0.0103	-0.2064	0.0053	0.0369
X15	-0.0902	-0.0074	0.1444	-0.0496	0.2384	0.0043	0.2221	0.1230
X16	-0.0122	-0.8013**	-0.1840	-0.4131**	-0.2089	-0.4775**	-0.0311	0.0431

Character	X9	X10	X11	X12	X13	X14	X15	X16
X9	1.00							
X10	0.3207*	1.00						
X11	-0.2275	-0.2976	1.00					
X12	0.2309	0.6310**	-0.5470**	1.00				
X13	0.4830**	0.7711**	-0.3576*	0.5981**	1.00			
X14	-0.2000	0.0264	0.3915*	-0.2697	0.0523	1.00		
X15	0.3216*	0.3742*	-0.3906*	0.2523	0.1841	-0.1666	1.00	
X16	-0.1619	-0.4751**	0.4302**	-0.5500**	-0.4300**	0.3145	-0.0640	1.00

X1 – Days to flowering, **X2** - Plant height (cm), **X3** - Leaf length (cm), **X4** - Leaf breadth (cm), **X5** - Leaf area index, **X6** - Length of panicle (cm), **X7** - No. of tillers $hill^{-1}$, **X8** - No. leaves $hill^{-1}$, **X9** - No. of panicles $hill^{-1}$, **X10** - Green fodder yield (t/ha), **X11** - Leaf-stem ratio, **X12** - Wt. of seeds $hill^{-1}$ (g), **X13** - Dry fodder yield (t/ha), **X14** - Crude protein content (%), **X15** - Crude fibre content (%), **X16** – Gibberellic acid content (µg/g)

Number of leaves hill^{-1} showed significant positive correlation with number of panicles hill^{-1} (0.6815). Number of panicles hill^{-1} showed significant positive correlation with dry fodder yield (0.3635). Leaf stem ratio showed significant positive correlation with gibberellic acid content (0.3478) and significant negative correlation with weight of seeds hill^{-1} (-0.4018). Weight of seeds hill^{-1} showed significant positive correlation with dry fodder yield (0.5210) and significant negative correlation with gibberellic acid content (-0.4712). Dry fodder yield showed significant negative correlation with gibberellic acid content (-0.3364).

4.1.5.2 *Genotypic correlation coefficient*

Genotypic correlation coefficients between green fodder yield and sixteen contributing traits are presented in Table 6.

Green fodder yield showed significant positive correlation with dry fodder yield (0.7711), weight of seeds hill^{-1} (0.6310) and crude fibre content (0.3742). It also exhibited significant negative correlation with gibberellic acid content (-0.4751). Days to flowering showed significant positive correlation with plant height (0.5936), weight of seeds hill^{-1} (0.5358) and length of panicle (0.3935). It exhibited significant negative correlation with leaf stem ratio (-0.3442). Plant height showed significant positive correlation with green fodder yield (0.5354), length of panicle (0.4217), weight of seeds hill^{-1} (0.3959), dry fodder yield (0.3797) and leaf breadth (0.3411). It also exhibited significant negative correlation with gibberellic acid content (-0.8813) and number of leaves hill^{-1} (-0.3686). Leaf length showed significant positive correlation with leaf area index (0.4304) and length of panicle (0.3407). Leaf breadth showed significant positive correlation with length of panicle (0.6898) and leaf stem ratio (0.4243). It also exhibited significant negative correlation with gibberellic acid content (-0.4131). Leaf area index showed significant positive correlation with number of tillers hill^{-1} (0.9463), number of panicles hill^{-1} (0.8922), number of leaves hill^{-1} (0.8079), dry fodder yield (0.4964) and leaf stem ratio (0.3470).

Length of panicle showed significant positive correlation with green fodder yield (0.5372), weight of seeds hill^{-1} (0.3472) and dry fodder yield (0.3389). It also exhibited significant negative correlation with gibberellic acid content (-0.4775). Number of tillers hill^{-1} showed significant positive correlation with number of leaves hill^{-1} (0.9788), number of panicles hill^{-1} (0.8876) and dry fodder yield (0.4603). Number of leaves hill^{-1} showed significant positive correlation with number panicles hill^{-1} (0.7140) and dry fodder yield (0.4393). Number of panicles hill^{-1} showed significant positive correlation with dry fodder yield (0.4830), crude fibre content (0.3216) and green fodder yield (0.3207). Leaf stem ratio showed significant positive correlation with gibberellic acid content (0.4302) and crude protein content (0.3915). It also exhibited significant negative correlation with weight of seeds hill^{-1} (-0.5470), crude fibre content (-0.3906) and dry fodder yield (-0.3576). Weight of seeds hill^{-1} showed significant positive correlation with dry fodder yield (0.5981) and significant negative correlation with gibberellic acid content (-0.5500). Dry fodder yield showed significant negative correlation with gibberellic acid content (-0.4300).

4.1.6 Path coefficient analysis

Pearson's correlation between yield and its component characters were portioned into different components to find out the direct and indirect contribution of each character on yield. Days to flowering, plant height, leaf breadth, leaf area index, length of panicle, leaf stem ratio, weight of seeds hill^{-1}, dry fodder yield and gibberellic acid content were selected for path coefficient analysis. Direct and indirect effects of yield components are presented in Table 7.

Days to flowering showed negative direct effect (-0.2399) and had strong positive association with green fodder yield (0.2964). This was mainly because of its indirect positive effect through dry fodder yield (0.1821), length of panicle (0.1263), weight of seeds hill^{-1} (0.1143), plant height (0.0943), gibberellic acid content (0.0844) and length of internode (0.0220). Negative indirect effect through leaf breadth (-0.0407), leaf stem ratio (-0.0380) and leaf area index (-

Table 7. Direct and indirect effects of yield components of guinea grass

Character	Days to flowering	Plant height (cm)	Leaf breadth (cm)	Leaf area index	Length of internode (cm)	Length of panicle (cm)	Leaf stem ratio	Weight of seeds $hill^{-1}$ (g)	Dry fodder yield (t/ha)	Gibberellic acid content (µg /g)	Correlation with Green fodder yield (t/ha)
Days to flowering	-0.2399	0.0943	-0.0407	-0.0085	0.0220	0.1263	-0.0380	0.1143	0.1821	0.0844	0.2964
Plant height (cm)	-0.1246	0.1817	-0.0614	-0.0102	0.0159	0.1324	-0.0310	0.0815	0.2348	0.0549	0.4743
Leaf breadth (cm)	-0.0712	0.0813	-0.1372	-0.0191	0.0118	0.1774	0.0368	0.0591	0.1668	0.0262	0.3322
Leaf area index	-0.0236	0.0212	-0.0300	-0.0871	0.0153	0.0409	-0.0025	0.0435	0.2828	0.0146	0.2751
Length of internode (cm)	-0.0814	0.0446	-0.0250	-0.0204	0.0650	0.0565	-0.0510	0.1022	0.1790	0.0409	0.3105
Length of panicle (cm)	-0.1037	0.0823	-0.0833	-0.0122	0.0125	0.2922	-0.0022	0.0845	0.2209	0.0410	0.5322
Leaf stem ratio	0.0704	-0.0435	-0.0389	0.0017	-0.0255	-0.0051	0.1296	-0.1119	-0.1996	-0.0353	-0.2583
Weight of seeds $hill^{-1}$ (g)	-0.1129	0.0609	-0.0334	-0.0156	0.0273	0.1016	-0.0597	0.2431	0.3398	0.0464	0.5977
Dry fodder yield (t/ha)	-0.0708	0.0692	-0.0371	-0.0399	0.0188	0.1047	-0.0419	0.1339	0.6166	0.0347	0.7883
Gibberellic acid content (µg /g)	0.2166	-0.1068	0.0385	0.0136	-0.0285	-0.1283	0.0490	-0.1207	-0.2290	-0.0935	-0.3890

0.0008) also contributed to green fodder yield. Plant height showed positive direct effect (0.1817) on green fodder yield (0.4773). However, its strong positive association with green fodder yield was mainly due to positive indirect effect through dry fodder yield (0.2348), length of panicle (0.1324), weight of seeds hill^{-1} (0.0815), gibberellic acid content (0.0549), length of internode (0.0159) and negative indirect effect through days to flowering (-0.1246), leaf breadth (-0.0614), leaf stem ratio (-0.0310) and leaf area index (-0.0102). Leaf breadth contributed negative direct effect (-0.1372) had strong positive association with green fodder yield (0.3322). This was mainly because of its indirect positive effect through length of panicle (0.1774), dry fodder yield (0.1668), plant height (0.0813), weight of seeds hill^{-1} (0.0591), leaf stem ratio (0.0368), gibberellic acid content (0.0262), length of internode (0.0118) and negative indirect effect through days to flowering (-0.0712) and leaf area index (-0.0191). Leaf area index showed negative direct effect (-0.0871) had strong positive association with green fodder yield (0.2751). Thus it was contributed by negative direct effect and by indirect positive effect through dry fodder yield (0.2828), weight of seeds hill^{-1} (0.0435), length of panicle (0.0409), plant height (0.0212), length of internode (0.0153), gibberellic acid content (0.0146) and negative indirect effect through leaf breadth (-0.0300), days to flowering (-0.0236) and leaf stem ratio (-0.0025). Length of internode showed positive direct effect (0.0650) and had strong positive association with green fodder yield (0.3105). However, its strong positive association with green fodder yield was mainly of its positive indirect effect through dry fodder yield (0.1790), weight of seeds hill^{-1} (0.1022), length of panicle (0.0565), plant height (0.0446), gibberellic acid content (0.0409) and negative indirect effect through days to flowering (-0.0814), leaf stem ratio (-0.0510), leaf breadth (-0.0250) and leaf area index (-0.0204). Length of panicle showed positive direct effect (0.2922) and had strong positive association with green fodder yield (0.5322). This was mainly because of its indirect positive effect through dry fodder yield (0.2209), weight of seeds hill^{-1} (0.0845), plant height (0.0823), gibberellic acid content (0.0410), length of internode (0.0125) and

Table 8. Early, mid and late flowering genotypes of guinea grass

Sr. No.	Genotypes	Early flowering		Genotypes	Mid flowering		Genotypes	Late flowering	
		Days to flowering	Gibberellic acid content (μg/g)		Days to flowering	Gibberellic acid content (μg/g)		Days to flowering	Gibberellic acid content (μg/g)
1	PM-1188	32.7	81.18	MS-4688	36.6	57.25	PGG-293	40.2	41.37
2	FP-553	30.45	84.78	PGG-316	36.2	56.52	MS-4681	39.4	47.15
3	PGG-14	32.4	82.75	FR-428	34.9	57.80	MS-4600	39.1	41.12
4	MS-4733	30.55	85.50	MS-4675	36.1	56.27	PGG-200	38.75	43.87
5	FR-600	32.35	82.80	PGG-327	33.7	65.17	PGG-208	40.5	38.95
6	MS-4690	31.05	85.45	MS-4732	36.1	55.00	PGG-251	40.3	42.25
7	FR-426	32.75	77.40	PGG-227	34.3	57.25	MC-14	37.85	50.60
8	Haritha	29.9	99.75	PGG-192	37.8	60.60	PGG-9	43.3	47.57
9	Marathakam	29.9	95.10	PGG-202	35.1	56.72	PGG-277	39.85	50.00
10	Vellayani local	32.85	70.70	PM-4728	37.3	55.25			
11				MS-4687	35.1	57.75			
12				MS-4691	35	57.25			
13				PGG-205	34.8	57.15			
14				PM-FR-600	33.5	65.50			
15				MC-16	33.45	65.20			
16				PGG-195	33.65	60.26			
17				MS-4685	33.65	64.50			
18				PR-553	33.7	60.60			

negative indirect effect through days to flowering (-0.1037), leaf breadth (-0.0833), leaf area index (-0.0122) and leaf stem ratio (-0.0022).

Leaf stem ratio showed positive direct effect (0.1296) had strong negative association with green fodder yield (-0.2583). This was mainly because of its indirect positive effect through days to flowering (0.0704), leaf area index (0.0017) and negative indirect effect through dry fodder yield (-0.1996), weight of seeds $hill^{-1}$ (-0.1119), plant height (-0.0435), leaf breadth (-0.0389), gibberellic acid content (-0.0353), length of internode (-0.0255) and length of panicle (-0.0051). Weight of seeds $hill^{-1}$ showed positive direct effect (0.2431) and had strong positive association with green fodder yield (0.5977). This was mainly because of its indirect positive effect through dry fodder yield (0.3398), length of panicle (0.1016), plant height (0.0609), gibberellic acid content (0.0464), length of internode (0.0273) and indirect negative effect through days to flowering (-0.1129), leaf stem ratio (-0.0597), leaf breadth (-0.0334) and leaf area index (-0.0156). Dry fodder yield showed positive direct effect (0.6166) and had strong positive association with green fodder yield (0.7883). This was mainly because of its indirect positive effect through weight of seeds $hill^{-1}$ (0.1339), length of panicle (0.1047), plant height (0.0692), gibberellic acid content (0.0347), length of internode (0.0188) and indirect negative effect through days to flowering (-0.0708), leaf stem ratio (-0.0419), leaf area index (-0.0399) and leaf breadth (-0.0371). Gibberellic acid content showed negative direct effect (-0.0935) had strong negative association with green fodder yield (-0.3890). Most of it was contributed by negative direct effect and by indirect positive effect through days to flowering (0.2166), leaf stem ratio (0.0490), leaf breadth (0.0385), leaf area index (0.0136) and negative indirect effect through dry fodder yield (-0.2290), length of panicle (-0.1283), weight of seeds $hill^{-1}$ (-0.1207), plant height (-0.1068) and length of internode (-0.0285).

The thirty seven accessions were grouped into three classes based on days to flowering and gibberellic acid content *i.e.* early flowering, mid flowering and late flowering (Table 8). Two promising accessions from early (FP-553 and MS-

Table 9. Selected genotypes of guinea grass for mutation

Characters	FP-553	MS-4690	MS-4600	PGG-208
Days to flowering	30.45	31.05	40.10	40.50
Plant height (cm)	141.75	129.75	161.85	154.10
Leaf length (cm)	56.60	64.30	64.65	75.30
Leaf breadth (cm)	2.29	2.23	2.44	2.36
Leaf area index	3.72	5.37	7.42	5.86
Length of internode (cm)	25.20	24.01	25.35	26.98
Length of panicle (cm)	38.05	37.80	46.55	44.6
No. of tillers $hill^{-1}$	22.45	30.30	38.85	25.00
No. leaves $hill^{-1}$	126.6	150.4	191.45	113.10
No. of panicles $hill^{-1}$	16.35	21.70	25.80	18.70
Green fodder yield (t/ha)	82.02	57.03	125.62	82.81
Leaf-stem ratio	0.72	0.89	0.86	0.52
Wt. of seeds $hill^{-1}$ (g)	11.85	8.10	11.20	12.80
Dry fodder yield (t/ha)	20.49	14.90	30.23	21.59
Crude protein content (%)	11.40	12.05	13.40	12.20
Crude fibre content (%)	27.00	24.50	32.50	33.50
Gibberellic acid content (µg /g)	84.78	85.45	41.12	38.95

4690) and late flowering (MS-4600 and PGG-208) were identified, presented in Table 9. These accessions were subjected to mutation breeding with gamma rays using seeds and slips.

4.2 INDUCED MUTAGENESIS

Induced mutagenesis was carried out as a part of the investigation entitled "Induced mutagenesis for delayed flowering and high tillering in guinea grass (*Panicum maximum* Jacq.)". In this study, two genotypes each selected from late flowering and early flowering were subjected to gamma rays on seeds and slips. The genotypes selected were MS-4600 and PGG-208 under late flowering and MS-4690 and FP-553 under early flowering. The objective of study was to create variation in guinea grass using gamma radiations. The results obtained during the experimentation were statistically analysed, tabulated and reported as under:

4.2.1 Induced mutagenesis using gamma rays on M_1 generation

4.2.1.1. ***Fixing LD_{50} value for seeds***

The trial for fixing LD_{50} dose for each genotype was carried out separately. For fixing LD_{50} value, trials were conducted employing six doses (including control) from 60 Gy to 140 Gy gamma rays. Effect of different doses of gamma radiations studied on germination of seeds, survival of seedlings and height of seedlings in the four genotypes are presented in Table 10.

4.2.1.1.1. ***Effect of gamma irradiation on germination of seeds***

The results revealed significant effects of radiation doses on germination percentage (Table 10). The low doses of gamma radiation recorded maximum germination percentage when compared with higher doses. The highest germination percentage was obtained for 60 Gy in all genotypes, whereas the dose of 120 Gy seeds gave the lowest germination percentage.

Table 10. Estimation of LD_{50} value for gamma rays on seeds

Accessions	Dose	Germination (%)	Survival of seedlings (%) After 30th days	Height of seedling (cm) After 30th days
FP-553	Control	84.33	84.33	35.25
	60Gy	69.33	58.00	32.28
	80Gy	58.33	52.33	29.39
	100Gy	33.67	32.67	24.97
	120Gy	16.54	11.50	21.37
	140Gy	0.00	0.00	0.00
MS-4600	Control	91.00	91.00	36.24
	60Gy	63.00	54.00	33.42
	80Gy	52.00	49.33	28.77
	100Gy	31.67	30.00	26.35
	120Gy	13.81	10.00	22.65
	140Gy	0.00	0.00	0.00
MS-4690	Control	85.00	85.00	34.28
	60Gy	70.00	60.33	31.79
	80Gy	62.33	53.67	27.59
	100Gy	42.33	34.00	24.43
	120Gy	18.12	12.10	20.43
	140Gy	0.00	0.00	0.00
PGG-208	Control	89.33	89.33	37.97
	60Gy	72.67	63.33	35.47
	80Gy	59.00	57.33	30.23
	100Gy	40.00	35.67	27.47
	120Gy	20.63	15.80	23.33
	140Gy	0.00	0.00	0.00

Table 11. Doses fixed for mutation based on LD_{50} value for survival percentage in seeds

Name of genotype	LD_{50} Stat. value	Doses fixed (Gy)		
		1	2	3
FP-553	75.07	60	80	100
MS-4600	72.29	60	80	100
MS-4690	78.02	60	80	100
PGG-208	83.02	60	80	100

Table 12. Analysis of variance of M_1 generation from seeds

Source of Variation	D.F	Plant height (cm)	Length of internode (cm)	Number of tillers $hill^{-1}$	Days to flowering	Green fodder yield (t/ha)	Dry fodder yield (t/ha)	Number of leaves $hill^{-1}$
Treatment	3	4006.23**	389.12**	29.87**	58.67**	296.76**	42.08**	3163.87**
Variety	3	1060.27**	33.94**	113.28**	183.37**	1035.16**	43.80**	4303.72**
T x V	9	898.72**	19.51**	23.84**	14.44**	803.83**	33.49**	883.56**
Error	30	23.65	2.88	2.98	2.65	48.91	1.51	151.23

Source of Variation	D.F	Leaf stem ratio	Leaf length (cm)	Leaf breadth (cm)	Leaf area index	Root length (cm)	Root spread (cm)	Root dry weight (g)	Root shoot ratio
Treatment	3	0.009	129.89**	0.062**	57.51**	144.21**	9.94**	129.01	0.164
Variety	3	0.008	138.43**	0.034*	22.10**	35.39**	0.057	335.91**	0.583**
T x V	9	0.007	35.50**	0.009	9.03**	57.51**	2.71**	206.30**	0.089
Error	30	0.004	10.59	0.007	0.911	7.49	0.863	58.97	0.057

4.2.1.1.2. ***Effect of gamma irradiation on survival of seedlings***

The sensitivity of seeds to gamma radiation was evaluated by comparing the survival rate (%) among low doses, higher doses and control. Highly significant differences were observed among the low and higher doses of irradiation (Table 10). The results showed that (*i.e.* control, 60 Gy, 80 Gy, 100 Gy and 120 Gy) the plant survival percentage linearly decreased with the increase of gamma radiation doses in all genotypes.

4.2.1.1.3. ***Effect of gamma irradiation on height of seedlings (cm)***

From the obtained it as data noticed that gamma rays have a highly significant impact on plant height (Table 10). The tallest plants were observed on the control when compared with mutants from all genotypes. In contrast by increasing radiation dose from 60 Gy to 120 Gy in seeds seedling height decreased in all genotypes.

4.2.1.2 ***Effect of gamma irradiation on morphological characters of mutants from seeds***

The results of statistical analysis for different characters are presented in Table 12. The table revealed that the treatment related to plant height (cm), length of internode (cm), number of tillers hill^{-1}, days to flowering, green fodder yield (t/ha), dry fodder yield (t/ha), number of leaves hill^{-1}, leaf length (cm), leaf breadth (cm), leaf area index, root length (cm) and root spread (cm) were significantly different from one another except root dry weight (g) and root shoot ratio. Interaction effect between treatment and variety were also found to be significant for all characters except for leaf breadth (cm) and root shoot ratio at 5% level of significance.

4.2.1.2.1. ***Plant height*** **(cm)**

The data related to this aspect has been presented in Table 13. An assessment of the data revealed that gamma ray treatment had a significant effect

Table 13. Mean performance of plant height (cm) in M_1 generation

Variety	Plant height (cm)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	144.13	153.86	207.91	210.66
MS-4600	171.27	207.39	216.77	205.26
MS-4690	165.35	187.61	177.34	198.49
PGG-208	160.14	206.50	176.35	193.83
Mean	160.22	188.84	194.59	202.00
	CD at 5%		SE±	
Variety (V)	4.07		1.40	
Treatments (T)	4.07		1.40	
V*T	8.14		2.80	

Table 14. Mean performance of length of internode (cm) in M_1 generation

Variety	Length of internode (cm)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	26.41	28.40	39.15	35.87
MS-4600	26.71	35.11	40.98	38.56
MS-4690	23.87	26.70	37.93	39.34
PGG-208	30.24	34.19	36.12	38.70
Mean	26.80	31.10	38.54	38.12
	CD at 5%		SE±	
Variety (V)	1.42		0.49	
Treatments (T)	1.42		0.49	
V*T	2.84		0.98	

Table 15. Mean performance of number of tillers $hill^{-1}$ in M_1 generation

Variety	Number of tillers $hill^{-1}$			
	Control	60 Gy	80 Gy	100 Gy
FP-553	25.44	29.31	31.86	27.57
MS-4600	35.53	32.97	30.56	35.50
MS-4690	32.60	39.14	33.34	37.25
PGG-208	30.75	31.99	26.64	34.58
Mean	31.08	33.35	30.60	33.72
	CD at 5%		SE±	
Variety (V)	1.44		0.49	
Treatments (T)	1.44		0.49	
V*T	2.89		0.99	

on number plant height in all the genotypes of guinea grass. A gradual increase in plant height was recorded with gradual increase in dose of gamma rays. Control plants showed a height of 160.22 cm which is lower than mutant plants. Among the treatments, mutants from 100 Gy exhibited the maximum height of 202.00 cm, whereas mutant from 80 Gy showed 194.59 cm followed by 60 Gy with 188.84 cm plant heights. In FP-553, the highest plant height of 210.66 cm was observed in mutants from 100 Gy followed by mutants from 80 Gy and 60 Gy with 207.91 cm and 153.86 cm respectively. Lowest plant height was observed in control plants (144.13 cm). In MS-4600, the highest plant height of 216.77 cm was observed in mutants from 80 Gy followed by mutants from 60 Gy and 100 Gy being 207.39 cm and 205.26 cm respectively. The lowest plant height of 171.27 cm was observed in control plants. In MS-4690 maximum plant height (198.49 cm) was observed in mutants from 100 Gy followed by mutants from 60 Gy and 80 Gy with 187.61 cm and 177.34 cm respectively. The minimum plant height of 165.35 cm was observed in control plants. In the genotype PGG-208, the lowest plant height of 160.14 cm was observed in control plants. The highest plant height of 206.50 cm was observed in mutants from 60 Gy followed by mutants from 100 Gy and 80 Gy with 193.83 cm and 176.65 cm respectively.

4.2.1.2.2. *Length of internode (cm)*

The data presented in Table 14 revealed that length of internode were significantly different among treatments. Among the different gamma ray doses internode length of 26.80 cm was recorded in control which was found to be divergent from all other treatments. The lesser internode length recorded was 31.10 cm in 60 Gy and highest in mutants from 80 Gy with 38.54 cm followed by mutant from 100 Gy dose 38.12 cm respectively. In FP-553 lowest length of internode (26.41cm) was recorded in control plants. Mutants from 80 Gy recorded highest length of internode followed by mutants from 100 Gy and 60 Gy with 35.87 and 28.40 respectively. Data of MS-4600 revealed that mutants from 80 Gy recorded maximum internode length of 40.98 cm which was found to be significantly different from all other treatments. Mutants from 100 Gy and 60 Gy recorded internode length of 38.56 cm and 35.11 cm respectively. Minimum length of internode recorded was 26.71 cm in control plants. In MS-4690 mutants from 100 Gy recorded maximum length of internode 39.34 cm followed by mutants from 80 Gy and 60 Gy with 37.93 cm and 26.70 cm, whereas in control plants length of internode recorded was 23.87 cm. In PGG-208, lowest length of internode 30.24 cm was recorded in control plants and highest length of internode 38.54 cm was recorded in mutants from 80 Gy.

4.2.1.2.3. ***Number of tillers hill^{-1}***

Data presented in Table 15 revealed that number of tillers hill^{-1} were significantly different. Control plants showed 31.08 numbers of tillers hill^{-1}. Maximum numbers of tillers hill^{-1} were found in dose of 100 Gy (33.72) followed by dose of 60 Gy (33.35), whereas plants treated with a dose of 80 Gy (30.60) showed significant drop in numbers of tillers hill^{-1}. In case of FP-553, the highest number of tillers hill^{-1} of 31.86 was recorded in mutants from 80 Gy followed by mutants from 60 Gy and 100 Gy with 29.31and 27.57 respectively. The lowest number of tillers hill^{-1} of 25.44 was recorded in control. In MS-4600, control recorded highest number of tillers hill^{-1} of 35.53 whereas the mutants from 80 Gy recorded lowest number of tillers hill^{-1} of 30.56. Mutants from 100 Gy and 60 Gy recorded 35.50 and 32.97 respectively. In MS-4690, the maximum numbers of tillers hill^{-1} (39.14) was observed in mutants from 60 Gy followed by mutants from 100 Gy and 80 Gy with 37.25 and 33.34 whereas in control plants number of tillers hill^{-1} of 32.60 was recorded. In PGG-208, the minimum number of tillers hill^{-1} (26.64) was recorded in mutants from 80 Gy and maximum number of tillers hill^{-1} were recorded in mutants from 100 Gy (34.58), whereas mutants from 60 Gy and control recorded 31.99 and 30.75 respectively.

4.2.1.2.4. ***Days to flowering***

Data presented in Table 16 indicates days to flowering influenced by gamma irradiation in the different genotypes. Control took 35.31 days to flowering, whereas mutants from 60 Gy had slightly reduced days to flowering

Table 16. Mean performance of days to flowering in M_1 generation

Variety	Days to flowering			
	Control	60 Gy	80 Gy	100 Gy
FP-553	30.97	31.40	35.14	33.05
MS-4600	39.30	36.27	40.48	43.44
MS-4690	31.08	36.66	33.57	38.24
PGG-208	39.92	36.69	41.65	44.79
Mean	35.31	35.25	37.71	39.88
	CD at 5%		SE±	
Variety (V)	1.36		0.47	
Treatments (T)	1.36		0.47	
V*T	2.72		0.94	

Table 17. Mean performance of green fodder yield (t/ha) in M_1 generation

Variety	Green fodder yield (t/ha)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	82.63	83.90	93.13	79.44
MS-4600	128.74	101.92	88.82	106.50
MS-4690	61.10	110.25	95.25	107.03
PGG-208	87.74	98.42	77.57	95.45
Mean	90.05	98.62	88.69	97.11
	CD at 5%		SE±	
Variety (V)	5.85		2.01	
Treatments (T)	5.85		2.01	
V*T	11.71		4.03	

Table 18. Mean performance of dry fodder yield (t/ha) in M_1 generation

Variety	Dry fodder yield (t/ha)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	22.57	23.51	26.00	25.20
MS-4600	31.66	26.35	24.63	30.83
MS-4690	16.97	27.98	26.07	28.70
PGG-208	23.32	26.71	22.36	25.62
Mean	23.63	26.14	24.76	27.58
	CD at 5%		SE±	
Variety (V)	1.03		0.35	
Treatments (T)	1.03		0.35	
V*T	2.06		0.71	

35.25 compared to control. Maximum days to flowering was recorded by mutants from 100 Gy followed by 80 Gy, being 39.88, 37.71 days respectively. Data of genotype FP-553 revealed that control plants recorded earliest days to flowering (30.97) whereas maximum days to flowering (35.14) was observed in mutants from 80 Gy followed by mutants from 100 Gy and 60 Gy being 33.04 and 31.40 days respectively. In MS-4600, among the different gamma ray doses, minimum days to flowering of 36.27 was recorded in mutants from 60 Gy and maximum days to flowering 43.44 was recorded in mutants from 100 Gy followed by mutants from 80 Gy and control plants with 40.48 and 39.30 days respectively. In the genotype MS-4690, control plants recorded minimum days to flowering (31.08), whereas maximum days to flowering was recorded in mutants from 100 Gy (38.24) followed by mutants from 60 Gy and 80 Gy with 36.66 and 33.57 days respectively. In PGG-208 minimum days to flowering was recorded in mutants from 60 Gy (36.69) and maximum days to flowering was recorded in mutants from 100 Gy (44.79) followed by mutants from 80 Gy and control with 41.65 and 39.92 days respectively.

4.2.1.2.5. *Green fodder yield* (t/ha)

The data pertaining to green fodder yield is presented in Table 17. The data revealed that significant differences for this character was recorded in all the genotypes used. Control plants produced 90.05 t/ha green fodder yield, whereas mutants from 80 Gy recorded 88.69 t/ha. Maximum green fodder yield (98.62 t/ha) was recorded in mutants from 60 Gy followed by mutants from 100 Gy (97.11 t/ha). FP-553 showed a significant difference in green fodder yield between the mutant and control plants. Mutants from 100 Gy (79.44 t/ha) recorded lowest green fodder yield which was lower than the control plants 82.63 t/ha, whereas highest green fodder yield was recorded in mutants from 80 Gy (93.13 t/ha) followed by mutants from 60 Gy with 83.90 t/ha. In MS-4600, the control plants recorded maximum green fodder yield of 128.74 t/ha whereas the irradiation treatment with 80 Gy recorded a minimum green fodder yield of 88.82 t/ha. The mutants from 100 Gy and 60 Gy recorded 106.50 t/ha and 101.92 t/ha respectively. This showed that exposure to gamma ray reduced the green fodder yield significantly in this genotype. In MS-4690, control plants recorded minimum green fodder yield of 61.10 t/ha whereas mutants from 60 Gy recorded maximum green fodder yield of 110.25 t/ha. Mutants from 100 Gy and 80 Gy recorded 107.03 t/ha and 95.25 t/ha respectively. In PGG -208, the mutants from 80 Gy recorded lowest green fodder yield of 77.57 t/ha and maximum green fodder yield recorded in mutants from 60 Gy was 98.42 t/ha followed by mutants from 100 Gy and control being 95.45 t/ha and 87.74 t/ha, respectively.

4.2.1.2.6. *Dry fodder yield* (t/ha)

The data related to dry fodder yield are consolidated in table 18. The data revealed that gamma ray treatment had a significant effect on dry fodder yield. The control plants produced 23.63 t/ha dry fodder yield. The mutants from 100 Gy recorded a dry fodder yield of 27.58 t/ha which was significantly higher than control. Mutants from 60 Gy and 80 Gy recorded dry fodder yield of 26.14 t/ha and 24.76 t/ha. In FP-553 minimum dry fodder yield was 22.57 t/ha in control, which was significantly different from mutants, while the maximum dry fodder yield 26.00 t/ha was from mutant 80 Gy followed by mutants from 100 Gy and 60 Gy with 25.20 t/ha and 23.51 t/ha. Data in MS-4600 revealed that mutants from different treatments, maximum dry fodder yield 31.66 t/ha was recorded in control plants. Mutants from 60 Gy, 80 Gy and 100 Gy recorded 26.35 t/ha, 24.63 t/ha and 30.83 t/ha which was lower compared to control plants. In MS-4690 from different mutants maximum dry fodder yield 28.70 t/ha was recorded in mutants from 100 Gy followed by mutants from 60 Gy and 80 Gy with 27.98 t/ha and 26.07 t/ha whereas the minimum dry fodder yield 16.97 t/ha was recorded in control. In PGG-208 maximum dry fodder yield 26.71 t/ha was recorded in mutants from 60 Gy followed by mutants from 100 Gy and 80 Gy with 25.62 t/ha and 22.36 t/ha whereas in control dry fodder yield was 23.32 t/ha.

Table 19. Mean performance of number of leaves hill^{-1} in M_1 generation

Variety	Number of leaves hill^{-1}			
	Control	60 Gy	80 Gy	100 Gy
FP-553	130.89	162.03	160.46	161.78
MS-4600	188.95	169.62	152.78	209.16
MS-4690	161.34	215.37	165.09	191.29
PGG-208	120.64	162.13	133.24	165.09
Mean	150.45	177.29	152.89	181.83
	CD at 5%		SE±	
Variety (V)	10.30		3.55	
Treatments (T)	10.30		3.55	
V*T	20.60		7.10	

Table 20. Mean performance of leaf stem ratio in M_1 generation

Variety	Leaf stem ratio			
	Control	60 Gy	80 Gy	100 Gy
FP-553	0.70	0.80	0.90	0.81
MS-4600	0.83	0.79	0.78	0.82
MS-4690	0.77	0.81	0.76	0.84
PGG-208	0.69	0.77	0.74	0.79
Mean	0.75	0.79	0.79	0.82
	CD at 5%		SE±	
Variety (V)	NS		0.01	
Treatments (T)	NS		0.01	
V*T	NS		0.03	

Table 21. Mean performance of leaf length (cm) in M_1 generation

Variety	Leaf length (cm)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	60.82	56.55	62.68	68.59
MS-4600	71.46	60.70	68.26	72.33
MS-4690	65.13	62.33	61.25	64.55
PGG-208	75.57	64.94	68.87	66.20
Mean	68.25	61.13	65.26	67.92
	CD at 5%		SE±	
Variety (V)	2.72		0.93	
Treatments (T)	2.72		0.93	
V*T	5.45		1.87	

4.2.1.2.7. *Number of tillers hill^{-1}*

The data related with number of leaves hill^{-1} presented in Table 19. The control plants produced lowest number of leaves hill^{-1} (150.45), whereas, mutants recorded 181.83, 177.29 and 152.89 in 100 Gy, 60 Gy and 80 Gy doses of gamma rays respectively. The maximum number of leaves hill^{-1} was recorded in the treatment with the highest dose of gamma rays *i.e.* at 100 Gy (181.83). In FP-553 among the different treatments maximum number of leaves hill^{-1} 162.03 was recorded in mutants from 60 Gy followed by mutants from 100 Gy and 80 Gy with 161.78 and 160.46 whereas minimum number of leaves hill^{-1} 130.89 was recorded in control. In the genotype MS-4600, minimum number of leaves hill^{-1} 152.78 was recorded in mutants from 80 Gy and maximum number of leaves hill^{-1} 209.16 was recorded in mutants from 100 Gy followed by control and 60 Gy with 188.95 and 169.62 respectively. In MS-4690, among the different gamma ray treatments, maximum number of leaves hill^{-1} 215.37 was recorded in mutants from 60 Gy followed by 100 Gy (191.29) and 80 Gy (165.09) whereas minimum number of leaves hill^{-1} 161.34 was recorded in control plants. In PGG-208, among the gamma ray treatments, minimum numbers of leaves hill^{-1} 120.64 was recorded in control plants. Mutants from 100 Gy recorded number of leaves hill^{-1} of 165.09 followed by mutants from 60 Gy and 80 Gy with 162.13 and 133.24 respectively.

4.2.1.2.8. *Leaf stem ratio*

The data recorded in Table 20 showed that the lowest leaf stem ratio was found in control plants. Among the treatments, mutants from 100 Gy showed a leaf stem ratio of 0.82 which was the highest as compared to treatments with lower doses. The leaf stem ratio 0.79 was found in mutants from 60 Gy and 80 Gy doses of gamma rays. In FP-553 it was evident from the data that the maximum leaf stem ratio 0.90 was recorded in mutants from 80 Gy which was significantly different from other mutants whereas minimum leaf stem ratio 0.70 was recorded in control plants. Mutants from 100 Gy and 60 Gy recorded 0.81 and 0.80 respectively. Data of MS-4600 revealed that among the different gamma ray doses the maximum leaf stem ratio of 0.83 was recorded in control plants which were found to be significantly different from all other treatments. Mutants from 60 Gy recorded 0.79, 80 Gy recorded 0.78 and 100 Gy recorded 0.82 leaf stem ratio respectively. In MS-4690 among the different treatments minimum leaf stem ratio of 0.76 was recorded in mutants from 80 Gy whereas maximum leaf stem ratio of 0.84 was recorded in mutants from 100 Gy followed by 60 Gy and control with 0.81 and 0.77 respectively. The leaf stem ratio in PGG-208, among the different gamma rays doses recorded a maximum leaf stem ratio of 0.79 in 100 Gy followed by mutants from 60 Gy and 80 Gy with 0.77 and 0.74, while minimum leaf stem ratio of 0.69 was recorded in control plants.

4.2.1.2.9. *Leaf length* (cm)

The data related to leaf length is presented in Table 21. The recorded data revealed that the effect of gamma rays on leaf length was highly significant between the control plants and mutant plants. Control plants showed highest leaf length 68.25 cm compared to mutant plants. Mutants showed a gradual increase in length as the dose of gamma rays increased. The mutants from 100 Gy showed a leaf length of 67.92 cm which was significantly higher as compared to mutants from 80 Gy followed by 60 Gy, being 65.26 cm and 61.13 cm respectively. In FP-553, control showed a leaf length of 60.82 cm. Maximum leaf length of 68.59 cm was recorded in mutants from 100 Gy followed by mutants from 80 Gy and 60 Gy with 62.68 cm and 56.55 cm, respectively. In MS-4600, the control plants showed a leaf length of 71.46 cm whereas the highest leaf length was recorded in mutants from 100 Gy with 72.33 cm followed by mutants from 80 Gy with 68.26 cm and 60 Gy recorded lowest leaf length of 60.70 cm. In MS-4690, the control plants recorded maximum leaf length of 65.13 cm compared to mutants. Mutants from 60 Gy, 80 Gy and 100 Gy recorded leaf length of 62.33 cm, 61.25 cm and 64.55 cm, respectively. In PGG-208, control plants recorded maximum leaf length of 75.57 cm followed by 60 Gy, 80 Gy and 100 Gy with leaf length of 64.94 cm, 68.87 cm and 66.20 cm, respectively.

Table 22. Mean performance of leaf breadth (cm) in M_1 generation

Variety	Leaf breadth (cm)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	2.21	2.23	2.32	2.49
MS-4600	2.39	2.33	2.40	2.55
MS-4690	2.25	2.32	2.32	2.40
PGG-208	2.36	2.42	2.43	2.42
Mean	2.30	2.32	2.37	2.46
	CD at 5%		SE±	
Variety (V)	0.07		0.02	
Treatments (T)	0.07		0.02	
V*T	NS		0.04	

Table 23. Mean performance of leaf area index in M_1 generation

Variety	Leaf area index			
	Control	60 Gy	80 Gy	100 Gy
FP-553	4.88	8.06	9.46	9.70
MS-4600	8.55	10.00	8.71	10.10
MS-4690	5.97	8.46	7.54	8.21
PGG-208	7.83	9.00	8.66	9.94
Mean	6.81	8.88	8.59	9.48
	CD at 5%		SE±	
Variety (V)	0.79		0.27	
Treatments (T)	0.79		0.27	
V*T	1.59		0.55	

Table 24. Mean performance of root length (cm) in M_1 generation

Variety	Root length (cm)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	68.26	71.28	68.66	65.52
MS-4600	67.33	83.33	63.44	67.81
MS-4690	69.30	74.52	67.89	68.92
PGG-208	62.16	67.33	71.26	66.29
Mean	66.76	74.11	67.81	67.13
	CD at 5%		SE±	
Variety (V)	2.32		0.80	
Treatments (T)	2.32		0.80	
V*T	4.64		1.59	

4.2.1.2.10. ***Leaf breadth*** **(cm)**

The data related to leaf breadth has been compiled in Table 22. The data revealed that leaf breadth increased with increase in dose of gamma rays. Minimum leaf breadth of 2.30 cm was recorded in control. In treatments maximum leaf breadth 2.46 cm was recorded in mutants from 100 Gy followed by mutants from 80 Gy and 60 Gy being 2.37 cm and 2.32 cm, respectively. In FP-553, highest leaf breadth of 2.49 cm was recorded in mutants from 100 Gy followed by mutants from 80 Gy and 60 Gy with 2.32 cm and 2.23 cm whereas lowest leaf breadth of 2.21 cm was recorded in control plants. In genotype MS-4600 highest leaf breadth of 2.55 cm was recorded in mutants from 100 Gy followed by 80 Gy and 60 Gy with 2.40 cm and 2.33 cm. Control plants recorded lowest leaf breadth of 2.39 cm. In MS-4690, lowest leaf breadth 2.25 cm was recorded in control plants. Mutants from 100 Gy recorded maximum leaf breadth of 2.40 cm followed by mutants from 60 Gy and 80 Gy with 2.32 cm. In PGG-208 minimum leaf breadth of 2.36 cm was recorded in control plants whereas maximum leaf breadth of 2.43 cm was recorded in mutants from 80 Gy followed by mutants from 100 Gy and 60 Gy with 2.42 cm.

4.2.1.2.11. ***Leaf area index***

The data pertaining to the effect of gamma rays on the leaf area index is presented in Table 23. The data revealed that significant differences for this character was recorded in all genotypes used. Control plants had the lowest leaf area index of 6.81. Mutants from 100 Gy recorded highest leaf area index (9.48), whereas the mutants from 60 Gy and 80 Gy recorded 8.88 and 8.59 leaf area index respectively. In FP-553, among the different treatments, maximum leaf area index 9.70 was recorded in mutants from 100 Gy followed by 80 Gy and 60 Gy with 9.46 and 8.06, respectively whereas minimum leaf area index of 4.88 was recorded in control plants. In the genotype MS-4600 data revealed that among the different treatments, maximum leaf area index of 10.10 was recorded in mutants from 100 Gy, which was significantly different from all other treatments. Mutants from 60 Gy recorded 10.00 and 80 Gy recorded 8.71 whereas minimum leaf area index (8.55) was recorded in control plants. In MS-4690, control plants recorded minimum leaf area index of 5.97, whereas maximum leaf area index of 8.46 was recorded in mutants from 60 Gy followed by mutants from 80 Gy (7.54) and 100 Gy (8.21). In PGG-208, among different the treatments maximum leaf area index of 9.94 was recorded in mutants from 100 Gy followed by mutants from 60 Gy and 80 Gy with 9.00 and 8.66, respectively. Minimum leaf area index of 7.83 was recorded in control plants.

4.2.1.2.12. *Root length* (cm)

The data represented in Table 24 revealed that root length was significantly different among treatments. Control plants recorded the lowest root length of 66.76 cm as compared to mutant plants. Maximum root length (74.11 cm) was observed in mutant from 60 Gy followed by mutants from 80 Gy and 100 Gy being 67.81 cm and 67.13 cm, respectively. As the dose of gamma rays increased, there was significant decline in the root length. In FP-553, among the different treatments, maximum root length of 71.28 cm was recorded in mutants from 60 Gy followed by mutants from 80 Gy and 100 Gy with 68.66 cm and 65.52 cm respectively. Control plants recorded root length of 68.26 cm. In genotype MS-4600, data revealed that among the different treatments, mutants from 60 Gy recorded maximum root length of 86.33 cm which was significantly different from all other treatments. Minimum root length of 63.44 cm was recorded in mutants from 80 Gy, while mutants from 100 Gy and control recorded 67.81 cm and 67.33 cm. In MS-4690, among the different treatments, minimum root length was 67.89 cm recorded in mutants from 80 Gy whereas maximum root length of 74.52 cm was recorded in mutants from 60 Gy followed by mutants from 100 Gy and control plants with 68.92 cm and 69.30 cm. In the genotype PGG-208, among the different treatments, maximum root length of 71.26 cm was recorded in mutants from 80 Gy followed by mutants from 60 Gy and 100 Gy with 67.33 cm and 66.29 cm, respectively. Control plants recorded minimum root length of 62.16 cm.

Table 25. Mean performance of root spread (cm) in M_1 generation

Variety	Root spread (cm)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	17.90	18.52	18.69	16.70
MS-4600	20.56	18.33	16.55	17.07
MS-4690	18.38	18.48	18.40	17.29
PGG-208	19.88	17.85	18.05	16.83
Mean	19.18	18.29	17.97	16.97
	CD at 5%		SE±	
Variety (V)	NS		0.26	
Treatments (T)	0.77		0.26	
V*T	0.55		0.53	

Table 26. Mean performance of root dry weight (g) in M_1 generation

Variety	Root dry weight (g)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	82.38	93.48	93.78	87.85
MS-4600	94.97	89.81	99.70	120.66
MS-4690	88.00	91.74	97.37	86.74
PGG-208	94.72	92.81	97.18	88.26
Mean	90.02	91.96	97.00	95.88
	CD at 5%		SE±	
Variety (V)	6.43		2.21	
Treatments (T)	NS		2.21	
V*T	12.86		4.43	

Table 27. Mean performance of root shoot ratio in M_1 generation

Variety	Root shoot ratio			
	Control	60 Gy	80 Gy	100 Gy
FP-553	0.86	1.13	1.03	0.98
MS-4600	1.06	1.55	1.17	1.48
MS-4690	0.71	0.81	0.88	0.77
PGG-208	0.98	1.10	1.54	0.97
Mean	0.90	1.15	1.15	1.05
	CD at 5%		SE±	
Variety (V)	0.20		0.06	
Treatments (T)	NS		0.06	
V*T	NS		0.13	

4.2.1.2.13. *Root spread* (cm)

The data pertaining to root spread has been consolidated in Table 25. The data revealed that root spread decreased with increase in dose of gamma rays. Maximum root spread (19.18 cm) was recorded in control. In the treatments maximum root spread (18.29 cm) was recorded in mutants from 60 Gy followed by mutants from 80 Gy and 100 Gy being 17.97 cm and 16.97 cm, respectively. In FP-553 the highest root spread (18.69 cm) was recorded in mutants from 80 Gy followed by mutants from 60 Gy with 18.52 cm and 100 Gy with 16.70 cm which was lowest than the control plants (17.90 cm). In the genotype MS-4600, data revealed that the highest root spread 20.56 cm was recorded in control plants. Among the different treatments, mutants from 60 Gy recorded highest root spread of 18.33 cm followed by mutants from 100 Gy and 80 Gy which recorded 17.07 cm and 16.55 cm respectively. In MS-4690 highest root spread 18.48 cm was recorded in mutants from 60 Gy followed by 80 Gy and 100 Gy with 18.40 cm and 17.29 cm respectively. Control plants recorded 18.385 cm root spread. In PGG-208 highest root spread 19.88 cm was recorded in control plants. Mutants from 60 Gy, 80 Gy and 100 Gy recorded root spread of 17.85 cm, 18.05 cm and 16.83 cm respectively.

4.2.1.2.14. *Root dry weight* (g)

The data recorded in Table 26 showed that the lowest root dry weight was recorded in control plants. Among the treatments, mutant from 80 Gy showed 97.00 g root dry weight which was the highest as compared to mutant from 100 Gy and 60 Gy being 95.88 g and 91.96 g. In case of FP-553, highest root dry weight (93.78 g) was recorded in mutants from 80 Gy followed by mutants from 60 Gy and 100 Gy with 93.48 g and 87.85 g whereas lowest root dry weight of 82.38 g recorded in control plants. In MS-4600, mutants from 100 Gy recorded highest root dry weight of 120.66 g followed by 80 Gy and 60 Gy with 99.70 g and 89.81 g respectively. Control plants recorded 94.97 g root dry weight. In MS-4690, the highest root dry weight 97.37 g was recorded in mutants from 80 Gy followed by 60 Gy and 100 Gy recording 91.74 g and 86.74 g respectively. Control plants recorded root dry weight of 88.00 g. In PGG-208 highest root dry weight of 97.18 g was recorded in mutants from 80 Gy followed by 60 Gy with 92.81 g and 100 Gy with 88.26 g. Control plants recorded 94.72 g root dry weight.

4.2.1.2.15. *Root shoot ratio*

Data (Table 27) for root shoot ratio indicated that there was an increase in root shoot ratio over control among all the genotypes. Lowest root shoot ratio (0.90) was recorded with control which was significantly different from all doses of gamma rays. Mutants from 60 Gy and 80 Gy recorded 1.15 and mutants from 100 Gy recorded 1.05 root shoot ratio. In the genotype FP-553, maximum root shoot ratio of 1.13 was recorded in mutants from 60 Gy followed by 80 Gy and 100 Gy with 1.03 and 0.98, whereas minimum root shoot ratio 0.86 was recorded in control plants. In MS-4600, control plants recorded lowest root shoot ratio of 1.06. Maximum root shoot ratio of 1.55 was recorded in mutants from 60 Gy which was significantly different from other treatments. Mutants from 100 Gy and 80 Gy recorded 1.48 and 1.17 respectively. In MS-4690, the minimum root shoot ratio of 0.71 was recorded in control plants and maximum root shoot ratio was recorded in mutants from 80 Gy (0.88) followed by 60 Gy and 100 Gy with 0.81 and 0.77 respectively. In PGG-208, the maximum root shoot ratio 1.54 was recorded in mutants from 80 Gy followed by mutants from 60 Gy and 100 Gy with 1.10 and 0.97 respectively. Control plants recorded 0.90 root shoot ratio.

4.2.2 Induced mutagenesis using gamma rays on M_1V_1 generation

4.2.1.1. *Fixing LD_{50} value for slips*

The trial for fixing LD_{50} dose for each genotype was carried out separately. For fixing LD_{50} value, trials were conducted employing six doses (including control) 20 Gy, 40 Gy, 60 Gy, 80 Gy and 100 Gy gamma rays. Effect of different doses of gamma radiations was studied on regeneration of shoots from

Table 28. Estimation of LD_{50} value for gamma rays on slips

Accessions	Dose	Regeneration (%)	Survival of shoots (%) (%) After 30th days	Height of plant (cm) After 30th days
FP-553	Control	90.67	89.33	34.04
	20Gy	92.67	66.33	42.75
	40Gy	85.67	56.67	34.20
	60Gy	76.33	40.67	24.09
	80Gy	63.71	21.50	20.21
	100Gy	23.76	0.00	0.00
MS-4600	Control	88.33	87.67	36.45
	20Gy	93.00	73.00	48.25
	40Gy	82.33	61.67	37.39
	60Gy	73.33	42.67	28.75
	80Gy	60.24	19.40	23.11
	100Gy	30.87	0.00	0.00
MS-4690	Control	91.00	90.33	32.19
	20Gy	93.67	68.33	39.93
	40Gy	83.67	54.67	30.17
	60Gy	70.67	37.33	26.58
	80Gy	54.22	13.70	20.65
	100Gy	30.20	0.00	0.00
PGG-208	Control	93.33	91.67	39.50
	20Gy	94.67	72.00	51.17
	40Gy	86.67	53.67	38.59
	60Gy	74.33	38.00	31.63
	80Gy	58.22	15.20	24.55
	100Gy	33.68	0.00	0.00

Table 29. Doses fixed for mutation based on LD_{50} value for survival percentage in slips

Name of genotype	LD_{50} Stat. value	Doses fixed (Gy)		
		1	2	3
FP-553	47.11	20	40	60
MS-4600	51.78	20	40	60
MS-4690	45.01	20	40	60
PGG-208	45.77	20	40	60

slips, survival of shoots and height of plants in the four genotypes are presented in Table 28.

4.2.1.1 .1. ***Effect of gamma irradiation on regeneration of shoots from slips***

Results showed that, regeneration percentages decreased after irradiation (Table 28). For gamma ray, regeneration percentages started to decrease from 20 Gy in all genotypes, it decreased gradually with the increase of dose rate. The low doses of gamma radiation increased the regeneration percentage when compared with control and higher doses, whereas the dose of 100 Gy for slips gave the lowest regeneration percentage. Decrease in regeneration was proportional to the increase in dosage was the definite pattern observed in all the genotypes for gamma ray irradiation.

4.2.1.1.2. ***Effect of gamma irradiation on survival of shoots***

The sensitivity of slips to gamma radiation was evaluated by comparing the survival rate (%) among low doses, high doses and non-irradiated shoots. Highly significant differences were observed among the low and higher doses of irradiation (Table 28). The results showed that in control, 20 Gy, 40 Gy, 60 Gy and 80 Gy of shoots, there was a linear decrease in plant survival percentage with an increase in gamma radiation doses in all genotypes.

4.2.1.1.3. ***Effect of gamma irradiation on height of plants*** **(cm)**

From the data it is noticed that gamma ray has a highly significant impact on plant height (Table 28). The tallest plants were observed on the low dose of 20 Gy in slips of all genotypes when compared with control and higher doses. In contrast increasing radiation dose from 20 Gy to 80 Gy plant height decreased in all genotypes.

Table 30. Analysis of variance of M_1V_1 generation from slips

Source of Variation	D.F	Plant height (cm)	Length of internode (cm)	Number of tillers hill^{-1}	Days to flowering	Green fodder yield (t/ha)	Dry fodder yield (t/ha)	Number of leaves hill^{-1}
Treatment	3	5327.25**	324.68**	54.33**	161.80**	1563.50**	51.41**	1391.51**
Variety	3	220.44**	16.52*	67.17**	390.65**	816.63**	51.90**	1066.58**
T x V	9	227.19**	8.85	33.52**	23.26**	1112.76**	53.84**	968.27**
Error	30	7.30	4.47	3.95	0.79	24.27	1.67	202.34

Source of Variation	D.F	Leaf stem ratio	Leaf length (cm)	Leaf breadth (cm)	Leaf area index	Root length (cm)	Root spread (cm)	Root dry weight (g)	Root shoot ratio
Treatment	3	0.020**	25.88**	0.151**	62.16**	105.82**	1.55	43.65	0.083**
Variety	3	0.004	229.63**	0.050**	13.24**	13.29	11.05**	11.11	0.086**
T x V	9	0.005**	12.72**	0.005	3.29	17.81	3.59**	44.97	0.143**
Error	30	0.002	3.33	0.003	1.58	8.94	0.98	24.68	0.012

4.2.2 Effect of gamma radiation on M_1V_1 damages and morphological characters of mutants from slips

The observations on morphological characters of four genotypes of gamma rays treated M_1V_1 generation is presented below.

The results of statistical analysis for different morphological characters are presented in Table 30. The table showed that the treatments related to plant height (cm), length of internode (cm), number of tillers hill^{-1}, days to flowering, green fodder yield (t/ha), dry fodder yield (t/ha), number of leaves hill^{-1}, leaf length (cm), leaf breadth (cm), leaf area index, root length (cm), root spread (cm) and root shoot ratio were significantly different from one another except root dry weight. Interaction effect between treatment and variety was also found to be significant for all these characters except for length of internode, leaf breadth, leaf area index, root length and root dry weight at 5% level of significance.

4.2.2.1. *Plant height* (cm)

Data related to effect of various doses of mutagen on plant height is depicted in Table 31. Among the mutated population plant height was lowest at 20 Gy (198.83 cm) and highest plant height was recorded in mutants from 60 Gy (201.96 cm) followed by 40 Gy (199.35 cm). The lowest plant height was observed in the control (157.93 cm) when compared with mutant. In the genotype FP-553, the highest plant height of 204.38 cm was observed in mutants from 60 Gy and minimum plant height was observed in control plants 148.52 cm. Mutants from 20 Gy and 40 Gy recorded plant height of 204.11 cm and 193.61 cm respectively. In MS-4600, the maximum plant height 212.29 cm was observed in mutants from 40 Gy which was significantly different from all other treatments. Mutants from 20 Gy and 60 Gy recorded 200.59 cm and 197.79 cm respectively. Minimum plant height of 171.84 cm was observed in control plants. In the genotype MS-4690, the highest plant height of 205.87 cm was observed in mutants from 60 Gy followed by mutants from 20 Gy and 40 Gy with 199.96 cm and 192.09 cm respectively, whereas lowest plant height of 145.33 cm was

Table 31. Mean performance of plant height (cm) in M_1V_1 generation

Variety	Plant height (cm)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	148.52	204.11	193.61	204.38
MS-4600	171.84	200.59	212.29	197.79
MS-4690	145.33	199.96	192.09	205.87
PGG-208	166.02	190.66	198.53	199.80
Mean	157.93	198.83	199.35	201.96
	CD at 5%		SE±	
Variety (V)	2.26		0.78	
Treatments (T)	2.26		0.78	
V*T	4.52		1.56	

Table 32. Mean performance of length of internode (cm) in M_1V_1 generation

Variety	Length of internode (cm)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	26.68	38.54	38.00	38.35
MS-4600	28.31	38.58	39.18	42.03
MS-4690	25.26	37.18	36.67	37.59
PGG-208	30.48	36.42	38.58	35.70
Mean	27.68	37.68	38.11	38.42
	CD at 5%		SE±	
Variety (V)	1.77		0.57	
Treatments (T)	1.77		0.57	
V*T	NS		1.14	

Table 33. Mean performance of number of tillers $hill^{-1}$ in M_1V_1 generation

Variety	Number of tillers $hill^{-1}$			
	Control	20 Gy	40 Gy	60 Gy
FP-553	23.02	29.84	28.54	31.66
MS-4600	36.20	26.64	31.25	31.99
MS-4690	28.63	32.04	31.97	33.52
PGG-208	30.59	31.16	34.50	39.88
Mean	29.61	29.92	31.56	34.26
	CD at 5%		SE±	
Variety (V)	1.66		0.57	
Treatments (T)	1.66		0.57	
V*T	3.33		1.14	

recorded in control plants. In PGG-208, the minimum plant height of 166.02 cm was observed in control plants. Mutants from 60 Gy recorded maximum plant height of 199.80 cm followed by 40 Gy and 20 Gy with 198.53 cm and 190.66 cm, respectively.

4.2.2.2. *Length of internode* (cm)

Observations on length of internode was recorded at maturity and data are presented in Table 32. The effect of gamma rays on length of internode was found to be significant between mutant and control plants. Control plants recorded the lowest internode length of 27.68 cm as compared to mutant plants. Mutants from 60 Gy recorded the highest length (38.42 cm) followed by mutants from 40 Gy and 20 Gy being 38.11 cm and 37.68 cm, respectively. As the dose of gamma rays increased, there was significant increase in length of internode. In case of FP-553, maximum length of internode 38.54 cm was recorded in mutants from 20 Gy and minimum length of internode 26.68 cm was recorded in control plants. Mutants from 40 Gy and 60 Gy recorded internode length of 38.00 cm and 38.35 cm respectively. In MS-4600, control plants recorded minimum length of internode of 28.31 cm whereas mutants from 60 Gy recorded maximum length of internode of 42.03 cm which was significantly different from other treatments. Mutants from 20 Gy and 40 Gy recorded 38.58 cm and 39.18 cm, respectively. In MS-4690, the highest length of internode 37.59 cm was observed in mutants from 60 Gy followed by mutants from 20 Gy and 40 Gy i.e. 37.18 cm and 36.67 cm respectively. Control plants observed lowest length of internode of 25.26 cm. In PGG-208, the highest length of internode of 38.58 cm was recorded in mutants from 40 Gy followed by 20 Gy and 100 Gy with 36.42 cm and 35.70 cm, respectively. Control plants recorded lowest internode length of 30.48 cm.

4.2.2.3. *Number of tillers hill^{-1}*

The data pertaining to this attribute has been presented in Table 33. An appraisal of the data elucidates that gamma ray treatment had a significant effect on number of tillers hill^{-1} in all the genotypes of guinea grass. Among the different treatments lowest number of tillers hill^{-1} was recorded in control (29.61). While maximum on number of tillers hill^{-1} (34.26) was with 60 Gy followed by mutants from 40 Gy (31.56), 20 Gy (29.92). In FP-553, among the different gamma ray doses, maximum number of tillers hill^{-1} of 31.66 was recorded in mutants from 60 Gy whereas minimum number of tillers hill^{-1} of 23.02 was recorded in control plants. Mutants from 20 Gy and 40 Gy recorded 29.84 and 28.54 number of tillers hill^{-1}. In MS-4600, data revealed that among the different gamma ray doses, maximum number of tillers hill^{-1} (36.20) was recorded in control plants, while the minimum number of tillers hill^{-1} (26.64) was recorded in mutants from 20 Gy followed by 40 Gy (31.25) and 60 Gy (31.99). In MS-4690, among the different treatments, maximum number of tillers hill^{-1} of 33.32 was recorded in mutants from 60 Gy followed by 20 Gy and 40 Gy with 32.04 and 31.97 respectively. Minimum number of tillers hill^{-1} 28.63 was recorded in control plants. In PGG-208, data revealed that among the different gamma ray doses, maximum number of tillers hill^{-1} 39.88 was recorded in mutants from 60 Gy which was significantly different from other treatments, while the minimum number of tillers hill^{-1} 30.59 was recorded in control plants. Mutants from 20 Gy and 40 Gy recorded 31.16 and 34.50 number of tillers hill^{-1}, respectively.

4.2.2.4. *Days to flowering*

The data related to days to flowering showed that treatments significantly delayed flowering in all the genotypes (Table 34). Among the different treatments, minimum days to flowering of 35.71 recorded in control which was found to be significantly different from all other treatments. Mutants from 20 Gy recorded 38.03 days followed by mutants from 40 Gy and 60 Gy being 39.63 days and 44.39 days, respectively. In FP-553, among the different gamma ray treatments, minimum days to flowering (31.25) was recorded with control plants. The maximum days to flowering of 34.50 was recorded in mutants from 20 Gy followed by mutants from 40 Gy and 60 Gy with 32.90 and 33.22 respectively. In MS-4600 data revealed that among the different gamma ray treatments earliest days to flowering 39.96 was recorded with control plants. The longest days to

Table 34. Mean performance of days to flowering in M_1V_1 generation

Variety	Days to flowering			
	Control	20 Gy	40 Gy	60 Gy
FP-553	31.25	34.50	32.90	33.22
MS-4600	39.96	40.88	43.33	46.61
MS-4690	30.89	35.03	37.42	42.94
PGG-208	40.73	41.70	44.85	54.79
Mean	35.71	38.03	39.63	44.39
	CD at 5%		SE±	
Variety (V)	0.74		0.25	
Treatments (T)	0.74		0.25	
V*T	1.49		0.51	

Table 35. Mean performance of green fodder yield (t/ha) in M_1V_1 generation

Variety	Green fodder yield (t/ha)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	86.25	84.50	80.49	96.80
MS-4600	131.62	66.55	90.33	96.12
MS-4690	62.93	88.99	90.78	104.15
PGG-208	90.86	82.91	105.14	136.84
Mean	92.91	80.74	91.69	108.48
	CD at 5%		SE±	
Variety (V)	4.12		1.42	
Treatments (T)	4.12		1.42	
V*T	8.25		2.84	

Table 36. Mean performance of dry fodder yield (t/ha) in M_1V_1 generation

Variety	Dry fodder yield (t/ha)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	21.01	24.31	22.64	26.83
MS-4600	34.31	21.78	24.84	25.78
MS-4690	16.76	23.59	25.44	27.83
PGG-208	25.88	24.12	27.48	32.59
Mean	24.49	23.45	25.10	28.26
	CD at 5%		SE±	
Variety (V)	1.08		0.37	
Treatments (T)	1.08		0.37	
V*T	2.16		0.74	

flowering 46.61 was recorded in with mutants from 60 Gy, whereas 40 Gy and 20 Gy recorded 43.33 and 40.88 respectively. In MS-4690, among the different gamma ray treatments, the minimum days to flowering of 30.89 was recorded in control plants. The maximum days to flowering of 42.94 was recorded in mutants from 60 Gy followed by 40 Gy and 20 Gy with 37.42 and 35.03, respectively. In PGG-208, minimum days to flowering of 40.73 were recorded in control plants, whereas longest days to flowering of 54.79 were recorded in mutants from 60 Gy which was significantly different from other treatments. Mutants from 20 Gy and 40 Gy recorded 41.70 and 44.85 days to flowering respectively.

4.2.2.5. ***Green fodder yield*** **(t/ha)**

The data pertaining to the field evaluation of gamma rays treated slips on the green fodder yield are presented in Table 35. The control plants had significantly higher green fodder yield (92.91 t/ha) than the mutants from 20 Gy (80.74 t/ha) and 40 Gy (91.69 t/ha). Maximum green fodder yield was recorded in 60 Gy (108.48) dose of gamma ray as compared to control, 20 Gy and 40 Gy doses. In FP-553, the highest green fodder yield of 96.80 t/ha was recorded in mutants from 60 Gy and the lowest green fodder yield was recorded in 40 Gy with 80.49 t/ha. Mutants from 20 Gy and control plants recorded 84.50 t/ha and 86.25 t/ha green fodder yield. In MS-4600, the control plants recorded maximum green fodder yield of 131.62 t/ha which was significantly different from other treatments. Mutants from 60 Gy, 40 Gy and 20 Gy recorded green fodder yield of 96.12 t/ha, 90.33 t/ha and 66.55 t/ha, respectively. In MS-4690, the control plants recorded minimum green fodder yield of 62.93 t/ha whereas mutants from 60 Gy recorded maximum green fodder yield of 104.15 t/ha followed by 40 Gy and 20 Gy with 90.78 t/ha and 88.99 t/ha, respectively. In PGG-208, the lowest green fodder yield of 82.91 t/ha was recorded in mutants from 20 Gy whereas maximum green fodder yield of 136.86 t/ha was recorded in mutants from 60 Gy followed by 40 Gy and control plants with 105.14 t/ha and 90.86 t/ha, respectively.

4.2.2.6. *Dry fodder yield* (t/ha)

The data related to dry fodder yield are compiled in Table 36. The data confirmed that gamma ray treatment had a significant effect on dry fodder yield. The mutants from 60 Gy showed a dry fodder yield of 28.26 t/ha which was significantly higher, as compared to dry fodder yield produced from control (24.49 t/ha), mutants from 40 Gy (25.10 t/ha) and least dry fodder yield was produced in dose of 20 Gy (23.45 t/ha). In FP-553, data revealed that the maximum dry fodder yield of 26.83 t/ha was recorded in mutants from 60 Gy followed by mutants from 20 Gy and 40 Gy with 24.31 t/ha and 22.64 t/ha whereas minimum dry fodder yield of 21.01 t/ha recorded in control plants. In MS-4600, the maximum dry fodder yield of 34.31 t/ha was recorded in control plants which was significantly different from other treatments. Mutants from 20 Gy, 40 Gy and 60 Gy recorded 21.78t/ha, 24.84t/ha, 25.78 t/ha dry fodder yield. In MS-4690, among the different gamma ray doses, the minimum dry fodder yield of 16.76 t/ha was recorded in control plants. Mutants from 60 Gy recorded maximum dry fodder yield of 27.83 t/ha followed by 40 Gy and 20 Gy with 25.44 t/ha and 23.59 t/ha, respectively. In PGG-208, maximum dry fodder yield of 32.59 t/ha was recorded in mutants from 60 Gy followed by 40 Gy and 20 Gy with 27.48 t/ha and 24.12 t/ha, respectively. Control plants recorded dry fodder yield of 25.88 t/ha.

4.2.2.7. *Number of leaves hill^{-1}*

The data presented in Table 37 revealed that there was significant effect of gamma radiation and genotypes on number of leaves hill^{-1}. The mutants from 20 Gy (151.25), irrespective of genotypes caused significant reduction in number of leaves hill^{-1}. The maximum number of leaves hill^{-1} was recorded in mutants from 60 Gy (174.47) followed by mutants from 40 Gy (163.19), compared to control plants (152.77). In FP-553, mutants from 60 Gy produced highest number of leaves hill^{-1} (157.83) whereas the other treatments recorded 150.65 and 142.78 in 20 Gy and 40 Gy respectively. Control plants produced minimum number of

Table 37. Mean performance of number of leaves hill^{-1} in M_1V_1 generation

Variety	Number of leaves hill^{-1}			
	Control	20 Gy	40 Gy	60 Gy
FP-553	135.47	150.65	142.78	157.83
MS-4600	188.15	135.00	158.24	171.11
MS-4690	149.00	159.90	177.96	168.12
PGG-208	138.46	159.44	173.79	200.83
Mean	152.77	151.25	163.19	174.47
	CD at 5%		SE$\pm$	
Variety (V)	11.91		4.10	
Treatments (T)	11.91		4.10	
V*T	23.83		8.21	

Table 38. Mean performance of leaf stem ratio in M_1V_1 generation

Variety	Leaf stem ratio			
	Control	20 Gy	40 Gy	60 Gy
FP-553	0.67	0.77	0.78	0.83
MS-4600	0.78	0.77	0.77	0.82
MS-4690	0.71	0.84	0.72	0.79
PGG-208	0.67	0.74	0.77	0.77
Mean	0.71	0.78	0.76	0.80
	CD at 5%		SE$\pm$	
Variety (V)	NS		0.01	
Treatments (T)	0.03		0.01	
V*T	0.06		0.02	

Table 39. Mean performance of leaf length (cm) in M_1V_1 generation

Variety	Leaf length (cm)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	60.56	67.05	65.96	65.53
MS-4600	69.23	72.87	71.55	70.77
MS-4690	62.42	67.18	69.07	63.83
PGG-208	75.66	73.39	73.02	73.46
Mean	66.97	70.12	69.90	68.40
	CD at 5%		SE$\pm$	
Variety (V)	1.53		0.52	
Treatments (T)	1.53		0.52	
V*T	3.06		1.05	

leaves hill^{-1} of 135.47. In MS-4600, the control plants produced the highest number of leaves hill^{-1} (188.15) whereas mutants from 60 Gy, 40 Gy and 20 Gy produced 171.11, 158.24 and 135.00 number of leaves, respectively. In MS-4690, the lowest number of leaves hill^{-1} of 149.00 was recorded in control plants. Mutants from 40 Gy produced highest number of leaves hill^{-1} of 177.96 followed by mutants from 20 Gy and 60 Gy with 159.90 and 168.12 number of leaves hill^{-1}, respectively. In PGG-208, the maximum number of leaves hill^{-1} of 200.83 was produced in mutants from 60 Gy which was significantly different from other treatments. Mutants from 20 Gy and 40 Gy produced 159.44 and 173.79 number of leaves, whereas minimum number of leaves hill^{-1} of 138.46 was recorded in control plants.

4.2.2.8. *Leaf stem ratio*

The data represented in Table 38 revealed that leaf stem ratio was significantly different between treatments. Maximum leaf stem ratio was observed in mutants from 60 Gy (0.80) followed by 20 Gy (0.78) and 40 Gy (0.76). Minimum leaf stem ratio was recorded in control (0.71). In case of FP-553, the highest leaf stem ratio of 0.83 was recorded in mutants from 60 Gy followed by 40 Gy and 20 Gy with 0.78 and 0.77 respectively, whereas lowest leaf stem ratio of 0.67 was recorded in control plants. In MS-4600, the lowest leaf stem ratio of 0.77 was recorded in mutants from 20 Gy and 40 Gy whereas maximum leaf stem ratio of 0.82 was recorded in mutants from 60 Gy followed by control plants with 0.78. In MS-4690, the highest leaf stem ratio of 0.84 was recorded in mutants from 20 Gy which was significantly different from other treatments. Mutants from 40 Gy and 60 Gy recorded 0.72 and 0.79 leaf stem ratio, respectively whereas lowest leaf stem ratio of 0.71 was recorded in control plants. In PGG-208, the lowest leaf stem ratio of 0.67 was recorded in control plants. Mutants from 40 Gy and 60 Gy recorded maximum leaf stem ratio of 0.77 followed by mutants from 20 Gy with 0.74.

4.2.2.9. *Leaf length* (cm)

Observations on leaf length were recorded at maturity and data are presented in Table 39. The effect of gamma rays on leaf length was found to be significant between mutant and control plants. Control plants recorded the lowest leaf length of 66.97 cm as compared to mutant plants. Mutants from 20 Gy treatment recorded the highest leaf length (70.12 cm) followed by mutants from 40 Gy (69.90 cm) and 60 Gy (68.40 cm). As the dose of gamma rays increased, there was significant decline in the leaf length. In FP-553, maximum leaf length of 67.05 cm was recorded in mutants from 20 Gy followed by 40 Gy and 60 Gy with 65.96 cm and 65.53 cm respectively. Control plants recorded lowest leaf length of 60.56 cm. In MS-4600, the highest leaf length 72.87 cm was recorded in mutants from 20 Gy followed by 40 Gy and 60 Gy with 71.55 cm and 70.77 cm, whereas control plants recorded lowest leaf length of 69.23 cm. In MS-4690, the minimum leaf length of 62.42 cm was recorded in control plants. Mutants from 40 Gy recorded maximum leaf length of 69.07 cm followed by 20 Gy and 60 Gy with 67.18 cm and 63.83 cm respectively. In PGG-208, the maximum leaf length of 75.66 cm recorded in control plants which were significantly different from other treatments. Mutants from 20 Gy, 40 Gy and 60 Gy recorded 73.39 cm, 73.02 cm and 73.76 cm respectively.

4.2.2.10. *Leaf breadth* (cm)

The data related to leaf breadth is compiled in Table 40. The recorded data revealed that the effect of gamma rays on leaf breadth was significantly different between control plants and mutant plants. Control plants showed lowest leaf breadth of 2.30 cm. Mutants from 20 Gy and 60 Gy showed same leaf breadth 2.52 cm, whereas maximum recorded in mutants from 40 Gy (2.53 cm). In case of FP-553, maximum leaf breadth of 2.51 cm was recorded in mutants from 40 Gy followed by mutants from 20 Gy and 60 Gy with 2.50 cm and 2.45 cm. Minimum leaf breadth of 2.17 cm was recorded in control plants. In MS-4600, the minimum leaf breadth of 2.41 cm was recorded in control plants. Mutants from 20 Gy, 40

Table 40. Mean performance of leaf breadth (cm) in M_1V_1 generation

Variety	Leaf breadth (cm)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	2.17	2.50	2.51	2.45
MS-4600	2.41	2.57	2.57	2.57
MS-4690	2.25	2.47	2.50	2.40
PGG-208	2.38	2.56	2.55	2.59
Mean	2.30	2.52	2.53	2.52
	CD at 5%		SE±	
Variety (V)	0.04		0.86	
Treatments (T)	0.04		0.86	
V*T	NS		1.72	

Table 41. Mean performance of leaf area index in M_1V_1 generation

Variety	Leaf area index			
	Control	20 Gy	40 Gy	60 Gy
FP-553	6.63	7.54	8.75	9.23
MS-4600	8.77	9.00	9.27	10.00
MS-4690	6.56	7.50	8.00	9.44
PGG-208	6.53	7.64	9.78	10.04
Mean	7.12	7.82	8.82	9.67
	CD at 5%		SE±	
Variety (V)	1.05		0.36	
Treatments (T)	1.05		0.36	
V*T	NS		0.72	

Table 42. Mean performance of root length (cm) in M_1V_1 generation

Variety	Root length (cm)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	67.62	73.63	74.11	71.23
MS-4600	67.63	74.78	74.66	73.12
MS-4690	70.89	73.55	72.26	69.66
PGG-208	62.22	69.74	73.89	74.00
Mean	67.09	72.85	73.73	72.00
	CD at 5%		SE±	
Variety (V)	NS		0.86	
Treatments (T)	2.50		0.86	
V*T	NS		1.72	

Gy and 60 Gy recorded leaf breadth of 2.57cm. In MS-4690, control plants recorded lowest leaf breadth of 2.25 cm whereas mutants from 40 Gy recorded maximum leaf breadth of 2.50 cm followed by mutants from 20 Gy and 60 Gy with 2.47 cm and 2.40 cm respectively. In PGG-208, the highest leaf breadth of 2.59 cm was recorded in mutants from 60 Gy which was significantly different from other treatments. Mutants from 20 Gy and 40 Gy recorded 2.56 cm and 2.55 cm, whereas lowest leaf breadth of 2.38 cm was recorded in control plants.

4.2.2.11. *Leaf area index*

Data presented in Table 41 revealed that leaf area index were significantly different between treatments. Lowest leaf area index were found in control plants (7.12) as compared to mutants from 20 Gy, 40 Gy and 60 Gy doses of gamma rays with leaf area index of (7.82, 8.82 and 9.67). As dose of gamma rays increased there was significant effect on leaf area index. In case of FP-553, maximum leaf area index of 9.23 was recorded in mutants from 60 Gy followed by mutants from 40 Gy and 20 Gy with 8.75 and 7.54, respectively. Minimum leaf area index of 6.63 was recorded in control plants. In MS-4600, the minimum leaf area index of 8.77 was recorded in control plants whereas maximum leaf area index of 10.00 was recorded in mutants from 60 Gy followed by 40 Gy and 20 Gy with 9.27 and 9.00 respectively. In MS-4690, the maximum leaf area index of 9.44 was recorded in mutants from 60 Gy followed by mutants from 40 Gy and 20 Gy with 8.00 and 7.50. Control plants recorded minimum leaf area index of 6.56. In PGG-208, the maximum leaf area index of 10.04 was recorded in 60 Gy which was significantly different from other treatments. Mutants from 40 Gy and 20 Gy recorded leaf area index of 9.78 and 7.64, respectively. Minimum leaf area index of 6.53 was recorded in control plants.

4.2.2.12. *Root length* (cm)

The data recorded in Table 42 showed that the minimum root length was found in control plants. Mutants from 40 Gy showed longest roots of 73.73 cm as compared to mutants from 20 Gy (72.85 cm), whereas shortest roots was recorded at highest dose of 60 Gy (72.00 cm). In case of FP-553, maximum root length of 74.11 cm was recorded in mutants from 40 Gy followed by 20 Gy and 60 Gy with 73.63 cm and 71.23 cm, whereas minimum root length of 67.62 cm was recorded in control plants. In MS-4600, the minimum root length of 67.63 cm was recorded in control plants whereas maximum root length of 74.78 cm was recorded in mutants from 20 Gy which was significantly different from other treatments. Mutants from 40 Gy and 60 Gy recorded 74.66 cm and 73.12 cm, respectively. In MS-4690, the maximum root length of 73.55 cm was recorded in mutants from 20 Gy followed by mutants from 40 Gy and 60 Gy with 72.26 cm and 69.66 cm respectively. Control plants recorded minimum root length of 70.89. In PGG-208, the maximum root length of 74.00 was recorded in mutants from 60 Gy followed by mutants from 40 Gy and 20 Gy with 73.89 cm and 69.74 cm, respectively. Minimum root length of 62.22 cm was recorded in control plants.

4.2.2.13. *Root spread* (cm)

The data pertaining to root spread in M_1V_1 are presented in Table 43. Control plants showed a root spread of 19.33 cm. Among the treatments, mutants from 20 Gy showed maximum root spread (19.49 cm), followed by mutants from 40 Gy (19.15 cm) and 60 Gy (18.66 cm). Root spread showed a decreasing trend with the increase in doses of mutagens. In FP-553, among the different gamma ray doses, the minimum root spread of 18.15 cm was recorded in mutants from 20 Gy whereas maximum root spread of 18.92 cm was recorded in 60 Gy followed by mutants from 40 Gy and control plants with 18.63 cm and 18.19 cm respectively. In MS-4600, data revealed that among the different gamma ray doses the maximum root spread of 20.29 cm was recorded in control plants and minimum root spread of 17.48 cm was recorded in mutants from 20 Gy followed by 40 Gy and 60 Gy with 18.03 cm and 18.11 cm respectively. In MS-4690, the maximum root spread of 20.50 cm was recorded in 20 Gy followed by mutants from 40 Gy and 60 Gy with 18.77 cm and 18.70 cm, respectively. Control plants recorded root spread of 18.77 cm. In PGG-208, the maximum root spread of 21.86 was recorded in 20 Gy which was significantly different from other treatments.

Table 43. Mean performance of root spread (cm) in M_1V_1 generation

Variety	Root spread (cm)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	18.19	18.15	48.63	18.92
MS-4600	20.29	17.48	18.03	18.11
MS-4690	18.77	20.50	18.77	18.70
PGG-208	20.07	21.86	21.18	18.92
Mean	19.33	19.49	19.15	18.66
	CD at 5%		SE±	
Variety (V)	0.83		0.28	
Treatments (T)	NS		0.28	
V*T	1.66		0.57	

Table 44. Mean performance of root dry weight (g) in M_1V_1 generation

Variety	Root dry weight (g)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	81.62	86.88	84.89	85.54
MS-4600	90.85	78.70	82.15	83.15
MS-4690	84.10	81.55	89.14	81.91
PGG-208	90.44	81.40	84.07	87.86
Mean	86.75	82.13	85.06	84.62
	CD at 5%		SE±	
Variety (V)	NS		1.43	
Treatments (T)	NS		1.43	
V*T	NS		2.86	

Table 45. Mean performance of root shoot ratio in M_1V_1 generation

Variety	Root shoot ratio			
	Control	20 Gy	40 Gy	60 Gy
FP-553	0.86	0.73	0.64	0.55
MS-4600	1.11	0.72	0.75	0.61
MS-4690	0.74	0.91	0.66	1.30
PGG-208	0.99	0.75	0.88	0.60
Mean	0.92	0.78	0.73	0.76
	CD at 5%		SE±	
Variety (V)	0.09		0.03	
Treatments (T)	0.09		0.03	
V*T	0.18		0.06	

Mutants from 40 Gy and 60 Gy recorded root spread of 21.18 cm and 18.92 cm. Control plants recorded root spread of 20.07cm.

4.2.2.14. *Root dry weight* (g)

The data related to root dry weight are presented in Table 44. The data revealed that gamma ray treatment could not significantly influence root dry weight (g). The control plants produced the highest root dry weight (86.75 g) followed by mutants from 40 Gy (85.06 g), 60 Gy (84.62 g) and 20 Gy (82.13 g). In FP-553, the highest root dry weight of 86.88 g was recorded in mutants from 20 Gy followed by 40 Gy and 60 Gy with 84.89 g and 85.54 g, respectively. The lowest root dry weight of 81.62 g was recorded in control plants. In MS-4600, the highest root dry weight of 90.85 g recorded in control plants which were significantly different from other treatments. Mutants from 20 Gy, 40 Gy and 60 Gy recorded root dry weight of 78.70 g, 82.15 g and 83.15 g respectively. In case of MS-4690, the maximum root dry weight of 89.14 g was recorded in mutants from 40 Gy followed by 20 Gy and 40 Gy with 81.55 g and 81.91 g respectively. Control plants recorded 84.10 g root dry weight. In PGG-208, the maximum root dry weight of 90.44 was recorded in control plants. Mutants from 20 Gy, 40 Gy and 60 Gy recorded root dry weight of 81.40 g, 84.07 g and 87.86 g, respectively.

4.2.2.15. *Root shoot ratio*

Data pertaining to root shoot ratio in M_1V_1 generation are tabulated in Table 45. A gradual decrease in root shoot ratio was recorded with gradual increase in the dose of gamma rays. Control plants showed the highest (0.92) root shoot ratio. Among the treatments, mutants from 20 Gy recorded (0.78) highest root shoot ratio followed by mutants from 60 Gy (0.76) and lowest root shoot ratio was depicted dose 40 Gy (0.73) respectively. In FP-553, the highest root shoot ratio of 0.86 was recorded in control plants. Mutants from 20 Gy, 40 Gy and 60 Gy recorded root shoot ratio of 0.73, 0.64 and 0.55, respectively. In MS-4600, the highest root shoot ratio of 1.11 recorded in control plants was significantly different from other treatments. Mutants from 20 Gy, 40 Gy and 60 Gy recorded

Table 46. Effect of gamma rays on germination and spectrum of chlorophyll mutants in M_2 generation

Accessions	Doses	Germination / 100 seeds	Survival of seedlings	Plant reduction on 30 day	Mutant seedlings	Mutagenic effectiveness	Mutagenic efficiency
FP-553	Control	98	98	-	-	-	-
	60Gy	91	68	23	3	0.50	0.13
	80Gy	87	59	28	7	0.88	0.25
	100Gy	74	42	32	12	1.20	0.38
MS-4600	Control	96	96	-	-	-	-
	60Gy	89	71	18	5	0.83	0.28
	80Gy	82	57	25	8	1.00	0.32
	100Gy	78	44	34	14	1.50	0.41
MS-4690	Control	93	93	-	-	-	-
	60Gy	87	66	21	2	0.33	0.10
	80Gy	80	53	27	5	0.63	0.19
	100Gy	75	42	33	9	0.90	0.27
PGG-208	Control	99	99	-	-	-	-
	60Gy	92	72	20	6	1.00	0.30
	80Gy	87	61	26	9	1.13	0.35
	100Gy	79	46	33	15	1.30	0.45

root shoot ratio of 0.72, 0.75 and 0.61 respectively. In MS-4690, the highest root shoot ratio of 1.30 was recorded in mutants from 60 Gy followed by mutants from 20 Gy and 40 Gy with 0.91and 0.66 respectively. Control plants recorded root shoot ratio of 0.74. In PGG-208, the highest root shoot ratio of 0.99 was recorded in control plants. Mutants from 20 Gy, 40 Gy and 60 Gy recorded root shoot ratio of 0.75, 0.88 and 0.60, respectively.

4.3.1 Study of M_2 generation

4.3.1.1. ***Spectrum of chlorophyll mutants***

Among the treatments, the 100 Gy gamma rays produce high frequency of albino plants (Table 46). Next common chlorophyll mutant observed was xantha in all genotypes. Xantha mutants were less frequent and found only in 80 Gy and 100 Gy treatments. The frequency of chlorophyll mutations varied with the genotype as well as mutagen doses in M_2 generation. Total frequency of chlorophyll mutations was relatively higher in MS-4600 and PGG-208.

4.3.1.2. ***Mutagenic effectiveness and efficiency***

Mutagenic effectiveness and efficiency (mutations per unit dose) varied with doses in different genotypes as given in Table 46. It was also observed that, the mutagenic efficiency was lowest at 100 Gy dose in all genotypes, because percentage survival reduction was observed in 100 Gy dose followed by 80 Gy dose which resulted in decrease in the mutagenic efficiency in 100 Gy and 80 Gy doses. In PGG-208, maximum mutagenic efficiency was recorded in 100 Gy dose (0.45) followed by 80 Gy dose (0.35).

4.3.2. Effect of gamma radiation on morphological characters of mutants from irradiated seeds

The results of statistical analysis for different characters are presented in Table 47. The table revealed that the treatments related to plant height (cm), length of internode (cm), number of tillers hill^{-1}, days to flowering, green fodder

Table 47. Analysis of variance of M_2 generation from seeds

Source of Variation	D.F	Plant height (cm)	Length of internode (cm)	Number of tillers $hill^{-1}$	Days to flowering	Green fodder yield (t/ha)	Dry fodder yield (t/ha)	Number of leaves $hill^{-1}$	Leaf stem ratio	Leaf length (cm)
Treatment	3	3076.47**	424.61**	39.74**	63.22**	1457.81**	56.16**	4913.32**	0.013**	338.57**
Variety	3	744.91**	33.28**	90.27**	208.72**	1128.50**	45.99**	3229.16**	0.014**	336.18**
T x V	9	1361.30**	20.40*	53.93**	29.25*	1067.98**	99.61**	1081.49**	0.017**	91.66**
Error	30	27.59	6.80	8.50	10.06	27.19	7.01	43.04	0.002	16.45

Source of Variation	D.F	Leaf breadth (cm)	Leaf area index	Root length (cm)	Root spread (cm)	Root dry weight (g)	Root shoot ratio	Crude protein content (%)	Crude fibre content (%)	Gibberellic acid (µg/g)
Treatment	3	0.107**	13.94**	208.37**	14.39*	336.05**	0.240**	10.41**	7.19**	99.61**
Variety	3	0.021**	18.85**	12.88	2.05	294.41**	0.517**	7.50*	118.97	5920.51**
T x V	9	0.042**	9.16**	116.37**	8.73*	311.56**	0.100**	2.93	19.56**	47.23**
Error	30	0.004	1.86	17.22	3.56	37.54	0.012	2.17	5.44	8.01

yield (t/ha), dry fodder yield (t/ha), number of leaves hill^{-1}, leaf length (cm), leaf breadth (cm), leaf area index, root length (cm), root spread (cm), root dry weight (g), root shoot ratio, crude protein content (%), crude fibre content (%) and gibberellic acid were significantly different from one another. Interaction effect between treatment and variety was also found to be significant for all characters except for crude protein content (%) at 5% level of significance.

4.3.2.1. ***Plant height*** **(cm)**

The result related to the effect of gamma rays on plant height are presented in Table 48. There was a significant difference between the control and mutant plants. A gradual increase in plant height was recorded with gradual increase in dose of gamma rays. Control plants recorded a height 161.03 cm which is lesser than mutant plants. Among the treatments, plants treated with a dose of 100 Gy recorded the maximum height of 198.57 cm followed by 80 Gy (188.08 cm) and 60 Gy (187.52 cm), respectively. In case of FP-553, the maximum plant height of 209.49 cm was recorded in mutants from 100 Gy whereas minimum plant height of 145.50 cm was recorded in control plants. Mutants from 60 Gy and 80 Gy recorded plant height of 150.32 cm and 201.50 cm respectively. In MS-4600, the maximum plant height of 218.92 cm was recorded in mutants from 80 Gy which was significantly different from other treatments, whereas minimum plant height of 169.85 cm was recorded in control plants. Mutants from 60 Gy and 100 Gy recorded plant height of 204.64 cm and 186.88 cm, respectively. In the genotype MS-4690, the maximum plant height of 200.85 cm was recorded in 100 Gy followed by mutants from 60 Gy and 80 Gy with plant height of 188.00 cm and 170.24 cm respectively. Control plants recorded minimum plant height of 167.20 cm. In the genotype of PGG-208, minimum plant height of 161.57 cm was recorded in control plants. Mutants from 60 Gy recorded maximum plant height of 207.13 cm followed by 100 Gy and 80 Gy with 197.07 cm and 161.69 cm, respectively.

Table 48. Mean performance of plant height (cm) in M_2 generation

Variety	Plant height (cm)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	145.50	150.32	201.50	209.49
MS-4600	169.85	204.64	218.92	186.88
MS-4690	167.20	188.00	170.24	200.85
PGG-208	161.57	207.13	161.69	197.07
Mean	161.03	187.52	188.08	198.57
	CD at 5%		SE±	
Variety (V)	4.40		1.51	
Treatments (T)	4.40		1.51	
V*T	8.80		3.03	

Table 49. Mean performance of length of internode (cm) in M_2 generation

Variety	Length of internode (cm)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	25.76	26.07	38.80	34.56
MS-4600	26.58	32.56	40.74	35.32
MS-4690	24.21	23.80	36.17	39.14
PGG-208	30.58	29.49	37.38	38.74
Mean	26.78	27.98	38.27	36.94
	CD at 5%		SE±	
Variety (V)	2.18		0.75	
Treatments (T)	2.18		0.75	
V*T	4.37		1.50	

Table 50. Mean performance of number of tillers $hill^{-1}$ in M_2 generation

Variety	Number of tillers $hill^{-1}$			
	Control	60 Gy	80 Gy	100 Gy
FP-553	24.83	28.02	33.75	24.20
MS-4600	34.14	31.20	27.69	36.56
MS-4690	31.31	39.88	29.86	35.42
PGG-208	29.38	32.32	26.15	34.52
Mean	29.91	32.85	29.36	32.67
	CD at 5%		SE±	
Variety (V)	2.44		0.84	
Treatments (T)	2.44		0.84	
V*T	4.88		1.68	

4.3.2.2. *Length of internode* (cm)

The data presented in Table 49 revealed that there was significant effect of gamma rays with respect to treatment doses and genotypes on length of internode. The treatment of plants with gamma rays, irrespective of genotypes caused significant increase in length of internode. Control plants observed the lowest length of internode (26.78 cm). In the treatments maximum length of internode 38.27 cm was observed in 80 Gy followed by 100 Gy and 60 Gy being 36.94 cm and 27.98 cm respectively. In FP-553 highest length of internode (38.80 cm) was observed in mutants from 80 Gy followed by mutants from 100 Gy and 60 Gy with 34.56 cm and 26.07 cm, respectively. Minimum length of internode (25.76 cm) was observed in control plants. Data of MS-4600 revealed that mutants from 80 Gy recorded highest length of internode (40.74 cm) which was significantly different from other treatments. Mutants from 60 Gy and 100 Gy observed 32.56 cm and 35.32 cm, whereas lowest length of internode of 26.58 cm was observed in control plants. In the genotype MS-4690, minimum length of internode (23.80 cm) was observed in mutants from 60 Gy and maximum length of internode (39.14 cm) was observed in 100 Gy followed by 80 Gy and control plants with 36.17 cm and 24.21 cm respectively. In PGG-208, the maximum length of internode 38.74 cm was observed in mutants from 100 Gy whereas minimum length of internode of 29.49 cm was observed in 60 Gy. Mutants from 80 Gy showed 37.38 cm length of internode. Control plants recorded internode length of 30.58 cm.

4.3.2.3. *Number of tillers Hill^{-1}*

The data pertaining to field evaluation of gamma ray treatment on the number of tillers hill^{-1} are presented in Table 50. It is evident from the data that significant differences for this character was recorded in all the genotypes studied. The mutants with 80 Gy produced lowest number of tillers hill^{-1} (29.36) compared to control plants (29.91), whereas maximum number of tillers hill^{-1} was recorded in 60 Gy (32.85) followed by 100 Gy (32.67). In case of FP-553, the maximum number of tillers $hill^{-1}$ (33.75) was produced in mutants from 80 Gy and minimum number of tillers $hill^{-1}$ (24.20) was produced in mutants from 100 Gy followed by mutants from 60 Gy with 28.02 tillers. In the genotype MS-4600, control plants produced 34.14 tillers $hill^{-1}$ whereas mutants from 100 Gy produced maximum number of tillers $hill^{-1}$ (36.56) followed by mutants from 60 Gy and 80 Gy with 31.20 and 27.69 respectively. In MS-4690, the maximum number of tillers $hill^{-1}$ was produced in mutants from 60 Gy which was significantly different from other treatments. Mutants from 100 Gy and 80 Gy produced 35.42 and 29.86 tillers $hill^{-1}$. Control plants produced 31.31 tillers $hill^{-1}$. In case of PGG-208, mutants from 100 Gy produced maximum number of tillers $hill^{-1}$ of 34.52 followed by mutants from 60 Gy and 80 Gy with 32.32 and 26.15 respectively. Control plants produced 29.38 tillers $hill^{-1}$.

4.3.2.4. *Days to flowering*

The data pertaining to this attribute shows that there is significant difference between mutant and control plants in all genotypes (Table 51). Among the different treatments, a minimum day taken to flowering was 34.92 days and was recorded in 60 Gy which was lower than control (35.09 days). The maximum (39.86 days) was recorded with 100 Gy treatment followed by 80 Gy being 36.85 days. In the genotype FP-553, control plants observed minimum days to flowering of 30.75 whereas maximum days to flowering 36.12 was observed in mutants from 80 Gy followed by 60 Gy and 100 Gy with 32.61 and 31.58 respectively. In MS-4600, maximum days to flowering (44.76) was recorded in mutants from 100 Gy followed by mutants from 80 Gy and 60 Gy with 39.53 and 35.04 respectively. Control plants recorded 39.14 days to flowering. In MS-4690, the minimum days to flowering of 29.93 was observed in control plants. Mutants from 100 Gy observed maximum days to flowering of 38.25 followed by mutants from 60 Gy with 35.51 and 80 Gy with 30.11 respectively. In case of PGG-208, the highest days to flowering of 44.88 was observed in mutants from 100 Gy which was significantly different from other gamma ray doses. Mutants from 60

Table 51. Mean performance of days to flowering in M_2 generation

Variety	Days to flowering			
	Control	60 Gy	80 Gy	100 Gy
FP-553	30.75	32.61	36.12	31.58
MS-4600	39.14	35.04	39.53	44.76
MS-4690	29.93	35.51	30.11	38.25
PGG-208	40.55	36.51	41.64	44.88
Mean	35.09	34.92	36.85	39.86
	CD at 5%		SE±	
Variety (V)	2.65		0.91	
Treatments (T)	2.65		0.91	
V*T	5.31		1.83	

Table 52. Mean performance of green fodder yield (t/ha) in M_2 generation

Variety	Green fodder yield (t/ha)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	80.77	82.66	94.10	78.36
MS-4600	126.36	103.68	86.03	110.31
MS-4690	62.30	117.86	72.14	110.81
PGG-208	88.72	128.62	79.20	95.01
Mean	89.54	108.21	82.87	98.62
	CD at 5%		SE±	
Variety (V)	4.36		1.50	
Treatments (T)	4.36		1.50	
V*T	8.73		3.01	

Table 53. Mean performance of dry fodder yield (t/ha) in M_2 generation

Variety	Dry fodder yield (t/ha)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	22.90	22.63	28.12	20.85
MS-4600	30.92	28.17	22.36	31.98
MS-4690	17.21	26.40	33.34	27.02
PGG-208	21.63	36.14	21.95	26.82
Mean	23.16	28.33	26.44	26.67
	CD at 5%		SE±	
Variety (V)	2.21		0.76	
Treatments (T)	2.21		0.76	
V*T	4.43		1.52	

Gy and 80 Gy observed 36.51 and 41.64 days to flowering. Control plants observed 40.55 days to flowering.

4.3.2.5. *Green fodder yield* (t/ha)

The data pertaining to green fodder yield is presented in Table 52. Significant difference was found between mutant and control genotypes of guinea grass. The highest green fodder yield 108.21 t/ha was recorded in 60 Gy followed by 100 Gy being 98.62 t/ha, whereas lowest green fodder yield 82.87 t/ha was recorded in 80 Gy compared to the control 89.54 t/ha. In FP-553, lowest green fodder yield of 78.36 t/ha was recorded in mutants from 100 Gy and highest green fodder yield of 94.10 t/ha was recorded in mutants from 80 Gy followed by 60 Gy (82.66 t/ha) and control plants (80.77 t/ha). In the genotype MS-4600, the control plants recorded highest green fodder yield of 126.36 t/ha whereas the irradiation treatment with 80 Gy recorded a lowest green fodder yield of 86.03 t/ha. The mutants from 60 Gy and 100 Gy recorded 103.68 t/ha and 110.31 t/ha respectively. In the genotype MS-4690, the highest green fodder yield of 117.86 t/ha was recorded in mutants from 60 Gy followed by 100 Gy and 80 Gy with 110.81 t/ha and 72.14 t/ha respectively. Lowest green fodder yield of 62.30 t/ha was recorded in control plants. In PGG-208, the maximum green fodder yield of 128.62 t/ha was recorded in mutants from 60 Gy which was significantly different from other gamma ray doses. Mutants from 80 Gy and 100 Gy recorded green fodder yield of 79.20 t/ha and 95.01 t/ha respectively. Control plants recorded green fodder yield of 88.72 t/ha.

4.3.2.6. *Dry fodder yield* (t/ha)

The data presented in Table 53 revealed that there was a significant effect of treatment doses and genotypes on dry fodder yield. The lowest dry fodder yield 23.16 t/ha was recorded in control plants. The highest dry fodder yield was recorded in 60 Gy (28.33 t/ha) followed by 100 Gy (26.67 t/ha) and 80 Gy (26.44 t/ha) respectively. In case of FP-553, the highest dry fodder yield of 28.12 t/ha was recorded in mutants from 80 Gy whereas lowest dry fodder yield of 20.85

t/ha was recorded in mutants from 100 Gy followed by 60 Gy with 22.63 t/ha. Control plants recorded 22.90 t/ha dry fodder yield. In MS-4600, highest dry fodder yield (31.98 t/ha) was recorded in mutants from 100 Gy followed by 60 Gy and 80 Gy with 28.17 t/ha and 22.36 t/ha respectively. Dry fodder yield of 30.92 t/ha was recorded in control plants. In MS-4690, the maximum dry fodder yield of 33.34 t/ha was recorded in mutants from 80 Gy followed by 100 Gy and 60 Gy with 27.02 t/ha and 26.40 t/ha respectively whereas the lowest dry fodder yield 17.21 t/ha was recorded in control plants. In case of PGG-208, the lowest dry fodder yield of 21.63 t/ha was recorded in control plants. Highest dry fodder yield of 36.14 t/ha was recorded in mutants from 60 Gy which was significantly different from other treatments. Mutants from 80 Gy and 100 Gy recorded dry fodder yield of 21.95 t/ha and 26.82 t/ha respectively.

4.3.27. *Number of leaves hill^{-1}*

The data pertaining to this attribute has been presented in Table 54 and an appraisal of the data elucidates that gamma ray treatment had a significant effect on number of leaves hill^{-1} in all the genotypes of guinea grass. Among the different treatments, minimum number of leaves hill^{-1} was 149.96, recorded in control plants, while the maximum number of leaves hill^{-1} (188.16) was with 100 Gy followed by 60 Gy (181.81) and 80 Gy (150.50) which was slightly higher than control plants. In FP-553 among the different treatments maximum number of leaves hill^{-1} (175.39) was recorded in mutants from 60 Gy followed by mutants from 100 Gy (163.79) and 80 Gy (159.20) whereas minimum number of leaves hill^{-1} of 131.25 was recorded in control plants. In the genotype MS-4600, the maximum number of leaves hill^{-1} (211.54) was recorded in mutants from 100 Gy followed by mutants from 60 Gy and 80 Gy with 168.84 and 156.87 respectively. Number of leaves hill^{-1} of 185.00 was recorded in control plants. In MS-4690, the minimum number of leaves hill^{-1} (159.46) was recorded in control plants whereas maximum number of leaves hill^{-1} (219.65) was recorded in mutants from 60 Gy which was significantly different from other gamma ray doses. Mutants from 80 Gy and 100 Gy recorded 162.78 and 188.26 number of leaves hill^{-1}. In the

Table 54. Mean performance of number of leaves hill^{-1} in M_2 generation

Variety	Number of leaves hill^{-1}			
	Control	60 Gy	80 Gy	100 Gy
FP-553	131.25	175.39	159.20	163.79
MS-4600	185.00	168.84	156.87	211.54
MS-4690	159.46	219.65	162.78	188.26
PGG-208	124.12	163.36	123.17	189.07
Mean	149.96	181.81	150.50	188.16
	CD at 5%		SE±	
Variety (V)	5.49		1.89	
Treatments (T)	5.49		1.89	
V*T	10.99		3.78	

Table 55. Mean performance of leaf stem ratio in M_2 generation

Variety	Leaf stem ratio			
	Control	60 Gy	80 Gy	100 Gy
FP-553	0.71	0.76	0.95	0.81
MS-4600	0.84	0.77	0.70	0.84
MS-4690	0.77	0.81	0.73	0.86
PGG-208	0.67	0.74	0.71	0.80
Mean	0.75	0.77	0.77	0.82
	CD at 5%		SE±	
Variety (V)	0.03		0.01	
Treatments (T)	0.03		0.01	
V*T	0.07		0.02	

Table 56. Mean performance of leaf length (cm) in M_2 generation

Variety	Leaf length (cm)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	61.02	55.59	62.86	72.81
MS-4600	72.06	59.64	69.29	79.94
MS-4690	66.80	61.46	55.81	66.60
PGG-208	75.75	63.83	81.64	72.00
Mean	68.91	60.13	67.40	72.83
	CD at 5%		SE±	
Variety (V)	3.39		1.17	
Treatments (T)	3.39		1.17	
V*T	6.79		2.34	

genotype PGG-208, the maximum number of leaves hill^{-1} (189.07) was recorded in mutants from 100 Gy whereas minimum number of leaves hill^{-1} (123.17) was recorded in mutants from 80 Gy followed by 60 Gy and control plants with 163.36 and 124.12 respectively.

4.3.2.8. *Leaf stem ratio*

The perusal of the data on leaf stem ratio indicates that there was increase in leaf stem ratio in treatments of guinea grass over control with increase in doses of gamma rays (Table 55). It is evident from the data that the maximum leaf stem ratio (0.82) was observed in 100 Gy and was significantly different from all the other doses. In 80 Gy and 60 Gy leaf stem ratio of 0.77 were observed. The lowest leaf stem ratio of 0.75 was observed in control plants. Data of genotype FP-553 revealed that among the different gamma ray doses the maximum leaf stem ratio of 0.95 was recorded in mutants from 80 Gy followed by mutants from 100 Gy and 60 Gy with 0.81 and 0.76 respectively. Minimum leaf stem ratio of 0.71 was recorded in control plants. In the genotype MS-4600, the maximum leaf stem ratio of 0.84 was recorded in mutants from 100 Gy followed by 60 Gy with 0.77 and 80 Gy with 0.71 respectively. Leaf stem ratio of 0.84 was recorded in control plants. In MS-4690 among the different treatments, maximum leaf stem ratio of 0.86 was recorded in mutants from 100 Gy whereas minimum leaf stem ratio of 0.73 was recorded in mutants from 80 Gy followed by 60 Gy with 0.81. Control plants recorded 0.77 leaf stem ratio. In PGG-208, among the different gamma ray doses maximum leaf stem ratio of 0.80 in 100 Gy followed by mutants from 60 Gy and 80 Gy with 0.74 and 0.71 respectively. Minimum leaf stem ratio of 0.67 was recorded in control plants.

4.3.2.9. *Leaf length* (cm)

The data pertaining to the field evaluation of gamma rays treatment on the leaf length are presented in Table 56. It is evident from the data that differences for this character was recorded in all the genotypes studied. The data revealed that irrespective of genotypes, plants treated with 100 Gy recorded longest leaf length

(72.83 cm) whereas shortest leaf length was observed in 60 Gy (60.13 cm) followed by 80 Gy (67.40 cm) as compared to control (68.91 cm). In FP-553, highest leaf length of 72.81 cm was recorded in mutants from 100 Gy followed by 80 Gy with 62.86 cm and control plants with 61.02 cm whereas lowest leaf length of 55.59 cm was recorded in mutants from 60 Gy. In the genotype MS-4600, the highest leaf length of 79.94 cm was recorded in mutants from 100 Gy followed by mutants from 80 Gy and 60 Gy with 69.29 cm and 59.64 cm respectively. Control plants recorded 72.06 cm leaf length. In case of MS-4690, control plants recorded highest leaf length of 66.80 cm compared to mutants. Mutants from 60 Gy, 80 Gy and 100 Gy recorded 61.46 cm, 55.81 cm and 66.60 cm leaf length respectively. In PGG-208, highest leaf length of 81.64 cm was recorded in mutants from 80 Gy which was significantly different from other treatments. Control plants recorded 75.75 cm leaf length which was highest compared to mutants from 100 Gy and 60 Gy with 72.00 cm and 63.83 cm respectively.

4.3.2.10. ***Leaf breadth*** **(cm)**

The data presented in Table 57 revealed that there was significant effect of gamma radiations on leaf breadth in the mutants in M_2 generation. A gradual increase in leaf breadth was recorded with gradual increase in the dose of gamma rays. Untreated plants showed the smallest leaf breadth of 2.31 cm. Among the treatments, plants treated with 100 Gy showed the largest leaf breadth 2.52 cm followed by 80 Gy (2.38 cm) and 60 Gy (2.33 cm) respectively. In FP-553 data revealed that among the different gamma ray doses the largest leaf breadth of 2.66 cm was recorded in mutants from 100 Gy followed by mutants from 80 Gy and 60 Gy with 2.33 cm and 2.26 cm respectively whereas smallest leaf breadth of 2.25 cm was recorded in control plants. In MS-4600, among the different treatments largest leaf breadth of 2.65 cm was recorded in mutants from 100 Gy which was significantly different from other gamma ray doses. Mutants from 80 Gy and 60 Gy recorded leaf breadth of 2.40 cm and 2.32 cm, whereas control plants recorded 2.39cm. In MS-4690, data revealed that the largest leaf breadth of 2.49 cm was recorded in mutants from 100 Gy followed by mutants from 60 Gy and 80 Gy

Table 57. Mean performance of leaf breadth (cm) in M_2 generation

Variety	Leaf breadth (cm)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	2.25	2.26	2.33	2.66
MS-4600	2.39	2.32	2.40	2.65
MS-4690	2.27	2.33	2.27	2.49
PGG-208	2.35	2.43	2.51	2.30
Mean	2.31	2.33	2.38	2.52
	CD at 5%		SE±	
Variety (V)	0.05		0.01	
Treatments (T)	0.05		0.01	
V*T	0.10		0.03	

Table 58. Mean performance of leaf area index in M_2 generation

Variety	Leaf area index			
	Control	60 Gy	80 Gy	100 Gy
FP-553	5.31	5.75	8.40	7.88
MS-4600	8.69	9.88	8.25	9.98
MS-4690	6.25	9.85	8.91	6.32
PGG-208	7.61	9.90	7.49	9.49
Mean	6.96	8.84	8.26	8.41
	CD at 5%		SE±	
Variety (V)	1.14		0.39	
Treatments (T)	1.14		0.39	
V*T	2.28		0.78	

Table 59. Mean performance of root length (cm) in M_2 generation

Variety	Root length (cm)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	67.42	72.70	67.11	63.21
MS-4600	66.05	85.57	60.55	65.83
MS-4690	68.55	75.09	65.64	70.62
PGG-208	62.87	67.83	76.86	69.83
Mean	66.22	75.29	67.54	67.37
	CD at 5%		SE±	
Variety (V)	NS		1.19	
Treatments (T)	3.47		1.19	
V*T	6.95		2.39	

with 2.33 cm and 2.27 cm respectively. Leaf breadth of 2.27 cm was recorded in control plants. In PGG-208, among the different gamma ray doses 80 Gy recorded a largest leaf breadth of 2.51 cm followed by mutants 60 Gy and 100 Gy with 2.43 cm and 2.30 cm respectively. Leaf breadth of 2.35 cm was recorded in control plants.

4.3.2.11. *Leaf area index*

The data pertaining to leaf area index in mutants in M_2 generation are presented in Table 58 and leaf area index differed significantly with treatment. Maximum leaf area index 8.84 was found in mutants from 60 Gy followed by 100 Gy (8.41) and 80 Gy (8.26) respectively. Control plants recorded minimum leaf area index of 6.96. In the genotype FP-553, the data revealed that the maximum leaf area index of 8.40 was recorded in mutants from 80 Gy followed by mutants from 100 Gy (7.88) and 60 Gy (5.75) whereas minimum leaf area index of 5.31 was recorded in control plants. In case of MS-4600, data revealed that among the different gamma ray doses the maximum leaf area index of 9.98 was recorded in mutants from 100 Gy which were found to be significantly different from all other treatments. Mutants from 60 Gy and 80 Gy recorded 9.88 and 8.25 leaf area index whereas control plants recorded 8.69. In MS-4690 among the different treatments minimum leaf area index of 6.25 was recorded in control plants. Mutants from 60 Gy recorded maximum leaf area index of 9.85 followed by mutants from 80 Gy (8.91) and 100 Gy (6.32). The leaf area index in PGG-208, among the different gamma ray doses recorded a maximum leaf area index of 9.90 in 60 Gy followed by mutants from 100 Gy and 80 Gy with 9.49 and 7.49 respectively. Control plants recorded 7.61 leaf area index.

4.3.2.12. *Root length* (cm)

The data related to root length have been compiled in Table 59. The data revealed that the effect of gamma rays on root length reduction was significant in all the treatments. A gradual decrease in root length was recorded with gradual increase in the dose of gamma rays. Among the treatments, mutants from 60 Gy showed the longest root length (75.29 cm), whereas mutants from 80 Gy (67.54 cm) and 100 Gy (67.37 cm) showed decline in root length. Control plants had smallest root length, 66.22 cm. In FP-553, among the different treatments longest root length 72.70 cm was recorded in mutants from 60 Gy followed by mutants 80 Gy and 100 Gy with 67.11 cm and 63.21 cm respectively. Control plants recorded root length of 67.42 cm. In genotype MS-4600, data revealed that among the treatments, mutants from 60 Gy recorded longest root length of 85.57 cm which was significantly different from all other treatments. Smallest root length of 60.55 cm was recorded in mutants from 80 Gy, while mutants from 100 Gy and control plants recorded 65.83 cm and 66.05 cm. In MS-4690, among the different treatments, longest root length of 75.09 cm was recorded in mutants from 60 Gy whereas smallest root length of 65.64 was recorded in mutants from 80 Gy followed by 100 Gy with 70.62 cm. In control plants root length recorded 68.55 cm. In the genotype PGG-208 among the different treatments, smallest root length of 62.87 cm was recorded in control plants whereas longest root length of 76.86 cm was recorded in mutants from 80 Gy followed by mutants from 100 Gy and 60 Gy with 69.83 cm and 67.83 cm respectively.

4.3.2.13. *Root spread* (cm)

The data pertaining to root spread in the field evaluation of M_2 generation after gamma ray treatment is presented in Table 60. It is evident from the data that significant differences for this character were recorded in all the treatments studied. Mutants from 100 Gy recorded minimum root spread of 17.27 cm and maximum root spread was recorded in mutants from 60 Gy (19.93 cm) followed by 80 Gy (18.77 cm). Root spread in control plants was 18.92 cm. Higher doses reduced root spread compared to lower doses. In genotype FP-553, the maximum root spread of 21.24 cm was recorded in mutants from 80 Gy followed by mutants from 60 Gy (18.64 cm) and 100 Gy (17.21 cm) respectively. Control plants recorded root spread of 17.52 cm. In MS-4690, data revealed that among the different gamma ray doses maximum root spread of 21.57 cm was recorded in mutants from 60 Gy which were significantly different from all other treatments.

Table 60. Mean performance of root spread (cm) in M_2 generation

Variety	Root spread (cm)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	17.52	18.64	21.24	17.21
MS-4600	20.59	21.48	16.39	18.01
MS-4690	18.82	21.57	18.26	17.17
PGG-208	18.77	18.02	19.20	16.71
Mean	18.92	19.93	18.77	17.27
	CD at 5%		SE±	
Variety (V)	NS		0.54	
Treatments (T)	1.58		0.54	
V*T	3.16		1.09	

Table 61. Mean performance of root dry weight (g) in M_2 generation

Variety	Root dry weight (g)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	80.25	85.92	93.97	86.72
MS-4600	90.13	84.80	95.16	124.74
MS-4690	87.06	92.59	99.25	87.03
PGG-208	92.07	87.11	99.91	86.30
Mean	87.38	87.60	97.07	96.19
	CD at 5%		SE±	
Variety (V)	5.13		1.76	
Treatments (T)	5.13		1.76	
V*T	10.26		3.53	

Table 62. Mean performance of root shoot ratio in M_2 generation

Variety	Root shoot ratio			
	Control	60 Gy	80 Gy	100 Gy
FP-553	0.81	1.17	0.99	0.89
MS-4600	1.03	1.60	1.16	1.43
MS-4690	0.76	0.81	0.98	0.75
PGG-208	0.93	1.15	1.52	0.93
Mean	0.88	1.18	1.16	1.00
	CD at 5%		SE±	
Variety (V)	0.09		0.03	
Treatments (T)	0.09		0.03	
V*T	0.18		0.06	

Mutants from 80 Gy and 100 Gy recorded root spread of 18.26 cm and 17.17 cm respectively which was lower compared to control plants (18.82 cm). In PGG-208, maximum root spread of 19.20 cm was recorded in mutants from 60 Gy and 100 Gy with 18.02 cm and 16.71 cm respectively. Control plants recorded 18.77 cm root spread.

4.3.2.14. *Root dry weight* (g)

The data related to root dry weight is compiled in Table 61. The data revealed that gamma ray treatment had a significant effect on root dry weight. A gradual increase in root dry weight was recorded with gradual increase in the dose of gamma rays. Mutants from 80 Gy produced a root dry weight of 97.07 g which was significantly higher, as compared to root dry weight produced from mutants of 100 Gy (96.19 g) and 60 Gy (97.60 g). Lowest root dry weight was shown by control (87.38 g). In case of FP-553, maximum root dry weight of 93.97 g was produced in mutants from 80 Gy followed by mutants from 100 Gy with 86.72 g and 60 Gy with 85.92 g whereas minimum root dry weight of 80.25 was produced in control plants. In MS-4600, the maximum root dry weight of 124.74 g was recorded in mutants from 100 Gy followed by mutants from 80 Gy and 60 Gy with 95.16 g and 84.80 g respectively. Root dry weight of 90.13 g was produced in control plants. In MS-4690, minimum root dry weight of 87.03 g was recorded in 100 Gy whereas maximum root dry weight of 99.25 g was recorded in mutants from 80 Gy followed by mutants 60 Gy with 92.59 g and control plants with 87.06 g. In PGG-208 maximum root dry weight of 99.91 g was recorded in mutants from 80 Gy followed by mutants from 60 Gy and 100 Gy with 87.11 g and 86.30 g respectively. Control plants recorded 92.07 g root dry weight.

4.3.2.15. *Root shoot ratio*

The data pertaining to the field evaluation of gamma ray mutants from seeds on the root shoot ratio are presented in Table 62. The mutants from 60 Gy produced the highest root shoot ratio (1.18) followed by doses 80 Gy and 100 Gy being 1.16 and 1.00 respectively. The lowest root shoot ratio was recorded in control plants (0.88). In FP-553, the highest root shoot ratio of 1.17 was recorded in mutants from 60 Gy followed by mutants in 80 Gy (0.99) and 100 Gy (0.89) whereas lowest root shoot ratio of 0.81 was recorded in control plants. In MS-4600 mutants from 60 Gy recorded highest root shoot ratio of 1.60 which was significantly different from all other treatments. Mutants from 100 Gy and 80 Gy recorded root shoot ratio of 1.43 and 1.16, while control plants recorded lowest root shoot ratio of 1.03. In MS-4690, the highest root shoot ratio of 0.98 was recorded in mutants from 80 Gy followed by mutants 60 Gy with 0.81and 100 Gy with 0.75 respectively. Root shoot ratio of 0.76 was recorded in control plants. In PGG-208 control plants recorded 0.93 root shoot ratio. Mutants from 60 Gy recorded highest root shoot ratio of 1.18 followed by mutants from 80 Gy and 100 Gy with 1.16 and 1.00 respectively.

4.3.2.16. *Crude protein content* (%)

The data described in Table 63 revealed that crude protein content differed significantly with treatment. Plants treated with 80 Gy recorded lowest crude protein content of 11.46 % whereas mutants from 60 Gy produced highest crude protein content of 13.69 % followed by 100 Gy being 12.67 % respectively. Control plants recorded 12.20 % crude protein content. In FP-553, among the different treatments, highest crude protein content 13.46 % was recorded in mutants from 60 Gy followed by mutants 80 Gy (11.57 %) and 100 Gy (10.56 %) respectively. Control plants recorded 11.03 % crude protein content. In the genotype MS-4600, data revealed that among the different treatments, highest crude protein content of 15.15 % was recorded in mutants from 100 Gy which was significantly different from all other treatments. Mutants from 60 Gy and 80 Gy recorded crude protein content of 13.30 % and 12.52 % whereas control plants recorded 13.22 %. In MS-4690, control plants recorded 12.08 % crude protein content. Mutants from 60 Gy recorded highest crude protein content of 13.39 % followed by mutants 100 Gy and 60 Gy with 12.46 % and 11.16 % respectively. In PGG-208, among the different treatments highest crude protein content 14.60 % was recorded in mutants from 60 Gy followed by mutants from 80 Gy and 100

Table 63. Mean performance of crude protein content (%) in M_2 generation

Variety	Crude protein content (%)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	11.03	13.46	11.57	10.56
MS-4600	13.22	13.30	12.52	15.15
MS-4690	12.08	13.39	11.16	12.46
PGG-208	12.50	14.60	10.62	12.49
Mean	12.20	13.69	11.46	12.67
	CD at 5%		SE±	
Variety (V)	1.23		0.42	
Treatments (T)	1.23		0.42	
V*T	NS		0.85	

Table 64. Mean performance of crude fibre content (%) in M_2 generation

Variety	Crude fibre content (%)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	28.48	25.18	31.45	26.80
MS-4600	32.67	30.85	31.54	34.59
MS-4690	24.33	28.01	24.13	26.05
PGG-208	32.64	32.26	27.27	34.20
Mean	29.58	29.07	28.60	30.41
	CD at 5%		SE±	
Variety (V)	1.95		0.67	
Treatments (T)	NS		0.67	
V*T	3.91		1.34	

Table 65. Mean performance of gibberellic acid (μg/g) in M_2 generation

Variety	Gibberellic acid (μg /g)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	84.27	83.94	77.59	82.02
MS-4600	41.63	48.89	42.36	39.50
MS-4690	84.07	78.24	83.97	72.01
PGG-208	39.04	48.35	40.92	38.06
Mean	62.25	64.86	61.21	57.89
	CD at 5%		SE±	
Variety (V)	2.37		0.81	
Treatments (T)	2.37		0.81	
V*T	4.74		1.63	

Gy with 10.62 % and 12.49 % respectively. Control plants recorded 12.50 % crude protein content.

4.3.2.17. *Crude fibre content* (%)

Data presented in Table 64 revealed that crude fibre content was significantly different among treatments. Crude fibre content was found to be maximum in plants treated with 100 Gy (30.41 %) whereas minimum crude fibre content was recorded in the dose of 80 Gy (28.60 %) and 60 Gy (29.07 %). Both treatments produced crude fibre content comparable to that of control (29.58 %). In FP-553 minimum crude fibre content 25.18 % was recorded in mutants from 60 Gy and maximum crude fibre content 31.45 % was recorded in mutants from 80 Gy followed by mutants in 100 Gy with 26.80 % and control plants with 28.48 %. Data in MS-4600 revealed that in mutants from different treatments, maximum crude fibre content 34.59 % was recorded in mutants from 100 Gy which was significantly different from all other treatments. Mutants from 80 Gy and 60 Gy recorded 31.54 % and 30.85 % crude fibre content whereas control plants recorded 32.67 %. In MS-4690, maximum crude fibre content 28.01 % was recorded in mutants from 60 Gy followed by mutants from 100 Gy (26.05 %) and 80 Gy (24.13 %) respectively. Control plants recorded 24.33 % crude fibre content. In PGG-208 maximum crude fibre content 34.20 % was recorded in mutants from 100 Gy. Mutants from 60 Gy and 80 Gy recorded 32.26 % and 27.27 % which was lower compared to control plants with 32.64 % crude fibre content.

4.3.2.18. *Gibberellic acid content* (µg/g)

The data related to gibberellic acid content is compiled in Table 65. The data shows that the effect of gamma rays on gibberellic acid content was highly significant between the control and the mutants. Among the treatments plants treated with 100 Gy produced minimum gibberellic acid content of 57.59 µg/g whereas the irradiation treatment with 60 Gy recorded maximum gibberellic acid content of 64.86 µg/g followed by plants treated with 80 Gy of 61.21 µg/g.

Table 66. Effect of gamma rays on germination and spectrum of chlorophyll mutants in M_1V_2 generation

Accessions	Doses	Regeneration / 100 slips	Survival of seedlings	Plant reduction on 30 day	Mutant seedlings	Mutagenic effectiveness	Mutagenic efficiency
FP-553	Control	97	97	-	-	-	-
	20Gy	94	69	25	5	2.50	0.20
	40Gy	87	58	29	7	1.75	0.24
	60Gy	79	44	35	10	1.67	0.37
MS-4600	Control	99	99	-	-	-	-
	20Gy	97	76	21	6	3.00	0.29
	40Gy	88	60	28	11	2.75	0.39
	60Gy	77	41	36	16	2.67	0.44
MS-4690	Control	98	98	-	-	-	-
	20Gy	95	73	22	5	2.50	0.23
	40Gy	90	63	27	7	1.75	0.26
	60Gy	75	38	37	10	1.67	0.27
PGG-208	Control	100	100	-	-	-	-
	20Gy	98	78	20	6	3.00	0.30
	40Gy	90	64	24	9	2.25	0.35
	60Gy	80	46	34	13	2.17	0.38

Control plants recorded gibberellic acid content of 62.25 μg/g. In the genotype FP-553, control plants recorded maximum gibberellic acid content of 84.27 μg/g whereas minimum gibberellic acid content of 77.59 μg/g was recorded in mutants from 80 Gy followed by mutants 100 Gy and 60 Gy with 82.02 μg/g and 83.94 μg/g respectively. In MS-4600, among different gamma ray doses, minimum gibberellic acid content of 39.50 μg/g was recorded in mutants from 100 Gy followed by mutants from 80 Gy with 42.36 μg/g and 60 Gy with 48.89 μg/g respectively. Control plants recorded 41.63 μg/g gibberellic acid content. In the genotype MS-4690, control plants recorded maximum gibberellic acid content of 84.07 μg/g whereas minimum gibberellic acid content of 72.01 μg/g was recorded in mutants from 100 Gy followed by mutants from 60 Gy and 80 Gy with 78.24 μg/g and 83.97 μg/g respectively. In PGG-208, there was a significant difference in gibberellic acid content between the mutants and control plants. Mutants from 100 Gy recorded minimum gibberellic acid content of 38.06 μg/g which were significantly different from all other treatments. Mutants from 60 Gy and 80 Gy recorded 48.35 μg/g and 40.92 μg/g respectively whereas control plants recorded 39.04 μg/g gibberellic acid content.

4.3.1 Study of M_1V_2 generation

4.3.1.1. *Spectrum of chlorophyll mutants*

Among the treatments, the 100 Gy gamma rays produced high frequency of albino (Table 66). Next common chlorophyll mutant observed was viridis in all genotypes. Xantha mutants were less frequent and found only in 80 Gy and 100 Gy treatments. The frequency of chlorophyll mutations varied with the genotype as well as mutagen doses in M_2 generation. Total frequency of chlorophyll mutations was relatively higher in MS-4600 and PGG-208.

4.3.1.2. *Mutagenic effectiveness and efficiency*

Mutagenic effectiveness and efficiency (mutations per unit dose) varies with doses in different genotypes given in Table 66. It was also observed that, the

Table 67. Analysis of variance of M_1V_2 generation from slips

Source of Variation	D.F	Plant height (cm)	Length of internode (cm)	Number of tillers $hill^{-1}$	Days to flowering	Green fodder yield (t/ha)	Dry fodder yield (t/ha)	Number of leaves $hill^{-1}$	Leaf stem ratio	Leaf length (cm)
Treatment	3	3527.03**	180.15**	157.68**	455.90**	4034.35**	319.76**	3450.19**	0.043**	81.48**
Variety	3	333.82	180.01**	162.74**	617.16**	2622.76**	121.69**	1754.01**	0.007**	261.67**
T x V	9	651.86*	31.91**	37.32**	28.65**	678.01**	70.42**	952.41**	0.008**	109.55**
Error	30	217.43	7.22	7.89	8.96	19.13	5.90	32.00	0.001	13.85

Source of Variation	D.F	Leaf breadth (cm)	Leaf area index	Root length (cm)	Root spread (cm)	Root dry weight (g)	Root shoot ratio	Crude protein content (%)	Crude fibre content (%)	Gibberellic acid (µg/g)
Treatment	3	0.193**	18.85**	238.85**	8.32	160.09**	0.035**	18.26**	22.34*	222.65**
Variety	3	0.186**	9.14**	50.86*	13.81*	109.55**	0.080**	12.36**	56.72**	4867.34**
T x V	9	0.121**	3.09**	76.30**	10.01**	84.06**	0.051**	6.25**	16.54*	51.37**
Error	30	0.004	0.934	13.98	3.17	8.68	0.002	1.29	5.67	7.50

mutagenic efficiency was lowest at 100 Gy dose in all genotypes, because percentage survival reduction was observed in 100 Gy dose followed by 80 Gy dose which resulted in decrease in the mutagenic efficiency in 100 Gy and 80 Gy doses. In MS-4600, maximum mutagenic efficiency was recorded in 100 Gy dose (0.44) followed by 80 Gy dose (0.39)

4.3.3 Effect of gamma radiation on morphological characters of mutants from slips

The observations on gamma ray mutants from slips in M_1V_2 generation are presented below. The results of statistical analysis for different characters are presented in Table 67. The table confirms that the treatments related to plant height (cm), length of internode (cm), number of tillers hill^{-1}, days to flowering, green fodder yield (t/ha), dry fodder yield (t/ha), number of leaves hill^{-1}, leaf length (cm), leaf breadth (cm), leaf area index, root length (cm), root dry weight (g), root shoot ratio, crude protein content (%), crude fibre content (%) and gibberellic acid were significantly different from one another except root spread (cm). Interaction effect between treatment and variety was also found to be significant for all characters at 5% level of significance.

4.3.3.1. *Plant height* (cm)

Data pertaining to plant height in Table 68 revealed that plant height was significantly different between treatments. A gradual increase in plant height was recorded with gradual increase in dose of gamma rays. Control plants showed a height of 159.26 cm which is lesser than treated plants. Among the treatments, mutants from 60 Gy showed the highest height of 195.84 cm, whereas the mutants from doses 40 Gy and 20 Gy recorded 195.22 cm, 180.90 cm respectively. In the genotype FP-553, the highest plants of 199.09 cm was recorded in mutants from 40 Gy followed by mutants from 20 Gy and 60 Gy with 180.30 cm and 176.78 cm respectively. Control plants recorded lowest plants height of 151.67 cm. In case of MS-4600, the highest plant height of 214.73 cm was recorded in mutants from 40 Gy which was significantly different from all other treatments. Mutants from 60

Table 68. Mean performance of plant height (cm) in M_1V_2 generation

Variety	Plant height (cm)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	151.67	180.30	199.09	176.78
MS-4600	170.28	176.78	214.73	193.54
MS-4690	148.94	195.83	170.40	205.49
PGG-208	166.16	170.71	196.66	207.54
Mean	159.26	180.90	195.22	195.84
	CD at 5%		SE±	
Variety (V)	NS		4.25	
Treatments (T)	12.35		4.25	
V*T	24.70		8.51	

Table 69. Mean performance of length of internode (cm) in M_1V_2 generation

Variety	Length of internode (cm)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	26.94	24.33	26.80	30.57
MS-4600	27.95	26.51	30.28	37.84
MS-4690	25.69	35.21	28.30	33.70
PGG-208	29.92	33.93	37.38	44.80
Mean	27.63	29.99	30.69	36.73
	CD at 5%		SE±	
Variety (V)	2.25		0.77	
Treatments (T)	2.25		0.77	
V*T	4.50		1.55	

Table 70. Mean performance of number of tillers $hill^{-1}$ in M_1V_2 generation

Variety	Number of tillers $hill^{-1}$			
	Control	20 Gy	40 Gy	60 Gy
FP-553	23.94	28.51	24.29	31.22
MS-4600	36.26	26.39	32.12	41.80
MS-4690	27.82	32.89	28.41	32.96
PGG-208	31.08	31.06	35.32	42.80
Mean	29.78	29.79	30.03	37.11
	CD at 5%		SE±	
Variety (V)	2.35		0.81	
Treatments (T)	2.35		0.81	
V*T	4.70		1.62	

Gy and 20 Gy recorded 193.54 cm and 176.78 cm whereas lowest plant height of 170.28 cm was recorded in control plants. In MS-4690, the highest plant height of 205.49 cm was recorded in mutants from 60 Gy whereas lowest plant height of 148.94 cm was recorded in control plants. Mutants from 20 Gy and 40 Gy recorded 195.83 cm and 170.40 cm respectively. In the genotype PGG-208, the highest plant height of 207.54 cm was recorded in mutants from 60 Gy followed by mutants from 40 Gy and 20 Gy with 196.66 cm and 170.71 cm respectively. Lowest plant height of 166.16 cm was recorded in control plants.

4.3.3.2. ***Length of internode*** **(cm)**

The data pertaining to length of internode of M_1V_2 gamma ray mutants is presented in Table 69. It is evident from the data that significant differences for this character were recorded in all the genotypes studied. Control plants observed the lowest length of internode 27.63 cm as compared to mutants. Mutants from 60 Gy observed highest length of internode 36.73cm followed by mutants from 40 Gy and 20 Gy being 30.69 cm and 29.99 cm respectively. FP-553 showed significance difference in length of internode between the control plants and mutants. Mutants from 60 Gy observed highest length of internode (30.57 cm) followed by mutants from 40 Gy and 20 Gy with 26.80 cm and 24.33 cm respectively. Control plants observed 26.94 cm internode length. In MS-4600, mutants from 60 Gy observed highest internode length of 37.84 cm followed by mutants from 40 Gy with 30.28 cm and 20 Gy with 26.51 cm whereas control plants observed 27.95 cm. In the genotype MS-4690, the lowest length of internode 25.69 cm was observed in control plants whereas highest length of internode 35.21 cm was observed in mutants from 20 Gy followed by mutants 40 Gy (28.30 cm) and 60 Gy (33.70 cm). In case of PGG-208, the highest length of internode 44.80 cm was observed in mutants from 60 Gy followed by mutants from 40 Gy and 20 Gy with 35.32 cm and 31.06 cm respectively. Control plants observed 31.08 cm length.

4.3.3.3. *Number of tillers hill^{-1}*

The data pertaining to this attribute has been presented in Table 70 and an estimate of the data revealed that gamma ray treatment had a significant effect on number of tillers hill^{-1} over the control in all the genotypes. Among the different gamma ray doses, maximum number of tillers hill^{-1} (37.11) was produced in mutants from 60 Gy which was found to be significantly different from all other treatments, while minimum number of tillers hill^{-1} (27.63) was produced in control. Mutants from 40 Gy and 20 Gy had tillers hill^{-1} as 30.03 and 29.99 respectively. In FP-553, minimum number of tillers hill^{-1} (23.94) was produced in control plants whereas maximum number of tillers hill^{-1} (31.22) was produced in mutants from 60 Gy followed by mutants from 20 Gy (28.51) and 40 Gy (24.29). Data in MS-4600 revealed that mutants from different treatments, maximum number of tillers hill^{-1} (41.80) was produced in mutants from 60 Gy whereas minimum number of tillers hill^{-1} (26.39) produced in mutants from 20 Gy followed by 40 Gy and control plants with 32.12 and 36.26 respectively. In MS-4690 maximum number of tillers hill^{-1} (32.96) was produced in mutants from 60 Gy followed by mutants 20 Gy and 40 Gy with 32.89 and 28.41 respectively. Control plants produced minimum numbers of tillers hill^{-1} (27.82). In PGG-208 maximum number of tillers hill^{-1} (42.80) was produced in mutants from 60 Gy which was significantly different from other treatments. Mutants from 40 Gy and 20 Gy produced 35.32 and 31.06 tillers hill^{-1}. Control plants produced 31.08 tillers hill^{-1}.

4.3.3.4. *Days to flowering*

The data pertaining to this attribute has been presented in Table 71. The data revealed that gamma ray treatment delayed flowering significantly in all the guinea grass genotypes. Among the gamma ray treatments highest days to flowering (48.83) were observed in mutants from 60 Gy which was found to be significantly different from all other treatments, followed by mutants from 40 Gy and 20 Gy being 38.48 days and 37.25 days respectively. A lowest day to

Table 71. Mean performance of days to flowering in M_1V_2 generation

Variety	Days to flowering			
	Control	20 Gy	40 Gy	60 Gy
FP-553	30.41	30.07	33.25	36.27
MS-4600	38.39	41.60	43.22	58.20
MS-4690	29.48	35.46	32.30	42.58
PGG-208	41.23	41.88	45.17	58.27
Mean	34.88	37.25	38.48	48.83
	CD at 5%		SE±	
Variety (V)	2.50		0.86	
Treatments (T)	2.50		0.86	
V*T	5.01		1.72	

Table 72. Mean performance of green fodder yield (t/ha) in M_1V_2 generation

Variety	Green fodder yield (t/ha)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	86.07	84.46	82.44	99.83
MS-4600	129.52	85.09	95.13	140.75
MS-4690	62.52	69.23	91.54	104.02
PGG-208	91.80	81.59	106.80	148.79
Mean	92.48	80.09	93.98	123.34
	CD at 5%		SE±	
Variety (V)	3.66		1.26	
Treatments (T)	3.66		1.26	
V*T	7.33		2.52	

Table 73. Mean performance of dry fodder yield (t/ha) in M_1V_2 generation

Variety	Dry fodder yield (t/ha)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	22.88	25.50	22.58	28.92
MS-4600	34.59	22.43	26.39	39.61
MS-4690	18.42	23.26	31.57	31.78
PGG-208	25.73	24.17	33.78	41.62
Mean	25.41	23.84	28.58	35.48
	CD at 5%		SE±	
Variety (V)	2.02		0.70	
Treatments (T)	2.02		0.70	
V*T	4.07		1.40	

flowering 34.88 was observed in control plants. In FP-553, data revealed that the highest days to flowering 36.27 was observed in mutants from 60 Gy and lowest days to flowering 30.07 was observed in mutants from 20 Gy followed by control plants and 40 Gy with 30.41 and 33.25 respectively. In MS-4600, among the different gamma ray doses the highest days to flowering (58.20) was observed in mutants from 60 Gy which was significantly different from other treatments. Mutants from 40 Gy and 20 Gy observed 43.22 and 41.60 days to flowering whereas lowest days to flowering 38.39 were observed in control plants. In MS-4690 among the different treatments lowest days to flowering 29.48 was observed in control plants. Highest days to flowering 42.58 were observed in mutants from 60 Gy followed by 20 Gy and 40 Gy with 35.46 and 32.30 respectively. In PGG-208 among the different gamma ray doses highest days to flowering (58.27) was observed in mutants from 60 Gy which was significantly different from all other treatments. Mutants from 40 Gy and 20 Gy observed 45.17 and 41.88 days to flowering whereas lowest days to flowering (41.23) were observed in control plants.

4.3.3.5. *Green fodder yield* (t/ha)

The data related to green fodder yield is presented in Table 72. It is evident from the data that significant differences for this character was recorded in all the genotypes used. Data revealed that among the different gamma ray doses, highest green fodder yield (123.34 t/ha) was recorded in mutants from 60 Gy which was found to be significantly different from all other treatments, while lowest green fodder yields 80.09 t/ha was recorded with 20 Gy. Control plants recorded 92.48 t/ha and mutants from 40 Gy produced 93.98 t/ha which was slightly higher than control. In the genotype FP-553, among the different treatments, highest green fodder yield of 99.83 t/ha was recorded in mutants from 60 Gy whereas lowest green fodder yield of 82.44 t/ha was recorded in mutants from 40 Gy followed by 20 Gy with 84.46 t/ha and control plants with 86.07 t/ha respectively. In MS-4600, data revealed that among the different treatments, highest green fodder yield (140.75 t/ha) was recorded in mutants from 60 Gy followed by mutants 20 Gy and 40 Gy with 84.46 t/ha and 82.44 t/ha respectively. Control plants recorded 129.52 t/ha green fodder yield. In MS-4690 mutants from 60 Gy recorded highest green fodder yield of 104.02 t/ha whereas lowest green fodder yield of 62.52 t/ha was recorded in control plants followed by mutants from 20 Gy and 40 Gy with 69.23 t/ha and 91.54 t/ha respectively. In PGG-208 among the different treatments highest green fodder yield of 148.79 was recorded in mutants from 60 Gy which was significantly different from other treatments. Mutants from 20 Gy and 40 Gy recorded 81.59 t/ha and 106.80 t/ha respectively whereas control plants recorded 92.48 t/ha green fodder yield.

4.3.3.6. *Dry fodder yield* (t/ha)

The data pertaining to dry fodder yield is consolidated in Table 73. The data revealed significant difference for this character in all the genotypes. Control plants produced 25.41 t/ha dry fodder yield. The mutants from 60 Gy recorded maximum dry fodder yield of 35.48 t/ha followed by mutants from 40 Gy with 28.58 t/ha. Minimum dry fodder yield was recorded in mutants from 20 Gy being 23.84 t/ha. This shows that exposure of gamma rays increased the dry fodder yield significantly in almost all the genotypes. In FP-553, maximum dry fodder yield of 28.92 t/ha was recorded in mutants from 60 Gy and minimum dry fodder yield of 22.58 t/ha was recorded in mutants from 40 Gy followed by control plants and mutants from 20 Gy with 22.88 t/ha and 25.50 t/ha respectively. In the genotype MS-4600, the maximum dry fodder yield of 39.61 t/ha was recorded in mutants from 60 Gy. Control plants recorded 34.59 t/ha dry fodder yield which was higher than mutants from 40 Gy (26.39 t/ha) and 20 Gy (22.39 t/ha) respectively. In MS-4690, among the different gamma ray doses, maximum dry fodder yield of 31.78 t/ha was recorded in mutants from 60 Gy followed by 40 Gy with 31.57 t/ha and 20 Gy with 23.26 t/ha whereas minimum dry fodder yield of 18.42 t/ha was recorded in control plants. In case of PGG-208, maximum dry fodder yield of 41.62 t/ha was recorded in mutants from 60 Gy which was significantly different from all other treatments. Mutants from 20 Gy and 40 Gy recorded dry fodder yield of 24.17 t/ha and 33.78 t/ha whereas control plants recorded 25.73 t/ha.

Table 74. Mean performance of number of leaves hill^{-1} in M_1V_2 generation

Variety	Number of leaves hill^{-1}			
	Control	20 Gy	40 Gy	60 Gy
FP-553	136.00	151.18	143.21	170.41
MS-4600	186.13	149.82	164.73	203.41
MS-4690	149.74	159.17	184.87	167.35
PGG-208	141.93	157.35	185.24	217.48
Mean	153.45	154.38	169.51	189.66
	CD at 5%		SE±	
Variety (V)	4.73		1.63	
Treatments (T)	4.73		1.63	
V*T	9.47		3.26	

Table 75. Mean performance of leaf stem ratio in M_1V_2 generation

Variety	Leaf stem ratio			
	Control	20 Gy	40 Gy	60 Gy
FP-553	0.69	0.71	0.77	0.84
MS-4600	0.77	0.75	0.79	0.90
MS-4690	0.71	0.85	0.71	0.82
PGG-208	0.68	0.68	0.78	0.86
Mean	0.71	0.75	0.76	0.85
	CD at 5%		SE±	
Variety (V)	0.03		0.01	
Treatments (T)	0.03		0.01	
V*T	0.06		0.02	

Table 76. Mean performance of leaf length (cm) in M_1V_2 generation

Variety	Leaf length (cm)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	61.57	69.86	62.29	65.33
MS-4600	70.85	75.72	70.99	80.47
MS-4690	62.65	67.46	71.99	63.42
PGG-208	74.83	63.09	67.55	83.95
Mean	67.47	69.03	68.21	73.29
	CD at 5%		SE±	
Variety (V)	3.11		1.07	
Treatments (T)	3.11		1.07	
V*T	6.23		2.14	

4.3.3.7. *Number of tillers hill^{-1}*

The data presented in Table 74 revealed that there was significant effect of gamma radiation and genotypes on the number of leaves hill^{-1} with the exposure of plants to gamma rays, a gradual increase in number of leaves hill^{-1} was recorded with gradual increase in dose. The maximum number of leaves hill^{-1} 189.66 was produced in mutants from 60 Gy followed by mutants from 40 Gy and 20 Gy with 169.51 and 154.38 respectively. Minimum number of leaves hill^{-1} 153.45 was produced in control plants. In the genotype FP-553, among the different treatments maximum number of leaves hill^{-1} (170.41) was produced in mutants from 60 Gy followed by 20 Gy and 40 Gy with 151.18 and 143.21 respectively. Minimum number of leaves hill^{-1} 136.00 was produced in control plants. In MS-4600, the maximum number of leaves hill^{-1} (203.41) was produced in mutants from 60 Gy followed by mutants 40 Gy (164.73) and 20 Gy (149.82) respectively. Control plants produced 186.13 numbers of leaves hill^{-1}. In case of MS-4690, among the different gamma ray doses maximum number of leaves hill^{-1} 184.87 was produced in mutants from 40 Gy whereas minimum number of leaves hill^{-1} 149.93 was produced in control plants. Mutants from 20 Gy and 60 Gy produced 159.17 and 167.35 number of leaves hill^{-1} respectively. In PGG-208 among the different gamma ray doses maximum number of leaves hill^{-1} 217.48 was produced in mutants from 60 Gy which was significantly different from all other treatments. Mutants from 20 Gy and 40 Gy produced 157.35 and 185.24 number of leaves whereas minimum number of leaves hill^{-1} 141.93 was produced in control plants.

4.3.3.8. *Leaf stem ratio*

Observations on leaf stem ratio were recorded at maturity and the data is compiled in Table 75. The effect of gamma rays on leaf stem ratio was found to be significant between mutant and control plants. Control plants recorded the lowest leaf stem ratio 0.71 as compared to mutants. Mutants from 60 Gy treatment recorded highest leaf stem ratio of 0.85 followed by mutants from 40 Gy (0.76) and 20 Gy (0.75) respectively. Leaf stem ratio increased with increase in dose of gamma rays. In FP-553 data revealed that the highest leaf stem ratio 0.84 was recorded in mutants from 60 Gy followed by mutants from 40 Gy and 20 Gy with 0.77 and 0.71 respectively. Lowest leaf stem ratio of 0.69 was recorded in control plants. In MS-4600 among the different gamma ray doses the highest leaf stem ratio 0.90 was recorded in mutants from 60 Gy which was significantly different from all other treatments. Mutants from 20 Gy and 40 Gy recorded 0.75 and 0.79 leaf stem ratio. Control plants recorded 0.77 leaf stem ratio. In MS-4690, among the different gamma ray doses highest leaf stem ratio of 0.85 was recorded in mutants from 20 Gy followed by 60 Gy and 40 Gy with 0.82 and 0.71 respectively. Control plants recorded leaf stem ratio 0.71. In the genotype PGG-208, among different gamma ray doses highest leaf stem ratio of 0.86 was recorded in mutants from 60 Gy followed by mutants from 40 Gy and 20 Gy with 0.78 and 0.68 respectively. Leaf stem ratio of 0.68 was recorded in control plants.

4.3.3.9. *Leaf length* (cm)

The data depicted in Table 76 explained that leaf length differed significantly with treatment. Maximum leaf length 73.29 cm was found in mutants from 60 Gy followed by 20 Gy having 69.03 cm and 40 Gy with 68.21 cm respectively. Minimum leaf length 67.47 cm was found in control plants. In FP-553 control plants showed minimum leaf length of 61.57 cm. Maximum leaf length 69.86 cm was recorded in mutants from 20 Gy followed by 60 Gy and 40 Gy with 65.33 cm and 62.29 cm respectively. In MS-4600, mutants from 60 Gy recorded maximum leaf length of 80.47 cm whereas minimum leaf length of 70.85 cm was recorded in control plants. Mutants from 20 Gy and 40 Gy recorded leaf length of 75.72 cm and 70.99 cm respectively. In the genotype MS-4690, control plants recorded minimum leaf length of 62.65 cm compared to mutants. Mutants from 40 Gy recorded maximum leaf length of 71.99 cm followed by mutants 20 Gy and 60 Gy with 67.46 cm and 63.42 cm respectively. In PGG-208 among the different gamma ray doses maximum leaf length of 83.95 cm was recorded in mutants from 60 Gy which was significantly different from all other

Table 77. Mean performance of leaf breadth (cm) in M_1V_2 generation

Variety	Leaf breadth (cm)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	2.22	2.54	2.62	2.36
MS-4600	2.46	2.46	2.57	2.94
MS-4690	2.26	2.26	2.60	2.30
PGG-208	2.43	2.61	2.38	2.98
Mean	2.34	2.47	2.54	2.64
	CD at 5%		SE±	
Variety (V)	0.05		0.01	
Treatments (T)	0.05		0.01	
V*T	0.10		0.03	

Table 78. Mean performance of leaf area index in M_1V_2 generation

Variety	Leaf area index			
	Control	20 Gy	40 Gy	60 Gy
FP-553	6.34	8.64	6.32	9.09
MS-4600	8.64	8.50	9.26	10.01
MS-4690	6.68	6.87	8.44	9.72
PGG-208	7.10	8.00	9.35	9.95
Mean	7.19	8.00	8.34	9.69
	CD at 5%		SE±	
Variety (V)	0.81		0.27	
Treatments (T)	0.81		0.27	
V*T	1.62		0.55	

Table 79. Mean performance of root length (cm) in M_1V_2 generation

Variety	Root length (cm)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	64 .01	66.03	74.14	71.42
MS-4600	67.16	71.03	74.07	81.68
MS-4690	71.46	76.02	72.76	68.83
PGG-208	62.67	69.48	74.84	84.79
Mean	66.32	70.64	73.95	76.68
	CD at 5%		SE±	
Variety (V)	3.13		1.07	
Treatments (T)	3.13		1.07	
V*T	6.26		2.15	

treatments. Control plants recorded leaf length of 74.83 cm which was higher than mutants from 20 Gy (63.09 cm) and 40 Gy (67.55 cm).

4.3.3.10. *Leaf breadth* (cm)

The data pertaining to leaf breadth in M_1V_2 is presented in Table 77. A gradual increase in leaf breadth was recorded with gradual increase in the dose of gamma rays. Control plants showed the lowest leaf breadth of 2.34 cm. Among the treatments, mutants from 60 Gy showed the highest leaf breadth of 2.64 cm followed by mutants from 40 Gy and 20 Gy with 2.54 cm and 2.47 cm respectively. In the genotype FP-553, highest leaf breadth of 2.62 cm was showed in mutants from 40 Gy whereas lowest leaf breadth of 2.22 cm was showed in control plants. Mutants from 20 Gy and 60 Gy showed leaf breadth of 2.54 cm and 2.36 cm respectively. In case of MS-4600 highest leaf breadth 2.94 cm was shown in mutants from 60 Gy followed by mutants from 40 Gy with 2.57 cm and mutants from 20 Gy with 2.46 cm. Control plants showed leaf breadth of 2.46 cm. In MS-4690 highest leaf breadth of 2.60 cm was showed in mutants from 40 Gy followed by mutants 60 Gy and 20 Gy with 2.30 cm and 2.26 cm respectively. Control plants showed 2.26 cm leaf breadth. In PGG-208, the lowest leaf breadth of 2.38 cm was showed in mutants from 40 Gy and highest leaf breadth of 2.98 cm was shown in mutants from 60 Gy which was significantly different from other treatments. Mutants from 20 Gy showed 2.61 cm whereas control plants showed 2.43 cm leaf breadth.

4.3.3.11. *Leaf area index*

The data related to leaf area index in M_1V_2 is presented in Table 78. A gradual increase in leaf breadth was recorded with gradual increase in the dose of gamma rays. Control plants observed significantly lowest leaf area index 7.19 whereas the mutants from gamma ray dose, 60 Gy observed the highest leaf area index 9.69 followed by mutants from 40 Gy and 20 Gy with 8.34 and 8.00 respectively. In FP-553 among the different gamma ray doses highest leaf area index 9.09 was observed in mutants from 60 Gy followed by mutants 20 Gy and

40 Gy with 8.64 and 6.32 respectively. Leaf area index of 6.34 was observed in control plants. In MS-4600, data revealed that among the different treatments highest leaf area index 10.01 was observed in mutants from 60 Gy followed by mutants from 40 Gy and 20 Gy with 9.26 and 8.50 respectively. Leaf area index of 8.64 was observed in control plants. In MS-4690, control plants recorded lowest leaf area index (6.68) whereas highest leaf area index of 9.72 was observed in mutants from 60 Gy followed by mutants 40 Gy and 20 Gy with 8.44 and 6.87 respectively. In the genotype PGG-208, among the different treatments highest leaf area index of 9.95 was observed in mutants from 60 Gy and lowest leaf area index of 7.10 was observed in control plants. Mutants from 20 Gy and 40 Gy observed leaf area index of 8.00 and 9.35 respectively.

4.3.3.12. *Root length* (cm)

The data related to root length is compiled in Table 79. The data showed that the effect of gamma rays on root length was highly significant between the control plants and mutants. Control plants observed lowest root length of 66.32 cm. Mutants showed a gradual increase in root length as the dose of gamma rays increased. The mutants from 60 Gy observed a root length 76.68 cm whereas in mutants from 40 Gy and 20 Gy it was 73.95 cm and 70.64 cm respectively. In the genotype FP-553 among the different gamma ray doses highest root length of 74.14 cm was observed in mutants from 40 Gy followed by mutants 60 Gy and 20 Gy with 71.42 cm and 66.03 cm respectively. Lowest root length of 64.01 cm was observed in control plants. In the genotype MS-4600, data revealed that among the different treatments, maximum root length of 81.68 cm was observed in mutants from 60 Gy and lowest root length of 67.16 cm was observed in control plants. Mutants from 20 Gy and 40 Gy observed root length of 71.03 cm and 74.07 cm respectively. In MS-4690 among the different gamma ray doses, lowest root length of 68.83 cm was observed in mutants from 60 Gy and highest root length of 76.02 cm was observed in mutants from 20 Gy followed by 40 Gy with 72.76 cm and control plants with 71.46 cm respectively. In PGG-208 data revealed that highest root length of 84.79 cm was observed in mutants from 60 Gy

Table 80. Mean performance of root spread (cm) in M_1V_2 generation

Variety	Root spread (cm)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	17.74	17.21	18.31	16.11
MS-4600	19.74	18.10	16.06	22.33
MS-4690	17.77	20.05	18.54	17.89
PGG-208	19.75	19.66	17.75	22.48
Mean	18.75	18.75	17.66	19.70
	CD at 5%		SE±	
Variety (V)	1.49		0.51	
Treatments (T)	NS		0.51	
V*T	2.98		1.02	

Table 81. Mean performance of root dry weight (g) in M_1V_2 generation

Variety	Root dry weight (g)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	81.71	83.90	80.31	83.02
MS-4600	91.74	81.04	86.05	95.47
MS-4690	85.11	78.96	91.34	81.22
PGG-208	88.09	79.37	85.34	98.70
Mean	86.66	80.81	85.76	89.60
	CD at 5%		SE±	
Variety (V)	2.46		0.85	
Treatments (T)	2.46		0.85	
V*T	4.93		1.70	

Table 82. Mean performance of root shoot ratio in M_1V_2 generation

Variety	Root shoot ratio			
	Control	20 Gy	40 Gy	60 Gy
FP-553	0.85	0.74	0.64	0.55
MS-4600	0.90	0.71	0.75	1.02
MS-4690	0.74	0.96	0.69	0.80
PGG-208	0.89	0.77	0.86	1.02
Mean	0.84	0.80	0.73	0.85
	CD at 5%		SE±	
Variety (V)	0.03		0.01	
Treatments (T)	0.03		0.01	
V*T	0.07		0.02	

which was significantly different from all other treatments. Lowest root length of 62.67 cm was observed in control plants. Mutants from 20 Gy and 40 Gy observed root length of 69.48 cm and 74.84 cm respectively.

4.3.3.13. ***Root spread*** **(cm)**

The data corresponding to root spread is compiled in Table 80. The mutants from 40 Gy recorded lowest root spread of 17.66 cm whereas mutants from 60 Gy recorded highest root spread of 19.70 cm. Control plants and mutants from 20 Gy recorded equal root spread of 18.75 cm. In FP-553, the lowest root spread of 16.11 cm was recorded in mutants from 60 Gy whereas highest root spread of 18.31 cm was recorded in mutants from 40 Gy followed mutants 20 Gy with 17.21 cm and control plants with 17.74 cm respectively. In case of MS-4600 data revealed that the highest root spread of 22.33 cm was recorded in mutants from 60 Gy. Control plants recorded 19.74 cm which was higher than mutants from 20 Gy and 40 Gy recorded 18.10 cm and 16.06 cm respectively. In MS-4690 among the different treatments highest root spread of 20.05 cm was recorded in mutants from 20 Gy followed by mutants 40 Gy with 18.54 cm and 60 Gy with 17.89 cm respectively. Lowest root spread of 17.77 cm was recorded in control plants. In PGG-208 highest root spread of 22.48 cm was recorded in mutants from 60 Gy which was significantly different from all other treatments. Mutants from 20 Gy and 40 Gy recorded root spread of 19.66 cm and 17.75 cm respectively. Control plants recorded 19.75 cm root spread.

4.3.3.14. ***Root dry weight*** **(g)**

The data pertaining to this attribute has been presented and an assessment of the data confirmed that gamma ray treatment had a significant effect on root dry weight in all genotypes of guinea grass (Table 81). Among the different treatments, minimum root dry weight 80.81 g was recorded in mutants from 20 Gy which was less compared to the control (86.66 g). Mutants from 60 Gy recorded maximum root dry weight of 89.60 g followed by 40 Gy with 85.76 g. In the genotype FP-553 among the different gamma ray doses maximum root dry weight of 83.90 g was recorded in mutants from 20 Gy followed by mutants 40 Gy (80.31 g) and 60 Gy (83.02 g) respectively. Control plants recorded 81.71 g root dry weight. In the genotype MS-4600, among the different treatments, maximum root dry weight of 95.47 g was recorded in mutants from 60 Gy. Control plants recorded 91.74 g root dry weight which was higher than the mutants from 40 Gy and 20 Gy with 86.05 g and 81.04 g respectively. In MS-4690 data revealed that the maximum root dry weight of 91.34 g was recorded in mutants from 40 Gy and minimum root dry weight of 78.96 g was recorded in mutants 20 Gy followed by 60 Gy with 81.22 g and control plants with 85.11 g respectively. In genotype PGG-208, the maximum root dry weight of 98.70 g was recorded in mutants from 60 Gy followed by mutants from 40 Gy (85.34 g) and 20 Gy (79.37 g) respectively. Control plants recorded 88.09 g root dry weight.

4.3.3.15. *Root shoot ratio*

The data presented in Table 82 showed that root shoot ratio differed significantly in between control and mutant plants. The data revealed that irrespective of genotypes, mutants from 40 Gy observed lowest root shoot ratio of 0.73, whereas mutants from 60 Gy recorded highest root shoot ratio of 0.85 followed by control (0.84) and 20 Gy (0.80) respectively. In the genotype FP-553 among the different gamma ray doses highest root shoot ratio of 0.85 was recorded in control plants. Mutants from 20 Gy, 40 Gy and 60 Gy recorded root shoot ratio of 0.74, 0.64 and 0.55 respectively. In MS-4600, the highest root shoot ratio 1.02 was recorded in mutants from 60 Gy which was significantly different from other treatments. Control plants recorded root shoot ratio of 0.90 which was higher compared to the mutants from 20 Gy (0.71) and 40 Gy (0.75) respectively. In MS-4690 among the different gamma ray doses highest root shoot ratio of 0.96 was recorded in mutants from 20 Gy whereas lowest root shoot ratio of 0.69 was recorded in mutants 40 Gy followed by mutants from 60 Gy with 0.80 and control plants with 0.74 respectively. In case of PGG-208, highest root shoot ratio of 1.02 was recorded in mutants from 60 Gy followed by mutants from 40 Gy and 20 Gy

Table 83. Mean performance of crude protein content (%) in M_1V_2 generation

Variety	Crude protein content (%)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	11.94	11.79	10.06	14.01
MS-4600	13.32	14.18	13.14	16.01
MS-4690	12.24	10.38	13.79	12.17
PGG-208	12.56	13.04	10.42	16.37
Mean	12.51	12.35	11.85	14.64
	CD at 5%		SE±	
Variety (V)	0.95		0.32	
Treatments (T)	0.95		0.32	
V*T	1.90		0.65	

Table 84. Mean performance of crude fibre content (%) in M_1V_2 generation

Variety	Crude fibre content (%)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	27.27	26.59	30.97	27.79
MS-4600	32.04	28.66	30.23	34.67
MS-4690	25.28	29.72	26.47	31.09
PGG-208	33.22	32.66	28.80	34.59
Mean	29.45	29.41	29.11	32.04
	CD at 5%		SE±	
Variety (V)	1.99		0.68	
Treatments (T)	1.99		0.68	
V*T	3.99		1.37	

Table 85. Mean performance of gibberellic acid (µg/g) in M_1V_2 generation

Variety	Gibberellic acid (µg /g)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	82.36	85.03	79.93	76.29
MS-4600	42.91	47.94	41.02	39.41
MS-4690	83.12	74.82	77.42	62.88
PGG-208	41.09	50.92	41.91	39.90
Mean	62.37	64.67	60.07	54.62
	CD at 5%		SE±	
Variety (V)	2.29		0.79	
Treatments (T)	2.29		0.79	
V*T	4.58		1.58	

with 0.86 and 0.77 respectively. Control plants recorded 0.89 root shoot ratio which was higher than mutants 20 Gy and 40 Gy.

4.3.3.16. ***Crude protein content*** **(%)**

The data pertaining to crude protein content is presented in Table 83. It is evident from the data that significant differences for this character was recorded in all the genotypes studied. Control plants observed crude protein content 12.51 %. Among the treatments, mutants from 60 Gy observed the maximum crude protein content 14.64 % followed by 20 Gy with 12.35 % whereas mutants from 40 Gy observed lowest crude protein content 11.85 % compared to control plants. In FP-553 among the different treatments maximum crude protein content 14.01 % was observed in mutants from 60 Gy whereas minimum crude protein content 10.06 % was observed in mutants from 40 Gy followed by mutants 20 Gy with 11.79 % and control plants with 11.94 % respectively. Data of MS-4600 revealed that among the different gamma ray doses the maximum crude protein content 16.01 % was observed in mutants from 60 Gy followed by mutants 20 Gy and 40 Gy with 14.18 % and 13.14 % respectively. Control plants observed 13.32 % crude protein content. In MS-4690 among the different treatments, minimum crude protein content 10.38 % was observed in mutants from 20 Gy whereas maximum crude protein content 13.79 % was observed in mutants 40 Gy followed by mutants from 60 Gy with 12.17 % and control plants with 12.24 % respectively. The crude protein content in PGG-208, among the different gamma ray doses observed maximum crude protein content of 16.37 % in 60 Gy followed by mutants 20 Gy and 40 Gy with 13.04 % and 10.42 % respectively. Control plants observed 12.56 % crude protein content.

4.3.3.17. ***Crude fibre content*** **(%)**

The data related to crude fibre content are compiled in Table 84. The data revealed that the gamma ray treatment had a significant effect on crude fibre content (%). Mutants from 60 Gy showed a crude fibre content of 32.04 % which was significantly higher, as compared to crude fibre content produced by plants treated with 20 Gy and 40 Gy being 29.41 % and 29.11 % respectively. Control plants produced crude fibre content of 29.45 % which was higher than 20 Gy and 40 Gy. In case of FP-553, highest crude fibre content of 30.97 % was recorded in mutants from 40 Gy followed by mutants from 60 Gy and 20 Gy with 27.79 % and 26.59 % respectively. Control plants recorded 27.27 % crude fibre content. In MS-4600 data revealed that among the different treatments, highest crude fibre content 34.67 % was recorded in mutants from 60 Gy and lowest crude fibre content 28.66 % was recorded in mutants 20 Gy followed by 40 Gy with 30.23 % whereas control plants recorded 32.04 % crude fibre content. In MS-4690 control plants recorded lowest crude fibre content of 25.28 % whereas highest crude fibre content of 31.09 % was recorded in mutants from 60 Gy followed by mutants 20 Gy with 29.72 % and 40 Gy with 26.47 % respectively. In the genotype PGG-208 among the different treatments highest crude fibre content 34.59 % was recorded in mutants from 60 Gy which was significantly different from all other treatments. Control plants recorded 33.22 % crude fibre content which was higher than the mutants from 20 Gy and 40 Gy with 32.66 % and 28.80 % respectively.

4.3.3.18. *Gibberellic acid content* (μg/g)

The data related to gibberellic acid content is compiled in Table 85. The data confirmed that the effect of gamma rays on gibberellic acid content was highly significant between the mutant and control plants. Control plants recorded a gibberellic acid content of 62.37 μg/g. Mutants showed a gradual decrease in gibberellic acid content as the dose of gamma rays increased. Lowest gibberellic acid content 54.62 μg/g was recorded in mutants from 60 Gy followed by 40 Gy and 20 Gy being 60.07 μg/g and 64.67 μg/g respectively. In genotype FP-553 among the different treatments lowest gibberellic acid content of 76.29 μg/g was recorded in mutants from 60 Gy followed by mutants from 40 Gy and 20 Gy with 79.93 μg/g and 85.03 μg/g respectively. Control plants recorded 82.36 μg/g gibberellic acid content. In the genotype MS-4600 data revealed that among the different gamma ray doses, lowest gibberellic acid content 39.41 μg/g was recorded in mutants from 60 Gy followed by mutants from 40 Gy with 41.02 μg/g

Table 86. Analysis of variance of M_3 generation from seeds

Source of Variation	D.F	Plant height (cm)	Number of tillers $hill^{-1}$	Number of leaves $hill^{-1}$	Leaf stem ratio	Green fodder yield (t/ha)	Dry fodder yield (t/ha)
Treatment	3	3669.21**	94.93**	4648.30**	0.043**	1409.94**	100.64**
Variety	3	683.33**	91.00**	2447.69**	0.001	1757.81**	28.28*
T x V	9	657.34**	46.14**	946.43**	0.012**	977.43**	29.97**
Error	30	21.18	10.58	50.92	0.003	37.53	7.33

and 20 Gy with 47.94 µg/g respectively. Control plants recorded 42.91 µg/g gibberellic acid content. In MS-4690 among the different treatments lowest gibberellic acid content of 62.88 µg/g was recorded in mutants from 60 Gy followed by mutants 20 Gy and 40 Gy with 74.82 µg/g and 77.42 µg/g respectively. Highest gibberellic acid content 83.12 was recorded in control plants. In the genotype PGG-208 among the different treatments, highest gibberellic acid content of 50.92 µg/g was recorded in mutants from 20 Gy and lowest gibberellic acid content 39.90 µg/g was recorded in mutants from 60 Gy which significantly different from all other treatments. Mutants from 40 Gy recoded 41.91 µg/g gibberellic acid content whereas control plants recorded 41.09 µg/g gibberellic acid content.

4.4.1 Effect of gamma radiations on M_3 damages and morphological characters of mutants from seeds

The observations on morphological characters of four genotypes treated with gamma rays in M_3 generation are presented below.

The results of statistical analysis for different morphological characters are presented in Table 86. The table revealed that the treatments related to plant height (cm), number of tillers hill^{-1}, number of leaves hill^{-1}, leaf stem ratio, green fodder yield (t/ha), dry fodder yield (t/ha), were significantly different from one another. Interaction effect between treatment and variety were also found to be significant for all these characters at 5% level of significance.

4.4.1.1. *Plant height* (cm)

The data related to plant height has been presented and an evaluation of the data revealed that gamma ray treatment had a significant effect on plant height in all the genotypes (Table 87). Among the different treatments, maximum plant height of 202.95 cm was recorded in mutants from 100 Gy treatments which was found to be significantly different from all other treatments. Mutants from 80 Gy recorded 190.01 cm followed by 185.28 cm in 60 Gy. Plant height was found

Table 87. Mean performance of plant height (cm) in M_3 generation

Variety	Plant height (cm)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	147.62	157.87	189.63	210.96
MS-4600	170.00	187.38	214.26	203.41
MS-4690	164.86	185.18	176.60	198.33
PGG-208	162.04	210.69	179.56	199.11
Mean	161.13	185.28	190.01	202.95
	CD at 5%		SE±	
Variety (V)	3.85		1.32	
Treatments (T)	3.85		1.32	
V*T	7.71		2.65	

Table 88. Mean performance of number of tillers hill^{-1} in M_3 generation

Variety	Number of tillers hill^{-1}			
	Control	60 Gy	80 Gy	100 Gy
FP-553	24.73	27.98	31.62	25.92
MS-4600	34.05	33.25	29.69	38.34
MS-4690	31.43	37.13	26.74	35.99
PGG-208	29.72	30.18	25.31	39.12
Mean	29.98	32.13	28.34	34.84
	CD at 5%		SE±	
Variety (V)	2.72		0.93	
Treatments (T)	2.72		0.93	
V*T	5.45		1.87	

Table 89. Mean performance of number of leaves hill^{-1} in M_3 generation

Variety	Number of leaves hill^{-1}			
	Control	60 Gy	80 Gy	100 Gy
FP-553	136.23	173.74	159.34	165.77
MS-4600	187.38	171.69	156.77	214.00
MS-4690	161.84	215.83	168.95	194.02
PGG-208	130.10	168.38	138.77	200.89
Mean	153.89	182.41	155.96	193.67
	CD at 5%		SE±	
Variety (V)	5.97		2.06	
Treatments (T)	5.97		2.06	
V*T	11.95		4.12	

lower in control plants compared to mutants (161.13cm). In FP-553, among the different gamma ray doses, maximum plant height of 210.96 cm was recorded in mutants from 100 Gy whereas minimum plant height of 147.62 cm was recorded in control plants. Mutants from 60 Gy and 80 Gy recorded plant height of 157.87 cm and 189.63 cm respectively. Data in MS-4600 revealed that among different treatments, maximum plant height of 214.26 cm was recorded in mutants from 80 Gy which was found to be significantly different from all other treatments. The doses 60 Gy and 100 Gy recorded 187.38 cm and 203.41 cm plant height whereas minimum plant height of 170.00 cm was recorded in control plants. In MS-4690, among the different treatments maximum plant height of 198.33 cm was recorded in mutants from 100 Gy followed by mutants from 60 Gy and 80 Gy with 185.18 cm and 176.60 cm, whereas minimum plant height of 164.86 cm was recorded in control plants. In PGG-208, among the different treatments, minimum plant height 162.04 cm was recorded in control plants whereas maximum plant height 210.69 cm was recorded in mutants from 60 Gy followed by mutants 80 Gy (179.56 cm) and 100 Gy (199.11 cm).

4.4.1.2. *Number of tillers hill^{-1}*

Data with regard to number of tillers hill^{-1} is given in table 88. Irradiation caused significant variation in number of tillers hill^{-1}. In general, irradiation treatment caused noticeable increase in number of tillers plant^{-1}. The maximum numbers of tillers were present in mutants population of 100 Gy (34.84). Mutants from 80 Gy plant had least mean number of tillers hill^{-1} (28.34) compared to control plants (29.98). Mutants from 60 Gy had mean number of tillers of (32.13). In case of FP-553, minimum number of tillers hill^{-1} (24.73) was recorded in control plants. In the treatments maximum number of tillers hill^{-1} (31.62) was recorded in mutants from 80 Gy followed by 60 Gy and 100 Gy being 27.98 and 25.92 respectively. In MS-4600, the control plants recorded 34.05 number of tillers hill^{-1} which was higher than the mutants from 60 Gy and 80 Gy with 33.25 and 29.69 respectively. Mutants from 100 Gy recorded maximum number of tillers hill^{-1} (38.34). In MS-4690, the maximum numbers of tillers hill^{-1} (37.13) were recorded in mutants from 60 Gy and minimum numbers of tillers hill^{-1} (26.74) were recorded in mutants from 80 Gy followed by mutants from 100 Gy with 35.99 whereas control plants recorded 31.43 number of tillers hill^{-1}. In PGG-208, the maximum number of tillers hill^{-1} (39.12) recorded in mutants from 100 Gy which was significantly different from all other treatments. Minimum number of tillers hill^{-1} (25.31) was recorded in mutants 80 Gy followed by control plants with 29.72 and mutants from 60 Gy with 30.18 respectively.

4.4.1.3. *Number of leaves hill^{-1}*

Data presented in Table 89 revealed that number of leaves hill^{-1} were significantly different between the control plants and mutant plants. Control plants showed the lowest number of leaves hill^{-1} (153.89) compared to mutants. Among the treatments, mutants from 100 Gy showed the highest number of leaves (193.67) followed by 60 Gy (182.84), whereas plants treated with 80 Gy (155.96) showed a significant drop in number of leaves hill^{-1} compared to other two treatments. In FP-553, control plants recorded lowest number of leaves hill^{-1} (136.23) whereas highest number of leaves hill^{-1} (173.74) was recorded in mutants from 60 Gy followed by mutants from 100 Gy and 80 Gy with 165.77 and 159.34 respectively. In MS-4600, there was a significant difference between the treated and control plants for this character. The control plants recorded 187.38 leaves hill^{-1} which was higher than the mutants from 60 Gy (171.69) and 80 Gy (159.34). Highest number of leaves hill^{-1} 214.00 was recorded in mutants from 100 Gy. In MS-4690, the control plants recorded lowest number of leaves hill^{-1} (161.84) whereas highest number of leaves hill^{-1} 215.83 was recorded in mutants from 60 Gy which was significantly different from all other treatments. Mutants from 80 Gy and 100 Gy recorded 168.95 and 194.02 number of leaves hill^{-1}. In PGG-208, the highest number of leaves hill^{-1} (200.89) was recorded in mutants from 100 Gy followed by 60 Gy (168.38) and 80 Gy (138.77), whereas lowest number of leaves hill^{-1} 130.10 was recorded in control plants.

Table 90. Mean performance of leaf stem ratio in M_3 generation

Variety	Leaf stem ratio			
	Control	60 Gy	80 Gy	100 Gy
FP-553	0.69	0.79	0.94	0.83
MS-4600	0.82	0.78	0.83	0.87
MS-4690	0.77	0.82	0.76	0.86
PGG-208	0.70	0.78	0.83	0.97
Mean	0.74	0.79	0.84	0.88
	CD at 5%		SE±	
Variety (V)	N/A		0.016	
Treatments (T)	0.46		0.016	
V*T	0.09		0.031	

Table 91. Mean performance of green fodder yield (t/ha) in M_3 generation

Variety	Green fodder yield (t/ha)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	82.51	84.63	95.59	81.14
MS-4600	131.75	114.69	86.79	128.50
MS-4690	64.27	113.52	98.88	116.70
PGG-208	89.77	105.85	82.60	127.88
Mean	91.90	104.67	90.96	113.55
	CD at 5%		SE±	
Variety (V)	5.13		1.76	
Treatments (T)	5.13		1.76	
V*T	10.26		3.53	

Table 92. Mean performance of dry fodder yield (t/ha) in M_3 generation

Variety	Dry fodder yield (t/ha)			
	Control	60 Gy	80 Gy	100 Gy
FP-553	24.21	23.47	27.64	28.74
MS-4600	30.27	27.61	24.72	32.55
MS-4690	17.18	28.76	24.64	30.30
PGG-208	23.88	27.51	23.62	30.64
Mean	23.88	26.84	25.15	30.55
	CD at 5%		SE±	
Variety (V)	2.26		0.78	
Treatments (T)	2.26		0.78	
V*T	4.53		1.56	

4.4.1.4. *Leaf stem ratio*

The data related to leaf stem ratio is shown in Table 90. The data revealed that the effect of gamma rays on leaf stem ratio was highly significant between mutants. Control plants recorded lowest leaf stem ratio (0.74). Mutants showed a gradual increase in leaf stem ratio as the dose of gamma rays increased. The mutants from 100 Gy showed a leaf stem ratio 0.88 which was significant as compared to mutants from 80 Gy (0.84) followed by 60 Gy (0.79). Control plants recorded lowest leaf stem ratio of 0.74 as compared to mutant plants. In FP-553, maximum leaf stem ratio of 0.94 was recorded in mutants from 80 Gy and was significantly different from all the other doses of gamma rays. Minimum leaf stem ratio of 0.69 was recorded in control plants whereas mutants from 60 Gy and 100 Gy recorded 0.79 and 0.83 respectively. In MS-4600, the data revealed that among the different gamma ray doses, the maximum leaf stem ratio of 0.87 was recorded in mutants from 100 Gy and minimum leaf stem ratio of 0.78 was recorded in mutants from 60 Gy followed by control plants with 0.82 and mutants from 80 Gy with 0.83 respectively. In MS-4690, among the different treatments, maximum leaf stem ratio of 0.86 was recorded in mutants from 100 Gy followed by mutants from 60 Gy and 80 Gy with 0.82 and 0.76 respectively. Control plants recorded 0.77 leaf stem ratio. The leaf stem ratio in PGG-208 was the maximum in 100 Gy (0.97) followed by 0.78 and 0.83 in the 60 Gy and 80 Gy respectively. Minimum leaf stem ratio of 0.70 was recorded in control plants.

4.4.1.5. *Green fodder yield* (t/ha)

The data pertaining to this attribute has been presented and an assessment of the data shows that gamma treatment had a significant effect on green fodder yield in all genotypes of guinea grass (Table 91). Among the different treatments, minimum green fodder yield (90.96 t/ha) was observed in 80 Gy treatment which was found to be significantly different from all other treatments. In the other treatments, maximum green fodder yield 113.55 t/ha was observed in 100 Gy treatment followed by 60 Gy (104.67 t/ha). Control plants showed slightly higher green fodder yield (91.90 t/ha) compared to 80 Gy treatments. In FP-553, mutants from 100 Gy observed minimum green fodder yield of 81.14 t/ha whereas mutants from 80 Gy observed maximum green fodder yield of 95.59 t/ha followed by mutants 60 Gy with 84.63 t/ha. Control plants observed 82.51 t/ha green fodder yield. In MS-4600, the control plants observed green fodder yield of 131.75 t/ha which was significantly different from mutants. Mutants from 60 Gy, 80 Gy and 100 Gy observed green fodder yield of 114.69 t/ha, 86.79 t/ha and 128.50 t/ha respectively. In MS-4690, the control plants observed the minimum green fodder yield of 64.27 t/ha whereas gamma ray treatment at 100 Gy observed the maximum green fodder yield of 116.70 t/ha followed by mutants 60 Gy and 80 Gy with 113.52 t/ha and 98.88 t/ha respectively. In PGG-208 the maximum green fodder yield of 127.88 t/ha was observed in mutants from 100 Gy followed by mutants 60 Gy and 80 Gy with 105.85 t/ha and 82.60 t/ha respectively. Control plants recorded 89.77 t/ha green fodder yield.

4.4.1.6. ***Dry fodder yield*** **(t/ha)**

The data related to dry fodder yield is compiled in Table 92. The data revealed that gamma ray treatment could make a significant difference between mutant and control plants. The control plants produced the lowest dry fodder yield (23.88 t/ha) whereas, 100 Gy treatment recorded highest dry fodder yield (30.55 t/ha) followed by 60 Gy (26.84) and 80 Gy treatment produced lowest dry fodder yield (25.15) compared to other two treatments. In FP-553, the mutants from 100 Gy produced highest dry fodder yield of 28.74 t/ha whereas mutants from 60 Gy produced lowest dry fodder yield of 23.47 t/ha followed by mutants from 80 Gy with 27.64 t/ha. Control plants produced 24.21 t/ha dry fodder yield. In MS-4600, the highest dry fodder yield of 32.55 t/ha was produced in mutants from 100 Gy which significantly different from all other treatments. Control plants produced 30.27 t/ha dry fodder yield which was higher than the mutants from 60 Gy (27.61 t/ha) and 80 Gy (24.72 t/ha) respectively. In MS-4690, there was significant different between the mutants and control plants for this character. The control plants produced the lowest dry fodder yield of 17.18 t/ha whereas the treatments

Table 93. Analysis of variance of M_1V_3 generation from slips

Source of Variation	D.F	Plant height (cm)	Number of tillers hill^{-1}	Number of leaves hill^{-1}	Leaf stem ratio	Green fodder yield (t/ha)	Dry fodder yield (t/ha)
Treatment	3	5990.44**	153.73**	3782.36**	0.061**	4858.35**	261.34**
Variety	3	399.79**	144.43**	2074.52**	0.006*	1989.40**	111.89**
T x V	9	233.13**	15.41	1163.90**	0.013**	834.55**	43.10**
Error	30	29.85	8.84	41.00	0.001	26.19	5.71

60 Gy, 80 Gy and 100 Gy produced dry fodder yield of 28.76 t/ha, 24.64 t/ha and 30.30 t/ha respectively. In PGG-208 highest dry fodder yield of 30.64 t/ha was produced in mutants from 100 Gy followed by mutants in 60 Gy and 80 Gy with 27.51 t/ha and 23.62 t/ha. Control plants produced 23.88 t/ha dry fodder yield.

4.4.2 Effect of gamma radiations on M_1V_3 damages and morphological characters of mutants from slips

M_1V_3 generation was evaluated with respect to six quantitative morphological characters. The results are presented below.

The results of statistical analysis for different morphological characters are presented in Table 93. The table depicts that the treatments related to plant height (cm), number of tillers hill^{-1}, number of leaves hill^{-1}, leaf stem ratio, green fodder yield (t/ha) and dry fodder yield (t/ha) were significantly different from one another. Interaction effect between treatment and genotype was also found to be significant for all these characters except for number of tillers per hill at 5% level of significance.

4.4.2.1. *Plant height* (cm)

The data pertaining to the effect on gamma rays on plant height is presented in Table 94. It is evident from the data that significant differences for this character was recorded in all the genotypes used. Control plants showed a height of 158.48 cm which is lowest than mutant plants. Among the treatments, mutants from 60 Gy showed maximum height of 205.62 cm, whereas mutant from 20 Gy showed 201.85 cm which was slightly higher than mutants from 40 Gy being 201.58 cm. In FP-553 among the different gamma ray doses, maximum plant height of 207.10 cm was observed in mutants from 20 Gy followed by mutants from 60 Gy and 40 Gy with 205.94 cm and 195.61 cm respectively, while the minimum plant height of 149.40 cm was observed in control plants. Data of MS-4600 revealed that among the different gamma ray doses, maximum plant height of 218.43 cm was observed in mutants from 40 Gy which was found to be

Table 94. Mean performance of plant height (cm) in M_1V_3 generation

Variety	Plant height (cm)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	149.40	207.10	195.61	205.94
MS-4600	170.05	202.41	218.43	206.24
MS-4690	147.99	206.53	189.89	198.39
PGG-208	166.51	201.83	202.38	211.93
Mean	158.48	201.85	201.58	205.62
	CD at 5%		SE±	
Variety (V)	4.57		1.57	
Treatments (T)	4.57		1.57	
V*T	9.15		3.15	

Table 95. Mean performance of number of tillers hill^{-1} in M_1V_3 generation

Variety	Number of tillers hill^{-1}			
	Control	20 Gy	40 Gy	60 Gy
FP-553	23.37	27.73	24.20	32.72
MS-4600	34.34	29.25	33.30	39.69
MS-4690	28.08	32.25	33.26	35.54
PGG-208	31.02	31.51	34.83	40.82
Mean	29.20	30.18	31.40	37.19
	CD at 5%		SE±	
Variety (V)	2.49		0.85	
Treatments (T)	2.49		0.85	
V*T	N/A		1.71	

Table 96. Mean performance of number of leaves hill^{-1} in M_1V_3 generation

Variety	Number of leaves hill^{-1}			
	Control	20 Gy	40 Gy	60 Gy
FP-553	141.65	155.73	148.66	162.80
MS-4600	190.73	145.23	168.11	215.71
MS-4690	150.55	162.09	177.22	170.33
PGG-208	144.81	162.93	179.91	228.62
Mean	156.93	156.49	168.48	194.36
	CD at 5%		SE±	
Variety (V)	5.36		1.84	
Treatments (T)	5.36		1.84	
V*T	10.73		3.69	

significantly different from all other treatments, while the mutants from 20 Gy and 60 Gy had 202.41 cm and 206.24 cm plant height. Minimum plant height of 170.05 cm was observed in control plants. In MS-4690 among the different gamma ray treatments, maximum plant height of 206.53 cm was observed in mutants from 20 Gy and minimum plant height of 147.99 cm was observed in control plants. The treatments 40 Gy and 60 Gy observed plant height of 189.89 cm and 198.39 cm respectively. In PGG-208 among the different gamma ray doses, minimum plant height of 166.51 cm was recorded in control plants and maximum plant height of 211.93 cm was recorded in mutants from 60 Gy followed by mutants 40 Gy and 20 Gy with 201.83 cm and 202.38 cm respectively.

4.4.2.2. *Number of tillers hill^{-1}*

The data presented in Table 95 revealed that there was significant effect between treatments of gamma radiation and genotypes on the number of tillers hill^{-1}. A gradual increase in number of tillers hill^{-1} was recorded with increase in dose of gamma rays. Control plants recorded less number of tillers hill^{-1} (29.20) compared to mutant plants. Among the treatments, mutants from 60 Gy recorded more number of tillers hill^{-1} (37.19) followed by 40 Gy and 20 Gy being 31.40 and 30.18 respectively. In case of FP-553, the highest number of tillers hill^{-1} of 32.72 was recorded in mutants from 60 Gy followed by mutants 20 Gy (27.73) and 40 Gy (24.20) while lowest number of tillers hill^{-1} of 23.37 was recorded in control plants. In MS-4600, control plants recorded 34.34 number of tillers hill^{-1} which was higher than the mutants from 20 Gy (29.25) and 40 Gy (33.30) whereas highest number of tillers hill^{-1} of 39.69 was recorded in mutants from 60 Gy. In MS-4690, the highest number of tillers hill^{-1} (35.54) was recorded in mutants from 60 Gy while lowest number of tillers hill^{-1} (28.08) was recorded in control plants. Mutants from 20 Gy and 40 Gy recorded 31.51 and 34.83 number of tillers hill^{-1} respectively. In PGG-208, the highest number of tillers hill^{-1} 40.82 was recorded in mutants from 60 Gy which was found to be significantly different from all other treatments and minimum number of tillers hill^{-1} 31.02 was recorded in control plants. Mutants from 20 Gy recorded 31.51 and 40 Gy recorded 34.83 number of tillers hill^{-1}.

4.4.2.3. *Number of leaves hill^{-1}*

The data correspondent to number of leaves hill^{-1} is compiled in Table 96. Data revealed that the effect of gamma rays on number of leaves hill^{-1} was highly significant between the mutant plants and control plants. 20 Gy treatments recorded the least number of leaves hill^{-1} of 156.49 which was slightly lower than the control plants 156.93. Maximum number of leaves hill^{-1} were found in 60 Gy (194.36) followed by dose of 40 Gy (168.48). Mutant plants showed an increase in number of leaves hill^{-1} as the dose of gamma rays increased. In FP-553, the control plants recorded minimum number of leaves hill^{-1} (141.65) whereas maximum number of leaves hill^{-1} 162.80 was recorded in mutants from 60 Gy followed by mutants 20 Gy (155.73) and 40 Gy (148.66) respectively. In MS-4600, the control plants recorded 190.73 leaves hill^{-1} which was higher than the mutants from 20 Gy (145.23) and 40 Gy (168.11) whereas maximum number of leaves hill^{-1} 215.71 was recorded in mutants from 60 Gy. In MS-4690, the minimum number of leaves hill^{-1} 150.55 was recorded in control plants. Mutants from 40 Gy recorded maximum number of leaves hill^{-1} 177.22 followed by mutants 60 Gy and 20 Gy with 170.33 and 162.09 respectively. In PGG-208, there was a significant difference in control and mutant plants. Mutants from 60 Gy recorded maximum number of leaves hill^{-1} 228.62 which was significantly different from all other treatments. Mutants from 20 Gy and 40 Gy recorded 162.93 and 179.91 leaves hill^{-1} whereas minimum number of leaves hill^{-1} 144.81 was recorded in control plants.

4.4.2.4. *Leaf stem ratio*

The data presented in Table 97 revealed that leaf stem ratio differed significantly between the mutant and control plants. Among the treatment mutants from 60 Gy showed the maximum leaf stem ratio of 0.88, whereas mutants from 40 Gy and 20 Gy showed leaf stem ratio of 0.78. Control plants showed the

Table 97. Mean performance of leaf stem ratio in M_1V_3 generation

Variety	Leaf stem ratio			
	Control	20 Gy	40 Gy	60 Gy
FP-553	0.66	0.76	0.78	0.84
MS-4600	0.77	0.75	0.82	0.87
MS-4690	0.71	0.87	0.72	0.81
PGG-208	0.68	0.77	0.79	1.00
Mean	0.70	0.78	0.78	0.88
	CD at 5%		SE±	
Variety (V)	0.03		0.01	
Treatments (T)	0.03		0.01	
V*T	0.06		0.02	

Table 98. Mean performance of green fodder yield (t/ha) in M_1V_3 generation

Variety	Green fodder yield (t/ha)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	86.05	82.65	78.22	105.47
MS-4600	132.89	78.30	104.21	141.55
MS-4690	66.04	88.87	98.27	119.17
PGG-208	91.94	85.26	110.31	155.28
Mean	93.23	83.77	97.75	130.37
	CD at 5%		SE±	
Variety (V)	4.28		1.47	
Treatments (T)	4.28		1.47	
V*T	8.57		2.95	

Table 99. Mean performance of dry fodder yield (t/ha) in M_1V_3 generation

Variety	Dry fodder yield (t/ha)			
	Control	20 Gy	40 Gy	60 Gy
FP-553	22.42	26.85	24.16	28.92
MS-4600	33.20	25.02	28.91	37.91
MS-4690	18.43	27.22	28.56	34.03
PGG-208	26.64	26.91	31.72	41.68
Mean	25.17	26.50	28.33	35.63
	CD at 5%		SE±	
Variety (V)	2.00		0.69	
Treatments (T)	2.00		0.69	
V*T	4.00		1.38	

minimum leaf stem ratio (0.70) as compared to mutant plants. In case of FP-553, highest leaf stem ratio of 0.84 was observed in mutants from 60 Gy followed by mutants from 40 Gy with 0.78 and 20 Gy with 0.76 while lowest leaf stem ratio of 0.66 was observed in control plants. In MS-4600, control plants observed 0.77 leaf stem ratio whereas highest leaf stem ratio of 0.87 was observed in mutants from 60 Gy followed by mutants 40 Gy and 20 Gy with 0.82 and 0.75 respectively. In MS-4690, the highest leaf stem ratio of 0.87 was observed in mutants from 20 Gy and the lowest leaf stem ratio of 0.71 was observed in control plants. Mutants from 40 Gy and 60 Gy observed 0.72 and 0.81 leaf stem ratio respectively. In PGG-208, the highest leaf stem ratio of 1.00 was observed in mutants from 60 Gy which was significantly different from all other treatments. Minimum leaf stem ratio of 0.68 was recorded in control plants. Mutants from 20 Gy and 40 Gy recorded leaf stem ratio of 0.77 and 0.79 respectively.

4.4.2.5. *Green fodder yield* (t/ha)

The data related to green fodder yield have been compiled in Table 98. The data revealed that the effect of gamma rays on green fodder yield was significant in all genotypes. Lowest green fodder yield was recorded in mutants from 20 Gy (83.77 t/ha) as compared to control plants (94.23 t/ha). Highest green fodder yield was recorded in dose of 60 Gy (130.37 t/ha) followed by 40 Gy (97.75 t/ha). In FP-553, the highest green fodder yield of 105.47 t/ha was observed in mutants from 60 Gy and the lowest green fodder yield of 78.22 t/ha was observed in mutant from treatment 40 Gy followed by mutants from 20 Gy with 82.65 t/ha. Control plants observed 86.05 t/ha green fodder yield. In MS-4600, the highest green fodder yield of 141.55 t/ha was observed in mutants from 60 Gy which was significantly different from all other treatments. Control plants observed 132.89 t/ha green fodder yield which was higher than the mutants from 20 Gy and 40 Gy with 78.30 t/ha and 104.21 t/ha respectively. In MS-4690, the highest green fodder yield of 119.17 t/ha was observed in mutants from 60 Gy and the lowest green fodder yield of 66.04 t/ha in control plants. Mutants from 20 Gy and 40 Gy observed green fodder yield of 88.87 t/ha and 98.27 t/ha respectively.

In the genotype PGG-208, the highest green fodder yield of 155.28 t/ha was observed in mutants from 60 Gy which was significantly different from all other treatments. Mutants from 20 Gy and 40 Gy observed 85.26 t/ha and 110.31 t/ha green fodder yield. Control plants observed 91.94 t/ha green fodder yield.

4.4.2.6. ***Dry fodder yield*** **(t/ha)**

The data presented in Table 99 revealed that dry fodder yield varied significantly between mutant plants and control plants. Control plants showed lowest dry fodder yield of 25.17 t/ha compared to mutant plants. Among the different treatments, maximum dry fodder yield (35.63 t/ha) was recorded in 60 Gy treatment which was found to be significantly different from all other treatments, followed by 40 Gy and 20 Gy being 28.33 t/ha and 26.50 t/ha, respectively. In FP-553 among the different gamma ray doses, the minimum dry fodder yield of 22.42 t/ha was recorded in control plants while the maximum dry fodder yield of 28.92 t/ha was recorded in mutants from 60 Gy followed by mutants from 20 Gy (26.85 t/ha) and 40 Gy (24.16 t/ha). Data of MS-4600 revealed that among the different gamma ray doses, maximum dry fodder yield of 37.91 t/ha was recorded with mutants from 60 Gy which was found to be significantly different from all other treatments, while the mutants from 40 Gy and 20 Gy recorded 28.91 t/ha and 25.02 t/ha dry fodder yield, respectively. Control plants recorded 33.20 t/ha dry fodder yield. In MS-4690 among the different gamma ray treatments, maximum dry fodder yield of 34.03 t/ha was recorded in mutants from 60 Gy followed by mutants 40 Gy (28.56 t/ha) and 20 Gy (27.22 t/ha) whereas minimum dry fodder yield of 18.43 t/ha was recorded in control plants. In PGG-208 among the different gamma ray doses, maximum dry fodder yield of 41.68 t/ha was recorded in mutants from 60 Gy and minimum dry fodder yield of 26.64 t/ha was recorded in control plants. Mutants from 20 Gy and 40 Gy recorded 26.91 t/ha and 31.72 t/ha dry fodder yield.

Table 100. Characters of best mutants in M_1 generation

Characters	Genotype	Dose (Gy)	Mutant value	Control value
Days to flowering	PGG-208	100	44.79	39.92
Plant height (cm)	MS-4600	80	216.77	171.27
Leaf length (cm)	PGG-208	80	68.87	75.57
Leaf breadth (cm)	MS-4600	100	2.55	2.39
Leaf area index	MS-4600	100	17.10	8.55
Length of internode (cm)	MS-4600	80	40.98	26.71
No. of tillers per hill	MS-4690	60	39.14	32.60
No. leaves per hill	MS-4690	60	215.37	161.34
Green fodder yield (t/ha)	MS-4600	100	106.50	128.74
Leaf-stem ratio	FP-553	80	0.90	0.70
Dry fodder yield (t/ha)	MS-4600	100	30.83	31.66
Root length (cm)	MS-4600	60	83.33	67.33
Root spread (cm)	MS-4600	60	18.33	20.56
Root dry weight (g)	MS-4600	100	120.66	94.97
Root shoot ratio	MS-4600	60	1.55	1.06

Table 101. Characters of best mutants in M_1V_1 generation

Characters	Genotype	Dose (Gy)	Mutant value	Control value
Days to flowering	PGG-208	60	54.79	40.73
Plant height (cm)	MS-4600	40	212.29	171.84
Leaf length (cm)	PGG-208	60	73.46	75.66
Leaf breadth (cm)	PGG-208	60	2.59	2.38
Leaf area index	PGG-208	60	14.94	6.53
Length of internode (cm)	MS-4600	60	42.03	28.31
No. of tillers per hill	PGG-208	60	39.88	30.59
No. leaves per hill	PGG-208	60	200.83	138.46
Green fodder yield (t/ha)	PGG-208	60	136.84	90.86
Leaf-stem ratio	MS-4690	20	0.84	0.71
Dry fodder yield (t/ha)	PGG-208	60	34.31	25.88
Root length (cm)	MS-4600	20	74.78	67.63
Root spread (cm)	PGG-208	20	21.86	20.07
Root dry weight (g)	MS-4600	60	83.15	90.85
Root shoot ratio	MS-4690	60	1.30	0.74

Table 102. Characters of best mutants in M_2 generation

Characters	Genotype	Dose (Gy)	Mutant value	Control value
Days to flowering	PGG-208	100	44.88	40.55
Plant height (cm)	MS-4600	80	218.92	169.85
Leaf length (cm)	PGG-208	80	81.64	75.75
Leaf breadth (cm)	FP-553	100	2.66	2.25
Leaf area index	MS-4600	100	12.34	8.69
Length of internode (cm)	MS-4600	80	40.74	26.58
No. of tillers per hill	MS-4690	60	39.88	31.31
No. leaves per hill	MS-4690	60	219.65	159.46
Green fodder yield (t/ha)	PGG-208	60	128.62	88.72
Leaf-stem ratio	FP-553	80	0.95	0.71
Dry fodder yield (t/ha)	PGG-208	60	36.14	21.63
Root length (cm)	MS-4600	60	85.57	66.05
Root spread (cm)	MS-4690	60	21.57	18.82
Root dry weight (g)	MS-4600	100	124.74	90.13
Root shoot ratio	MS-4600	60	1.60	1.03
Crude protein content (%)	MS-4600	100	15.15	13.22
Crude fibre content (%)	MS-4600	100	34.59	32.67
Gibberellic acid content (μg/g)	PGG-208	100	38.06	39.04

Table 103. Characters of best mutants in M_1V_2 generation

Characters	Genotype	Dose (Gy)	Mutant value	Control value
Days to flowering	PGG-208	60	58.27	41.23
Plant height (cm)	MS-4600	40	214.73	170.28
Leaf length (cm)	PGG-208	60	83.95	74.83
Leaf breadth (cm)	PGG-208	60	2.98	2.43
Leaf area index	PGG-208	60	11.52	7.10
Length of internode (cm)	PGG-208	60	44.80	29.92
No. of tillers per hill	PGG-208	60	42.80	31.08
No. leaves per hill	PGG-208	60	217.48	141.93
Green fodder yield (t/ha)	PGG-208	60	148.79	91.80
Leaf-stem ratio	MS-4600	60	0.90	0.77
Dry fodder yield (t/ha)	PGG-208	60	41.62	25.73
Root length (cm)	PGG-208	60	84.79	62.67
Root spread (cm)	PGG-208	60	22.48	19.75
Root dry weight (g)	PGG-208	60	98.70	88.09
Root shoot ratio	MS-4600/ PGG-208	60	1.02	0.90/ 0.89
Crude protein content (%)	PGG-208	60	16.37	12.56
Crude fibre content (%)	MS-4600	60	34.67	32.02
Gibberellic acid content (µg/g)	PGG-208	60	39.90	41.09

Table 104. Characters of best mutants in M_3 generation

Characters	Genotype	Dose (Gy)	Mutant value	Control value
Plant height (cm)	MS-4600	80	214.26	170.00
No. of tillers per hill	PGG-208	100	39.12	29.72
No. leaves per hill	MS-4690	60	215.83	161.84
Green fodder yield (t/ha)	MS-4600	100	128.30	131.75
Leaf-stem ratio	PGG-208	100	0.97	0.70
Dry fodder yield (t/ha)	MS-4600	100	30.27	32.55

Table 105. Characters of best mutants in M_1V_3 generation

Characters	Genotype	Dose (Gy)	Mutant value	Control value
Plant height (cm)	MS-4600	40	218.43	170.05
No. of tillers per hill	PGG-208	60	40.82	31.02
No. leaves per hill	PGG-208	60	228.62	144.81
Green fodder yield (t/ha)	PGG-208	60	155.28	91.94
Leaf-stem ratio	PGG-208	60	1.00	0.68
Dry fodder yield (t/ha)	PGG-208	60	41.68	26.64

Discussion

5. DISCUSSION

Guinea grass (*Panicum maximum* Jacq.) is fast growing, nutritious and drought tolerant. As a perennial crop, it is suitable for cultivation in humid, tropical and subtropical areas with more than 900 mm of rainfall on a wide range of soils. The deep, dense and fibrous root system and hardy nature allows guinea grass to survive long drought periods and it performs best on well drained soils of good fertility in high rainfall. It is much valued for its productivity, palatability and good persistence. It responds well to cutting and grazing management and is fairly pest-tolerant. It is considered as a suitable grass to stop soil erosion as it has well developed root system.

The present investigation entitled "Induced mutagenesis for delayed flowering and high tillering in guinea grass (*Panicum maximum* Jacq.)", was carried out to analyze the genetic diversity among different guinea grass genotypes using morphological characters and to analyze the effectiveness of gamma rays on inducing variability in guinea grass seeds and slips. The salient findings revealed from the investigation are presented here.

5.1 EVALUATION AND CHARACTERISATION OF GERMPLASM

The thirty seven guinea grass accessions were subjected to detailed study on genetic variability, heritability, genetic advance as per cent of mean, correlation and path analysis.

5.1.1 Mean performance of accessions

The analysis of variance among thirty seven accessions indicated significant differences among the genotypes for all the characters studied except length of internode. All the genotypes exhibited considerable amount of variability in their mean performance with respect to all the characters. Success of crop improvement lies in the selection of suitable parents. While evaluating the genotypes, the high mean value for characters is considered as the acceptable procedure for a long time among the breeders.

In the present study, significant differences were recorded among genotypes for all characters studied indicating sufficient variability in the experimental material. The characters studied were plant height, number of tillers hill^{-1}, number of leaves hill^{-1}, leaf stem ratio, leaf

Plate 1. Field view of experiment I

area index, length of internode, leaf length, leaf breadth, days to flowering, length of panicle, number of panicles hill^{-1}, weight of seeds hill^{-1}, green fodder yield, dry fodder yield, crude protein content, crude fibre content and gibberellic acid content. Similar results showing significant differences for all characters except length of internode have been obtained by Ramakrishnan *et al.* (2013) in guinea grass germplasm accessions and Wouw *et al.* (2008) in the characterization of perennial *Panicum* species.

Mean performance of the genotypes revealed that no single genotype was superior for all traits. Different genotypes were identified to be superior for each trait. Plant height was higher for PGG-200, MS-4600 and MS-468. The genotypes MS-4600, PGG-202 and MS-4733 were superior in respect of number of tillers hill^{-1}. The genotypes MS-4691, MS-4600 and MS-4733 had maximum number of leaves hill^{-1}. Leaf stem ratio was higher for Vellayani local, Marthakam and MS-4690. The genotypes MS-4600, MS-4733 and PGG-202 were superior with respect to leaf area index. Length of internode was higher for PGG-293, PGG-227 and PGG-316. Leaf length was higher for PGG-208, PGG-327 and MS-4732. The genotypes which were having more leaf breadth were Vellayani local, PM-4688 and MS-4600. The desirable genotypes for late flowering were PGG-109, PGG-251 and PGG-293.

The genotypes MS-4688, PM-1188 and MS-4600 had higher length of panicle. The desirable genotypes in respect of number of panicles hill^{-1} were PGG-202, MS-4600 and MS-4733. The genotypes PGG-208, FR-428 and FP-553 were superior with respect to weight of seeds hill^{-1}. Green fodder yield was higher for MS-4600, FR-428 and PM-4728. The genotypes which were having more dry fodder yield were MS-4600, PM-4728 and PGG-202. The genotypes MS-4600, PM-4728, Vellayani local and PGG-316 had maximum crude protein content. Crude fibre content was higher for Harithasree, PGG-202, MC-16 and MS-4687. The desirable genotypes for low gibberellic acid content were PGG-208, MS-4600 and PGG-293. Similar findings were also reported earlier by Ramakrishnan *et al.* (2013) in guinea grass and Wouw *et al.* (2008) in characterization of perennial *Panicum* species.

5.1.2 Genetic variability, heritability and genetic advance

Successful crop improvement programme depends upon nature and magnitude of genetic variability. The variability available in the population can be partitioned into heritable and non

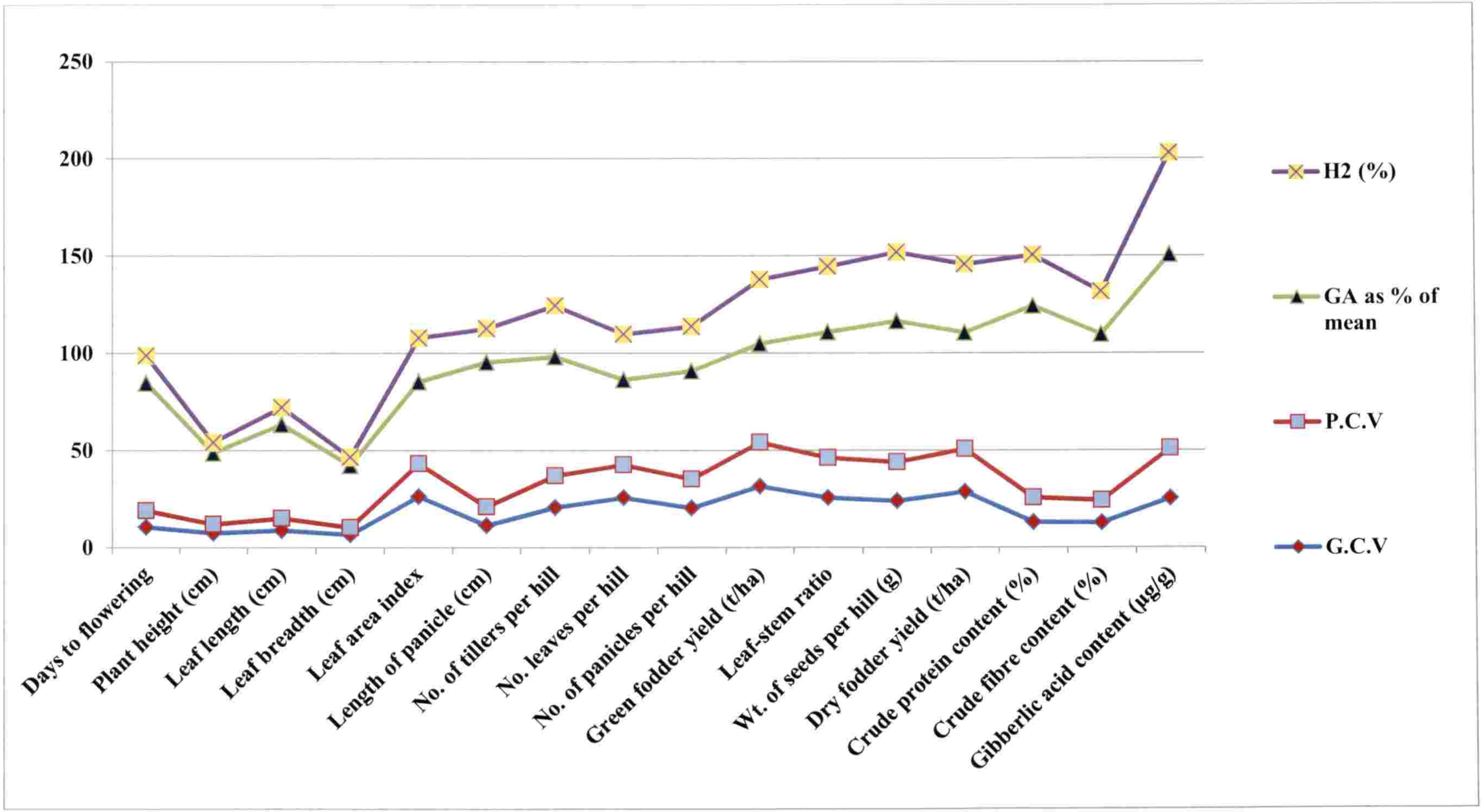

Fig 1. Estimattion of genetic parameters for sixteen characters in Guinea grass (*Panicum maximum* Jacq.)

heritable components *viz*., phenotypic and genotypic coefficients of variation, heritability and genetic advance on which selection can be effectively carried out. The value of these types of coefficients gives an idea about magnitude of variability present in the genetic population. High phenotypic and genotypic coefficients of variation values indicated the presence of variation among the genotypes under study and facilitated the selection of desirable genotypes for improving characters. However, presence of sufficient variation is not enough unless the character is additively inherent. High heritability accompanied with high genetic advance confirms the additively inherent nature of particular character. Heritability and genetic advance are important selection parameters. High heritability alone is not enough for a rewarding selection, unless accompanied by substantial amount of genetic advance (Johnson *et al*., 1955).

Various genetic parameters like phenotypic and genotypic coefficients of variability, heritability, genetic advance as per cent of mean for seventeen characters were measured for guinea grass and are discussed below.

5.1.2.1 *Genetic variability*

The estimates of phenotypic coefficient of variation (PCV) were higher than the estimates of genotypic coefficient of variation (GCV) for all the traits studied indicating predominance of the environmental influence over the traits (fig. 1). In guinea grass genotypes, high estimates of PCV and GCV were observed for green fodder yield followed by leaf stem ratio, weight of seeds per hill, dry fodder yield and gibberellic acid content. High magnitude of PCV and GCV indicated presence of wide genetic variability for these traits and chances for improvement of these characters are fairly high. High and significant variability was reported by Ghazy *et al.* (2012), Shanmuganathan *et al.* (2006), Nagar *et al.* (2006), Dhedhi *et al.* (2015) and Nagendra and Shekhawat, (2015) in pearl millet. The high and moderate estimates of PCV and GCV were observed for leaf area index followed by number of leaves hill^{-1}, number of tillers hill^{-1} and number of panicles hill^{-1}. Moderate PCV and GCV were observed for crude protein content and crude fibre content. Selection will be effective based on the heritable nature of these traits. Similar results were reported by Vidyadhar *et al.* (2007) in pearl millet, Ramakrishnan *et al.* (2013) in guinea grass, Govindaraj *et al.* (2011) in pearl millet, Kavya *et al.* (2017) in foxtail millet and Kour and Pradhan (2016) in forage sorghum.

5.1.2.2 *Heritability and genetic advance*

High heritability coupled with the high genetic advance was observed for number of tillers hill^{-1} followed by leaf stem ratio, weight of seeds hill^{-1}, crude protein content, crude fibre content and gibberellic acid content. High heritability coupled with moderate genetic advance as per cent of mean was observed for days to flowering and length of panicle. The high heritability may be due to additive gene effects hence, these traits are likely to respond to direct selection. It is in accordance with the findings of Bhagirath *et al*. (2007) and Dhedhi *et al.* (2015) in pearl millet. Moderate heritability coupled with high genetic advance as per cent of mean was recorded for leaf area index, number of leaves hill^{-1}, number of panicles hill^{-1}, green fodder yield and dry fodder yield which revealed the additive gene effects coupled with high environmental impact. The present results are in agreement with the findings of Warkad *et al.* (2008) in sorghum and Aditya and Bhartiya (2013) in rice.

5.1.3 Correlation Studies

Studies on the association of characters is an important tool in plant breeding, since it helps to determine the relationship of yield with its components which in turn helps to select superior genotypes from diverse genetic populations.

Correlation provides information on the nature and extent of relationship between characters. The estimates of phenotypic and genotypic correlation coefficients between various characters help to quantify the intensity and to identify the direction of association. Genotypic correlations provide a reliable measure of genetic association between characters and help to differentiate the vital association useful in breeding from non vital ones (Falconer, 1981). Therefore analysis of yield in terms of genotypic and phenotypic correlation coefficients of component characters helps to identify the characters that can form the basis of selection.

5.1.3.1 *The phenotypic and genotypic correlation coefficients in guinea grass*

In the present investigation, the correlation coefficients were estimated among different characters. Green fodder yield was highly significant and positively associated with dry fodder yield and weight of seeds hill^{-1}. It exhibited significant negative correlation with gibberellic acid content at phenotypic level. Green fodder yield showed significant positive correlation with dry fodder yield, weight of seeds hill^{-1} and crude fibre content. It also exhibited significant negative correlation with gibberellic acid content at genotypic level. Among the yield components, gibberellic acid content had negative and significant correlation with green fodder yield at phenotypic and genotypic level. This is also a desirable association because reduced amount of gibberellic acid content delayed flowering and favorable fodder quantity and quality could be easily combined. This was in close agreement with early findings of Sukhchain and Siddhu (1992b) in guinea grass, Iyanar *et al.* (2010) in fodder sorghum and Ramakrishnan *et al*. (2013) in guinea grass. Interestingly, there was significant correlation existing among the above characters as well as green fodder yield which, suggested that these characters may be considered for improvement of fodder yield.

5.1.4 Path analysis

Path analysis partitions the total correlation coefficient into direct and indirect effects and measures the relative importance of the causal factor (Dewey and Lu, 1959). Thus path analysis helps in partitioning the genotypic correlation coefficient into direct and indirect effects on the yield on the basis of which improvement programmes can be devised effectively. If the correlation between yields and any of its components is due to the direct effect, it reflects a true relation between them and selection can be practiced for such character in order to improve yield. But if the correlation is due to indirect effect of another component trait, the breeder has to select the latter trait through which the indirect effect is exerted.

In the present study, green fodder yield was considered as dependent character and other characters were taken as independent characters. The residual effect of path analysis was 0.244. The lower residual effect indicated that the characters chosen for path analysis were adequate and appropriate. Dry fodder yield followed by length of panicle, weight of seeds hill^{-1}, plant height and leaf stem ratio had very high positive direct effect on green fodder yield indicating that there is always scope for enhancement of fodder yield by selection of this trait. Thus the relationship between these characters and green fodder yield was true and positive and emphasis should be given on these characters for green forage improvement in the guinea grass. Among the traits, days to flowering had high positive indirect effect via plant height, length of internode, length of panicle, weight of seeds $hill^{-1}$ and dry fodder yield. However days to flowering had high negative indirect effect via leaf breadth, leaf area index and leaf stem ratio. Leaf stem ratio had high positive indirect effect via days to flowering, leaf area index and negative indirect effect via plant height, leaf breadth, length of internode, length of panicle, weight of seeds $hill^{-1}$, dry fodder yield and gibberellic acid content on green fodder yield. Hence, selection for either one of the components will have an adverse effect on the other and affects yield. The present results are in agreement with findings of Sukhchain and Sidhu (1992b) in guinea grass, Anup and Vijayakumar (2000) in sudan grass, Deepalakshmi and Ganesamurthy (2007) in sorghum, John (2008) in napier grass, Iyanar *et al.* (2010) in fodder sorghum, Shinde *et al.* (2010) in bajra napier hybrid and Gore *et al.* (2016) in marvel grass.

5.2 INDUCED MUTAGENESIS

Mutation breeding is a tool in the hands of the breeder to create variability in plant populations and to make selection in such populations with a view to bring about further improvement in respective crop. It has advantage mainly in improvement of specific characteristics in well adapted and highly desirable genotypes without altering their acceptable phenotype. The role of mutation in enlarging the genetic variability and scope for making selection in many characters like yield, earliness, numbers of branches, plant height, disease resistance and grain colour have been made in various crop plants.

Gamma rays are known to influence plant growth and development by inducing cytological, genetic, biochemical, physiological and morphogenetic changes in cells and tissues (Gunckel and Sparrow 1961). Several positive mutations have been created in agricultural crops by using gamma irradiations. Crops with improved characteristics have successfully been developed by mutagenic inductions (Javed *et al.* 2000). Gustaffson *et al.* (1971) developed a high yielding barley variety with early maturity, high protein content and stiff straw by mutation breeding techniques.

Plate 2. Nursery view of M_1 and M_1V_1 generation

Plate 3. Field view of experiment II for M_1 and M_1V_1 generation

Plate 4. Mutants from M_1 and M_1V_1 generation

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Genetic improvement of crop primarily depends upon extent of genetic variability present in the population. Experimentally induced mutations provide the fundamental variability required for plant improvement. Mutation breeding has become increasingly popular in recent times as an effective tool for crop improvement (Acharya *et al.* 2007). Mutation breeding can be a valuable supplement to conventional plant breeding methods. Induced mutation is highly effective in enhancing natural genetic resources and has been used in developing improved cultivars of cereals and other crops (Lee *et al.* 2002). These mutations provide beneficial variations for practical plant breeding. The objective of the present investigation was to study the variation caused by physical mutagens in seeds and slips. The results obtained during the course of study are discussed here under:

5.2.1 Induced mutagenesis using gamma rays on seeds

5.2.1.1 LD_{50} *dose*

The success of mutation using the gamma ray depends on its dose. Low dose cannot cause mutation and therefore there are no changes in mutated seeds, but high dose can cause death of the mutated seeds, sterility, and other deleterious effect. The LD_{50} (lethal dose) was first determined, a dose that causes 50% mortality to the seeds or a safe dose where 50% of the seeds can survive. The radio-sensitivity varies from species and genotype, depending on the content of water inside the seeds. The seeds which contain much water and oxygen are more sensitive to gamma ray because gamma ray can interact with atoms or molecules in the cell, particularly water, producing free radicals (Kovacs and Keresztes, 2002). Therefore, it is very important to determine the LD_{50} value prior to inducing mutation in the plants. The LD_{50} is one of parameters to predict radio-sensitivity level in plants.

The physical mutagen used was gamma rays from ^{60}Co source and the initial trial was for fixing LD_{50} value. For this, seeds of four varieties *viz.*, FP-553, MS-4600, MS-4690 and PGG-208 were treated with six doses of gamma rays ranging from 60 to 140 Gy along with control. The effects of gamma rays were studied on different parameters such as germination percentage, seedling height and survival in M_1 generation (fig. 2). Reduction of germination, seeding height and survival were studied. Survival was completely suppressed at 140 Gy. In general, LD_{50} for all the four genotypes was beyond 60 Gy gamma ray. Accordingly LD_{50} doses were fixed and

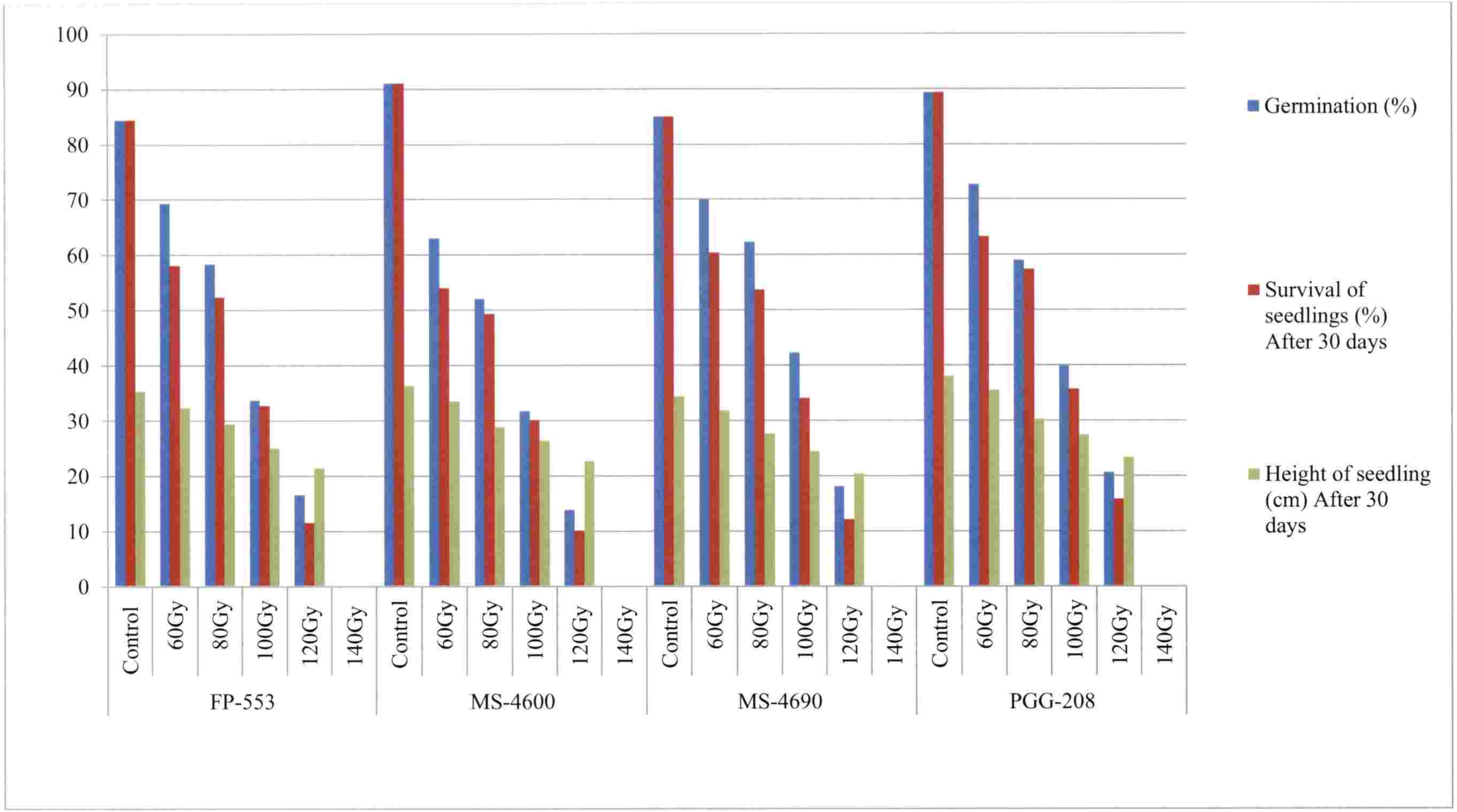

Fig 2. Effect of gamma rays on germination, survival and height of seedling in M_1 generation

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three doses 60, 80 and 100 Gy were administered to the seeds of four different varieties. In the present study using four guinea grass genotypes, LD_{50} ranged from 72.29-83.02 Gy. These results are in conformity with results of Harding and Mohamad (2009) in roselle, Kahrizi *et al.* (2010) in rose, Horn *et al.* (2010) in pearl millet, Talebi and Talebi (2012) in rice, Horn and Shimelis (2013) in cowpea and Kumar *et al.* (2013) in rice.

5.2.1.2 *Effect on seed germination* (%)

There was significant reduction in germination percentage with increasing gamma ray doses. All the treatments differed significantly with each other with respect to germination percentage. Days to initiation of germination and days to completion of germination were significantly delayed by higher doses of gamma irradiation. Delay in germination may be due to be inhibitory effects of gamma rays on seed dormancy. The reduction in germination per cent due to gamma rays may be attributed to a drop in the auxin level (Gordon and Webber, 1955) or chromosomal aberrations as reported by Sparrow (1961). Similar results have been reported by Cheema and Atta (2003) in rice, high dose of gamma irradiation had destructed cell components and caused chromosomal damage (Kiong *et al.* 2008). Talebi *et al.* (2012) reported seedling height and root length decreased with the increase in gamma dose and an abnormal decrease in germination was observed in rice. Rani *et al.* (2016) in rice, and Yadav *et al.* (2016) in *Coracana decurrens* also reported the same results.

5.2.1.3 *Effect on survival of seedling*

The gamma dose caused a negative effect on seedling survival as indicated by the reduction of the number of survival plantlets with increasing gamma ray. The result agreed with the report of Tangpong *et al.* (2009) and Cheema and Atta (2003) in three Basmati rice cultivar exposed to 150 Gy, 200 Gy, 250 Gy and 300 Gy of gamma rays. With the increase in radiation dose, a decrease in germination, seedling height, root length and emergence under field conditions was observed in M_1 generation.

5.2.1.4 *Effect on seedling height* (cm)

As the doses of gamma rays increased, the seedling height decreased. Maximum seedling height was observed in control seedlings. Among the treatments higher doses showed a decrease

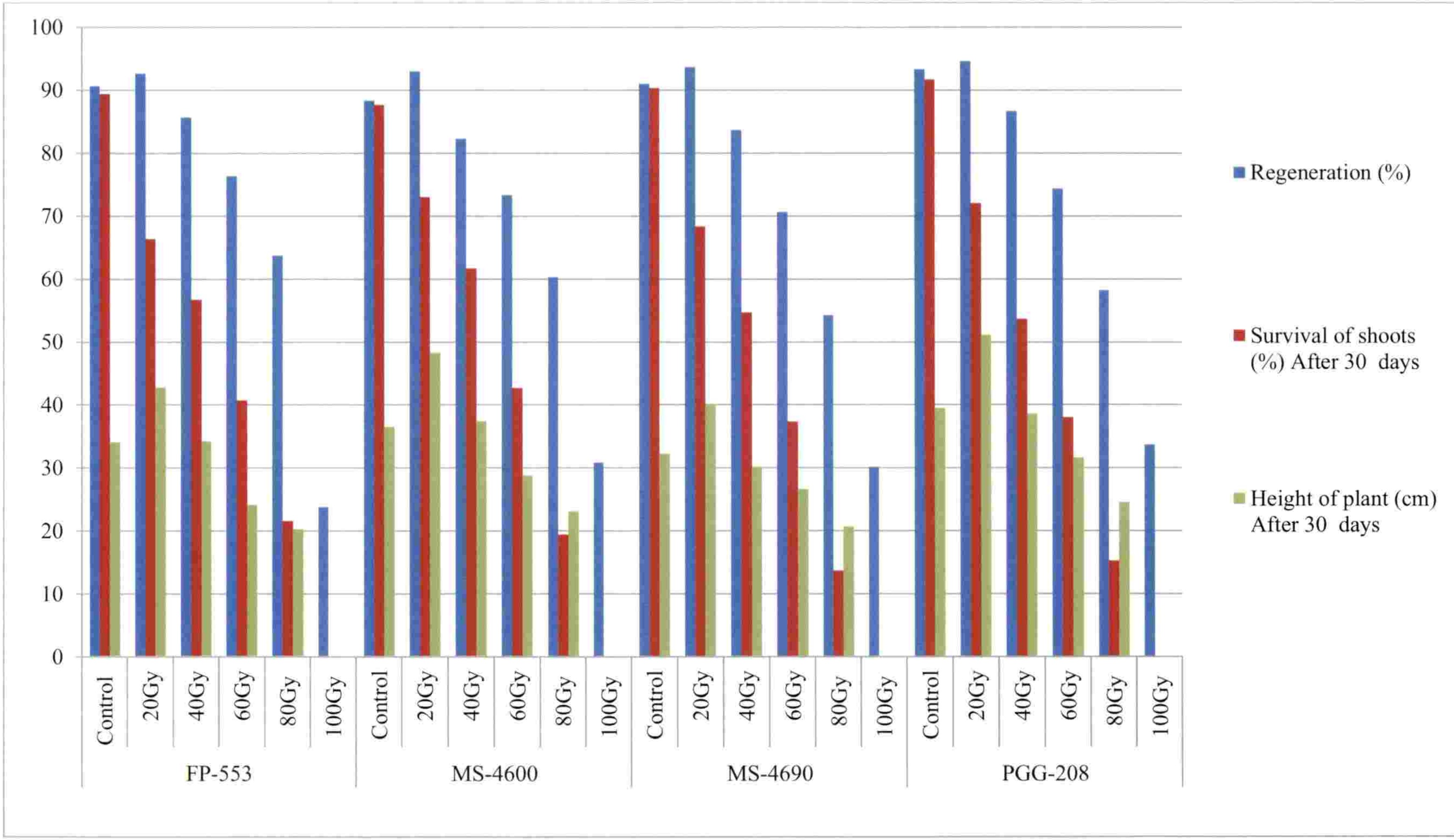

Fig 3. Effect of gamma rays on regeneration, survival and height of plant in M_1V_1 generation

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in seedling height as compared to lower doses. Barakat *et al.* (2010) reported that by increasing the gamma ray exposure, there was a significant decrease in plant height. Sasikala and Kalaiyarasi (2010) also reported that seedling height decreased in decreasing manner with the increase of irradiation dose in rice.

5.2.2 Induced mutagenesis using gamma rays on slips

5.2.2.1 *LD_{50} dose*

Mutagenesis by gamma ray irradiation was employed to treat slips of four genotypes *viz.*, FP-553, MS-4600, MS-4690 and PGG-208. They were treated with six doses of gamma ray ranging from 20 to 100 Gy along with control for fixing LD_{50} value. The effects of the irradiation doses were studied on regeneration, survival of shoots and height of plants (fig. 3). Survival was completely suppressed at 100 Gy. Based on LD_{50} value, three doses 20, 40 and 60 Gy were administered along with control to the different varieties. Similar observations on varying mortality of treated material and variations in radiation sensitivity among genotypes of a crop were reported by Salahbiah and Rusli (2006) in rose, Dwivedi and Banerji (2008) in dahlia and Sutarto *et al*. (2009) in citrus.

5.2.2.2 *Effect of gamma irradiation on regeneration of shoots from slips*

The low doses of gamma radiation increased the regeneration percentage of slips when compared with control, whereas the higher dose gave the lowest regeneration percentage. Decrease in regeneration was proportional to the increase in dosage; this definite pattern was observed in all the genotypes for gamma ray irradiation. According to Kaicker (1992) reduction in survival at higher doses is due to toxic effect of radiations in rose. Reduction in survival rate at higher doses may be also be attributed to genetic loss due to chromosomal aberrations and gene mutations in marigold as reported by Tiwari and Kumar (2011). Significant reduction in sprouting was noticed by Banerji and Datta (1992) in chrysanthemum.

5.2.2.3 *Effect of gamma irradiation on survival of shoots*

Highly significant differences were observed among the low and higher doses of irradiation. There was a linear decrease in plant survival percentage with an increase in gamma radiation doses in all genotypes. Dilta *et al.* (2003) reported that with an increase in dose of gamma rays the per cent survival decreased in chrysanthemum which is in agreement with the current results.

5.2.2.4 *Effect of gamma irradiation on height of plants* (cm)

The tallest plants were observed on the low dose in slips of all genotypes when compared with control and higher doses. In contrast by increasing radiation dose plant height decreased in all the genotypes. Significant reduction in plant height was noticed by Banerji and Datta (2001) on treated rooted cuttings of chrysanthemum using gamma rays. They found that higher doses showed reduction in plant height. The results obtained by Dilta *et al.* (2003) and Boersen *et al.* (2006) in chrysanthemum confirm the results of the present study. Reduction in vegetative growth after radiations might be due to interference in normal mitosis and frequent occurrence of mitotic aberrations, inhibition in the rate of assimilation and consequent change in the nutrient level in the plant (Ehrenberg,1995) and inactivation of vital enzymes, especially those associated with respiration (Casarett, 1968). Reduction in vegetative growth due to changes in auxin level or due to inactivation of auxin was hypothesized by Datta and Datta (1953) in rose.

5.3 EFFECT OF GAMMA RADIATION ON MORPHOLOGICAL CHARACTERS

Evaluation of M_1 generation for the morphological characters of mutants derived through gamma radiation is discussed below.

The four varieties after exposure to different doses of gamma rays were evaluated with respect to several morphological characters. The characters studied were to plant height, length of internode, number of tillers hill^{-1}, days to flowering, green fodder yield, dry fodder yield, number of leaves hill^{-1}, leaf length, leaf breadth, leaf area index, root length, root spread, root dry weight, root shoot ratio, crude protein content, crude fibre content and gibberellic acid content. In general it was found that the different morphological traits showed increased expression as compared to control plants with mutagen treatment. This increase was directly proportional to the dose employed. Results similar to the present findings were reported by Hayat *et al.* (1990) for days to 50% flowering, plant height and grain yield in sorghum. Bretaudeau (1995) reported that variation was observed in several characters such as plant height, resistance to lodging, plant architecture, drought tolerance, panicle length and compactness, seed size and color, seed quality

Plate 5. Field view of experiment III

Plate 6. Albino Mutants

Plate 7. Xantha Mutants

and protein content, glume color and structure, flowering date (early and late maturity), and tillering capacity in sorghum cultivars.

5.3.1 *Plant height*

A gradual increase in plant height was recorded with gradual increase in dose of gamma rays. Maximum plant height was observed in treated plants at higher dose than the control plants in M_1, M_2 and M_3 generation. Among the mutated population highest plant height was recorded in mutants from the higher dose in M_1V_1, M_1V_2 and M_1V_3 generation. Dose dependent increase in frequency of macro mutations was observed in the variety indicating positive relationship between dose of mutagenic treatment and frequency of morphological mutation. Increase in plant height may be chromosomal aberrations, small deficiencies or duplication and most probably point or gene mutation. Results similar to the present findings were reported by Kumar *et al.* (2016) in pea. Contrary to this result Singh and Balyan (2009) reported reduced height with increased dose of gamma rays on bread wheat (*Triticum aestivum* L.) *Cv.* Kharchia. 65 mutants were characterized by reduced plant height. Induced mutations enabled the formation of novel gene structures due to genotypic frequency changes or chromosome alterations (Sahasrabudhe *et al.* 1991). However, these changes occur randomly along the DNA molecule, producing modifications either in a small number of genes with large effects on genotypes or in a large number of genes with small effects on genotypes (Gregory, 1969). Slightly increased plant height was recorded in the population irradiated at 5kR in mulberry. In some cases mutations are not stable and they will undergo recombination during meiosis. Multicellular organisms have the ability to recover from sub lethal doses of ionizing radiations. Even within a cell, non-damaged molecule may be able to take over metabolic process and exert a gradual recovery to normal levels. The efficiency of selecting the desired mutant is controlled by single gene (Ramesh *et al.* 2012).

5.3.2 *Length of internode*

Length of internode was significantly different between treatments. As the dose of gamma rays increased there was a significant increase in length of internode. The maximum length of internode was recorded in the treatment with medium dose of gamma rays in M_1 and M_2 generation. The effect of gamma rays on length of internode was found to be significant between mutant and control plants. Mutants from higher dose recorded the longest length of internode in M_1V_1 and M_1V_2 generation. This increase may be due to increase in plant height with increase in gamma ray doses as reported by Kumar *et al.* (1995) in finger millet. The internodal length was found to be affected by cell number and cell length or both in barley (Blonstein and Gale, 1984). Contrary to this result Ramesh *et al.* (2012) observed important features like shortened internodal distance and increased leaf area in mulberry. Lee *et al.* (2013) observed distinctly different phenotype of *B. decumbens* mutant with short internodes. Yadav (2016) reported more number of nodes with shorter internodes in *Canscora decurrens* exposed to gamma radiation.

5.3.3 *Number of tillers hill^{-1}*

Irradiation caused significant variation in number of tillers hill^{-1}, maximum number of tillers hill^{-1} was recorded at highest dose in M_1 and M_3 generation. Maximum number of tillers hill^{-1} was recorded in lower doses in M_2 generation. Gamma ray treatment had a significant effect on number of tillers hill^{-1} in all the genotypes of guinea grass. Maximum number of tillers hill^{-1} was recorded with higher doses in M_1V_1, M_1V_2 and M_1V_3 generation. Similar results have also been reported by Nirmalakumari *et al.* (2007) in little millet. Premnath *et al.* (2010) reported increased number of branches in hedge lucerne. Ramesh *et al.* (2012) reported increased number of branches at lower dose and reduced branches at higher doses in mulberry. This is due to the fact that primary injuries are retardation or inhibition of cell division, cell death and changes in plant morphology. If the dose is too low, there will not be enough mutation because of low mutation frequency and results in small mutated sector. Bhave *et al.* (2014) irradiated seeds of proso millet with six doses of gamma rays and reported maximum number of tillers at lower treatment. Contradictory to this result reduction in tiller numbers using gamma rays was reported by Lee *et al.* (2013) in *Brachypodium.*

5.3.4 *Days to flowering*

Days to flowering showed a dose dependent increase in the different genotypes as compared to control. Maximum days to flowering were recorded by mutants from highest dose in M_1 and M_2 generation. Gamma ray treatment delayed flowering significantly in all the guinea grass genotypes. Mutants from highest dose showed delay in flowering in M_1V_1 and M_1V_2

generation. This delay might be due to the slow in vegetative growth, which was more prevalent in higher dose exposures. Suppression of flowering has many advantages in a forage crop. Such genotypes are not only expected to give more yields but also to be more nutritious. The plant remains in juvenile stage and is unable to differentiate flower heads due to gamma irradiation. As a result of irradiation many biosynthetic pathways are altered which are directly and indirectly associated with the flowering physiology as reported by Mahure *et al.* (2010) in chrysanthemum. Current results agree with the findings of Shivashankar *et al.* (1988) in panic grass, Bretaudeau (1995) observed late flowering in sorghum, Kumar *et al.* (1995) reported grassy non-flowering type finger millet, Kumar *et al.* (2016) observed late maturity in pea. Contradictory to this result earliness to flowering was reported by Issac and Baba (2016) in pearl millet. Laghari *et al.* (2012) reported two wheat mutants which matured earlier than check varieties.

5.3.5 *Green fodder yield* (t/ha)

Significant differences for this character were recorded in all the genotypes used. Maximum green fodder yield was recorded in mutants from lowest dose in M_1 and M_2 generation whereas in M_3 generation maximum green fodder yield was observed at higher doses. Maximum green fodder yield was recorded in highest dose of gamma ray as compared to control in M_1V_1, M_1V_2 and M_1V_3 generation. Abo-EI-Seoud *et al.* (1994) assumed the stimulation of gamma radiation on the auxin balance within the plant tissues. The reduction in fresh weight of plant may be due to reduced moisture content due to radiation stress, when exposed to high gamma radiation dose. Similar trends have been reported by Premnath *et al.* (2010) in Desmanthus. Sherif *et al.* (2011) reported in *Hibiscus sabdariffa* L. the enhancement in fresh weight of leaves, when treated with gamma radiation.

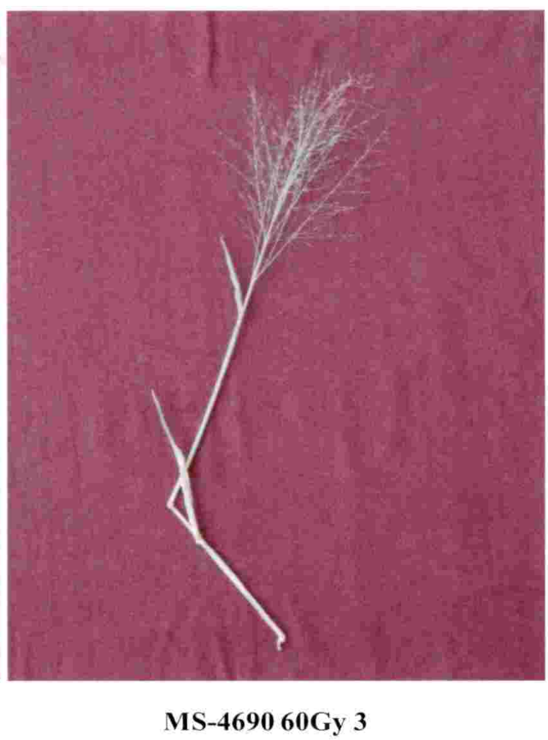
5.3.6 *Dry fodder yield* (t/ha)

The mutants from highest dose recorded maximum dry fodder yield in M_1, M_2 and M_3 generation. The mutants from highest dose showed maximum dry fodder yield as compared to dry fodder yield from control in M_1V_1, M_1V_2 and M_1V_3 generation. Induced mutations enabled the formation of novel gene structures due to genotypic frequency changes or chromosome alterations as reported by Sahasrabudhe *et al.* (1991), however, these changes occur randomly along the DNA molecule, producing modifications either in a small number of genes with large

PGG-208 40Gy 2

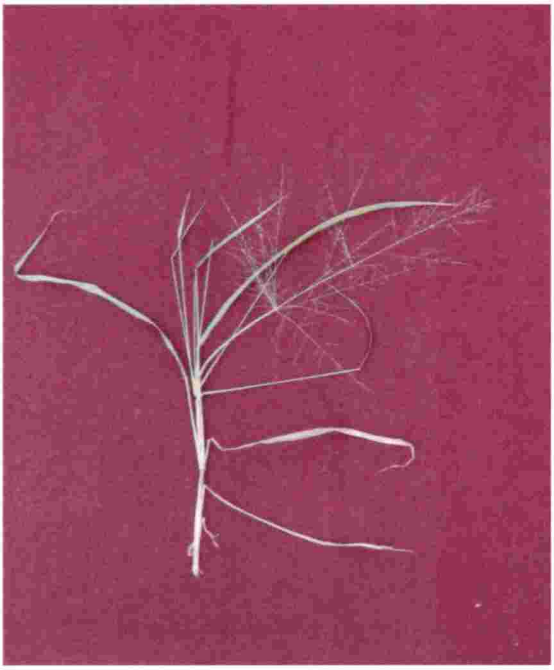
PGG-208 60Gy 1

MS-4690 60Gy 2

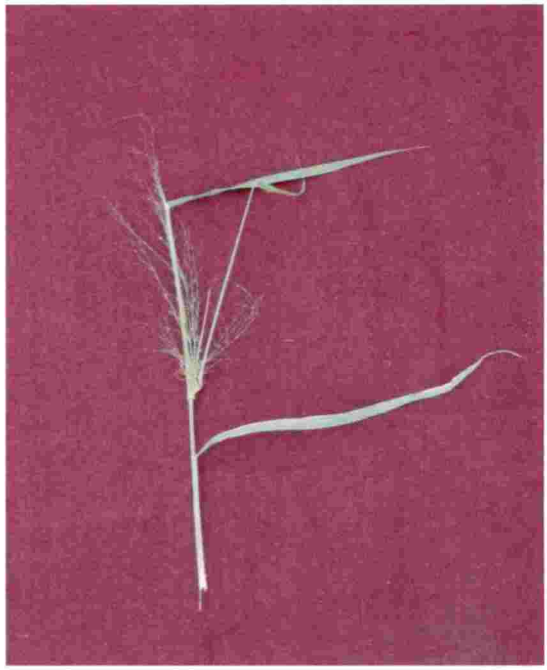


MS-4690 60Gy 3

Plate 8. Mutants from M_2 and M_1V_2 generation

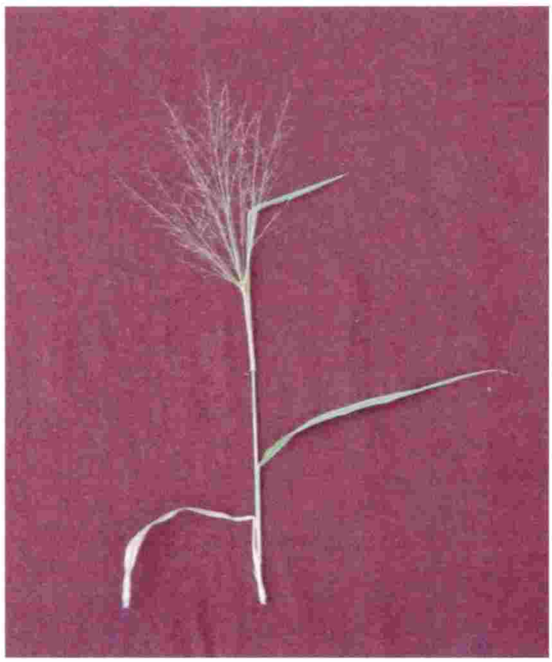


PGG-208 40Gy 1



PGG-208 20Gy 1

FP-553 60Gy 2



MS-4600 20Gy 1

Plate 9. Mutants from M_2 and M_1V_2 generation

MS-4690 40Gy 1

MS-4690 60 Gy 1

MS-4690 60Gy

PGG-208 60Gy

Plate 10. Mutants from M_2 and M_1V_2 generation

PGG-208 100Gy

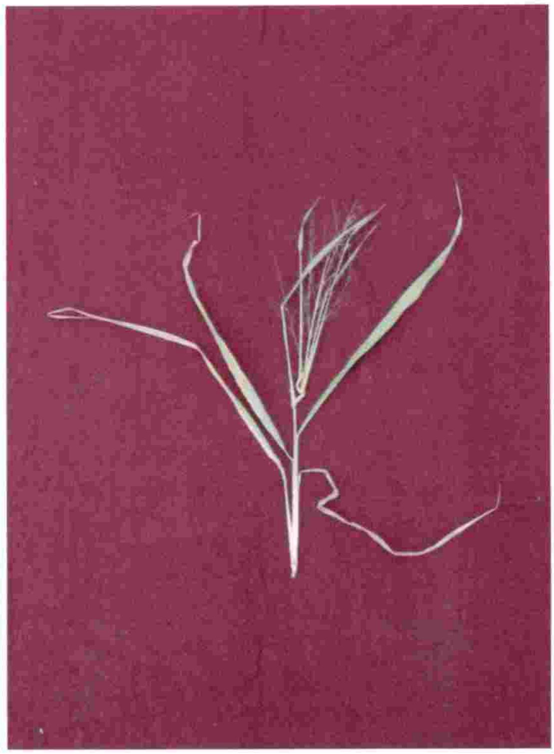
FP-553 20Gy 1

FP-553 80Gy

FP-4690 100Gy

Plate 11. Mutants from M_2 and M_1V_2 generation

MS-4600 60Gy



MS-4600 100Gy

Plate 12. Mutants from M_2 and M_1V_2 generation

effects on genotypes or in a large number of genes with small effects on genotypes (Gregory, 1969). Abo-EI-Seoud *et al.* (1994) assumed the stimulation of gamma radiation to its impact on the auxin balance within the plant tissues. The reduction in dry weight of plant may be due to reduced moisture content due to radiation stress, when exposed to high gamma radiation doses. Tan *et al.* (2009) isolated increased shoot dry weight mutants of *Stylosanthes guianensis* using gamma ray irradiation of seeds. Sherif *et al.* (2011) reported in *Hibiscus sabdariffa* L. the enhancement in dry weight with gamma radiation. Akshatha *et al.* (2013) irradiated seeds of *Terminalia arjuna* with gamma rays. Dry weights of the plants were found to be significantly higher at lower doses. Silveira *et al.* (2014) observed that gamma irradiation increased dry matter yield.

5.3.7 *Number of leaves hill^{-1}*

Significant effect of gamma radiation on the number of leaves hill^{-1} was studied and a gradual increase in number of leaves hill^{-1} was recorded with gradual increase in dose. The maximum number of leaves hill^{-1} was recorded in the treatment with the highest dose of gamma rays in M_1, M_2 and M_3 generation. The maximum number of leaves hill^{-1} was recorded in mutants from highest treatment in M_1V_1, M_1V_2 and M_1V_3 generation. These results are in conformity with that reported by Amnueysit (1999) in forage sorghum and Akshatha *et al.* (2013) in *Terminalia arjuna.* Kham *et al.* (2015) irradiated seeds of local cultivar of sorghum and obtained increased number of leaves plant^{-1}. Contradictory to this result by Animasaun *et al.* (2014) reported that number of leaves was significantly affected by gamma irradiation in *Digitaria exilis.* Reduction in vegetative growth after radiation might be due to interference in normal mitosis and frequent occurrence of mitotic aberrations, inhibition of rate of assimilation and consequent change in the nutrient level in the plant (Ehrenberg, 1995). Reduction in vegetative growth due to changes in auxin level or due to inactivation of auxin was hypothesized by Datta and Datta (1953) in rose.

5.3.8 *Leaf stem ratio*

Among the treatments, mutants from higher dose showed a maximum leaf stem ratio as compared to treatments with lower doses in M_1 M_2 and M_3 generation. Leaf stem ratio was significantly different with treatments and maximum leaf stem ratio was observed in mutants from the highest dose in M_1V_1, M_1V_2 and M_1V_3 generation. This correlates with the findings of Lee *et al.* (2013) in *Brachypodium decumbens* where the leaf to stem ratio was greater in the mutant.

5.3.9 *Leaf length* (cm)

Control plants showed highest leaf length compared to mutant plants in M_1 generation. Plants treated with higher dose recorded longest leaf length in M_2 generation. The effect of gamma rays on leaf length was found to be significant in mutants. Mutants from lower treatment recorded the highest leaf length in M_1V_1 generation. Maximum leaf length was found in mutants from higher dose in M_1V_2 generation. Reduction in vegetative growth due to gamma ray treatment was evident for leaf length. Banerji *et al.* (1994) had reported that reduction in leaf length was found in gladiolous after treating corms with higher dose of gamma rays. Li *et al.* (2010) employed mutagenesis by gamma ray irradiation to treat *St. Augustine grass* for reduced leaf blade length. Contrary to this result Ramesh *et al.* (2012) obtained enlarged leaf in mulberry. Yadav (2016) reported increase in leaf size and area in *Coracana decurrens* when exposed to gamma radiation.

5.3.10 *Leaf breadth* (cm)

Leaf breadth increased with increase in dose of gamma rays, maximum leaf breadth was recorded in mutants from highest dose in M_1 and M_2 generation. Effect of gamma rays on leaf breadth was significantly different between control plants and mutant plants. Maximum leaf breadth was recorded in mutants from medium dose of gamma rays in M_1V_1 generation. Mutants from higher dose showed the highest leaf breadth in M_1V_2 generation. Contradictory to this result Datta and Banerji (1993) observed reduction in leaf size after exposing rooted cuttings of chrysanthemum with 150, 200 and 250 Gy doses of gamma rays. Jain *et al.* (2012) reported broad and narrow leaves in isabgol. Dai and Magnusson (2012) reported various variations including characteristics of leaves. Lee *et al.* (2013) observed distinctly different phenotype of *B. decumbens.* The mutant leaves were also wider and shorter. Htun *et al.* (2015) studied M_2 generation and reported leaf mutations (narrow, broad) in sorghum.

5.3.11 *Leaf area index*

Significant differences in lea area index was recorded in all genotypes used. Mutants from highest dose recorded maximum leaf area index in M_1 generation. Maximum leaf area index was found in mutants from lower dose in M_2 generation. As dose of gamma rays increased there was significant increase in leaf area index. The maximum leaf area index was recorded in higher doses which was significantly different from other treatments in M_1V_1 and M_1V_2 generation. Ramesh *et al.* (2012) reported increased leaf area in mulberry. Yadav (2016) studied seeds of *Coracana decurrens* exposed to gamma radiation and found increase in leaf size and area.

5.3.12 *Root length* (cm)

Effect of gamma rays on root length was highly significant between the control plants and mutants. Maximum root length was observed in mutant from lowest dose in M_1 and M_2 generation. Mutants from medium dose of gamma ray showed longest root length as compared to control in M_1V_1 generation. The mutants from higher dose observed maximum root length in M_1V_2 generation. Cheema and Atta (2003) reported that with the increase in radiation dose, a decrease in root length and emergence under field conditions was observed in M_1 generation. Sasikala and Kalaiyarasi (2010) studied the effect of gamma irradiation on root length in rice. Sherif *et al.* (2011) reported reduction root in length at higher doses in *Hibiscus Sabdariffa*. This reduction could be attributed to reduced mitotic activity in meristematic tissues and reduced moisture content in hibiscus seeds. Talebi *et al.* (2012) reported that root length decreased with the increase in gamma dose in rice.

5.3.12 *Root spread* (cm)

Root spread decreased with increase in dose of gamma rays. Maximum root spread was recorded in control plants compared to mutants in M_1 generation. Maximum root spread was recorded in mutants from lower treatment in M_2 generation. Root spread showed a decreasing trend with the increase in doses of mutagens. Mutants from lower doses showed maximum root spread in M_1V_1 generation and mutants from higher doses recorded highest root spread in M_1V_2 generation.

5.3.14 *Root dry weight* (g)

Among the treatments, mutant from medium dose recorded highest root dry weight compared to control in M_1 and M_2 generation. Gamma ray treatment had a non significant effect on root dry weight; the control plants produced the highest root dry weight in M_1V_1 generation. Mutants from higher doses recorded highest root spread in M_1V_2 generation.

5.3.15 *Root shoot ratio*

Root shoot ratio indicates that there was a general increase in root shoot over control among all the genotypes. Maximum root shoot ratio was recorded in mutants from lower treatment in M_1 and M_2 generation. A gradual decrease in root shoot ratio was recorded with gradual increase in the dose of gamma rays. Control plants showed the highest root shoot ratio compared to mutant plants in M_1V_1 generation. Mutants from higher treatment recorded highest root shoot ratio in M_1V_2 generation.

5.3.16 *Crude protein content* (%)

Crude protein content differed significantly with doses; mutants from lower doses produced highest crude protein content in M_2 generation. Among the treatments, mutants from higher doses observed the maximum crude protein content in M_1V_2 generation. Gustafsson *et al.* (1971) developed a high yielding barley variety with high protein content. Krishna *et al.* (1984) reported mutants of rhodes grass with increased crude protein. Bretaudeau (1995) reported increased protein content in sorghum mutant. Nayeem *et al.* (1999) observed nine radiation induced mutants in wheat with improved pattern of water soluble protein. Rahimi and Bahrani (2011) reported that 25 and 50 Gy gamma irradiation produced the highest grain protein content in wheat. Gamma rays belong to ionizing radiation and interact on atoms or molecules to produce free radicals in cells. These radicals can damage or modify important components of plant cells and have been reported to affect differentially the morphology, anatomy, biochemistry and physiology of plants depending on the irradiation level. These effects include changes in the plant cellular structure and metabolism as reported by Kim *et al.* (2004). Lee *et al.* (2013) observed significantly greater crude protein concentration as compared to control in

Brachypodium. Mahmoud (2002) reported an increase in carbohydrates and soluble sugars in response to seed irradiation.

5.3.17 ***Crude fibre content*** **(%)**

Crude fibre content was found maximum in plants treated with higher doses whereas minimum crude fibre content was recorded in the lower doses compare to control. Minimum crude fibre content was recorded in the medium dose of gamma rays in M_2 generation. Lowest crude fibre content was recorded in mutants from the medium treatment in M_1V_2 generation. Shivashankar *et al.* (1988) reported that the crude fibre content was reduced by 2% in green panic grass subjected to gamma ray treatment. This could be due to changes in the plant cellular structure and metabolism as reported by Kim *et al.* (2004).

5.3.18 ***Gibberellic acid content*** **(µg/g)**

Mutants showed a gradual decrease in gibberellic acid content as the dose of gamma rays increased. Among the treatments plants treated with higher dose produced minimum gibberellic acid content in M_2 generation. Lowest gibberlic acid content was recorded in mutants from highest dose in M_1V_2 generation. Sachs and Bertz (1962) reported gibberellic acid inhibited flower formation in fuchsia hybrid. King *et al.* (2006) reported role of gibberellic acid in floral transition. Joseph and Viktoria (2009) reported minor effects in flowering due to reduced gibberellic acid level. This study supports earlier findings of Tan *et al.* (2009) who reported that mutant lines had reduced gibberellic acid levels *in vivo* than the parents in *Stylosanthes guianensis.*

5.4 SPECTRUM OF CHLOROPHYLL MUTANTS

They have been extensively used to find out sensitivity of crop plants to mutagens and to elucidate effectiveness and efficiency of mutagen (Gustafsson, 1940).

Among the treatments, the highest dose of gamma rays produced high frequency of albino mutants. The other common chlorophyll mutant xantha was observed in all genotypes. The frequency of chlorophyll mutations varied with the genotype as well as mutagen doses in M_2 generation. The differential response of genotypes for the induction of chlorophyll mutations was possible due to differences in the genetic makeup of the varieties used for mutagenesis. Mutagenic sensitivity of higher plants varies depending upon factors such as the physiological stage and structure of the tissue, capacity for reproduction and growth, synthetic ability and capacity for tissue repair, genotypic constitution, quantity of DNA and time of replication in the early stage of growth and conditions before, during and after treatment (Sreeramulu 1975). This indicates that information on mutagenic sensitivity has to be obtained independently for each crop species. Several workers also reported a higher frequency of chlorophyll mutant in irradiated population; Krishna *et al.* (1984) determined the sensitivity of rhodes grass by exposing to gamma rays and found that chlorophyll mutant spectrum included albina, xantha, chlorina, viridis, tigrina, striata, albo-xantha and albo-viridis. Kumar *et al.* (1995) irradiated varieties of finger millet with gamma rays and in M_2 generation reported chlorophyll mutants albino, xantha, viridis, striata and tigrina. Jain *et al.* (2012) subjected isabgol variety to gamma-rays and observed that the spectrum of chlorophyll mutants included albina, xantha, chlorina, viridis, tigrina and others. Chakravarti *et al.* (2013) studied mutagenic effect on aromatic rice cultivars; different types of chlorophyll mutations observed in M_2 generation were albino, xantha, striata and viridis. Ambavane *et al.* (2014) irradiated seeds of two finger millet cultivars and in M_1 generation, three types of chlorophyll mutations *viz.*, albino, xantha and viridis were observed. Ramezani and More (2014) treated grass pea variety Pusa -24 with Gamma rays, three different types of chlorophyll mutants, such as, albina, xantha and viridis were induced with the effect of mutagens. Aradhya *et al.* (1977) studied the effect of gamma-rays and EMS on finger millet. The spectrum consisted of albino, chlorina, xantha, albo-viridis, tigrina (3 types) and striata (2 types), with tigrina being predominant.

5.4.1 Mutagenic effectiveness and efficiency

Effectiveness refers to the ability of mutagen to induce desirable mutations (Awnirdra *et al.* 2001) and therefore, it is a measure of mutation rate relative to doses. Efficiency, on the other hand, gives an idea of the proportion of mutations in relation to other associated undesirable biological effects such as gross chromosomal aberrations; lethality and sterility induced by the mutagen. The usefulness of mutagen depends both on its mutagenic effectiveness and efficiency, efficient mutagenesis is the production of maximum desirable changes accompanied by the least possible undesirable changes. The mutagenic effectiveness (mutations per unit dose) increased

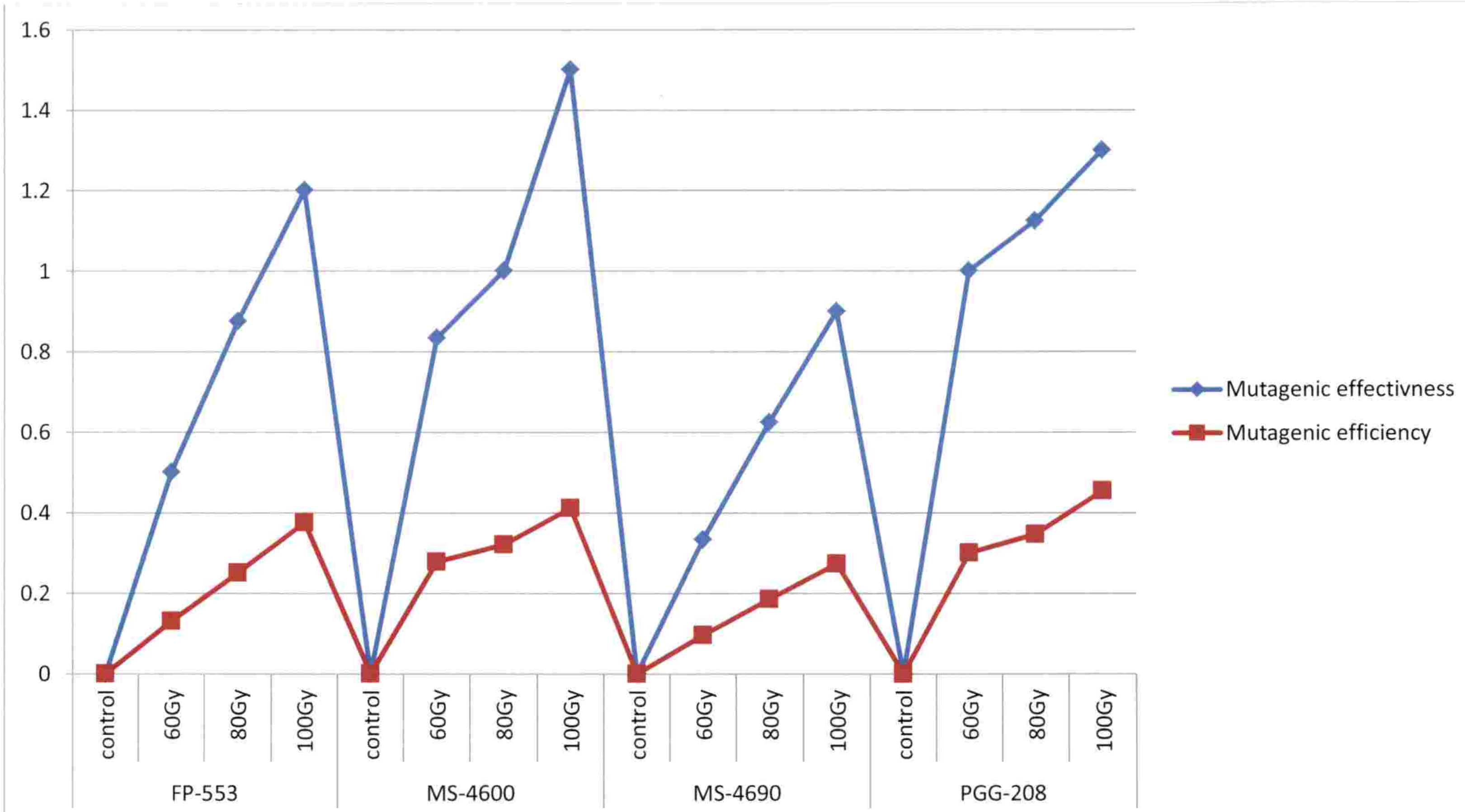


Fig 4. Mutagenic effectiveness and efficiency in M_2 generation

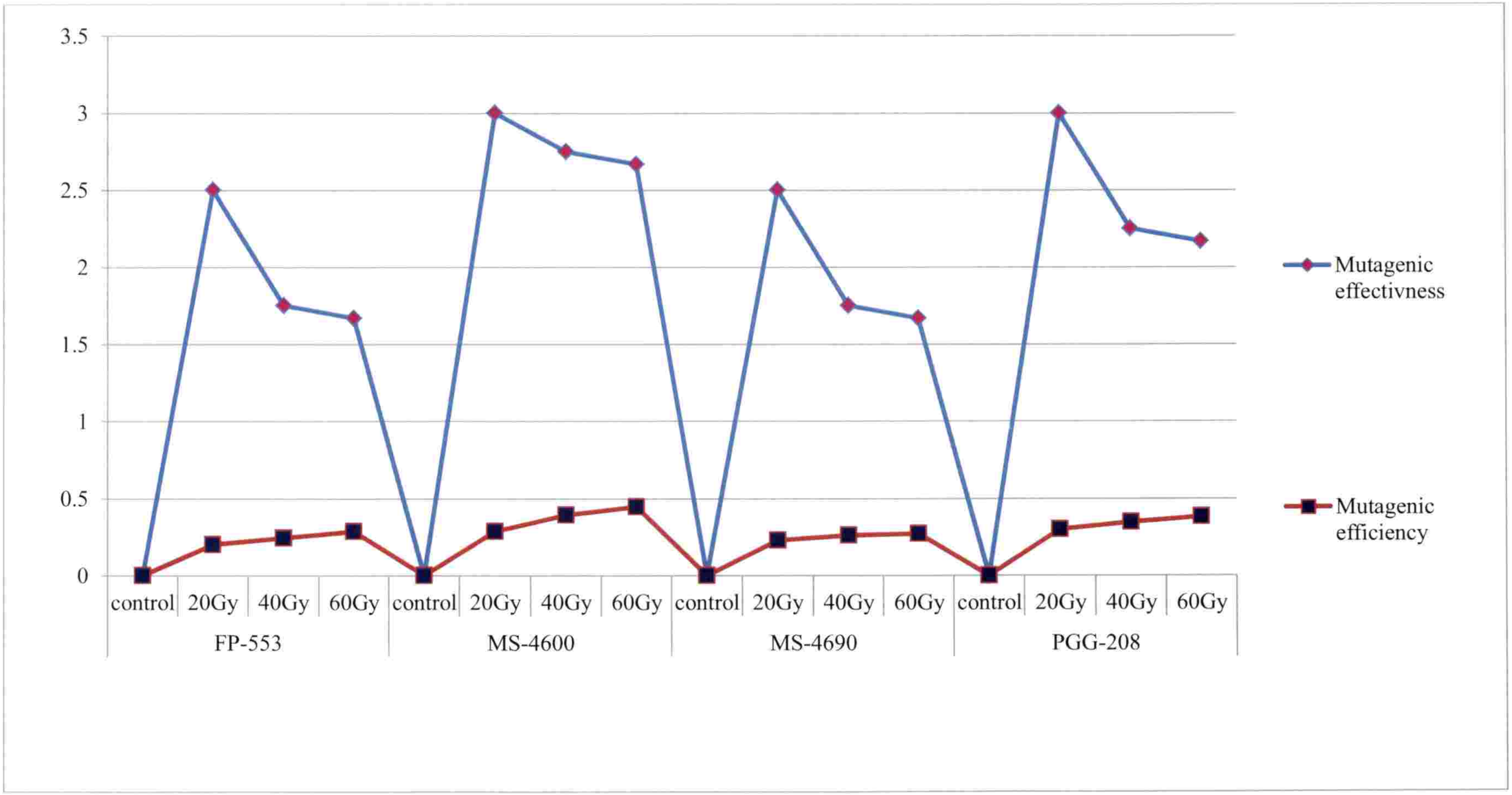


Fig 5. Mutagenic effectiveness and efficiency in M_1V_2 generation

with the increase in dose of mutagen in both the genotypes, indicating a positive relationship between effectiveness and dose of mutagen in M_2 generation (fig. 4). Mutagenic effectiveness decreased with increase in strength of gamma rays in both the genotypes, indicating negative relationship between effectiveness and dose of mutagen. Mutagenic efficiency increased with increase in dose of gamma rays in M_1V_2 (fig. 5). This was in conformation with the finding of Muduli and Misra (2008) in finger millet, Kumar *et al.* (1995) in finger millet, Kumar and Ratnam (2010) in sunflower, Makeen and Babu (2010) in urd bean, Subramanian *et al.* (2011) in kodo millet, Mangaiyarkarasi *et al.* (2014) in *Catharanthus roseus*, Ambli *et al.* (2016) in *Pennisetum typhoides* and Mullainathan and Suthakar (2015) in sorghum.

Plate 13. Best mutants of PGG-208 and MS- 4600 at 60 Gy obtained from slips

Summary

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6. SUMMARY

The present investigation entitled "Induced mutagenesis for delayed flowering and high tillering in guinea grass (*Panicum maximum* Jacq.)." was carried out at College of Agriculture Vellayani during the period 2014-2017. The major objective of the study was to develop high yielding guinea grass types with delayed flowering and high tillering through induced mutagenesis.

The first experiment consisted of evaluation and characterization of germplasm of guinea grass. For assessing genetic variability and diversity, thirty seven germplasm accessions were studied with respect to fourteen morphological and three biochemical characters. Analysis of variance revealed highly significant differences among the genotypes for all the traits analysed except length of internode. High estimates of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were obtained for green fodder yield, dry fodder yield, leaf stem ratio, weight of seeds hill^{-1} and gibberellic acid content and high PCV and moderate GCV were obtained for leaf area index, number of tillers hill^{-1}, number of leaves hill^{-1} and number of panicles hill^{-1}. Moderate values of PCV and GCV were obtained for crude protein content and crude fibre content. High heritability coupled with high genetic advance as percent of mean was observed for number of tillers hill^{-1}, leaf stem ratio, weight of seeds hill^{-1}, crude protein content, crude fibre content and gibberellic acid content respectively which indicates the lesser influence of environment in the expression of these characters and prevalence of additive gene action in their inheritance. Hence selection of these traits in breeding programme would facilitate the improvement of both fodder yield and quality. High heritability coupled with moderate genetic advance as percent of mean was observed for days to flowering and length of panicle. Moderate heritability coupled with high genetic advance as percent of mean was observed for number of leaves hill^{-1}, number of panicles hill^{-1} and green fodder yield which revealed the additive gene effects coupled with high environmental impact. Green fodder yield showed significant positive correlation with dry fodder yield and weight of seeds hill^{-1} at phenotypic level. Green fodder yield showed significant positive correlation with dry fodder yield, weight of seeds hill^{-1} and crude fibre content at genotypic level. Significant correlation exists among the above characters as well as green fodder yield which, suggested that these characters may be considered for improvement of fodder yield. Path coefficient analysis revealed that green fodder yield showed high positive direct effect on dry fodder yield followed by length of panicle, weight of seeds $hill^{-1}$, plant height and leaf stem ratio. Thus the relationship between these characters and green fodder yield was true and positive and emphasis should be given on these characters for green forage improvement in guinea grass. Leaf stem ratio had high indirect effect via days to flowering, leaf area index and negative indirect via plant height, leaf breadth, length of internode, length of panicle, weight of seeds $hill^{-1}$, dry fodder yield and gibberellic acid content on green fodder yield. Hence, selection for either one of the components will have an effect on the other and lead to effect in yield. Based on observations four varieties *viz* two early flowering (FP-553, MS-4690) and two late flowering (PGG-208, MS-4600) were selected for further studies.

The second experiment included induced mutagenesis using physical mutagens on seeds and slips. The physical mutagen used was gamma rays from ^{60}Co source and the initial trial was for fixing LD_{50} value. For this, seeds of four varieties *viz.*, FP-553, MS-4600, MS-4690 and PGG-208 were treated with six doses of gamma rays ranging from 60 to 140 Gy along with control. The effects of gamma rays on different parameters such as germination percent, seedling height and survival were studied to fix the LD_{50} dose. Accordingly LD_{50} dose was fixed and three doses 60, 80 and 100 Gy were administered to the seeds of four different varieties and field planting of M_1 was done. M_1 was evaluated for fifteen morphological characters. Statistical analysis of quantitative characters showed that for an increase in gamma ray doses, a proportionate significant increase for various plant growth parameters was evident. Occurrence of major viable mutants from seedling to adult growth stages *viz.*, broad and narrow leaves, paired panicle, early and late maturity, dwarf and tall plants, low and high number of tillers and leaves $hill^{-1}$, short and long internode.

Mutagenesis by gamma ray irradiation was employed to treat slips of four genotypes *viz.*, FP-553, MS-4600, MS-4690 and PGG-208. They were treated with six doses of gamma ray ranging from 20 to 100 Gy along with control for fixing LD_{50} value. The effects of the irradiation doses were studied on regeneration, survival of shoots and height of plants. Based on LD_{50} value, three doses 20, 40 and 60 Gy were administered along with control to the different varieties and field planting of M_1V_1 was done. M_1V_1 were evaluated for fifteen morphological characters.

Most of quantitative characters showed an increase in mean values with increase in doses of mutagen. Analysis of data showed that all characters studied were significantly affected by irradiation at 60 Gy and it was found that in addition to more number of tillers $hill^{-1}$, more number of leaves $hill^{-1}$, high leaf area index and leaf stem ratio were recorded in mutants than the control plants.

The third experiment was on the study of frequency and spectrum of chlorophyll and viable mutants, mutagenic efficiency and effectiveness in M_2 generation while employing the three doses of gamma rays and one control. In general the frequencies of chlorophyll mutations increased in linear fashion at low (60 Gy) and medium (80 Gy) doses and the frequency was erratic at higher (100) doses. The spectrum of chlorophyll mutants included albino and xantha. The frequency of chlorophyll mutations varied with the genotype as well as mutagen doses in M_2 generation. The highest frequency of viable mutants was produced at 60 Gy dose. The mutagenic effectiveness and efficiency increased with the increase in dose of mutagen in both the genotypes, indicating positive relationship between effectiveness and dose of mutagen in M_2 generation. There were variations in the occurrence of major viable mutants during the crop growth period stages *viz.*, broad and narrow leaves, paired panicle, days to maturity, dwarf and tall plants, high and low tillering with variations in number of leaves $hill^{-1}$, short and long internode, plant height, protein content, fibre content and gibberellic acid content.

In the M_1V_2 generation, the chlorophyll mutation frequency increased in a linear fashion at low (20 Gy) and medium (40 Gy) doses and was erratic at higher doses (60 Gy). The chlorophyll mutant spectrum included albino and xantha. The frequency of these mutants varied with treatments. Mutagenic effectiveness decreased with increase in strength of gamma rays in both the genotypes, indicating that negative relationship between effectiveness and dose of mutagen. Mutagenic efficiency increased with increase in dose of gamma rays in M_1V_2. Superior plants with high green fodder yield as a result of increased number of tillers ranging from 37-42 were observed in 60 Gy populations of MS-4600 and PGG-208 when compared to the control (30-32 tillers). Based on single plant performance, plants which recorded high biomass were identified and M_1V_2 slips were collected and studied in further generations. The mutagenic treatments were effective in inducing various types of chlorophyll and morphological mutations, such as those with significant change in days to flowering, plant height, leaf mutations (narrow, broad, wrinkled); panicle mutations (twin panicle, compact, spread) and biochemical variations in fibre content and protein content. Genotypes with late flowering habit had low gibberellic acid content recorded at higher dose.

The fourth experiment was the study of M_3 and M_1V_3 generation. The altered morphological traits were stable as shown by their growth performance in different seasons. The mutagenic treatments were effective in inducing both qualitative and quantitative characters. Tall mutants with delayed flowering, high green fodder and dry fodder yield displayed two fold increases in number of tillers and leaves $hill^{-1}$ compared to control at 60 Gy irradiations. Variations in number of days to flowering and green fodder yield were recorded in FP-553, MS-4600, MS-4690 and PGG-208. Out of these, the best mutant isolated from slips of MS-4600 and PGG-208 at 60 Gy is a novelty and these mutants were found to be stable in growth performance.

In the present study the genetic variability was found to be high among the genotypes of guinea grass. Gibberellic acid content was found to vary with genotypes. Genotypes with late flowering habit had low gibberellic acid content. The germination percentage was significantly decreased with increased gamma doses while seedling lethality increased with an increase in dose of mutagenic treatments of gamma rays. Mutagenic effectiveness and efficiency varies with different dose of mutagen. Gamma rays induced variations in both seeds and slips for plant height, days to flowering, number of tillers $hill^{-1}$, number of leaves $hill^{-1,}$ green fodder yield, crude protein content and gibberellic acid content at dose of 60 Gy. The study yielded mutants with delayed flowering and high tillering which were found to be stable in growth performance in M_3 and M_1V_3. The present investigation revealed that, the isolation of late maturing mutants with high green fodder yield and yield component characters is possible in 60 Gy doses of gamma irradiation in guinea grass using slips. These stable genotypes could be carried forward to develop better varieties.

Future line of work

The outcome of the study will be helpful in future to induce mutations in guinea grass. Mutants identified in the study can be used for further breeding programmes or it can be released as varieties, after completing mandatory trials.

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INDUCED MUTAGENESIS FOR DELAYED FLOWERING AND HIGH TILLERING IN GUINEA GRASS (*Panicum maximum* Jacq.)

by

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ABSTRACT

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ABSTRACT

The present investigation entitled "Induced mutagenesis for delayed flowering and high tillering in guinea grass (*Panicum maximum* Jacq.)", was carried out at College of Agriculture, Vellayani during the period 2014-2017. The major objective of the study was to develop high yielding guinea grass types with delayed flowering and high tillering through induced mutagenesis.

The first experiment consisted of evaluation and characterization of germplasm accessions of guinea grass. For assessing genetic variability and diversity, thirty seven germplasm accessions were studied with respect to fourteen morphological and three biochemical characters. ANOVA revealed highly significant differences among the genotypes for all the traits analysed except length of internode. High estimates of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were obtained for green fodder yield, dry fodder yield, leaf stem ratio, weight of seeds hill^{-1} and gibberellic acid content and high PCV and moderate GCV were obtained for leaf area index, number of tillers hill^{-1}, number of leaves hill^{-1} and number of panicles hill^{-1}. Moderate values of PCV and GCV were obtained for crude protein content and crude fibre content. High heritability coupled with high genetic advance as percent of mean was observed for number of tillers hill^{-1}, leaf stem ratio, weight of seeds hill^{-1}, crude protein content, crude fibre content and gibberellic acid content. High heritability coupled with moderate genetic advance as percent of mean was observed for days to flowering and length of panicle. Moderate heritability coupled with high genetic advance as percent of mean was observed for number of leaves hill^{-1}, number of panicles hill^{-1} and green fodder yield. Green fodder yield showed significant positive correlation with dry fodder yield and weight of seeds hill^{-1} at phenotypic level. Green fodder yield showed significant positive correlation with dry fodder yield, weight of seeds hill^{-1} and crude fibre content at genotypic level. Path coefficient analysis revealed that green fodder yield showed high positive direct effect on dry fodder yield followed by length of panicle, weight of seeds hill^{-1}, plant height and leaf stem ratio. Based on

observations four varieties *viz.* two early flowering (FP-553, MS-4690) and two late flowering (PGG-208, MS-4600) were selected for further studies.

The second experiment included induced mutagenesis using physical mutagens on seeds and slips. The physical mutagen used was gamma rays from ^{60}Co source and the initial trial was for fixing LD_{50} value. For this, seeds of four varieties *viz.*, FP-553, MS-4600, MS-4690 and PGG-208 were treated with six doses of gamma rays ranging from 60 to 140 Gy along with control. The effects of gamma rays were studied on different parameters such as germination percent, seedling height and survival in M_1 generation. Reduction of germination, seeding height and survival were studied. Accordingly LD_{50} doses were fixed and three doses 60, 80 and 100 Gy were administered to the seeds of four different varieties and field planting of M_1 was done. M_1 was evaluated for fifteen morphological characters. Statistical analysis of quantitative characters showed that for an increase in gamma ray doses, a proportionate significant increase for various plant growth parameters was evident. Occurrence of major viable mutants from seedling to adult growth stages varied *viz.*, broad and narrow leaves, paired panicle, early and late maturity, dwarf and tall plants, low and high number of tillers and leaves $hill^{-1}$, short and long internode.

Mutagenesis by gamma ray irradiation was employed to treat slips of four genotypes *viz.*, FP-553, MS-4600, MS-4690 and PGG-208. They were treated with six doses of gamma ray ranging from 20 to 100 Gy along with control for fixing LD_{50} value. The effects of the irradiation doses were studied on regeneration, survival of shoots and height of plants. Based on LD_{50} value, three doses 20, 40 and 60 Gy were administered along with control to the different varieties and field planting of M_1V_1 was done. M_1V_1 were evaluated for fifteen morphological characters. Most of quantitative characters showed an increase in mean values with increase in doses of mutagen. Analysis of data showed that all characters studied were significantly affected by irradiation at 60 Gy.

The third experiment was the study of frequency and spectrum of chlorophyll and viable mutants, mutagenic efficiency and effectiveness in M_2 generation while employing the three doses of gamma rays and one control. In general the frequencies of chlorophyll mutations increased in linear fashion at low (60 Gy) and medium (80 Gy) doses and the frequency was erratic at higher (100 Gy) doses. The spectrum of chlorophyll mutants included albina and xantha. The highest frequency of viable mutants was produced at 60 Gy dose. There were variations in the occurrence of major viable mutants during the crop growth period stages *viz.*, broad and narrow leaves, paired panicle, days to maturity, dwarf and tall plants, high and low tillering with variations in number of leaves hill^{-1}, short and long internode, plant height, protein content, fibre content and gibberellic acid content.

In the M_1V_2 generation, the chlorophyll mutation frequency increased in a linear fashion at low (20 Gy) and medium (40 Gy) doses and was erratic at higher doses (60 Gy). The chlorophyll mutant spectrum included albino and xantha. The frequency of these mutants varied with treatments. Superior plants with high green fodder yield as a result of increased number of tillers ranging from 37-42 were observed in 60 Gy populations of MS-4600 and PGG-208 when compared to the control (30-32 tillers). Based on single plant performance, plants which recorded high biomass were identified and M_1V_2 slips were collected and studied in further generations. The mutagenic treatments were effective in inducing various types of chlorophyll and morphological mutants, such as those with significant change in days to flowering, plant height, leaf mutations (narrow, broad, wrinkled); panicle mutations (twin panicle, compact, spread) and biochemical variations in protein content, fibre content and gibberellic acid content.

The fourth experiment was the study of M_3 and M_1V_3 generation. The altered morphological traits were stable as shown by their growth performance in different seasons. The mutagenic treatments were effective in inducing both qualitative and quantitative characters. Tall mutants with delayed flowering, high green fodder and dry fodder yield displayed two fold increase in number of tillers and leaves hill^{-1} compared to control at 60 Gy irradiation. Considerable variation was observed with regard to leaf stem ratio at 60 Gy from slips.

To conclude genetic variability was found to be high among the genotypes of guinea grass. Gibberellic acid content was found to vary with genotypes. Genotypes with late flowering habit had low gibberellic acid content. Gamma rays induced variations in both seeds and slips for plant height, days to flowering, number of tillers hill^{-1}, number of leaves hill^{-1}, green fodder yield, crude protein content and gibberellic acid content at dose of 60 Gy. The study yielded mutants with delayed flowering and high tillering which were found to be stable in growth performance in M_3 and M_1V_3. These stable genotypes could be carried forward to develop better varieties.