# INDUCTION OF GENETIC VARIABILITY IN SELECTED GROUNDNUT (*ARACHIS HYPOGAEA* L.) GENOTYPES USING NEUTRON IRRADIATION

**BY**

**Hauwa Oziohu AHMED, B. Agric (ABU, Zaria) 2010**

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## DECLARATION

I declare that the work in this dissertation entitled induction of genetic variability in selected groundnut (*Arachis hypogaea* L.) genotypes using neutron irradiation has been carried out by me in the Department of Plant science. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any other institution.

| | | |
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## CERTIFICATION

This dissertation entitled induction of genetic variability in selected groundnut (*Arachis hypogaea* L.) genotypes using neutron irradiation by Hauwa Oziohu AHMED meets the regulations governing the award of the degree of Masters of Science in Plant breeding of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

| | | |
|---|---|---|
| Hauwa Oziohu Ahmed | _____ | _____ |
| | Signature | Date |
| Prof. C. A. Echekwu | | |
| Chairman, Supervisory Committee | _____ (Signature) | _____ Date |
| Prof. M. F. Ishiyaku | | |
| Member, Supervisory Committee | _____ (Signature) | _____ Date |
| Dr M. D. Katung | | |
| Member, Supervisory Committee | _____ (Signature) | _____ Date |
| Dr U. S. Abdullahi | | |
| Head of Department | _____ (Signature) | _____ Date |
| Prof. Kabir Bala | | |
| Dean, School of Postgraduate Studies | _____ (Signature) | _____ Date |

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## ABSTRACT

Improvement of groundnut *(Arachis hypogaea* L.) is constrained by its narrow genetic base. Studies were conducted to compare the sensitivity of groundnut genotypes to different doses of thermal neutron irradiation, to determine the effective dose for the induction of variability among the genotypes and to evaluate the variability for farmer preferred traits induced by the irradiation. Three genotypes of groundnut; SAMNUT 21 SAMNUT 23 and SAMNUT 24 obtained from the Institute for Agricultural research were irradiated with five doses of thermal neutron irradiation, 0 Gy, 3 Gy, 6 Gy, 9 Gy and 12 Gy at the Centre for Energy Research and Training, Ahmadu Bello University, Zaria in 2013. The irradiated seeds and their respective controls were sown in a randomized complete block design with three replications in the screen house to produce $M_1$ plants. A total of 96 $M_1$ families generated from $M_1$ plus three controls were evaluated using 11 x 12 augmented designs in 2014. Data were collected on plant height, number of branches per plant, days to 50% flowering, canopy spread, number of pods per plant, 100 seed weight, pod yield per plant, shelling percentage, kernel yield per plant and pod yield at $M_2$. Significant differences ($P<0.05$) were observed among the genotypes for seedling traits measured in the $M_1$ generation. Progressive decrease in seedling height and other seedling growth parameters with increase in radiation doses was observed in all the genotypes indicating their sensitivity to irradiation. SAMNUT 21 and SAMNUT 23 were found to be more sensitive to thermal neutron irradiation than SAMNUT 24 as they recorded lower survival at 12 Gy. Seedling height varied from 8.57 to 10.03 cm in materials derived from SAMNUT 21. It varied from 9.90 to 11.17 cm in SAMNUT 23 and from 10.83 to 12.50 cm in SAMNUT 24. Among the various doses, neutron irradiation at 3 Gy resulted in increases in plant height, number of pods per plant, pod yield and kernel yield per plant especially for SAMNUT 24 at $M_2$

generation. The mutagenic effectiveness of irradiation doses at $M_2$ ranged between 0.1% for 12 Gy and 2.6 % for 3 Gy. Thermal neutron irradiation at 6 Gy had higher efficiency in SAMNUT 21 (1.05 %) and SAMNUT 23 (0.72 %) while 3 Gy had higher efficiency in SAMNUT 24 (0.46 %). There were highly significant differences ($P<0.01$) among the plant progenies for all the traits measured at $M_2$. In mutants derived from SAMNUT 21, pod yield ranged between 321.43 for S21-12-1 and 1537.74 kg $ha^{-1}$ for S21-3-3 compared to 1081.88 kg $ha^{-1}$of the control. It ranged between 1310.06 for S23-9-3 and 2649 kg $ha^{-1}$ for S23-6-8 in SAMNUT 23 and varied from 876.99 for S24-12-1 to 2671.47 kg $ha^{-1}$ for S24-3-10 in SAMNUT 24 compared to 1697.48 kg $ha^{-1}$ and 1204.68 kg $ha^{-1}$ of the controls respectively. The mutants had significantly higher variability than the controls, indicating that genetic variability was induced for the agronomic traits. The induced variability for agronomic traits measured offers possibility for future selection and improvement of these traits.

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# CHAPTER ONE

## 1 INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is a self-pollinated crop, an allotetraploid (2n = 4x = 40), belonging to the family Fabaceae, sub-family Papilionidae, tribe Aeschomeneae, sub-tribe Stylosanthinae, genus *Arachis* and species *hypogaea* (Isleib *et al*., 1994). Groundnut is an annual herb of indeterminate growth habit. It ranks thirteenth among the world food crops, fourth as most important source of edible oil and third as most important source of vegetable protein (FAOSTAT, 2011). It is cultivated in more than 100 countries on about 23.95 million hectares. The total annual production is about 36.5 metric tons with an average yield of 1520 kg $ha^{-1}$, of which China (41%), India (21%), Nigeria (8%) and United States of America (7%) are the largest producers (FAOSTAT, 2011).

Globally, the largest use of groundnut is for oil, with the meal being used as a high protein dietary supplement for human and animal consumption. The kernels are rich in protein and vitamins A, E and some members of B group. It is an important protein supplement in animal rations. Groundnut is also of value as a rotation crop.

Increasing land salinization and drought have focused breeding objectives of peanut on the development of high-yielding, stress-tolerant peanut cultivars (Wang *et al.*, 2015). However, obtaining high-yielding, stress-tolerant peanut cultivars with conventional breeding methods is difficult, as stress-resistant germplasm is scarce due to the limited genetic diversity in the peanut (Sui *et al.*, 2013). Cultivated groundnut exhibits a narrow genetic base despite having extensive morphological, agronomic and physiological variability (Badigannava and Murty, 2007). Plant breeders have almost exhausted the natural genetic variability amenable to genetic improvement of the crop. The scarcity of

endogenous genetic variability therefore makes groundnut vulnerable to a wide range of biotic and abiotic stresses as well as dearth of quality traits for improvement. Breeding for improved crop varieties depends on the availability of genetic variation and effective selection methods. Hybridization followed by selection in segregating generations has been used to generate variability in groundnut varieties. Emasculation and pollination procedures of hybridization are cumbersome and the success rate of making crosses is generally low (Janila *et al*., 2013). Mutation breeding has been reported to be an important technique for inducing new variability in the changing agricultural pattern of the day (Bhagwat *et al*., 1997). Mutation breeding in crop plants is an effective approach in the improvement of crops having narrow genetic base such as groundnuts.

The knowledge and understanding of the reaction of groundnut genotypes to different doses of irradiation as well as the effective irradiation dose for induction of variability among genotypes developed by Institute for Agricultural Research (IAR) is currently unavailable. The present investigation was undertaken with the general objective of using induced mutations with thermal neutron irradiation to generate variability in groundnut. The specific objectives of the study were to:

1. determine the sensitivity of three groundnut genotypes to different doses of thermal neutron irradiation.
2. determine the effective irradiation dose for induction of variability among the genotypes.
3. evaluate variability for agronomic traits induced by the irradiation with thermal neutrons.

# CHAPTER TWO

# 2 LITERATURE REVIEW

## 2.1 Groundnut

Groundnut (*Arachis hypogaea* L.), also known as peanut originated in South America where it was cultivated as early as 1000 B.C. The crop was introduced to Africa, Asia, Europe and Pacific Islands presumably in the sixteenth and seventeenth centuries with the discovery voyages of the Spanish, Portuguese, British and Dutch (Isleib *et al*., 1994). Today it is grown in areas between latitude $40^0$ South and $40^0$ North of the equator, where average rainfall is 500 to 1200 mm and mean daily temperature is higher than $20^0$C.

## 2.2 Genetic Variability in Groundnut

Groundnut has a narrow genetic base because of its monophyletic origin, lack of gene flow due to ploidy barrier and self-pollination (Mondal *et al.*, 2006; Nadaf *et al*., 2009). Consequently, the extent to which groundnut cultivars may be improved through conventional breeding methods is limited. The usual breeding strategy in self pollinating crops such as groundnut involves the selection of potential genotypes from the existing germplasm, utilizing them in hybridization programmes and isolating superior recombinants in the segregating populations. The success of a selection programme depends upon the magnitude of genetic variability and the actual heritable variation in the progeny (Kavera, 2008). Mutation breeding supplements conventional breeding as a means of increasing variability and could confer specific improvement without significantly altering the acceptable phenotype of the irradiated genotype (Ojomo *et al*., 1979; Mensah and Obadoni, 2007). The genetic variability in groundnut is low due to the evolution of the crop through a single hybridization event between two diploid

species followed by a chromosome doubling and development of crossing barriers with wild diploid species (Janila *et al*., 2013).

### 2.3 Mutation Breeding in Groundnut.

Mutation breeding is the process of exposing seeds to chemicals or radiation in order to generate mutants with desirable traits which are either utilized directly or indirectly by hybridization with other cultivars. Plants created using mutagenesis are called mutagenic plants. Mutation breeding has been successful for induction of desirable variability and its utilization in developing high-yielding varieties (Chopra, 2005). The prime strategy in mutation-based plant breeding has been to upgrade the well-adapted varieties by altering one or two major traits which contribute to increased yield and quality (Ahloowalia *et al*., 2004). Mutation breeding offers the possibility of inducing desired attributes that cannot be found either in nature or have been lost during evolution (Roychowdhury and Tah, 2013). The induction of a wide spectrum of genetic variability with physical and chemical mutagens enhances the available spontaneous variability for crop improvement (Animasaun *et al*., 2014). In order to induce variability and utilize useful mutations for efficient plant breeding, the systematic study of induced viable morphological mutations in $M_1$ and $M_2$ (first and second mutant generation) is the most dependable index (Kharkwall, 2000).

Groundnut is one of the main economic crops of the world, which has been exposed to mutagenic treatments for induction of variability (Hiremathchannayya *et al*., 2011). The crop is suited for mutagenesis because it is a self-pollinated species. Ever since the epoch-making discoveries made by Muller and Stadler, a large amount of genetic variability has been induced by various mutagens and contributed to modern plant breeding (Kharkwall and Shu, 2009). Mutation breeding is an alternative technique that

was used extensively in many areas for groundnut improvement programme since conventional breeding program through crossing and selection is difficult in groundnut (Sorour *et al*., 1999). Both the direct and indirect utilization of mutants in groundnut has resulted in the release of commercial varieties in India (Murty *et al.*, 2004). Radiation induced mutation have played a significant role for the improvement of groundnut by developing a large number of high-yielding varieties in many countries (Ahloowalia *et al*., 2004). Nadaf *et al* (2009) observed similar trend in yield contributing traits in the mutant variety compared to the parent variety. Mutagenesis through ethyl methane sulphonate (EMS) yielded a very high frequency of mutants for intra-specific differentiation in groundnut (Gowda *et al*, 1996). Branch (2002) detected large variability among advanced gamma-irradiation induced large-seeded mutant breeding lines in the 'Georgia Browne' peanut cultivar. D'Souza *et al* (2009) reported that farmers have been realizing the high-yielding ability of groundnut varieties by harvesting record groundnut yields in many parts of India and the groundnut productivity in major groundnut states had almost doubled by cultivating mutant varieties. Tshilenge-Lukanda *et al* (2012) observed that gamma radiation increased grain yield, number of pods per plant and number of seeds per plant significantly compared to the control without irradiation in groundnut. Satpute and Suradkar (2011) obtained seed coat colour mutants at $M_3$ generation from a groundnut variety irradiated with gamma rays. Kavera and Nadaf (2009) observed highly significant variation for palmitic, stearic, oleic, linoleic and arachidic acids in groundnut varieties treated with gamma radiation and EMS.

### 2.3.1 Traits improved using mutation in groundnut

Induced mutations have been used to generate genetic variability and have been successfully utilized to improve yield components of various crops like sunflower

(Elangovan, 2001), sesame (Mensah *et al*., 2007), soybean (Sodkiewicz and Sodkiewicz, 1999) and groundnut (Badigannavar and Murty, 2007)). A wide range of characters which have been improved through induced mutation breeding include plant architecture, yield, flowering and maturity duration, quality and tolerance to biotic and abiotic stresses (Kon *et al*., 2007). Mutations in plant height, leaf, pod, seed and oil characteristics, disease and salinity tolerance have been reported in groundnut (D'Souza *et al*., 2009). Mondal *et al.,* (2006) reported considerable genetic variability for plant height, plant habit, leaf related traits, flower colour, pod traits, seed size and testa colour among induced mutants of groundnut. One of the most important objectives in oilseed breeding has been the genetic modification of seed oil quality by changing the proportion of fatty acids suitable for either nutritional or industrial purposes (Luhs and Friedt, 1998).

### 2.3.2 Mutagenic agents

The use of physical and chemical mutagens, or a combination of both, has been important tools for the induction of genetic variability in economic traits. Several workers have successfully induced mutation by using either physical or chemical mutagens for evolving new genotypes (Hassan and Khan, 1991; Shamsuzzaman and Shaikh, 1991). Physical mutagens such as, X-rays (Lancu and Soare, 2012), gamma rays (Benlismani and Khelifi, 2009), and fast neutrons (Falusi *et al*., 2013) have been reported to be very effective. Chemical mutagens like EMS, ethidium bromide, acryflavine (Levy, 1976), and sodium azide (Mensah and Obadoni, 2007) have also been used to create genetic variability in groundnut. Earlier study indicated that ionizing radiation caused permanent genetic effects, lethal or beneficial mutations, morphological modifications and other effects in plants (Aparna *et al.,* 2012). Gamma rays and EMS are the most widely used and most effective mutagens in groundnut.

However, neutrons have been reported to be up to 40 times more effective than sparsely-ionizing radiations on dormant seeds at the $LD_{50}$ level of damage (Conger *et al*., 1973). Fast neutron (FN) radiation is therefore a potential source of mutagenesis due to its ability to create DNA deletions (Li and Zhang, 2002). Radio-mutagenesis is known to significantly improve the frequency of induced changes which can be used to widen the genetic variability to be integrated in many varietal selections (Benlismani and Khelifi, 2009). Spontaneous mutations are random and they create the genetic diversity that drives evolution and selective breeding. About 89% of mutant varieties have been developed using physical mutagens whereas gamma rays accounted for 60% of the mutant varieties (Kharkwall, 2000).

Majority of works in mutation induction through seed irradiation have mainly made use of sparsely-ionizing radiations, such as X-rays and gamma rays, and only a few studies have dealt with densely-ionizing radiations due more or less to the unavailability of sources of the latter (Joventino, 1984). This could be due to the complexity in the design and construction of a standard neutron irradiation facility and an appropriate shielding device for treatment of biological materials with fast neutrons. The majority of mutations that result from fast neutrons bombardment are DNA deletions that range in size from a few base pairs to several megabases (Li *et al*., 2001; Men *et al*., 2002). Reduced oxygen effect, which is an advantage of employing neutrons in practical mutation breeding, is widely recognized (Ramulus and Sreerangaswasmy, 1972).

### 2.3.3 Effectiveness and efficiency of mutagens

The term effectiveness refers to the frequency of mutations induced by unit dose of mutagen, whereas efficiency refers to the proportion of mutations in relation to other associated undesirable biological effects like lethality induced by the mutagen.

Efficiency is considered a measure of damage (Konzak *et al.*, 1965; Begum and Dasgupta, 2010). Determination of effective irradiation dose is prerequisite for mutation breeding and development of genetic variability by induced mutation. The mutagenic efficiency of a physical mutagen depends not only on the properties of the physical agent, but also on the genotype. The findings of Lancu and Soare (2012) indicated that different species and even cultivars may respond differently to irradiation.

Chlorophyll mutations are considered as the most dependable indices for evaluating the efficiency of different mutagens in inducing the genetic variability for crop improvement. Chlorophyll mutants are employed as markers for the evaluation of gene action of mutagenic factors in induced mutation studies (Gaul, 1964; Shah *et al.*, 2006). The spectrum and frequency of chlorophyll mutations are easily assessed in $M_2$ population and used as an index of effectiveness of mutagens. The occurrence of chlorophyll mutations after treatments with physical or chemical mutagens have been reported in several crops (Reddy and Gupta, 1989; Mitra and Bhowmik, 1999; Solanki, 2005; Shah *et al*., 2006). The knowledge and understanding of the relative biological effectiveness and efficiency of various mutagens is therefore important before the commencement of any mutation breeding programme. Various attempts in this direction have been made by different researchers to determine the most effective mutagenic treatment for the induction of desirable traits in groundnut (Mondal *et al*., 2006).

### 2.3.4 Radiosensitivity of groundnut to irradiation

Radiosensitivity is the relative susceptibility of cells, tissues, organs or organisms to harmful effect of ionizing radiation. Seedling height response has been widely used as an early indicator of the degree of genetic effects of radiation on seeds considering that reductions in growth of seedlings and chromosomal breakage are highly correlated

(Conger and Constantin, 1979). The radiosensitivity of crops to irradiation largely depends on the genotype. Tshilenge-Lukanda *et al* (2012) observed that the sensitivity to irradiation varied with genotype while working with three groundnut cultivars irradiated with gamma rays. Benslimani and Khelifi (2009) used four local non-dormant groundnut seeds "Berrihane, Boumalek, Tonga and El Frine" to examine varietal differences in radiosensitivity to gamma radiation. In their study, they exposed groundnut seed to 50, 100, 150, 200, 300 and 450 Gy doses of gamma irradiation and observed that increase in radiation dose resulted in decrease in germination, seedling height, root length and emergence under field conditions in $M_1$ generation. Wang *et al* (2015) reported that the $M_2$ generation plants from most of the regenerated cultivars of groundnut irradiated with fast neutrons at dosages of 9.7, 14.0 and 18.0 Gy exhibited variations and segregation in vigor, plant height, branch and pod number, pod size, and pod shape. Aparna *et al* (2012) reported that germination percentage in groundnut decreased after irradiation and the effect became stronger with increase of gamma dose. Parameters such as germination percentage, speed of germination, mean daily germination, peak value and germination value, root length, shoot length, vigour index and root/shoot length ratio expressed higher reduction at higher doses as compared to non irradiated control.

## 2.4 Heritability and variability components among mutants

Heritability expresses the reliability of the phenotypic value as a guide to breeding. Characters with high heritability can therefore be improved rapidly through selection than those with low heritability, since the latter are influenced by environmental factors. High heritability and genetic advance in mutagen treated populations have been reported for crops such as sesame (Chavan and Chopde, 1982), mustard (Labana *et al.,* 1980) sunflower (Jagadeesan *et al*., 2008) and groundnut (Mathur *et al.,* 2000). Mensah

and Obadoni (2007) reported increase in genetic parameters such as heritability and genetic gain for pods per plant and seeds per plant of groundnut under chemical treatment (sodium axide) at $M_2$ generation and indicated the possibility of evolving higher yield variants through proper crop selection. Badigannavar and Murty (2007) reported a high heritability associated with a high genetic advance for plant height, pod yield and seed yield in gamma rays induced mutants of groundnut at $M_8$ generation.

## 2.5 Role of Mutation Breeding in Groundnut

The available genetic variability in groundnut has been intensely exploited. Plant breeders can create novel variability in groundnut using induced mutations since generation of crosses in groundnut is difficult. Radiation mutagenesis can promote gene recombination, break undesirable gene linkages, and produce DNA mutations (Tiwari *et al*., 2012) or chromosome variations (Wu *et al*., 2011). The utilization of variability from wild *Arachis* species has been limited due to reproductive isolation of the cultivated species, *A. hypogaea*, an allotetraploid, from its diploid wild species due to ploidy differences and sterility (Janila *et al*., 2013). Population improvement procedures are not commonly used in groundnut because of the difficulty in making large number of crosses required for population improvement (Janila *et al*., 2013). Therefore, there is a need to explore novel variability in groundnut generated from induced mutations for crop improvement. A recently released peanut mutant cultivar 'TG-26', developed at Bhabha Atomic Research Center, Bombay, India yielded 4.6 t $ha^{-1}$ nuts, an increase of 40.9 % over the checks (Kale *et al*., 2000).

# CHAPTER THREE

# 3 MATERIALS AND METHODS

## 3.1 The Study Area

The research was conducted at the Institute for Agricultural Research Farm Samaru, Zaria ($11^{0}11^{1}$ N: $7^{0}38^{1}$ E; 686 m asl, 1200 mm annual rainfall) situated in the northern Guinea savannah.

## 3.2 Experimental Materials

### 3.2.1 Parental genotypes

The experimental materials comprised of three genotypes of groundnut which include, SAMNUT 21, SAMNUT 23 and SAMNUT 24. The basic characteristics of the genotypes are given in Table 3.1.

### 3.2.2 Development of populations

Dry seeds of three groundnut genotypes; SAMNUT 21, SAMNUT 23 and SAMNUT 24 were exposed to thermal neutrons at 4 different doses (3 Gy, 6 Gy, 9 Gy and 12 Gy) from an Americium-Berylium (Am-Be) source at the Centre for Energy Research and Training (CERT), Ahmadu Bello University, Zaria in 2013 to generate $M_1$ seeds. Samples of 100 dry, healthy and uniform sized seeds per genotype were irradiated. The Americium-Berylium neutron source had a thermal neutron flux of $1.3 \times 10^{4}$ n $cm^{-2}$ $s^{-1}$. The irradiation assembly consisted of a paraffin cylinder having six symmetrical irradiation positions with the Americium-Berylium neutron source at the centre. The source was cylindrical with dimensions 30 mm diameter x 48 mm. The arrangement provided for simultaneous irradiation of six samples.

**Table 3.1. Basic characteristics of three groundnut genotypes used in the study.**

| Features | Samnut 21 | Samnut 23 | Samnut 24 |
|---|---|---|---|
| Source | IAR* | IAR | IAR |
| Botanical type | Virginia | Spanish | Spanish |
| Maturity (days) | Medium maturing (115-120) | Early maturing (90-100) | Extra-early maturing (80-90) |
| Pod yield (t $ha^{-1}$) | 2.5 | 2-2.5 | 2-2.5 |
| Haulm yield (t $ha^{-1}$) | 4-5 | 2 | 2.5-3 |
| Oil content (%) | 51 | 53 | 53 |

*IAR- Institute for Agricultural Research.

The dose rate of the neutron source was $8.15x10^{-2}$ Sv $h^{-1}$. This was used to calculate the duration of exposure for each dose using the formula below.

$$duration\ of\ \text{exp}\ osure = \frac{dose}{dose\ rate}$$

1 Gray (Gy) = 1 Sievert (Sv) x RBE

Where, Gray = unit of irradiation and RBE = Relative biological effectiveness of a mutagen.

The seeds were placed in the six paraffin cylinders and lowered into the irradiation chamber with the aid of a thread for the required period for each dose. These irradiated seeds formed the $M_1$ seeds. Unirradiated seeds stocks of the respective genotypes were used as control (0Gy).

The $M_1$ generation was raised by selfing $M_1$ plants for each genotype.

Respective $M_2$ seeds were planted to produce the $M_2$ plants. The $M_2$ generation was raised by growing seeds from $M_1$ plants to progeny rows.

### 3.3 Evaluations

#### 3.3.1 Assessment of sensitivity to irradiation

Twenty $M_1$ seeds per dose for each genotype including the control were sown in a randomized complete block design (RCBD) with three replications in the screen house in November 2013 to produce $M_1$ plants. The plants were watered daily up to maturity. Seedling characteristics; seedling height, root length, leaflet length, leaflet width and number of leaflets per plant were monitored and measured. Radiosensitivity was evaluated by assessing morphological damage in the developing $M_1$ seedlings. At maturity, harvesting was done on single plant basis.

### 3.3.2 Field evaluation of $M_2$ for variability for agronomic traits

The $M_2$ plant progenies numbering 96 were carefully evaluated using 11 x 12 augmented designs on the field during the 2014 growing season. The $M_2$ seeds were sown in the field at a spacing of 0.75 m between rows and 0.40 m between plants in a row. Plot size was a single 4 m row. Two seeds were planted per hill and seedlings were thinned to one plant per stand two weeks after emergence to achieve 11 plants per row, giving a population density of 33 333 plants $ha^{-1}$.

### 3.3.3 Cultural practices

The field was sprayed with glyphosate to suppress the growth of weeds. Manual hoe weeding was carried out at three and six weeks after sowing. Ridge moulding was done at 8 weeks after sowing to allow for the penetration of pods. This was followed by hand-pulling of weeds at 10 weeks after sowing. Fertilizer application was done immediately after the first hoe weeding. NPK 15-15-15 and single supper phosphate at the rates of 30 kg $ha^{-1}$ and 60 kg $ha^{-1}$ respectively were applied. Harvesting was carried out at maturity by carefully digging out the pods. This was followed by manual picking of the pods. The effects of the different doses of neutron irradiation on agronomic traits of groundnut were determined using the non-irradiated seeds as control.

## 3.4 Data Collection

### 3.4.1 $M_1$ evaluation

Data were recorded on plot basis on the $M_1$ plants for the following traits.

1. **Emergence rate:** observation on field emergence was recorded 15 days after sowing and the percentage calculated using the following formula:

$$\text{Emergence rate (\%)} = \frac{Number\ of\ emerged\ \ plants}{Total\ number\ of\ \ seeds\ sown} \times \ \ 100$$

2. **Survival percent:** observation on the survival of seedlings was recorded at the time of harvest and survival percentage calculated by using the following formula:

$$\text{Survival Percent (\%)} = \frac{Number\ of\ \ plants harvested}{Total\ number\ of\ \ ger\min ated\ seeds} \times 100$$

3. **Seedling height (cm):** height of the main axis from ground level to the apical leaflet was measured 30 days after sowing and mean of five random plants was recorded.
4. **Number of leaves:** total number of leaves per plant was counted 30 days after sowing and mean of five randomly selected plants was recorded.
5. **Leaflet length (cm):** length of fully expanded apical leaflet was recorded 30 days after sowing and mean of five leaflets was recorded.
6. **Leaflet width (cm):** width of fully expanded apical leaflet was measured at midpoint 30 days after sowing and mean of five leaflets was recorded.
7. **Seedling root length (cm):** length of the seedling root was measured 30 days after sowing and mean of five randomly selected plants recorded.

### 3.4.2 $M_2$ evaluation

1. **Plant height (cm):** height of the main axis from ground level to the apical leaflet for each plant was measured at maturity.
2. **Number of branches per plant:** number of branches borne on the main axis for each plant was recorded.
3. **Days to 50% flowering:** the time taken in days from sowing for 50% of the population to produce flowers.
4. **Number of pods per plant:** the total number of matured pods per plant was recorded at the time of harvest.

5. **100 seeds weight (g):** weight of 100 seeds collected from well dried and cleaned pods.

6. **Pod weight per plant (g plant$^{-1}$) =** $\frac{pod\ yield\ per\ plot\ (g)}{number\ of\ plants\ per\ plot}$

7. **Shelling percentage (%):** This was computed by shelling 100g random sample of dry pods for each genotype.

$$shelling\ percentage = \frac{\text{ker}nel\ weight\ (g)}{pod\ weight\ (g)} \times 100$$

8. **Kernel yield per plant (g):** Kernel yield per plant was computed using the formula given below:

$$Kernel\ yield = \frac{Pod\ weight \times shelling\ percentage}{100}$$

### 3.5 Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA) using the procedures for general linear model (GLM) of the Statistical Analysis System (SAS). The mean value, range and coefficient of variation (CV) for each trait were estimated in $M_2$. Mean separation was undertaken using LSD at 5% level of probability.

The statistical model for the analysis of variance for the combined effect of genotypes and doses is based on the linear model described by Kaps and Lamderson, (2004) as follows:

$$Y_{ijk} = \mu + G_i + D_j + R_k + (GD)_{ij} + E_{ijk}$$

Where,

$Y_{ij}$ = an observation in treatment i and block j; $\mu$ = the overall mean

$G_i$ = Effect of treatment ith variety, $i = 1, 2,3$

$D_j$ = Effect of jth dose of irradiation $j = 1, 2,3,4,5$

$R_k$ = Effect of kth replication, k= 1, 2, 3

$(GD)_{ij}$ = interaction effect of the ith variety with jth dose.

$\varepsilon_{ijk}$ = random error with mean 0 and variance $\sigma^2$

The form of analysis of variance (ANOVA) and expected mean squares for each trait at $M_1$ is presented on Table 3.2. The form of analysis of variance (ANOVA) and expected mean squares for each trait at $M_2$ based on the model described by Federer and Searle, 1976 is presented on Table 3.3.

**Table 3.2. Form of analysis of variance (ANOVA) and expected mean squares for the combined effect of genotypes and doses in $M_1$**

| Source of variation | Df | MS | EMS |
|---|---|---|---|
| Replications | $(r-1)$ | | |
| Genotypes | $(g-1)$ | $m_g$ | $\sigma_e^2 + rd\sigma_g^2$ |
| Doses | $(d-1)$ | $m_d$ | $\sigma_e^2 + rg\sigma_d^2$ |
| Genotypes × doses | $(g-1)(d-1)$ | $m_{dg}$ | $\sigma_e^2 + r\sigma_{dg}^2$ |
| Error | $(dg-1)$ | $m_e$ | $\sigma_e^2$ |

Where;

$r$ = number of replications; $g$ = number of genotypes; $v$ = number of doses

$\sigma_e^2$ = error variance $\sigma_g^2$ = genetic variance among genotypes

$\sigma_d^2$ = dosage variance among genotypes

$\sigma_{dg}^2$ = genotype x doses variance among varieties

$m$ Subscript = observed mean squares of the subscripted effect

**Table 3.2. Form of analysis of variance (ANOVA) and Expected Mean Squares for the effect of mutants and contrast with controls in an augmented design in $M_2$.**

| Source of variation | Df | MS | EMS |
|---|---|---|---|
| Block | $(b-1)$ | | $\sigma_e^2 + 4\sigma_b^2$ |
| Entries | $(e-1)$ | $m_5$ | |
| Control | $(c-1)$ | $m_4$ | $\sigma_e^2 + \sum_{i=1}^{4} u_{i..}^2 - \frac{1}{4}\left(\sum_{i=1}^{4} u_{i.}\right)^2$ |
| Mutants | $(m-1)$ | $m_3$ | $\sigma_e^2 + \sigma_g^2$ |
| Controls x Mutants | 1 | $m_2$ | |
| Error | $(b-1)(e-1)$ | $m_1$ | $\sigma_e^2$ |

Where;

$b$ = number of blocks; $e$ = number of entries

$c$ = number of controls; $m$ = number of mutants

$\sigma_e^2$ = error variance; $\sigma_g^2$ = Genetic variance among mutants

$\sigma_b^2$ = variance among blocks

$m$ Subscript = observed mean squares of the subscripted effect

### 3.6 Determination of Effective Doses

#### 3.6.1 Estimation of mutation frequency

Mutation frequency was estimated using the formular described by Sasikala and Kamala (1988).

$$\text{Mutation frequency (\%)} = \frac{Number\ of\ mu\tan ts}{Total\ number\ of\ \ plants scored} \times 100$$

#### 3.6.2 Estimation of mutagenic effectiveness and efficiency

The mutagenic effectiveness and efficiency were estimated using the formula suggested by Sasikala and Kamala (1988).

$$\text{Mutagenic effectiveness} = \frac{Mutation\ frequency}{Dose} \times 100$$

$$\text{Mutagenic efficiency} = \frac{Mutation\ frequency}{Percentage\ \ lethality} \times 100$$

### 3.7 Estimation of Coefficients of Variation

Variance components were estimated from the expected mean squares using observed mean squares. Thus:

$$\sigma_g^2 = m_3 - m_1 \qquad\qquad \sigma_{ph}^2 = \sigma_g^2 + \sigma_e$$

The genotypic and phenotypic coefficients of variation were estimated using the formula suggested by Singh and Chaudhary, (1985).

$$\text{Genotypic coefficient of variation (G.C.V)} = \frac{\sqrt{\sigma_g^2}}{\bar{x}} x\,100$$

Phenotypic coefficient of variance (P.C.V) = $\frac{\sqrt{\sigma^2_{ph}}}{\bar{x}} x\, 100$

Where;

$\sigma^2_g$ = genotypic variance; $\sigma^2_{ph}$ = phenotypic variance

$\bar{x}$ = mean of character

# CHAPTER FOUR

# 4 RESULTS

## 4.1 Analysis of Variance for Seedling Growth Parameters in $M_1$ Generation

The analysis of variance revealed that there was significant ($P < 0.05$) effect of the irradiation doses on the emergence rate, survival rate, seedling height and leaflet length in all the genotypes (Table 4.1). Highly significant differences ($P < 0.01$) were observed for root length, leaflet width and number of leaves per seedling. There was significant ($P < 0.05$) difference among the doses for root length. Highly significant ($P < 0.01$) effect for genotype by dose interaction was observed for leaflet width.

## 4.2 Mutagenic Effect on Seedling Growth Parameters in $M_1$ Generation

The effect of thermal neutron irradiation on survival of the genotypes is presented in Table 4.2. Thermal neutron irradiation at 12 Gy recorded the highest lethality in all the genotypes. The survival rate of SAMNUT 21 (60.07 %) and SAMNUT 23 (66.67 %) at 12Gy was less than SAMNUT 24 (81.57 %) indicating that SAMNUT 21 and SAMNUT 23 were more sensitive to thermal neutron irradiation than SAMNUT 24. Survival rate decreased progressively with increase in irradiation dose (Fig. 1). Emergence rate decreased at all irradiation doses compared to the control. Emergence rate varied from 16.67 to 44.33 % in SAMNUT 21, from 20.00 to 40.00 % in SAMNUT 23 and varied from 30.00 to 60.00 % in SAMNUT 24 (Table 4.2).

Generally, a progressive decrease in seedling height was observed as irradiation dose increased in all the genotypes. This was depicted with the comparison of SAMNUT 24 and its mutant in Plate 1. However, there was an unexpected increase in seedling height in SAMNUT 21 (10.03 cm) and SAMNUT 23 (11.17 cm) at 12 Gy.

**Table 4.1. Mean squares for seedling traits of three genotypes of groundnut (*Arachis hypogaea* L.) irradiated with thermal neutrons in $M_1$**

| Source of variation | DF | Emergence rate | Survival rate | Seedling height | Root length | Leaflet length | Leaflet width | Number of leaflets per plant |
|---|---|---|---|---|---|---|---|---|
| Rep | 2 | 82.22 | 114.19 | 0.97 | 3.91 | 0.05 | 0.09 | 89.60 |
| Genotypes | 2 | 1082.22 | 939.76* | 35.87* | 38.61** | 0.82* | 0.64** | 1473.07** |
| Doses | 4 | 74.44 | 702.28 | 2.84 | 10.89* | 0.22 | 0.19 | 266.13 |
| Genotypes*Doses | 8 | 1.57 | 507.10 | 2.75 | 2.51 | 0.15 | 0.25** | 54.4 |
| Error | 28 | 215.56 | 799.34 | 3.16 | 2.25 | 0.09 | 0.05 | 81.22 |

*= Significant ($P < 0.05$) **= Significant ($P < 0.01$)

**Table 4.2. Effect of different doses of neutron irradiation on seedling traits of groundnut genotypes evaluated in the screen house at IAR, Zaria in 2013.**

| Genotype | Treatment | Emergence rate | Survival rate | Seedling height | Root length | leaflet length | leaflet width | no of leaflets/ plant |
|---|---|---|---|---|---|---|---|---|
| | | -------- (%) -------- | | ---------- (cm) ---------- | | | | |
| SAMNUT 21 | 0Gy (control) | 44.33 | 96.67 | 9.73 | 14.50 | 3.77 | 2.43 | 73.33 |
| | 3Gy | 20.00 | 90.25 | 8.57 | 12.33 | 3.70 | 2.43 | 78.67 |
| | 6Gy | 16.67 | 84.59 | 8.63 | 13.00 | 3.10 | 2.07 | 68.67 |
| | 9Gy | 33.33 | 74.55 | 7.60 | 10.83 | 3.17 | 2.27 | 65.00 |
| | 12Gy | 20.00 | 60.07 | 10.03 | 10.23 | 3.00 | 1.57 | 64.00 |
| | Mean | 26.87 | 81.35 | 8.91 | 12.18 | 3.35 | 2.15 | 69.93 |
| SAMNUT 23 | 0Gy (control) | 40.00 | 99.11 | 13.07 | 11.00 | 3.10 | 2.00 | 61.33 |
| | 3Gy | 26.67 | 92.78 | 11.13 | 12.10 | 3.00 | 2.20 | 64.00 |
| | 6Gy | 20.00 | 75.44 | 10.73 | 10.67 | 3.13 | 2.27 | 49.33 |
| | 9Gy | 26.67 | 70.77 | 9.90 | 9.77 | 2.63 | 1.50 | 53.33 |
| | 12Gy | 23.33 | 66.67 | 11.17 | 8.83 | 2.93 | 2.13 | 49.00 |
| | Mean | 25.33 | 84.15 | 11.20 | 10.47 | 2.96 | 2.02 | 55.40 |
| SAMNUT 24 | 0Gy (control) | 60.00 | 99.43 | 11.73 | 9.17 | 3.33 | 2.40 | 46.67 |
| | 3Gy | 53.33 | 93.89 | 12.50 | 10.43 | 3.40 | 2.43 | 49.33 |
| | 6Gy | 46.67 | 91.67 | 11.77 | 8.50 | 3.47 | 2.47 | 45.33 |
| | 9Gy | 30.00 | 83.33 | 12.47 | 8.77 | 3.43 | 2.50 | 45.00 |
| | 12Gy | 43.33 | 81.57 | 10.83 | 8.00 | 3.27 | 2.33 | 44.67 |
| | Mean | 46.67 | 89.99 | 11.86 | 8.97 | 3.38 | 2.43 | 46.20 |
| Mean | | 30.89 | 84.93 | 10.658 | 10.54 | 3.229 | 2.2 | 56.53 |
| LSD $_{(0.05)}$ | | 16.95 | 32.65 | 2.06 | 1.73 | 0.34 | 0.27 | 10.40 |
| C V (%) | | 47.53 | 33.29 | 16.69 | 14.23 | 9.14 | 10.483 | 15.94 |

0 Gy = Non-irradiated seed (control); 3 Gy = irradiated at 3 Gy; 6 Gy = irradiated at 6 Gy, 9Gy = irradiated at 9 Gy and 12 Gy = irradiated at 12 Gy.

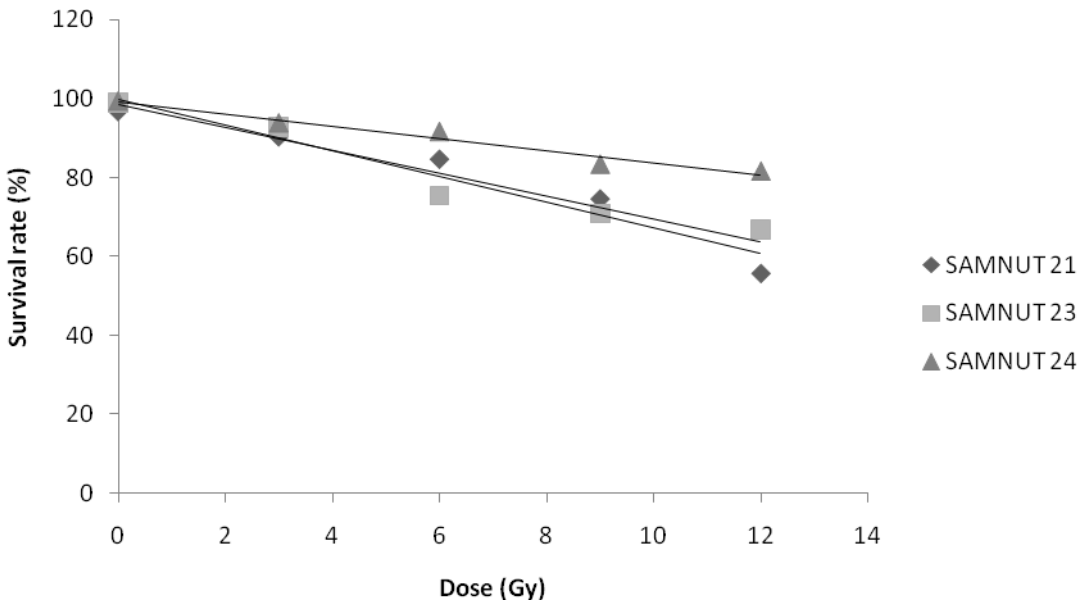



Fig.1. Survival rate of three groundnut genotypes subjected to different doses of irradiation




Plate 1. Effects of irradiation on SAMNUT 24 at 12 Gy at $M_1$ generation.

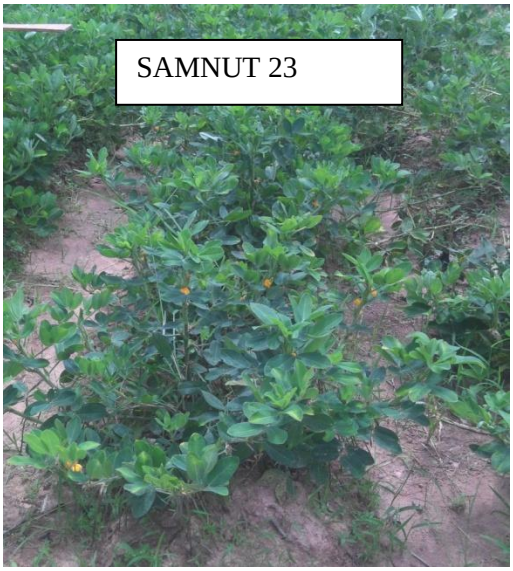
Seedling height varied from 8.57 to 10.03 cm in entries derived from SAMNUT 21, it varied from 9.90 to 11.17 cm in entries derived from SAMNUT 23 and varied from 10.83 to 12.50 cm in entries derived from SAMNUT 24 (Table 4.2). There was significant reduction in root length at 12 Gy in all the genotypes. Leaflet length decreased progressively in all genotypes with increase in radiation doses. Leaflet width decreased as irradiation doses increased in SAMNUT 21 and the highest reduction was recorded at 12 Gy. There was a significant decrease in the number of leaflets per seedling at 6 Gy and 12 Gy in SAMNUT 23. The number of leaflets per seedling varied from 64.00 to 78.67 in entries derived from SAMNUT 21. It also varied from 49.33 to 64.00 in entries derived from SAMNUT 23 and varied from 45 to 49.33 in entries derived from SAMNUT 24.

## 4.3 Mutation Frequency in $M_2$ Generation

The morphological mutations induced in the present study included plant type (dwarf/tall), leaf modification (small) and seed size (Plate 2). The frequency of morphological mutations on $M_2$ plant basis is presented in Table 4.3. The ratio of the variants observed in relation to the total number of plants scored decreased with increase in doses of radiation in SAMNUT 21 and SAMNUT 23. Mutation frequency was highest at 3 Gy in SAMNUT 21 (6.67 %) and SAMNUT 23 (7.78 %). However, in SAMNUT 24, mutation frequency increased with increase in doses of irradiation with the highest frequency at 12 Gy (4.13 %).

### 4.3.1 Mutagenic effectiveness and efficiency in $M_2$ generation

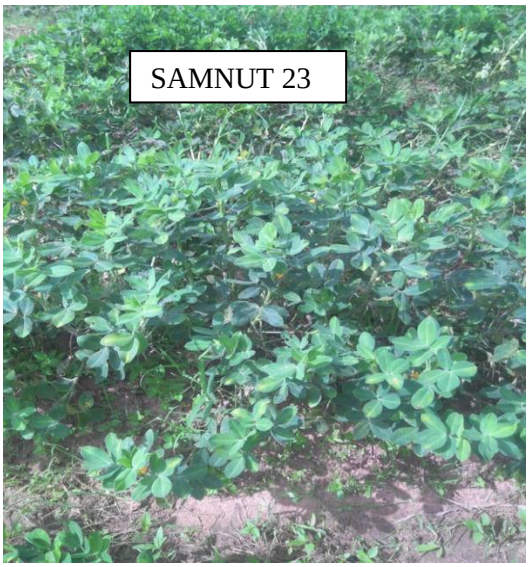
Mutagenic effectiveness refers to the rate of point mutations relative to dose, whereas efficiency refers to the rate of point mutations relative to other biological effects induced by the mutagen.



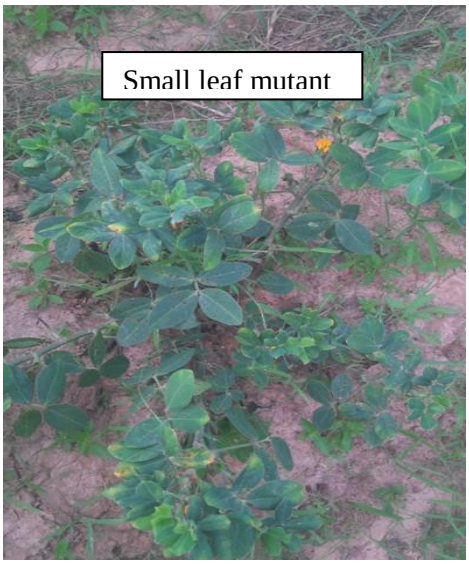

a.



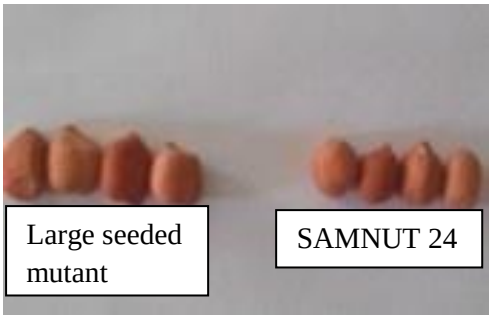

b.




c.




d.




e.

Plate 2. Morphological mutations: a. SAMNUT 23, b. dwarf (left) and tall (right) mutants, c. SAMNUT 23, d. small leaf mutant, e. large seeded mutant (left) and Parent (right).

**Table 4.3. Effect of thermal neutron irradiation on mutagenic frequency, effectiveness and efficiency of groundnut in $M_2$ generation evaluated at Samaru in 2014.**

| Treatment | Number of variants | Mutation frequency (%) | Mutagenic effectiveness | Mutagenic efficiency |
|---|---|---|---|---|
| 3Gy | | | | |
| SAMNUT 21 | 2 | 6.67 | 2.22 | 0.73 |
| SAMNUT 23 | 7 | 7.78 | 2.59 | 0.43 |
| SAMNUT 24 | 4 | 3.05 | 1.02 | 0.46 |
| 6Gy | | | | |
| SAMNUT 21 | 3 | 4.76 | 0.79 | 1.05 |
| SAMNUT 23 | 4 | 4.88 | 0.81 | 0.72 |
| SAMNUT 24 | 4 | 3.10 | 0.52 | 0.32 |
| 9Gy | | | | |
| SAMNUT 21 | 3 | 4.17 | 0.46 | 0.64 |
| SAMNUT 23 | 1 | 1.56 | 0.17 | 0.52 |
| SAMNUT 24 | 2 | 2.78 | 0.31 | 0.33 |
| 12Gy | | | | |
| SAMNUT 21 | 3 | 5.88 | 0.49 | 0.81 |
| SAMNUT 23 | 1 | 1.67 | 0.14 | 0.18 |
| SAMNUT 24 | 5 | 4.13 | 0.34 | 0.27 |

The effectiveness of 3 Gy varied from 1.02 % in SAMNUT 24 to 2.59 % in SAMNUT 23. The estimate of mutagenic efficiency based on lethality percentage in the $M_2$ generation is shown in Table 4.3. Mutagenic effectiveness varied from 0.14 for 12 Gy in SAMNUT 23 to 2.59 % for 3 Gy IN SAMNUT 23. The effectiveness of thermal neutron irradiation indicated that 3 Gy was the most effective dose for production of morphological mutations in all the genotypes (Table 4.3). Mutagenic efficiency varied from 0.18 for 12 Gy in SAMNUT 23 to 1.05 % for 6 Gy in SAMNUT 21. The results indicated that 6 Gy was the most efficient irradiation dose for SAMNUT 21 (1.05 %) and SAMNUT 23 (0.72 %) while 3 Gy was the most efficient dose for SAMNUT 24 (0.46 %).

### 4.4 Analysis of Variance for Agronomic Traits Measured at $M_2$ Generation

There were highly significant differences ($P < 0.01$) among the plant progenies for all the traits measured (Table 4.4). Highly significant differences were also observed among the controls for all the traits measured. The contrast between the treatments and their respective controls also had highly significant differences.

### 4.5 Mean Performance of $M_2$ Plant Progenies.

The mean performance for pod yield and other agronomic traits of $M_2$ progenies of mutants derived from SAMNUT 21 subjected to different doses of neutron irradiation are presented in Table 4.5. Days to 50% flowering varied from 32 for S21-9-1 to 38 days for S21-12-1 with a mean of 36.80 days in mutants derived from SAMNUT 21. Plant height varied from 8.47 for S21-12-1 to 21.30 cm for S21-12-5 with a mean of 14.28 cm. Number of branches per plant varied from11.39 for S21-3-1 to 35.55 for S21-6-4 with a mean of 21.84. Canopy spread varied from 29.54 for S21-3-1 to 66.17 cm for S21-9-3 with a mean of 48.38 cm. Number of pods per plant ranged between 5.16 for S21-12-1 and 41.06 for S21-3-3 with a mean of 25.68.

**Table 4.4. Mean squares for effect of neutron irradiation on groundnut (*Arachis hypogaea* L.) in $M_2$ generation evaluated at Samaru in 2014.**

| Source | DF | Days to 50% flowering | Plant height | Number of branches | Canopy spread | Number of pods per plant | Pod weight per plant | Kernel yield per plant | 100 seed weight | Shelling percentage | Pod yield (kg $ha^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Block | 11 | 2.20** | 6.21 | 27.47 | 69.21 | 160.42 | 102.52 | 52.52 | 16.94 | 0.003 | 3132062.40** |
| Entries | 98 | 50.90** | 759.04** | 264.81** | 719.55** | 1205.96** | 1094.94** | 181.28** | 153.60** | 0.07** | 766065.05** |
| Control (C) | 2 | 85.36** | 1127.94** | 699.53** | 673.84** | 2040.65** | 2027.22** | 125.53** | 402.40** | 0.15** | 1273771.52** |
| Treatment (T) | 95 | 49.01** | 742.56** | 159.19** | 780.95** | 1134.36** | 967.86** | 195.73** | 121.42** | 0.06** | 609627.65** |
| C Vs T | 1 | 259.66** | 2020.20** | 1383.92** | 1113.64** | 4186.49** | 3158.16** | 145.19* | 718.45** | 0.22** | 888934.75 |
| Error | 22 | 0.91 | 15.24 | 25.14 | 69.67 | 125.21 | 100.84 | 34.67 | 18.18 | 0.003 | 286696.06 |

**Table 4.5. Mean performance of agronomic traits in $M_2$ progenies of mutants derived from SAMNUT 21 subjected to different doses of neutron irradiation evaluated at Samaru in 2014.**

| Name | Days to 50% flowering | Plant height (cm) | Number of branches | Canopy spread (cm) | Pods per plant | Pod weight (g) | Kernel yield (g) | shelling percent (%) | 100 seed weight (g) | Pod yield (kg ha$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|
| S21-3-3 | 38.00 | 13.42 | 28.07 | 53.21 | 41.06 | 46.13 | 28.97 | 67.36 | 46.40 | 1537.74 |
| S21-6-3 | 37.00 | 14.92 | 25.47 | 46.86 | 37.31 | 39.61 | 22.87 | 59.59 | 43.00 | 1320.22 |
| S21-9-3 | 33.00 | 14.67 | 28.39 | 66.17 | 30.88 | 36.91 | 23.74 | 65.52 | 55.40 | 1230.47 |
| S21-12-3 | 36.00 | 16.00 | 20.45 | 52.21 | 33.55 | 36.21 | 24.02 | 61.16 | 47.20 | 1207.01 |
| S21-6-5 | 37.00 | 14.30 | 23.93 | 54.80 | 34.30 | 34.72 | 26.08 | 66.13 | 45.20 | 1157.44 |
| S21-6-4 | 36.00 | 11.98 | 35.55 | 55.34 | 33.15 | 32.83 | 24.66 | 69.93 | 45.60 | 1094.41 |
| S21-9-5 | 34.00 | 20.12 | 20.02 | 43.25 | 32.84 | 32.58 | 21.10 | 63.84 | 43.00 | 1085.93 |
| S21-9-7 | 34.00 | 13.57 | 23.88 | 50.99 | 39.69 | 26.80 | 18.15 | 62.62 | 28.60 | 893.23 |
| S21-3-2 | 38.00 | 17.11 | 22.73 | 53.17 | 28.42 | 26.52 | 17.79 | 63.60 | 37.60 | 883.96 |
| S21-6-1 | 36.00 | 17.02 | 23.35 | 49.43 | 22.80 | 25.33 | 16.08 | 61.26 | 44.00 | 844.47 |
| S21-9-4 | 35.00 | 14.51 | 29.67 | 59.07 | 24.44 | 24.72 | 16.49 | 64.45 | 50.40 | 824.55 |
| S21-6-6 | 38.00 | 11.03 | 23.12 | 54.02 | 22.48 | 21.56 | 14.39 | 64.21 | 47.22 | 718.70 |
| S21-9-6 | 38.00 | 12.50 | 21.55 | 38.46 | 18.55 | 20.58 | 14.09 | 61.97 | 44.00 | 686.01 |
| S21-9-1 | 32.00 | 13.22 | 28.23 | 55.69 | 19.08 | 19.52 | 13.22 | 66.49 | 44.50 | 650.73 |
| S21-12-4 | 37.00 | 12.95 | 15.68 | 38.35 | 22.88 | 19.48 | 10.54 | 55.79 | 40.00 | 649.30 |
| S21-9-2 | 36.00 | 13.04 | 20.86 | 44.12 | 23.94 | 19.36 | 11.17 | 59.95 | 40.40 | 645.18 |
| S21-12-2 | 37.00 | 11.84 | 14.19 | 46.72 | 20.54 | 17.70 | 13.51 | 70.94 | 36.50 | 590.17 |
| S21-3-1 | 38.00 | 15.52 | 11.39 | 29.54 | 19.36 | 16.95 | 12.88 | 65.20 | 39.40 | 564.91 |
| S21-6-2 | 38.00 | 12.59 | 15.60 | 45.64 | 15.40 | 15.94 | 11.25 | 57.96 | 41.20 | 531.26 |
| S21-12-5 | 38.00 | 21.13 | 14.28 | 41.26 | 13.51 | 15.21 | 8.45 | 46.82 | 37.20 | 507.03 |
| S21-12-1 | 38.00 | 8.47 | 12.19 | 37.66 | 5.16 | 9.64 | 4.09 | 59.12 | 46.00 | 321.43 |
| S21 | 35.17 | 15.99 | 26.40 | 54.92 | 36.06 | 32.46 | 21.06 | 63.00 | 42.22 | 1081.88 |
| Mean | 36.38 | 14.28 | 21.84 | 48.38 | 25.68 | 25.63 | 16.84 | 62.57 | 42.97 | 854.46 |
| LSD $_{(0.05)}$ | 0.60 | 1.80 | 2.85 | 4.32 | 5.18 | 5.29 | 3.47 | 3.13 | 3.59 | 176.47 |
| CV (%) | 3.19 | 21.78 | 22.59 | 15.45 | 34.95 | 35.77 | 35.66 | 8.67 | 14.49 | 35.77 |

Pod weight per plant ranged between 9.64 for S21-12-1 and 46.13 g for S21-3-3 with a mean of 25.63 g. Kernel yield varied from 4.09 for S21-12-1 to 28.97 g for S21-3-3 with a mean of 16.84 g. Shelling percentage varied from 46.82 for S21-12-5 to 70.94 % for S21-12-2 with a mean of 62.57 %. The 100 seed weight varied from 28.60 to 55.40 g for S21-9-3 with a mean of 42.97 g. Pod yield varied from 321.43 for S21-12-1 to 1537.74 kg $ha^{-1}$ for S21-3-3 with a mean of 854.46 kg $ha^{-1}$.

In mutants derived from SAMNUT 23, days to 50% flowering varied from 29 for S23-6-7 to 34 days for S23-12-4 with a mean of 32.5 days (Table 4.6). Plant height varied from 15.43 for S23-3-1 to 31.22 cm for S23-6-3 with a mean of 23.41 cm. Number of branches per plant varied from 3.59 for S23-6-7 to 18.89 for S23-3-5 with a mean of 11.86. Canopy spread varied from 42.62 for S23-3-1 to 75.59 cm for S23-3-8 with a mean of 56.27 cm. Number of pods per plant ranged between 33.66 for S23-12-2 and 77.49 for S23-3-5 with a mean of 53.09. Pod weight per plant varied from 39.30 for S23-9-3 to79.50 g for S23-6-8 with a mean of 57.05 g. Kernel yield per plant ranged between 13.69 for S23-12-6 and 33.03 g for S23-6-7 with a mean of 23.74 g. Shelling percentage varied from 32.22 for S23-12-6 to 51.95 % for S23-3-2 with a mean of 42.58 %. 100 seed weight varied from 24.20 for S23-3-8 to 37.20 g for S23-3-9 with a mean of 31.82 g. Pod yield ranged between 1310.06 for S23-9-3 to 2649 kg $ha^{-1}$ for S23-6-8 with a mean of 1267.69 kg $ha^{-1}$.

In mutants derived from SAMNUT 24, days to 50% flowering varied from 29 for S24-3-5 to 33 days for S24-9-2 with a mean of 30.5 days (Table 4.7). Plant height varied from 28.14 for S24-12-8 to 49.01 cm for S24-3-11 with a mean of 37.44 cm. Number of branches per plant varied from 4.66 for S24-3-2 to 18.49 for S24-3-10 with a mean of 11.24.

**Table 4.6. Mean performance of agronomic traits in $M_2$ progenies of mutants derived from SAMNUT 23 subjected to different doses of neutron irradiation evaluated at Samaru in 2014.**

| Name | Days to 50% flowering | Plant height | Number of branches | Canopy spread | Pods per plant | Pod weight | Kernel yield | shelling percent | 100 seed weight | Pod yield |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (cm) | | (cm) | | ----------g---------- | | (%) | (g) | (kg $ha^{-1}$) |
| S23-6-8 | 33.00 | 25.12 | 16.37 | 56.96 | 73.71 | 79.50 | 31.46 | 40.15 | 30.80 | 2649.89 |
| S23-6-6 | 33.00 | 24.60 | 15.85 | 52.46 | 61.65 | 71.55 | 30.20 | 38.82 | 30.40 | 2385.01 |
| S23-3-5 | 33.00 | 23.12 | 18.89 | 62.39 | 77.49 | 71.43 | 32.37 | 42.86 | 29.20 | 2381.14 |
| S23-6-7 | 29.00 | 26.54 | 3.59 | 53.47 | 65.34 | 67.41 | 33.03 | 51.72 | 31.20 | 2247.16 |
| S23-9-2 | 32.00 | 29.28 | 10.90 | 56.63 | 66.22 | 66.88 | 28.79 | 39.97 | 28.60 | 2229.19 |
| S23-6-3 | 32.00 | 31.22 | 13.19 | 62.54 | 62.29 | 64.16 | 30.55 | 46.32 | 32.60 | 2138.80 |
| S23-3-9 | 33.00 | 18.68 | 11.32 | 66.08 | 56.04 | 62.98 | 23.61 | 41.17 | 37.20 | 2099.43 |
| S23-3-7 | 33.00 | 26.63 | 17.92 | 67.47 | 55.88 | 62.58 | 23.30 | 40.61 | 33.80 | 2086.03 |
| S23-12-1 | 33.00 | 26.97 | 14.43 | 70.62 | 58.58 | 61.08 | 24.63 | 40.62 | 33.00 | 2036.14 |
| S23-12-6 | 32.00 | 23.67 | 17.11 | 57.30 | 34.65 | 50.33 | 13.69 | 32.22 | 28.00 | 1955.00 |
| S23-6-1 | 32.00 | 24.65 | 8.34 | 54.42 | 54.74 | 56.82 | 21.69 | 38.43 | 34.00 | 1893.85 |
| S23-12-4 | 34.00 | 21.96 | 14.53 | 54.79 | 35.22 | 51.20 | 15.30 | 34.00 | 29.30 | 1860.00 |
| S23-3-8 | 33.00 | 21.53 | 7.35 | 75.59 | 56.74 | 53.84 | 21.27 | 40.63 | 24.20 | 1794.68 |
| S23-3-10 | 33.00 | 19.32 | 7.99 | 64.02 | 36.60 | 52.33 | 14.25 | 35.64 | 29.00 | 1789.00 |
| S23-12-5 | 32.00 | 30.75 | 12.53 | 51.83 | 34.50 | 54.22 | 16.34 | 33.00 | 28.44 | 1766.00 |
| S23-12-3 | 33.00 | 23.22 | 9.07 | 50.10 | 34.55 | 51.22 | 15.33 | 33.65 | 28.93 | 1762.00 |
| S23-12-2 | 34.00 | 23.98 | 7.99 | 48.43 | 33.66 | 52.57 | 14.69 | 33.52 | 28.20 | 1752.44 |
| S23-3-3 | 32.00 | 20.92 | 8.37 | 43.46 | 44.01 | 51.47 | 20.81 | 43.75 | 34.80 | 1715.55 |
| S23-3-6 | 33.00 | 22.74 | 12.64 | 57.88 | 45.71 | 50.33 | 20.40 | 44.76 | 31.00 | 1677.80 |
| S23-9-5 | 30.00 | 23.85 | 12.44 | 55.07 | 45.94 | 49.67 | 23.87 | 47.97 | 29.40 | 1655.51 |
| S23-9-1 | 32.00 | 26.30 | 9.57 | 46.62 | 40.36 | 49.25 | 20.56 | 39.12 | 33.00 | 1654.33 |
| S23-6-4 | 33.00 | 26.07 | 12.35 | 63.00 | 54.00 | 59.00 | 31.00 | 45.52 | 33.00 | 1600.38 |
| S23-3-4 | 32.00 | 18.43 | 15.78 | 52.51 | 43.00 | 45.00 | 22.00 | 43.33 | 34.00 | 1600.00 |
| S23-9-6 | 33.00 | 25.01 | 11.36 | 44.81 | 42.22 | 47.64 | 19.35 | 38.46 | 34.00 | 1587.98 |
| S23-9-4 | 33.00 | 22.85 | 13.20 | 51.85 | 50.52 | 52.30 | 22.30 | 44.52 | 32.00 | 1560.52 |
| S23-3-2 | 32.00 | 18.06 | 0.79 | 58.12 | 42.01 | 46.14 | 23.23 | 51.95 | 34.60 | 1538.00 |
| S23-6-5 | 33.00 | 22.71 | 17.26 | 61.68 | 54.00 | 58.00 | 30.00 | 44.57 | 33.00 | 1500.42 |
| S23-3-1 | 33.00 | 15.43 | 13.32 | 42.62 | 42.08 | 42.96 | 16.77 | 41.87 | 33.30 | 1432.03 |
| S23-6-2 | 33.00 | 17.89 | 10.00 | 44.27 | 40.60 | 42.60 | 19.47 | 47.10 | 34.00 | 1420.13 |
| S23-9-3 | 33.00 | 20.87 | 11.31 | 61.11 | 36.90 | 39.30 | 15.30 | 40.88 | 32.00 | 1310.06 |
| S23 | 32.41 | 27.53 | 12.90 | 56.88 | 57.38 | 60.69 | 25.39 | 43.00 | 29.49 | 1697.48 |
| Mean | 32.53 | 23.41 | 11.86 | 56.27 | 53.09 | 57.05 | 23.74 | 42.58 | 31.82 | 1267.69 |
| $LSD_{(0.05)}$ | 0.60 | 1.69 | 2.53 | 4.96 | 7.56 | 6.71 | 3.21 | 2.69 | 1.78 | 542.52 |
| CV (%) | 3.19 | 12.48 | 37.00 | 15.26 | 24.68 | 20.38 | 23.45 | 10.96 | 9.71 | 74.12 |

**Table 4.7. Mean performance of agronomic traits in $M_2$ progenies of mutants derived from SAMNUT 24 subjected to different doses of neutron irradiation evaluated at Samaru in 2014.**

| Name | Days to 50% flowering | Plant height (cm) | Number of branches | Canopy spread (cm) | Pods per plant | Pod weight ----------g---------- | Kernel yield | shelling percent (%) | 100 seed weight (g) | Pod yield (kg $ha^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|
| S24-3-10 | 31.00 | 41.22 | 18.49 | 88.89 | 99.19 | 80.14 | 49.80 | 60.54 | 33.60 | 2671.47 |
| S24-12-7 | 30.00 | 38.71 | 6.97 | 78.99 | 78.96 | 69.50 | 41.08 | 60.89 | 35.80 | 2316.56 |
| S24-3-12 | 30.00 | 31.74 | 6.39 | 66.92 | 73.34 | 64.54 | 39.68 | 64.19 | 35.40 | 2151.50 |
| S24-3-5 | 29.00 | 40.52 | 13.57 | 72.46 | 74.21 | 62.05 | 37.85 | 62.56 | 30.20 | 2068.22 |
| S24-12-10 | 31.00 | 31.60 | 9.85 | 63.61 | 64.95 | 57.58 | 36.48 | 58.37 | 34.00 | 1919.34 |
| S24-12-11 | 30.00 | 33.40 | 13.14 | 80.82 | 68.56 | 56.92 | 34.85 | 64.13 | 42.20 | 1897.36 |
| S24-3-2 | 30.00 | 38.00 | 4.66 | 77.31 | 65.51 | 54.61 | 34.18 | 62.79 | 36.80 | 1820.50 |
| S24-6-5 | 31.00 | 38.52 | 15.29 | 72.39 | 66.59 | 53.66 | 29.60 | 50.83 | 42.40 | 1788.80 |
| S24-6-12 | 30.00 | 39.12 | 11.47 | 70.76 | 52.21 | 53.66 | 30.46 | 58.29 | 40.60 | 1788.55 |
| S24-3-1 | 29.00 | 42.14 | 44.94 | 47.34 | 54.35 | 53.24 | 32.70 | 60.67 | 39.80 | 1774.61 |
| S24-3-3 | 29.00 | 37.11 | 6.33 | 75.27 | 51.02 | 52.22 | 31.70 | 60.89 | 38.00 | 1740.62 |
| S24-3-6 | 31.00 | 32.95 | 9.60 | 65.02 | 60.06 | 51.69 | 28.57 | 57.58 | 34.00 | 1722.92 |
| S24-3-9 | 32.00 | 32.18 | 11.62 | 86.58 | 49.00 | 50.00 | 26.00 | 56.00 | 34.00 | 1698.00 |
| S24-3-11 | 32.00 | 49.01 | 12.19 | 87.93 | 48.62 | 50.71 | 30.43 | 61.77 | 39.00 | 1690.22 |
| S24-3-7 | 31.00 | 42.93 | 11.88 | 77.06 | 51.00 | 39.00 | 25.00 | 54.00 | 35.00 | 1689.00 |
| S24-12-6 | 32.00 | 36.98 | 12.26 | 81.82 | 63.01 | 50.01 | 27.58 | 53.96 | 36.60 | 1667.11 |
| S24-12-12 | 29.00 | 33.15 | 11.24 | 62.37 | 64.54 | 49.89 | 32.12 | 62.92 | 39.00 | 1662.85 |
| S24-6-2 | 29.00 | 36.52 | 11.39 | 74.84 | 61.59 | 49.33 | 27.79 | 50.80 | 38.00 | 1644.47 |
| S24-3-8 | 32.00 | 40.38 | 12.99 | 65.43 | 52.00 | 46.00 | 22.00 | 55.00 | 33.00 | 1600.00 |
| S24-6-8 | 31.00 | 42.40 | 11.45 | 70.06 | 52.15 | 46.95 | 28.01 | 54.85 | 36.80 | 1565.01 |
| S24-6-7 | 32.00 | 38.48 | 9.61 | 65.51 | 44.00 | 27.00 | 26.00 | 58.50 | 35.00 | 1560.00 |
| S24-6-1 | 30.00 | 46.03 | 13.57 | 77.62 | 53.77 | 46.33 | 28.77 | 62.71 | 35.60 | 1544.35 |
| S24-6-6 | 31.00 | 37.23 | 14.08 | 67.26 | 50.00 | 45.00 | 25.00 | 55.00 | 32.00 | 1542.00 |
| S24-6-10 | 32.00 | 35.23 | 11.26 | 65.97 | 48.00 | 34.00 | 27.00 | 54.00 | 32.00 | 1500.00 |
| S24-6-3 | 31.00 | 29.73 | 14.74 | 64.60 | 59.36 | 44.47 | 28.31 | 60.03 | 39.00 | 1482.32 |
| S24-12-3 | 31.00 | 40.90 | 9.25 | 78.51 | 45.00 | 36.00 | 23.00 | 56.00 | 36.00 | 1450.00 |
| S24-9-7 | 29.00 | 42.91 | 10.73 | 73.52 | 64.22 | 43.47 | 23.27 | 52.79 | 30.00 | 1448.96 |
| S24-12-5 | 30.00 | 37.98 | 11.35 | 79.50 | 50.00 | 40.00 | 30.00 | 44.00 | 35.00 | 1400.00 |
| S24-9-2 | 33.00 | 32.40 | 5.75 | 63.11 | 48.65 | 41.30 | 25.60 | 57.06 | 38.00 | 1376.67 |
| S24-3-4 | 31.00 | 43.56 | 11.01 | 85.75 | 43.25 | 39.80 | 24.63 | 63.30 | 36.00 | 1326.59 |
| S24-9-3 | 30.00 | 46.28 | 8.42 | 66.23 | 44.00 | 36.00 | 22.00 | 56.00 | 35.00 | 1325.00 |
| S24-6-4 | 32.00 | 31.88 | 11.62 | 74.43 | 51.00 | 39.00 | 24.00 | 53.00 | 31.00 | 1320.00 |
| S24-6-13 | 30.00 | 38.78 | 13.01 | 61.01 | 35.00 | 29.22 | 27.00 | 61.22 | 38.00 | 1300.00 |
| S24-9-5 | 30.00 | 39.98 | 9.52 | 67.98 | 45.00 | 37.00 | 21.00 | 55.00 | 35.00 | 1298.00 |
| S24-9-4 | 29.00 | 34.51 | 7.15 | 74.35 | 44.78 | 38.54 | 23.36 | 57.71 | 36.20 | 1284.74 |
| S24-3-13 | 30.00 | 38.55 | 9.84 | 66.07 | 50.84 | 38.45 | 20.90 | 54.37 | 34.20 | 1281.51 |
| S24-9-1 | 31.00 | 39.59 | 6.59 | 69.44 | 46.70 | 38.17 | 23.55 | 61.28 | 35.20 | 1272.33 |
| S24-12-2 | 30.00 | 40.42 | 6.77 | 75.27 | 45.66 | 36.71 | 23.09 | 59.45 | 36.00 | 1223.55 |
| S24-6-11 | 32.00 | 32.51 | 10.03 | 74.82 | 51.32 | 36.04 | 20.39 | 55.56 | 30.00 | 1201.29 |
| S24-9-6 | 29.00 | 30.51 | 13.40 | 67.98 | 40.17 | 35.22 | 20.00 | 55.28 | 37.00 | 1174.00 |
| S24-12-4 | 29.00 | 38.66 | 8.71 | 65.74 | 36.00 | 28.00 | 13.00 | 58.00 | 32.00 | 1001.00 |
| S24-12-8 | 30.00 | 28.14 | 11.08 | 57.02 | 35.00 | 27.00 | 12.00 | 57.00 | 34.00 | 987.22 |
| S24-12-9 | 29.00 | 32.13 | 7.77 | 56.85 | 34.79 | 28.09 | 17.30 | 62.50 | 35.00 | 936.27 |
| S24-6-9 | 31.00 | 36.81 | 6.95 | 70.13 | 34.88 | 27.95 | 17.06 | 55.65 | 41.80 | 931.70 |
| S24-12-1 | 30.00 | 32.98 | 7.92 | 78.32 | 34.56 | 26.31 | 11.12 | 48.37 | 21.60 | 876.99 |
| S24 | 29.83 | 35.21 | 13.38 | 58.96 | 56.75 | 47.83 | 28.55 | 62.00 | 34.80 | 1204.68 |
| Mean | 30.47 | 37.44 | 11.24 | 71.40 | 56.51 | 47.66 | 28.39 | 58.45 | 36.06 | 1094.48 |
| LSD $_{(0.05)}$ | 0.63 | 2.73 | 3.28 | 5.06 | 8.25 | 6.66 | 4.35 | 2.36 | 2.27 | 477.76 |
| CV (%) | 3.58 | 12.64 | 50.50 | 12.28 | 25.29 | 24.21 | 26.51 | 6.99 | 10.92 | 75.61 |

Canopy spread varied from 47.34 for S24-3-1 to 88.89 cm for S24-3-10 with a mean of 71.40 cm. Number of pods per plant ranged between 34.56 for S24-12-1 and 99.19 for S24-3-10 with a mean of 56.51. Pod weight per plant ranged between 26.31 for S24-12-1 and 80.14 g for S24-3-10 with a mean of 47.66 g. Kernel yield varied from 11.12 for S24-12-1 to 49.80 g for S24-3-10 with a mean of 28.39 g. Shelling percentage ranged between 44.00 for S24-12-5 and 64.19 % for S24-3-12 with a mean of 58.45 %. The 100 seed weight ranged between 21.60 for S24-12-1 and 42.40 g for S24-6-5 with a mean of 36.06 g. Pod yield varied from 876.99 kg $ha^{-1}$ for S24-12-1 to 2671.47 kg $ha^{-1}$ for S24-3-10 with a mean of 1094.48 kg $ha^{-1}$.

### 4.6 Variability for Agronomic Traits in $M_2$ Generation

The three genotypes studied responded to induced mutagenesis as reflected by change in their means, ranges and magnitudes of variance for various characters compared to respective controls. The highest changes for these traits were observed in SAMNUT 24 variety at 3 Gy. The mutant populations derived from the three genotypes also recorded wider range for canopy spread, number of pods per plant, pod weight per plant, kernel yield and pod yield compared to the controls. The coefficient of variation was lowest for days to 50% flowering while pod yield per plant recorded the highest coefficient of variation (Table 4.8). The mean number of days to 50% flowering increased at all doses except at 9 Gy where a reduction was observed in SAMNUT 21. Reduction in mean plant height was observed at all doses in SAMNUT 21 and SAMNUT 23 compared to control (Table 4.8). However, in SAMNUT 24 thermal neutron irradiation at 3 Gy increased plant height significantly by 11 %. Plant height ranged between 8.47 and 49.01 cm across the irradiated entries. There was reduction in mean number of branches per plant at all doses in all the genotypes compared to their respective controls.

**Table 4.8. Mean performance of agronomic traits in $M_2$ generation of three groundnut genotypes subjected to different doses of neutron irradiation.**

| Genotypes | Treatment | Days to 50% flowering | | | Plant height | | | Number of branches | | | Canopy spread | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Range | SE | Mean | Range | SE | Mean | Range | SE | Mean | Range | SE |
| SAMNUT 21 | 0Gy | 35.17 | 34-36 | 0.17 | 15.95 | 11.9-22.00 | 0.91 | 26.36 | 18.44-32.10 | 1.90 | 54.58 | 43.55-64.90 | 1.61 |
| | 3Gy | 38.06 | 37-38 | 0.14 | 15.44 | 13.42-17.11 | 0.56 | 21.05 | 11.39-28.07 | 2.57 | 45.92 | 29.54-53.21 | 4.12 |
| | 6Gy | 37.16 | 36-38 | 0.27 | 13.53 | 11.03-17.03 | 0.66 | 24.15 | 15.60-35.55 | 1.93 | 52.42 | 45.64-55.34 | 1.28 |
| | 9Gy | 34.64 | 32-38 | 0.60 | 14.92 | 12.50-20.12 | 0.78 | 23.76 | 20.02-29.67 | 1.22 | 51.49 | 38.46-66.17 | 2.97 |
| | 12Gy | 37.22 | 36-38 | 0.25 | 13.73 | 8.47-21.13 | 1.44 | 15.98 | 12.19-20.45 | 0.94 | 43.03 | 37.66-52.21 | 1.86 |
| SAMNUT 23 | 0Gy | 32.41 | 31-33 | 0.20 | 27.53 | 20.6-32.27 | 1.16 | 12.90 | 8.55-19.50 | 0.85 | 56.88 | 45.09-66.10 | 1.80 |
| | 3Gy | 32.74 | 32-33 | 0.15 | 20.72 | 15.43-26.63 | 1.01 | 11.12 | 7.35-18.89 | 1.72 | 57.69 | 42.62-75.59 | 3.30 |
| | 6Gy | 32.28 | 29-33 | 0.42 | 24.97 | 17.89-31.22 | 1.13 | 12.01 | 3.59-17.36 | 1.40 | 55.39 | 44.27-63.00 | 1.92 |
| | 9Gy | 32.01 | 30-33 | 0.35 | 24.76 | 20.87-29.28 | 0.88 | 10.77 | 9.57-13.20 | 0.38 | 54.56 | 44.81-61.11 | 1.87 |
| | 12Gy | 32.87 | 32-34 | 0.27 | 24.12 | 19.32-30.75 | 0.97 | 12.26 | 7.99-17.11 | 1.05 | 55.65 | 48.43-70.62 | 2.43 |
| SAMNUT 24 | 0Gy | 29.83 | 29-32 | 0.25 | 35.21 | 31.18-38.00 | 0.64 | 13.38 | 6.77-13.14 | 0.75 | 68.56 | 42.62-75.59 | 3.28 |
| | 3Gy | 30.68 | 29-32 | 0.34 | 39.19 | 31.74-49.01 | 1.50 | 13.66 | 4.66-1.94 | 3.06 | 74.00 | 47.34-88.89 | 3.60 |
| | 6Gy | 30.88 | 29-32 | 0.29 | 36.90 | 29.73-46.03 | 1.31 | 12.09 | 6.95-15.29 | 0.69 | 70.61 | 61.01-77.62 | 1.47 |
| | 9Gy | 30.06 | 29-33 | 0.44 | 38.41 | 30.51-46.28 | 1.73 | 8.89 | 5.75-13.40 | 0.80 | 69.35 | 63.11-74.35 | 1.19 |
| | 12Gy | 29.95 | 29-32 | 0.27 | 35.39 | 28.14-40.90 | 1.22 | 10.18 | 6.77-13.14 | 0.64 | 70.35 | 56.85-81.62 | 2.91 |
| Mean | | 32.42 | | | 27.51 | | | 14.79 | | | 61.19 | | |
| $LSD_{(0.05)}$ | | 0.552 | | | 2.254 | | | 2.896 | | | 4.82 | | |
| C V (%) | | 2.95 | | | 14.19 | | | 33.91 | | | 13.64 | | |

It varied from 3.59 to 35.55. Reduction in canopy spread was observed in SAMNUT 21 and SAMNUT 23 at all the irradiation doses. Whereas in SAMNUT 24, 3Gy recorded increased mean canopy spread of 74 cm compared to 68.56 cm of control (Table 4.8). Canopy spread varied from 29.54 to 88.89 cm. There was reduction in number of pods per plant as dosages increased in all the genotypes with the exception of 3 Gy in SAMNUT 24 which recorded increased mean number of pods of 62.79 (11 %) compared to 56.75 of the control (Table 4.9). Number of pods per plant ranged between 5.16 and 99.19. Reduction in weight of pods per plant was observed at all doses in SAMNUT 21 and SAMNUT 23 compared to control. In SAMNUT 24, 3 Gy recorded mean pod weight of 55.45 g compared to 47.83 g of the control (Table 4.9). Pods weight per plant was increased by 16 % SAMNUT 24 at 3 Gy.

Reduction in mean kernel yield per plant was observed at all doses in SAMNUT 21. In contrast, 3 Gy in SAMNUT 24 had higher mean kernel yield per plant of 33.66 g compared to 28.55 g of the control (Table 4.9). Kernel yield per plant was increased by 18 % in SAMNUT 24 at 3 Gy. In SAMNUT 21, 3 Gy recorded increased mean shelling percentage of 66.17% compared to 63.20 % of the control (Table 4.10). In contrast, reduction in shelling percentage was observed in SAMNUT 23 and SAMNUT 24 at all the irradiation doses. Increased mean 100 seed weight per plant was recorded at all doses in all the genotypes. 6 Gy of thermal neutron irradiation recorded increased mean 100 seed weight of 44.69 g in SAMNUT 21, 32.51 g in SAMNUT 23 and 38.67 g in SAMNUT 24 compared to the controls (42.22, 29.49 and 34.80 g) respectively (Table 4.10). Thermal neutron irradiation at 6 Gy increased 100 seeds weight significantly by 11 %, 10 % and 6 % in SAMNUT 24, SAMNUT 23 and SAMNUT 21 respectively.

**Table 4.9. Mean performance of pods per plant, pods weight per plant and kernel yield per plant in $M_2$ generation of three groundnut genotypes subjected to different doses of neutron irradiation.**

| Genotypes | Treatment | Pods per plant | | | Pod weight per plant | | | Kernel yield per plant | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Range | SE | Mean | Range | SE | Mean | Range | SE |
| SAMNUT 21 | 0Gy | 32.06 | 20.38-43.56 | 2.07 | 32.46 | 19.01-41.61 | 1.84 | 21.06 | 15.85-27.34 | 1.03 |
| | 3Gy | 27.38 | 19.36-41.06 | 3.29 | 28.76 | 16.95-46.13 | 4.49 | 19.51 | 12.88-28.97 | 2.49 |
| | 6Gy | 27.59 | 15.40-37.31 | 2.59 | 28.29 | 15.94-39.61 | 2.69 | 19.53 | 11.25-26.08 | 1.84 |
| | 9Gy | 26.54 | 18.55-39.69 | 2.34 | 24.99 | 19.36-36.91 | 2.06 | 16.19 | 11.17-23.74 | 1.35 |
| | 12Gy | 20.45 | 5.16-33.55 | 3.20 | 20.47 | 9.64-19.48 | 3.01 | 12.81 | 4.09-24.02 | 2.26 |
| SAMNUT 23 | 0Gy | 57.38 | 44.20-73.90 | 2.71 | 60.69 | 44.43-77.38 | 3.12 | 25.93 | 17.30-32.12 | 1.40 |
| | 3Gy | 53.16 | 42.09-77.49 | 3.61 | 55.71 | 42.96-71.43 | 2.91 | 23.21 | 16.77-32.67 | 1.35 |
| | 6Gy | 57.35 | 40.60-73.71 | 3.38 | 61.69 | 42.6-79.50 | 3.86 | 26.48 | 19.47-33.03 | 1.71 |
| | 9Gy | 46.81 | 36.90-66.22 | 3.86 | 48.93 | 39.30-66.88 | 3.49 | 20.71 | 15.30-28.79 | 1.75 |
| | 12Gy | 44.71 | 33.66-58.58 | 5.31 | 56.97 | 36.21-61.08 | 1.81 | 19.69 | 14.69-24.63 | 2.12 |
| SAMNUT 24 | 0Gy | 56.75 | 43.00-70.63 | 3.28 | 47.83 | 35.29-62.75 | 2.54 | 28.55 | 19.10-37.83 | 1.85 |
| | 3Gy | 62.79 | 43.25-99.19 | 5.04 | 55.45 | 38.45-80.54 | 3.65 | 33.66 | 20.80-49.80 | 2.45 |
| | 6Gy | 50.97 | 34.88-66.59 | 2.85 | 42.79 | 27.95-53.66 | 2.66 | 25.21 | 17.06-30.46 | 1.46 |
| | 9Gy | 48.78 | 40.17-64.22 | 2.75 | 39.07 | 35.22-43.47 | 0.95 | 22.99 | 20.00-25.60 | 0.61 |
| | 12Gy | 58.21 | 34.56-78.96 | 4.96 | 48.19 | 26.31-69.50 | 4.59 | 28.85 | 11.12-41.08 | 3.08 |
| Mean | | 46.92 | | | 45.52 | | | 24.09 | | |
| $LSD_{(0.05)}$ | | 6.455 | | | 5.798 | | | 3.338 | | |
| C V (%) | | 23.85 | | | 22.53 | | | 24.45 | | |

**Table 4.10. Mean performance of shelling percentage, 100 seed weight and pod yield per plant in $M_2$ generation of three groundnut genotypes subjected to different doses of neutron irradiation.**

| Genotypes | Trreatment | Shelling percent | | | 100 seed weight | | | Pod yield | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Range | SE | Mean | Range | SE | Mean | Range | SE |
| SAMNUT | 0Gy | 63.20 | 51.63-70.15 | 1.50 | 42.22 | 36.00-52.00 | 1.35 | 1081.88 | 633.75-1387.14 | 61.3 |
| 21 | 3Gy | 66.17 | 63.59-67.36 | 0.57 | 42.07 | 37.60-46.40 | 1.40 | 585.03 | 564.91-1537.73 | 149.5 |
| | 6Gy | 64.39 | 57.95-69.62 | 1.34 | 44.69 | 41.20-47.20 | 0.64 | 939.81 | 531.25-1320.21 | 89.5 |
| | 9Gy | 63.21 | 59.95-66.48 | 0.67 | 42.67 | 28.60-55.40 | 2.53 | 713.90 | 645.18-1230.46 | 68.6 |
| | 12Gy | 59.06 | 46.82-70.94 | 2.64 | 42.09 | 36.50-47.20 | 1.49 | 604.04 | 321.43-1207.01 | 100.2 |
| SAMNUT | 0Gy | 43.01 | 34.54-49.92 | 1.32 | 29.49 | 25.00-32.80 | 0.71 | 1697.48 | 1480.95-2579.33 | 256.9 |
| 23 | 3Gy | 43.37 | 40.61-51.95 | 1.13 | 31.66 | 24.20-37.20 | 1.23 | 1560.37 | 1432.23-2381.13 | 206.0 |
| | 6Gy | 43.35 | 38.42-51.79 | 1.63 | 32.51 | 30.40-34.00 | 0.48 | 1315.26 | 1420.12-2649.88 | 315.5 |
| | 9Gy | 41.70 | 38.45-47.96 | 1.27 | 30.08 | 28.60-34.00 | 0.75 | 1015.24 | 1310.06-2229.18 | 279.0 |
| | 12Gy | 37.67 | 33.51-40.62 | 1.51 | 30.27 | 28.30-32.00 | 1.02 | 1062.48 | 1752.43-2036.13 | 296.2 |
| SAMNUT | 0Gy | 61.94 | 58.40-72.83 | 1.31 | 34.80 | 31.2-39.2 | 0.66 | 1204.68 | 1176.33-2091.66 | 230.6 |
| 24 | 3Gy | 60.73 | 54.37-64.19 | 0.88 | 36.11 | 30.2-39.80 | 0.87 | 1407.40 | 1281.51-2671.46 | 263.3 |
| | 6Gy | 56.70 | 50.80-62.70 | 1.26 | 38.67 | 30.00-42.40 | 1.21 | 942.96 | 931.69-1788.80 | 237.9 |
| | 9Gy | 56.72 | 52.79-61.27 | 0.95 | 35.42 | 30.00-38.00 | 0.94 | 995.64 | 1173.99-1448.95 | 194.6 |
| | 12Gy | 58.58 | 48.37-64.13 | 1.60 | 35.11 | 21.60-42.20 | 1.81 | 1182.99 | 876.98-2316.55 | 262.2 |
| | Mean | 55.58 | | | 36.73 | | | 1159.35 | | |
| | $LSD_{(0.05)}$ | 2.655 | | | 2.462 | | | 535.443 | | |
| | C V (%) | 8.32 | | | 11.61 | | | 46.18 | | |

There was reduction in mean pod yield in SAMNUT 21 and SAMNUT 23 at all the irradiation doses. In contrast, SAMNUT 24 recorded 17 % increased mean pod yield of 1407 kg $ha^{-1}$ at 3 Gy dosage of radiation compared to control of 1204.68 kg $ha^{-1}$ (Table 4.10).

## 4.7 Estimates of Coefficients of Variation

Generally, the phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV). However, the differences between the two parameters were low for days to 50% flowering and plant height (Table 4.11). The differences were higher for number of pods per plant, pods weight per plant, pod yield and 100-seed weight. The genotypic coefficient of variation ranged from 0.01 for shelling percentage to 2.21 for plant height. The phenotypic coefficient of variation ranged from 0.10 for shelling percentage to 4.37 for pods per plant.

## 4.8 Mutants with Improved Yield and Other Agronomic Traits

The mean values of top 20 mutants for pod yield and other agronomic traits at $M_2$ generation are presented in Table 4.12. The mutant line, S21-9-3 recorded the highest 100-seed weight (55.40 g) among the mutants while S24-3-10 recorded the highest yield of 2671.47 kg $ha^{-1}$. In SAMNUT 21, three mutants (S21-3-3, S21-6-3 and S21-9-3) were significantly higher yielding than the parent and the other mutant had significantly higher 100-seed weight than the parent. The mutant line, S21-3-3 recorded the highest pod yield of 1537.74 kg $ha^{-1}$ and S21-9-3 had the highest 100-seed weight of 55.40 g. In SAMNUT 23, the mutant lines, S23-3-3 and S23-3-9 had significantly higher 100-seed weight and the other mutants had significantly higher pod yield as well as 100-seed weight than the parent.

**Table 4.11. Estimates of genotypic and phenotypic coefficients of variation for agronomic traits of $M_2$ generation of groundnut evaluated at Samaru in 2014.**

| Traits | Mean | Range | GCV | PCV |
|---|---|---|---|---|
| Days to 50% flowering | 32.42 | 29 - 38 | 0.12 | 0.15 |
| Plant height (cm) | 27.51 | 8.47 - 49.01 | 2.21 | 2.76 |
| Number of branches | 14.79 | 3.59 - 35.55 | 0.75 | 2.44 |
| Canopy spread (cm) | 61.19 | 29.54 - 88.89 | 0.97 | 2.10 |
| Pods per plant | 46.92 | 5.16 - 99.19 | 1.76 | 4.37 |
| Pods weight per plant (g) | 45.52 | 9.64 - 29.50 | 1.59 | 3.80 |
| Kernel yield per plant (g) | 29.09 | 4.09 - 49.80 | 0.54 | 1.95 |
| Shelling percentage (%) | 55.58 | 33.51 - 70.94 | 0.01 | 0.10 |
| 100 seed weight (g) | 36.73 | 21.60 - 55.40 | 0.23 | 0.73 |
| Pod yield (kg $ha^{-1}$) | 1159.35 | 531.25 - 2671.46 | 0.23 | 2.71 |

**Table 4.12. Mutants with improved yield and other agronomic traits in $M_2$ generation of groundnut evaluated at Samaru in 2014.**

| Mutants | Days to 50% flowering | Plant height | Number of branches | Canopy spread | Pods per plant | Pod weight | Kernel yield | shelling percent | 100 seed weight | Pod yield |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (cm) | | (cm) | | ----------g---------- | | (%) | (g) | (kg/ha) |
| S21-3-3 | 38.00 | 13.42 | 28.07 | 53.21 | 41.06 | 46.13 | 28.97 | 67.36 | 46.40 | 1537.74 |
| S21-6-3 | 37.00 | 14.92 | 25.47 | 46.86 | 37.31 | 39.61 | 22.87 | 59.59 | 43.00 | 1320.22 |
| S21-9-3 | 33.00 | 14.67 | 28.39 | 66.17 | 30.88 | 36.91 | 23.74 | 65.52 | 55.40 | 1230.47 |
| S21-9-4 | 35.00 | 14.51 | 29.67 | 59.07 | 24.44 | 24.72 | 16.49 | 64.45 | 50.40 | 824.55 |
| S21-6-6 | 38.00 | 11.03 | 23.12 | 54.02 | 22.48 | 21.56 | 14.39 | 64.21 | 47.22 | 718.70 |
| S21(control) | 35.17 | 15.99 | 26.40 | 54.92 | 36.06 | 32.46 | 21.06 | 63.00 | 42.22 | 1081.88 |
| LSD $_{(0.05)}$ | 0.60 | 1.80 | 2.85 | 4.32 | 5.18 | 5.29 | 3.47 | 3.13 | 3.59 | 176.47 |
| S23-3-3 | 32.00 | 20.92 | 8.37 | 43.46 | 44.01 | 51.47 | 20.81 | 43.75 | 34.80 | 1715.55 |
| S23-3-9 | 33.00 | 18.68 | 11.32 | 66.08 | 56.04 | 62.98 | 23.61 | 41.17 | 37.20 | 2099.43 |
| S23-6-8 | 33.00 | 25.12 | 16.37 | 56.96 | 73.71 | 79.50 | 31.46 | 40.15 | 30.80 | 2649.89 |
| S23-6-6 | 33.00 | 24.60 | 15.85 | 52.46 | 61.65 | 71.55 | 30.20 | 38.82 | 30.40 | 2385.01 |
| S23-3-5 | 33.00 | 23.12 | 18.89 | 62.39 | 77.49 | 71.43 | 32.37 | 42.86 | 29.20 | 2381.14 |
| S23-6-7 | 29.00 | 26.54 | 3.59 | 53.47 | 65.34 | 67.41 | 33.03 | 51.72 | 31.20 | 2247.16 |
| S23(control) | 32.41 | 27.53 | 12.90 | 56.88 | 57.38 | 60.69 | 25.39 | 43.00 | 29.49 | 1697.48 |
| LSD $_{(0.05)}$ | 0.60 | 1.69 | 2.53 | 4.96 | 7.56 | 6.71 | 3.21 | 2.69 | 1.78 | 542.52 |
| S24-3-10 | 31.00 | 41.22 | 18.49 | 88.89 | 99.19 | 80.14 | 49.80 | 60.54 | 33.60 | 2671.47 |
| S24-12-7 | 30.00 | 38.71 | 6.97 | 78.99 | 78.96 | 69.50 | 41.08 | 60.89 | 35.80 | 2316.56 |
| S24-3-12 | 30.00 | 31.74 | 6.39 | 66.92 | 73.34 | 64.54 | 39.68 | 64.19 | 35.40 | 2151.50 |
| S24-3-5 | 29.00 | 40.52 | 13.57 | 72.46 | 74.21 | 62.05 | 37.85 | 62.56 | 30.20 | 2068.22 |
| S24-12-10 | 31.00 | 31.60 | 9.85 | 63.61 | 64.95 | 57.58 | 36.48 | 58.37 | 34.00 | 1919.34 |
| S24-12-11 | 30.00 | 33.40 | 13.14 | 80.82 | 68.56 | 56.92 | 34.85 | 64.13 | 42.20 | 1897.36 |
| S24-3-2 | 30.00 | 38.00 | 4.66 | 77.31 | 65.51 | 54.61 | 34.18 | 62.79 | 36.80 | 1820.50 |
| S24-6-5 | 31.00 | 38.52 | 15.29 | 72.39 | 66.59 | 53.66 | 29.60 | 50.83 | 42.40 | 1788.80 |
| S24-6-9 | 31.00 | 36.81 | 6.95 | 70.13 | 34.88 | 27.95 | 17.06 | 55.65 | 41.80 | 931.70 |
| S24(control) | 29.83 | 35.21 | 13.38 | 58.96 | 56.75 | 47.83 | 28.55 | 62.00 | 34.80 | 1204.68 |
| LSD $_{(0.05)}$ | 0.63 | 2.73 | 3.28 | 5.06 | 8.25 | 6.66 | 4.35 | 2.36 | 2.27 | 477.76 |

*The first and second numbers represent the genotype and irradiation dose.

The mutant line, S23-6-8 recorded the highest yield of 2649.89 kg $ha^{-1}$ while S23-3-9 recorded the highest 100-seed weight of 37.20 g. In mutants derived from SAMNUT 24, the highest yield of 2671.47 kg $ha^{-1}$ was recorded by S24-3-10 while S24-6-5 recorded the highest 100-seed weight (42.40 g).

# CHAPTER FIVE

## 5 DISCUSSSION

The significant effect of the irradiation dosages on the seedling growth parameters measured indicates that thermal neutron irradiation induced variations in the groundnut genotypes. The variation observed in the response of the genotypes to the different doses of thermal neutrons indicates that the response was genotype specific. Mutagenic sensitivity is known to be influenced by a variety of factors which include moisture content, temperature, pH, concentration of catalytic ions, various pre and post-treatment conditions, genetic constitution of the material, strength of the mutagen used and duration of the treatment (Konzak *et al*., 1965; Kavera 2008). In the present study, thermal neutron irradiation was effective in reducing the survival of $M_1$ plants indicating that the groundnut genotypes were sensitive to thermal neutron irradiation. The reduction in survival in all the genotypes observed as irradiation doses increased indicates that the genotypes were sensitive to thermal neutron irradiation. Also, the lower survival rate observed at 12 Gy in SAMNUT 21 and SAMNUT 23 show that they were more sensitive to thermal neutron irradiation than SAMNUT 24. The present findings in respect of dose dependent reduction in survival and differential response of groundnut genotypes to irradiation are in conformity with the earlier reports of Kavera (2008). The decrease in survival percentage has been attributed to the physiological disturbance or chromosomal damage caused to the cells of the plant by the mutagen (Mensah and Obadoni, 2007).

The level of biological damage expressed in terms of reduction in seedling growth parameters induced by thermal neutron irradiation in the three genotypes showed that 12

Gy recorded higher reduction compared to control. Similar effects in groundnut were observed with the use of gamma rays (Tshilenge-Lukanda *et al.,* 2013 and Benlismani and Khelifi, 2009). Mutagenic sensitivity can be attributed to the level of differentiation of rudimentary plant parts at the time of treatment on one hand and the extent of damage to the growth components like rate of cell division, cell elongation and various hormones and biosynthetic pathways related to growth and development on the other (Burghate *et al*., 2013). In addition, the sensitivity of peanut seedlings and growing plants may have been brought about by its well differentiated seed embryo (Joventino, 1984).

The significant effect of thermal neutron irradiation on the measured agronomic traits shows that genetic variability had been created in the groundnut genotypes. The low frequency of mutations observed in $M_2$ plants indicates that the genetic response of groundnut at the mature stage is low. Joventino (1984) reported that the low response of peanut to fast neutrons is most probably due to the tetraploid genome and the somatic competition that invariably occurs between normal and mutated cells during the growth stages of the $M_1$ plant. The effectiveness and efficiency of mutagens are pre-requisite for induction and utilization of mutations. Efficient mutagenesis is the production of desirable changes with minimum undesirable changes. In the present study, the higher effectiveness and efficiency of thermal neutron irradiation at 3 Gy and 6 Gy indicates that lower doses of irradiation were more effective in inducing variability in agronomic traits of groundnut. Begum and Dasgupta (2010) also reported that lower doses of mutagens were effective in causing polygenic variability in various quantitative characters of sesame treated with gamma rays and EMS. The differences in the mutagenic effectiveness of the genotypes studied indicate that the genotypes respond differently to irradiation. Lancu and Soare

(2012) reported that different species and even cultivars of groundnut may respond differently to irradiation. The results of the present study are in agreement with the findings of Roychowdhury *et al* (2004) in mungbean and Dhanavel *et al* (2008) in cowpea.

The significantly higher coefficients of variation of the irradiated entries observed compared to the controls indicates that more genetic variability had been induced for the agronomic traits. The inconsistence of variances with varying doses of irradiation observed has been reported in sunflower (Jagadeesan *et al*., 2008). The increased variability for agronomic traits offers possibility for future selection and improvement of these traits. Mensah and Obadoni (2007) reported such increase in variability for pods per plant and seeds per plant at $M_2$ generation in groundnut. The positive as well as negative shifts in the mean of the irradiated entries from the mean of the control for the different traits show that polygenic variability was induced in the agronomic traits. Mutation in quantitatively inherited characters would depend on number of genes involved and the increase or decrease in the relative proportion of genes with positive or negative effects would have caused the shift in the mean of the treated genotypes (Kavera, 2008). The change in mean value was generally accompanied with increase in range for most of the traits. Similar results showing a significant increase of the mean of a treated population over control has been reported by Tshilenge-Lukanda *et al* (2013) in groundnut. Hanan *et al* (2011) reported that this may be due to the stimulation of cell division or elongation, or the alteration of metabolic processes that affect the synthesis of phyto-hormones or nucleic acids. The varied performance of the irradiated materials observed shows that the three genotypes differed in their response to thermal neutron irradiation. Nadaf *et al* (2009) also reported a wide range of performance among groundnut mutants and cultivars and the fact that the

genotypes differed in their response to mutagenic treatment. Increase in pod yield and 100-seed weight clearly indicates the superiority of the mutants identified over the parental genotypes. Large seeds have consumer and market preference especially for confectionery and value addition. High yielding, large-seeded groundnut mutants have been isolated (Nadaf *et al*., 2009). The genotype SAMNUT 24 was found to be more amenable to mutagenesis as reflected by greater change in mean and range compared to SAMNUT 21 and SAMNUT 23. The differential response of cultivars to mutagenic treatments was also evident from the studies of Tshilenge-Lukanda *et al* (2013).

The genotypic coefficient of variation was highest for plant height (2.21) indicating a high degree of genotypic variability. The phenotypic coefficient of variation was highest for pods per plant (4.37) indicating higher degree of phenotypic variability. Abimiku and Belo (2010) revealed that genotypic coefficient of variation helps to measure the range of variability in a character and provide a measure to compare variability present in a population. The low differences observed between the phenotypic and genotypic coefficients of variation for plant height and days to 50 % flowering indicates little influence of the environment on the expression of these traits. Higher differences observed for 100-seed weight and kernel yield was also reported by Mensah and Obadoni (2007).

# CHAPTER SIX

## 6 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Mutation induction has become a highly efficient and environmentally acceptable technology for creating novel variability in crops having narrow genetic base. Therefore, studies were conducted to (i) determine the sensitivity of groundnut genotypes to different doses of thermal neutron irradiation, (ii) determine the effective dose for the induction of variability among the genotypes and (iii) evaluate the variability for farmer preferred traits induced by the irradiation.

Three genotypes of groundnut were irradiated with five doses of thermal neutron irradiation. The irradiated seeds were planted in the screen house to produce $M_1$ plants. Seedling traits were measured for the assessment of sensitivity of the genotypes to thermal neutron irradiation. A total of 96 $M_1$ families generated as well as the parental genotypes were evaluated on the field. The results obtained from the study are summarized as follows:

1. Significant differences ($P<0.05$) were observed among the genotypes for the seedling traits measured in the $M_1$ generation. The seedling growth parameters such as seedling height, number of leaves per seedling, leaf length, leaf width and root length decreased gradually with increasing dose of thermal neutron irradiation indicating low sensitivity of the genotypes to thermal neutron irradiation.
2. SAMNUT 21 and SAMNUT 23 were more sensitive to thermal neutron irradiation than SAMNUT 24 as they had lower survival rate at 12 Gy.
3. Thermal neutron irradiation at 3 Gy was found to be the most effective dose in all the genotypes.

4. Thermal neutron irradiation at 6 Gy had higher efficiency in SAMNUT 21 and SAMNUT 23 while 3 Gy had higher efficiency in SAMNUT 24 indicating that lower doses of thermal neutron irradiation were more efficient in inducing variability in the genotypes.

5. The mutants had significantly higher variability than the controls, indicating the induced genetic variability for the agronomic traits. The mutant line, S21-9-3 recorded the highest 100-seed weight (55.40 g) among the mutants while S24-3-10 recorded the highest yield of 2671.47 kg $ha^{-1}$.

**Conclusions**

The three genotypes studied were sensitive to thermal neutron irradiation and their sensitivity varied with the irradiation doses. Thermal neutron irradiation at 3 Gy was most effective for the induction of variability in agronomic traits among the genotypes. Variability for agronomic traits was created at various doses of thermal neutron irradiation. Varying doses of thermal neutrons could be utilized to create variability in groundnut that would ultimately increase the possibility of isolating beneficial mutants for improvement of groundnut.

**Recommendations**

Genetic variations created by mutation represent a more efficient source of genetic variability in groundnut as it is largely self pollinating. Therefore, future breeding programmes can utilize varying doses of thermal neutron irradiation in groundnut to realize

better results. Also, the large seeded mutants identified could be used for varietal development.

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## Appendix A

Mean performance of agronomic traits in $M_2$ progenies of 96 $M_1$ families.

| Entry | Name | Days to 50% flowering | Plant height | Number of branches | Canopy spread | Pods per plant | Pod weight | Kernel yield | shelling percent | 100 seed weight | Pod yield |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S21-3-1 | 38 | 15.52 | 11.39 | 29.54 | 19.36 | 16.95 | 12.88 | 65.2 | 39.4 | 564.9134 |
| 2 | S21-3-2 | 38 | 17.11 | 22.73 | 53.17 | 28.42 | 26.52 | 17.79 | 63.6 | 37.6 | 883.957 |
| 3 | S21-3-3 | 38 | 13.42 | 28.07 | 53.21 | 41.06 | 46.13 | 28.97 | 67.36 | 46.40 | 1537.738 |
| 4 | S21-6-1 | 36 | 17.02 | 23.35 | 49.43 | 22.80 | 25.33 | 16.08 | 61.26 | 44.00 | 844.4741 |
| 5 | S21-6-2 | 38 | 12.59 | 15.60 | 45.64 | 15.40 | 15.94 | 11.25 | 57.96 | 41.20 | 531.26 |
| 6 | S21-6-3 | 37 | 14.92 | 25.47 | 46.86 | 37.31 | 39.61 | 22.87 | 59.59 | 43 | 1320.22 |
| 7 | S21-6-4 | 36 | 11.98 | 35.55 | 55.34 | 33.15 | 32.83 | 24.66 | 69.93 | 45.6 | 1094.408 |
| 8 | S21-6-5 | 37 | 14.30 | 23.93 | 54.80 | 34.30 | 34.72 | 26.08 | 66.13 | 45.2 | 1157.443 |
| 9 | S21-6-6 | 38 | 11.03 | 23.12 | 54.02 | 22.48 | 21.56 | 14.39 | 64.21 | 47.22 | 718.6969 |
| 10 | S21-9-1 | 32 | 13.22 | 28.23 | 55.69 | 19.08 | 19.52 | 13.22 | 66.49 | 44.50 | 650.734 |
| 11 | S21-9-2 | 36 | 13.04 | 20.86 | 44.12 | 23.94 | 19.36 | 11.17 | 59.95 | 40.4 | 645.1809 |
| 12 | S21-9-3 | 33 | 14.67 | 28.39 | 66.17 | 30.88 | 36.91 | 23.74 | 65.52 | 55.4 | 1230.47 |
| 13 | S21-9-4 | 35 | 14.51 | 29.67 | 59.07 | 24.44 | 24.72 | 16.49 | 64.45 | 50.4 | 824.55 |
| 14 | S21-9-5 | 34 | 20.12 | 20.02 | 43.25 | 32.84 | 32.58 | 21.10 | 63.84 | 43 | 1085.928 |
| 15 | S21-9-6 | 38 | 12.50 | 21.55 | 38.46 | 18.55 | 20.58 | 14.09 | 61.97 | 44 | 686.0065 |
| 16 | S21-9-7 | 34 | 13.57 | 23.88 | 50.99 | 39.69 | 26.80 | 18.15 | 62.62 | 28.6 | 893.2266 |
| 17 | S21-12-1 | 38 | 8.47 | 12.19 | 37.66 | 5.16 | 9.64 | 4.09 | 59.12 | 46 | 321.433 |
| 18 | S21-12-2 | 37 | 11.84 | 14.19 | 46.72 | 20.54 | 17.70 | 13.51 | 70.94 | 36.5 | 590.166 |
| 19 | S21-12-3 | 36 | 16.00 | 20.45 | 52.21 | 33.55 | 36.21 | 24.02 | 61.16 | 47.2 | 1207.007 |
| 20 | S21-12-4 | 37 | 12.95 | 15.68 | 38.35 | 22.88 | 19.48 | 10.54 | 55.79 | 40 | 649.3021 |
| 21 | S21-12-5 | 38 | 21.13 | 14.28 | 41.26 | 13.51 | 15.21 | 8.45 | 46.82 | 37.2 | 507.0297 |
| 22 | S23-3-1 | 33 | 15.43 | 13.32 | 42.62 | 42.08 | 42.96 | 16.77 | 41.87 | 33.3 | 1432.03 |
| 23 | S23-3-2 | 32 | 18.06 | 0.79 | 58.12 | 42.01 | 46.14 | 23.23 | 51.95 | 34.6 | 1537.999 |
| 24 | S23-3-3 | 32 | 20.92 | 8.37 | 43.46 | 44.01 | 51.47 | 20.81 | 43.75 | 34.8 | 1715.553 |
| 25 | S23-3-4 | 32 | 18.43 | 15.78 | 52.51 | 43.00 | 45.00 | 22.00 | 43.33 | 34 | 1600 |
| 26 | S23-3-5 | 33 | 23.12 | 18.89 | 62.39 | 77.49 | 71.43 | 32.37 | 42.86 | 29.2 | 2381.136 |
| 27 | S23-3-6 | 33 | 22.74 | 12.64 | 57.88 | 45.71 | 50.33 | 20.40 | 44.76 | 31 | 1677.797 |
| 28 | S23-3-7 | 33 | 26.63 | 17.92 | 67.47 | 55.88 | 62.58 | 23.30 | 40.61 | 33.8 | 2086.03 |
| 29 | S23-3-8 | 33 | 21.53 | 7.35 | 75.59 | 56.74 | 53.84 | 21.27 | 40.63 | 24.2 | 1794.682 |
| 30 | S23-3-9 | 33 | 18.68 | 11.32 | 66.08 | 56.04 | 62.98 | 23.61 | 41.17 | 37.2 | 2099.433 |
| 31 | S23-3-10 | 33 | 19.32 | 7.99 | 64.02 | 36.60 | 52.33 | 14.25 | 35.64 | 29 | 1789 |
| 32 | S23-6-1 | 32 | 24.65 | 8.34 | 54.42 | 54.74 | 56.82 | 21.69 | 38.43 | 34 | 1893.848 |
| 33 | S23-6-2 | 33 | 17.89 | 10.00 | 44.27 | 40.60 | 42.60 | 19.47 | 47.1 | 34 | 1420.129 |
| 34 | S23-6-3 | 32 | 31.22 | 13.19 | 62.54 | 62.29 | 64.16 | 30.55 | 46.32 | 32.6 | 2138.802 |
| 35 | S23-6-4 | 33 | 26.07 | 12.35 | 63.00 | 54.00 | 59.00 | 31.00 | 45.52 | 33 | 1600.38 |
| 36 | S23-6-5 | 33 | 22.71 | 17.26 | 61.68 | 54.00 | 58.00 | 30.00 | 44.57 | 33 | 1500.42 |

| Entry | Name | Days to 50% flowering | Plant height | Number of branches | Canopy spread | Pods per plant | Pod weight | Kernel yield | shelling percent | 100 seed weight | Pod yield |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 37 | S23-6-6 | 33 | 24.60 | 15.85 | 52.46 | 61.65 | 71.55 | 30.20 | 38.82 | 30.4 | 2385.007 |
| 38 | S23-6-7 | 29 | 26.54 | 3.59 | 53.47 | 65.34 | 67.41 | 33.03 | 51.72 | 31.2 | 2247.16 |
| 39 | S23-6-8 | 33 | 25.12 | 16.37 | 56.96 | 73.71 | 79.50 | 31.46 | 40.15 | 30.8 | 2649.886 |
| 40 | S23-9-1 | 32 | 26.30 | 9.57 | 46.62 | 40.36 | 49.25 | 20.56 | 39.12 | 33 | 1654.33 |
| 41 | S23-9-2 | 32 | 29.28 | 10.90 | 56.63 | 66.22 | 66.88 | 28.79 | 39.97 | 28.6 | 2229.188 |
| 42 | S23-9-3 | 33 | 20.87 | 11.31 | 61.11 | 36.90 | 39.30 | 15.30 | 40.88 | 32 | 1310.061 |
| 43 | S23-9-4 | 33 | 22.85 | 13.20 | 51.85 | 50.52 | 52.30 | 22.30 | 44.52 | 32 | 1560.52 |
| 44 | S23-9-5 | 30 | 23.85 | 12.44 | 55.07 | 45.94 | 49.67 | 23.87 | 47.97 | 29.4 | 1655.514 |
| 45 | S23-9-6 | 33 | 25.01 | 11.36 | 44.81 | 42.22 | 47.64 | 19.35 | 38.46 | 34 | 1587.976 |
| 46 | S23-12-1 | 33 | 26.97 | 14.43 | 70.62 | 58.58 | 61.08 | 24.63 | 40.62 | 33 | 2036.136 |
| 47 | S23-12-2 | 34 | 23.98 | 7.99 | 48.43 | 33.66 | 52.57 | 14.69 | 33.52 | 28.2 | 1752.438 |
| 48 | S23-12-3 | 33 | 23.22 | 9.07 | 50.10 | 34.55 | 51.22 | 15.33 | 33.65 | 28.93 | 1762 |
| 49 | S23-12-4 | 34 | 21.96 | 14.53 | 54.79 | 35.22 | 51.20 | 15.30 | 34 | 29.3 | 1860 |
| 50 | S23-12-5 | 32 | 30.75 | 12.53 | 51.83 | 34.50 | 54.22 | 16.34 | 33 | 28.44 | 1766 |
| 51 | S23-12-6 | 32 | 23.67 | 17.11 | 57.30 | 34.65 | 50.33 | 13.69 | 32.22 | 28 | 1955 |
| 52 | S24-3-1 | 29 | 42.14 | 44.94 | 47.34 | 54.35 | 53.24 | 32.70 | 60.67 | 39.8 | 1774.606 |
| 53 | S24-3-2 | 30 | 38.00 | 4.66 | 77.31 | 65.51 | 54.61 | 34.18 | 62.79 | 36.8 | 1820.499 |
| 54 | S24-3-3 | 29 | 37.11 | 6.33 | 75.27 | 51.02 | 52.22 | 31.70 | 60.89 | 38 | 1740.624 |
| 55 | S24-3-4 | 31 | 43.56 | 11.01 | 85.75 | 43.25 | 39.80 | 24.63 | 63.3 | 36 | 1326.585 |
| 56 | S24-3-5 | 29 | 40.52 | 13.57 | 72.46 | 74.21 | 62.05 | 37.85 | 62.56 | 30.2 | 2068.22 |
| 57 | S24-3-6 | 31 | 32.95 | 9.60 | 65.02 | 60.06 | 51.69 | 28.57 | 57.58 | 34 | 1722.924 |
| 58 | S24-3-7 | 31 | 42.93 | 11.88 | 77.06 | 51.00 | 39.00 | 25.00 | 54 | 35 | 1689 |
| 59 | S24-3-8 | 32 | 40.38 | 12.99 | 65.43 | 52.00 | 46.00 | 22.00 | 55 | 33 | 1600 |
| 60 | S24-3-9 | 32 | 32.18 | 11.62 | 86.58 | 49.00 | 50.00 | 26.00 | 56 | 34 | 1698 |
| 61 | S24-3-10 | 31 | 41.22 | 18.49 | 88.89 | 99.19 | 80.14 | 49.80 | 60.54 | 33.6 | 2671.469 |
| 62 | S24-3-11 | 32 | 49.01 | 12.19 | 87.93 | 48.62 | 50.71 | 30.43 | 61.77 | 39 | 1690.221 |
| 63 | S24-3-12 | 30 | 31.74 | 6.39 | 66.92 | 73.34 | 64.54 | 39.68 | 64.19 | 35.4 | 2151.499 |
| 64 | S24-3-13 | 30 | 38.55 | 9.84 | 66.07 | 50.84 | 38.45 | 20.90 | 54.37 | 34.2 | 1281.514 |
| 65 | S24-6-1 | 30 | 46.03 | 13.57 | 77.62 | 53.77 | 46.33 | 28.77 | 62.71 | 35.6 | 1544.352 |
| 66 | S24-6-2 | 29 | 36.52 | 11.39 | 74.84 | 61.59 | 49.33 | 27.79 | 50.8 | 38 | 1644.469 |
| 67 | S24-6-3 | 31 | 29.73 | 14.74 | 64.60 | 59.36 | 44.47 | 28.31 | 60.03 | 39 | 1482.321 |
| 68 | S24-6-4 | 32 | 31.88 | 11.62 | 74.43 | 51.00 | 39.00 | 24.00 | 53 | 31 | 1320 |
| 69 | S24-6-5 | 31 | 38.52 | 15.29 | 72.39 | 66.59 | 53.66 | 29.60 | 50.83 | 42.4 | 1788.802 |
| 70 | S24-6-6 | 31 | 37.23 | 14.08 | 67.26 | 50.00 | 45.00 | 25.00 | 55 | 32 | 1542 |
| 71 | S24-6-7 | 32 | 38.48 | 9.61 | 65.51 | 44.00 | 27.00 | 26.00 | 58.5 | 35 | 1560 |
| 72 | S24-6-8 | 31 | 42.40 | 11.45 | 70.06 | 52.15 | 46.95 | 28.01 | 54.85 | 36.8 | 1565.007 |
| 73 | S24-6-9 | 31 | 36.81 | 6.95 | 70.13 | 34.88 | 27.95 | 17.06 | 55.65 | 41.8 | 931.6977 |
| 74 | S24-6-10 | 32 | 35.23 | 11.26 | 65.97 | 48.00 | 34.00 | 27.00 | 54 | 32 | 1500 |

| Entry | Name | Days to 50% flowering | Plant height | Number of branches | Canopy spread | Pods per plant | Pod weight | Kernel yield | shelling percent | 100 seed weight | Pod yield |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 75 | S24-6-11 | 32 | 32.51 | 10.03 | 74.82 | 51.32 | 36.04 | 20.39 | 55.56 | 30 | 1201.29 |
| 76 | S24-6-12 | 30 | 39.12 | 11.47 | 70.76 | 52.21 | 53.66 | 30.46 | 58.29 | 40.6 | 1788.55 |
| 77 | S24-6-13 | 30 | 38.78 | 13.01 | 61.01 | 35.00 | 29.22 | 27.00 | 61.22 | 38 | 1300.00 |
| 78 | S24-9-1 | 31 | 39.59 | 6.59 | 69.44 | 46.70 | 38.17 | 23.55 | 61.28 | 35.2 | 1272.33 |
| 79 | S24-9-2 | 33 | 32.40 | 5.75 | 63.11 | 48.65 | 41.30 | 25.60 | 57.06 | 38 | 1376.67 |
| 80 | S24-9-3 | 30 | 46.28 | 8.42 | 66.23 | 44.00 | 36.00 | 22.00 | 56 | 35 | 1325.00 |
| 81 | S24-9-4 | 29 | 34.51 | 7.15 | 74.35 | 44.78 | 38.54 | 23.36 | 57.71 | 36.2 | 1284.74 |
| 82 | S24-9-5 | 30 | 39.98 | 9.52 | 67.98 | 45.00 | 37.00 | 21.00 | 55 | 35 | 1298.00 |
| 83 | S24-9-6 | 29 | 30.51 | 13.40 | 67.98 | 40.17 | 35.22 | 20.00 | 55.28 | 37 | 1174.00 |
| 84 | S24-9-7 | 29 | 42.91 | 10.73 | 73.52 | 64.22 | 43.47 | 23.27 | 52.79 | 30 | 1448.957 |
| 85 | S24-12-1 | 30 | 32.98 | 7.92 | 78.32 | 34.56 | 26.31 | 11.12 | 48.37 | 21.6 | 876.9886 |
| 86 | S24-12-2 | 30 | 40.42 | 6.77 | 75.27 | 45.66 | 36.71 | 23.09 | 59.45 | 36 | 1223.55 |
| 87 | S24-12-3 | 31 | 40.90 | 9.25 | 78.51 | 45.00 | 36.00 | 23.00 | 56 | 36 | 1450.00 |
| 88 | S24-12-4 | 29 | 38.66 | 8.71 | 65.74 | 36.00 | 28.00 | 13.00 | 58 | 32 | 1001.00 |
| 89 | S24-12-5 | 30 | 37.98 | 11.35 | 79.50 | 50.00 | 40.00 | 30.00 | 44 | 35 | 1400.00 |
| 90 | S24-12-6 | 32 | 36.98 | 12.26 | 81.82 | 63.01 | 50.01 | 27.58 | 53.96 | 36.6 | 1667.11 |
| 91 | S24-12-7 | 30 | 38.71 | 6.97 | 78.99 | 78.96 | 69.50 | 41.08 | 60.89 | 35.8 | 2316.56 |
| 92 | S24-12-8 | 30 | 28.14 | 11.08 | 57.02 | 35.00 | 27.00 | 12.00 | 57 | 34 | 987.22 |
| 93 | S24-12-9 | 29 | 32.13 | 7.77 | 56.85 | 34.79 | 28.09 | 17.30 | 62.5 | 35 | 936.2718 |
| 94 | S24-12-10 | 31 | 31.60 | 9.85 | 63.61 | 64.95 | 57.58 | 36.48 | 58.37 | 34 | 1919.34 |
| 95 | S24-12-11 | 30 | 33.40 | 13.14 | 80.82 | 68.56 | 56.92 | 34.85 | 64.13 | 42.2 | 1897.359 |
| 96 | S24-12-12 | 29 | 33.15 | 11.24 | 62.37 | 64.54 | 49.89 | 32.12 | 62.92 | 39 | 1662.848 |
| 97 | S21 | 35.17 | 15.99 | 26.40 | 54.92 | 36.06 | 32.46 | 21.06 | 63 | 42.22 | 1081.88 |
| 98 | S23 | 32.41 | 12.77 | 12.90 | 56.88 | 57.38 | 60.69 | 25.39 | 43 | 29.49 | 1697.48 |
| 99 | S24 | 29.83 | 13.61 | 13.38 | 58.96 | 56.75 | 47.83 | 28.55 | 62 | 34.8 | 1204.68 |
| Mean | | 32.42 | 27.44 | 14.87 | 61.27 | 47.86 | 45.52 | 24.64 | 55.58 | 36.73 | 1159.35 |
| LSD | | 0.552 | 3.58 | 4.32 | 8.04 | 12.24 | 12.12 | 6.68 | 2.66 | 2.462 | 535.44 |
| C.V | | 2.95 | 22.56 | 50.43 | 22.76 | 44.43 | 46.12 | 46.93 | 8.32 | 10 | 46.18 |