STUDIES ON THE EFFECTS OF FAST NEUTRON IRRADIATION AND SODIUM AZIDE ON MORPHOLOGICAL AND YIELD PARAMETERS OF SESAME

(*Sesamum indicum L.***)**

BY

GADO, Aishatu Adamu
M.TECH/SSSE/2011/2936

DEPARTMENT OF BIOLOGICAL SCIENCES,
FEDERAL UNIVERSITY OF TECHNOLOGY,
MINNA.

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ABSTRACT

This investigation was carried out to study the effects of Fast Neutron Irradiation (FNI) and Sodium Azide (SA) on three varieties of Sesame (*Sesamum indicum*) viz; Kenana - 4, Ex-Sudan and E-8. Three hundred seeds of each variety were exposed to (FNI) from Americium-Beryllium source with flux $1.5x10^4$ $n.cm^{-2}s^{-1}$ given the does 0,4,8,12 and 16µSv. Three hundred seeds of each variety were also treated with sodium azide at five different concentrations, 0.00%, 0.02%, 0.04%, 0.06%, 0.08%. The irradiated, the chemically treated seeds and the control seeds were grown to maturity. The morphological and yield parameters, survival, flowering and oil content were taken. The result showed that 12µSv had significantly higher values ($p<0.05$) with respect to plant height, number of leaves, length of petiole and number of seeds. The survival percentage in Ex-Sudan and E-8 were higher at 0µSv (60 and 60%) respectively, while in Kenana-4 at 16 µSv with 53%. The 16µSv and 8 µSv have a consistent highest percentage oil content in all the three varieties. In terms of flowering percentage in Kenana-4, 8µSv and 12µSv have higher values (75 and 75%) than control. However in Ex-Sudan and E-8, 4µSv (78.1 and 46.8%) did better than the control. In the case of sodium azide the result showed that 0.02% had significantly higher values ($p<0.05$) with respect to plant height, number of leaves, length of petiole, leave surface area and weight of capsule. The survival percentage in Ex-Sudan, Kenana-4 and E-8 were higher at 0.02, 0.08 and 0.04% (80, 93 and 94%) respectively. Kenana-4 and E-8 were higher (37.7 and 28.6%) at 0.08% and Ex-Sudan (30%) at 0.00% with respect to oil content. Ex-Sudan and E-8 have higher values (75 and 53.1%) at 0.02% while Kenana-4 (78%) at 0.04% with respect flowering percentage. Thus Fast neutron and Sodium azide have potential of creating genetic variability in sesame, certain concentrations of sodium azide 0.02% through 0.04% sodium azide concentration and 12usv have the potentiality of inducing variability that could be used in the improvement of sesame.

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ABBREVIATION OF GLOSSARIES

Ex – Ex sudan

Ke – Kenana-4

Am – Be:Americium Beryllium

ANOVA: Analysis of Variance

CERT: Centre for Energy Research and Training

n. cm^{-2} S^{1} n. neutron cm: centimeter and S: second

FNI: Fast Neutron Irradiation

SA : Sodium Azide

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Sesame is considered to be the oldest oilseed crop known to man. The crop has been domesticated well over 5000 years (Bisht, Mahajan, Loknathan and Agrawal, 1998). It belongs to the family Pedaliaceae and genus *Sesamum*. The genus consist of about 36 species out of which the commonly recognized is *Sesamum indicum* L. (Falusi, 2006). *Sesamum indicum* is very drought tolerant. It has been called a survivor crop because of its ability to grow where most plants fail.

The crop is believed to have originated from Africa where the greatest diversity of the genus sesame and its family Pedaliaceae is present (Falusi and Salako, 2003). Some of the local names of the crop in Nigeria are ("Ridi" Hausa) ("Ishwa" Tiv), ("Gorigo" Igbira), ("Eeku" Yoruba) and ("Doo"Jukun) (Falusi, Salako and Ishaq, 2001). Currently it is cultivated in the tropical and sub tropical region of Africa, South America, North America and Asia principally for its seeds which contains about 50-52 % oil, 17-19 % Protein and 16-18 % carbohydrate (Falusi and Salako, 2003).

It is an annual plant growing to 50 - 100cm (1.6 to 3.3 ft) tall, with opposite leaves 4 - 14cm (1.6 – 55 in) long with an entire margin: they are broad lanceolate, to 5cm (2in) broad at the base of the plant, narrowing to just 1 cm (0.4in) broad on the flowering stem. The flowers are yellow, tubular, 3 to 5cm (1.2 to 2.0m) long, with four lobed mouths. The flower may vary in colour with some being white, blue or purple. Sesame fruit is a capsule, normally pubescent, rectangular in section and typically grooved with a short triangular beak. The length of the fruit capsule varies from 2 to 8 cm. Its width varies between 0.5 to 2cm, and the number of loculi from 4 to 12. The fruit naturally splits opens (dehisces) to release the seed by splitting along the septa from top to bottom

or by means of two apical pores, depending on the varietal cultivar. Sesame seeds are small, about 3to4mm long by 2mm wide and 1mm thick. The seeds are ovate, slightly flattened and somewhat thinner at the eye of the seed (helium) than the opposite end with the weight of the seed between 20 to 40 mg. Sesame is grown primarily for its oil-rich seeds.

The oil is used locally for cooking as well as for medicinal purposes such as the treatment of ulcers and burns. The stem and the oil extracts are equally used in making local soup. The products are locally processed and utilized in various forms. Principally among the products are “KATUN RIDI” and “KANUN RIDI”. After oil has been extracted from the seeds, the cake is made into “Kuli Kuli” which together with the leaves is used to prepare local soup known as “MIYAR TAUSHE”.

The uses of Sesame have triggered increasing demand for the crop. This has made it necessary to increase its production to meet up with its needs. However, several attempts have been made to increase supply through cultivation of different varieties and species; but the successes of such attempts were prejudice by challenges ranging from environmental factors, availability of manpower and inadequate farming techniques. It is against these shortcomings that attention is shifting towards improving genetic quality of the existing species through plant breeding and selection made possible by radiation-induced genetic variability.

Mutation refers to the change in DNA sequence, which may involve only few bases or the large scale chromosome abnormality. Induced mutations have recently become the subject of biotechnology and molecular investigation leading to description of the structure and function of related genes. Induced mutations are highly effective in enhancing natural genetic resources and have been used in developing beneficial

variation for practical plant breeding purpose and novel crop cultivars (Lee and Lee, 2002). During the last seven decades, more than 2,252 mutant varieties have been officially released in the world (Maluszynski, Nichterlein, Zanten and Ahloowalia, 2000). Induced mutation have been used to improve major crop such as wheat, rice, sesame, barley, cotton, peanut and Cowpea , which are seed propagated (Khan, 2009).

Ionizing radiation has been routinely used to generate genetic variability for breeding and genetic studies (Boureim, Diouf, Slime, Diop, Vandamme and Cagirgan, 2009). Food and Agricultural Organisation, (2009) reported that year 2008 marked the 80th anniversary of mutation induction in plants. The wide spread use of induced mutants in plant breeding programmes throughout the world has led to the official release of more than 2,700 plant mutant varieties (FAO, 2009). According to Falusi, Daudu and Jaime (2012), three varieties of Nigerian pepper (*Capsicum annuum* var. *Accuminatum, C. annuum* var. *abbreviatum* , and *C. annuum* var. *grossum*) were exposed to fast neutron irradiation. All the plants produced from the non-irradiated seeds which served as the control produced normal leaves. However, this was not the case among plants whose seeds were irradiated.

1.2 Justification of the Study

Nigeria has a great potential for sesame production for domestic and export market, but the yield of this valuable crop is relatively low and varies from one area to another due to lack of improved varieties and seed capsule shatter causing a loss of large amount of seed. Considering the importance of the crop it is anticipated that the variety grown by farmers can be developed. Artificial induction of mutation is of scientific and commercial interest as it is one of the methods used in improving the growth and yield of economic plants. It provides raw materials for the genetic improvement of economic crops (Adamu, Chung and Abubakar, 2004). Although *Sesamum indicum* has a wide

range of genetic variability, there is still need to find certain highly desirable trait such as good retention and resistance of diseases (Ashri, 1998). With all these facts in view the present research is design to critically look at the effect of the physical and chemical mutagens on morphological and yield parameters of sesame.

1.3 Aim and Objectives

1.3.1 Aim

The main aim of this research is to study the effect of sodium azide (chemical mutagen) and fast neutron irradiation (physical mutagen) on morphological and yield parameters of sesame (*Sesanum indicum*).

1.3.2 Objectives

The objectives of this study are

1. To determine the effect of fast neutron irradiation (physical mutagen) and Sodium azide (chemical mutagen) on the morphological characteristics of sesame.

2. To determine the effect of fast neutron irradiation (physical mutagen) and Sodium azide (chemical mutagen) on the yield parameters of sesame.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The Sesame Plant

Sesame (*Sesamum indicum* L.) is an ancient oil crop considered to be still at early stage in breeding. The fact that sesame is a crop of mainly developing countries with limited available research funds for long term breeding programmes resulted in very few breeding efforts in research stations. Furthermore, sesame is not a mandate crop of any of the International agriculture research centres, (International Atomic Energy Agency, 2001).

Sesame is one of the ancient oilseed crops known to human race and has been in cultivation since centuries for its edible oil and protein. The genus *Sesamum* belongs to the family Pedaliaceae and order Tubiflorae. The cultivated species *Sesamum indicum* L. is a diploid (2n=26) grown in the tropic as well as temperate zones, mostly between latitudes of 40° N and 40° S. Owing to high yield and quality of the oil and meal, it is often called as the "Queen of oilseeds" (Weiss, 1971).

Plant breeder is mainly concerned with quantitative characters showing continuous variation such as yield. As such, the inheritance studies of these characters have attracted the attention of biometricians. To breed better crops with higher yield, the breeder should select on the sliding scale of ever changing environment. Further, yield is a complex quantitative character. Yield of any crop has been described as the product of its components, (Grafius, 1956; Dewey and Lu, 1959). Number of capsules per plant, seeds per capsule and 1000 seed weight are important yield components in sesame. Observation of these components will sometime furnish a clue as to why the complex trait failed to respond to selection in an expected manner. Selection for yield, ignoring the components may produce very unusual and unstable results.

De vries (1909), who first recognized clearly the role of mutation in evolution, had naturally hoped that if man learns to command the origin of mutations and thereby generate the allelic variability upon which recombination and selection could operate, he can achieve more speedily his goal of creating superior strains of domesticated plants and animals. For the first time he used the term mutation for the appearance of new types in evening primrose (*Oenothera*). Muller (1927), was first to induce mutation in *Drosophila* fly using X-rays. Though, Stadler (1928a) had started working simultaneously on barley and maize using mutations, he was late in reporting mutation due to longer life cycle of these plants compared to *Drosophila*. Since then, high energy radiations has proved to be only one of various mutagenic agents, which now include ultra violet radiation and a large number of chemical mutagens.

2.1.1 Taxonomy and Cytogenetic

The genus *Sesamum* consists of many species and the most cultivated is *Sesamum indicum* L. (Ashri, 1998). According to Kobayashi, Kinosita, Ogawa, Tsuboi, Ishida and Saito (1990), 36 species have been identified of which 22 species have been found in Africa, five in Asia, seven in both Africa and Asia, and one species each in Crete and Brazil. There are three cytogenetic groups of which 2n = 26 consist of the cultivated *S. indicum* along with *S. alatum, S. capense, S. schenckii, S. malabaricum*; 2n = 32 consist of *S. prostratum, S. laciniatum, S. angolense, S. angustifolium;* while *S. radiatum, S. occidentale, S. schinzianum* belong to 2n = 64. Mainly due to the difference in chromosomal numbers across the three cytotaxonomic groups, there is limited cross compatibility among the species. Therefore, it has been difficult to transfer desirable characteristics such as drought tolerance, pest, and resistance to diseases, from wild relatives into cultivated sesame (Carlsson, Chanana, Gudu, Suh and Were, 2008).

2.1.2 Economic Importance of Sesame

Although sesame seeds are used as an ingredient in many different food supplies, a major part of the sesame seed production is processed into oil and meal (Morris, 2002). Sesame oil is, as mentioned before, an excellent vegetable oil because of its high contents of antioxidants such as sesamin, sesamol and sesamolin and its fatty acid composition (Suja, Abraham, Thamizh, Jayalekshmy and Arumughan, 2004). The antioxidants make the oil very stable and it has therefore a long shelf life, (Chung, Lee & Choe, 2004) and Suja *et al*. (2004).

In sesame oil, oleic (C18:1) and linoleic (C18:2) acids are the predominant fatty acids and make up more than 80% of the total fatty acids. The high levels of unsaturated (UFA) and polyunsaturated fatty acids (PUFAs) increase the quality of the oil for human consumption (Nupur, Bhat and Srivastava, 2010). Moreover, high level of PUFAs in sesame oil is claimed to reduce blood cholesterol, high blood pressure and play an important role in preventing atherosclerosis, heart diseases and cancers (Hibasami, Fujikawa, Takeda, Nishibe, Satoh, Fujisawa and Nakashima, 2000) and (Miyahara, Hibasami, Katsuzaki, Imai and Komiya, 2001).

People in Vietnam use sesame oil for cooking fish, meat, and frying vegetable. Sesame seed flour has a high protein content, with high levels of the essential amino acids methionine and tryptophan, contains about 10 to 12% of oil and has three times more calcium than milk (Morris, 2002). The meal that remains after oil extraction from sesame seeds is an excellent feed for poultry and livestock.

A potential problem, though, with sesame when used for human consumption is that it contains one of the top food allergens. Its allergenicity emanates from protein sources, such as the 14 kDa 2S albumin precursor, which belongs to one of four protein families

known to be allergenic and several oleosins (15 and 17 kDa), also known to cause hypersensitivity (Wolff, Cogan, Admon, Dalal, Katz, Hodos,…..and Yannai, 2003) and (Leduc, Moneret-Vautrin, Tzen, Morisset, Guerin and Kanny, 2006). Therefore, food products that contain sesame as an ingredient are now required to be labeled as potential allergenic in Europe and Canada (Carlsson *et al.*, 2008).

2.1.3 Conservation and Breeding of Sesame

The purpose of conservation is to conserve plant genetic resources for potential future usage, and as such it should support basic research and improvement of crops. Core collections of sesame germplasm have been established by the Oil Crop Research Institute of the Chinese Academy of Agricultural Sciences, and the National Bureau of Plant Genetic Resources (NBPGR) of India in collaboration with the International Plant Genetic Resources Institute (IPGRI). Thus, NBPGR maintains 6658 accessions of sesame where 4136 are indigenous and 2522 are from exotic sources (Bisht *et al.*, 1998).

The Gene Bank of Rural Development Administration (RDA) located in Suwon, Korea have collected 7698 sesame accessions, that consist of 3538 exotic collections, 2660 indigenous collections, 1072 improved genetic stocks and 428 others (Kang, Kim, Lee, Mathur, Hodgkin, Zhou and Lee, 2006).

In addition, conservation efforts of sesame have been done by other organization and gene banks in the world. For example the United States Department of Agriculture (USDA), Agricultural Research Service (ARS), Plant Resources Conservation Unit (PGRCU) has conserved 1226 sesame accessions originating from Europe, Africa, Asia, North America and South America (Morris, 2009). Although, sesame is considered to be the oldest of the oilseed plants and has been under cultivation in Asia for over 5000

years (Bisht *et al.*, 1998), in comparison with many other oil crops it has a low seed yield with a world average of about 477 kg ha^{-1} and about 500 kg ha^{-1} in Vietnam (FAOSTAT, 2008). The low seed yield of sesame is a consequence of a lack in breeding attention (Ashri, 1998).

Sesame production is also limited by pests, diseases, lack of uniform maturity of capsules, and seed shattering (Langham and Wiemers, 2002). Screening for resistance to diseases was done among sesame from Kenya and two cultivars, SPS045 and SIK013, were found to be resistant to angular leaf spot (*Cercospora sesamicola*) and white leaf spot (*Cercospora sesame*), respectively while another cultivar SIK031 was resistance to both of those diseases (Nyanapah, Ayiecho and Nyabundi, 1995).

In another study sesame mutants were screened for resistance to *Fusarium* wilt disease (Silme and Cagirgan, 2010), and 25 sesame genotypes were evaluated for their reaction to *Fusarium oxysporium*. It was reported that four genotypes, Birkan, Cambidi, WS-143 and WS-313 were classified as resistant (R), and genotype Birkan was released as a cultivar for high seed yield and resistant to *Fusarium* wilt disease. It was suggested that genotype Birkan could be used as a source for resistance to *Fusarium* wilt disease in sesame breeding program.

Efforts to reduce shattering in sesame (non-dehiscent sesame) in order to improve seed yield and make this crop suitable for mechanical harvesting has been undertaken in the United States (Langham and Wiemers, 2002). Molecular markers linked to traits such as closed capsule (or non-dehiscent capsule) and growth habit were developed to identify sesame cultivars with the desired traits at an early developmental stage (Uzun, Lee, Donini and Cagirgan, 2003) (Uzun and Cagirgan, 2009). Recently, the exploitation of genetic diversity and heterosis has been another approach to improve the seed yield as

well as some other traits in sesame varieties. Crossing experiments of different sesame lines resulted in hybrid vigor, particularly in seed yield. Agro-morphological evaluation of sesame to select good varieties has resulted in varieties that can reach over 1 ton of seed ha^{-1} (Furat and Uzun, 2010). However, those sesame varieties should be grown in their recommended specific region, because sesame is very sensitive to climatic conditions such as temperature, day length and related humidity. Sesame produces no seed or a very low seed yield if it is grown under unfavorable environmental conditions (Pham, Bui, Werlemark, Bui, Merker and Carlson, 2009).

In general, the breeding strategies for sesame are similar to those applicable in other crops and include higher yields, improved plant architecture, length of growing season, resistance to diseases and pests (Ashri, 1998). Specific objectives for sesame breeding vary with the level of technology and were summarized by (Ashri,1998) as follows: (1) high and stable seed yield of good quality under a wide range of environmental conditions, (2) resistance to water logging, drought, salinity, pests, diseases, shattering and other abiotic stresses, (3) increased number of capsules per leaf axil, full seed-set without aborted ovules, and (4) uniform plant type, rapid growth, good adaptation to varying environment conditions and seasons. These objectives are applicable to all sesame producing countries including Vietnam and Cambodia.

2.1.4 Oil Content and Fatty acid Composition

Among oil crops, sesame is one of the highest in oil content. Generally, the oil content in sesame ranges from 34 to 63% (Yermanos, Saleeb, Hemstree and Huszar, 1972), (Ashri, 1998) (Baydar, Marquard and Turgut, 1999) (Uzun ,Ulger and Cagirgan, 2002) and (Were, Okware, Gudu, Welander and Carlson, 2006b). Genetic and environmental factors influence the oil content and fatty acid compositions in sesame (Carlsson *et al.*, 2008). Late maturing cultivars are reported to have higher oil content than early

cultivars (Yermanos *et al.*, 1972) and the indeterminate cultivars accumulated more oil than determinate ones (Uzun *et al*., *2002*). Sesame contains high levels of antioxidants such as sesamol, sesamin, sesamolin and sesaminol. Therefore, sesame oil is called the queen of the vegetable oils because of its antioxidants.

The composition of sesame oil consist of mainly four fatty acids (palmitic–C16:0, stearic–C18:0, oleic–C18:1 and linoleic–C18:2), while other fatty acids appear in very small amounts (Ashri, 1998). Even though different fatty acid compositions of sesame oil have been reported the major fatty acids are oleic and linoleic acids (Kamaleldin, Yousif, Iskanda and Appelqvist, 1992). Yermanos *et al.* (1972), reported oleic acid level ranging from 32.7% to 58.2% and linoleic acid from 27.3% to 59.0%. Were *et al.*, (2006b) reported variation in the quantities of palmitic, stearic, oleic and linoleic acids, with palmitic and stearic acids ranging from 7.2 to 9.6% and 3.7 to 5.6%, respectively, while high levels of oleic acid and linoleic acid ranged from 31.6 to 41.9% and 42.9 to 53.9%. Linolenic acid was found but in very small amount (0.5%).

2.1.5 Genetic Diversity and Biotechnology Studies in Sesame

Genetic diversity of crops plays an important role in sustainable development and food security Esquinas-Alcazar (2005), as it allows the cultivation of crops in the presence of various biotic and abiotic stresses. It is also important for selection of parents that can be used in plant breeding programs. Information on genetic diversity is important when working to improve crop varieties. Genetic diversity is studied by using various methods such as morphological, biochemical and molecular markers. Morphology has been a primary tool to estimate genetic differences among sesame genotypes. Several studies based on morphological markers have found a high genetic diversity in sesame populations Bedigian and Harlan (1986), Ganesh and Thangavelu (1995), Bisht *et al.*

(1998), (Arriel , Mauro, Arriel, Uneda-Trevisole, Costa, Barbaro and Muniz, 2007). However, morphological markers have limitations in their ability to estimate genetic diversity because of strong influence from environmental factors, which make them highly dependent on the cultivation conditions. Molecular markers overcome this limitation. Molecular markers techniques such as amplified fragment length polymorphism (AFLP), random amplified polymorphic DNA (RAPD), inter simple sequence repeats (ISSR) and simple sequence repeats (SSR) have been widely used in genetic diversity studies in sesame. Low genetic diversity (0.14–0.21) among groups was reported by Laurentin and Karlovsky (2006), in 32 sesame germplasm collections using amplified fragment length polymorphism (AFLP).

Kim, Zur, Danin-Poleg, Lee, Shim, Kang and Kashi (2002), reported that an ISSR-based study of sesame from Korea and other countries revealed a low level of polymorphism and the genetic distance between populations ranged from 0 to 0.25. In contrast, Bhat, Babreka and Lakhanpaul (1999), reported a high genetic diversity of 0.35 among 58 sesame accessions from the Indian subcontinent (36 accessions) and other countries (22 accessions). Ercan, Taskin and Turgut (2004), using RAPD markers reported a genetic diversity among 38 Turkish sesame accessions ranging from 0.14 to 0.40.

Similarly, a high genetic diversity of sesame in Vietnam and Cambodia was found using RAPD, as estimated by percent polymorphism (83%) and genetic distance coefficient (0.03-0.31) (Pham, Bui, Werlemark, Bui, Merker and Carlson, 2009). Microsatellites are one of the most commonly used molecular markers to determine the genetic diversity in crop species. However, only a few studies used microsatellites to evaluate genetic diversity in sesame (Dixit, Jin, Chung,Yu, Chung, Ma, and Cho, 2005) (Wei,

Zhang, Zheng , Guo, and Zhang, 2008). Molecular markers have been developed to identify morphological traits of sesame such as growth habit and closed capsule trait (Uzun *et al.*, 2003; Uzun and Cagirgan, 2009). Moreover, biotechnology techniques such as *in vitro* regeneration and genetic transformation have also been developed for sesame (Were *et al.*, 2006a) (Yadav, Chaudhary, Sainger and Jaiwal, 2010).

2.2 Mutation Breeding

Mutation breeding involves induction of new genetic variability through spontaneous or artificial mutagens (chemicals or physical). It minimizes our dependence on the use of wild species or species from other cultivars. Induced mutants are evaluated and selected for desired traits. However, development of large number of mutants with undesirable traits limits its wide application in the breeding programs.

Mutagenic techniques are successfully employed in sesame to induce genetic variability. Applications of appropriate doses of physical mutagen or concentration of chemical mutagen are important to get adequate mutations that could benefit sesame breeding program. Researchers at FAO/IAEA have initiated coordinated research project for genetic improvement in sesame, and developed 142 mutants having agronomically useful characters by using both physical and chemical mutagens and devised method for mutation breeding for sesame (Van Zanten, 2001).

Following were the recommendations for mutagen treatment. Well-adapted, homozygous and uniform varieties should be selected for mutation induction for improvement of one or two characters at a time. Lower dose ranges of mutagens are more suitable for inducing desirable mutations, i.e., g-rays 150–800 Gy, fast neutrons' irradiation 30–80 Gy. For chemical mutagenesis, first seeds are pre-soaked in water for 24 h (4°C). Then soaking into chemical mutagen, e.g., in ethyl methane sulfonate

(EMS) solution (0.4–1.0% v/v) with phosphate buffer (pH = 7) for 2–4 h or in sodium azide (NaN_3) solution (4–6 mM) with Sörenson phosphate buffer (pH = 3) for 4–6 h at 18–24°C. Sesame mutants have been selected for desirable traits of higher yield and quality, improved plant architecture, seed retention, larger seed size and seed color (Hoballah, 1999).

A research program on radiation-induced mutagenesis has been initiated to induce genetic variations and to screen desirable "plant type", a narrow leaf mutant in sesame through nitrous acid and hydrogen peroxide treatments in different doses, and the mutant yielded higher number of capsule per plant on the main axis than control. Early maturing and high-yielding sesame mutants have been developed by using NaN_3 and colchicines, and Mensah, Obadoni, Akomeah, Ikhajiagbe and Ajibolu (2007), found that 0.0625% NaN_3 and 0.125% colchicine were the most efficient concentration for inducing mutations in sesame.

The g-ray-induced mutants with improved plant architecture were developed having closed capsule, determinate growth habit, resistance to *Fusarium* blight, etc. These mutants had improved oil quality with considerably higher oleic acid and low linoleic acid contents. Indeterminate sesame habit is a challenge for sesame breeders, and mutagenic breeding approach is applied to solve this problem. A spontaneous indehiscent mutant "id" was discovered in 1942 in Venezuela by Langham. However, due to its low yield and other undesirable side effects it was not used in commercial varieties. The first determinate sesame mutant (dt-45) was selected by Ashri (1981), from an M2 population by irradiating Israeli variety "No-45" with 5 Sesame 139 g-rays (500 Gy). They also proved that selection of determinate growth habit mutants depends upon population size, cultivar response to mutagenic treatment and careful screening.

Marker traits are always useful in genetics and breeding as they are easily scorable and selectable in field conditions.

Cytogenetical and agronomical aspects of some morphological (leaf and pollen related) marker mutants were induced following different doses of X-rays and g-rays .These morphological sesame mutants exhibited distinctive traits viz., narrow, elongated, thick leaf types, ovate, ternate elongated petiole type and white, pigmented flower type. Out of different mutants, thick leaf mutants were the most desirable plant types possessing superior agronomic traits such as plant height, primary and total branches per plant, capsule on main axis, distance from base to first branching, total capsule per plant, seed yield and seed protein content than control. JavaMary and Jayabalan (1995), induced mutation-affecting leaf morphology in sesame at M2 following EMS treatments to seeds.

2.2.1 Natural Mutants

Langham (1945) spotted out a natural mutant with indehiscent capsule, Venezuela 52, and was reported to be useful in breeding programmes of sesame (Langham and Radriguez, 1947). The indehiscence was important for mechanized crop production but this desirable character was found to be associated with undesirable characters like semi-sterility, cupped leaves, twisted stems, short capsules and low yield. This mutant was used as parent in recombination breeding in USA and other parts of the world for transferring of ‘id’ gene for indehiscent capsules.

From the variety St.23B, Yadav (1968), isolated spontaneous tricarpellated-capsule mutant, which had larger capsule and a quadrified stigma. He showed that bicarpellary condition is controlled by a single dominant gene while the quadrified stigma is pleiotropically controlled by the gene for tri carpellary ovary.

2.2.2 Induced Mutants Pertaining to Yield and Yield Components

Chaudhary and Das (1954) were first to initiate irradiation work on sesame in India. They reported that in types No.12 and No.6 there was a significant increase in yield over control at 14.4 kR and 20 kR doses of X-rays. They also noticed the increased percentage of pollen sterility with dosage up to 40 kR but decreased with higher doses in West Bengal types Nos. 10 and 12. In another variety, TMV-2 the percentage of pollen sterility increased with dose throughout the range of treatment of 1.4 kR to 80 kR (Chaudhary and Das, 1956).

High yielding and early maturing mutants were isolated in M5 generation at Bose Research Institute. A mutant type No. 16 showed increase in oil content from 41.2 to 53.5per cent. Rai and Jacob (1957), studied induced mutations in a black seeded variety T.16 by treating with X-rays and reported increase in number of capsules, earliness in flowering, large pollen diameter, high degree of pollen sterility and more productive plants in later generations. They isolated a white flowered and small seeded mutant in M3 and M4 generations respectively and both were found to have higher oil percentage (52.10%).

The seeds of *sesamum orientale*, a brown seeded West Bengal type were irradiated with 12 kR of X-rays. In M3 generation, three selections gave smaller, smoother and lighter coloured seeds than parental variety and bred true in M4 and was released as SSM-2 having 55.48 per cent oil with an increase of 8 per cent over that of the parent. The dormant seeds were treated with X-rays at a rate of 384.5 R per minute and with doses ranging from 8-12 kR by Kobayashi (1958 a, b), in order to compare the effects of such exposure with those of 32p. The frequency of chromosomal aberrations at M1 showed a

linear increase with dose, the frequency being higher at the later dose. The types of aberrations induced were in general, similar to those resulting from 32P treatment.

Kobayashi (1955, 1958c), also noticed morphological variations induced by treating three Japanese types B1D, WD and WCB with beta-rays, X-rays, gamma rays and beta rays + X-rays, like alteration of phyllotaxins, development of nectars into functional flower and increase in locule number per capsule. When 400 plants of NP6 were treated with X-ray and fast neutron irradiation, variety of mutants were observed which had hairy capsules, changed fruit phyllotaxy, multiple fruits per axil, pink flowers, brown seeds and combination of these characters . A small seeded mutant (SSM-2) with a mean oil content of 55.48 per cent compared with 47.82 per cent in the parent from M3 population of brown seeded variety exposed to X-rays. Seeds of this mutant were light in colour than that of the parent.

Three local types of sesame were irradiated with four different ionizing radiations *i.e.*, beta-rays from 32P injected into stems, X-rays, gamma rays and thermal neutrons (Kobayashi, 1964). In the plants, which originally had alternate phyllotaxy, the mutants had opposite phyllotaxy and increased number of capsules per plant. The extra floral nectary of two varieties was converted into a functional flower, there by producing two extra capsules per axil. Other mutants produced were those with indehiscent capsules, dwarfs with short internodes and early types. The sesamum seeds were subjected to recurrent irradiation with X-rays. In the M2 generation, it was concluded that the material subjected to one radiation treatment showed great degree of resistance compared to those of the subsequent treatment with X-rays.

Nayar and George (1969), treated NP6 a white seeded type with doses ranging from 25 kR to 100 kR to know the effect of gamma rays. They have not reported any

morphological deviations in M1. In one of the M2 families derived from 50 kR treatment a few plants showed faster growth rate than the rest and they were taller. These plants had larger internodes and most of them were non-branching. The tall mutant (TM) attained a height of about 1 ½ times that of NP6. Nayar (1969), irradiated the seeds of T10 with 75, 100 and 125 kR of X-rays. In M1 and M2 generations, the plants were normal; in M3 out of 33 plants from 100 kR treatments, he observed a single plant showing chlorophyll deficiency from the seedling stage to maturity. The plant had short internodes, weak branching, retarded growth and flowered late, producing small few seeded capsules. The pollen sterility was 63.2 per cent as against 10.6 per cent in the control.

Rajan (1969), exposed two varieties of sesame to gamma rays with doses ranging from 39 x 103 to 97 x 103 rads. He noticed delayed germination in the treated seeds; stimulatory effect of irradiation was found at lower doses. Cleft cotyledons, tricotyledons and unicotyledons were also noticed. Maximum reduction in height was noticed on 30th day. LD50 for germination was recorded at about 83 kR of gamma rays. Sawant and Dhagat (1970) described a petaloid mutant in sesame in which the staminal filaments were petaloid, forming a structure resembling a corolla tube within the normal corolla tube. In this mutant four functional anther lobes producing viable pollen were attached to the inner corolla tube; the progeny breed true for the petaloid character.

Arzumanova and Pravikoskaya (1973), studied growth and development of sesame as affected by seed irradiation with gamma rays. They found that lower doses have little effect in generating variability, and greatest variability was observed with the higher doses 60-80 kR. They observed greatest diversity of forms in both morphological and economic characters in the M3 and stable forms with improved yield were also isolated. In order to study the effect of gamma rays and ethyl methane sulfonate on sesame,

Rangaswamy (1973) treated two varieties KRR-2 and TMV-3 with doses ranging from 50 to100 kR of gamma rays and 25 to 150 mM of EMS. He reported inhibition in germination at higher doses, reduction in plant survival, reduced plant height on 30th day and at maturity, increased pollen sterility and morphological abnormalities in M1 generation. He could identify 20 different ideotypes in M2 of which 19 had desirable traits.

A true breeding mutant possessing more than one capsule per leaf axil and with normal branching was isolated by Nair, Santhakumari and Gopalakrishnan (1975), from variety Kayamkulam-1. This mutant out yielded the check varieties viz., Byalettu, Kayamkulam- 1 and B-9 by 19.9, 19.8 and 18.0per cent respectively. Nair and Nair (1978) irradiated dry seeds of Kayamkulam-1 with six doses of X-rays varying from 5 to 30 kR and concluded that X-rays in low to medium doses can be used for inducing mutations in sesamum. Irradiation had no effect on germination, seedling emergence and plant height in M1 but increased dose caused a decrease in survival and pollen fertility. The frequency of chlorophyll mutants was higher in M1 than that in M2.

Nair and Nair (1978), also reported mutants which were dwarf, lanky, had flat stem and twisted, curly, small, clustered or forked leaves, abnormal flowers. Sarafi (1978), obtained more variability following hybridization than mutation for yield and yield components in sesamum. He followed 5 per cent selection from F2 to F6 and M2 to M6 generations.

Chavan and Chopde (1979), treated three sesamum varieties with four doses of gamma rays, and reported mutants with hairy capsules, early maturing and basally branched dwarf mutants in M2. Hairy capsules were frequent in 58-2, early mutants in D7-11-1

and 85, basally branched dwarf mutants in D7-11-1. The maximum frequency of mutation varied according to the variety and dose.

Murty (1979), obtained true breeding mutants with multiloculed capsules, multicapsules and with large capsules and seeds, after exposing N62-32 seeds to gamma rays. Six crosses between M4 mutants including three multiloculed mutants, showed heterosis for seed yield. In two of the crosses, the hybrids had a higher 1000 seed weight and more capsules per plant than the better parent. He also screened a mutant which had more but smaller capsules and fewer seeds, higher 1000 seed weight and lower oil content. This character was controlled by a single recessive gene for which the symbol 'SC' was proposed (Murty, 1980a). The mutants with higher yields and higher oil percentage than the parent were also reported (Murty, 1980b).

Rangaswamy (1980), observed in the M2 and M3 generation a decrease in mean for plant height, number of capsules, capsule length, seeds per capsule and yield in Si-3500; for capsule girth, seeds per capsule, 1000 seed weight and oil content in TMV-2 and for capsule length in hybrid progenies. Further he also noticed that decreased mean in M2 and increased mean in M3 for capsule girth and seeds per capsule in the hybrid and for capsule girth in Si 3500. Further, he reported an increase in genotypic coefficient of variation (GCV) in the treated populations compared with that of the control. The hybrid as well as the varieties under the treatments showed significant differences for GCV.

However, the GCV for plant height and number of capsules per plant in the hybrid under treatment was on par with that of the untreated. Heritability and genetic advance tended to increase in the treated population, similar to that of GCV. Again, the heritability and genetic advance for plant height was not improved by the treatments in

the hybrid progenies. He also found that the micro mutational spectrum for the combination of the eight economic characters was high in the treated population of the hybrid followed by that of the varieties and the untreated hybrid.

Ashri (1981), reported that high mutation rates in seedlings can be obtained with Xrays and EMS. Determinate plants, probably originating from a single mutation, were found in the M2 of the Israeli variety-45 irradiated with 50 kRad X-rays. The determinate habit was true breeding, monogenic and recessive. Kobayashi (1981), irradiated seeds of BAN, 3BO, QAN types with X-rays, gamma rays and thermal neutrons. BAN gave a higher frequency of mutation than did other types. High yielding mutants were found among 3BO, BAN, QAN and mutants with short internodes.

Chavan and Chopde (1982), evaluated eighty two M2 progenies derived from gamma irradiation of three varieties for twelve yield component traits. Number of primary branches, height up to first branch and number of capsules on the main shoot showed higher variability. High heritability estimates accompanied by high expected genetic advance were found for number of capsules per plant, number of primary branches, height up to first capsule and number of capsules on the main shoot. Number of days to 50 per cent flowering had high heritability with moderate genetic advance.

Rangaswamy and Rathinam (1982), observed male sterility in M2 generation of two varieties and their hybrid following treatments with X-rays and EMS. The male sterile character was found to be monogenically recessive. Thangavelu and Rajasekaran (1982), assessed phenotypic and genotypic coefficients of variation, broad sense heritability and genetic advance for seed yield and eight yield contributing characters in 40 genotypes. Heritability estimate was high for all the characters. Selection based on branches per plant, capsules per plant and seed yield per plant was recommended. Ibrahim, Elkadi, Ahmed and Sheriefi (1983), studied twelve homozygous M6 mutants

of Giza-24 obtained through gamma irradiation, which revealed positive correlation for number of days to flowering, number of capsules per plant and negative correlation for 1000 seed weight and seed yield per plant.

Kamala and Sasikala (1985), reported four high yielding mutants developed by gamma irradiation from 'TMV 5' and IS 103 varieties of sesamum, gave 3-30 per cent more seed yield and 5-13 per cent more oil content. The protein content however remained unchanged. Four high yielding mutants from gamma ray treatments were detected in the 2 varieties in the M2. Two high yielding mutants in 'IS 103' were screened from 20 kR and 40 kR treatments. In 'TMV 5' one of the mutants from 5 kR had whorled capsule phyllotaxy and another from 40 kR had normal alternate capsule set-up.

Murty and Oropeza (1989), detected a narrow lamina mutant with only vestiges of lamina around the veins in progeny in the M4 generation of a variety Ven-52 for resistance to charcoal rot using locally adapted cultivars in venezuela. The material was derived from an initial seed treatment of a dose of 60 kR of radiation from a 60Co source. The number and size of capsules and seed size in the mutant were comparable to its normal counterpart. The genetics of this character was analysed in the subsequent generations indicating that the mutant genotype is duplicate-recessive.

Seeds of four local cultivars were irradiated with 20, 40, 60 and 80 kR by Kamala (1990), data from seven yield components were recorded in the M1, M2 and M3. The highest levels of genotypic and phenotypic variance were noted for seed yield followed by number of capsules per plant, Number of branches per plant, plant height and seeds per pod. A mutant with free corolla lobes (N 29) designated as polypetalous corolla mutant was isolated in the M2 generation obtained after irradiating seeds of CV. N. 62-32 with 1.6kR fast neutrons by Murty and Bhatia (1990). Segregation ratios indicates

that the mutation was controlled by a single recessive gene, crossing to another induced mutant having a gamopetalous corolla with a band of pink dots produced a genetic stock with two recessive markers.

Layrisse, Nava and Monteverde (1992), tested seven venezuelan cultivars for their gamma rays LD50 value. Even for the most sensitive cultivars, the LD50 was 630 Gy, and for the more resistant one it was 800 Gy. Pathirana (1992a), also reported differences in cultivar tolerance to seed irradiation; 'M 13' was much more tolerant to gamma rays than 'M 12' although both were very tolerant. Pathirana (1992a), also induced mutations for resistance to *Phytophthora* and one of them was released as a cultivar ANK-82. Sesame variety was irradiated with various doses by Pathirana (1992b) and selections were based on M2 and M3 plant performance. Seed yield showed high environmental variability and low heritability. The direct effect of 1000 seed weight was positive in spite of the negative correlation. The variability and mutant parent to progeny heritability of most characters were greater in the M3 than the M2. The preliminary results with sesame mutants indicated that the selections carried out after the 200-600 Gy treatments for increased capsule number and seed size were best.

Seeds of sesamum varieties Jordan early and Bangalore local were irradiated with 10, 20, 30, 40, 50, 60 and 70 kR by (Paramesh, Satyan and Mohankumar, 1994). Selfed seeds from normal M1 plants were bulked and an M2 generation raised. Plants of the M3 and M4 generations were screened for mutations. Genotypic variance increased from M3 to M4 in Jordan early while in Bangalore local it decreased, from M3 to M4 generations only in three out of seven treatments. High heritability in broad sense was obtained in both the varieties with highest genetic advance in lower doses.

A monogenic, recessive, determinate growth habit mutant with very unique plant architecture and with clustered capsules was induced by Ashri (1988, 1995), with 500 Gy gamma rays in the Israeli cultivar 'No. 45'. In this mutant, the apical flowers are often 6- parted instead of the standard 5-parted condition in corolla lobes and anthers are bell shaped.

Ganesan (1995), treated the seeds of Co1 variety with good general combining ability and suitable for hybrid breeding with 50 kR gamma rays and 1.0 per cent EMS. M1 generation was screened for pollen sterility by 1.0 per cent Acetocarmine stain and two male sterile plants with more than 90 per cent sterile pollens were identified from the EMS treatment. Male sterile plants were selfed or sibmated. Sibmated progenies segregated as 1:1 in the M2 generation indicating that the male sterility system in sesame is governed by monogenic recessive alleles.

JeyaMary and Jayabalan (1995), treated the seeds of sesame with EMS ranging from 10 mM to 50 mM at an interval of 10 mM each, induced variability in morphological characters. Some of the variants observed in response to EMS treatment are height mutants, branching mutants, leaf mutants, plant colour and texture mutants, mutants for maturity period, floral and sterile mutants, capsule mutants and seed mutants. The analysis of their breeding behaviour showed a dose dependent increase in the frequency of such mutations.

Kang, Kim, Lee, Mathur, Hodgkin, Zhou and Lee (1996), released a variety Yangbackkae developed from Danbackkae seeds treated with 2 mM Sodium azide for 3h. Yangbackkae has not only a higher yield than its control variety but also improved oil quality. Another semi dwarf mutant Suwon 128, obtained after treatment with Sodium azide, has excellent lodging resistance and a good yield potential when planted

in high density. Six varieties and nine hybrids of sesame were subjected to gamma irradiation by Govindarasu (1997), the effects of irradiation on seven yield related traits were evaluated in the M2 and M3 generations.

In general, irradiation of hybrids and varieties produced more or less similar patterns of mutations, with negative shift for most of the characters studied. Non alteration of population means for plant height and 1000 seed weight were observed in M2 and M3 generations. In F2M2 and F3M3 generations, 1000 seed weight remained unaltered. Most of the other characters which showed negative shifts in the F2M2 generation recorded non-alteration in the F3M3 generation. Fourteen officially released cultivars have been produced through the use of induced mutations, 12 direct and 2 through hybridization. UMA, USHA and Kalika are important tin Orissa state in India while the remaining cultivars cover small areas (Ashri, 1998).

Govindarasu and Ramamoorthi (1998), irradiated nine F1 crosses in sesame with gamma rays at 20 and 30 kR doses using cobalt-60 gamma source. They studied the progenies of both irradiated and non irradiated segregating populations for association of characters in the third generation. Only two component traits viz., branch number and capsule number maintained strong positive correlation with seed yield as well as among themselves in both the populations. They also had high positive direct effects on seed yield in the progenies of irradiated and non irradiated hybrids, revealing that these two are the most important traits in the determination of seed yield. The other character pairs viz., plant height, capsule length, seed number per capsule and 1000 seed weight expressing significant correlation in the untreated segregating progenies did not maintain the same level of association in gamma irradiated segregating progenies.

Seeds of six varieties and nine hybrids in sesame were treated with gamma rays by (Govindarasu and Ramamoorthi, 1998). Macro mutations affecting chlorophyll, plant size, leaf characters, capsule characters and sterile plants were studied in M2 and F2M2 populations. Frequencies of deviations were more in F2M2 than M2 for all these characters, except plant size, indicating the efficiency of irradiation of hybrids in producing major deviations. The plants of F2 and F2M2 generations were studied for frequency distribution for seed yield, branch number and capsule number. Transgressive distribution was observed towards the positive direction for all three characters. Irradiated hybrid progenies showed a better symmetry in distribution with positive transgression, suggesting the better chance for selection of high yielding genotypes.

In an attempt to create better male sterile material which can be used directly in sesame breeding work,(Li-Ying , Chen-qingmei and Chen, 1998). Irradiated dry seeds of the good variety Yuzhi 4 with 60Co- gamma rays at 300, 500 and 700 Gy. From 60,000 M2 plants, 10 male sterile mutants were obtained, which were used for further investigation in the M3 and M4. Six mutants were selected which exhibited full male sterility and full female fertility. The male sterility shown to be genetic sterility and controlled by one pair of recessive genes.

Shahin (1998), studied the effect of different factors including gamma radiation on the growth and aflatoxin production of *Aspergillus flavus* in sesame seeds. Sesame seeds were inoculated with aflatoxigenic *Aspergillus flavus*, and then irradiated at different doses. Irradiation decreased aflatoxin production in the seeds and the decrease was proportional to the irradiation dose. Aflatoxin production was completely prevented in inoculated sesame seeds by an irradiation dose of 2.5 k Gy, even under conditions optimum for fungal growth.

Sorour, Hussein and Imam (1999), irradiated the seeds of sesame cultivars Giza 25 and Giza 32 with 100, 200, 300 and 400 Gy of gamma-radiation. M1 plants irradiated with 400 Gy had lower means than the parent plants in all the characters studied, but had much higher coefficients of variation. In addition, highly significant variation was observed in the M2, allowing selection of number of useful mutants. In general, all doses except 100 Gy were effective for selection in M2 and M3 generations.

Mutants with more capsules, long capsules, multi-capsules per leaf axil, semi-shattering capsules and early maturity were selected. Yuzhi11 was developed from a single mutant plant of CV. Yuzhi 4 found in 1991 by (Wei-Wenxing, Wei-shuangling, Zhang-hai Yang, Ding-fa Yuan, Zhang, Ti de and Lu-feng Yin, 1999). In trials (1994-98) the average seed yield of Yuzhi 11 was 1.01 t per ha which was 7.93 per cent higher than the yield of Yuzhi 4. Yield of Yuzhi 11 was also more stable than that of Yuzhi 4, seed oil content was 56.66 per cent, which was slightly higher than that of Yuzhi 4, 1000-seed weight was 2.7-3.0 gm and seeds were white. Yuzhi 11 showed high resistance to *Fusarium oxysporum f.sp. sesami, Macrophomina phaseolina and Cercospora sesami*.

Govindarasu (2000), irradiated the seeds of 3 varieties TMV 3, TMV 4 and TMV 6 with gamma rays at LD50 value of 20 kR and crossed individually with RJS 199. The mean performance of F2 in all the three crosses was significantly better than M2 of all the three varieties for seed yield, branch number, capsule number and 1000 seed weight. A similar trend was also noticed in F3 and M3 populations. Genotypic variability was relatively of higher magnitude in F2’s and F3’s than M2’s and M3’s for seed yield, branch number and capsule number. Estimates of heritability and genetic advance also showed the same trend.

The effects of sesamol, a phenolic compound responsible for the high resistance of sesame oil to oxidative deterioration as compared with other vegetable oils, were investigated by (Kaur, Amapreet, Saini and Saini, 2000), after mutagen treatment in various strains of *Salmonella typhimurium*. Mutagenicity was induced by the generation of oxygen radicals by tert-butyl hydroperoxide (t- B00H) or hydrogen peroxide (H2O2); the anti mutagenic property of sesamol was attributed to its antioxidant properties.

Sheeba, Ibrahim, Yogameenakshi, and Babu, (2003), subjected two sesame varieties viz., SVPR 1 and Co 1 to gamma irradiation (30, 40, 50, 60 and 70 kR) and EMS (0.8, 1.0, 1.2, 1.4 and 1.6%) treatments. They observed comparatively higher GCV for capsule length followed by number of seeds per capsule in both the varieties, 1000 seed weight in Co1 and single plant yield in SVPR registered high GCV. In SVPR 1, maximum heritability was recorded by 40 kRad (99.4%) for number of capsules per plant in gamma rays treated progenies and by 1.0per cent (98.4%) for single plant yield in EMS treated progenies.

In Co 1, 60 kRad (99.9%) of gamma rays and 1.4 per cent (99.8%) of EMS registered maximum heritability for number of branches per plant and capsule length respectively. Narrow leaf mutants were identified by Sonali and Animeshkumar (2005), in the M2 generation of sesame, cultivar B-67 treated with nitrous acid (0.25%, 2h-6.25% and 0.25%, 6h-2.50%) and hydrogen peroxide (0.25%, 2h-6.25%; 1.0%, 4h-0.63%; 0.25%, 6h-4.69% and 1.0%, 6h-3.28%). The estimated frequency of the mutant plant over the M2 population (6137 plants scored) was 0.28 per cent. The leaves of the mutant plants were narrow and oblong to lanceolate in shape with entire to undulated margins. The narrow leaf mutant plants have higher number of capsules per plant, and on the main axis and smaller distance from base to first branching compared to controls.

2.2.3 Induced Mutants Pertaining to Seed Quality

Rai and Jacob (1957), studied induced mutations in a black seeded variety T 16 by treating with X-rays. They isolated small seeded mutant in M4 generation and it had higher oil percentage (52.1%). Later the seeds of *sesamum orientale*, a brown seeded West Bengal type were irradiated with 12 kR of X-rays. In M3 generation, three selections gave smaller, smoother and lighter coloured seeds than parental variety and bred true in M4 and was released as SSM-2 having 55.48 per cent oil with an increase of 8 per cent over that of the parent. When 400 plants of NP6 were treated with X-rays and fast neutron irradiation brown seeded mutant was observed. A small seeded mutant (SSM-2) with a mean oil content of 55.48 per cent compared with 47.82 per cent in the parent from M3 population of brown seeded variety exposed to X-rays. Seeds of this mutant were light in colour than that of the parent.

Murty (1979), obtained true breeding mutants with multiloculed capsules, multicapsules and with large capsules and seeds, after exposing N62-32 seeds to gamma rays. Six crosses between M4 mutants including three multiloculed mutants, showed heterosis for seed yield. In two of the crosses, the hybrids had a higher 1000 seed weight and more capsules per plant than the better parent.

Pathirana (1992b), irradiated the sesame variety with gamma rays of various doses and selections were based on M2 and M3 plant performance. The preliminary results with sesame mutants indicated that the selections carried out after the 200-600 Gy treatments for increased capsule number and seed size were best.

Jeya Mary and Jayabalan (1995), treated the seeds of sesame with EMS ranging from 10 mM to 50 mM at an interval of 10 mM each, induced variability in morphological

characters. They observed many morphological variants including seed mutants in response to EMS treatment.

Govindarasu, Natarajan, Subramanian and Ramamoorthi (1997), gamma irradiated six varieties and nine hybrids of sesame. In general irradiation of hybrids and varieties produced more or less similar pattern of mutations, with negative shifts for most of the characters studied. Non alteration of population means for plant height and 1000 seed weight were observed in the M2 and M3 generations. Yuzhi-11 was developed from a single mutant plant of cv. Yuzhi 4 found in 1991 by Wenxing *et al* (1999). Seed oil content was 56.66 per cent which was slightly higher than that of yuzhi-4, 1000 seed weight was 2.7-3.0 gm and seeds were white.

Govindarasu (2000), irradiated the seeds of 3 varieties viz., TMV 3, TMV 4 and TMV 6 with gamma rays at LD 50 value of 50 kR and crossed individually with RJS 199. The mean performance of F2 in all the three crosses was significantly better than M2 of the three varieties for seed yield, branch number, capsule number and 1000 seed weight. Sheeba, Ibrahim, Yogameenakshi and Babu, (2003), subjected two sesame varieties viz., SVPR-1 and Co-1 to gamma irradiation (30, 40, 50, 60 and 70 kR) and EMS (0.8, 1.2, 1.4 and 1.6%) treatments. They observed comparatively higher GCV for 1000 seed weight in Co 1 and single plant yield in SVPR.

2.2.4 Effects of Sodium azide and Colchicine Treatments on Morphological and Yield Traits of Sesame Seed (*sesamum indicum L.*)

The use of mutagens in crop improvement helps to understand the mechanism of mutation induction and to quantify the frequency as well as the pattern of changes in different selected plants by mutagens. Mutation breeding generates a knowledge base

that guides future users of mutation technology for crop improvement, the mutagenic effects of sodium azide have been documented in previous reports.

Kleinhofs, Owais and Nilan (1978), reported that sodium azide is a very potent mutagen in barley and induced chlorophyll deficiency as well as a wide range of morphological and physiological mutants. The chemical induces genetic sterility in rice without changes in vigour (Mensah, Akomeah and Ekpekuredu, 2005). On the other hand colchicine is both a polyploidising and mutagenic agent (Bragal, 1955). This chemical has been used for a long time to produce polyploid plants. The mutagenic effects on plant morphology, chlorophyll, sterility and yield have earlier been confirmed by Ahoowalia (1967), Mensah (1977), and (Castro, Olieviera and Calvaho, 2003).

Balkanjieva (1980) has reported the influence of genotype on mutagenic variability in barley following colchicine treatment. According to Mensah *et al* 2007, Seeds of Sesame (*Sesame indicum L.*) were exposed to varying concentrations of sodium azide and colchicine solutions ranging from 0 - 0.250% (w/v). Variations in the percentage germination and survival, number of days to maturity, plant heights, total leaf area/plant, chlorophyll content, pollen sterility, and dry matter and fruit size were recorded in the C1 and C2 generations. The frequency of mutation/injury increased with increasing concentrations of the mutagens.

The LC50 values based on survival percentages in the M1 generation were fixed at 0.0776 and 0.0473% for sodium azide and colchicines respectively. There were dose related effects of the mutagenic treatments on quantitative traits resulting in reductions in traits such as germination and survival percentages, plant height, number of fruit/plant, but increases in leaf area, maturity time and fruit size. Colchicine treatment produced shortened internodes, deformed leaves, and chlorophyll mutants. Low doses

of both mutagens (<0.125%) produced early maturing variants and robust/high yields and can be imposed to obtain beneficial mutants in sesame.

Artificial induction of mutation is of scientific and commercial interest as it is one of the methods used in improving the growth and yield of economic plants. It provides raw materials for the genetic improvement of economic crops (Adamu *et al.,* 2004).Although various mutagens were known to induce mutation in plants, this work has made use of colchicines, a poisonous alkaloid derived from the autumn crocus (Colchicum autumnale) in inducing genetic variability through mutagenesis to improve both the quality and quantity of sesame.

Mutation induction through the use of different concentrations of colchicines has proved vital in inducing variability that could be exploited in the improvements of sesame growth and yields. It is therefore the origin of genetic variability as suggested by (Tamarin, 1999). The increased mean germination percent due to various colchicines concentrations revealed the effects of the mutagen in the germination process.

The number of germinating seeds decreases with the increase in the concentration of colchicines, which is in agreement with the findings of Ulmalkar, Yawhare, Kashikar and Kashikar (1998), who reported high germination percentages in Capsicum annum due to Sodium Azide treatment but is in contrast to the work of Bird and Neuffer (1988), who reported reduction in the germinating rates in plants treated with mutagen.

The mean increase in plants heights at maturity of the two sesame varieties induced by colchicines was due to the alteration of their genome integrated by environmental signals as reported by (Uno, Storey and Moore, 2001), probably by increasing the rates of cellular division and expansion at their meristematic regions. This is also in agreement with the findings of Hoballah (1999), who reported increased in plant heights

of sesame due to radiation mutagenesis, but is in contrast to the findings of Anandakumar and Sree-Rangasamy (1995) and Maluszynski *et al.* (2001), who independently reported decrease in plant height due to induced mutation in rice and other cereals.

The increase in leaf number and internodes length with decrease in the concentrations of colchicines was in agreement with the findings of Hoballah (1999), who reported increased in leaf number and internodes length among sesame mutants due to gamma irradiation.

The increase in the leaf area of sesame due to colchicines means an increase in the surface area for gaseous ex-change which consequently affects the photosynthetic process. This agrees with the work of Maluszynski *et al.* (2001), who reported increase in the leaf area among Zea mays mutants due to irradiation. The increase in the number of pods facilitates increase in the number of seeds produced/pod due to colchicines concentrations. This is in conformity with the findings of Pathak (1991), in M2 cowpea mutants and Lonnig (1982), in the X-ray induced mutants of Pea.

The presence of some segments of chimeras among the mutants was in agreement with the findings of Ranchyalis, Girkontait and Burneikeng (1988), who reported the occurrence of chlorophyll mutation in plants due to mutagenesis.

Artificial induction of mutation through the use of colchicines proves vital in the improvement of genetic variability in sesame. Certain concentrations of colchicines (0.1mM through 2.0mM colchicines concentration) have the potentiality of inducing variability that could be used in the improvement of the yield of sesame.

Nura, Adamu, Muazu and Dangora (2011a), who studied the use of Chemical mutagenesis through the use of colchicine on the seeds of two varieties of sesame

(Sesamum indicum L. Var. Ex-Sudan and E-8) with the aim of inducing variability that could be exploited in the genetic improvement of its growth and yield was carried out. The sesame seeds were treated with colchicines at four different concentrations (0.1mM, 0.5mM, 1.0mM, 2.0mM and control) for two mutant generations (M1 and M2). Highly significant variation ($P \leq 0.01$) was observed in such quantitative traits like the germination percent, height at maturity, number of leaves produced per plant, internodes length, leaf area, number of pods/plant, number of seeds/pod and 1000 seeds weight which decreased with increase in colchicines concentrations. Besides these, a segment of chlorophyll deficient mutants such as: Chlorina, Xantha, Striata, Virescents and Lustescents were found among the mutant generations, with their frequency decreasing with increase in colchicines concentrations. Lower concentrations of colchicines were recommended for inducing genetic variability in sesame (Sesamum indicum L.) to improve the yield of such economic plant.

2.2.5 Genetic Variability, Heritability and Genetic Advance

Increasing yield is always paramount aim of any breeder. However, assessing factors responsible for increasing yield is always difficult. Yield is the end product of action and interaction of vital activities of plant throughout the life cycle and is controlled by numerous factors shaped by genetics and environment. Among these factors, most important is the inherent potential of the plant to produce higher yield which depends upon the hereditary make up of the plant. Therefore, for rational improvement of crop, understanding of the magnitude of genetic variability and the extent to which the desirable characters are heritable becomes essential.

The determination of genetic variability and its partitioning into various components, in any crop, is necessary to have an insight into the genetic nature of yield and its components. Thus, the magnitude of heritable variation, particularly its genetic

components, is clearly most important part of the breeding material which has close bearing on its response to selection.

The contribution of genetic and environmental components to the variance was studied by Johannsen (1909). He attributed the variation in a segregating population to both heritable and non-heritable factors. Later his suggestions were confirmed by Nilsson-Ehle (1909) and East (1916), who also showed the conformity of continuous variation with Mendelian genetics.

Genotypic variance was separated from total phenotypic variance by Charles and Smith (1939), Powers (1957) and (Powers, Locke and Garret, 1950) availing the estimate of environmental variance in non segregating population. The genotypic variance was further partitioned by Fisher *et al*. (1932), Smith (1936), Panse (1940) and Lush (1945), into additive and non-additive components. The non-additive component includes dominance and inter allelic interactions. Panse (1957), showed that the additive component of genetic variance is highly heritable and the characters are fixable through selection resulting in maximum genetic advance.

Heritability in broad sense, as the ratio of additive variance to the total variance was proposed by Lush (1949). Later, (Hanson, Robinson and Comstock, 1956) proposed heritability in broad sense as the ratio of genotypic variance to total variance in a non-segregating population.

Heritability influences the selection programme to a larger extent. According to Allard (1960), heritability of yield alone is less and that of yield components is more. However, the gain from selection for a particular character is the function of its heritability, selection pressure and the variance existing in the base populations. Thus, genetic gain was expressed by Burton and Devane (1953), as the product of heritability,

phenotypic standard deviation and selection differential. Though heritability value indicates the relative effectiveness of selection based on phenotypic expression of a trait, the genetic advance is more useful in predicting the actual value of selection as shown by (Johnson, Robinson and Comstock, 1955).

Yadava, Kumar and Yadav (1980), reported high phenotypic variability for number of primary branches, number of capsules on the main shoot, total number of capsules, plant height, 1000 seed weight, number of days to first flowering, 50 per cent flowering and maturity. While, Janardhanan, Ratnakar, Reddy, Satyanarayana and Subramanyam (1981), noticed high degree of genotypic and phenotypic coefficient of variation, high heritability and genetic advance for yield per plant.

High variability for capsule number per plant, number of primary branches per plant, capsule length and seed yield and further high heritability, genetic advance for capsule number, number of primary, secondary branches and seed yield was observed in segregating population of sesame by Paramasivam and Prasad (1981). High genotypic coefficient of variability, heritability and genetic advance for number of branches was reported by Rai *et al.* (1981).

Solanki and Paliwal (1981), found high genotypic and phenotypic variance for number of capsules per plant and number of seeds per capsule. High heritability was observed for 1000 seed weight, capsule length, number of seeds per capsule, number of days to maturity and capsule length. Medium heritability for seed yield per plant and number of capsules per plant and high heritability combined with high genetic advance was also observed for number of seeds per capsule and number of days to maturity.

Chavan and Chopde (1982), reported high variability for number of capsules per plant, number of primary branches, height up to first branch and number of capsules on the

main stem. High heritability along with high expected genetic advance was observed for number of capsules per plant, number of primary branches, height up to first capsule and number of capsules on main shoot, while number of days to 50 per cent flowering had highest heritability with moderate genetic advance. Expected genetic advance was highest for height to first capsule, seed yield and plant height.

In another study, Chandraprakash (1983) reported low heritability values for 1000 seed weight, capsule length, number of capsules on main stem, seed yield, height to first capsule and higher values for harvest index and number of capsules in primary branch. High heritability coupled with high genetic advance for clusters on branches and capsules on branches was reported in sesame by Gupta and Chopra (1984).

Shadakshari (1984) reported high genotypic and phenotypic coefficient of variability for number of capsules, number of branches and seed yield per plant. High heritability coupled with high genetic advance was observed for seed yield per plant, number of capsules and number of branches. High heritability and expected genetic advance was noticed by Kandaswamy (1985), for branch number, capsule number per branch, seed number per capsule and yield.

Pathak and Dixit (1986), observed high genetic advance for seed yield per plant. Wide variability and high heritability were observed for all characters except capsule length, capsule girth, and number of seeds per capsule. High phenotypic and genotypic coefficient of variability for height to first capsule and number of branches per plant was observed by Bakheit and Mahdy (1988).

Govindarasu *et al*. (1990), found that seed yield, capsules on primaries, capsule on secondaries and number of secondaries had high genotypic coefficient of variation, heritability estimates and genetic advance. Kandaswamy, Kadambavana, Sundaram,

Sridi-Iaran, and Sree Rangaswamy, (1990) reported high heritability with high genetic advance for seed yield per plant, high heritability with low genetic advance for days to 50 per cent flowering and low heritability with low genetic advance for number of capsules on main stem, number of capsules on branches and total number of capsules per plant.

Reddy and Dorairaj (1990) observed that the number of capsules per branch had high heritability combined with high genetic advance, while seeds per capsule had higher heritability with medium genetic advance. Raut, Khorgade, Bolke and Ingle (1991) observed a wide range of variation for plant height followed by days to maturity and number of seeds per capsule. Comparatively low magnitude of variation was exhibited by number of branches, 1000-seed weight and seed yield per plant.

Pathak and Dixit (1992), reported a wide range of variation in sesame for plant height, branches per plant, seed yield and capsules per plant, high heritability for protein and oil content, days to maturity, days to 50 per cent flowering and high genetic advance for plant height, branches per plant and protein content.

Chandrashekara and Reddy (1993a), observed high genotypic coefficient of variation for capsules on secondary branches and number of secondary branches but however it was low for days to maturity, length of capsule and oil content. All the characters observed had high heritability except for primary branches per plant and high genetic advance for capsules on secondary branches and low for days to maturity and length of capsule. By analysis of variance John, Nair and John (1993), observed significant variation for 14 out of 16 characters studied. They also obtained highest phenotypic and genotypic coefficient of variation for number of capsules on branch followed by seed yield per plant and number of capsules on main stem. Further they obtained highest

heritability value for seed protein content and seed oil content. Seed yield per plant followed by number of capsules on main stem recorded highest genetic advance.

High genotypic and phenotypic coefficient of variation for number of branches per plant and the height at which the first capsule formed was reported by Reddy and Haripriya (1992). High heritability coupled with moderate genetic advance was observed for days to 50 per cent flowering followed by days to maturity. Variability studies by Bhombe, Dawande, Jayade and Mundafale (1994), revealed that the genotypic coefficient of variability was high for capsules per plant and yield per plant. High heritability was observed for days to 50 per cent flowering and high expected genetic advance over mean for capsules per plant, yield per plant, seeds per capsule and days to 50 per cent flowering.

Shadakshari, Virupakshappa, and Shivashankar (1995), observed wide range of variability for 20 quantitative characters. PCV and GCV values observed were larger for number of capsules per axil, total number of capsules, total number of branches, seed yield per plant and node of first flowering and low for days to 50 per cent flowering, days to first branching, capsule length, capsule girth, oil content and days to maturity. High heritability coupled with high genetic advance was observed for number of capsules per axil, seed yield per plant, number of locules and total number of capsules while total number of branches, days to first branching, days to second branching, capsule length and oil content had high heritability with low genetic advance.

Biswas and Akbar (1995), in their study observed the highest genotypic coefficient of variation for seed yield per plant followed by number of branches per plant. They also showed that broad sense heritability was highest for days to flowering followed by days to maturity and 1000 seed weight. Highest genotypic coefficient of variability,

heritability and genetic advance for stem weight and lowest for root weight and seed yield, was recorded by Reddy and Dorairaj (1994). Patil and Sheriff (1996) reported high GCV and PCV for number of capsules followed by oil yield per plant. High heritability coupled with high genetic advance was observed for number of capsules and seed yield per plant.

Singh *et al*. (1997) observed wide range of variability for productive capsules, primary branches and seed yield per plant. High heritability coupled with high genetic advance was recorded for days to maturity, productive capsules and seed yield per plant. Shanmugavalli and Vanniarajan (1998), obtained significant differences between the genotypes of sesame for all the five characters they studied. Secondary branches per plant, number of capsules per plant and single plant yield had high genotypic coefficients of variation. Secondary branches per plant, number of capsules per plant and single plant yield had high heritability combined with high genetic advance.

Jayalakshmi, Reddy and Reddy (1998), observed high heritability and genetic advance for number of primary branches and days to 50 per cent flowering while days to maturity showed high heritability but low genetic advance. High heritability (72.63%) and per cent genetic gain (28.77%) for seed yield was reported by Arriel *et al*. (1999) Singh *et al*. (2000), revealed that the phenotypic coefficient of variability was higher than the genotypic coefficient of variation for all characters analysed. The highest GCV and PCV were obtained for number of primary branches per plant. Number of capsules per plant, total dry matter produced at all stages and seed yield per plant had high heritability with high genetic advance. High heritability with low genetic advance was obtained for 1000 seed weight, plant height, oil content and total dry matter produced at 75 DAS.

Reddy *et al*. (2001), found high GCV, PCV, heritability and genetic advance as per cent of mean for seed yield per plant, total number of capsules per plant, capsules on main stem, capsules on primary branches, capsule length, total dry matter production per plant, secondary branches per plant, plant height and oil content.

Krishnaiah, Reddy and Sekhar (2002), observed close resemblance between GCV and PCV for all characters they studied. High GCV and heritability coupled with high genetic advance were observed for capsules on secondary branches, capsules on primary branches, capsules on main stem and plant height. Saravanan, Nadarajan and Kumari (2003) obtained high heritability and genetic advance for single plant yield, plant height, photosynthetic rate, leaf area index and harvest index. Days to 50 per cent flowering exhibited high heritability, but low genetic advance.

High GCV and PCV estimates were observed for seed yield per plant, number of branches per plant and number of capsules per plant, in a study conducted by Solanki and Deepak (2003). Seed yield, number of capsules per plant, number of branches per plant were characterized by high heritability and high genetic advance. Babu, Reedy and Reddi (2004), recorded a wide range of variation for plant height, number of capsules per plant, number of seeds per capsule, 1000 seed weight, leaf area index, harvest index, seed yield per plant and oil yield per plant. The coefficients of variation were high for plant height and seed yield per plant. High heritability coupled with high genetic advance was observed for number of primaries, number of capsules per plant, seed yield per plant and oil yield per plant indicating the operation of additive gene action, 1000 seed weight and oil content showed low heritability as well as low genetic advance besides narrow range of variability.

Narian (2004), obtained highest genotypic coefficient of variation for seed yield per plant followed by harvest index, number of capsules per plant and primary branches per plant. High heritability and genetic advance were recorded for number of capsules per plant, seed yield per plant and harvest index.

Singh and Singh (2004), observed wide range of variation for all the characters except for capsule length. High heritability along with high magnitude of genetic advance was recorded for capsules per plant and grain yield. Days to maturity exhibited high heritability and low genetic advance. PCV was higher than the GCV for all the characters studied.

The analysis of genetic parameters revealed a narrow difference between the genotypic and phenotypic coefficients of variation in a study conducted by Babu, Kumar and Rani, (2005). Estimates of heritability were high for all the characters, while genetic advance as per cent mean was high for seed yield per plant, number of seeds per capsule, number of primaries, number of capsules per plant and 1000-seed weight. Medium genetic advance as per cent of mean was recorded by days to 50 per cent flowering and plant height. Oil content and days to maturity had a low genetic advance as per cent of mean.
Ganeshan (2005) observed low genotypic and phenotypic coefficient of variation for most traits. Number of capsules per plant recorded the highest coefficient of variation. High heritability (99.64%) coupled with high genetic advance as per cent of mean (67.55%) was recorded for number of capsules per plant. Plant height, number of seeds per capsule and 1000 seed weight also recorded high heritability estimates and moderate level of genetic advance as per cent of mean. Raghuwanshi (2005), observed high variability for all characters, except for 1000 seed weight which showed low to moderate variability. The genotypic variance was lower than the phenotypic variance.

2.3 Correlations and Path Coefficient Analysis

The attainment of characteristic form and function in crop plants depends upon a chain of interrelated events which are sequential in time. Moreover, these events do not occur haphazardly but follow an integrated pattern. Seed yield is an obvious example of such integration and its expression is dependent upon action and integration of various components. As Grafius (1956) has suggested, there may not be genes for yield *per seed* but, there are genes for various yield components. Association between quantitative characters statistically determined by Pearson's correlation coefficient (r) has been quite useful as basis for selection. The basic concept of correlation was elaborated and discussed by Fisher (1918, 1936) and Wright (1921) for plant breeding programmes.

Path coefficient analysis provides an effective means of partitioning direct and indirect causes of association with yield. It also reveals the magnitude of contribution made by different plant characters towards yield thereby imparting confidence in selection of important yield attributes. The method of path coefficients proved useful in analyzing correlation coefficient in this system of related variables. Path coefficient analysis was insinuated by Wright (1921) and its practical utility was demonstrated by Dewey and Lu (1959).

Gupta and Chopra (1984) found positive direct effect of capsules per branch on seed yield and negative direct effect of plant height on yield. Positive direct effect of plant height and capsule per plant and negative effect of branches per plant on seed yield was observed by (Reddy, Reddy and Rana, 1984).

Positive correlation of yield with plant height, growth of stem, number of branches and number of capsules was reported by Reddy *et al.* (1984). Shadakshari (1984), observed positive and significant association of seed yield with number of capsules, days to 50

per cent flowering, plant height, height to first branch, productive area, 1000 seed weight, oil content and days to maturity. Number of capsules had the highest direct effect on seed yield.

Sharma and Chauhan (1984), reported positive association of seed yield per plant with number of capsules, 1000 seed weight and oil content. While, Ranganatha (1985), recorded significant positive association of seed yield with number of capsules, number of branches and days to maturity. Godawat and Gupta (1986), observed positive significant correlation of seed yield with number of branches per plant, number of capsules per plant, capsule length and number of seeds per capsule. Number of capsules per plant showed greatest direct and indirect effect on seed yield.

Pathak and Dixit (1992), recorded highest direct effect of days to flowering, plant height, capsule length, seeds per capsule and 1000 seed weight on seed yield. Positive direct effect of 1000 seed weight, number of capsules per plant, and number of seeds per capsule on seed yield was observed by (Bhele, Khorgade and Narkhade, 1987). Majumdar, Barik, Bera and Gosh, (1987) reported positive significant correlation of seed yield with capsule number per plant, number of seeds per capsule,1000 seed weight and plant height. While, number of seeds per capsule showed highest direct effect on yield. High positive correlation of seed yield with plant height, days to first capsule, 1000 seed weight and capsules per plant was recorded by Bakheit and Mahdy, (1988).

Li (1988), reported significant correlation of seed yield with capsule number per plant, seeds per capsule and 1000 seed weight. Rong and Wu (1989) observed greater genotypic correlation than phenotypic correlation. Genotypically seed yield showed significant positive correlation with capsules per plant and significant negative correlation with seeds per capsule and 1000 seed weight. Capsules per plant exerted the

greatest direct effect on seed yield followed by 1000 seed weight.

Deshmukh and Chavan (1990), reported positive significant correlation of seed yield with number of capsules, capsule number, and number of grains per plant. Negative correlation was found between grain yield and plant height and number of leaves per plant. Positive, significant phenotypic, genotypic and environmental correlation was observed between number of capsules on main stem and total number of capsules per plant by (Kandaswamy, Kadambavana, Sundaram, Sridi-Iaran and Sree Rangaswamy, 1990).

Ramkrishnan and Soundarapandian (1990), observed significant positive correlation of seed yield with plant height, photosynthetic efficiency and number of capsules per plant. Reddy and Ramachandriah (1990) found that number of branches and number of capsules per plant had highly significant correlation with seed yield per plant in both parents and F1 hybrids.

Li & Zhang (1991), found that the most important contributor to single plant yield was 1000 seed weight followed by effective pods per plant and number of seeds per pod. Reddy & Haripriya (1991) reported significant positive correlation between number of branches and capsules per plant with oil and yield per plant. On the contrary, significant positive correlation of seed yield with plant height was noticed by Babu and Shivasubramanian (1992).

Positive significant association of seed yield with number of capsules on primaries, number of capsules per plant, seed yield on primaries and secondary was noticed by Reddy and Haripriya, (1992). Further by path analysis they revealed that seed yield on primaries and number of capsules per plant had the greatest direct contribution to seed yield.

Pathak and Dixit (1992), observed significant and positive genotypic correlation of seed yield with capsules per plant, capsule length and seed per capsule and oil content with days to flowering, days to maturity, plant height and capsules per plant. Further, by path coefficient analysis it was revealed that days to maturity, branches per plant, capsule girth are the major components for seed yield while branches per plant, capsule girth and seeds per capsule are the major components for oil content in black seeded sesame.

Vadhvani, Kakudi and Parmal (1992), during their investigation observed significant negative correlation between seed yield and oil content. They also noticed that capsule number had greatest effect on yield. Chandrashekara and Reddy (1993b), observed that the total number of capsules had high phenotypic and genotypic correlation with capsules on primary branches, capsules on main stem number of secondary branches, plant height and number of primary branches per plant. It was also noticed that harvest index, total dry matter production and capsules on primary branches had high direct effect on seed yield.

Chandrashekara and Reddy (1993c), obtained positive phenotypic correlation of oil yield per plant with seed yield, 1000 seed weight and number of seeds per capsule. Path coefficient analysis revealed that seed yield per plant had greatest direct effect on oil yield. An investigation by (Subramanian and Subramanian 1994) in F4 and F5 generation of two crosses revealed that the magnitude and direction of correlation between eight pairs of traits varied with generations in both the crosses. They also showed that plant height and capsule number was significantly and positively correlated with each other. Path coefficient analysis revealed that primary branches, secondary branches, capsule number per plant, seed number per capsule and 1000 seed weight should be considered for improving the seed yield and selection of parents.

Vanishri, Raghunathan and Ranganatha (1994), reported that seed yield per plant was positively correlated with number of secondary branches, capsules on primaries, number of productive capsules per plant, capsule length, 1000 seed weight, harvest index and oil yield per plant. Path analysis indicated that number of productive capsules, capsule weight and number of seeds per capsule had the greatest positive direct effect on seed yield.

Reddy and Dorairaj (1994), obtained highest genotypic correlation for stem weight followed by capsule weight, root weight and leaf weight with seed yield. Further they reported that dry matter production and harvest index had the greatest positive direct effect on seed yield. They found that the traits also had positive indirect effect on seed yield through a number of other characters.

Biswas and Akbar (1995), in their study revealed that seed yield was significantly positively correlated with days to maturity, plant height, number of branches per plant, number of capsules per plant and 1000 seed weight at genotypic level. Positive correlation of seed yield with capsule number, capsules on main branch, primary branches, number of leaves and plant height was observed by Chaudhary (1995).

Mishra, Yadav and Tiwari (1995), observed that seed yield was significant and positively correlated with number of fruiting nodes per plant and number of capsules per plant. Path coefficient analysis revealed the maximum direct effect of number of capsules per plant followed by number of seeds per capsule and days to 50 per cent flowering on seed yield per plant.

Patil and Sheriff (1996), observed significant and positive association of seed yield with number of capsules per plant, plant height, capsule girth, productive area, number of branches, and height to first capsule, days to maturity, 1000 seed weight and capsule

length. Path coefficient analysis revealed highest direct effect of number of capsules on seed yield per plant followed by days to maturity, productive area and 1000 weight, while number of branches per plant had negative direct effect on seed yield per plant.

Thiyagarajan and Ramanathan (1996), observed that seed yield per plant was positively correlated with number of capsules on branches, total dry matter production, plant height, oil content, capsule bearing portion of main stem, first capsule bearing node, harvest index, 1000 seed weight and capsule length and possessed positive direct and positive indirect effect via other characters on seed yield. In a study during two seasons, Subbalaxmi (1996) observed that in kharif, seed yield was significant and positively correlated with number of capsules and number of branches. The number of capsules had high positive direct effect on seed yield followed by plant height. While, in summer, seed yield had positive correlation with capsule length, number of branches and number of capsules, while capsule length had the highest direct effect.

Rai, Sah, Varshnaj, Mandal, Kumar and Kumar (1997), found that seed yield had significant positive phenotypic and genotypic association with secondary branches per plant, capsules per plant, capsules per main shoot, and seeds per capsule, biological yield and harvest index. Biological yield, harvest index and secondary branches per plant had a positive direct effect on seed yield. Singh, Dixit and Yadav (1997) observed significant positive correlation of seed yield with number of primary branches and productive capsules per plant. Significant positive correlation of seed yield with siliqua per plant, seeds per siliqua and primary branches per plant were observed by Tak (1997). Further path analysis revealed that number of primary branches per plant, siliqua per plant and seeds per siliqua had high degree of direct and indirect effects on seed yield. Manivannan (1998), observed that branches, capsules on main stem and capsules on branches were positively correlated with seed yield. Path coefficient

analysis revealed that capsules on branches, had high direct effect on seed yield.

Siddiqui *et al*. (1998), observed that plant height, days to 50 per cent flowering and seed weight per capsule had greatest positive direct effect on seed yield per plant, while the greatest direct effects were observed by days to 50 per cent flowering, days to maturity, number of capsules per plant and days to first flowering. Significant and positive correlation between seed yield per plant and capsule number, 1000 seed weight and plant height was observed by (Backiyarani, Subramanian and Shanthi, 1999). They also revealed that seed yield per plant was negatively correlated with seed oil percentage. Further by path analysis they observed the importance of the number of primary branches as a selection criterion for yield improvement.

Alam, Biwas and Mandal (1999), observed that seed yield per plant and oil yield per plant had highly significant and positive correlation with root length, root dry weight, maturity plant height, branches per plant, capsule on main branch, capsules per plant, 1000 seed weight and harvest index. The highest direct and positive contribution at genotypic level was made by maturity followed by harvest index, capsules per plant, root weight, branches per plant and seeds per capsules.

Tomar, Srivastava, Tiwari and Triphati (1999), found that capsule per plant had positive direct effect on the seed yield, followed by seeds per capsule and 1000 seed weight. Number of branches and dry matter production, also showed considerable direct effect on seed yield. Arriel *et al*. (1999), observed highly significant genetic correlation between the yield and the total number of capsules (0.77) and this variable was significantly correlated with plant height (0.69). The genetic correlation showed that the largest yield per plant was obtained from genotypes with larger number of fruits.

Positive and significant correlation of seed yield with plant height, number of branches

per plant, number of seeds per capsule, total dry matter, production at 75 DAS and total dry matter production at maturity was observed by (Singh, Nagaiah and Singh, 2000).

Uzun and Carigan (2001), observed that number of capsule per plant was highly correlated with seed yield. Path coefficient analysis revealed that plant height had the greatest direct effect on seed yield. Significant and positive association of seed yield with number of branches and number of capsules per plant were observed by Arulmozhi *et al* (2001). Path coefficient analysis revealed the maximum direct effects of number of branches, number of capsules and 1000 seed weight on seed yield.

Pawar, Chetti and Jahagirda (2002), observed that seed yield was strongly associated with leaf area, 1000 seed weight, total dry matter, chlorophyll, oil and protein contents. It also exhibited a positive significant correlation with number of capsules per plant, number of branches per plant and harvest index.

Mukhekar, Bangar, Lad, Bhor and Mungse (2003), found that seed yield was significantly and positively correlated with plant height, 1000 seed weight and days to 50 per cent flowering. Positive correlation of seed yield with plant height, number of capsules per plant and 1000-seed weight was observed by (Raghuwanshi, Bangar, Lad, Bhor and Mungse, 2003). The number of days to 50 per cent flowering, number of days to maturity and number of branches per plant were negatively correlated with seed yield. Positive and significant correlation of seed yield per pant with plant height, number of primary branches per plant, capsule length, number of capsules per plant and 1000 seed weight was observed by (Sankar and Kumar 2003). Number of capsules per plant contributed directly to the seed yield and other characters contributed indirectly through number of capsules per plant.

Tamina and Dasgupta (2003), found that plant height, number of branches per plant, number of capsules per plant, capsule length and number of seeds per capsule were significantly and positively correlated both with seed yield at genotypic and phenotypic levels. 1000 seed weight was negatively correlated with seed yield, whereas number of capsules per plant had the highest positive direct effect on seed yield followed by number of seeds per capsule.

Babu *et al.* (2004), reported that oil yield per plant was positively associated with number of primaries per plant, number of capsules per plant, number of seeds per capsule, 1000- seed weight, leaf area index, harvest index and seed yield per plant both at genotypic and phenotypic level. Seed yield per plant exerted the highest positive direct effect on oil yield per plant followed by number of primaries per plant, oil content, leaf area index and harvest index.

Bhuvan and Sharma (2004), observed that seed yield was significantly and positively correlated with number of capsules per plant, number of branches per plant, plant height and 1000-seed weight. Number of capsules per plant and number of primary and secondary branches per plant had a relatively high direct positive effect on seed yield per plant. The number of capsules per plant and harvest index was significantly correlated with seed yield per plant having also maximum direct positive effect on it, as suggested by (Narian, Gupta and Singh, 2004). Plant height and number of capsules exhibited significant positive association with seed yield in a study conducted by Mothilal (2005). A positive direct effect with seed yield was observed via 1000-seed weight, plant height, number of branches, fruiting stem length and number of capsules per plant. Siddiqui, Brag and Patil (2005), observed that the seed yield was significantly and positively correlated with days to first flowering, days to 50 per cent flowering,

days to maturity, number of branches per plant, plant height, number of capsules per plant, length of capsule and 1000 seed weight. Strong positive direct effects were observed for plant height, days to 50 per cent flowering and weight of seed per capsule. The indirect negative effects on yield were observed for days to first flowering, days to maturity, number of branches per plant, number of capsules per plant and length of capsule.

Vidhyavathi, Manivannan and Muralidharan (2005), observed that number of capsules per plant, plant height and number of primary branches had positive significant association with seed yield. High positive direct effect of number of capsules per plant and plant height on seed yield was observed.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

3.1.1 Study Area

The study was carried out at the experimental garden; Centre for Preliminary and Extra-mural Studies, Federal University of Technology, Minna, Niger State, Nigeria.

3.1.2 Collection of Sesame seeds: The seeds were obtained from National Cereal Research Institute (NCRI) Baddegi, Niger State. Three varieties namely, Ex-Sudan, Kenana 4 and E8 were collected

3.2 Methods

3.2.1 Irradiation: The seeds were irradiated with fast neutron at the Centre for Energy and Research training (CERT), Ahmadu Bello University Zaria, Kaduna state, Nigeria. Three varieties (namely, Ex-Sudan, Kenana 4 and E8) were subjected to different doses of fast neutron. Each of the variety was divided into five equal parts and exposed to 0, 4,8,12 and16µsv.

3.2.2 Chemical Mutagenesis

The seeds were treated with sodium Azide at five different concentrations, 0.00%, 0.02%, 0.04%, 0.06%, 0.08%. Sodium azide was diluted to the required concentration by using distilled water, 0.02g, 0.04g, 0.06g and 0.08g were dissolved in 100ml of water respectively to make 0.02,0.04,0.06,0.08%. Seeds were soaked in the water for six hours to initiate Biochemical reaction. The presoaked seeds were put in flask and Sodium azide was added and left for eight hours. Intermittent shaken was given to ensure

uniform exposure of the chemicals. The chemical was drained after the treatment time is over. The seeds were washed immediately not less than 30mins.

3.3 Experimental Design: Two factors were involved; the variety and irradiation for physical, variety and chemical for the chemical. Factorial design was adopted with two (2) plants per pot with a total of 15 combinations per plot. The arrangement used was a randomized block design with thirty (30) pots per block. The experiment was replicated in three making a total of 90 pots for physical and 90 pots for chemical. Ten seeds were planted per pot (i.e. five per hole in a pot). Three weeks after planting each pot was thinned to two plants per pot. A total of eight (8) pots for each treatment combination were used.

3.4 Collection of Data

The following data were taken during the period of study;

1. Plant height at 2, and 4weeks after planting and at maturity: The distance from ground level up to the terminal bud on main axis of a plant in cm using metre rule
2. Length of petiole (cm) using metre rule
3. Leaf surface area in cm^2
4. Survival rate 21 days after planting: this was taken in percentage
5. Length of capsule (in cm) using venire calipers
6. Number of seeds per capsule using direct counting
7. Number of capsules per plant by direct counting
8. Percentage flowering 45days after planting
9. Weight per capsule were taken using electric weighing balance
10 Oil extraction using soxhlet apparatus.

Preparation for the Extraction

Place 3 or 4 boiling chips into the Solvent vessel (e.g round bottom flask or cylindrical flask). Dry the solvent vessel in a drying oven to constant (about 1 hour) at 103±℃ .Fill the silica gel into the desiccators and insert the desiccator plate. Allow the desiccator to cool to room temperature (about 30 minutes). Weigh the solvent vessel containing the boiling chips to an accuracy of ±1 mg. Homogenize or grind the sample.

Dry sample

Weigh the ground dry sample into the extraction thimble. For example, weigh out 6.6 g with an expected fat content of at most 2 g. Mix the sample with anhydrous sodium sulfate. Use a cotton swab, which has been moistened with extraction solvent, to wipe the sample into the extraction thimble.

Extraction

Close the extraction thimble with a fat – free cotton wad, insert the thimble into the soxhlet extractor, if the soxhlet extractor has a spigot for solvent draining, close the spigot. Fill the solvent into the solvent vessel extract at a temperature of 110 – 130 ℃ for 20 – 30 extraction cycles (4 - 6 hours), depending on the nature of the sample and the solvent employed. Drain the solvent into a suitable container by opening the spigot on the soxhlet extractor. Continue to heat the solvent vessel until all of the solvent has been evaporated and condensed in the soxhlet extractor (spigot closed). Care must be taken not to heat the fat residue to decomposition. Place the vessel containing the fat residue in a drying oven at 103±2℃ and heat to constant weight (indicating evaporation of all solvent). After every completion of the solvent evaporation step, air the drying oven out by leaving the door open. Observe carefully all safety guidance of the oven manufacturer. Allow the vessels containing the fat to cool to room temperature (about 30 minutes). Weigh the vessel containing the boiling chip and fat residue.

Compute the fat content according to the following:

$$F\,[\%] = \frac{M2-M1}{E} \bullet 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(i).where}$$

M1 is the weight of the dry empty vessel in grams, including the boiling chips,

M2 is the weight of the vessel, grams, containing the boiling chips and fat residue after evaporation of the solvent and

E is the sample weight in grams.

3.5 Statistical Analysis

The result of this research was subjected to analysis of variance (ANOVA) to show whether there were significant differences among the morphological parameters and yield parameters. Duncan multiple range was used to separate the means. The survival rate, flowering percentage and oil content were converted to simple percentages. The pearman correlation was used to show relationships between the irradiation and chemical level and both the morphological and yield parameters, test of significance was also carried out to show weather the correlations are significant. The results are represented in tables and charts.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

4.1.1 Morphological Parameters

4.1.1.1 Plant Height

The three varieties showed no significant differences in height at the different doses of FNI except Kenena-4, which showed significant differences at 4^{th} and 6^{th} week (Table 4.1) the correlations were not significant except in variety E-8 at 6 week 0.897^{*} and Ex at 2 week (-0.953^{*}) (Table 4.3).

The three varieties showed significant difference in height at different concentration of Sodium azide except E8, which showed no significant difference at 6^{th} week (Table 4.2). The correlations were not significant (Table 4.4).

4.1.1.2 Number of Leaves/Plant and Length of Petiole

The numbers of leaves/plant were not significantly difference except in Ex-Sudan, which showed slight difference at 12μSv (Table 4.1). The three varieties showed significant difference in length of petiole and the dose 12μSv has the highest mean among the doses (Table 4.1). The correlations were all positive and not significant (Table 4.3).

The number of leaves and length of petiole were significantly different in all the three varieties and the dose 0.2% has the highest mean among the doses in terms of number of leaves per plant (Table 4.2). The correlations were all negative and not significant (Table 4.4).

4.1.1.3 Leaf Surface Area

The result showed significant differences in the leaf surface area of the three varieties treated with FNI at $p<0.05$ (Table 4.1). The correlation in E8 was positive (0.978^{*}) (Table 4.3) and significant, indicating that increase in irradiation dose also increases the leaf surface area.

Similarly all the three varieties treated with Sodium azide showed significant differences in the leaf surface area at $p<0.05$ level of significance (Table 4.2). The correlation in E8 was positive (0.991^{*}) (Table 4.4) and significant.

4.1.1.4 Survival Percentage.

For the effect of fast neutron irradiation on survival percentage, 16usv and 8usv in Kenena- 4 performed better (53% and 50%) than the control 0usv (45%). But the correlation was weak and not significant (0.23) (Table 4.3).

However, variety E8 has the highest survival percentage at 0usv (60%) and the least in 12usv and 16usv with the percentage of (40% and 40%) respectively. The correlation was modest and not significant (-0.55) (Table 4.3).

Similarly in Ex Sudan 0usv assumed the highest with (60%) while the least was recorded in 12usv (20%). The correlation was weak and not significant (-0.3) (Table 4.3).

For the effect of sodium azide on survival percentage in Kenena 0.08%, 0.02% and 0.06% (93%, 73% and 50%) performed better than the control (45%). However in E8, 0.04% assumed the highest with (95%) while the least was recorded in 0.8% (45%). Similarly in Ex-sudan 0.2% assumed the highest with (80%) while the least was 0.8%

(35%). The correlations were modest in Ke and Ex (0.528 and -0.456) (Table 4.4) but not significant. The correlation in E-8 was strong and significant (0.890^{*}) (Table4.4).

Table 4.1: The Morphological Parameters of the Three Varieties at Different Doses of Fast Neutron

TREATMENT COMBINATION	PLANT HEIGHT 2 WEEK	4 WEEK	6 WEEK	NO. OF LEAVE PER PLANT	LENGTH OF PETIOLE	LEAVE SURFACE AREA
KENENA-4						
0µSv	6.87±1.76^{a}	23.78±1.74^{ab}	57.30±14.99^{ab}	10.20±1.22^{a}	2.90±0.96^{ab}	42.18±12.63^{b}
4µSv	5.67±1.42^{a}	23.71±3.80^{ab}	58.89±17.7^{ab}	9.80±1.54^{a}	3.84±1.32^{b}	38.18±4.79^{ab}
8µSv	6.70±1.68^{a}	21.22±2.83^{a}	61.50±17.10^{ab}	10.90±1.59^{a}	3.45±0.84^{b}	37.43±23.57^{ab}
12µSv	6.63±1.35^{a}	25.73±3.45^{b}	70.25±20.93^{b}	10.90±1.72^{a}	5.10±1.55^{c}	30.95±2.50^{ab}
16µSv	6.16±1.89^{a}	20.93±2.57^{a}	53.60±13.83^{a}	11.10±1.37^{a}	2.18±0.50^{a}	25.61±9.84^{a}
E-8						
0µSv	6.75±1.03$^{a\,a\,a}$	21.02±1.90^{a}	51.05±13.07^{a}	10.20±1.31^{a}	2.21±0.49^{a}	22.39±6.69^{a}
4µSv	6.80±1.30^{a}	21.99±2.75^{a}	53.01±13.27^{a}	10.30±2.11^{a}	3.51±0.80^{b}	23.84±7.59^{a}
8µSv	6.08±1.39^{a}	22.01±3.25^{a}	51.57±14.26^{a}	9.90±2.28^{a}	2.28±0.95^{a}	32.04±6.69^{ab}
12µSv	5.86±1.65^{a}	25.24±3.95	56.45±17.68^{a}	10.60±1.17^{a}	3.76±1.21^{b}	38.04±10.90^{bc}
16µSv	6.50±0.83^{a}	23.70±2.87^{b}	59.52±20.66^{a}	10.20±1.39^{a}	3.69±2.19^{b}	40.45±15.25^{c}
EX-SUDAN						
0µSv	7.52±1.74^{a}	27.20±4.75^{a}	73.10±11.34^{a}	10.60±1.34^{a}	4.33±2.11^{a}	41.13±17.76^{a}
4µSv	7.28±1.93^{a}	21.50±2.98^{a}	70.67±11.45^{a}	10.80±1.22^{ab}	4.33±1.00^{a}	37.40±7.55^{a}
8µSv	7.00±0.92^{a}	26.07±4.64^{a}	61.91±15.18^{a}	9.50±0.97^{a}	3.48±1.21^{a}	29.05±8.21^{a}
12µSv	7.06±1.36^{a}	26.28±4.05^{a}	71.70±23.65^{a}	13.50±6.04^{b}	6.51±2.20^{b}	58.33±21.15^{b}
16µSv	6.65±1.21^{a}	24.88±3.39^{a}	65.05±12.10^{a}	10.90±1.28^{ab}	3.87±0.84^{a}	32.09±8.66^{a}

*Values are mean ± SD. Values followed by the same letter (s) within the same column do not statistically differ at the 5% level according to DMRT, analysed for the Treatment combination

Table 4.2: The Morphological Parameters of the Three Varieties at Different Concentration of Sodium Azide

TREATMENT COMBINATION	PLANT HEIGHT 2 WEEK	4 WEEK	6 WEEK	NO. OF LEAVE PER PLANT	LENGTH OF PETIOLE	LEAVE SURFACE AREA
KENENA						
0.00%	3.90±0.68^{a}	23.78±5.32^{c}	57.30±14.99^{b}	10.20±1.22^{a}	2.90±0.96^{b}	42.18±12.63^{b}
0.02%	6.45±1.37^{b}	22.60±5.39^{c}	58.29±15.47^{b}	27.30±7.74^{c}	2.23±0.92^{ab}	38.70±4.85^{ab}
0.04%	4.29±1.18^{a}	21.97±5.73^{bc}	45.36±10.80^{a}	25.00±7.87^{c}	1.09±0.16^{a}	39.93±22.63^{b}
0.06%	3.80±1.15^{a}	12.64±5.06^{a}	48.60±7.67^{ab}	16.60±10.37^{ab}	1.11±0.32^{a}	27.11±2.93^{a}
0.08%	6.20±1.12^{b}	17.80±3.88^{b}	51.05±13.07^{ab}	21.60±11.22^{bc}	2.39±3.37^{ab}	32.05±8.56^{ab}
E-8						
0.00%	4.66±1.03^{b}	21.02±1.90^{c}	51.05±13.07^{a}	10.20±1.31^{a}	2.21±0.49^{c}	22.39±6.69^{a}
0.02%	6.53±1.46^{c}	19.98±4.07^{bc}	52.16±14.35^{a}	23.00±4.92^{b}	1.75±0.34^{b}	26.33±6.23^{b}
0.04%	6.37±1.03^{c}	17.77±2.15^{b}	45.99±10.62^{a}	22.60±8.60^{b}	1.23±0.76^{a}	32.62±6.34^{bc}
0.06%	3.47±1.51^{a}	8.91±3.44^{a}	49.95±16.49^{a}	17.60±9.87^{ab}	1.29±0.21^{a}	38.37±10.79^{c}
0.08%	7.29±1.40^{c}	19.20±4.70^{bc}	48.78±12.78^{a}	24.80±17.97^{b}	1.26±0.34^{a}	40.87±15.18^{c}
EX-SUDAN						
0.00%	4.59±069^{ab}	27.20±4.75^{d}	73.10±11.34^{c}	10.60±1.34^{a}	4.33±2.11^{c}	41.13±17.76^{a}
0.02%	8.63±1.91^{d}	23.44±4.90^{cd}	59.86±11.55^{b}	29.80±7.64^{c}	2.50±0.35^{b}	37.82±7.22^{a}
0.04%	6.28±1.55^{c}	20.60±5.24^{bc}	43.65±14.47^{a}	24.40±6.00^{bc}	1.08±0.14^{a}	30.00±7.60^{a}
0.06%	3.68±1.06^{a}	12.99±3.66^{a}	45.50±18.37^{a}	18.60±6.04^{ab}	1.18±0.21^{a}	59.12±20.51^{b}
0.08%	5.62±1.10^{b}	17.81±7.35^{b}	50.60±10.09^{ab}	20.50±16.50^{b}	1.13±0.22^{a}	33.09±7.75^{a}

*Values are mean ± SD. Values followed by the same letter (s) within the same column do not statistically differ at the 5% level according to DMRT, analysed for the Treatment combination

Table 4.3: Correlations of the Various Morphological Parameters with the Irradiation Doses

	PLANT HEIGHT						
Variety	2 WEEK	4 WEEK	6 WEEK	PL (cm)	NOL/P	LSA (cm^2)	Survival %
Kenana-4	-0.148	-0.287	0.100	-0.026	0.827	-0.417	0.23
Ex-Sudan	-0.953*	-0.624	-0.498	0.169	0.353	0.06	-0.55
E-8	-0.549	0.813	0.897*	0.653	0.188	0.978*	-0.3

*PL=Petiole length, NOL/P=Number of leaves per plant, LSA=Leaf surface area.

$r_{0.05(2),3} = 0.878$

*Significant

Table 4.4: Correlations of the Various Morphological Parameters with the Chemical Treatment

	PLANT HEIGHT						
Variety	2 WEEK	4 WEEK	6 WEEK	PL (cm)	NOL/P	LSA (cm2)	Survival %
Kenana-4	0.238	-0.757	-0.629	-0.418	0.278	-0.315	0.528
Ex-Sudan	-0.242	-0.854	-0.773	-0.866	0.19	0.072	-0.456
E-8	-0.225	-0.476	-0.45	-0.873	0.636	0.991*	0.890*

*PL=Petiole length, NOL/P=Number of leaves per plant, LSA=Leaf surface area

$\mathbf{r}_{0.05(2),3} = 0.878$

*Significant

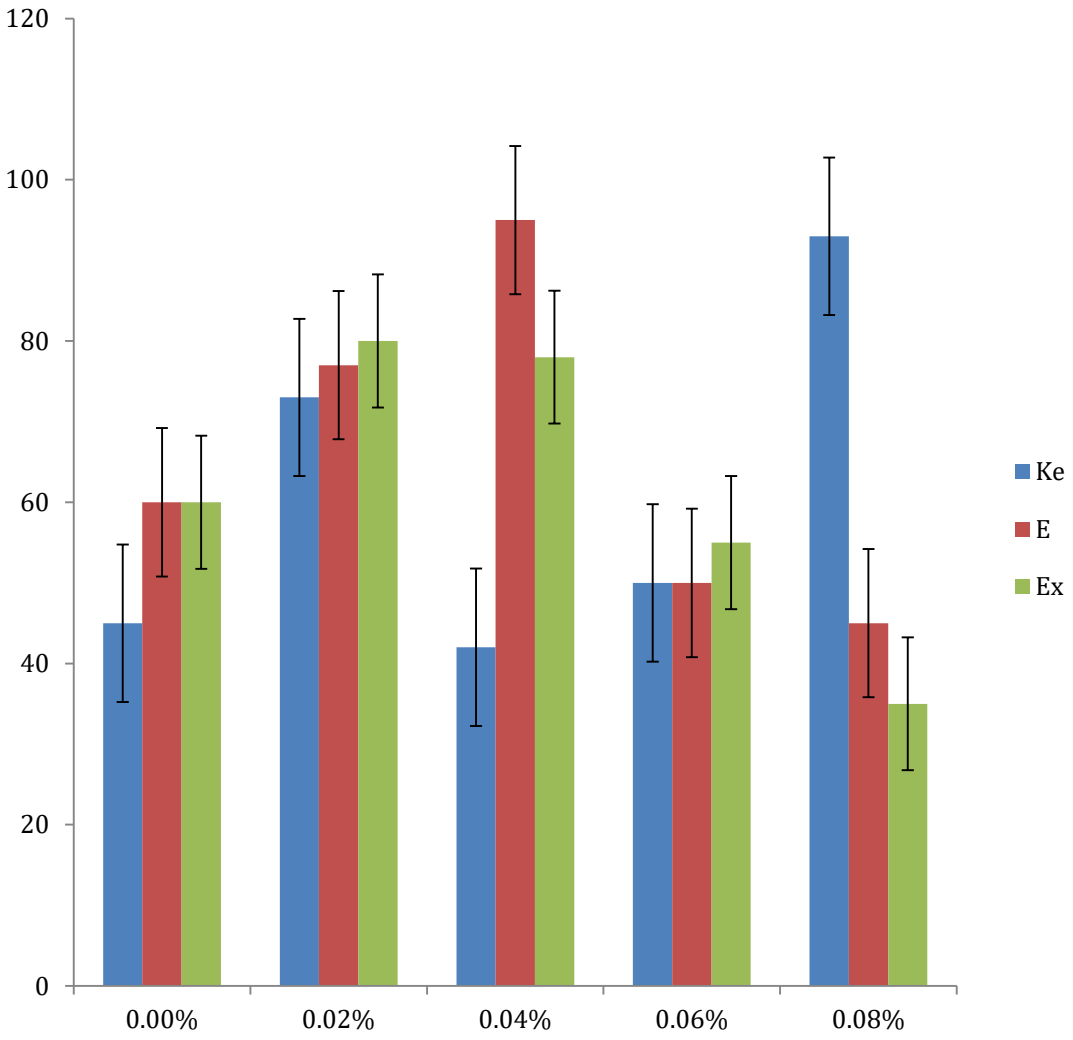

Figure 4.1: Survival Percentages (%±SE) of the three varieties at Different Concentration of SA.

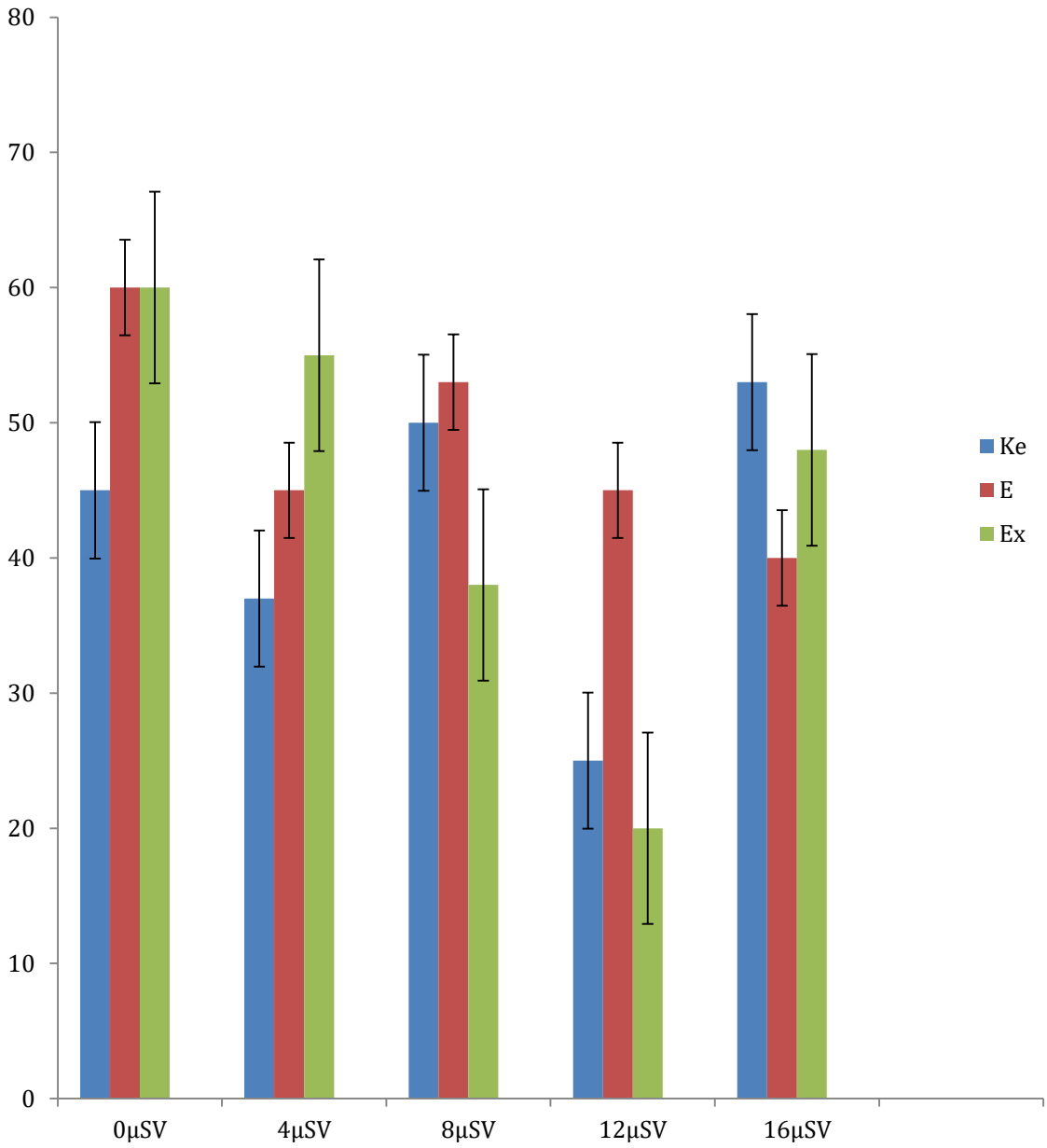

Figure 4.2: Survival Percentages (%±SE) of the three Varieties at Different Doses of FNI

4.1.2 Yield Parameter

4.1.2.1 Number of Flowers per Plant, Number of Capsules per Plant and Length of Capsule.

The number of flowers per plant and number of capsule per plant were not significantly different in the three varieties at different doses of FNI at $p>0.05$ (Table 4.5). The correlations in flower number and capsule number were both negative (-0.617 and -0.745 respectively) in Kenana-4, E-8 (-0.429 and -0.110 respectively) and (-343 and -0.142 respectively) in Ex-Sudan.

The number of flowers per plant were not significantly different in Kenana 4 and Ex-Sudan at different concentrations of SA at $p<0.05$ level of significance (Table 4.6), while for number of capsule per plant all the three varieties showed statistical differences. The correlations in flower number and capsule number were both negative (-0.067 and -0.685 respectively) in Kenana-4, (-0.932^{*} and -0.870 respectively) in Ex-Sudan and (-0.817 and-0.841 respectively) in E8.

Similarly, the length of capsule in E-8 was not significantly different ($p>0.05$) at different doses of FNI but the Kenana-4 and Ex-Sudan showed significant differences at certain doses of FNI (at $p<0.05$) (Table 4.5). However, there were negative correlations in Ex-sudan and E-8 (-0.223 and -0.220 respectively) but positive in Kenena4 (0.025) (Table 4.7). Similarly, the capsule length in E-8 and Ex-Sudan were not significantly different at different doses of SA but Kenana-4 showed significant differences at certain doses of SA at $p<0.05$ (Table 4.6). However, there were negative correlations in both Ex-Sudan and E-8 (-0.431and -0.484 respectively) but positively modest (0.537) in (Table 4.8).

4.1.2.2 Weight per Capsule and Number of Seeds per Capsule

The three varieties showed significant difference in weight per capsule at doses of FNI (table 4.5). The number of seeds per capsule in both Ex-Sudan and Kenana were significantly different ($p<0.05$) at different doses of FNI. However, E8 showed no significant difference ($p>0.05$) (Table 4.5). The correlations in number of seed per capsule and weight of capsule were both negative (-0.732 and -0.646 respectively) in Kenana-4, (0.716 and 0.213 respectively) in Ex-Sudan and (0.086 and-0.236 respectively) in E8.

Similarly the three varieties treated with sodium azide showed significant differences ($p<0.05$) with respect to capsule Weight, (Table 4.6). Kenana and E8, showed no significant differences ($p>0.05$) with respect to number of seed per capsule, while, in Ex-Sudan 0.4% performed better than all the other doses (Table 4.6). The correlations in number of seed per capsule in Kenena was negative and significant (-0.915^{*})(Table 4.6). Similarly in Ex-Sudan and E8 the correlations were all negative (-0.278 and -0.726) but not significant. The correlations in the weight per capsule were all negative and not significant (Table 4.6).

4.1.2.3 Percentage Flowering

The flowering percentages were taken 45days after planting .The flowering percentages in the three varieties were affected by irradiation with Kenana-4 having greatest (75%) at 8µSv and 12µSv (Figure 4.5). E-8 and Ex-Sudan on the other hand showed highest value at 4µSv (46.88 and 78.13 respectively) (Figure 4.5) .The flowering percentages were taken 45days after planting. The flowering percentages in the three varieties were affected by chemical with Kenana-4 having greatest (78.12%) at 0.04% (Figure 4.6). E-8 showed highest value at (53.12%) while Ex-sudan at 0.00 and 0.02% (75%).

4.1.2.4 Percentage Oil

In kenana-4 there were variations in oil content at different doses of FNI but only the doses 12µSv (18.53%) performed below the control (24.45%) (Figure 4.4). Similarly in E-8, all the doses performed better than the control (25.43%) except 4µSv (21.01%) and 12µSv (24.54%) and the16µSv still maintain the highest value (30.68%). In contrary, Ex-Sudan had highest oil percentage at control (30.01**%**) and 4µSv was the least (18.97%) (Figure 4.4).

In kenana-4 there were variations in oil content at different treatment of sodium azide but only the doses 0.6% (16.53%) performed below the control (24.45%) (Figure 4.3). Similarly in E-8, all the doses performed better than the control (25.43%) except 0.2% (19.06%) and 0.6 (22.53%) and 0.08% has the highest value (28.68%). In contrast, Ex-Sudan had highest oil percentage at control (30.01**%**) and 0.2% has the least (17.21%) (Figure 4.3)

Table 4.5: Yield Parameters of the three Varieties at Different Doses Fast Neutron

TREATMENT COMBINATION	NO. OF FLOWER PER PLANT	NO. OF FRUIT PER PLANT	LENGTH OF CAPSULE	NO. OF SEED PER CAPSULE	WEIGHT OF CAPSULE
KENENA-4					
0µSv	29.80±16.23[a]	31.10±6.69[a]	2.35 ±0.44[a]	54.70±11.49a	0.49±0.19[b]
4µSv	31.00±18.58[a]	31.40±17.25[a]	2.51±0.18[ab]	49.10±9.01ab	0.22±0.05[a]
8µSv	25.90±12.11[a]	24.80±24.8[a]	2.40±0.19[ab]	51.80±7.17ab	0.19±0.05[a]
12µSv	31.40±9.45[a]	30.10±15.81[a]	2.61±0.20[b]	51.00±5.16ab	0.29±0.04[a]
16µSv	21.10±5.52[a]	20.50±5.68[a]	2.30±0.18[a]	46.40±5.18b	0.20±0.09[a]
E-8					
0µSv	21.40±9.75[a]	21.60±4.40[a]	2.37±0.50[a]	49.10±11.37[a]	0.35±0.05[a]
4µSv	20.40±4.14[a]	25.70±12.51[a]	2.39±0.17[a]	49.40±6.86[a]	0.43±0.09[b]
8µSv	21.20±10.69[a]	25.10±15.35[a]	2.26±0.18[a]	52.50±6.04[a]	0.56±0.08[c]
12µSv	17.50±5.29[a]	22.00±9.23[a]	2.31±0.33[a]	49.50±10.01[a]	0.32±0.09[a]
16µSv	20.70±10.44[a]	22.80±9.90[a]	2.37±0.33[a]	48.70±8.62[a]	0.33±0.11[a]
EX-SUDAN					
0µSv	29.90±12.62[a]	32.90±16.46[a]	2.37±0.18[a]	51.70±8.99[a]	0.28±0.06[a]
4µSv	31.00±10.93[a]	33.80±20.20[a]	2.53±0.15[b]	47.30±2.75[a]	0.24±0.04[a]
8µSv	27.10±10.02[a]	34.60±16.13[a]	2.54±0.18[b]	50.40±7.07[a]	0.49±0.60[a]
12µSv	34.30±27.48[a]	46.00±21.27[a]	2.57±0.18[b]	52.50±9.78[ab]	0.31±0.08[a]
16µSv	24.00±9.89[a]	29.60±10.78[a]	2.61±0.14[b]	58.70±4.64[b]	0.31±0.05[a]

*Values are mean ± SD. Values followed by the same letter (s) within the same column do not statistically differ at the 5% level according to DMRT, analysed for the Treatment combination

Table 4.6: Yield Parameters of the three Varieties at Different Concentration of Sodium Azide.

TREATMENT COMBINATION	NO. OF FLOWER PER PLANT	NO. OF FRUIT PER PLANT	LENGTH OF CAPSULE	NO. OF SEED PER CAPSULE	WEIGHT OF CAPSULE
KENENA					
0.00%	29.80±16.23^{b}	31.10±6.69^{b}	2.35±0.44^{bc}	54.70±11.49a	0.49±0.19^{c}
0.02%	14.60±6.48^{a}	12.90±6.20^{a}	2.10±0.38^{ab}	49.50±10.76a	0.21±0.06^{b}
0.04%	21.80±14.82^{ab}	19.90±14.21^{a}	2.49±0.21^{c}	50.70±4.52a	0.27±0.03^{b}
0.06%	14.70±8.30^{a}	12.70±6.81^{a}	2.22±0.32^{abc}	48.00±9.61a	0.22±0.08^{b}
0.08%	15.70±7.21^{a}	14.30±7.42^{a}	1.91±0.31^{a}	46.00±5.07a	0.11±0.01^{a}
E-8					
0.00%	21.40±9.75^{a}	21.60±4.40^{b}	2.37±0.50^{a}	49.10±11.37^{a}	0.35±0.05^{c}
0.02%	19.70±8.60^{a}	18.00±8.51^{ab}	2.13±0.35^{a}	49.50±10.76^{a}	0.18±0.04^{a}
0.04%	13.90±7.95^{a}	12.90±6.74^{a}	2.14±0.22^{a}	47.80±10.47^{a}	0.22±0.06^{ab}
0.06%	16.10±9.43^{a}	14.80±8.25^{a}	2.17±0.32^{a}	45.40±11.73^{a}	0.20±0.07^{ab}
0.08%	14.90±3.75^{a}	13.60±2.98^{a}	2.20±0.23^{a}	49.60±6.60^{a}	0.24±0.02^{b}
EX-SUDAN					
0.00%	29.90±12.62^{b}	32.90±16.46^{b}	2.37±0.18^{a}	51.70±8.99^{b}	0.28±0.06^{c}
0.02%	23.40±10.23^{ab}	22.10±9.09^{a}	2.08±0.28^{a}	49.40±4.90^{ab}	0.20±0.03^{b}
0.04%	20.70±9.42^{ab}	19.40±8.04^{a}	2.21±0.33^{a}	52.20±6.89^{b}	0.23±0.02^{b}
0.06%	20.70±10.93^{ab}	19.90±10.11^{a}	2.06±0.57^{a}	43.10±11.20^{a}	0.15±0.04^{a}
0.08%	17.50±10.16^{a}	16.70±9.40^{a}	2.21±0.17^{a}	45.90±5.25^{ab}	0.19±0.04^{ab}

*Values are mean ± SD. Values followed by the same letter (s) within the same column do not statistically differ at the 5% level according to DMRT, analysed for the Treatment combination

Table 4.7: Correlations of the Various Yield Parameters with the Irradiation Doses

Variety	NOF/P	NOC/P	LOC (cm)	WCP (g)	NOC/C	OIL %	FLW %
Kenana-4	-0.617	-0.745	0.025	-0.646	-0.732	0.45	-0.648
Ex-Sudan	-0.343	-0.142	-0.223	0.213	0.716	0.073	0.953*
E-8	-0.429	-0.11	-0.22	-0.236	0.086	0.562	0.706

*NOF/P=Number of flower/plant, NOC/P=Number of capsule/plant, LOC=Length of capsule, WCP=Weight/capsule, NOS/C=Number of seed/capsule, FLW%= Flowering percentage

$\mathbf{r}_{0.05(2),3} = 0.878$

*=Significant

Table 4.8: Correlations of the Various Yield Parameters with the Chemical Treatment

Variety	NOF/P	NOC/P	LOC (cm)	WCP (g)	NOC/C	OIL %	FLW %
Kenana-4	-0.067	-0.685	0.537	-0.84	-0.915*	0.375	0.012
Ex-Sudan	-0.932	-0.87	-0.431	-0.75	-0.278	0.823	0.555
E-8	-0.817	-0.841	-0.484	-0.475	-0.726	0.559	-0.319

*NOF/P=Number of flower/plant, NOC/P=Number of capsule/plant, LOC=Length of capsule, WCP=Weight/capsule, NOS/C=Number of seed/capsule, FLW%= Flowering percentage

$\mathbf{r}_{0.05(2),3} = 0.878$

*Significant

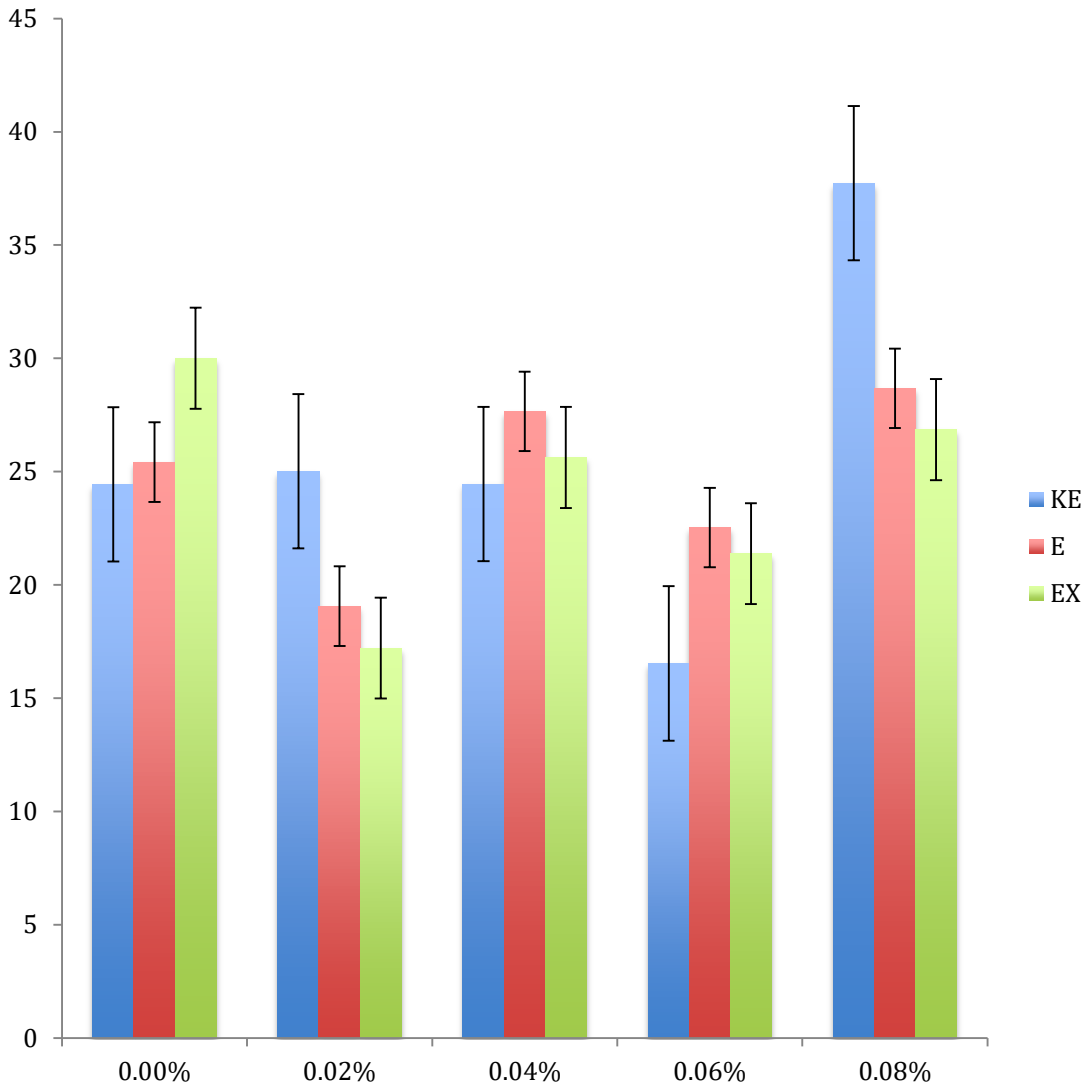

Figure 4.3: Percentage oil (%±SE) of the Three Varieties at Different Doses SA

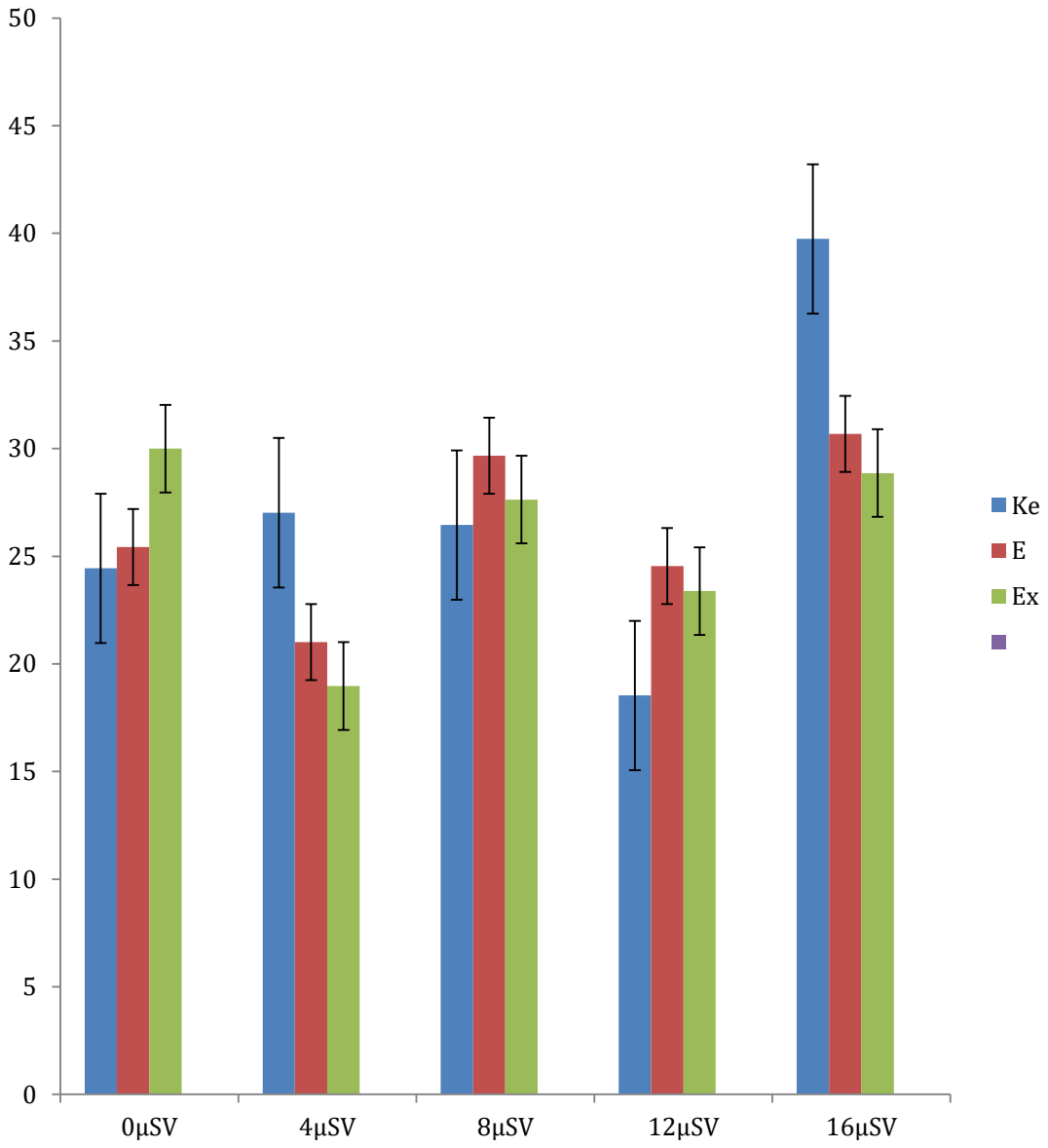

Figure 4.4: Percentage oil (%±SE) of the Three Varieties at Different Doses of FNI

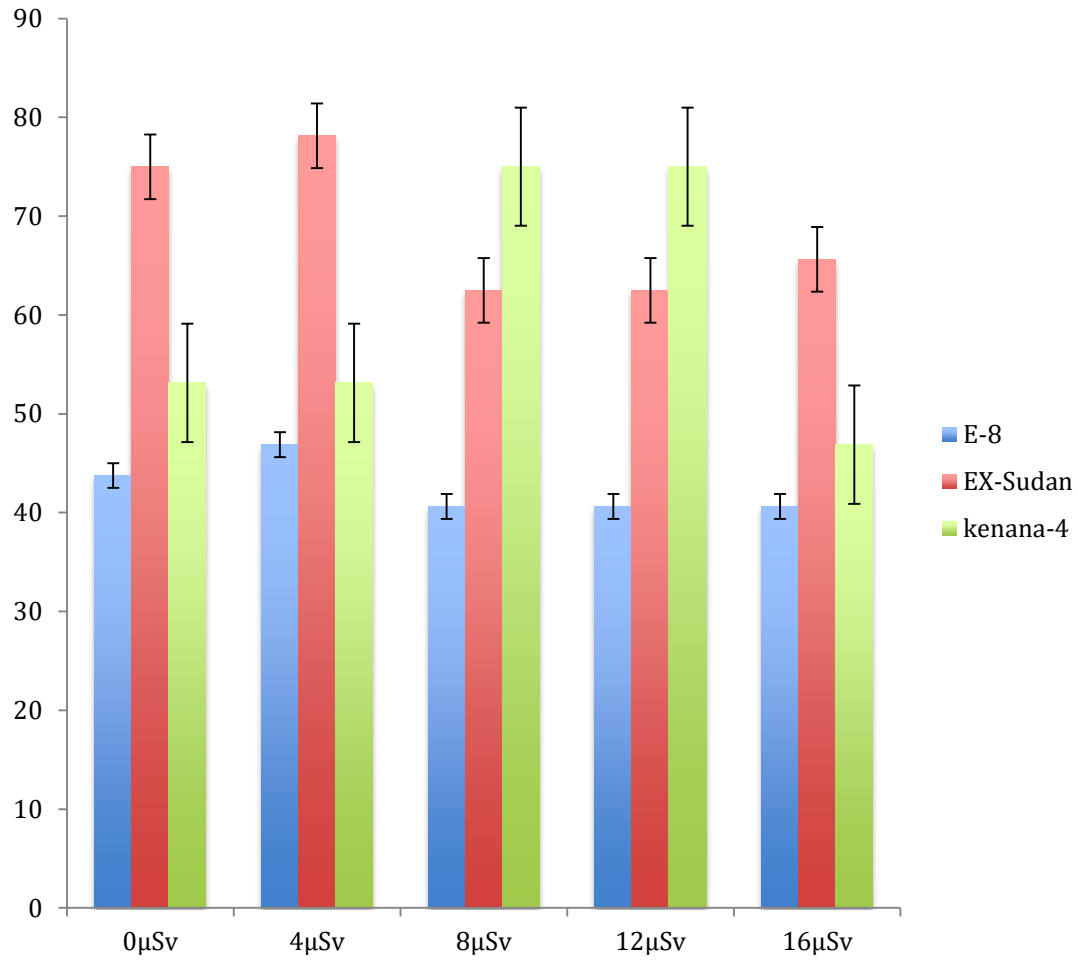

Figure 4.5: Flowering Percentage (%±SE) 45 Days after Planting

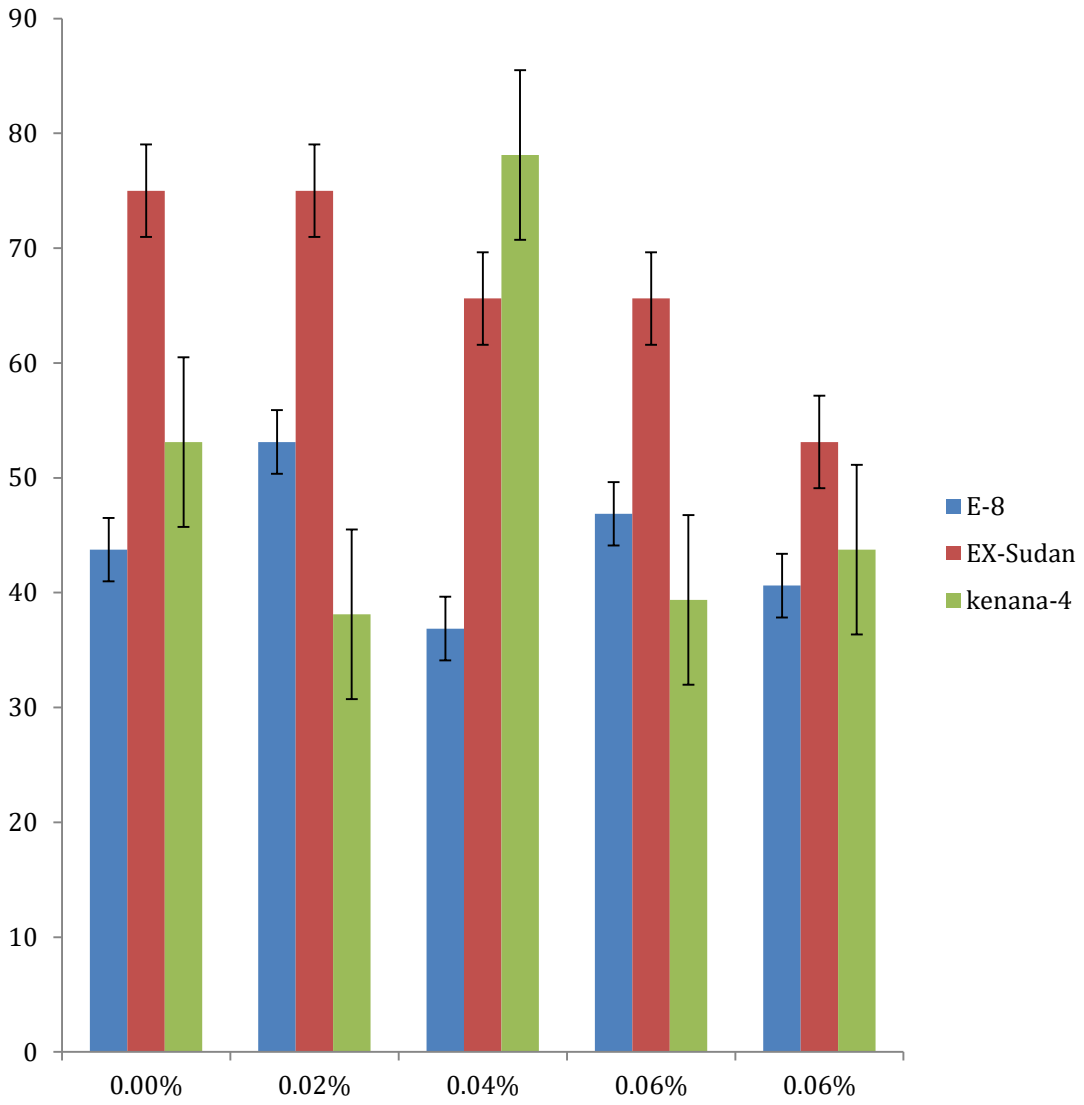

Figure 4.6: Flowering Percentage (%±SE) 45 Days after Planting

Plate I: Flowering/Fruiting Stage of Ex-Sudan (control)

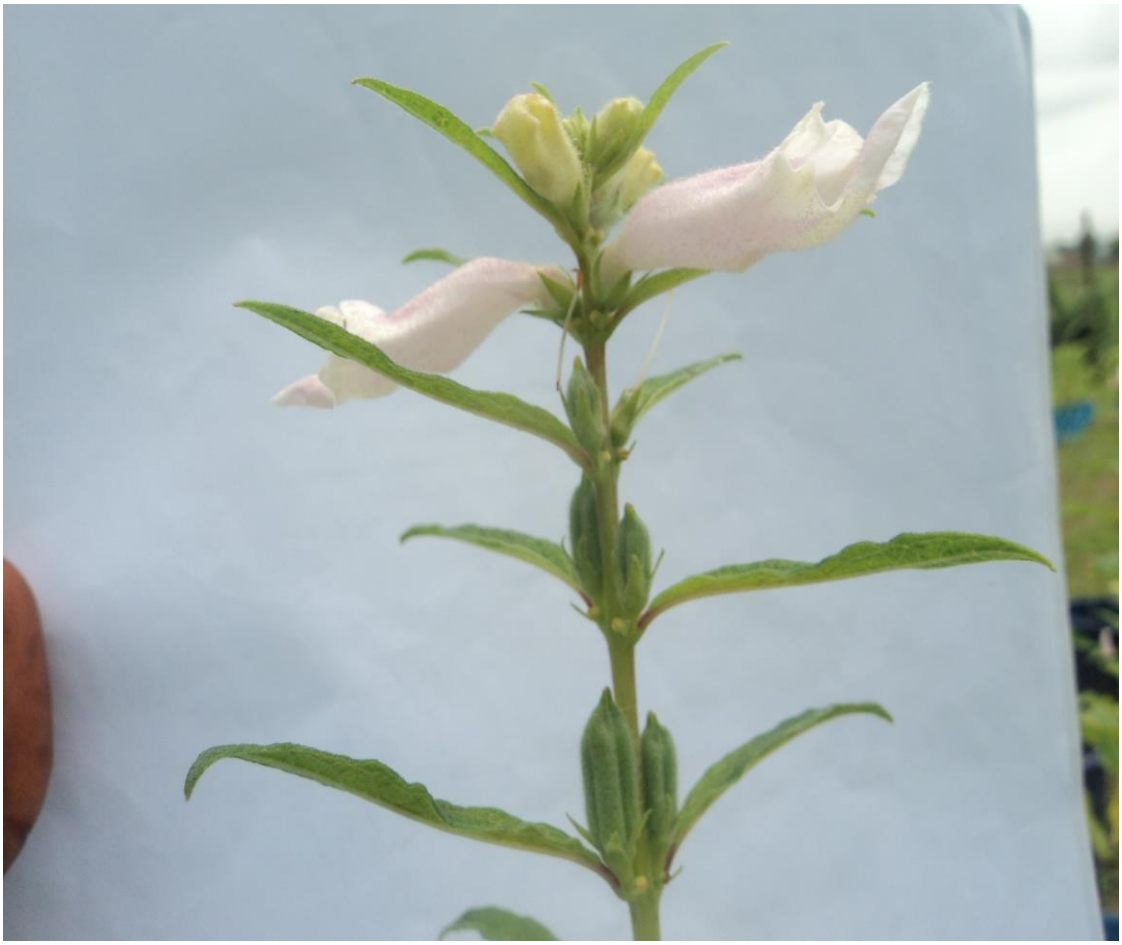

Plate II: Flowering/Fruiting Stage of Kenana-4 (control)

Plate III: Flowering/Fruiting Stage of E-8 (control)

Plate IV: Flowering/Fruiting Stage of KE12

Plate V: Flowering/Fruiting Stage of Ex12

Plate VI: Flowering /Fruiting Stage of E 0.04%

Plate VII: Flowering/Fruiting Stage of E0.08%

Plate VIII: Flowering/Fruiting Stage of Ex12

Plate IX: Flowering/Fruiting Stage of EX 0.02%

4.2 Discussion

4.2.1 Morphological Parameters

The significant variations observed in some morphological parameters like plant height, length of petiole and number of leaves per plant might be due to the alteration of their genome affected by environmental conditions, probably by increasing the rates of cellular division and expansion at their meristematic regions, the variation also suggest that there is a store of genetic variability which can be exploited for improvement purpose and that both FNI and SA could be used to generate variability in the crop. This is in agreement with Arzumanova and Pravikoskaya (1973), work on sesame. Where they found that lower doses have little effect in generating variability, and greatest variability was observed with the higher doses 60-80 kR.

Daudu and Falusi (2011), observed pronounced variations in plant height of pepper when exposed to different doses FNI. This is also in agreement with the findings of Hoballah(1999), who reported increase in plant heights of sesame due to radiation mutagenesis. The result is however in contrast to the findings of Anandakumar and Sree-Rangasamy (1995) and Maluszynski *et al*. (2001), who independently reported decrease in plant height due to induced mutation in rice and other cereals. The increase in leaf number and length of petiole with increase in the concentrations of sodium azide and fast neutron is an indication that they could be used for improvement of sesame. This is in agreement with the findings of Hoballah (1999), who reported increase in leaf number and internodes length among sesame mutants due to gamma irradiation.

The results also showed both positive and negative correlations between irradiation doses and the parameters. The negative correlations observed are in agreement with Muhammad, Akbar, Muhammad and Zia, (2003), who reported highly significant negative correlation with seedling shoot length (-0.998), when they irradiated five

varieties of Basmati rice with gamma-rays. Similarly the positive correlations recorded are in agreement with the report of Falusi *et al*., (2012), who reported pronounced positive trend in plant height when they studied mutagenic effects of FNI on pepper. This is also in line with the work of Asmahan and Nada (2006); Daudu *et al*., (2012); Fahd (2009); Hegazi and Hamideldin (2010). They reported that an increase in irradiation dose tended to increase certain morphological traits such as plant height.

The variation in the strength of correlation coefficients among the varieties might be due to fact that the radiosensitivity varies among sesame cultivars and that the seeds are highly resistant to irradiation as reported by Pathirana and Subasingbe, (1993); IAEA, (1994). The increase in the leaf area of sesame due to the mutagens means an increase in the surface area for gaseous exchange which consequently affects the photosynthetic process. This agrees with the work of Maluszynski *et al*. (2001), who reported increase in the leaf area among Zea mays mutants due to irradiation.

4.2.2 Yield Parameters

The insignificant differences in number of flower and capsule number per plant in the three varieties irradiated with fast neutron could be associated to high irradiation tolerance of sesame as reported by (IAEA, 1994). However, the variations observed in the Kenana-4 and Ex-Sudan in length of capsule might be due to varietal response to irradiation as reported by Pathirana and Subasingbe, (1993).

The negative correlations observed with respect to some of the parameters imply that as the irradiation level increases, these parameters decrease. This is close to the findings of Muhammad, Akbar, Muhammad, and Zia (2003), who reported that Seedling emergence, panicle fertility and grain yield declined with increasing dose level in all the varieties of Basmati rice studied. The negative correlation is in line with the report of

Nura, *etal.* (2011), they observed highly significant variation (P≤0.01) in number of pods/plant which decreased with increase in colchicines concentrations.

The positive correlations observed with respect to some of the parameters imply that as the irradiation level increases, these parameters also increase. This is in line with Falusi *et al* (2012); Daudu *et al*., 2012.They all reported positive correlations between the irradiation exposure period with certain morphological and yield traits. The positive correlations are in agreement with the report of Daudu *et al*. (2012), they observed that yield parameters such as number of fruits/plant, number of seeds per fruit, length of fruit (cm), width of fruit (cm) and weight of fruit (g) increased as the Irradiation Exposure Period increased. Ibrahim *et al.* (1983), who studied twelve homozygous M6 mutants of Giza-24 obtained through gamma irradiation, which revealed positive correlation for number of days to flowering, number of capsules per plant and negative correlation for 1000 seed weight and seed yield per plant.

The variations in oil contents obtained might be due to environmental factors. This is in close agreement with Carlsson *et al.*, 2008; Rai and Jacob, (1957). Carlsson *et al.*, 2008 reported that Genetic and environmental factors influence the oil content and fatty acid compositions in sesame. Rai and Jacob (1957), studied induced mutations in a black seeded variety T.16 by treating with X-rays and reported mutant in M3 and M4 generations respectively and both were found to have higher oil percentage (52.10%).

The results also showed that flowering percentages were affected by irradiation doses which are in close agreement with Shad, Tariq, Said and Shamsur (1986), who reported that Days to flowering were significantly affected both by gamma ray and fast neutron but differences in days to flowering were not significant statistically for varieties.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Genetic diversity is of great significance for breeding programmes as well as for taxonomic studies. Combining the results from both the morphological and yield parameters of the three varieties, Kenana-4 appeared to be the most sensitive to FNI and Ex-Sudan is the least while Ex-Sudan appeared to be the most sensitive to Sodium azide and Kenana-4 is the least. The dose 12µSv and 0.02% show more significant effects in the three varieties. Thus FNI can serve as useful tool for creating variability in sesame.Artificial induction of mutation through the use of sodium azide proves vital in the improvement of genetic variability in sesame. Certain concentrations of Sodium azide (0.02% through 0.04% sodium azide concentration) have the potentiality of inducing variability that could be used in the improvement of the yield of sesame.

5.2 Recommendations

The results of this finding showed that the three varieties showed some changes in response to FNI and SA. Thus the following are recommended,

1. Similar research should be carried out on other sesame cultivars
2. More research should be carried out on the M2 and M3 generations of the three varieties to see whether or not the changes will be expressed.
3. More research should be carried out using dose 12µSv and 0.2%.
4. Molecular analysis should be carried out to see whether there are changes at molecular level.

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APPENDICES

APPENDIX A

Anova For Kenana-4 Radiated with FNI

		Sum of Squares	Df	Mean Square	F	Sig.
Plt hgt at 2 weeks	Between Groups	11.454	4	2.864	1.067	.382
	Within Groups	147.628	55	2.684		
	Total	159.082	59			
Plt hgt at 4 weeks	Between Groups	191.873	4	47.968	3.452	.014
	Within Groups	764.289	55	13.896		
	Total	956.162	59			
Plt hgt at 8 weeks	Between Groups	1874.083	4	468.521	1.602	.187
	Within Groups	16084.887	55	292.452		
	Total	17958.969	59			

Plt hgt= Plant height

APPENDIX B

Anova for Weight of Capsule Per Plant

		Sum of Squares	df	Mean Square	F	Sig.
weight of capsule per plant for Kenana-4	Between Groups	.635	4	.159	13.667	.000
	Within Groups	.523	45	.012		
	Total	1.157	49			
weight of capsule per plant for E-8	Between Groups	.401	4	.100	12.725	.000
	Within Groups	.355	45	.008		
	Total	.756	49			
weight of capsule per plant for Ex-Sudan	Between Groups	.384	4	.096	1.263	.299
	Within Groups	3.417	45	.076		
	Total	3.801	49			

APPENDIX C

Anova for Number of Capsule Per Plant

		Sum of Squares	Df	Mean Square	F	Sig.
Kenana-4	between groups	911.880	4	227.970	1.633	.182
	within groups	6280.300	45	139.562		
	total	7192.180	49			
(E-8)	between groups	137.320	4	34.330	.288	.884
	within groups	5359.000	45	119.089		
	total	5496.320	49			
(Ex-Sudan)	between groups	1554.480	4	388.620	1.288	.289
	within groups	13575.300	45	301.673		
	total	15129.780	49			

APPENDIX D

Anova for Length of Petiole and Length of Capsule E-8

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	24.158	4	6.039	3.744	.010
Within Groups	72.587	45	1.613		
Total length of petiole	96.745	49			
Between Groups	.116	4	.029	.267	.898
Within Groups	4.884	45	.109		
Total length of Capsule	5.000	49			

APPENDIX E

Anova for Length of Petiole and Length of Capsule Ex-Sudan

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	55.351	4	13.838	5.529	.001
Within Groups	112.628	45	2.503		
Total length of petiole	167.979	49			
Between Groups	.335	4	.084	2.823	.036
Within Groups	1.336	45	.030		
Total length of Capsule	1.671	49			

APPENDIX F

Anova for Length of Petiole and Length of Capsule Kenana-4

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	47.803	4	11.951	9.852	.000
Within Groups	54.585	45	1.213		
Total length of petiole	102.388	49			
Between Groups	.629	4	.157	2.281	.075
Within Groups	3.103	45	.069		
Total length of Capsule	3.732	49			

APPENDIX G

Anova for Weight of Capsule Per Plant Treated with SA

		Sum of Squares	Df	Mean Square	F	Sig.
weight of capsule per plant for Kenana-4	Between Groups	.812	4	.203	19.193	.000
	Within Groups	.476	45	.011		
	Total	1.288	49			
weight of capsule per plant for E-8	Between Groups	.189	4	.047	15.316	.000
	Within Groups	.138	45	.003		
	Total	.325	49			
weight of capsule per plant for Ex-Sudan	Between Groups	.083	4	.021	10.759	.000
	Within Groups	.087	45	.002		
	Total	.169	49			

APPENDIX H

Anova for Number of Capsule Per Plant Treated With SA

	Sum of Squares	Df	Mean Square	F	Sig.
between groups	2428.480	4	607.120	7.849	.000
within groups	3480.900	45	77.353		
total Kenana-4	5909.380	49			
between groups	520.080	4	130.020	3.033	.027
within groups	1929.300	45	42.873		
total (E-8)	2449.380	49			
between groups	1578.800	4	394.700	3.239	.020
within groups	5483.200	45	121.849		
total (Ex-Sudan)	7062.000	49			

APPENDIX I

Anova for Length of Petiole and Length of Capsule E-8 Treated with SA

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	7.297	4	1.824	8.252	.000
Within Groups	9.948	45	.221		
Total length of petiole	17.245	49			
Between Groups	.383	4	0.96	.815	.523
Within Groups	5.287	45	.117		
Total length of Capsule	5.670	49			

APPENDIX J

Anova for Length of Petiole and Length of Capsule Ex-Sudan Treated With SA

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	79.449	4	19.862	21.083	.000
Within Groups	42.394	45	.942		
Total length of petiole	121.843	49			
Between Groups	.643	4	.161	1.353	.265
Within Groups	5.346	45	.119		
Total length of Capsule	5.989	49			

APPENDIX K

Anova for Length of Petiole and Length of Capsule Kenana-4 Treated With SA

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	26.195	4	6.549	2.063	.102
Within Groups	142.828	45	3.174		
Total length of petiole	169.023	49			
Between Groups	2.001	4	.500	4.201	.006
Within Groups	5.359	45	.119		
Total length of Capsule	7.360	49			