

**ASSESSMENT OF THE GROWTH RESPONSES OF SESAME (*SESAMUM INDICUM* L.)
AND FALSE SESAME (*CERATOTHECA SESAMOIDES* ENDL.) TO COLCHICINE
TREATMENTS**

ABSTRACT

Aim: The aim of this study was to assess the responses of sesame and false sesame to different colchicine concentrations in order to determine the concentration(s) that could be best utilized in the genetic improvement of the plants.

Study design: The treated seeds were sown in a plot with three blocks in a randomized complete block design (RCBD) with three replications in a factorial arrangement for two mutant generations (M_0 and M_1).

Place and Duration of Study: The study was conducted at the Botanical Garden of the Department of Biological Sciences, Ahmadu Bello University Zaria, Nigeria in 2006 and 2007 growing seasons.

Methodology: The seeds of sesame and false sesame were treated with five different colchicine concentrations (0.1mM, 0.5mM, 1.0mM, 2.0mM and 0.0mM as control) for two mutant generations (M_0 and M_1). Data collected included germination percents (14 DAS), root length, height at maturity, number of leaves/plant, leaf area, internodes length, 1000 seeds weight and dry weight.

Results: The results obtained showed highly significant difference ($P \leq 0.01$) in the effects of the mutagen on the germination percents, root length, height at maturity, leaf area, internodes length, 1000 seeds weight and dry weight in almost all the mutant generations except in the number of leaves/plant of the M_1 where the effect is significant ($P = 0.05$). The effect of the mutagen is concentration dependent, decreases with increase in concentration). The result shows that 0.1mM colchicines concentration produced mutants with high rate of germination that are tall in stature. More so, the mutants produced high number of leaves that are larger in size and which are far distant apart; with higher seed and dry weight.

Conclusion: 0.1mM colchicine concentration was found to be more effective in the genetic improvement of sesame and false sesame growth parameters. The response of sesame to the mutagen was found to be the best.

Key Words: Colchicine, False sesame, Sesame, Mutation.

INTRODUCTION

Sesame (*Sesamum indicum* L.) commonly called beniseed [1] and false sesame (*Ceratotheca sesamoides* Endl.) known as Bungu [2] in Nigeria belong to the plant family *Pedaliaceae* [3, 4, 5]. They are among the most ancient plants that are native to Africa [6, 7] and were cultivated in the African sub-region since 3050-3500 B.C [8,9]. Sesame seeds contained high level of PUFAs used in reducing blood cholesterol, high blood pressure and play an important role in preventing atherosclerosis, heart diseases and cancers [10, 11, 12]. Sesame is one of the oldest cultivated plants in the world [13] grown mainly for its seeds that contain approximately 50% oil and 25% protein [14] and sometimes for its edible leaves [15] used as vegetables. It is ranked as sixth most important oilseeds crop in the world [16].

False sesame is widely distributed in variable forms in Nigeria and consumed as a leaf vegetable in the savanna ecological zones. The leaves and flowers of false sesame are consumed as a vegetable

[4] rich in protein, fat, carbohydrate and minerals such as calcium, phosphorus and iron. In addition, the seeds are also rich in thiamin, riboflavin and niacin [17]. The oil extracted from the seeds is similar in composition to sesame oil. It contains the phenylpropanoid lignan sesamin which showed antioxidant, anti-inflammatory, antihypertensive, cytotoxic (including anti-tumor) and insecticidal activities [4]. *C.sesamoides* shows strong antibacterial activity [18]. Its decoction is used against diarrhea, while the leaves are stepped in water and the slimy liquid dropped into the eyes to treat conjunctivitis. Its leaf maceration also facilitates delivery in both humans and animals, while the leaves when ground with the rhizome of *Anchomanes difformis* can be applied topically in cases of leprosy [4]. False sesame is also reported to be used as an aphrodisiac, against jaundice, snakebites and skin diseases [19]. Ironically, despite all the benefits endowed within these plants, little effort has been made on their improvement in Nigeria. The vast reservoir of wealth of these leafy vegetables is deteriorating due to neglect by the scientific and development communities as reported by Attere [20]. An effort is needed to explore the benefits of using these plants and to stimulate interest in their utilization beyond the traditional localities as they are potent supplements to the starchy staple foods which are typically consumed. Also, the prohibitive cost of animal protein in developing countries (of which Nigeria is one) calls for extensive exploitation of plant protein sources, which are often economically cheaper [21].

Mutation (a change in genetic material of an organism) induced both in seeds and vegetatively propagated crops are of scientific and commercial interest to improve both the growth and yield parameters of economic plants. It provides raw materials for the genetic improvement of economic crops [22], and facilitates the isolation, identification and cloning of genes which would ultimately help in designing crops with improved yield, increased stressed tolerance, and longer life span and reduced agronomic in-puts [23]. The aim of this research is to use colchicine (a poisonous alkaloid from autumn crocus plant, *Colchicum autumnale*) to induce beneficial mutation in sesame and false sesame to determine the effectiveness of different concentrations of colchicine that could be beneficial to the genetic improvement of these two plants.

MATERIALS AND METHODS

The research was conducted at the Botanical Garden of the Department of Biological Sciences, Ahmadu Bello University Zaria (Lat $11^{\circ} 11' N$; Long $7^{\circ} N 38^{\circ} E$) during the 2006 and 2007 growing seasons. The seeds of sesame and false sesame were obtained from the Institute for Agricultural Research (IAR), Ahmadu Bello University, Zaria, Nigeria. The seeds were pre-soaked at five different colchicine concentrations (0.1mM, 0.5mM, 1.0mM, 2.0mM and untreated soaked in distilled water) for four hours and then washed thoroughly in running water. The treated seeds were sown in a plot with three blocks in a randomized complete block design (RCBD) with three replications in a factorial arrangement for two mutant generations (M_0 and M_1). All cultural practices followed the protocols described by Kano State Agricultural and Rural Development Authority crop production guide [24] and Bedigian and Adetula [4]. Data collected included: Percents germination 14 (DAS), root length, height at maturity, number of leaves/plant, leaf area, internodes length, 1000 seeds weight and dry weight. All the data were analyzed using factorial analysis in a CRBD format with Duncan's Multiple Range Test to separate the means.

RESULTS

Results obtained from the M_0 analysis of variance following treatment of sesame and false sesame with colchicine showed highly significant difference ($P \leq 0.01$) in the effect of different colchicine concentrations on the selected traits of the two plants (Table 1). Similarly, results showed a significant difference ($P \leq 0.01$) in the response of the two plants to different colchicine concentrations with the exception of percent germination (Table 1).

Table 1: M_0 Mean Squares at Different Concentrations of Colchicine on Some Traits of False Sesame and Sesame

Sources of Variation	Df	Germination Percent (14 DAS)	Root Length (cm)	Height at Maturity (cm)	Number of Leaves / Plant	Leaf Area (cm ²)	Internodes Length (cm)	1000 Seeds Weight (g)	Dry Weight (g)
Blocks	2	0.9*	12**	1753**	150**	10540**	9**	0.04**	0.3*

Concentration	4	82**	8**	345**	36**	1677**	49**	0.1**	24**
Variety	2	0.3 ^{ns}	33**	1566**	110**	10141**	47**	0.1**	1.4**
Error	208	0.3	0.8	18	3.5	35	0.1	0.003	0.1

95 Keys: ns= No significant difference * = Significant difference ($P=0.05$) **= Highly significant difference ($P\leq 0.01$)

96 Furthermore, the result from the responses of sesame and false sesame to various colchicine
 97 concentrations (Table 2) in M_0 generation showed a greater response by sesame in all the selected traits
 98 with the exception of germination percents.

99 Table 2: M_0 Mean Responses of Sesame and False Sesame to Different Colchicine Concentrations

Variety	Germination Percent (14DAS)	Root Length (cm)	Height at Maturity (cm)	Number of Leaves/plant	Leaf Area (cm ²)	Internodes Length (cm)	1000 Seeds Weight (g)	Dry Weight (g)
Sesame	84 ^{a1}	4.9 ^a	56 ^a	24.3 ^a	57 ^a	7 ^a	3.2 ^a	21 ^a
False sesame	81 ^a	4.7 ^b	57 ^a	18.8 ^b	8 ^b	4 ^b	2.8 ^b	17 ^b
S.E $\pm$	1.3	0.7	11.6	2.9	7.1	0.5	0.1	1.4

100 N.B: Means within the columns with the same letter(s) are not significantly different ($P=0.05$)

101 Results of the mean effect of different colchicine concentrations on the traits of sesame are
 102 presented in Table 3. The results showed high germination (90%) was found among the mutants treated
 103 with 0.1mM concentration. It was also found that the 0.1mM treated mutants' roots grow to a depth of
 104 6.00 cm and 75 cm above the ground. More so, the mutants produced 22 leaves that are 78 cm² in cross
 105 sectional area with internodes length of 9 cm in between. Similarly, the 1000 seeds weight and dry weight
 106 of the mutants treated by 0.1 mM colchicines concentration weigh 3.4g and 23g respectively.

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110 Table 3: M_0 Means of some Traits at Different Colchicine Concentrations in Sesame

Concentration	Germination Percent (14 DAS)	Root Length (cm)	Height at Maturity (cm)	Number of Leaves/Plant	Leaf Area (cm ²)	Internodes Length (cm)	1000 Seeds Weight (g)	Dry Weight (g)
0.0 mM	78 ^{d1}	4 ^b	57 ^c	20 ^d	41 ^e	6 ^c	2.9 ^c	16 ^c
0.1 mM	90 ^a	6 ^a	75 ^a	29 ^a	78 ^a	9 ^a	3.4 ^a	23 ^a
0.5 mM	88 ^b	5 ^{ba}	70 ^{ba}	26 ^b	65 ^b	8 ^{ba}	3.2 ^b	22 ^b
1.0 mM	86 ^b	5 ^{ba}	66 ^b	24 ^b	56 ^c	7 ^b	3.2 ^b	22 ^b
2.0 mM	82 ^c	5 ^{ba}	64 ^b	22 ^c	51 ^d	7 ^b	3.1 ^{ba}	22 ^b
S.E $\pm$	1.9	2.5	3.0	1.4	6.3	0.5	0.1	1.1

111 N.B: Means within the columns with the same letter(s) are not significantly different ($P=0.05$)

112 Similarly, the result of the mean effect of various concentrations of colchicine on the traits of false
 113 sesame (Table 4) showed higher rate of germination among 0.1mM treated mutants (86%). The result
 114 showed that, 0.1mM have roots that grow to a depth of 7.1 cm and height of 52 cm. The mutants were
 115 also found to produce high number of leaves that are larger in size and which are 4.5 cm apart; having
 116 1000 seeds weight of 3g and dry weight of 19.6g.

117 Table 4: M_0 Means of some Traits at Different Colchicine Concentrations in False Sesame

Concentration	Germination Percent (14 DAS)	Root Length (cm)	Height at Maturity (cm)	Number of Leaves/ Plant	Leaf Area (cm ²)	Internodes Length (cm)	1000 Seeds Weight (g)	Dry Weight (g)
0.0mM	73 ^{c1}	6 ^c	39 ^c	16 ^d	3.5 ^e	3.8 ^d	2.6 ^d	12 ^c

0.1mM	86 ^a	7 ^a	52 ^a	21 ^a	13 ^a	5 ^a	3.0 ^a	20 ^a
0.5mM	85 ^{ba}	7 ^a	48 ^{ab}	20 ^b	9.6 ^b	4 ^b	2.9 ^b	19 ^{ba}
1.0mM	83 ^b	7 ^a	46 ^{ba}	19 ^b	8 ^c	4 ^b	2.8 ^c	19 ^{ba}
2.0mM	78 ^b	6 ^b	45 ^b	19 ^b	5.9 ^d	3.9 ^c	2.8 ^c	18 ^b
.S.E±	2.2	0.3	2.2	0.9	1.6	0.1	0.1	1.3

118 N.B: ¹ Means within the columns with the same letter(s) are not significantly different ($P=0.05$)

119 The result from the analysis of variance of the M_1 (Table 5) showed high significant difference
120 ($P\leq 0.01$) in the effect of the mutagen on the two plants in all the selected traits; except in the number of
121 leaves produced per plant, where the effect is significant ($P=0.05$). Similar result is found in the response
122 of the plants to the mutagen; except in the root length (where no significant difference is found).

123 **Table 5: M_1 Mean Squares of the Effects of Different Concentrations of Colchicine on Some Traits of False Sesame and Sesame**

Sources of Variation	Df	Germination Percents (14DAS)	Root Length (cm)	Height at Maturity (cm)	Number of Leaves/ Plant	Leaf Area (cm ²)	Internodes Length (cm)	1000 Seeds Weight (g)	Dry Weight (g)
Blocks	2	0.4 ^{ns}	71 ^{**}	2423 ^{**}	236 ^{**}	10517 ^{**}	65 ^{**}	0.01 ^{**}	2.1 [*]
Concentration	4	33 ^{**}	7 ^{**}	107 ^{**}	24 [*]	162 ^{**}	1.3 ^{**}	0.18 ^{**}	41 ^{**}
Variety	2	16 ^{**}	0.8 ^{ns}	3204 ^{**}	416 ^{**}	11881 ^{**}	76 ^{**}	0.01 ^{**}	6 ^{**}
Error	208	0.3	0.9	13.7	4.8	23.9	0.3	0.003	0.6

124 Keys: ns= No significant difference

*= Significant difference ($P=0.05$)

** = Highly significant difference ($P\leq 0.01$)

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127 **Result** of the response of the two plants to the mutagen in the M_1 generation (Table 6) showed
128 that sesame has the highest response in almost all the selected traits.

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130 **Table 6: M_1 Responses of Sesame and False Sesame to Different Colchicine Concentrations**

Variety	Germination Percent (14 DAS)	Root Length (cm)	Height at Maturity (cm)	Number of Leaves/plant	Leaf Area (cm ²)	Internodes Length (cm)	1000 Seeds Weight (g)	Dry Weight (g)
Sesame	86 ^a	5.4 ^a	69 ^a	27 ^a	61 ^a	8 ^a	3.2 ^a	21 ^a
False sesame	76 ^b	5.5 ^b	44 ^b	19 ^{ba}	10 ^b	4 ^b	2.9 ^b	17 ^b
S.E±	3.5	0.05	8.6	2.8	18	1.2	0.1	1.4

131 N.B: Means within the columns with the same letter(s) are not significantly different ($P=0.05$)

132 More so, the mean effects of different colchicine treatments on the traits of sesame (Table 7)
133 showed that, 91% of the 0.1mM treated mutants germinated produced roots that are 6 cm in length and
134 attained a height of 79 cm at maturity. The mutants are also found to produce 32 leaves per plant which
135 are larger in size (76 cm²) and which are 9 cm apart. Similarly, 1000 seeds of the mutants weigh 3.6g with
136 3.2g dry weight.

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139 **Table 7: M_1 Generation Means of some Traits at Different Colchicine Concentrations in Sesame**

Concentration	Germination Percent (14 DAS)	Root Length (cm)	Height at Maturity (cm)	Number of Leaves/ Plant	Leaf Area (cm ²)	Internodes Length (cm)	1000 Seeds Weight (g)	Dry Weight (g)
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0.0 mM	82 ^{c1}	4.8 ^c	60 ^d	22 ^d	43 ^e	6 ^b	3.1 ^e	19 ^d
0.1 mM	91 ^a	6 ^a	79 ^a	32 ^a	76 ^a	9 ^a	3.6 ^a	32 ^a
0.5 mM	87 ^{ba}	5 ^{ba}	71 ^b	30 ^b	68 ^b	8 ^{ba}	3.5 ^b	30 ^b
1.0 mM	86 ^b	5 ^{ba}	69 ^{cb}	26 ^c	60 ^c	8 ^{ba}	3.4 ^c	26 ^c
2.0 mM	84 ^b	5 ^{ba}	67 ^c	25 ^c	56 ^d	8 ^{ba}	3.2 ^d	26 ^c
S.E±	1.4	0.9	3.1	1.8	5.5	0.5	0.08	1.9

N.B: Means within the columns with the same letter(s) are not significantly different at P=0.05

Furthermore, Table 8 shows the results of the M₁ traits of false sesame. It showed that, 0.1mM treated mutants germinated better than all the others. They showed taller stature, with their roots growing deeper. The result also showed that, the mutants produced high number of leaves that are larger in size and which are far distant apart. Similarly, the 1000 seeds and dry weight of the mutants weigh higher.

Table 8: M₁ Generation Means of some Traits at Different Colchicine Concentrations in False Sesame

Concentration	Germination Percent (14 DAS)	Root Length (cm)	Height at Maturity (cm)	Number of Leaves/ Plant	Leaf Area (cm ²)	Internodes Length (cm)	1000 Seeds Weight (g)	Dry Weight (g)
0.0 mM	72 ^{d1}	5 ^b	36 ^d	16 ^d	3.9 ^d	3.9 ^c	2.4 ^c	16 ^c
0.1 mM	79 ^a	6 ^a	50 ^a	22 ^a	14 ^a	5 ^a	3.2 ^a	19 ^a
0.5 mM	76 ^b	6 ^a	46 ^b	20 ^b	11 ^b	4 ^b	3.1 ^b	18 ^b
1.0 mM	76 ^b	6 ^a	45 ^b	20 ^b	10 ^c	4 ^b	3.2 ^a	18 ^b
2.0 mM	75 ^c	6 ^a	43 ^c	19 ^c	10 ^c	4 ^b	3.1 ^b	18 ^b
S.E±	1.0	0.17	2.4	0.6	1.7	0.2	0.1	0.4

N.B: Means within the columns with the same letter(s) are not significantly different at P=0.05

DISCUSSION

The results obtained in this research implied that sesame and false sesame responds well to different colchicine concentrations. The increased percent germination 14 days of planting due to various colchicine concentrations revealed the effects of the mutagen in the germination process. This was in agreement with the findings of Waghmare and Mehra [25] in grass pea due to increase in the concentration of Ethyl Methane Sulphonate (EMS). But, this finding was in contrast to the work of Bird and Neuffer [26] who reported reduction in the germinating rates in plants treated with mutagen. Germination being one of the critical stages required by sesame for its optimal growth as reported by Uzo [11] was improved through the use of colchicine mutagenesis. Chemical mutagenesis through the application of colchicine increases the germination potentiality of sesame and false sesame seeds after fourteen days of planting.

The increase in height and roots length of the plants induced by colchicine were due to the alteration of their genome integrated by environmental signals as reported by Uno *et al.* [27]; probably by increasing the rates of cellular division and expansion at their meristematic regions. This was in agreement with the findings of Hoballah [28] who reported increased in plant heights of sesame due to mutagenesis; but was in contrast to the findings of Maluszynski *et al.* [29] who reported decreased in plant height due to induced mutation in rice. The root length increase due to colchicine concentration was in agreement with the findings of Adamu [30] who reported root length increase in popcorn as a result of gamma and Thermal Neutrons irradiations. Certain genes that function in stress tolerance and cause changes in the root morphology were recently been identified through genetic mutation in *Arabidopsis* by

Maggio *et al.* [31] which might have consequently increased the roots absorption capacity. The mutagen might have probably influenced the activities of cytokinin, which is of paramount importance in the fundamental processes of plant development, including cell division and morphogenesis as suggested by Deikman and Ulrich [32].

Increased leaf area in sesame and false sesame mutants induced by different colchicine concentrations was in agreement with the findings of Maluszynski *et al.* [29] who reported an increase in leaf area among *Zea mays* mutants. The increase in leaf area provides an increase in the surface area for gaseous ex-change which has considerable effect on the process of photosynthesis as gene duplication has profound effect in the evolution of photosynthesis reaction center proteins as suggested by Lockhart *et al.* [33] thereby affecting plant productivity in terms of the **dry matter content and seed weight**. Similar findings were found in the work of Duranceau *et al.* [34] who reported a greater leaf mass per leaf area and enriched organic matter in the leaves of *Nicotiana sylvestris* mutants. This was also consistent with the assumption that mutation increases the genetic capacity for the utilization of photosynthates due to the ability of plants to sustain increased photosynthesis as suggested by Ainsworth *et al.* [35]. The mutagen stimulated growth of the cells of the lamina causing its remarkable expansion. Thus, increase in the leaf area of sesame and false sesame has a strong relationship with the yield components. Besides the leaf area, the number of leaves produced per plant and their proportionate distance from one another were increased under different concentrations of colchicine. This finding was in agreement with that of Hoballah [28] who reported increase in the number of branches among sesame mutants due to gamma irradiation. The increase of 1000 seeds weight of sesame and false sesame due to colchicine treatment was in line with the work of Shen *et al.* [36] who reported increase in grain weight of rice due to gamma rays in *in-vitro* mutagenesis. Increase in the dry weights of sesame and false sesame with decrease in colchicine concentration was in conformity with the work of Kolesnikova and Maksimova [37] who reported an increase in the dry matter contents of potato tuber mutants. It also tallies with the work of Stelling [38] who reported improvements in biomass besides other traits in faba bean mutants.

CONCLUSION

Induction of mutation through the use of colchicine on sesame and false sesame was found to improve the growth responses of the two plants. Improvements in these traits were due to the ability of the plants to respond to the effects of the mutagen in inducing favorable mutation. Thus, the responses of the traits of these plants were best under 0.1mM colchicines concentration.

ACKNOWLEDGEMENT

The authors would like to acknowledge the Department of Biological Sciences, Ahmadu Bello University Zaria for the assistance rendered to perform the experiment

REFERENCES

- [1] Abu GA, Abah D, Adogwu OS. Analysis of cost and return for sesame production in Nasarawa state: Implication for sustainable development in Nigeria. *Journal of Sustainable Development in Africa*. 2012; 13(3):238-249.
- [2] Fasakin K. Proximate composition of bungu (*Ceratotheca sesamoides* Endl.) leaves and seeds. *Biokemistri*. 2004; 16(2):88-92.
- [3] Purseglove JW. Tropical crops: Dicotyledons; vol 2 Wiley New York. pp 430-435. 1968.
- [4] Bedigian D, Adetula OA. *Ceratotheca sesamoides* Endl. In: Grubben, G.J.H. & Denton, O.A. (Editors). PROTA 2: Vegetables/Légumes. PROTA, Wageningen, Netherlands. 2004.
- [5] Pham DT, Nguyen TTD, Carlsson AS, Bui MT. Morphological evaluation of sesame (*Sesamum indicum* L.) varieties from different origins. *Australian Journal of Crop Science*. 2010; 4(7): 498-504.
- [6] Burkill HM. *Pedaliaceae In: The Useful Plants of West Tropical Africa*: 2nd ed, Vol. 4, Royal Botanic Garden, Kew pp 414-423. 1997.
- [7] Bedigian D. Slimy leaves and oily seeds: Distribution and use of wild relatives of Sesame in Africa. *Econ Bot*. 2005; 58 pp S3-S33.

- [8] Bedigian D, Harlan JR. Evidence for cultivation of sesame in the ancient world. *Econ. Bot.* 1986; 40(2): 137-154.
- [9] Mondal N, Bhat KV, Srivastava PS. Variation in Fatty Acid Composition in Indian Germplasm of Sesame. *Journal of the American Oil Chemists' Society.* 2010; 87(11): 1263-1269.
- [10] Ghafoorunissa: Dietary fats/oils and heart diseases. In: Prasad, M.V.R. (Ed.) *Proceedings of Sustainability in oil seeds.* Hyderabad. 1994; pp. 486-490: Indian Society of Oil Seed Research.
- [11] Hibasami H, Fujikawa T, Takeda H, Nishibe S, Satoh T, Fujisawa T, Nakashima K. Induction of apoptosis by *Acanthopanax senticosus* HARMS and its component, sesamin in human stomach cancer KATO III cells. *Oncol. Rep.* 2000; 7(6): 1213-1216.
- [12] Pamplona-Roger GD. Encyclopedia of medicinal plants, Education and health library; editorial sofeliz, S.L. Madrid, Spain. 1999; pp 611-612.
- [13] Oplinger ES, Putnam DH, Kaminski AR, Hanson CV, Oelke EA, Schulte EE, Doll JD. Sesame. Alternative field crops manual. University of Wisconsin- Extension, Cooperative Extension University of Minnesota; Center for Alternative Plant and Animal Products and the Minnesota Extension Services. 1990.
- [14] Burden D. Ssame profile. 2005 <http://www.cropprofiles.com> Retrieved 19th February, 2013.
- [15] Mann A, Gbate M, Umar AN. Medicinal and economic Plants of Nupe land. Jube -evans books and publications, Bida, Niger state pp 212. 2003.
- [16] Olowe VIO, Adeyemo YA, Adeniregun OO. Sesame: The Underexploited Organic Oilseed Crop. Research and Development Centre (RESDEC), University of Agriculture, Abeokuta, Nigeria. Pp 1-5. 2010.
- [17] Leung WTW, Busson F, Jardin C. Food composition table for use in Africa. FAO, Rome, Italy. 306 pp. 1968.
- [18] Maikere-Faniyo RL, Van Puyvelde A, Mutwew-Ingabo and Habiyaemo FX. Study of the Rwandese medicinal plants used in the treatment of diarrhea, I. *Journal of Ethnopharmacology.* 1989; 26:101-109.
- [19] Bedigian D. Evolution of sesame revisited: domestication, Diversity and prospects, *Genetic Resources and Crop Evolution.* 2003; 50:779-787.
- [20] Attere AF. Preface In: Chweya J.A. and Eyzaguirre P.B. (Eds.). *The Biodiversity of Traditional Leafy Vegetables:* IPGRI Rome ppVI-VII. 1999.
- [21] Mohan VR, Janardhanan K. Chemical Analysis and Nutritional Assessment of Lesser Known Pulses of the Genus Muccuna. *Food Chemistry.* 1995; 52:275 - 280.
- [22] Adamu AK, Chung SS, Abubakar S. The effect of ionizing radiation (Gamma rays) on tomato (s.n.), *Nig. Journal of Expt. Biol.* 2004; 5(2):185-193
- [23] Ahloowalia BS, Maluszynski M. Induced mutation: A new paradigm in plant breeding. *Euphytica.* 2001; 118:167-173.
- [24] KNARDA Kano state Agricultural and Rural Development Authority. Crop production guide for extension agents and farmers. pp1-2. 2005
- [25] Waghmare KN, Mehra RB. Induced mutation in grass pea (*Lathyrus sativus* L). *Lathyrism News L.* 2000; pp 786-796.
- [26] Bird RMCK, Neuffer MG. Induced mutations in Maize. *Plant breeding reviews.* 1988; 5: 141-178.
- [27] Uno G, Storey R, Moore R. *Principles of Botany.* Mc Graw Hill New York 1-550pp. 2001.
- [28] Hoballah AA. Selection and Agronomic evaluation of induced mutant lines of

- sesame. In: *Induced Mutations for Sesame Improvement* IAEA-TECDOC, IAEA, Vienna, pp 71-84. 1999.
- [29] Maluszynski M, Szarejko I, Barriga P, Balcerzyk A. Heterosis in crop mutant crosses and production of high yielding lines, using doubled haploid systems. *Euphytica*. 2001; 120:387-398.
- [30] Adamu AK. A Gamma ray (60 Co) and thermal neutron induced mutants in popcorn (*Zea mays* var. *Praecoxsturt*). *Nigerian J. of Sci. Res.* 2004; 4(2): 52-63.
- [31] Maggio A, Hasegawa PM, Bressan RA, Consiglio MF, Joly RJ. Unraveling the functional relationship between root anatomy and stress tolerance. *Aust. J. Plant Physiol.* 2001; 28:999-1004.
- [32] Deikman J, Ulrich M. A novel cytokinin-resistant mutant of *Arabidopsis* with Abbreviated shoot development. *Planta*. 1995; 195:440-449.
- [33] Lockhart PJ, Steel MA, Larkum AWD. Gene duplication and the evolution of photosynthetic reaction centre proteins. *FEBS Letters*, 1996 385.
- [34] Duranceau M, Ghashghaie J, Brugnoli E. Carbon Isotope discrimination during Photosynthesis and dark respiration in intact leaves of *Nicotiana sylvestris*: comparisons between wild type and mitochondrial mutant plants *Aust. J. Plant Physiol.* 2001. 28:65-71.
- [35] Ainsworth EA, Rogers A, Nelson R, Long SP. Testing the “source-sink” hypothesis of down-regulation of photosynthesis in elevated [CO₂] in the field with single gene substitutions in *Glycine max*. *Agric. And For. Meteorol.* 2004; 122:85-94.
- [36] Shen Y, Cai Q, Gao M, Liang Z. Isolation and genetic characterization of somaclonal mutants with large -sized grain in rice. *Cereal Res Commun*, 1995; 23(3):235-241.
- [37] Kolesnikova LG, Maksimova AD. Effect of chemical mutagens on the percentage of dry matter material and starch content in potato tubers. *Genetika* 1977; 13:1742-1753.
- [38] Stelling D. Heterosis and hybrid performance in topless faba beans (*Vicia faba* L.). *Euphytica*, 1997; 97:78-29.