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TITLE : The influence of varying gamma irradiation doses on the growth and yield of selected cowpea (Vigna unguiculata Walp) genotypes.

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ABSTRACT

Cowpea is an annual legume which is commonly referred to as southern pea or lubia it is one of the vital nourishment legumes and a valuable part of the old harvesting schemes in the semi-arid tropics. A field study was conducted at Omahenene Research Station, Northern Namibia to examine the influence of varying gamma irradiation doses on the growth and yield of cowpea (*V. unguiculata L.* Walp) genotypes. The experiment was done under rain fed conditions from January to April 2015. The experiment was conducted with two cowpea genotypes (Bira and Shindimba) treated with varying gamma irradiation doses of 200. 450. 600 and 0 Gy which served as a control. The data analysis was done using GenStat version 14. Data on pod length, seed yield and dry biomass of cowpea was collected. The outcomes demonstrated that increasing varying gamma irradiation doses significantly ($P<0.05$) improves the growth and yield of cowpea genotypes. Pod length, dry biomass and seed yield started to increase at 0 Gy and the highest pod length, dry biomass and seed yield was observed at 450 Gy in Bira and at 200 Gy in Shindimba. While 600 Gy resulted in a decreased pod length, dry biomass as well as seed yield in both cowpea genotypes. Increasing the dose level up to 450 Gy is advisable and resulted to be the optimum dose for Bira while 200 Gy was observed to be the optimum dose in Shindimba. Increasing the dose levels to 600 Gy is not advisable for cowpea production with respect to Bira and Shindimba in the experimental area. Though further investigation with the same experiment should be conducted in different regions of the country to put the recommendation on a strong basis. Depending on the crop of choice, farmers are ought to use Bira 450 Gy or Shindimba 200 Gy in order to achieve high seed yield.

Declaration

I thus proclaim that this thesis has been the consequences of my exertion and such work was not displayed somewhere else to any other institution of higher education. All extra facts was acknowledge by means of references.

Nahemi Herman

Signiture……………………………….   Date……/……./2016

Certification of thesis work

I, the signatories was the supervisor for the work done by Nahemi Herman (R123145B) and I officially state that this thesis was completed in fulfilment of the requirement of BSc Natural Resources Management has presented with the title:

The influence of varying gamma irradiation doses on the growth and yield of selected cowpea (*Vigna unguiculata Walp*) genotypes.

Supervisor

Mrs. Pilime

Signiture………………………………………… Date……/……/2016

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DEDICATION

To my two siblings, Haikali and Isabella Herman who always look up to me and take my advice, I hope you all will follow my footsteps and even go further than me. As well as my lovely daughter Shange Bailey who gave me a chance to come and complete my degree programme.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

Cowpea (*V. unguiculata* Walp) is one of the vital nourishment legumes and a valuable part of the old harvesting schemes in the semi-arid tropics (Ayisi et al., 2000; Singh et al., 2002). The harvest started and tame in Southern Africa, later spread to East and West Africa and Asia as reported by the International Institute for Tropical Agriculture (IITA), 2000). Cowpea ranks second after pearl millet in the Northern Namibia making it a produce of repute in the agronomic production. Be that it may, cowpea efficiency in the country is low (250 to 350 kg/ha) which is beneath the achievable yield of 1500 to 3000kg/ha (Adeola et al., 2011). The low yields are as an outcome of farmers growing unimproved landraces due to unavailability of improved and locally adapted cultivars. Thottappilly and Rossel (1992) reported that poor cultural practices and photoperiod sensitivity contributes to low productivity.

The induction of genetic variation is brought about with the treatment of gamma irradiation. The utilization of a mutagenic treatment in instigating hereditary variations in crop plants relies on upon the genetic mechanisms of test assortments and treatment dosage, among other dynamics. Radio sensitivity of the optimum dosage of radiation is a term describing a relation amount of the quantity of identifiable effects of a radiation exposure on the irradiated material. (Owoseni et al, 2007; Mba et al, 2010) proposed preliminary series of gamma irradiation dosages of 0 to 600 Gy that should be tested to determine the optimal treatment's condition on testing genotypes. The Namibian Radiation Regulatory Authority recommended gamma irradiation as a superior option as it is part of the physical agents used to advance the characters and efficiency of numerous foliage and the seeds are treated in a monitored environment without radio Mutation is an unexpected heritable change in an organism generally, the structural change in genes.

Mutation breeding is supportive in genetic enhancement aimed to develop suitable germplasm. Introduction of plant propagules, including seeds, tissues and organs to physical and chemical mutagents are methods for promoting mutations (Mba et al., 2010).

activity detoxification on the environment.

JUSTIFICATION

Although cowpea production has considerably increased, yield has remained stationary for the former few years due to the exposure of the crop to various abiotic constraints. Improvement can be achieved in vegetative characteristics and yield components of cowpeas by exposing the seeds to different gamma radiation doses as it is helpful in genetic improvement of the crop aimed to develop suitable germplasm.

Positive mutations caused by gamma radiation vary with different radiation doses. This study seek to evaluate gamma irradiation influence on *V. unguiculata* Walp by means of determining the ideal dosage that generate useful changeability as the crop has been liable to deviate from the old physical characters to new ones in the vegetative construction and recover the yield constituents of the crop.

Main objective

To determine the ideal dose of gamma radiation that increases yield of cowpea (*V. unguiculata L. Walp.*) genotypes.

Specific objectives

- To determine the effectiveness of varying gamma irradiation doses on the pod length of cowpea genotypes.
- To determine the effectiveness of varying gamma irradiation doses on the above ground dry biomass of cowpea genotypes.
- To determine the effectiveness of varying gamma irradiation doses on the seed yield of cowpea genotypes.

Hypotheses

- Increasing gamma irradiation doses significantly improves pod length of cowpea genotypes.
- Increasing gamma irradiation doses significantly improves above ground dry biomass of cowpea genotypes.
- Increasing gamma irradiation doses significantly improves seed yield of cowpea genotypes.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Induced mutation breeding

The Concise Oxford Dictionary 10th Edition defined mutation as an alteration in the construction of a genetic material occasioning in an alternative arrangement which possibly will be transferred to the next generations. Mutation breeding is defined as the practise of divulging seeds to chemicals or radiation in with an intent to produce mutants with necessary traits. Mutants are plants produced through mutagenesis (Plant Breeding and Genetics, 2014). Heritable dissimilarity of suitable characters for crop development is required by plant breeding. Often, however, preferred variation is lacking. van Harten (1998) suggested that mutagenic agents, for instance radiation now can be used to encourage mutations and create heritable dissimilarities from which preferred mutants possibly will be carefully chosen.

Creation of variation within a crop variety has been proved by induction of mutation. Induction of preferred characteristics that whichever cannot be found in natural surroundings or has vanished during evolution are as a result brought about by mutation breeding. Hereditary dissimilarity and selection are two principles which breeding for improved cultivars is based on. Since the 1930s induced mutagenesis has been practised with abundant achievement in crop breeding programmes in evolving countries as reported by Ahloowalia, et al., (2004).

It was further established by FAO (2004) that variants have been generated in inherited characters in many crops such as yield and maturity time. And that the introduction and succeeding improvement of legumes such as cowpeas through induced mutation could make it possible to an improved new germplasm. Plant structural design is accepted with one accord of the major trait for advanced yield in leguminous plants. Novak and Brunner (1992) reported that fast and direct outcomes to select useful traits may be caused by artificial mutagenesis not like the conventional techniques wherein up to ten years of selections are taken after wide-ranging crosses are applied in genetic development.

In the course of the past decades, mutation breeding has been used for creating genetic variation and breeding first-hand varieties (van Harten, 1998). Lately mutants by means of new agronomic characters for genetic studies to forecast the gene utility through identification of an allelic sequence by Targeting Induced Local Lesions IN Genomes (TILLING) has been created with the application of the technique (Till et al., 2003; Xin et al., 2008).

2.2 Gamma irradiation

2.2.1 Definition

Gamma radiation which is represented by the Greek letter Y, refers to electromagnetic radiation of an enormously high rate of recurrence and consequently comprises of high energy photons (https://www.stem.org.uk/audience/fe). Since irradiation is an ionic, no-heat procedure, it receives consideration by way of a protection and practical variation cause in polymer investigation and use (Abu et al., 2006).

2.2.2 Characteristics

The induction of genetic variation is brought about with the treatment of gamma irradiation as it is one of the main physical mutagens. They are characteristically formed by the decreasing of atomic nuclei by way of changing from a high energy state to an inferior state well-known as gamma decay. Gamma irradiation has a high power of penetration (Moussa, 2006). Radioactive isotopes which are cobalt (Co^{60}) is a source of gamma irradiation which is extensively used (Shimelis and Shiringani, 2010).

2.2.3 Importance

Moussa (2006), stated that gamma rays have demonstrated to be inexpensive and active compared to other ionizing radiations for the reason that they are easily accessible. In plant improvement, the irradiation of seeds may cause genetic, changeability that enable plant breeders to select new genotypes with improved characteristics such as precocity, salinity tolerance, grain yield and quality (Ashraf, 2003). The information enclosed in DNA is used by each plant cell to generate the proteins compulsory for life which supports the cells and help manage cell behaviour. Exposure of seeds to radiation causes mutations in the DNA of seeds (Plant Breeding and Genetics, 2014). Shimelis et al., (2010) also reported that the genetic change is associated to changes of DNA arrangements and thus modify the feature, characteristics and traits of the treated plant.

According to Gunckel and Sparrow, (1961), plant growth and expansion was increased through gamma irradiation by inducing cytological, biochemical, physical and morphogenetic changes in cells and tissues contingent on the irradiation dosage. Sharma and Rana, (2010) reported that gamma irradiation is a key physical agent used to expand the characters and production of numerous plants. Decline in shoot length at higher doses of gamma irradiation was reported in mung bean (Rakshit et al., 2001). As reported by Gregory et al., (1995), the variability of quantitative characters influencing yield may be much greater in mutagenic offspring than in the control plot.

A possible inhibiting action of the enzymes can lead to a reduction in pod length, above ground biomass and seed yield of some leguminous plants (Larik, 1975). Traits of plants were affected by the gamma ray in various ways and this was determined by the plant species and the irradiation dosage (Artk and Peksen 2006).

Gamma irradiation has led to several positive mutations in agricultural crops. Produces with enhanced features have fruitfully been established through mutagenic initiations. A high yielding barley genotype with rapid maturity, high protein constituents and stiff grass was established through mutation breeding practises. Khatri et al., (2005) composed three high grain yielding and prompt maturing mutants by subjecting seeds of *B. juncea* L. cv. S-9 to gamma rays (750-1000K Gy) and EMS.

A first-hand oil seed *B. napus* L. *cv.* ABASIN 95 was established by Shah et al., (2001) through induced mutation. Seeds of *B. napus* L. *cv.* Tower were exposed to 1.0, 1.2 and 1.4K Gy gamma irradiation and the consequential genotype was high yielding, resistant to Alternaria blight and white rust.

2.2.4 Optimal dose for gamma radiation

According to Mba et al., (2010) the dosage of a mutagen that is viewed as ideal is the one that accomplishes the optimum mutation occurrence. It was also reported that Mba et al., (2010) anticipated primary series of gamma irradiation dosages of 0 to 600 Gy that ought to be tested to regulate the ideal handling condition on trial genotypes. Rapid emergence, amplified percent germination and field endurance with strong and vigorous seedlings are as a result of low radiation doses. Nevertheless, this would perhaps be linked with slight mutation for occurrence with compact choice in response concerning aimed mutation. As seen from previous studies, exposure of seeds to a high dosage of gamma rays interrupts the protein production, hormone equilibrium, photosynthesis and enzyme movement (Hameed A. 2008). The morphological, mechanical and useful variations is believed to be depended on the power and length of gamma dosages of exposure.

Exposure might be long-lasting (non-stop low dosage ran for an extended time) or acute (high dosage ran for a short time e.g. seconds). Furthermost mutation inductions are of acute type.

High dosages do not essentially lead to the finest outcomes. Identification of treatments with high relative biological effectiveness (RBE) should be done in order to rise the number of mutants created and isolated. High ionizing densities in treatments are believed to be as a result of extreme RBE (Shimelis, 2010). Efficiency of treatments depends on treatment environments: for example oxygen and moisture content of plant material. The radiation must be applied at a suitable dosage, an aspect that is governed by the radiation power plus exposure time. Excellence of mutation is not automatically certainly linked with dosage level. A high dosage does not automatically yield the utmost outcomes (Horn and Shimelis, 2013).

2.2.5 Advantages and limitations of gamma radiation

The radiation process is believed to be more convenient. Equipment is simple and very strong and therefore has a greater penetrating power. The gamma radiation as a whole also has it's sadden part as radiographs can be of poorer quality. Exposure time might be longer and radiation cannot be switched off once it has started. It is also reported that sources need replacement over time. Gamma rays are believed to be biologically hazardous to humans since they are ionizing radiation. (www.twi-global.com/technical-knowledge/faqs/ndt/faq-what-are-the). Horn and Shimelis, (2013) reported that a decrease in seedling stature (often used to identify injury in the M1) and effects of the cells (chromosomal aberrations) are mutual biological damages instigated by the mutagenic usage.

2.3 Cowpea (*Vigna unguiculata* Walp)

Cowpea is an annual legume which is commonly referred to as southern pea or lubia. The disturbances of climate variation with the approaching threat of nourishment shortage and uncertainty, over millions underprivileged people of parched land locations of Africa make ends meet with legumes that are able to be grown on dry and water stressed surroundings (CGIAR, 2012). The rural people whose main livelihood is farming awaits their retrieving crops whose genetics are well understood and require low input to grow hybrids of improved yield and stable crops for such conditions. *V. unguiculata Walp* has a superior significance in the situation of fluctuating climate and cumulative call for massively beneficial nourishment with low price input as it is a chief crop element of food security in Africa.

(www.science.gov/topic pages/f/fodder.html).

2.3.1 Scientific Classification of *V. unguiculata Walp*

Kingdom:	Plantea
Phylum:	Angoispores
Class:	Eudicots
Subclass:	Rosids
Order:	Fabales
Family:	Fabacea
Genus:	*Vigna*
Species:	*V. unguiculata*

2.3.2 Origin and use

International Institute for Tropical Agriculture (IITA), (2000) reported that cowpea was brought about and tame in Southern Africa and progressively extended to West and East Africa and lastly Asia. Cowpea has an advantageous capability to fix stratospheric nitrogen by means of root nodules. In totaling, cowpea can tolerate shade, therefore it is well-suited and intercropped with cotton, sugarcane, millet, sugarcane, and maize. This brands cowpea as a significant constituent of old intercropping methods, particularly in the compound and well-designed existing agriculture schemes in the parched areas. Cowpea equilibriums basic cereals and starchy root crops as it is a protein-rich grain. In Namibia, some women are known to cook and trade appetizers made from cowpea, and are as well mostly involved in selling of green pods.

The crop can be harvested at three stages: when the pods are young and green, when the pods are mature and green, and when the pods are dry. Tender leaves, undeveloped pods, undeveloped seeds, and developed dry seeds are all used as nourishment. The leaves, stems, and creepers aid as animal forage and are kept for usage throughout the desiccated period (Aliero and Morakinyo, 2001).

2.3.3 Ecological requirements

Cowpea adjusts to harsh surroundings as well as life-threatening temperatures, poor soil fertility and drought. Shimelis and Shringani, (2010) reported that cowpeas yield better than other food legumes in poor environments.

2.3.4 Pests affecting cowpeas

Low yields of cowpea are as a result of insects as they disturb each tissue section and developmental phase of the vegetable. In extreme invasions, pest burden takes a responsibility for more than 85% damage in yield. The legume pod borer *Maruca vitrata* was reported to be the key pest of cowpea (Shama, 1998). It also roots the harm to the pods, flowers and flower buds of the plant. Additional chief pests include thrips, post-harvest weevil (*Callosobruchus maculates*) and pod sucking bugs.

2.3.5 Cowpea genotypes in Namibia

Consequently, three familiarized varieties were released during 1993. Shindimba (IT89D-245-1), Bira (IT87D-453-2) and Nakare (IT81D-984). The genotypes consist of a unique kernel form besides color plus hilum design. Nakare and Shindimba have a white seed coat, but the only difference is the hilum pattern. Nakare is one of the varieties referred to as “black eyed pea” because of an existing unique black spot at the hilum of the kernel. Shindimba has an orange-brown spot at the hilum. Bira is different from the two white coated seeds since it is brown in color, smaller and very hard. In this study, only two genotypes were used, which were: Shindimba and Bira.

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 Study Location

A field study was carried out at Omahenene Research Station during the January-April cropping season 2015. The station is located at the coordinates 17’30’S and longitude 14’50’E, receives an average annual rainfall between 350 mm to 700 mm. The station is at a height of 1100 meters above sea level (masl). The average temperatures in summer and winter are 35 and 18 °C respectively. The soil type is sandy loam with pH 6.

3.2 Gamma irradiation process

Seeds of the cowpea genotypes (Bira and Shindimba) were placed in dissimilar petri dishes and subjected to gamma irradiation doses of 200, 450, 600 and 0 Gy (Gray) which was kept as a control with one minute interval between radiations. The radiation was carried out at the International Atomic Energy Agencies (IAEA), Seibersdorf, Austria in a Cobalt^{60} gammacell.

3.3 Treatments

The treatments involved were two different cowpea genotypes namely Bira (IT87D-453) and Shindimba (IT89KD-245-2) subjected to four different radiation doses which were 0, 200, 450 and 600GY respectively.

3.4 Experimental design

The trial was a 2 × 4 factorial replicated 3 times. And it was laid out in a Randomized Complete Block Design (RCBD)

3.5 Field Procedure

3.5.1 Demarcation of plots

Each plot size measured 3.3 × 3.5m^2 while the blocks were outlined with 2m between blocks and 1m between plots. This resulted in 14.5 × 33.4m^2 as an overall size for the experimental area.

3.5.2 Sowing

250 g of basal NPK (2:3:2) was broadcasted in each plot before sowing. 30 cm in row and 70 cm between row spacing was measured using measuring sticks. Two M3 seeds were sown per hole. Each plot comprised of four rows of ten plants.

3.5.3 Parameters measured

The data collected were above ground dry biomass (kg/ha), pod length (cm)/5 pods from 5 tagged plants) and seed yield (kg/ha)/5tagged plants). Biomass was measured at 50% flowering by placing a (70 cm × 70 cm) quadrant in the middle of the plot then plant material within the quadrant was cut using a shear, weighing green fodder, drying in an open air circulated room for seven days and lastly weighing the dry fodder. Pods in the central two rows of each plot per 5 tagged plants were harvested after they turned light cream as a sign of maturity before they could open and scatter seeds. Pods were weighed to determine the seed yield for each tagged plant. Five pods from each tagged plant were randomly selected and measured with a measuring tape in order to determine the pod length for each plot.

3.5.4 Cultural Practices

Sprinkler irrigation was used to irrigate the plants twice a week. Weeding was done every 3 weeks using hoes. Endosulphan was sprayed using a knapsack sprayer at the beginning of two weeks after emergence and again when the thrips and pod sucking bugs increased. Spraying was done early in the morning when it was cool and not windy to escape pesticide drift.

3.6 Data analysis

GenStat version 14 was used to analyse variance and treatment means was separated using LSD at 5% level of significance.

CHAPTER 4

4.0 RESULTS

The results of the study focused on the dry biomass, pod length and seed yield of two cowpea genotypes (Bira and Shindimba) in response to different levels of gamma irradiation doses.

4.1 The influence of varying gamma irradiation doses on above ground biomass of selected cowpea genotypes

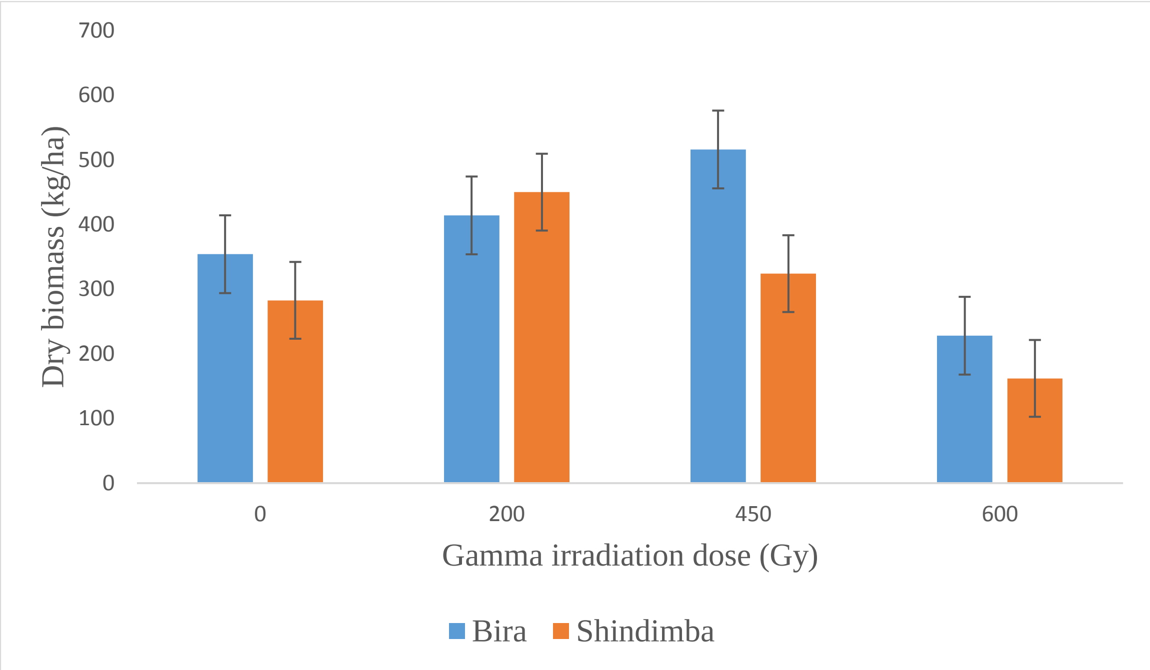

Figure 1: Mean dry biomass (kg/ha) of Bira and Shindimba in response to varying gamma irradiation doses.

The two way analysis of variance yielded a significant interaction between cowpea genotypes and varying gamma irradiation doses. The interaction effect (Variety × Dose) was statistically significant ($p = <.001$). There was a significant difference between the dry biomass of both genotypes at 450 Gy which resulted in the highest (516 kg/ha) in Bira and 324 kg/ha in Shindimba.

4.2 Influence of varying gamma irradiation doses on the pod length of selected cowpea genotypes

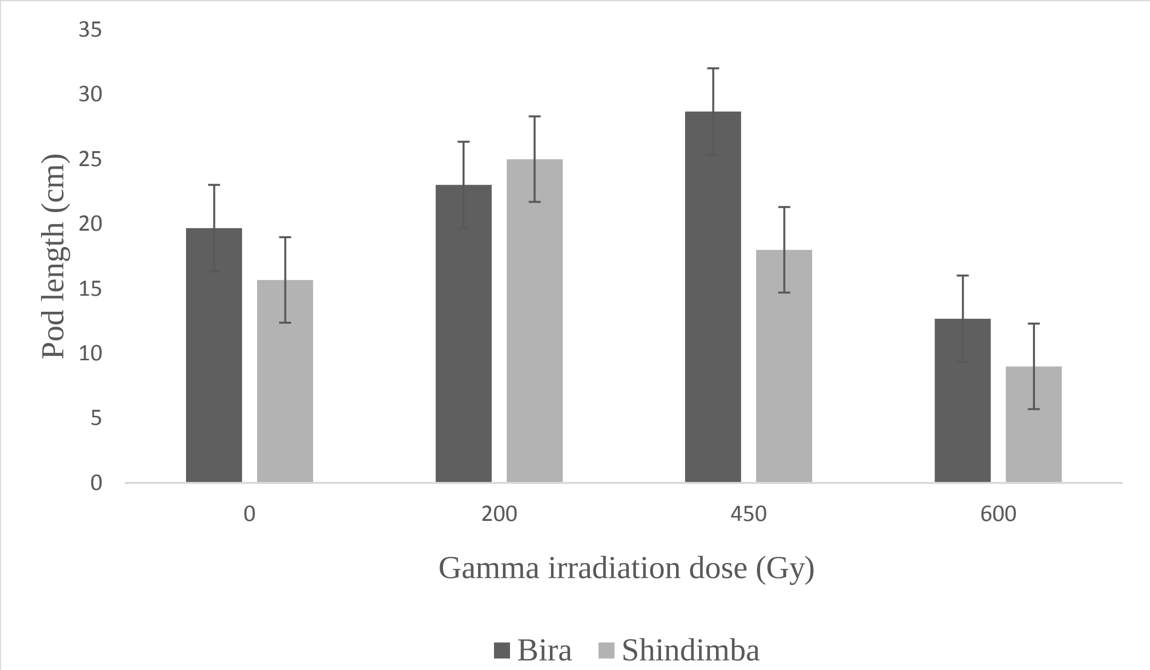

Figure 2: **Mean pod length of Bira and Shindimba in response to varying gamma irradiation doses.**

There was a significant interaction between the dose level and cowpea genotype. The interaction effect (Variety × Dose) was statistically significant (p = <.001). The pod length of Bira was 28 cm and Shindimba was 10 cm as a result of being treated with 450 Gy. The pairwise comparisons suggested that all the varying gamma irradiation doses in both cowpea genotypes produced different pod lengths.

4.3 Influence of varying gamma irradiation doses on the seed yield of selected cowpea genotypes

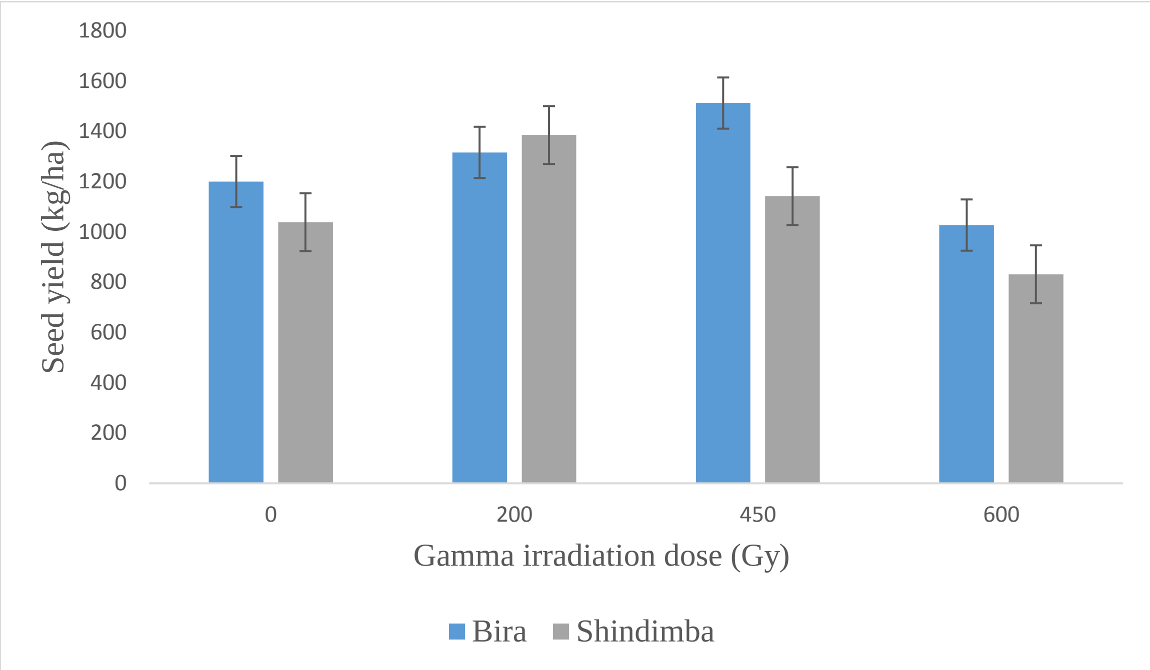

Figure 3: Mean seed yield (kg/ha) of Bira and Shindimba in response to varying gamma irradiation doses.

A simple effect analysis for cowpea genotypes indicated that the means for varying gamma irradiation were significantly different for pod length. The interaction effect (Variety × Dose) was statistically significant ($p = <.001$). There was a significant difference in seed yield of both cowpeas at a dose level of 450 Gy. Bira had the highest (1612 kg/ha) seed yield while Shindimba had a seed yield of 1142 kg/ha at 450 Gy.

CHAPTER 5

DISCUSSION

The experiment showed that fluctuating gamma irradiation doses have an influence on the growth and yield of two cowpea genotypes (Bira and Shindimba). Due to the fact that pod length, dry biomass and seed yield started to increase at 0 Gy and the highest pod length, dry biomass and seed yield was observed at 450 Gy in Bira and at 200 Gy in Shindimba. While 600 Gy resulted in a decreased pod length, dry biomass as well as seed yield in both cowpea genotypes. As seen from previous works conducted by various researches and this could be due to genetic changes which are associated to changes of DNA series and thus transformed the appearance on qualities and individualities of the treated plant part, (Shimelis et al., 2010).

450 Gy produced the highest mean biomass, mean pod length as well as highest mean seed yield (1512 kg/ha) in Bira compared to other irradiation doses. Related increase in yield due to gamma irradiation was reported by Shimelis and Shringani (2010). The seed yield of Bira 450 Gy obtained in the experiment reached the potential yield (1500 to 3000 kg/ha) mentioned by Adeola et al., (2011).

The mean pod length, mean seed yield and mean biomass obtained from 600 Gy reflects that 600 Gy does not improve the growth and yield of the two cowpea genotypes since the parameters measured are less than those obtained from 0 Gy which served as a control. Decrease in shoot length at higher dosages of gamma irradiation have been reported in mung bean (Rakshit et al., 2001).

It is vibrant to note that 0 Gy which served as the control in both cowpea genotypes has the lowest means pod length, means seed yield and means biomass compared 200 and 450 Gy. This existence is in agreement with the fact that the variability of measurable characters manipulating yield may be much greater in mutagenic progenies than in control as reported by Gregory (1995). Reduction in pod length, above ground dry biomass, seed yield at highest dose (600 Gy) may be due to the possible inhibiting action of enzymes. This has led to traits of physiological and biological disorders in the development of leguminous plants as already reported by Larik (1975).

CONCLUSION

- It can be concluded that increasing the gamma irradiation doses from 0 Gy to 600 Gy significantly improves the seed yield, dry biomass and pod length of cowpea genotypes. There was an interaction between cowpea genotypes and varying gamma irradiation doses.

- Based on the differences between the irradiated and non-irradiated seeds, different pod length, seed yield and above ground dry biomass were observed.

- It can be concluded that 450 Gy in Bira and 200 Gy in Shindimba are the optimum doses needed to achieve the highest pod length, dry biomass and seed yield

RECOMMENDATIONS

- Depending on the crop of choice, farmers are ought to use Bira 450 Gy or Shindimba 200 Gy in order to achieve high seed yield.
- Researchers should not increase the dose level to 600 Gy for Bira and Shindimba since it decreased pod length, dry biomass and seed yield.
- The same experiment should be conducted in different regions of the country to put the recommendation on a strong basis.

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APPENDICES

Appendix 1: Analysis of variance for dry biomass (kg/ha)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	120.3	60.2	0.10	
BLOCK.*Units* stratum					
VARIETY	1	32266.7	32266.7	53.76	<.001
DOSE	3	218108.0	72702.7	121.14	<.001
VARIETY×DOSE	3	39140.0	13046.7	21.74	<.001
Residual	14	8402.3	600.2		
Total	23	298037.3			

l.s.d. 42.90

s.e.d. 20.00

c.v% 7

Appendix 2: Analysis of variance for pod length (cm)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	0.333	0.167	0.09	
BLOCK.*Units* stratum					
VARIETY	1	100.042	100.042	53.19	<.001
DOSE	3	673.458	224.486	119.35	<.001
VARIETY.DOSE	3	120.792	40.264	21.41	<.001
Residual	14	26.333	1.881		
Total	23	920.958			

l.s.d. 2.402

s.e.d 1.120

cv% 7.2

Appendix 3: Analysis of variance for seed yield (kg/ha)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	4796.	2398.	0.88	
BLOCK.*Units* stratum					
VARIETY	1	162526	162526	59.58	<.001
DOSE	3	704696	234899	86.10	<.001
VARIETY.DOSE	3	146689	48896	17.92	<.001
Residual	14	38193	2728		
Total	23	1056900			

l.s.d. 2.648

s.e.d 1.234

cv% 4.4