GLOBAL JOURNAL OF PURE AND APPLIED SCIENCES, VOL. 12 NO. 2, MARCH, 2006: 221-224
 ISSN 1118-0579

MUTAGENESIS EFFECTS OF X-IRRADIATION ON THE GERMINATION, GROWTH AND DEVELOPMENT OF MAIZE (ZEA MAYS) SEEDS DUE TO TIME OF EXPOSURE (PART 1)

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(Received 8 June, 2005; Revision Accepted ,29 August, 2005)

ABSTRACT

The time of exposure and mutagenesis effects of X-ray on the germination, growth and development of maize (Zea mays) seeds have been investigated employing a nuclear source, (^{90}Sr as X-ray source; 3mA, 70kv). Five sects of zea mays seeds in different packs were irradiated in different times of exposure and later planted separately with another 6th non-irradiated sects (control experiment) on an open fertile land. Measurements at eight days interval were carried out on the plants' heights, its leaves widths, days to anther and silk for six consecutive times after planting. Results revealed, the day to anther (42) days and day to silk (35) days after planting respectively for the irradiated sects were delayed. A comparative study carried out on all the sects in terms of the plants' height and leaves' width indicated that 83 percent of the plants examined showing consistent mutation in both heights and leaves width as a function of time of exposure.

KEY WORDS: Mutation, X-ray, Exposure, Maize seed, irradiation.

INTRODUCTION

The assessment of the potentials for radiation to inhibit plant germination, and growth and development has a long and complex history. Such assessment of plant responses to radiation is seen within the context of the type/source of irradiation including X-rays and naturally occurring sources such as radium, cobalt and other elements that emit various types of radiation including gamma, beta alpha rays. The biological effects of radiation are essentially due to the chemical changes they induce in plant cells as a result of ionization, excitation, dissociation and atomic displacement. (Evans, 1955, Glenn, 1979, Anmohanran, et al, 2002). Plants are not excepted from these effects..

In spite of its usefulness in agriculture to produce improved varieties of agricultural products, development of improved varieties which have higher yield, production of disease resistant varieties of agricultural plants, development of agricultural products which are better adapted to mechanical harvesting, radiation has some deleterious effects. These effects can be somatic or genetic (Wall, et al, 1980, Mgbenu, et al 1992).

Ionizing radiation (X-ray) is composed of high-energy photons that are capable of damaging DNA and generating caustic free radicals (Hall, 1999,

Walter, 1997, Kevin et al, 1999). The complex molecules making up living organisms are composed of long strands of atoms forming proteins, carbohydrates and fats. They are held together by chemical bonds involving shared electrons. If the ionizing radiation displaces one of the electrons in a chemical bond, it can cause the chain of atoms of break apart, splitting the long molecule into fragments, or changing its shape by elongation. This is an ungluing of the complex chemical bonds so carefully structured to support and perpetuate plants life. The gradual breakdown of these molecular bonds destroys the templates used by the plant to make DNA and RNA (the information carrying molecules in the cell) or causes abnormal cell division.

There is evidence that exposure to X-rays accelerates this breakdown process (Bertell, 1977). Many workers have studied growth and development response to X-rays by plants. Yamada (1917); Nakamura (1923); Komuro (1923); Komuro (1924); Saeki (1936). Their findings revealed that low doses stimulate plants germination; growth and development while high doses inhibit germination and consequently development stages in plants.

Time of exposure must be taken into account in assessing the effects of radiations on population (Grover, et al 2002). An awareness of deleterious effect due to time of exposure and the fact that most radiation-induced mutation in plants are undesirable (Mgbenu, et al 2002) has prompted this study. This baseline study will form basis for assessing any future effect of radiations on plants due to exposure by plant breeders.

MATERIALS AND METHODS

Maize seeds (Ife-Brown) of high viability were collected from Agricultural Department, University of Ado-Ekiti, Nigeria. a very bushy, moist, loamy piece of land measured 600cm by 500cm. (300000cm^2) in the experimental garden of the Department of Plant Science and Forestry, University of Ado Ekiti which had been lying fallow for long was cleared off with cutlass. Land tilling was done with hoes to provide good and sufficient aeration to the soil. Prior to planting, soil sample was taken from the experimental site for analysis, to ascertain that soil and climatic requirements are normal as reported by (Sprague, et al, 1988). The physical and chemical characteristics of that soil sample are given in Table 1.

The seeds were air-dried prior to irradiation (Yamada, 1917, for 168 hours) for them to attain room temperature. The seeds were then packed into plastic dishes verified to be non-radioactive in six (6) different sects. Sect one (1) was not irradiated (control experiment) while sects two (2), three (3), four (4), five (5), and six (6) were irradiated at X-ray unit of State Hospital Ado-Ekiti in different periods of time; 1.0 second, 1.6 seconds, 2.5 seconds, 4.0 seconds and 5.0 second at the rate of 70kV per second in the same day.

Planting was done in the month of April year 2000 when rain had become consistent. Seeds were sown per row at two seeds per stand at 75cm between rows and 25cm between plants spacing with depth 5cm. Non-irradiated sects

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Table 1. Physical and Chemical characteristics of the soil sample

Properties	Value
PH	6.50
Organic Matter Content	3.50
Nitrogen (N)	0.08
Phosphorus (P)	3.50
Potassium (K)	1.36
% Sand	52
% Clay	26
% Silt	22

(Department of Agriculture, University of Ado-Ekiti)

Table 2: Recorded variation in heights (H) and widths (W) of leaves of maize plants

DAYS	Sects in seconds											
	1 0.00		2 1.00		3 1.60		4 2.50		5 4.00		6 5.00	
	Heights and Widths in cm											
	H_1	W_1	H_2	W_2	H_3	W_3	H_4	W_4	H_5	W_5	H_6	W_6
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	22.20	5.60	17.00	2.60	14.00	3.30	11.20	3.50	8.40	2.30	5.30	2.90
22	29.10	6.60	24.40	4.30	20.10	4.00	17.40	4.30	13.30	300	9.30	3.30
30	46.00	7.00	40.00	5.10	36.40	5.50	32.50	5.80	27.30	4.50	22.60	4.10
38	65.40	7.50	56.30	6.00	50.30	6.30	45.70	6.50	40.20	5.50	35.10	4.80
46	81.14	8.50	75.20	7.50	65.10	7.10	60.20	6.80	55.00	6.50	51.10	5.80
54	95.32	9.50	90.41	8.20	85.30	7.80	77.20	7.40	72.10	7.00	68.30	7.20

(control experiment) was planted in row one (1), while irradiated sects were planted in rows two (2), three (3), four (4), five (5) and (6). The area used was fenced with planks to prevent passers by or rodents from destroying the planted seeds. Weeding was done as necessary. The mean average heights and widths of leaves of plants in every row is taken with tape rule and recorded at eight days interval for fifty four days (54) as seen in Table 2. From the first day of planting, maximum vigilance was put to observe any changes on the farm. No noticeable change was recorded until the sixth day when the maize seeds started germinating.

RESULTS

After two weeks of planting, measurements and thorough observation commenced. The measurements carried out on the plants were based on variation in the heights in (cm) and the widths of leaves. The mean measured values are tabulated in table 2. These variations in heights and widths are shown graphically in figures 1 and 2. These figures are in good agreement with Dose-response curve (characteristic shape for a biological effect that exhibit a threshold dose) (Herman, 1989).

DISCUSSION

X-irradiation can cause germ-line mutations, potentially affecting future generation (Kevin, et al, 1999). Although X-ray is commonly believed to create bizarre mutations, data show that it merely increases the frequency of mutations occurring naturally in the general population (Wort, 1941). Time of exposure is required to double this baseline mutation rate (Smith, 1935). The results obtained in Table 2 show that there were drastic reduction in heights and widths in respect to time of exposure, which confirmed Smith report.

In addition, days to tasselling (period when the whorl protecting inflorescence split to expose the tassel), days to silking (time of appearance of the female inflorescence), days to anther (transition from vegetable phase to reproductive phase), were delayed in some of irradiated sects, while some could not reach these stages and dried-up gradually. These are in good agreement with the results obtained by (Shull, et al, 1933) that X-radiation seriously disrupts the chemistry of the cell.

The probability of cytotoxic mutation index in the nearest future generations was estimated using the (Nobuko et al, 1989) relationship, which is given as

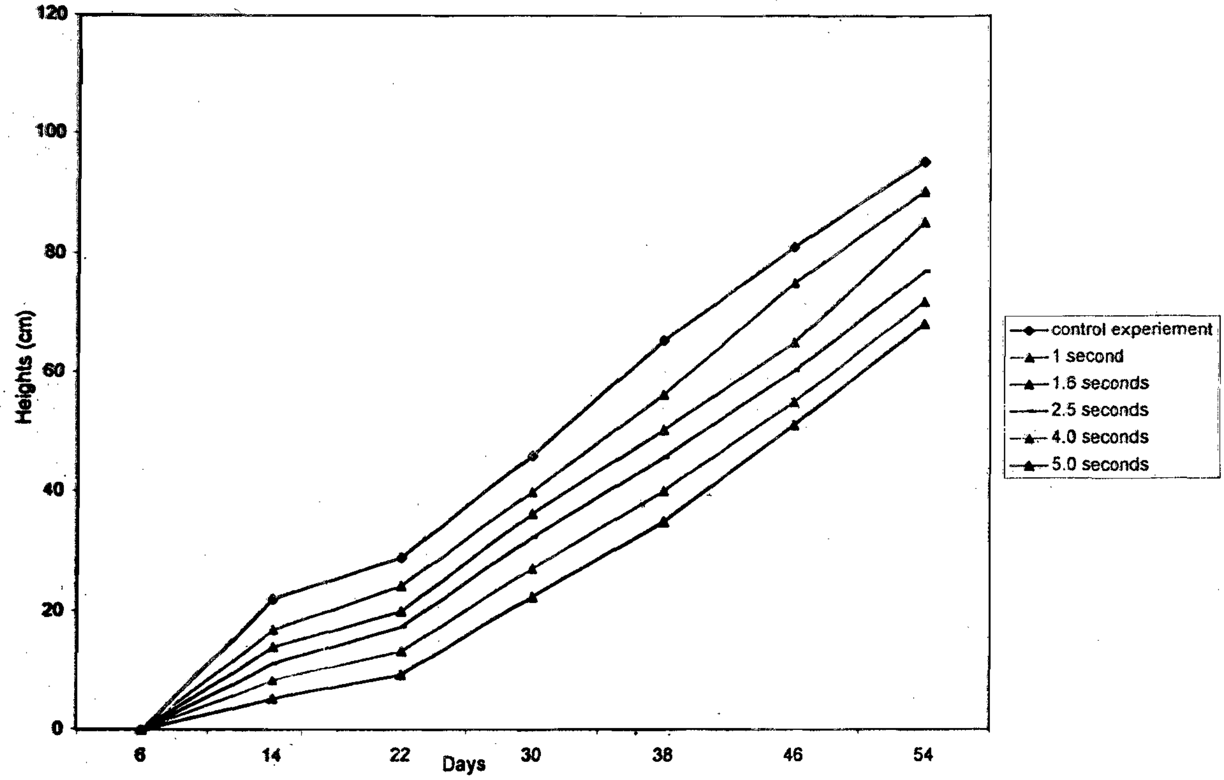

Fig. 1: Variation in heights of plants per day

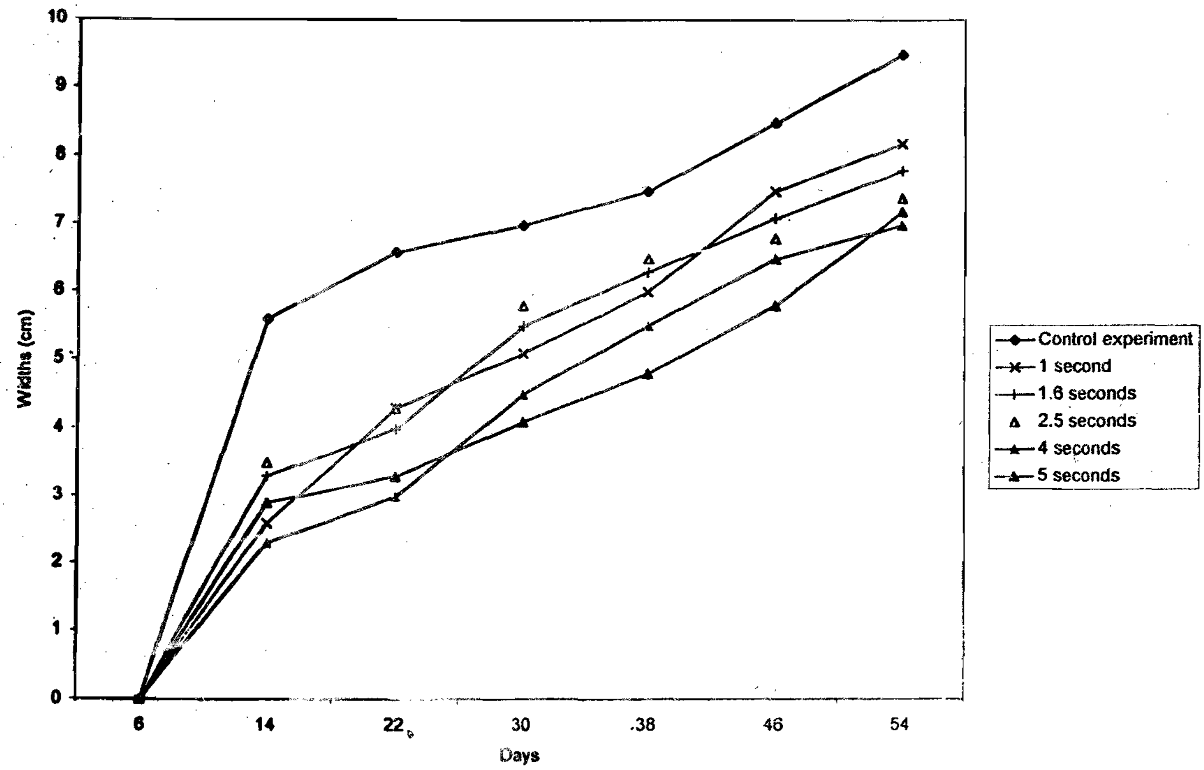

Fig. 2: Variation in widths of leaves per day

$$\% \text{ cytotoxic mutation index} = \left(\frac{T_P - T_S}{T_P}\right) 100$$

Where Ts represents number of non-irradiated row and T_p represents total numbers of rows. This was calculated to be 83%.

This result indicates that the genetic information of the maize seeds has been altered (point mutation) as seen in the overlapping areas of Figure 2. Since mutation results from damage to one point of gene, the maize seeds descendants may show some sort of abnormalities in future. The reduction in plants heights and widths of leaves of irradiated sects compared to non-irradiated sect can be seen to be significant over a long period of exposure. These are in good agreement with exposure relationship given as

$$\text{Exposure time} = \frac{\text{Exposure}}{\text{Exposure rate}} \quad \text{(Grover, et al, 2002)}$$

This algebraic expression simply implies that if the exposure time is kept long then the resulting harmful effects to plants is great.

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