



Full Length Article

Evaluating the Performance of Amiprophos Methyl and γ -irradiated Seeds on Growth and Yield Traits of Pigeon Pea

Ogbu Udensi^{1*} and Valentine Otang Ntui^{1,2}

¹Department of Genetics and Biotechnology, University of Calabar, PMB 1115, Calabar, Nigeria

²Laboratory of Plant Cell Technology, Graduate School of Horticulture, Chiba University, Japan

*For correspondence: princeuou4u@yahoo.com; ntuival@yahoo.com

Abstract

The seeds of two varieties of pigeon pea [*Cajanus cajan* (L.) Mill], brown “Fiofio” and white “Fiofio”, were treated with 0, 4, 6 and 8 ppm amiprophos methyl (APM) for 48 h, or exposed to γ -irradiation at 0, 200, 400, 600 Gy (Gray) from ⁶⁰Co source. There was significant ($P < 0.05$) effect of the mutagenic treatments on all the growth and yield traits evaluated except for percentage germination and these effects were dose-dependent. Seeds exposed to 200 Gy of γ -rays gave better seed yield when compared with APM soaked seeds. The treatment of pigeon pea seeds with APM and γ -rays could serve as alternative breeding and improvement techniques to achieve high seed productivity, especially at lower doses. Succinctly, it does suggest that if mutagenic process is monitored and directed carefully, it could proffer significant alternative for improving pigeon pea landraces, especially if the seeds are exposed to γ -irradiation at the dose of at least 200 Gy. © 2013 Friends Science Publishers

Keywords: Amiprophos methyl; γ -irradiation; Mutation breeding; Pigeon pea; Improvement

Introduction

Pigeon pea [*Cajanus cajan* (L.) Mill] is a multipurpose legume crop, which is well adapted even in marginal lands (Joshi *et al.*, 2009). Legumes are valuable sources of carbohydrates, dietary fibers, vitamins, minerals and particularly proteins (17-40%) higher than cereals (7-13%) but coincidentally equals to the protein in meat (18-25%) (Tharanathan and Mahadevamma, 2003; De Almeida Costa *et al.*, 2006; Udensi *et al.*, 2011a). Leaf preparations from pigeon pea have been used as therapy for jaundice, inflammation and sores of the mouth (Parrotta, 2001). The high adaptability, heritability, genetic variability and nutritive values reported of locally grown pulses (landraces) (Udensi *et al.*, 2011a, b) calls for concerted efforts towards its improvement.

It has been observed that genetic variability is very pivotal to successful breeding programme (Udensi *et al.*, 2011a). Mutagenic agents such as chemicals, γ -rays, x-rays, electron beam irradiation, etc. are usually employed to induce variability artificially. This process produces mutants (Ciftci *et al.*, 2006; Boureima *et al.*, 2009), which could then facilitate the isolation, identification and cloning of genes used in designing crops with yield and quality traits (Ahloowalia and Maluszynski, 2001). According to Mahandjiev *et al.* (2001) induced mutation has great potentials and serves as a complementary approach in genetic improvement of crops. Khan and Al-Qurainy (2009) highlighted the use of induced mutation in the improvement

of major crops such as wheat, rice, barley, cotton, peanut and cowpea, which are seed propagated. The ability of these mutagens to penetrate the cell of living organisms to interact with the DNA molecules produces the general toxic effects associated with their mutagenic properties.

The availability of seed germination system after irradiation is very crucial in achieving successful mutagenesis (Ciftci *et al.*, 2006). However, physiological and biochemical processes such as germination, seedling emergence and seedling survival have been reported to be affected by γ -irradiation stress and other mutagenic treatments. It has been reported that irradiation of seeds with high dose of γ -rays disturbs protein synthesis (Xiuzher, 1994), hormonal balance (Rabie *et al.*, 1996) leaf gas-exchange and enzyme activity (Stoeva and Bineva, 2001). It is widely believed that, increasing the ploidy level confers distinct advantages for the development of important agronomic traits in plants such as larger and deeper coloured flowers in carnation and cyclamen (Takamura and Miyajima, 1986; Yamaguchi, 1989), thicker and broader leaves that result in the production of larger fruits in apple (Soloveva, 1990). Furthermore, increased ploidy level can result in a better adaptability of individuals and increased organ and cell sizes in *Andropogon gerardii* (Keeler and Davis, 1999) and a tendency for stomata cell size to increase in *Manihot esculenta* (Carvalho *et al.*, 1999).

Amiprophos methyl (APM) is an example of a phosphoramidates herbicide, which has been used intensively in agriculture. This notwithstanding, it has been

reported to effect shoot and root elongation and development severely, causing both shoots and roots to be stunted with a characteristic swollen tip (Anthony and Hussey, 1999). Their action is such that they bind to the same site(s) on the α, β -tubulin dimer thus, inhibiting microtubule polymerization. This however, prevents the formation of chromatic fuses and inducing separation of the metaphasic chromosomes (Blume *et al.*, 2003).

Driven by the desire to improve the performance of pigeon pea landraces such that its production capacity can be increased significantly, a major objective of the present study was to evaluate comparatively the extent to which some of its agronomic traits could be influenced following treatment with amiprophos methyl (APM) and γ -rays.

Materials and Methods

Seeds of two varieties of pigeon pea (brown “Fiofio”, white “Fiofio”) were obtained from the germplasm collection of Udensi, O. Ugorji at the University of Calabar, Nigeria. The seeds were divided into two sets. For the first set, 30 seeds were soaked in 50 mL of each of the APM concentration, 0, 4, 6 and 8 ppm for 48 h bringing the final volume to 60 cm³, while the second set were exposed to γ -irradiation at the National Atomic Energy Commission (NAEC), Abuja, Nigeria at 0, 200, 400, 600 Gy (Gray) from ⁶⁰Co source for 120 seconds. The application was done according to the FAO/IAEA Agricultural and Biotechnology Laboratory in Seibersdorf, Austria in February 2008 (Ciftci *et al.*, 2006).

The treated seeds were then sown on a plot of land measuring 12x12 m using randomized complete block design in a 2x4x4 factorial layout with 6 replications. This experiment was carried out in the University of Calabar Experimental Farm, Calabar, Nigeria, during the 2009-2011 growing seasons. Sixteen beds were made with a spacing of 2 m between beds. Three seeds per variety were sown in a hole of 4cm deep according to the method of (Center for New Crops and Plants Products, 2002). A spacing of 20x75 cm was maintained between stands. After one month of planting, percentage germination and days to seedling emergence were estimated while percentage seedling survival was calculated after 2 months. Other morphological traits were also recorded after 3 and 6 months. For the estimation of the leaf area, the leaves were laid on a 1-cm grid (graph paper) and their outlines were traced. The numbers of cm² were calculated, including the partial square and multiplied by 0.1 cm². However, all partial squares that are less than half covered were excluded (Udensi *et al.*, 2012a). The seed yield per plant was estimated by multiplying the average number of seeds per pod per plant and the average number of pod per plant.

Data Analysis

Data on germination, morphological and yield attributes were recorded and subjected to analysis of variance

(ANOVA) while least significant difference (LSD) test was used in separating significant means (Obi, 2002).

Results

Germination Parameters

Results on percentage seed germination after treatment with the two mutagens show that there were no significant differences ($P > 0.05$) between the mutagens, dose or variety notwithstanding. There was also no significant effect ($P > 0.05$) of APM treatment on the days to 50% seedling emergence, but when the seeds were exposed to γ -irradiation, days to 50% seedling emergence was drastically delayed. Plants in the control experiment of the γ -irradiated seeds and the seeds exposed to 200 Gy showed no significant differences ($P > 0.05$) but when exposed to 400 and 600 Gy of γ -rays led to the death of the plants. However, for the APM treated seeds, there were significant differences ($P > 0.05$) even at the highest concentration (Fig. 1-3).

Phenological Attributes

The result showed that treatment of the seeds of pigeon pea with the different mutagens caused a dose-dependent effect on the days to 50% flowering. Days to 50% maturity was slightly affected by the mutagens used. There was no significant differences ($P > 0.05$) observed between the seeds soaked in 4, 6 and 8 ppm of APM and those treated with 200 Gy of γ -rays for brown “Fiofio”. The control of white “Fiofio” and the seeds exposed to 200 Gy showed no significant differences ($P > 0.05$) with those soaked in 6 ppm of APM (Figs. 4 and 5).

Morphological Attributes

There were significant ($P < 0.05$) effects of APM and γ -irradiation on all the morphological traits investigated (Table 1). As the concentration of APM increased, the number of branches per plant decreased. However, plants from seeds treated with γ -irradiation at 200 Gy produced maximum branches. The result revealed that at 4 ppm of APM, the number of leaves per plant increased, which reduced thereafter. For the γ -rays treated seeds, the maximum number of leaves 143 and 459 at 3 and 6 months, respectively was observed for the brown “Fiofio” when seeds were exposed to 200 Gy. On the other hand, the leaves from plants exposed to γ -irradiation were smaller in size than those treated with APM. Additionally, there was a dose-dependent effect of the mutagens used on the number of flowers per plant. The plants raised from seeds treated with 4 ppm APM and 200 Gy of γ -rays produced more flowers. Comparing the two mutagens, our result indicates that γ -irradiation induces more flowers per plant than APM treatment with the highest number (776.7) obtained for

Table 1: Effect of amiprofos methyl (APM) and γ -rays (Gy) treatments on morphological (growth) traits in *Cajanus cajan*

| Trait | White "Fiofio" | | | | Brown "Fiofio" | | | | White "Fiofio" | | | | Brown "Fiofio" | | | |
|------------------|-----------------|-----------------|-----------------|----------------|-----------------|----------------|----------------|----------------|-----------------|-----------------|-----|-----|-----------------|-----------------|-----|-----|
| | APM | | | | APM | | | | Gy | | | | Gy | | | |
| | 0 | 4 | 6 | 8 | 0 | 4 | 6 | 8 | 0 | 200 | 400 | 600 | 0 | 200 | 400 | 600 |
| PH ₃ | 120.7d ±5.2 | 130.2b ±1.9 | 123.3bc ±4.4 | 121.4d ±3.5 | 124.4bc ±3.7 | 131.7b ±5.6 | 134.9a ±1.6 | 132.1a ±2.7 | 93.17d ±2.4 | 111.3d ±6.9 | ND | ND | 86.0de ±3.3 | 102.8d ±8.6 | ND | ND |
| PH ₆ | 274.2a ±2.3 | 262.9b ±8.9 | 263.7b ±2.1 | 258.7b ±5.9 | 235.5c ±8.9 | 234.1c ±3.0 | 241.7c ±5.7 | 232.0c ±6.9 | 204.4de ±3.0 | 204.2de ±1.4 | ND | ND | 153.7de ±8.1 | 215.1cd ±2.5 | ND | ND |
| NB ₃ | 8.2a ±0.9 | 9.0a ±0.9 | 7.7b ±0.4 | 6.7c ±0.5 | 7.5b ±0.6 | 8.3a ±0.7 | 8.5a ±0.2 | 8.3a ±0.8 | 7.7b ±0.8 | 10.8a ±1.1 | ND | ND | 7.5b ±0.9 | 6.3cd ±0.9 | ND | ND |
| NB ₆ | 16.0a ±1.9 | 16.5a ±0.8 | 15.7a ±1.2 | 15.0b ±0.5 | 16.5a ±1.2 | 12.7c ±0.3 | 15.3b ±1.0 | 13.3c ±0.2 | 13.8b ±0.5 | 20.2a ±2.5 | ND | ND | 14.3b ±0.7 | 19.0a ±1.3 | ND | ND |
| NL ₃ | 100.8a ±8.4 | 112.7a ±8.4 | 101.7a ±4.2 | 84.5c ±3.3 | 117.8a ±5.4 | 128.7a ±9.1 | 91.7b ±3.3 | 88.3b ±3.9 | 99.0b ±5.9 | 134.0a ±2.0 | ND | ND | 85.67c ±7.6 | 143.8a ±1.2 | ND | ND |
| NL ₆ | 369.5b ±5.8 | 483.5a ±9.3 | 394.7b ±3.3 | 288.3d ±2.4 | 347.2b ±5.4 | 446.2b ±1.6 | 323.2d ±1.4 | 339.5c ±5.4 | 358.5b ±5.7 | 393.8b ±4.6 | ND | ND | 204.2d ±5.5 | 459.2a ±1.9 | ND | ND |
| INL ₃ | 5.7b ±0.2 | 4.4c ±0.2 | 4.8c ±0.3 | 4.6c ±0.2 | 5.6b ±0.1 | 5.0bc ±0.2 | 5.2b ±0.1 | 6.8a ±0.2 | 4.6c ±0.2 | 5.3b ±0.3 | ND | ND | 5.2b ±0.1 | 4.4c ±0.2 | ND | ND |
| INL ₆ | 6.0a ±0.3 | 6.1a ±0.4 | 6.1a ±0.3 | 6.2a ±0.2 | 5.7b ±0.2 | 6.3a ±0.1 | 6.0a ±0.1 | 5.9a ±0.2 | 5.5b ±0.3 | 5.3b ±0.1 | ND | ND | 6.0a ±0.3 | 5.1bc ±0.1 | ND | ND |
| PTL ₃ | 4.3a ±0.5 | 3.6b ±0.4 | 3.6b ±0.2 | 3.3b ±0.2 | 3.1b ±0.3 | 2.6bc ±0.2 | 2.9bc ±0.1 | 3.1b ±0.2 | 3.2b ±0.1 | 3.6b ±0.2 | ND | ND | 4.0a ±0.2 | 3.6b ±0.2 | ND | ND |
| PTL ₆ | 6.3a ±0.4 | 6.6a ±0.1 | 6.8a ±0.1 | 6.4a ±0.2 | 5.6b ±0.4 | 5.7b ±0.1 | 5.7b ±0.3 | 5.7b ±0.2 | 5.8b ±0.3 | 5.1c ±0.2 | ND | ND | 5.7b ±0.1 | 5.3b ±0.2 | ND | ND |
| LA ₃ | 70.6d ±3.5 | 83.5b ±3.1 | 92.3a ±3.9 | 82.4bc ±2.4 | 68.0d ±4.1 | 49.8e ±1.8 | 55.7e ±2.2 | 61.01d ±2.1 | 79.74c ±1.4 | 82.8b ±3.1 | ND | ND | 90.5a ±2.9 | 78.2d ±3.8 | ND | ND |
| LA ₆ | 107.87d ±6.3 | 119.7bc ±3.3 | 119.3d ±5.0 | 122.5b ±3.8 | 116.7d ±5.0 | 123.1b ±5.3 | 127.6a ±5.1 | 119.3d ±4.1 | 77.3de ±4.3 | 89.7d ±6.1 | ND | ND | 61.8de ±2.3 | 81.9de ±2.0 | ND | ND |
| NOF | 128.8f ±1.6 | 144.5e ±0.9 | 123.3g ±2.0 | 106.0i ±1.1 | 117.8i ±2.1 | 150.5e ±1.7 | 121.2h ±0.6 | 100.5j ±2.0 | 204.5c ±1.8 | 776.7a ±1.5 | ND | ND | 186.7d ±0.8 | 322.0b ±0.4 | ND | ND |

PH₃= Plant height at 3months; PH₆= Plant height at 6months; NB₃ = Number of branches at 3months; NB₆= number of branches at 6months; NL₃= Number of leaves at 3months; NL₆ = Number of leaves at 6months; INL₃= Inter-node length at 3months; INL₆ = Inter-node length at 6 months; PTL₃ = Petiole length at 3 months; PTL₆ = Petiole length at 6 months; LA₃= Leaf area at 3 months; LA₆ = leaf area at 6 months; NOF = Number of flowers per plant; ND= No data

*Means followed with the same case letter along each horizontal array indicate no significant difference (P > 0.05)

Table 2: Effect of amiprofos methyl (APM) and gamma rays (Gy) treatments on yield traits in *Cajanus cajan*

| Trait | White "Fiofio" | | | | Brown "Fiofio" | | | | White "Fiofio" | | | | Brown "Fiofio" | | | |
|--------|----------------|----------------|----------------|----------------|----------------|-----------------|----------------|----------------|----------------|-----------------|-----|-----|----------------|-----------------|-----|-----|
| | APM | | | | APM | | | | Gy | | | | Gy | | | |
| | 0 | 4 | 6 | 8 | 0 | 4 | 6 | 8 | 0 | 200 | 400 | 600 | 0 | 200 | 400 | 600 |
| NOP | 68.3h ±1.3 | 104.3e ±1.9 | 88.2f ±0.8 | 60.3h ±1.1 | 68.2h ±0.8 | 110.5e ±1.5 | 74.7g ±1.9 | 66.5h ±1.5 | 199.0b ±0.5 | 428.8a ±5.3 | ND | ND | 137.8d ±1.4 | 156.2c ±0.9 | ND | ND |
| NOS | 6.3c ±0.1 | 6.1cd ±0.1 | 6.0d ±0.2 | 6.2c ±0.1 | 5.6d ±0.2 | 6.0d ±0.2 | 5.7d ±0.1 | 5.8d ±0.2 | 6.5c ±0.2 | 7.3a ±0.3 | ND | ND | 7.0ab ±0.3 | 6.8b ±0.3 | ND | ND |
| POL | 5.5cd ±0.2 | 5.7c ±0.2 | 5.2d ±0.3 | 5.7c ±0.2 | 5.3d ±0.2 | 5.2d ±0.1 | 5.0d ±0.3 | 5.0d ±0.2 | 6.5b ±0.1 | 7.3a ±0.2 | ND | ND | 7.0ab ±0.4 | 6.8b ±0.2 | ND | ND |
| SY | 499.5d ±3.5 | 573.7d ±1.3 | 353.5e ±4.9 | 342.7e ±8.9 | 363.7e ±5.3 | 571.8d ±02.4 | 373.3e ±9.3 | 332.5e ±6.8 | 774.0c ±9.3 | 3155.3a ±3.9 | ND | ND | 963.2b ±1.4 | 1074.7b ±9.7 | ND | ND |
| 100-SW | 13.6ab ±0.2 | 14.2a ±0.2 | 14.1a ±0.3 | 13.4b ±0.3 | 11.7d ±0.4 | 11.4d ±0.3 | 11.2d ±0.3 | 12.4c ±0.2 | 11.0d ±0.2 | 13.6d ±0.6 | ND | ND | 12.7b ±0.1 | 11.8cd ±0.4 | ND | ND |

NOP = Number of pod per plant; NOS = Number of seeds per pod; POL = Pod length; SY = Seed yield; 100-SW = 100 Seed weight; ND= no data

*Means followed with the same case letter along each horizontal array indicate no significant difference (P > 0.05)

white "Fiofio" at 200 Gy.

Yield Attributes

Maximum numbers of pods were recorded in plants of both cultivars raised from seeds treated with 200 Gy γ -rays and 4 ppm APM. Concentrations of exposure of the two mutagens did not significantly affect (P > 0.05) number of seeds per pod, 1000-seed weight and pod length although white "Fiofio" produced the highest number (7.3) of seeds per pod

at 200 Gy. Moreover, higher seed yield was obtained in plants of both cultivars raised from seeds exposed to 200 Gy γ -rays and 4 ppm APM (Table 2).

Discussion

Mutation breeding has been used as an alternative technique for the improvement of desired traits in agricultural crops (Ciftci *et al.*, 2006; Boureima *et al.*,

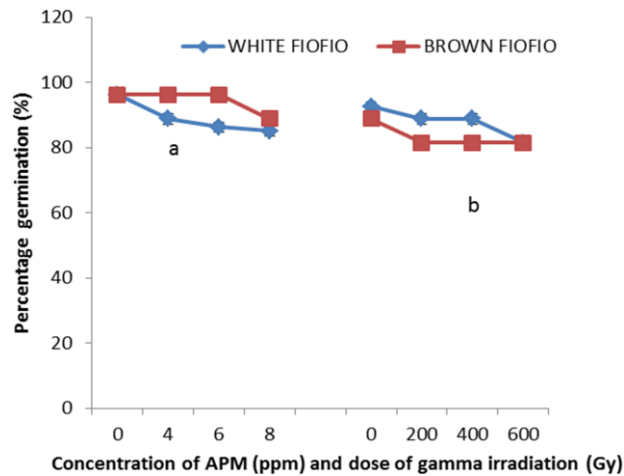


Fig. 1: Effect of (a) APM and (b) gamma rays treatments on percentage germination

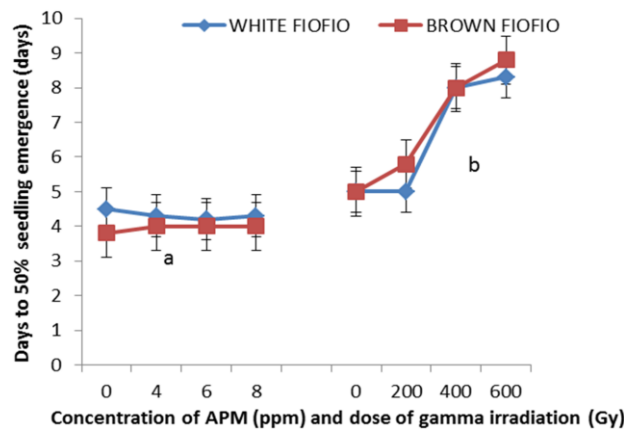


Fig. 2: Effect of (a) APM and (b) gamma rays treatment on days to seedling emergence

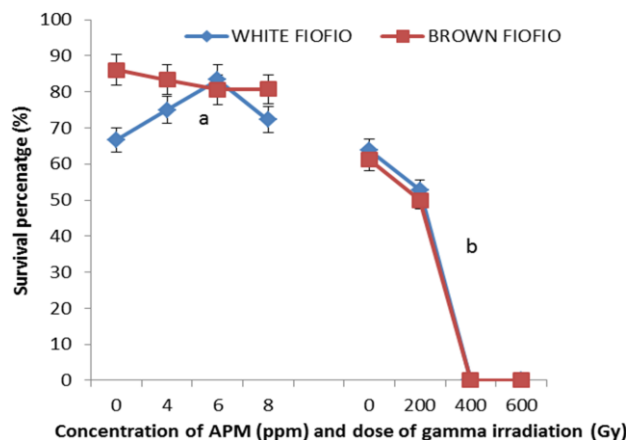


Fig. 3: Effect of (a) APM and (b) gamma rays treatment on survival percentage

2009). There are reports that the exposure of seeds to γ -irradiation either for improvement or seed preservation has

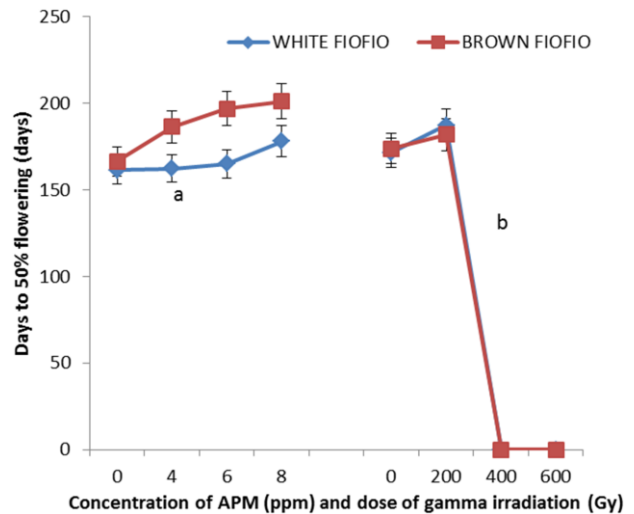


Fig. 4: Effect of (a) APM and (b) gamma rays treatment on days to 50% flowering

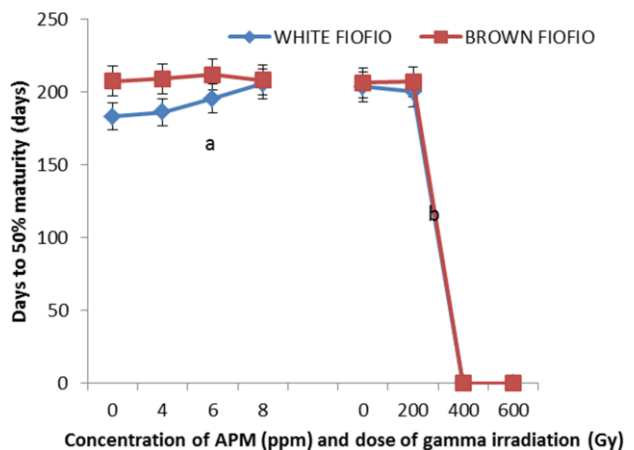


Fig. 5: Effect of (a) APM and (b) gamma rays treatment on days to 50% maturity

negative effects (Xiuzher, 1994; Rabie *et al.*, 1996; Stoeva and Bineva, 2001; Boureima *et al.*, 2009; Udensi *et al.*, 2012c), which might compromise the aim for the improvement as well as the quality of the seeds. Frequently observed symptoms in the low-or high-dose-irradiated plants are enhancement or inhibition of germination, seedling growth and other biological responses (Kim *et al.*, 2000; Wi *et al.*, 2007). Our results shows that there were significant effects ($P < 0.05$) of low concentration of APM and γ -irradiation treatments on germination, morphological and yield traits evaluated except on percentage germination. Though no certain explanations for the stimulatory effects of low-dose γ -radiation have been proffered, it is believed that at low dose irradiation there is induced growth stimulation by changing the hormonal signalling network in plant cells or by increasing the anti-oxidative capacity of the

cells to easily overcome daily stress factors (Wi *et al.*, 2007), while at high-dose irradiation that caused growth inhibition there is cell arrest of cycle at G2/M phase during somatic cell division and/or various damages in the entire genome (Preussa and Britta, 2003).

It has been reported that increasing dose of γ -irradiation caused reduction in germination percentage in crops such as cowpea (Uma and Salimath, 2001), chickpea (Toker and Cagiran, 2004), *Phaseolus lunatus* (Kumar *et al.*, 2003), lentil (Kumar and Sinha, 2003), rice (Pons *et al.*, 2001). This reduction has been largely attributed to a delay or inhibition in physiological and biological processes necessary for seeds to germinate, which include enzyme activity, hormonal imbalance and inhibition of mitotic process (Xiuzher, 1994; Rabie *et al.*, 1996; Stoeva and Bineva, 2001; Khan and Al-Qurainy, 2009). Contrary to our present result, the mutagenic treatments did not affect germination significantly. Arguably, the mutagenic treated seeds might have probably developed tolerance to the inhibitory effect of the treatments on germination and had therefore improved their physiological conditions resulting to delayed seed germination without necessarily affecting percentage germination.

It is not surprising that seeds treated with high doses of γ -rays as reported in the current study died. It has been reported that the ability of high concentrations of mutagens to interact with chromosomal deoxyribonucleic acid (DNA) is the underlying cause of the general toxic effects associated with their mutagenicity (Tosca *et al.*, 1995; Mensah and Akomeah, 1997; Kovács and Keresztes, 2002; Mensah *et al.*, 2005; Kiong *et al.*, 2008). Chromosome aberrations following amiprofos methyl treatment was reported by Udensi *et al.* (2011c). It is, therefore, reasonable to affirm that the generally lower survival percentages seen with the γ -irradiated seeds in this study, especially could be attributed mainly to either physiological disturbance, which possibly may have affected some biochemical pathways in the seedlings or this may have arisen as a result of chromosomal damages resulting from the toxicity associated with direct interaction between γ -rays and DNA molecules (Kovács and Keresztes, 2002; Ashraf *et al.*, 2003; Kiong *et al.*, 2008).

Plants raised from seeds exposed to 200 Gy γ -rays performed much better than the amiprofos methyl-soaked seeds for all the morphological characters evaluated, the early establishment of those treated with amiprofos methyl notwithstanding. This corroborates the findings of Toker *et al.* (2005) who reported that seedlings irradiated at 200 Gy had significant increase in their shoot length, but at 400 Gy an obvious depression in shoot length was observed on chickpea seeds.

APM soaked seeds grew taller than the plants grown from γ -irradiated seeds. Surprisingly, this however, did not give rise to more branches per plant compared to 200 Gy γ -rays treated seeds. The higher number of branches observed in plants from seeds exposed to 200 Gy of γ -rays resulted in

greater number of leaves plant⁻¹. Photosynthetically, it should be logical to assume that the more the number of leaves, the higher the seed yield. Undoubtedly, broader the leaf, more surface area will be exposed to photosynthetic activities (Fagwalawa, 2000; Udensi *et al.*, 2011a, b; 2012a, b). This relationship was not observed in the present study as APM soaked seeds had broader leaf surface than plants raised from γ -irradiated seeds but however, produced more seeds than the former. In the report of Udensi *et al.* (2012b), there was induction of polyploidy (chromosome doubling) when seeds of pigeon pea were soaked in 4 ppm APM. The leaf area of APM treated seeds was broader than the leaf area of the seeds exposed to γ -irradiation, which correlates with the findings of Udensi *et al.* (2011a).

Days to 50% flowering did not differ significantly ($P>0.05$) between plants from seeds treated with 4, 6 and 8 ppm APM and those exposed to 200 Gy of γ -rays, especially for the white variety. It is noteworthy that brown "Fiofio" flowered earlier when soaked in APM than when exposed to γ -irradiation. Furthermore, white "Fiofio" produced more flowers than the brown variety. It might suggest that the time of anthesis initiation does not correlate significantly with the number of flowers produced. It is worthy to note that one of the goals of genetic manipulation of crops is to reduce the time of maturity. It thus means that any breeding method that fails in this respect should be reconsidered. Landraces of pigeon pea mature approximately 180-190 days (Udensi *et al.*, 2011a, b, c). From our present report, the treatments seem to have delayed the maturity time of white "Fiofio".

The aim of plant breeders and farmers is to produce a high yielding crop variety. Our result revealed that plants had delayed maturity time produced greater number of seeds. Suggestively, though not disregarding the reduction in maturity time of the crop, if the delay could lead to increased seed yield, it will be a step in the right direction.

There is positive relationship between number of flower per plant, number of pod per plant, number of seeds per pod, pod length and seed yield. This position corroborates the earlier report of Udensi *et al.* (2012a, b). This association was so pronounced in plants from seeds treated with 4 ppm APM and 200 Gy of γ -irradiation. It will therefore be convincing to assert that improving these yield traits in pigeon pea will help in no small measure in boosting the crop yield (Udensi *et al.*, 2012a).

In conclusion, if this mutagenic process is monitored and directed carefully, it could proffer significant alternative for improving pigeon pea landraces, especially if the seeds are exposed to γ -irradiation @ 200 Gy. Comparatively, plants raised from seeds exposed to 200 Gy γ -irradiation did better than the plants raised from APM soaked seeds. White Fiofio was highly responsive to γ -irradiation and gave higher yield. Suggestively, doses of 200 to 300 Gy of γ -irradiation could be tried to evaluate the response of pigeon pea to growth and yield traits.

References

- Ahloowalia, B.S. and M. Maluszynski, 2001. Induced mutation: A new paradigm in plant breeding. *Euphytica*, 118: 167–173
- Anthony, R.G. and P.J. Hussey, 1999. Dinitroaniline resistance and the microtubule cytoskeleton. *Trends Plant Sci.*, 4: 112–116
- Ashraf, M., A.A. Cheema, M. Rashid and Z. Qamar, 2003. Effect of gamma rays on M1 generation in Basmati rice. *Pak. J. Bot.*, 35: 791–795
- Blume, Y.B., A.Y. Nyporko, A.I. Yemets and W.V. Baird, 2003. Structural modeling of the interaction of plant α -tubulin with dinitroaniline and phosphoramidate herbicides. *Cell Biol. Int.*, 27: 171–174
- Boureima, S., M. Diouf, R.S. Silme, T. Diop, P. Vandamme and M.I. Cagirgan, 2009. Radiosensitivity of African sesame cultivars to gamma-rays. *Turk. J. Field Crops*, 14: 181–190
- Carvalho, R., M. Guerra and P.C.L. Carvalho, 1999. Occurrence of spontaneous triploids in *Manihot esculenta* Crantz. *Cytologia*, 64: 137–140
- Center for New Crops and Plants Products, 2002. *Cajanus cajan* (L.) Millsp. Purdue University. http://www.hort.purdue.edu/newcrop/duke_energy/Cajanus_cajan.html
- Ciftci, C.Y., A. Turkan Divanli, K.M. Khawar, M. Atak, and S. Ozcan, 2006. Use of gamma rays to induce mutations in four pea (*Pisum sativum* L.) cultivars. *Turk. J. Biol.*, 30: 29–37
- De Almeida Costa, G.E., K. de Silva Queiroz-Monici, S.M.P. Reis and A.C. de Oliveira, 2006. Chemical composition, dietary fibre and resistant starch contents of raw and cooked pea, common bean, chickpea and lentil legumes. *Food Chem.*, 94: 327–330
- Fagwalawa, L.D., 2000. Agro-physiological characterization of some early, medium and late maturing varieties of cowpea under sole and inter-cropping systems. *Ph.D. Thesis*, Department of Biological Sciences, Bayero University, Kano, Nigeria
- Joshi, B.K., H.P. Bimb, D. Gauchan, J. Bajracharya, P. Shrestha, and M.P. Upadhyay, 2009. *Genetic Diversity and Population Structure of Pigeon Pea*. BNS E- Bulletin
- Keeler, H.K. and G.A. Davis, 1999. Comparison of common cytotypes of *Andropogon gerardii* (Andropogoneae, Poaceae). *Amer. J. Bot.*, 86: 974–979
- Khan, S. and F. Al-Qurainy, 2009. Mutagenic effects of sodium azide and its application in crop improvement. *World Appl. Sci. J.*, 6: 1589–1601
- Kim, J.S., E.K. Lee, M.H. Back, D.H. Kim and Y.B. Lee, 2000. Influence of Low dose γ radiation on the physiology of germinative seed of vegetable crops. *Kor. J. Environ. Agric.*, 19: 58–61
- Kiong, A., A. Ling Pick, S.H. Grace Lai and A.R. Harun, 2008. Physiological responses of *Orthosiphon stamineus* plantlets to gamma irradiation. *Am-Euras. J. Sustain. Agric.*, 2: 135–149
- Kovács, E. and Á. Keresztes, 2002. Effect of gamma and UV-B/c radiation on plant cells. *Micron*, 33: 199–210
- Kumar, D.S., T. Nepolean and A. Gopalan, 2003. Effectiveness and efficiency of the mutagens gamma rays and ethyl methane sulfonate on limabean (*Phaseolus lunatus* L.) *Ind. J. Agric. Res.*, 37: 115–119
- Kumar, R. and R.P. Sinha, 2003. Mutagenic sensitivity of lentil genotypes. *J. Appl. Biol.*, 13: 1–5
- Mahandjiev, A., G. Kosturkova and M. Mihov, 2001. Enrichment of *Pisum sativum* gene resources through combined use of physical and chemical mutagens. *Isr. J. Plant Sci.*, 49: 279–284
- Mensah, J.K. and P.A. Akomeah, 1997. Mutagenic effects of hydroxylamine and streptomycin on the growth and seed yield of the cowpea, *Vigna unguiculata* L. Walp. *Legume Res.*, 15: 39–44
- Mensah, J.K., P.A. Akomeah and E.O. Ekpekurede, 2005. Gamma irradiation induced variation of yield parameters in cowpea (*Vigna unguiculata* (L.) Walp.). *Global J. Pure Appl. Sci.*, 11: 327–330
- Obi, J.U., 2002. *Statistical Methods of Determining Differences between Treatment Means and Research Methodology Issues in Laboratory and Field Experiments*, SNAAP Press: Enugu
- Parrotta, J.A., 2001. *Healing Plants of Peninsular India*, p: 917. CABI Publishing, Wallingford, New York, USA
- Pons, L.M., W.A. Millan and G.M.C. Cepero, 2001. Radio-sensitivity of rice variety Perla. *Centro-Agricola*, 28: 5–8
- Preussa, S.B. and A.B. Britta, 2003. A DNA-damage-induced cell cycle checkpoint in *Arabidopsis*. *Genetics*, 164: 323–334
- Rabie, K., S. Shenata and M. Bondok, 1996. *Analysis of Agricultural Science*, pp: 551–566. Cairo University, Cairo, Egypt
- Soloveva, L.V., 1990. Number of chloroplasts in guard cells of stomata as an indicator of the ploidy level of apple seedlings. *Cytol. Genet.*, 24: 1–4
- Stoeva, N. and Z. Bineva, 2001. Physiological response of beans (*Phaseolus vulgaris* L.) to gamma-radiation contamination I. Growth, photosynthesis rate and contents of plastid pigments. *J. Environ. Prot. Ecol.*, 2: 299–303
- Takamura, T. and I. Miyajima, 1986. Colchicine induced tetraploids in yellow-flowered cyclamens and their characteristics. *Sci. Hort.*, 65: 305–312
- Tharanathan, R.N. and S. Mahadevamma, 2003. Grain legumes: A boon to human nutrition. *Trends Food Sci. Technol.*, 14: 507–518
- Toker, C. and M.I. Cagirgan, 2004. Spectrum and frequency of induced mutations in chickpea. *ICPN*, 11: 20–21
- Toker, C., B. Uzun, H. Canci and F. Oncu Ceylan, 2005. Effects of gamma irradiation on the shoot length of *Cicer* seeds. *Radiat. Phys. Chem.*, 73: 365–367
- Tosca, A., R. Pandolfi, S. Citterio, A. Fansoli and S. Sgorbati, 1995. Determination of flow-cytometry of the chromosome doubling capacity of colchicine and oryzalin in gynogenetic haploid of gerbera. *Plant Cell Rep.*, 14: 455–458
- Udensi, O., E.V. Ikpeme, E.A. Edu and D.E. Ekpe, 2012b. Relationship studies in cowpea [*Vigna unguiculata* (L.) Walp] landraces grown under humid lowland condition. *Int. J. Agric. Res.*, 7: 33–45
- Udensi, O., E.A. Edu, E.V. Ikpeme, J.K. Ebigwai and D.E. Ekpe, 2012a. Biometrical evaluation and yield performance assessment of cowpea [*Vigna unguiculata* (L.) Walp] landraces grown under lowland tropical condition. *Int. J. Plant Breed. Genet.*, 6: 47–53
- Udensi, O., G.A. Arong, J.A. Obu, E.V. Ikpeme and T.O. Ojobe, 2012c. Radio-Sensitivity of Some Selected Landraces of Pulses to Gamma Irradiation: Indices for Use as Improvement and Preservation Techniques. *Amer. J. Exp. Agric.*, 2: 320–335
- Udensi, O., E.A. Edu, U.J. Umana and E.V. Ikpeme, 2011a. Estimate of genetic variability in locally grown pulses [*Cajanus cajan* (L.) Millsp and *Vigna unguiculata* (L.) Walp]: A pancea for sourcing superior genotypes. *Pak. J. Biol. Sci.*, 14: 404–407
- Udensi, O., E.A. Edu, V.O. Ntui, P.A. Otu, I.S. Urua and G.A. Akpan, 2011c. Cyto-sensitivity of some locally grown pigeon pea [*Cajanus cajan* (L.) Millsp] to amiprophos methyl treatment as a guide for improvement. *Int. J. Curr. Res.*, 3: 176–180
- Udensi, O., U.J. Umana, E.A. Edu and E.V. Ikpeme, 2011b. Screening locally grown pulses for proximate, anti-nutritive and mineral compositions: Indices for conservation and improvement. *Int. J. Agric. Res.*, 6: 504–510
- Uma, M.S. and P.M. Salimath, 2001. Effects of ionizing radiations on germination and emergence of cowpea seeds. *Karnataka J. Agric. Sci.*, 14: 1063–1064
- Wi, S.G., B.Y. Chung, J.S. Kim, J.H. Kim, M.H. Baek, J.W. Lee and Y.S. Kim, 2007. Effects of gamma irradiation on morphological changes and biological responses in plants. *Micron*, 38: 553–564
- Xiuzher, L., 1994. Effect of irradiation on protein content of wheat crop. *J. Nucl. Agric. Sci. China*, 15: 53–55
- Yamaguchi, M., 1989. Basic studies on the flower colour breeding of carnations (*Dianthus caryophyllus* L.). *Bull. Fac. Hort. Minami Kyushu Univ. Kyushu Japan*, 19: 1–78

(Received 16 March 2012; Accepted 31 October 2012)