American-Eurasian J. Agric. & Environ. Sci., 15 (10): 1974-1983, 2015
ISSN 1818-6769

DOI: 10.5829/idosi.aejaes.2015.15.10.12803

Physiological Impacts Caused by Gamma Irradiation and Different Sowing Dates and Their Effects on Yield of Snap Bean

[1]A.M. Mounir, [2]A. Abo El-Yazid, [1]I.O.A. Orabi, [1]A.A. Zahran and [2]I.I. El-Oksh

[1]Department of Natural Products,
National Center for Radiation Research and Technology, Nasr City, Cairo, Egypt
[2]Department of Horticulture, Faculty of Agriculture, Ain Shams University, Shubra, Cairo, Egypt

Abstract: Seeds of snap beans (*Phaseoulus vulgaris*. L) cv. Paulista were irradiated with 0, 20 or 30 Gy of gamma radiation in seasons 2011 and 2012 prior to sowing using caesium as a radiation source. Early winter sowing dates investigated in this trial were 1st, 8th and 15th of October. The experiment was laid out in a factorial arrangement of three replicates in a randomized complete block design where snap bean seeds were sown 5 cm apart on the top of 60 cm wide rows in the experimental field of NCRRT, Nasr City, Cairo, Egypt. Concentrations of chlorophyll, carbohydrates, total soluble phenols and proline were determined in the fourth expanded upper leaf, 45 days after sowing while the concentrations of gibberellins, auxins and abscisic acid were recorded 30 days after sowing. Shoot fresh weight and dry weight were also determined 45 days after planting. At harvest time, pods were harvested at maturity stage, total sugars and total proteins were determined and different yield components where recoded. Delayed sowing generally resulted in increased chlorophyll, total soluble phenols and proline and reduced carbohydrates, gibberellins and auxins in leaves and among the sowing dates investigated, Oct. 8th was superior in regards of local exportable and total yield. On the other hand, investigated irradiation doses generally increased carbohydrates, total soluble phenols and proline and endogenous gibberellins and auxins in leaves. It also increased total pod sugars and proteins. Moreover, the 20 Gy dose proved to be useful in regards of local, exportable and total yield.

Key words: Snap bean · Sowing dates · Gamma irradiation · Chlorophyll · Carbohydrates · Total Soluble phenols · Proline · Yield

INTRODUCTION

Legumes grown for human and animal consumption belong to the family Fabaceae and are widely consumed in most tropical and subtropical countries. These crops are important for their nitrogen fixation capabilities and can be used in crop rotation systems to improve soil conditions [1]. Such capability is an alternative to nitrogen fertilization which represents a serious environmental threat. Among those crops, snap bean (*Phaseolus vulgaris* L.) is one of the most important sources of protein, which happens to be rich in vitamins, minerals and dietary fibers [2, 3]. Its pods are an important source of food in a lot of countries around the world and are known also as French beans, green beans or string beans.

Vegetable crops occupy a large share in the Egyptian exports to Europe. Among those vegetables, snap bean which is mostly consumed as green pods, occupy the second class in vegetable crops exported to European countries after potatoes in terms of foreign exchange earnings. Green pods are produced from cultivars dedicated for this purpose, while other cultivars, cultivated for local consumption are mostly dedicated for the production of dry seeds. Among the most important practices aiming at maximizing the economic value of snap bean' s yield, is early winter production. Relatively high prices in that time of the year in European and local markets makes the cultivation of snap beans very rewarding, though low dominant temperatures limits production. Based on previous research, irradiation is thought to be beneficial in this regard. Gamma rays are

Corresponding Author: A.M. Mounir, Department of Natural Products,
National Center for Radiation Research and Technology, Nasr City, Cairo, Egypt.

known to affect plant growth and development by inducing cytological, physiological and morphological changes in cells and tissues [4]. Several studies reported simulative effects for gamma irradiation on morphological trails [5, 6]. Gamma irradiation was reported to induce favorable and remarkable effects on seed germination potential [7-9]. Moreover, plant growth characteristics and yield were reported to be variously affected when seeds were gamma- irradiated prior to sowing [9-11]. Therefore this investigation was conducted to study how low gamma irradiation doses affects some physiological attributes and its reflection on yield components of Paulista, an export snap bean cultivar when cultivated in open field conditions on different dates for early winter production.

MATERIALS AND METHODS

The field experiment was carried out during the two successive seasons of 2011/2012 and 2012/2013 under open field conditions in the experimental field of the National Center for Radiation Research and Technology (NCRRT), Nasr City, Cairo, Egypt. Soil analysis conducted in the Faculty of Agriculture, Cairo University showed that the soil had a sandy clay loam texture. Soil chemical and physical analysis revealed that it consisted of (57.3- 58.4 % sand: 21.2-18.2 % silt: 21.5- 23.4 % clay) its initial pH was 7.32- 7.31 and its EC was 2.2- 1.8 dS/ m. The concentrations of soluble anions were 1.5- 1.2 CO_3 meq/ l, 4.5- 3.5 HCO_3 meq/ l, 8.8- 5.5 Cl meq/ l and 11.7- 9.2 SO_4 meq/ l. The concentrations of soluble cations were 10.5- 9.0 Ca meq/ l, 3.5- 2.0 Mg meq/ l, 0.5- 0.41 K meq/ l and 11.2- 9.34 Na meq/ l. All mentioned determinations were for the first- second experimental seasons and were determined according to Jackson [12].

Seeds of snap beans (*Phaseoulus vulgaris*. L) cv. Paulista were irradiated with 0, 20 and 30 Gy of gamma radiation in a self-contained dry-storage gamma irradiator with caesium-137 as a radiation source in NCRRT. Dose rates were 28.5 and 27.9 Gy/ h in the two consecutive seasons. During soil preparation, calcium super-phosphate (15% P_2O_5) at a rate of 300 kg/fed, was added on the 60 cm wide rows. Ammonium sulphate (20.5% N) and potassium sulphate (48%K_2O) were first applied to the soil two weeks after sowing at a rate of 125 and 50 kg/ fed, respectively, and an equal quantity was applied a month later. Afterwards, seeds were sown on Oct. 1st, 8th and 15th in 2011 and 2012 and normal agricultural practices and management, disease and pest control programs were followed according to the recommendations of the Egyptian Ministry of Agriculture and Land reclamation. Experimental plots were laid out in a factorial arrangement where the area of each experimental plot/ replicate was 3 m^2 and consisted of (2 x 0.6 m wide x 2.5 m long rows). Seeds were sown 5 cm apart on the top of the rows and the following data were recorded:

Shoot Fresh Weight and Dry Weight: Shoot fresh weight and dry weight were determined 45 days after planting, as follows:

- Shoot fresh weight was determined by calculating the average fresh weight of five plants per plot.
- Shoot dry weight was determined by calculating the average dry weight of five plants per plot. Samples were cleaned by washing using tap water then dried in an air-forced ventilated oven at 70°C for 24 hours to estimate dry weight [13].

Biochemical Determinations: The following determinations were made in the fourth full mature upper leaf excised from 5 randomly selected plants from the middle of the rows, 45 days after sowing, during flowering stage:

- Leaf chlorophyll reading (SPAD) was determined using a digital chlorophyll meter, Minolta SPAD- 502, (Minolta Company, Japan) and the readings were used as relative values for chlorophyll content.
- Total carbohydrates were determined in the dry matter using anthrone according to the AOAC [14].
- Total soluble phenols was determined in the fresh leaves using Folin- Ciocalteu reagent according to the AOAC [15].
- Proline was determined in leaves dry matter using acidic ninhydrin according to Troll and Lindsley [16].
- Phytohormones [Gibberellins (GAs), Indole acetic acid (IAA) and Abscisic acid (ABA) (µg / 100 gm FW)] were extracted from young leaves of snap bean plants, 30 days after planting and their concentrations were determined in an acidic ethyl acetate phase using GLC according to the method described by Shindy and Smith [17].
- Total soluble sugars concentration was determined using the phenol sulphuric acid method in fresh pods according to Dubois [18] and was expressed as a % dry matter.
- Total protein (%) in green pods was determined through the determination of pod total N and a factor of 6.25 was used for conversion of total N to protein percentage according to Kelly and Bliss [19].

Yield Constituents: Pods were harvested when they reached the optimum marketable stage of pod growth (bright green, fleshy pods containing small and green seeds). Green pods yield per feddan was calculated based on a planting rate of 80000 plant/ fed.

Local Yield: Includes the marketable yield which was not up to the European specifications.

Exportable Yield: Includes the exportable pods which are characterized to be shiny green, intact, straight, with a fresh appearance and without any defects.

Unmarketable Yield: Includes the defective, malformed and pale coloured pods.

Total Yield: Includes all harvested pods.

Statistical Analysis: The experiment was laid out in a factorial arrangement (3 sowing dates) x (3 gamma irradiation doses) x (3 replicates) in a randomized complete block design. All the data was analyzed by analysis of variance (ANOVA) which is the procedure used for testing the differences between the means of two or more treatments and the differences between means were detected using least significant difference (LSD) $P \leq 0.05$ according to Gomez and Gomez [20].

RESULTS AND DISCUSSION

Shoot Fresh and Dry Weight: Results presented in Table 1 show that regardless of irradiation dose applied, sowing delays resulted in significant reductions in shoot fresh weight in both seasons under investigation. Similar reductions were noticed in shoot dry weight, though delaying sowing from Oct. 8th to Oct. 15th in season 2011 had a trivial effect in this regard. In this regard, Abou El-Yazied [21] reported that sowing on Oct. 1st recorded that highest plant dry weight compared to sowing on Oct. 8th and Oct. 15th. Such enhanced growth recorded for plants sown on Oct. 1st might be because of the prevalent favorable weather conditions compared to conditions surrounding plants sown on latter investigated dates. It might also be attributed to the higher chlorophyll content which is to be discussed latter in this study and thus expectedly more active photosynthesis and assimilates accumulation compared to plants sown on latter dates which recorded less chlorophyll readings. Such high shoot fresh weight and dry weight recorded for plants sown on Oct. 1st might also be a reflection of high concentrations of GAs and auxins and low concentration of ABA detected in this study in plants sown on Oct. 1st. On the other hand and regardless of sowing date, the 20 Gy treatment significantly increased shoot fresh and dry weights in both seasons. Although the 30 Gy treatment had a less pronounced effect in this regard, but still, it resulted in significant increases in fresh weight compared to the control in seasons 2011 and 2012 and resulted in a significant increase in shoot dry weight compared to control in season 2011 only. Our results are in accordance with the findings of Orabi [22] who reported that relatively low gamma irradiation doses increased dry weight of cowpea plants. In this regard, Abou El-Yazied [21] reported that the highest vegetative values for Bronco snap bean plants were recorded in response to seed pre-sowing irradiation with a dose of 30 Gy. Finally, it is worth mentioning that irradiating Paulista seeds with a dose of 20 Gy prior to sawing on Oct. 1st led to the production of plants with the highest fresh weight in both investigated seasons. As for the highest shoot dry weight, it resulted from seed irradiation with doses of 20 and 30 Gy prior to sowing on Oct. 1st in seasons 2011 and 2012, respectively.

Leaves Biochemical Determinations: As shown in Table 2, compared to the control seeds, plants grown from 20 and 30 Gy- irradiated seeds produced leaves that recorded significantly high and low chlorophyll reading, respectively. In this regard, it is worth mentioning that different plants chlorophyll is affected in different manners. Abou El-Yazied [21] found that 20 and 30 Gy doses resulted in increased chlorophyll readings in snap bean leaves. Meanwhile, Hegazi and Hamideldin [23] reported insignificant response of total chlorophyll in okra leaves to irradiation. On the other hand, delayed sowing generally led to increased chlorophyll reading, however, sowing on Oct. 15th in season 2012 led to an insignificant increase in chlorophyll compared to sowing on Oct. 8th. This contradicts the result reported by Abou El-Yazied [21] who found that early sowing on Oct. 1st increased chlorophyll reading. Our results also show that the highest chlorophyll reading was recorded for 20 Gy-irradiated seeds sown on Oct. 15th in season 2011 and sown on Oct. 8th in the latter season.

Regardless of application dose investigated, irradiating seeds prior to sowing resulted in significant carbohydrates % increases in leaves, 45 days after sowing. This agrees with the results of Frank and Lendvi [24] and Mahmoud [25] who reported an increase in carbohydrates and soluble sugars in response to seed irradiation, respectively. However, a decrease in carbohydrate content was reported in other studies [26].

Table 1: Effect of pre-sowing seed irradiation and sowing dates on snap bean cv. Paulista shoot fresh weight and dry weight

		Sowing date (season 2011)				Sowing date (season 2012)			
	Irradiation dose	Oct. 1st	Oct. 8th	Oct. 15th	Mean (B)	Oct. 1st	Oct. 8th	Oct. 15th	Mean (B)
Shoot fresh weight (g)	0 Gy	41.46 b	33.02 e	30.20 f	34.90 c	38.01 c	31.08 d	29.76 d	32.95 c
	20 Gy	52.73 a	36.41 cd	36.51 c	41.89 a	48.83 a	41.88 b	36.26 c	42.32 a
	30 Gy	35.57 cd	40.31 b	33.99 de	36.62 b	46.65 a	42.44 b	31.98 d	40.36 b
	Mean (A)	43.26 a	36.58 b	33.57 c		44.50 a	38.47 b	32.67 c	
Shoot dry weight (g)	0 Gy	6.86 b	3.39 h	3.74 g	4.66 c	6.14 bc	5.16 de	4.64 ef	5.31 b
	20 Gy	7.87 a	4.81 e	5.63 c	6.11 a	6.99 a	6.60 ab	5.56 cd	6.38 a
	30 Gy	5.17 d	5.57 c	4.42 f	5.05 b	7.13 a	4.83 e	4.09 f	5.35 b
	Mean (A)	6.63 a	4.59 b	4.60 b		6.75 a	5.53 b	4.76 c	

For each factor (A, B or A x B) means bearing a common letter are insignificantly different at $P < 0.05$.

Table 2: Effect of pre-sowing seed irradiation and sowing dates on chlorophyll, carbohydrates, total soluble phenols and proline in leaves of snap bean cv. Paulista, 45 days after sowing

		Sowing date (season 2011)				Sowing date (season 2012)			
Leaf	Irradiation dose	Oct. 1st	Oct. 8th	Oct. 15th	Mean (B)	Oct. 1st	Oct. 8th	Oct. 15th	Mean (B)
Chlorophyll (SPAD)	0 Gy	38.55 ef	41.03 c	42.37 b	40.65 b	38.30 f	41.31 cd	41.59 bc	40.40 b
	20 Gy	40.09 cd	43.06 ab	43.70 a	42.28 a	38.60 ef	43.65 a	43.17 ab	41.81 a
	30 Gy	38.69 ef	38.04 f	39.34 de	38.69 c	38.27 f	39.08 ef	39.91 de	39.09 c
	Mean (A)	39.11 c	40.71 b	41.80 a		38.39 b	41.35 a	41.56 a	
Carbohydrates (%)	0 Gy	12.32 f	14.28 de	15.08 cd	13.89 b	11.98 cde	10.41 e	11.06 de	11.15 b
	20 Gy	18.61 a	13.36 ef	15.89 bc	15.95 a	15.74 a	12.60 bcd	14.00 ab	14.12 a
	30 Gy	15.14 bcd	16.47 b	15.41 bcd	15.67 a	13.84 abc	14.29 ab	13.39 bc	13.84 a
	Mean (A)	15.36	14.70	15.46		13.86 a	12.43 b	12.82 ab	
Total soluble phenols (%)	0 Gy	1.84 f	2.42 de	2.44 de	2.23 c	2.29 e	2.81 d	4.12 b	3.07 b
	20 Gy	2.28 de	2.47 d	3.79 b	2.85 b	2.36 e	3.40 c	5.23 a	3.67 a
	30 Gy	2.12 ef	3.08 c	4.56 a	3.25 a	2.84 d	3.53 c	4.35 b	3.57 a
	Mean (A)	2.08 c	2.66 b	3.60 a		2.50 c	3.25 b	4.57 a	
Proline (mg/ 100 g DW)	0 Gy	6.74 d	14.16 ab	9.57 cd	10.16 b	14.28 a	11.99 abc	9.80 c	12.02
	20 Gy	8.98 cd	9.56 cd	14.04 ab	10.86 b	11.67 abc	13.63 ab	11.13 abc	12.15
	30 Gy	11.99 bc	17.21 a	10.53 bc	13.24 a	10.38 bc	14.34 a	11.54 abc	12.09
	Mean (A)	9.24 c	13.64 b	11.38 a		12.11 ab	13.32 a	10.83 b	

For each factor (A, B or A x B) means bearing a common letter are insignificantly different at $P < 0.05$

Our results are also in harmony with results reported by Nassar *et al*. [27] and Abou El-Yazied [21] who recorded increments in chamomile and snap bean plants sugar content when seeds were irradiated. Contrarily, Hussein [28] obtained opposite results when mung bean seeds were irradiated prior to sowing. We also found that regardless or irradiation, sowing on Oct. 8th recorded the least carbohydrates %, however, a significant difference in favor of the latter date compared to the earlier date was recorded in season 2012. It was also found that seeds irradiated with 20 Gy prior to sowing on Oct. 1st recorded the highest carbohydrates % in both seasons under investigation. In another trial, Abou El-Yazied [21] found that late sowing on Oct. 15th increased leaves total sugars and attributed such increments to reduced consumption of accumulated sugars by the expectedly retarded respiration process which is a mechanism that enables plants to overcome cold weather.

Results in Table 2 also revealed that regardless of irradiation, total soluble phenols increased significantly in leaves with each delay in sowing date. This is most probably attributed to some form of an antioxidant protection system against cold unfavorable conditions which leads to subsequent phenolic metabolism and ultimately, increased total soluble phenolics [29]. We also found that, compared to unirradiated seeds, significant increases in total phenols were recorded in response to irradiation but statistical significance in favor of the 30 Gy treatment compared to the 20 Gy treatment was only detected in the first experimental season. The highest total soluble phenol contents were recorded for plants grown from seeds irradiated with 30 and 20 Gy prior to sowing on Oct. 15th in seasons 2011 and 2012, respectively. Such increases in leaf phenolics in response to irradiation might have contributed to the enhanced cold weather tolerance that was reflected in increased yields that are to be discussed latter in this study.

Proline concentration was significantly affected by irradiation in the first experimental season only when the 30 Gy treatment led to an increased concentration compared to the control and the 20 Gy treatments, between which, a trivial difference was detected. On the other hand and regardless of irradiation, proline concentration followed an inconsistent trend in response to sowing date. In season 2011, a significant increase in proline concentration was recorded with each delay in sowing date. In the latter season, sowing on Oct. 8th resulted in a significantly high proline concentration compared to sowing a week letter. The value calculated for sowing on Oct. 1st was in- between with no statistical differences compared to the other two sowing dates. Increased proline found in season 2011 with delayed sowing is in harmony with previously reported increased proline increases under cold conditions [30, 31].

Phytohormones: Results presented in Figure 1 demonstrate the effect of pre-sowing seed irradiation and sowing dates on endogenous GAs, IAA and ABA in Paulista snap bean leaves, 30 days after sowing. As shown, the least affected hormone was ABA. It's concentration in leaves was neither affected by pre-sowing irradiation treatments nor by sowing dates, nor by their interaction. Nevertheless, the 20 Gy dose and

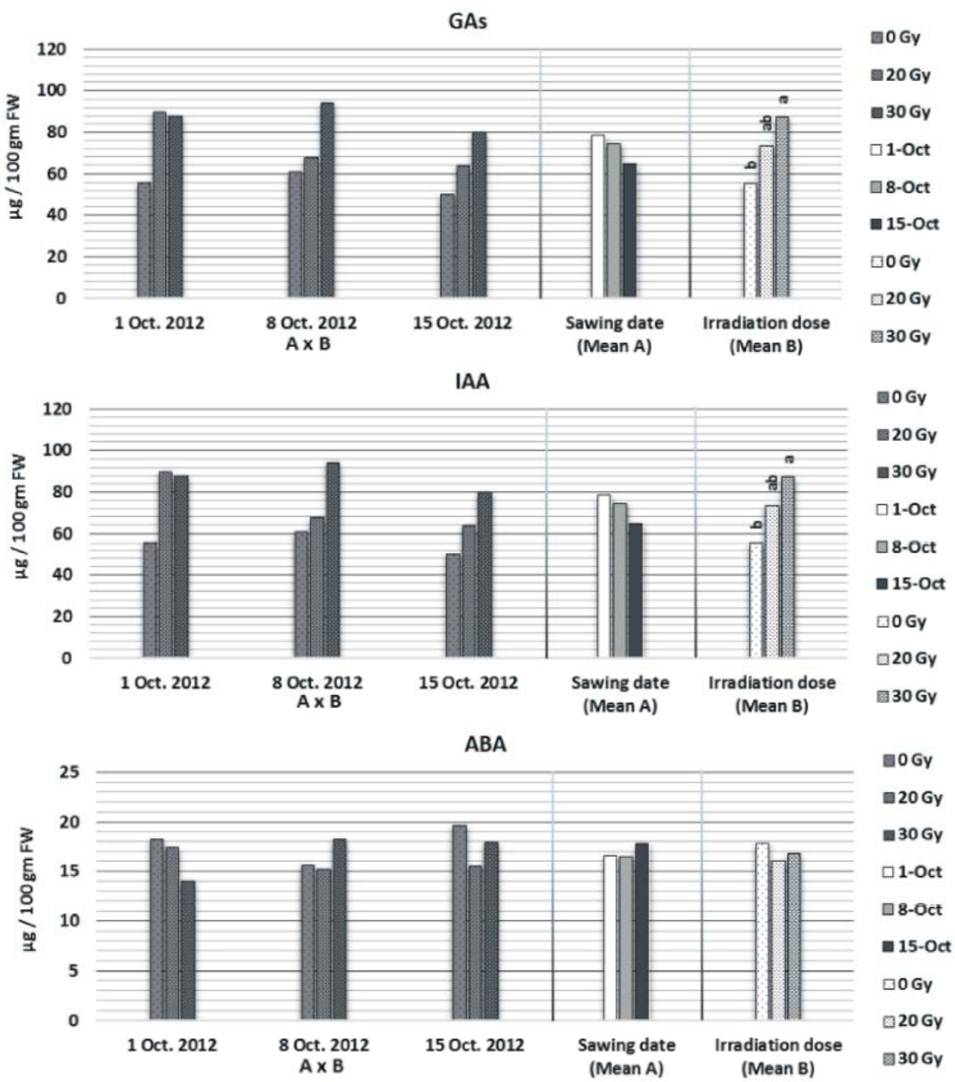

Fig. 1: Effect of pre-sowing seed irradiation and sowing dates on endogenous GAs, IAA and ABA (µg / 100 gm FW) in Paulista snap bean leaves, 30 days after sowing.
For each hormone, columns representing factor A, factor B or the interaction between A x B and bearing a common/ no letters are insignificantly different at $P < 0.05$.

sowing on 8th of Oct. resulted in the least ABA concentrations compared to other doses and sowing dates, respectively. On the other hand, GAs concentration varied significantly in response to different sowing dates and its interaction with pre-sowing seed irradiation treatments. Regardless of irradiation treatments, delayed sowing from 1st to 8th of Oct. and from 8 th to 15 th of Oct. resulted in GAs concentration reduction, but only the latter was statistically significant. Meanwhile and regardless of sowing dates, insignificant increases in GAs concentrations were recorded with radiation dose increments. IAA followed a trend similar to that of GAs in response to irradiation (regardless of sowing dates) but statistical significance was detected. Moreover, sowing delays were generally correlated with insignificant reductions in IAA concentrations. From our findings, it can be concluded that sowing Paulista beans on 1st of Oct. resulted in the highest endogenous growth promotors (GAs and IAA) and a relatively low growth inhibitor (ABA) concentration in leaves. Such hormonal state can also be reached through seed irradiation with a dose of 30 Gy prior to sowing.

Our results are in consensus with results of Abou El-Yazied [21] who reported that seed irradiation significantly raised auxins and GAs and reduced ABA concentrations in leaves. The author also reported that delayed sowing significantly reduced auxins, insignificantly reduced GAs and a significantly high ABA concentration was recorded for sowing on Oct. 15th compared to that recorded for sowing on Oct. 1st. Such results are also confirmed by results reported by Soliman and Abd-El Hamid [9]. Here is worth mentioning that high gamma ray doses generally result in drastic reductions in physiological characters [32]. This is because it induces oxidative stress with overproduction of reactive oxygen species such as super oxide radicals (O_2-), hydroxyl radicals (OH-) and hydrogen peroxides (H_2O_2) [33], which react rapidly with almost all structural and organic molecules causing disturbance of cellular metabolism [34].

Pod Chemical Determinations: Results presented in Table 3 show that pod total sugars and total proteins percentages were significantly affected by pre-sowing seed irradiation, sowing dates and the interaction between them. Sowing on Oct. 8th led to the production of pods with significantly high sugar % compared to the other two sowing dates, between which a significant difference in favor of the latest sowing date in season 2011 and in favor of the earliest sowing date in season 2012. On the other hand and regardless of sowing dates, seed irradiation prior to sowing significantly increased sugars % in pods. Moreover, in season 2012, increasing the treatment dose from 20 to 30 Gy was accompanied with a further significant sugar % increase. It was also noticed that irradiated seeds sown on Oct. 8th recorded the highest sugars percentages in both seasons under investigation. It was also found that seed irradiation had a significant positive impact in regards of pod protein %. Meanwhile, sowing on Oct. 15th resulted in pods with a significantly reduced protein % compared to those grown from seeds sown on Oct. 1st. in both seasons under investigation. It was also found that 30 Gy- irradiated seeds sown on Oct. 1st produced pods with the highest protein %.

Several studies have indicated that irradiation is important in agriculture for its role in improving not only crop productivity, but also in increasing nutritive value of produced crops [21]. It is well known that plant growth and yield alterations in response to abiotic stress are considered to be a reflection of some metabolic activity adjustments in tissue. In this regard, plant growth and yield characteristics were reported to be affected in response to seed pre-sowing gamma irradiation [9- 11]. Rahimi and Bahrani [35] also reported that a 50 Gy pre-sowing gamma irradiation dose resulted in a significant increase in grain protein content of cv. Zagros wheat. On the other hand and unlike our results, Abou El-Yazied [21] reported that early sowing resulted in increased pods proteins and attributed that effect to the prevalent favorable higher temperature compared to latter sowing dates.

Yield Components: Results displayed in Table 4 show that different yield components were affected by pre-sowing seed irradiation dose and sowing dates under investigation. In both seasons, sowing on different dates insignificantly affected unmarketable yield. Meanwhile and regardless of sowing dates, investigated irradiation doses reduced unmarketable yield but the 30 Gy dose in season 2012 was the only treatment that resulted in a significant reduction of unmarketable yield compared to unirradiated seeds. Meanwhile, sowing on 8th of Oct. and a 20 Gy pre-sowing seed irradiation dose proved to maximize local yield in both seasons under investigation. Delayed sowing till 15th of Oct. in the latter season also resulted in a significantly high local yield compared to sowing on 1st of Oct. It was also noticed that main factors trends were found to be persistent with the trend of their interactions, where the 20 Gy treatment followed by sowing on 8th of Oct. in season 2011 and 15th of Oct. in season 2012 maximized local yield in both seasons.

Table 3: Effect of pre-sowing seed irradiation and sowing dates on pod total sugars and total protein percentages

		Sowing date (season 2011)				Sowing date (season 2012)			
Pod	Irradiation dose	Oct. 1st	Oct. 8th	Oct. 15th	Mean (B)	Oct. 1st	Oct. 8th	Oct. 15th	Mean (B)
Total sugars (%)	0 Gy	3.85 e	4.66 bcd	4.15 de	4.22 b	5.90 d	8.21 b	4.62 e	6.24 c
	20 Gy	4.17 de	4.96 ab	4.81 bc	4.65 a	6.26 d	8.88 a	5.87 d	7.00 b
	30 Gy	4.39 cde	5.39 a	4.87 abc	4.88a	7.40 c	8.86 a	6.02 d	7.42 a
	Mean (A)	4.14 c	5.00a	4.61 b		6.52 b	8.65 a	5.50 c	
Total proteins (%)	0 Gy	24.41 d	25.62 bcd	22.49 e	24.17 b	20.91 bc	19.32 cd	17.85 d	19.36 b
	20 Gy	24.40 de	27.07 abc	25.31 cd	25.59 a	21.37 ab	20.92 bc	20.91 bc	21.07 a
	30 Gy	28.31 a	27.53 ab	23.57 de	26.47 a	23.01 a	21.80 ab	20.29 bc	21.70 a
	Mean (A)	25.71 a	26.74 a	23.79 b		21.76 a	20.68 b	19.69 b	

For each factor (A, B or A x B) means bearing a common letter are insignificantly different at $P < 0.05$.

Table 4: Effect of pre-sowing seed irradiation and sowing dates on pod yield components of snap bean cv. Paulista

		Sowing date (season 2011)				Sowing date (season 2012)			
Yield	Irradiation dose	Oct. 1st	Oct. 8th	Oct. 15th	Mean (B)	Oct. 1st	Oct. 8th	Oct. 15th	Mean (B)
Unmarketable (kg/ fed)	0 Gy	675.2 ab	701.7 ab	686.2 ab	687.7	283.4 abc	377.8 a	291.1 abc	317.4 a
	20 Gy	587.6 ab	561.1 b	714.7 a	621.1	263.7 bc	355.1 ab	267.3 bc	295.4 ab
	30 Gy	700.2 ab	595.4 ab	639.6 ab	645.1	294.3 abc	212.7 c	216.5 c	241.2 b
	Mean (A)	654.3	619.4	680.2		280.5	315.2	258.3	
Local (kg/ fed)	0 Gy	1104.5 bc	1002.5 bc	1012.0 bc	1039.7 b	1023.7 c	1920.4 b	1694.3 b	1546.1 b
	20 Gy	1208.2 ab	1491.9 a	1190.7 bc	1296.9 a	1111.5 c	2177.1 ab	2658.8 a	1982.5 a
	30 Gy	1117.5 bc	1136.7 bc	899.6 c	1051.3 b	1035.8 c	1951.1 b	2112.5 b	1699.8 ab
	Mean (A)	1143.4 ab	1210.4 a	1034.1 b		1057.0 b	2016.2 a	2155.2 a	
Exportable (kg/ fed)	0 Gy	1025.3 bcd	1268.4 bc	556.9 e	950.2 b	1148.8 ab	804.9 bcd	451.5 d	801.7 ab
	20 Gy	1055.3 bcd	1902.8 a	877.6 cde	1278.6 a	1090.4 ab	1311.7 a	625.6 cd	1009.2 a
	30 Gy	782.3 de	1352.6 b	936.2 b-e	1023.7 ab	900.4 abc	740.3 bcd	568.0 cd	736.3 b
	Mean (A)	954.3 b	1507.9 a	790.2 b		1046.6 a	952.3 a	548.4 b	
Total (kg/ fed)	0 Gy	2805.1 bc	2972.7 b	2255.1 c	2677.6 b	2455.9 cd	3103.1 abc	2436.9 cd	2665.3 b
	20 Gy	2851.2 bc	3955.7 a	2783.0 bc	3196.6 a	2465.6 cd	3843.9 a	3551.7 ab	3287.1 a
	30 Gy	2600.0 bc	3084.7 b	2475.4 bc	2720.0 b	2230.5 d	2904.2 bcd	2897.0 bcd	2677.3 b
	Mean (A)	2752.1 b	3337.7 a	2504.5 b		2384.0 b	3283.8 a	2961.9 a	

For each factor (A, B or A x B) means bearing a common letter are insignificantly different at $P < 0.05$

Exportable yield production was also enhanced by the 20 Gy treatment in both investigated seasons. As for the effect of sowing date on this yield component, it was found that 8th of Oct. sowing resulted in a significantly high exportable yield compared to other sowing dates in season 2011, between which an insignificant difference was recorded. In the latter season, 1st of Oct. recorded the highest exportable yield followed by the latter sowing date and both yielded significantly more than the latest sowing date. Finally, it is worth mentioning that effects of investigated factors on yield components were clearly reflected on total yield records. As shown in Table 4, the 20 Gy treatment significantly maximized total yield compared to 0 and 30 Gy treatments. On the other hand and regardless of irradiation, sowing on 8th of Oct. resulted in the highest total yield in both seasons under investigation. Total yield recorded for that date was significantly higher than those recorded for other dates in season 2011 while it showed an insignificant difference from yield recorded for the latest sowing date in the latter season. The interaction between sowing dates and pre-sowing seed irradiation doses also had a significant effect on total yield. Seeds irradiated with a dose of 20 Gy and sown on 8th of Oct. recorded the highest total yield which is in harmony with the effects recorded for each factor separately.

Planting date was reported to have a significant effect on snap bean, faba bean and cowpea yield [36-38]. Shamsi [39] confirmed such findings by reporting that the number of pods/ chickpea plant was among the characteristics that were highly affected by planting date and declined with delayed planting. McMurray *et al*. [40] added that earlier pea sowing dates were generally high yielding. In this regard, Abou El-Yazied [21] reported that early sowing on Oct. 1st gave the highest pod yield per feddan. Putting into consideration that temperature reductions occur as time passes by, the author attributed that to concurrent higher concentrations of growth promotors with suitable temperature conditions that in turn had a positive effect on flowering and fruit set and consequently, yield. In this regard, Mengistu and Yamoah [41] reported that the variation in flowering characters among different sowing dates could probably be related to the activity level of endogenous auxins and GA which are known to enhance flowering characters in high temperatures. On the other hand, the promoting effect seed irradiation has on yield is confirmed by results reported for snap bean and lentil [9, 42]. In another study, Abou El-Yazied [21] reported increased snap bean fruit set in response to pre-sowing seed irradiation with doses of 20 and 30 Gy. That can be attributed to increased endogenous hormones especially GA, which are known to be flowering hormones that enhance flowering and ultimately increase yield.

CONCLUSION

It can be concluded that irradiating Paulista seeds with low stimulatory gamma doses, especially 20 Gy prior to winter sowing on Oct. 8th was beneficial in regards of phytophormonal balance, assimilates allocation and nutritive pod value. Promoted growth followed by enhanced yield of Paulista grown in open field conditions in that time of the year is of great importance because of its high value in the Egyptian local and fresh produce export market.

REFERENCES

1. Amanuel, G.S., R.F. Kiihne, D.G. Tanner and P.L.G. Vlek, 2000. Biological nitrogen fixation in faba bean (*Vicia faba* L.) in the Ethiopian highlands as affected by P fertilization and inoculation. Biol. Fertil. Soils, 32: 353-359.
2. Chandran, D.A.B. and L. Mullainathan, 2009. Changes on protein and methionine content of black gram (*Vigna mungo* (L.) Hepper) induced by gamma rays and EMS. American Eurasian Journal of Scientific Research, 4: 68-72.
3. Ndegwa, A.M., M.N. Muchui, S.M. Wachiuri and J.N. Kimamira, 2006. Evaluation of snap bean varieties for adaptability and pod quality. In: Proceedings of the 10th KARI Biennial Conference. KAR I HQs, Nairobi, Kenya. 13th - 17th Nov. 2006.
4. Thapa, C.B., 2004. Effect of acute exposure of gamma rays on seed germination and seedling growth of *Pinus kesiya* and *P. walliachiana* A.B. Jacks. Our. Nature, 2: 13-17.
5. Irfaq, M. and K. Nawab, 2001. Effect of gamma irradiation on some morphological characteristics of three wheat (*Triticum aestivum* L.) cultivars. OnLine J. Biol. Sci., 1: 935-937.
6. Puzon, K.A.M., 2005. Mathematical analysis of root growth in gamma-irradiated cashew (*Anacardium occidentale* L. and mangosteen (*Garcinia mangastama* L.) using fractals. Nature and Science, 2: 59-64.
7. Vinod and J.P. Mishra 1999. Response of okra to gamma rays. National Academy Science Letters, 22: 84-85.
8. Wang, Z. and R. You, 2000. Changes in wheat germination following gamma-ray irradiation: an *in vivo* electronic paramagnetic resonance spin-probe study. Environmental and Experimental Botany, 43: 219-225.
9. Soliman, M.S.A. and M. Abd El-Hamid, 2003. Certain physiological, biological and molecular aspects of kidney bean plants originating from gamma-irradiated seeds during seed germination and plant development. Egypt. J. Rad. Sci. Applic., 16: 189-211.
10. Kumar, Y. and V.K. Mishra, 1999. Effect of gamma rays and diethyl sulphate on germination, growth, fertility and yield in greengram (*Vigna radiata* L. Wilczek). Annals of Agricultural Res., 20: 144-147.
11. Kurdali, F., M. Al-Shamma and Z. Ayyoubi, 2000. Stimulation of N_2 fixation in chickpea by gamma irradiation as affected by different levels of ammonium sulfate fertilizer. Communications in Soil Science and Plant Analysis, 1: 705-716.
12. Jackson, M.L., 1973. Soil Chemical Analysis. Prentice-Hall of India Pvt. Ltd., New Delhi, India.
13. AOAC, 1995. Association of Official Analytical Chemists Official Methods of Analysis. 16th Ed. Washington, D.C., U.S.A.
14. AOAC, 1990. Association of Official Analytical Chemists Official Methods of Analysis. 15th ed. Washington DC, USA.
15. AOAC, 1975. Association of Official Analytical Chemists Official Methods of Analysis. 12th Ed. Washington, D.C., U.S.A.
16. Troll, W. and J. Lindsley, 1955. A photometric method for determination of proline. J. Biol. Chem., 215: 655-660.

17. Shindy, W.W. and O. Smith, 1975. Identification of plant hormones from cotton ovules. Plant Physiol., 55: 550-554.
18. Dubois, M., K.A. Gilles, J.K. Hamilton and P.A. Rebers, 1956. Colourimetric methods of determination of sugar and related substances. Anal. Chem., 28: 350-356.
19. Kelly, J.D. and F.A. Bliss, 1975. Heritability estimates of percentage seed protein and available methionine and correlations with yield in dry bean. Crop Science, 15: 753-757.
20. Gomez, K.A. and A.A. Gomez, 1984. Statistical Procedures for Agricultural Research, 2nd edition, John Wiley and Sons, New York, USA, pp: 704.
21. Abou El-Yazied, A., 2011. Growth, biochemical constituents and yield of snap bean as influenced by low gamma irradiation doses under different sowing dates. Australian Journal of Basic and Applied Sciences, 5: 30-42.
22. Orabi, I.O.A., 1998. Effect of seed irradiation and salinity on growth, chemical composition, flowering and seed production and its quality of cowpea. Egypt. J. Appl. Sci., 13: 201-215.
23. Hegazi, A.Z. and N. Hamideldin, 2010. The effect of gamma irradiation on enhancement of growth and seed yield of okra (*Abelmoschus esculentus* L. Monech) and associated molecular changes. Journal of Horticulture and Forestery, 2(3): 38-51.
24. Frank, J. and Z. Lendvi, 1971. Effect of gamma irradiation on quantitative changes in the carbohydrate content of germinating peas. Acta Agron., 2: 123-127.
25. Mahmoud, F.A.N., 2002. Effect of gamma radiation and some agrochemicals on germination, growth and flowering of *Delphinium ajacis* and *Mathiola incana* plants. M.Sc. Thesis, Fac. Agric., Moshtohor (Benha branch), Zagazig Univ., Egypt.
26. Jiracek, V., R. Kryzenek and J. Kostir, 1970. Research on the radiation biochemistry of plants. The effect of chronic gamma rays irradiation on the metabolism of amino acids and sugars in pea and wheat. Sbornik Ceskoslovenske Akademie Zemedelskych Ved. Rada C. Rostlinna Vyroba, 16: 657-670.
27. Nassar, A.H., M.F. Hashim, N.S. Hassan and H. Abo-Zaid, 2004. Effect of gamma irradiation and phosphorus on growth and oil production of chamomile (*Chamomilla recutita* L. Rauschert). Int. J. Agri. Biol., 6: 776-780.
28. Hussein, O.S., 2006. Response of gamma irradiated mungbean seeds to salinity and ascorbic acid treatments. Egypt. J. Rad. Sci. Applic., 19: 257-270.
29. Pennycooke, J.C., S. Cox and C. Stushnoff, 2005. Relationship of cold acclimation, total phenolic content and antioxidant capacity with chilling tolerance in petunia (*Petunia* × *hybrida*). Environmental and Experimental Botany, 53: 225-232.
30. Dörffling, K., M. Abromeit, U. Bradersen, H. Dörffling and G. Melz, 1997. Plant Cold Hardiness, Involvement of Abscisic Acid and Proline in Cold Acclimation of Winter Wheat. Editors, Paul H. Li and Tony H.H. Chen, Hardcover ISBN 978-0-306-45712-8, Springer US, pp: 283-292.
31. Petcu, E., M. Þerbea, Z. Duþa and D. Ionescu, 2000. Study on the relationship between frost resistance and free proline content in some winter wheat and barley genotypes. Romanian Agricultural Research, 13: 37-41.
32. Grover, S. and A.S. Khan, 2014. Effect of ionizing radiation on some characteristics of seeds of wheat. International Journal of Scientific and Technology Research, 3: 32-39.
33. Xienia, U., G.C. Foote, S. Van, P.N. Devreotes, S. Alexander and H. Alexander, 2000. Differential developmental expression and cell type specificity of dictystelium catalases and their response to oxidative stress and UV light. Biochem. Biophys. Acta., 149: 295-310.
34. Salter, L. and C.N. Hewitt, 1992. Ozone-hydrocarbon interactions in plants. Phytochem., 31: 4045-4050.
35. Rahimi, M.M. and A. Bahrani, 2011. Influence of Gamma Irradiation on Some Physiological Characteristics and Grain Protein in Wheat (*Triticum aestivum* L.). World Applied Sciences Journal 15: 654-659.
36. Ramirez, S., N.E. Estrada, J.A. Gonzalez and M.T. Montes, 2008. Yield and quality of snap bean (*Phaseolus vulgaris* L.) through planting dates. Revista Fitotenca Mexicana, 31: 235-241.
37. Khalil, S.K., A. Wahab, A. Rehman, F. Muhammad, S. Wahab, A.Z. Khan, M. Zubair, M.K. Shah, I.H. Khalil and R. Amin, 2010. Density and planting date influence phonological development assimilate partitioning and dry matter production of faba bean. Pak. J. Bot., 42: 3831-3838.
38. Shiringani, R.P. and H.A. Shimelis, 2011. Yield response and stability among cowpea genotypes at three planting dates and test environments. African Journal of Agricultural Research, 6: 3259-3263.
39. Shamsi, K., 2010. The effect of sowing date and row spacing on yield and yield components on Hashem chickpea variety under rainfed condition. African Journal of Biotechnology, 9: 7-11.

40. McMurray, L.S., J.A. Davidson, M.D. Lines, A. Leonforte and M.U. Salam, 2011. Combining management and breeding advances to improve field pea (*Pisum sativum* L.) grain yields under changing climatic conditions in south-eastern Australia. Euphytica, 180: 69-88.
41. Mengistu, T. and C. Yamoah, 2010. Effect of sowing date and planting density on seed production of carrot (*Daucus carota* var. sativa) in Ethiopia. African Journal of Plant Science, 4: 270-279.
42. Dorgham, E.A., 1999. Effect of low gamma-ray and seedling rates on growth, yield and its components as well as seed quality of lentils (*Lens culinaries* Med). Arab Journal of Nuclear Sciences and Applications, 32: 249-256.