RESEARCH ARTICLE

Assessment of gamma rays effect on morphoagronomical quantitative traits of three genotypes of okra (*Abelmoschus esculentus* (L.) Moench) in Burkina Faso

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Article info:
Received: 15 September 2022
Accepted: 6 April 2023

ABSTRACT

Seeds of three Okra local genotypes of Burkina Faso, UAE22, KBG535 and KBG24, were irradiated with gamma rays at doses ranging from 200 to 3000 Gy using 60Co sources at IBD-CETT, in Burkina Faso. Seeds germination was evaluated in laboratory and then some were sown and plants maintained at two per pot. Traits were measured from germination to fruits maturity. Germination rate below 50% was observed at doses of 400 Gy and from 600 to 800 Gy for UAE22, and at 1600 Gy for KBG535. Up to 3000 Gy, seeds' germination rate was still above 20%. The survival rate at 60 DAS reached 0% at doses of 1400, 1600 and 2000 Gy respectively for KBG535, KBG24 and UAE22. Also, at doses below 600 Gy, time to budding and flowering was reduced for the 3 genotypes. UAE22 did not show any increase for fruit characteristics, except the number of fruits per plant from 200 to 800 Gy. KBG24 and KBG535 showed increases of fruit traits at some doses between 200 and 800 Gy. As for seeds traits, the dose of 200 Gy had an increasing effect for KBG535 and that of 400 Gy had the same effect for UAE22 and KBG24, except the weight of seeds per plant. All the traits studied showed significant variation depending on doses and also genotypes. Irradiation of okra seeds was therefore an appreciable source of induction of variation in quantitative traits.

Key words: Burkina Faso, Okra, quantitative traits, irradiation

Introduction

Okra (*Abelmoschus esculentus*) is a plant of the Malvaceae family which is well known in Burkina Faso. Its yield is quite low due to the lack of improved varieties to mitigate the effects of climate change, biotic and abiotic stresses such as diseases, pests, and edaphic factors (Aaron et al., 2017). Also, the genetic diversity of okra is low (Ouédraogo et al., 2016), which limits selection and varietal creation.

Okra is the most common vegetable in the sauces of people living in the city (Sawadogo et al., 2009). Local varieties are much appreciated for their high mucilage content, their low seed content and for their flavor but are quite neglected for their late cycle and low yield. There is strong consumer demand for improved traditional varieties and the availability of fresh fruit all over the year.

In Burkina Faso, researchers carried on studies of okra variability (Jiro et al. 2011), its response to stresses (Sawadogo et al., 2006; Konaté et al., 2016; Nana et al., 2019), its genetic diversity (Ouédraogo et al., 2016; Ouédraogo et al., 2018), its selection for yield attributing traits, etc.

Varietal improving methods used consisted on selection of ecotypes in controlled conditions or on hybrids production through breeding. Performant lines creation still remains a challenge which could be solved by exploiting variability due to radiation-induced mutagenesis.

Plant breeding can only occur when sufficient variation for a given trait is available to the breeder (Forster & Shu, 2011). In this context, radiation-induced mutagenesis is a way of creating variability, which exploitation could help meet the challenge of creating high-performance lines.

Many studies (FAO/IAEA, 2009; Pushparajan et al., 2014; Devmani & Dwivedi, 2014; Aaron et al., 2017; Amir et al., 2018; Kalyani & More, 2019; Nivedita et al., 2019; FAO/AIEA, 2020; etc.) dealt with effects of gamma rays and sometimes their combination with chemical mutagens like Ethyl methane sulphonate (EMS) and sodium azide in order to create an impact on morphoagronomical traits and perform selection. Indeed, radiation has proven to be the best tool for inducing genetic variability in a very short time and has been the most frequently used method of direct development of mutant varieties (Lagoda et al., 2009). According to recent studies (Pushparajan et al., 2014; Aaron et al., 2017; Nivedita et al., 2017; Amir et al., 2018), okra is recognized sensitive to irradiation with gamma rays.

The doses usually used ranged from 0 to 1000 grays (Gy) (Abdul, 2006; Aaron et al., 2017; Amir et al., 2018) with optimum effects within the interval of 400 to 500 Gy.

The objective of this study was to evaluate the effects of different doses of gamma radiation (from 200 to 3000 Gy) on germination and morphoagronomical quantitative traits of M1 generation of three Okra genotypes from Burkina Faso, in order to allow selection in further generations.

Materials and Methods

Plant material

Seeds of UAE22, KBG535 and KBG24, three genotypes of Okra commonly grown in Burkina Faso, were used. Seeds of UAE22 were collected at the University Joseph KI-ZERBO, then seeds of KBG535 and KBG24 were provided by the “Institut de l’Environment et de Recherches agricoles” (INERA).

Table 1. *Quantitative traits studied*

Quantitative traits and units	
1. Germination rate (%)	7. Diameter of matured fruit (cm)
2. Survival rate at 60 DAS (%)	8. Number of fruits per plant
3. Time of budding (d)	9. Number of seeds per fruit
4. Time of flowering (d)	10. Weight of fruits per plant (g)
5. Rate of plants bearing fruits at 60 DAS (d)	11. Weight of seeds per fruit (g)
6. Length of matured fruit (cm)	12. Weight of seeds per plant (g)

Legend: DAS= days after sowing d = days

Irradiation protocol

Seeds irradiation was carried out in August 2020 in Burkina Faso, using the Darsalamy IBD-CETT insectarium irradiator, equipped with 2 stationary 60Co gamma sources. Each source delivered a dose rate of 38 Gy/min, in the cylinder of suitable geometry, containing the seeds Seeds were put in a Petri dish and placed at the centre of the cylinder (Spencer-Lopes et al., 2020).

Due to the pioneering nature of this experiment in Burkina Faso on Okra, a wide range of doses was used. These were 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1200, 1400, 1600, 1800, 2000 and 3000 Gy.

Germination test

To determine germination rate, 50 seeds per genotype and per treatment were germinated on blotting paper, in Petri dishes, with 3 replicates per treatment. Additional water was provided as needed, while the germinated seeds were removed from the Petri dish and counted gradually until the 10th day.

Experiment in pots

Each dose-by-genotype treatment was represented by an Okra plant in 3 replicates, including the non-irradiated control treatment. Six seeds were sown during September 2020, in black plastic pots filled with about 10 dm3 of heat-sterilized soil and the plants number was reduced to 2 plants per pot. Pots were placed outside under ambient conditions, with temperature varying within 25 and 35°C, at the “Plant Protection” facilities in Bobo-Dioulasso. The watering of the pots and the weeding by uprooting were done on request. A phytosanitary treatment of plants against snail attacks was done using Methomyl 250 g/kg on the 8th DAS and the 25th DAS. Chemical fertilizer NPK (6g / pot) was supplied at 20 JAS.

Data on quantitative traits (Table 1) were collected from M1 plants, one plant per pot. The seeds of M1 were collected in order to constitute the M2 generation.

Due to the random nature of mutations, each plant was considered as an individual, not similar to another. Most of the characteristics measured were therefore assessed on the basis of the value of the individual which presents favorable characteristics.

Data collection and analysis

Phenotypic variation in characters was observed after sowing irradiated seeds at doses of 0, 200, 400, 500, 600, 800, 1000, 1200, 1400, 1600, 1800 and 2000 Gy in pots containing heat-sterilized soil. The evaluation focused on the one hand on the germination capacity for all the 16 doses of irradiation and on the other hand on the plants of the M1 generation raised in pots for the doses of 200, 400, 500, 600, 800, 1000, 1200, 1400, 1600, 1800 and 2000 Gy. A total of 12 quantitative variables were evaluated.

Data analysis and graph representation were made using XLSTAT 2016 and Excel 2013 softwares.

Results

Germination rate

Generally, the germination rates (Figure 1) varied from

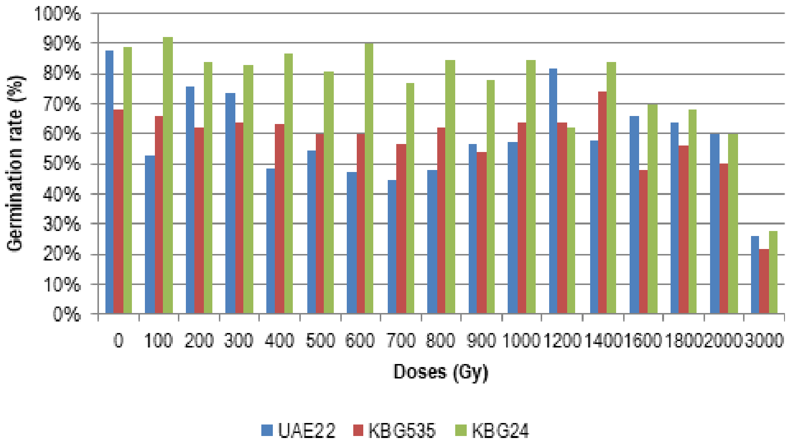

Figure 1. *Evolution of germination rate with doses*

89% for the KBG24 control to 22% for the 3000 Gy dose of KBG535. All three genotypes presented a germination rate with a relative downward trend, despite fluctuations, depending on the increase in the irradiation dose. Up to 2000 Gy, the KBG 24 genotype showed no germination rate lower than 50%, unlike UAE 22 which rates of 49%, 47%, 45% and 48% were observed respectively at 400, 600, 700 and 800 Gy and KBG535 which rates of 48% and 50% were observed respectively at 1600 and 2000 Gy. At 100 and 600 Gy for KBG24 and at 1400 Gy for KBG535, the germination rate was even

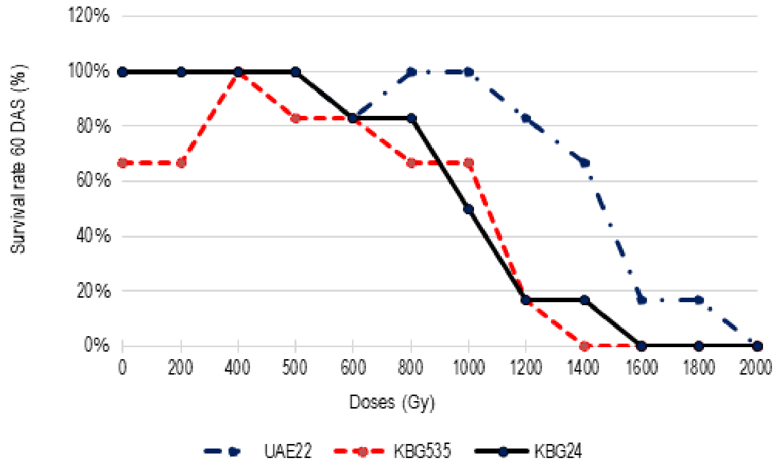

Figure 2. *Evolution of plant survival rate with doses*

higher than that of the control. Up to 3000 Gy lethal dose 100 (LD100) was not observed.

Plant survival rate

The plant survival rate (Figure 2) at 60 DAS varied from 100% in the controls to 0% (LD100) at doses of 1400 Gy for KBG535, 1600 Gy for KBG24 and 2000 Gy for UAE22. The genotype that survived the most to irradiation was UAE22, while KBG24 and KBG535 had substantially comparable decreasing evolutions from 500 Gy. Also, an abnormally low survival rate was observed at the 600 Gy dose, followed by a higher rate, for UAE22. A maximum survival rate of 100%, higher than that of the control (67%), was observed in KBG535 at 400 Gy. At 500 and 600 Gy, the rate was 83%. The survival rate of the three genotypes was superior or equal to that of the control, from 200 to 500 Gy.

Production being one of the objectives of Okra

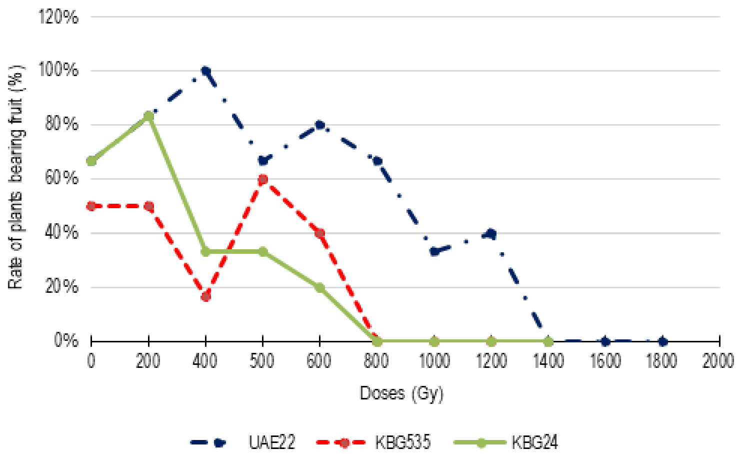

Figure 3. *Evolution of the rate of plants bearing fruits according to the dose*

varietal selection, the proportion of surviving plants that bore fruit was assessed (Figure 3). Thus, doses of 200, 400 and 500 Gy are those which presented the most plants bearing fruit respectively for KBG24, UAE22 and KBG535. From this dose, and for each genotype, a decrease in the proportion of fruit-bearing plants was observed. After 600 Gy, no fruiting plants were observed for KBG24 and KBG535 while UAE22 bore fruit up to 1200 Gy.

Flowering

Flower budding time ranged between 35 and 42 DAS (Table 2). For the three genotypes, its value was 38 DAS for the non-irradiated control. No significant difference from the control was noted.

The time to flowering varied from 48 DAS to 81 DAS. A non-significant reduction in flowering time was observed at doses below 500 Gy for UAE22 and at doses of 200, 500 and 600 Gy for KBG535. A significant decrease was noted at doses of 200 and 500 Gy for KBG24. Above 800 Gy the time of flowering increased significantly, with a peak of 81 days for KBG24 at 1200 Gy and 71 days for UAE 22 at 1600 Gy. No significant difference with the control was observed for KBG535.

Some doses below 1000 Gy had a reducing influence on the time of flowering. However, this influence varied according to the genotypes, except only the dose of 200 Gy which reducing effect is common to the 3 genotypes.

Characteristics of fruits

The characteristics of fruits, at maturity, underwent variations from one dose to another, and according to the genotypes (Table 2). For UAE22 and KBG24, doses of 200 to 800 Gy then 500 and 600 Gy for KBG535, resulted in an increase in the number of fruits compared to the control (2 fruits). The maximum number of fruits was 4 for UAE22 and KBG24, respectively at 500 Gy and 600 Gy and for KBG535 it was 3 at 500 and 600 Gy. No significant difference was recorded.

For UAE22, the fruit length decreased significantly when the dose increased, from 18 cm (control) to 6 cm (1200 Gy). For KBG24, significantly, an increase in length was observed for doses up to 600 Gy, with a maximum variation of +4 cm at 500 Gy, and a significant decrease for doses above 600 Gy. Finally, KBG535 showed small but significant variation, with an upward trend (up to +2 cm maximum at 800 Gy).

The diameter of mature fruit of KBG24 significantly increased for the doses of 400 and 500 Gy, with a maximum variation of +0.6cm at 400 Gy. For KBG535 at the dose of 200 Gy, the maximum significant increase was +0.3 cm. The diameter of the fruit was less than that of the control at all doses for UAE22 (from 1.4 to 0.6 cm) and for KBG535 (from 1 to 0.6 cm) after 400 Gy.

Fruit weight per plant fluctuations were recorded for KBG24 and KBG535. A significant increase in fruit weight compared to the control was noted at 200 Gy for KBG24 (+2 g) and KBG535 (+7 g), then at 600 Gy for KBG535 only (+3 g). A significant decrease was recorded for UAE22 at all doses and above 400 Gy for KBG24.

Characteristics of seeds

Increases in the number of seeds per fruit compared to the control were observed at doses below 600 Gy, for the 3 genotypes, except KBG535 at the dose of 400 Gy, where a decrease was observed (i.e. -10 seeds) (Table 2). The maximum for KBG535 was recorded at 200 Gy (83 seeds).

Table 2. *Analysis of variance of performances of quantitative traits in relation with doses*
Values followed with same letter are not significantly different at 5% level

	Time of budding (DAS)			Time of flowering (DAS)			Number of fruits/plant		
Doses(Gy)	UAE22	KBG24	KBG535	UAE22	KBG24	KBG535	UAE22	KBG24	KBG535
0	38ab	38ab	38ab	50ab	56b	58abc	2a	2ab	2a
200	36a	36ab	37ab	48a	48a	55a	3a	3b	2a
400	36a	37ab	38ab	48a	60bc	61bc	3a	3b	2a
500	37ab	35a	35a	54bcd	49a	56ab	4ab	3b	3ab
600	38ab	41b	38ab	51abc	62c	56ab	3a	4bc	3ab
800	36a	41b	41b	50ab	59bc	62c	3a	3b	2a
1000	41ab	41b	41b	57d	66d	62 c	2a	1a	2a
1200	42b	38ab		56cd	81e		2a	1a	
1400	41ab	41b		62e	61c		3a	2ab	
1600	41ab			71f			1a		
1800	41ab						1a		
2000									

	Length of matured fruit/plant (cm)			Diameter of matured fruit/plant (cm)			Matured fruits weight/plant (g)		
Doses(Gy)	UAE22	KBG24	KBG535	UAE22	KBG24	KBG535	UAE22	KBG24	KBG535
0	18,0e	12,3b	10,0a	1,46f	0,90b	1,00b	16,01h	13,02d	4,93 a
200	13,5c	13,5c	11,0b	0,92b	0,90b	1,30c	9,02d	15,07e	12,65b
400	14,5d	14,5d	11,3b	1,10d	1,50d	0,80ab	11,05f	13,11d	2,73a
500	14,5d	16,0e	11,3b	1,02cd	1,20c	0,80ab	14,00g	10,05c	4,93a
600	10,8b	13,5c	11,2b	0,59a	1,00bc	0,90b	4,03c	4,01b	8,24ab
800	11,1b	11,2a	12,0c	0,99bc	0,50a	1,00b	10,10e	2,21a	3,10a
1000	11,0b		11,3b	1,24e		0,60a	3,01b		3,10a
1200	6,0a			0,99bc			1,00a		
1400									
1600									
1800									
2000									

	Number of seeds / fruit			Seeds weight / fruit (g)			Seeds weight / plant (g)		
Doses	UAE22	KBG24	KBG535	UAE22	KBG24	KBG535	UAE22	KBG24	KBG535
0	40d	48c	30b	2,10b	3,07c	2,02b	7,21e	8,15d	3,03c
200	38d	63d	83d	2,02b	3,11c	5,07d	5,05c	8,17d	8,21e
400	47e	64d	20a	3,20c	4,21d	1,10a	6,07d	8,16d	2,12b
500	45e	64d	35bc	2,00b	3,04c	2,05b	6,11d	6,21c	3,04c
600	26c	28b	37c	1,07a	1,08b	3,10c	2,03b	2,03b	4,07d
800	19b	4a	24a	2,00b	0,50a	2,03b	6,12d	1,01a	4,08d
1000	14a		21a	1,05a		1,00a	1,04a		1,000 a
1200	12a			1,00a			1,11a		
1400									
1600									
1800									
2000									

The weight of seeds per fruit compared to the control increased at the dose of 400 Gy for UAE22 and KBG24. For KBG535, this increase was recorded at 200 and 600 Gy.

A significant increase in seed weight per plant was observed only for KBG535 at doses of 200, 600 and 800 Gy, with a maximum of +5,18 g at 200 Gy. For the other 2 genotypes, a general decrease in the weight of seeds per plant is noted, despite some significant fluctuations.

Discussion

Increasing the irradiation dose had an overall inhibiting effect on germination. This effect varied by genotype without clearly showing a dose-dependent degree of inhibition. Losing of germination capability can be considered as deterministic effect of gamma rays and explained by cell death. Fluctuation in the germination rate could be explained by a morphophysiological heterogeneity of the seeds and/or a heterogeneity of their exposure to gamma rays.

Results similar to this general trend of lower germination rate with increasing gamma ray dose are reported on Okra (Dhankhar & Dhankhar, 2004; Kumar & Mishra, 2004; Norfadzrin et al., 2007; Muralidharan & Rajendran, 2013) as well as *Phaseolus lunatus* at doses of 240, 300, 360 and 420 Gy (Kalyani & More, 2019) also 200, 400, 600, 800 and 1000 Gy (Kumar et al., 2003). A gradual decrease in the germination rate was reported on 3 genotypes of irradiated chickpea from 300 to 1200 Gy, 400 to 1200 Gy and 700 to 1200 Gy respectively (Tariq et al., 2008).

However, for wheat at doses of 100, 200, 300 and 400 Gy, it was found that the final germination rate was not significantly affected by gamma radiation (Borzouei et al. 2010).

A decreasing trend in survival rate with increasing radiation dose and for all genotypes was recorded, clearly after 500 Gy for KBG24 and KBG535 and after 1000 Gy for UAE22. However, the low survival rate of KBG535 at 0 and 200 Gy remained surprising. Gamma rays had negative effect on survival rate of the plants. Plant death is due to cell death at microscopic level, and this is also deterministic effect of radiation.

Results similar to this general trend are reported for wheat at doses of 100 to 400 Gy (Borzouei et al. 2010), *Phaseolus lunatus* at 240, 300, 360 and 420 Gy (Kalyani & More, 2019) also 200, 400, 600, 800 and 1000 Gy (Kumar et al., 2003), *Vigna unguiculata* at doses of 100, 200, 400, 500 Gy (Devmani & Dwivedi, 2014), pigeon pea at doses of 5, 10, 15 kR (Sangle et al., 2011), *Phaseolus vulgaris* at doses of 5 kR, 10 kR and 15 kR (Mahamune & Kothekar, 2012) and on okra (Norfadzrin et al., 2007; Muralidharan & Rajendran, 2013; Aaron et al., 2017). Mahamune & Kothebar (2012) also reported that gamma irradiation of seeds affects plant survival rates to maturity in a dose-dependent relationship.

For KBG535, some survival rates were higher than the control; for KBG24 and UAE22, some rates were equal to the control.

These results are similar to those of Aaron et al. (2017) who obtained a rate of 88% at 400 Gy with 81% for the control. However, UAE22 and KBG24 together exhibited a lower survival rate than the control at 600 Gy.

The UAE22 genotype showed the highest survival rate at all doses, followed by KBG24 and finally KBG535. Therefore, the survival of plants under the effect of irradiation depends on the genotype. Our results differed from those of Pushparajan et al. (2014) for whom the survival rate of plants at maturity dropped from 90% to 25% at a dose of 500 Gy, which may be partly related to the difference in genotype.

The reduction in plant survival is an index of post-germination mortality as a result of cytological and physiological disturbances due to the effect of radiation (Manju & Gopimony, 2009). Indeed, no germination rate lower than 40% was observed at doses less than or equal to 2000 Gy, but the survival rate was 0% at 1400 Gy and above.

The results obtained on *Orthosiphon stamineus*, showed that plant survival to maturity depended on the nature and extent of chromosomal alterations (Kiong et al., 2008).

Some plants surviving 60 DAS did not bear fruit. Indeed, the doses of 200, 400 and 500 Gy are those which presented the best fruitful plants survival rates respectively for KBG24, UAE22 and KBG535. It could be deduced that these doses, for each genotype, are those likely to produce a greater yield. Doses of more than 600 Gy had a total inhibiting effect on fruiting for KBG24 and KBG535, while this effect was observed after 1200 Gy for UAE22. These doses seemed to have flower sterilization effect.

The 3 genotypes behaved differently for time of budding and flowering. A reducing influence on time of budding is observed at doses below 600 Gy for all genotypes. Decreases in time of flowering were observed for doses less than or equal to 600 Gy. Beyond 600 Gy, the delay increased considerably with the dose. This influence varies however according to the genotypes, with only the dose of 200 Gy which reducing effect is common to the 3 genotypes.

The results of UAE22 are comparable to those of Aaron et al. (2017), for whom the dose of 400 Gy reduced the number of days to flowering, while the doses of 600, 800 and 1000 Gy had an effect of increase up to 128 DAS. The results differed however for KBG24 and KBG535.

It is noted that the reducing effect of the flowering time induced by irradiation is observed at relatively low doses. On the other hand, the higher doses would have a rather lengthening effect. Indeed, high doses seriously affect the survival of plants, so that they would take longer to develop and flower.

Gamma rays had a variable effect, depending on the dose and the genotype, on the time to flowering after budding. An opportunity of selection in favor of earliness remains possible.

The UAE22 and KBG24 genotypes showed an increase in the number of fruits per plant at doses ranging from 200 to 800 Gy. Also, the length of the fruit of KBG24 and KBG535 increased under the effect of doses of 200 to 800 Gy. As for the increase in diameter, it was noted in the KBG535 genotype at the dose of 200 Gy and KBG24 at the doses of 400 to 600 Gy. Fruit weight showed a decreasing trend for UAE22 and KBG24 and fluctuations for KBG535 under the effect of irradiation.

Aaron et al. (2017) and Pushparajan et al. (2014) reported an effect of increasing the number and length of fruits by the dose of 400 Gy, while Dubey et al. (2007), Mishra et al. (2007) and Sharma & Mishra (2007) found it at 2000 Rad and 30 kR respectively. Furthermore, the reduction effects at doses of 100, 150, 200, 300 and 500 Gy as well as 600, 800 and 1000 Gy that Pushparajan et al. (2014) and Aaron et al. (2017) respectively observed are not systematically noticed in our study.

Moreover, the doses of gamma rays at 5 kR and 10 kR caused an increase in the average length of the fruit of the

Okra variety Arka Anamika, while the opposite was observed in the Parbhani Kranti variety (Navnath & Mukund, 2014).

Pushparajan et al. (2014) found a decrease in fruit diameter with increasing dose, except at 400 Gy, while Aaron et al. (2017) and Dubey et al. (2007) observed a decrease in fruit weight with increasing dose, except at 2000 Rad.

Thus, it is established that irradiation with gamma rays at certain doses has positive effects on the number, length, diameter, weight of fruits per plant, hence a possibility of improving the yield of okra. However, these effects depend on the genotypes.

An increase in the number of seeds per fruit was observed at doses below 600 Gy for the 3 genotypes, except KBG535, where at 400 Gy the number of seeds was lower than that of the control. Also the seed weight per fruit is the best at 400 Gy for UAE22 and KBG24.

Our results are corroborated by those of Pushparajan et al. (2014) as well as Sharma & Mishra (2007) on Okra, for UAE22 and KBG24, where the 400 Gy dose had the best number of seeds. They were however different for KBG535.

The number of seeds per fruit had two different appreciations. Fruits with fewer seeds are appreciated for consumption, while on the contrary, fruits with many seeds are hoped for the production of seeds. Selection in either direction could be advantageous.

Seeds germination and plants survival were affected by radiation. This clearly highlighted gamma rays effect; testifying that also stochastic effects like mutations can be recorded in our experimentation. Indeed, variation recorded on plants traits should be studied in further generations in order to determine whether their character is genetic or morphophysiological disorder.

The doses that caused the most interesting variation are mainly those ranging from 200 to 600 Gy. Production of M1 seeds should be experimented by multiplying the number of radiation doses included in this interval.

The characters which have undergone a tangible variation and which would be correlated with the improvement of genotypes' performance are the rates of germination and survival, the flowering precocity, the number of fruits per plant, the dimensions of the fruits.

These differences in dose effect could be attributed to genotypic differences and to experimental conditions. Indeed, our study took place in pots and irradiation performed with a device usually dedicated to sterilization of flies.

Conclusion

Gamma radiation caused variation of all the parameters studied for the 3 Okra genotypes from Burkina Faso. The variations observed depended both on genotypes and doses.

Higher doses than 1400, 1600 and 2000 Gy, respectively for KBG535, KBG24 and UAE22, led to death of all the plants (LD100) depending on the genotypes. This meant that doses suitable to induce mutations might be found below this amount of dose for each genotype.

Lower doses than 600 Gy had a reducing effect on time to budding and flowering for the 3 genotypes. This range of doses could be used to induce mutation for productivity earliness. Yield attributing characters such as fruits and seeds traits were increased at doses ranging from 200 to 800 Gy. Indeed, it could be stated that, according to our study, doses below 800 Gy were the best to create interesting genetical variability in the three okra genotypes.

If trends have been observed with the increase in the dose for certain characters such as the germination rate and the survival rate, for other characters positive or negative effects at specific doses or a given dose range have been observed.

However, it should be noted that all the phenotypic changes that appeared in M1 are not necessarily due to mutations. Some deterministic effects, like plant death or absence of fruit, occurred above 600 Gy and testified real impact of doses used. The continuation of observations in further generations remains a fundamental step for the characterization of all the plants obtained. Nevertheless, a selection for different parameters of interest, such as budding and flowering earliness, number, length, diameter and weight of fruits per plant, can be hoped for satisfactory variability in M2.

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