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Scientific Article

Floral quality in third-generation descendants of outstanding gladiolus cultivars obtained by gamma irradiation

Eduardo Piña de Jesús [1], Jesus Ricardo Sanchez Pale [1*], Álvaro Castañeda-Vildózola [1], Omar Franco Mora [1], Arlin Emma Ayala Villada [1], Luis Demetrio Piña [1]

[1] Facultad de Ciencias Agrícolas, Universidad Autónoma del Estado de Mexico, Mexico City, Mexico.

Abstract

The gladiolus is one of the most commercially important cut flowers in Mexico. It was traditionally considered a funeral flower, but its uses have now diversified to many other decorative floral arrangements due to its variety of colors and forms. All the new varieties on the market in Mexico are of foreign origin, such that the generation of new genotypes is needed. In a previous study, flowers originating from irradiated Blanca Borrega variety corms expressed different floral characteristics, shape and size; however, it is unknown whether these characters are fixed in subsequent generations. The objective of the current work was therefore to evaluate the fixed characteristics in the ornamental quality of outstanding cultivars of Blanca Borrega variety gladiolus descended from irradiation with ^{60}Co. During the fall-winter (2020-2021) period, corms of outstanding cultivars generated by distinct irradiation doses were planted in sterilized substrate to evaluate corm germination (%), plant height, number of leaves per stem, spike length (cm), combined stem and spike length (cm), number of flowers per spike, flower size (cm), number of leaves, and survival, and to categorize cut flower quality under the United Nations Economic Commission for Europe (UN/ECE) criteria. Our results indicated that the outstanding cultivar derived from the 80 Gy dose presented a Class I classification (Second quality) of the UN/ECE parameters due to its stem height and number of buds, followed by the cultivars descended from irradiation at 10, 30 and 50 Gy and the control, which were placed in Class II (Third quality). Thus, in the third generation the favorable esthetic characteristics of the outstanding cultivars remain fixed.

Keywords: fixed characteristics, floral quality, *Gladiolus communis* L., irradiated genotypes UN/ECE.

Resumo

Qualidade floral em descendentes de terceira geração de excelentes cultivares de gladíolo obtidas por irradiação gama

O gladíolo é uma das flores de corte mais importantes comercialmente no México. Era tradicionalmente considerada uma flor funerária, mas seus usos agora se diversificaram para muitos outros arranjos florais decorativos devido à sua variedade de cores e formas. Todas as novas variedades no mercado mexicano são de origem estrangeira, de modo que é necessária a geração de novos genótipos. Em estudo anterior, flores provenientes de rebentos irradiados da variedade Blanca Borrega expressaram diferentes características florais, forma e tamanho; no entanto, não se sabe se esses caracteres são corrigidos nas gerações subsequentes. O objetivo do presente trabalho foi, portanto, avaliar as características fixas na qualidade ornamental de cultivares destacadas de gladíolo da variedade Blanca Borrega descendentes da irradiação com ^{60}Co. Durante o período de outono-inverno (2020-2021), rebentos de cultivares excepcionais gerados por diferentes doses de irradiação foram plantados em substrato esterilizado para avaliar a germinação do rebento (%), altura da planta, número de folhas por haste, comprimento do espigão (cm), combinado comprimento do caule e espiga (cm), número de flores por espiga, tamanho da flor (cm), número de folhas e sobrevivência, e para categorizar a qualidade da flor cortada sob os critérios da Comissão Econômica das Nações Unidas para a Europa (UN/ECE). Nossos resultados indicaram que a cultivar de destaque derivada da dose de 80 Gy apresentou classificação Classe I (Segunda qualidade) dos parâmetros UN/ECE devido à altura do caule e número de gemas, seguida pelas cultivares descendentes da irradiação aos 10, 30 e 50 Gy e o controle, que foram colocados na Classe II (Terceira qualidade). Assim, na terceira geração, as características estéticas favoráveis das cultivares de destaque permanecem fixas.

Palavras-chave: características fixas, genótipos irradiados, *Gladiolus communis* L., qualidade floral, UN/ECE.

* Corresponding Author: jrsanchezp@uaemex.mx

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Introduction

At the end of the twentieth century in Mexico, there was a search for novel and profitable economic activities in the agricultural sector, since traditional and low-yield crops did not allow the economic development of rural areas. One alternative to promote development was floriculture, within the ornamental trade circuit, there has always been a demand for new cultivars (Yan et al. 2019), especially in the southern regions of the states of Mexico, Morelos, and Puebla. This new agricultural activity increased producers' incomes in national, and to a lesser extent, international markets (~10% of the flower crop is exported; Ramírez and Avitia, 2017).

Currently, floriculture in Mexico is an economically important activity that generates more than 250 thousand jobs directly and nearly a million jobs indirectly (SADER, 2022). The sale price of flowers varies widely depending on quality, making floral characteristics and quality vitally important for both consumers and producers. Some quality parameters are defined by florists and decorators, who mainly consider floral architecture and the time that the flower retains its decorative qualities (i.e., the time until clear signs of senescence begin to appear (Moret, 2013). "Quality" is thus defined by a set of emotions, perceptions, and accumulated experiences that affect consumer satisfaction (Hernández et al., 2018), such that floral quality is a combination of the properties, needs, characteristics, and attributes that each actor seeks in the cut flower and foliage to produce, market, and satisfy the tastes of the consumer (Moret, 2013).

In Mexico, gladiolus production in 2020 reached 5.1 million gross flower spikes, with the states of Puebla and Mexico State leading production (SADER 2022). In the last two decades, Mexican floriculture has increased, particularly in terms of the growth in the volume of production of roses, gladiolus, chrysanthemum, and carnation (Estrada et al., 2022). Most of the commercial gladiolus varieties in Mexico come from the Netherlands (FAO, 2018), and just two varieties (Blanca Borrega and Roja Borrega) dominate the market, largely due to consumer preferences. Both varieties are considered public domain (Gámez et al., 2017), and there is a lack of improvement programs to generate new types with characteristics that surpass the parental varieties. One improvement method is the use of gamma irradiation, especially of varieties that are already preferred by consumers, to increase further improve their qualities.

Irradiation is a genetic improvement method that is used to induce mutations in plants with the objective of producing varieties that have better product quality, higher and more stable yields, better resistance to climate change, and better tolerance to environmental stressors (FAO, 2020). In a previous study, corms of the Blanca Borrega variety were irradiated with ^{60}Co at a range of radiation doses, and the resulting flowers showed expressed different floral characteristics, shape and size than the parental plants. However, it is unknown whether these characters are fixed in subsequent generations and could therefore be used to establish new commercial varieties that reliably produce favorable characteristics. Therefore, the objectives of this study were to evaluate the floral quality of the third-generation descendants of Blanca Borrega corms irradiated at different doses.

Materials and Methods

We used corms of outstanding gladiolus (*Gladiolus communis* L.) cultivars of the Blanca Borrega variety from the second generation after the initial irradiation with ^{60}Co to grow plants corresponding to the third generation post-irradiation. We planted the corms in 30 × 30 cm plastic bags filled with a substrate consisting of a homogeneous mixture of 30% agricultural soil, 50% organic matter, and 20% agricultural-grade perlite. The substrate was sterilized using Metam sodium to eliminate weeds, pest insects, and pathogens. The work was carried out during the fall-winter cycle of 2020-2021 under the seasonal environmental conditions in a greenhouse area where the predominant climate is temperate humid with rains in summer and low thermal oscillation.

We used 10-12 caliber corms of the second generation post-irradiation. The treatments were the radiation dose applied to the parental generation to produce each of the outstanding cultivars (0 to 100 Gy) and each consisted of ten repetitions. The experiment was performed in a random block design during the fall-winter cycle of 2020-2021; the experimental unit was the plant obtained from the corm planted in each bag. The variables evaluated were: corm germination (%), plant height, number of leaves per stem, plant survival over the complete cycle, flower spike length (cm), combined length of the stem and spike (cm), number of flowers per spike, flower size (cm), and number of leaves. For each of the data points recorded per treatment, we compared with the quality classification of the United Nations Economic Commission for Europe (UN/ECE) (1994), which defines the following three classes:

Extra class (Code 100-120): To enter this class, spikes must have at least ten flower buds, with no more than one bud open; flowers must have no parasite damage, no developmental defects or malformations, and no foreign matter present that affects the appearance; the stems must be straight and rigid and have at least four leaves. The combined stem and spike length must be 101 to >120 cm.

Class I (Code 60-80): To enter this class, spikes must have at least seven flower buds and two leaves. The specimen must have no parasite damage, developmental defects, or malformations. There may be some traces of foreign materials, as long as they do not negatively affect the appearance. The stems must be rigid and straight and have a combined stem-spike length of 61–100 cm.

Class II (Code 30-40): Gladioli in this class must have at least five flower buds and two leaves. They can have minor malformation and light parasite damage. The stems may be slightly curved, and it is permissible to remove the top part of the stem.

Another set of criteria used to determine gladiolus size is established by the North American Gladiolus Council (NAGC) (2015), according to the following measurements to classify the crop into different sizes:

1. Miniature Gladiolus: stem length of at least 33 cm (13 inches), open flower diameter less than 6.35 cm (2.5 inches)
2. Small Gladiolus: stem length of at least 38.1 cm (15 inches), open flower diameter 6.35–8.89 cm (2.5–3.5 inches)
3. Medium Gladiolus: stem length of at least 43.18 cm (17 inches), open flower diameter 8.89–11.43 cm (3.5–4.5 inches)
4. Large Gladiolus: stem length of at least 43.18 cm (17 inches), open flower diameter 11.43–13.97 cm (4.5–5.5 inches)
5. Giant Gladiolus: stem length of at least 43.18 cm (17 inches), open flower diameter over 13.97 cm (5.5 inches)

The values of each quality parameter per year were subjected to an analysis of variance to determine the behavior among the outstanding cultivars. The effect of each cultivar was determined using an analysis of variance (ANOVA) under a completely randomized design, using PROC ANOVA (SAS System ver. 9.2 Cary, N. C. USA) and mean separation under a Least Significant Difference (LSD) test with $\alpha = 0.05\%$.

Results and Discussion

The study was carried out in the facilities of the Agricultural Sciences Faculty of the Autonomous University of Mexico State (Facultad de Ciencias Agrícolas, Universidad Autonoma del Estado de México), located in the community of Cerrillo, Piedras Blancas (19° 14’ 35.52” N, 99° 24’ 43.2” W; 2,614 msnm), Toluca, Mexico State. Corm germination reached its maximum at 46 days. The cultivars descended from doses of 10, 40, 60, 80, and 100 Gy reached 100% germination. In the rest of the treatments including the control (Figure 1), dormancy was apparent, particularly in the 70 and 90 Gy treatments, which reached only 70% germination (Figure 1).

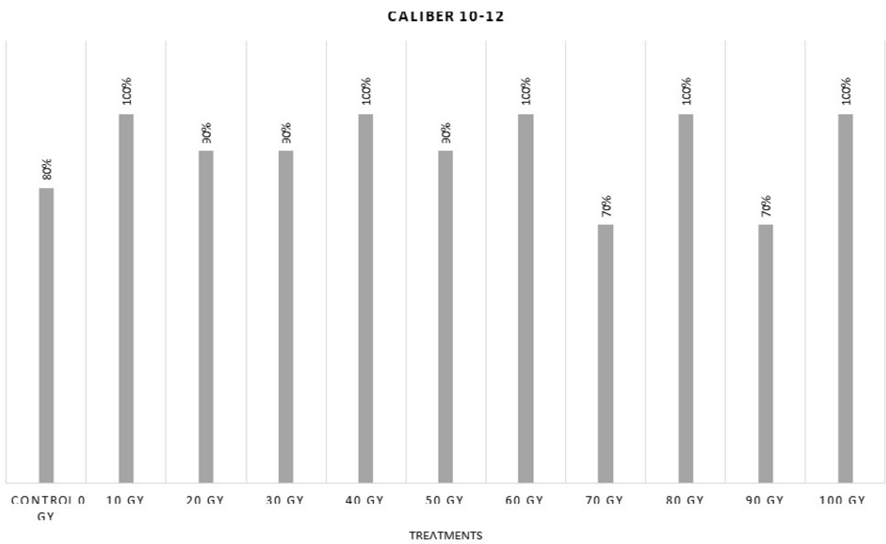

Figure 1. Corm germination (%) obtained from plants of the second generation following initial irradiation.

These results coincide with those mentioned by Gutiérrez et al. (2021), who observed that while low irradiation doses can increase germination, high doses can decrease germination. However, when evaluating germination, it is also necessary to consider the nutritional content of the new cormels, which constitute reserves for the initial growth of the plants in the subsequent growing cycle (Gómez et al. 2018).

The growth of the plants at each dose is indicated in Figure 2. The largest size was expressed by descendants of the 80 Gy dose, followed by the 10, 30 and 50 Gy doses. At the 80 Gy dose, there was 100% survival of the plants to the end of the cycle (Figure 1), indicating good health and no expression of dormancy. The cultivars generated by doses of 10 and 50 Gy expressed a survival percentage of 50%, which was higher than the control (Figure 2).

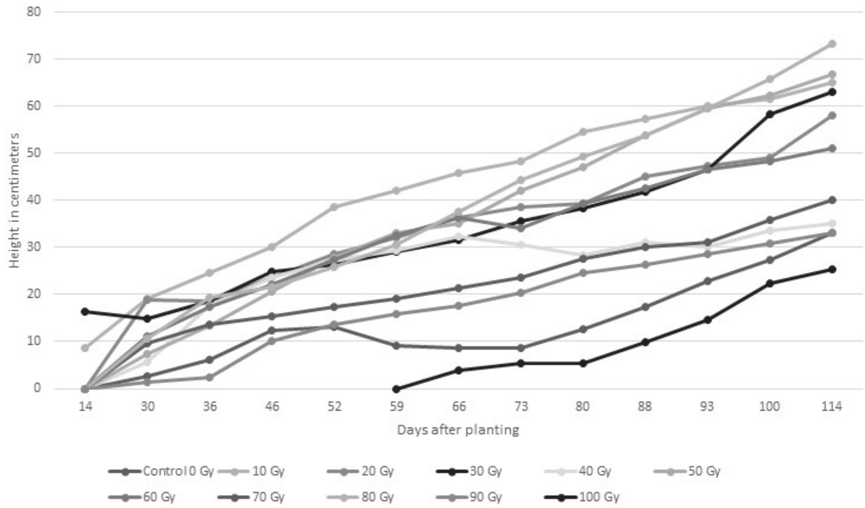

Figure 2. Plant growth progression for each outstanding gladiolus cultivar

The 100 Gy treatment expressed only 10% growth. Similar results were found in beans with a dose of 100 Gy, but the root development of the cultivar was stimulated (Ulukapi and Ozmen, 2017). The changes observed in the maturation, shape, size, and color of the flower and other physiological factors in the outstanding gladiolus cultivars at different gamma radiation doses are in accordance with reports in African daisy (*Osteospermum* L.), whose flower color was altered to deep orange, as well as in cyclamen (*Ciclamen* L.) whose flowers had a salmon pink color and increased flower diameter (Yamaguchi, 2018). In *Lilium* sp., the anthers were observed to be twisted, with lower pollen production and a survival rate of 75%, while in orchids, roses, geraniums, canna lilies, and carnations, flower color changed after irradiation according to the report by Yamaguchi (2018). The selection of changes in the esthetic qualities of outstanding cultivars varies, and it is possible to generate these changes using the application of different doses of gamma rays, such that they can be utilized to improve the production of ornamental flower crops (Anne and Hee, 2020).

The ANOVA for the variable of plant height (cm) indicated significant differences among treatments 46 days after planting (F = 114.94; D.F. = 10; $p < 0.0410$), and by 73 days there were highly significant differences (F = 1465.98; D.F. = 10; $p < 0.0001$). At the end of the study period at 114 days, we also found highly significant differences (F = 1665.72; D.F. = 10; $p < 0.0001$).

The cultivar that expressed the tallest plant height was 80 Gy at 114 days, followed by 10, 50 and 30 Gy, which were statistically similar to the 80 Gy treatment, and the shortest plant height was presented by the 90 and 100 Gy treatments (Figure 3).

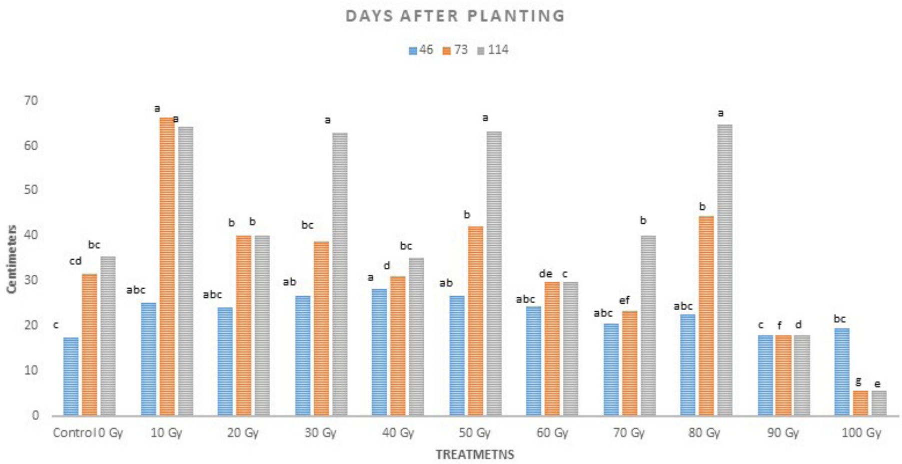

Figure 3. Separation of means for plant height (cm) in outstanding cultivars of gladiolus from the third generation after irradiation.

Similarly, Gálvez et al. (2018) mention that beginning at a radiation dose of 100 Gy there have been negative effects observed in variables such as plant height, number of leaflets, and leaf area. All treatments, including the control, had an adequate number of leaves to be classified as UN/ECE Class I, II, or Extra, since they all had on average at least the two leaves per stem required. The 10, 50 and 80 Gy treatments had 10, 9 and 11 leaves per stem on average, respectively (Figure 4).

Figure 4. Average number of leaves per stem in gladiolus plants from the third generation after irradiation.

With respect to the floral quality classifications, the number of flower buds per flower spike for the 10 and 80 Gy was adequate to consider them “Extra Class” under the UN/ECE. Under the NAGC (1964) criteria, the 80 Gy treatment was placed in the Medium Gladiolus category while the 10, 40, 50 and 70 Gy treatments fell in the Small Gladiolus category, as shown in figure 5.

All of the treatments presented favorable diameter of the flower opening, which was equal to or greater than the control, particularly in the 70, 50, 10 and 80 Gy treatments (Figure 6). These outstanding cultivars express stable genetic characteristics in flower quality, up to the second generation.

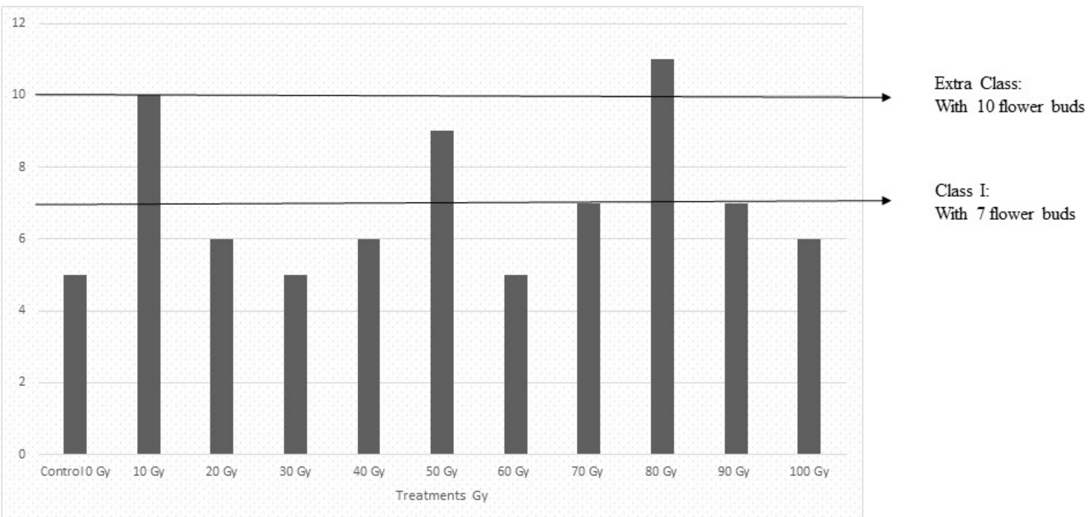

Figure 5. Average number of flower buds per flower spike in the outstanding cultivars of gladiolus from the third generation after irradiation.

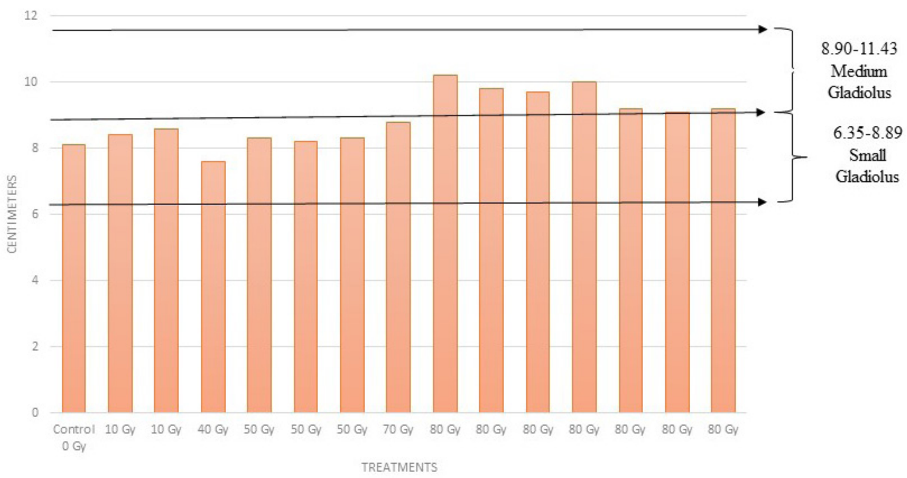

Figure 6 Average diameter of floral opening expressed in each outstanding gladiolus cultivar.

For the combined height of the stem and the flower spike, at the end of the cycle, the 10, 30, 50 and 80 Gy treatments were classified as Class I under the UN/ECE criteria (Figure 7) and from Medium to Giant class under the NAGC criteria (2015). The 20, 60 and 70 Gy treatments were classified in Class II, as were the 40 and 90 Gy and control treatments, although they were significantly shorter. The 100 Gy treatment did not fulfill the minimum height requirement to be placed in any of the quality classes.

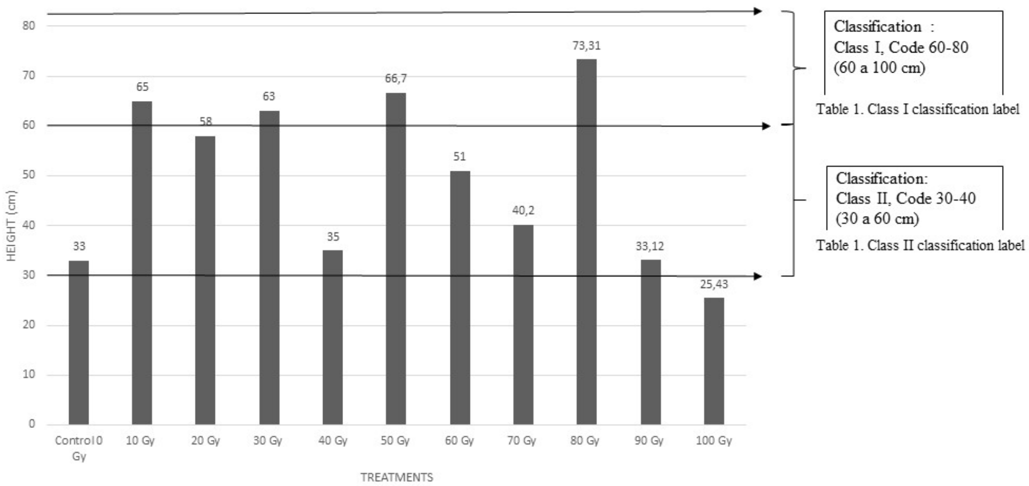

Figure 7. Average combined height of the stem and flower spike expressed in each cultivar at the end of the growing cycle (114 days after planting)

Sathyanarayana (2021) report that in height, number of leaves, color, and number of flowers per flower spike, treatments with 45 to 55 Gy had the best characteristics; Shafiei at al. (2019) revealed that 25 Gy gamma-ray irradiation is considered an appropriate dose to generate a mutation frequency in the chrysanthemum cut flower; in *Polianthes tuberosa,* Sharavani et al. (2019) report that variegated leaves and mutant cultivars were found with 20 Gy; however, their maximum dose was only 55 Gy. This may explain why our results differed in that the 80 Gy treatment had the best results compared to the remaining treatments and the control.

There was incidence of *Fusarium* sp. which led to wilt in 30% of the plants in the control, 90 Gy, and 100 Gy treatments. There was also some damage due to thrips. Thrip damage was lowest in the 80 and 90 Gy treatments, moderate in the 20, 30 and 100 Gy treatments, and highest in the control. Thrips are considered the most limiting pest for gladiolus production due to the serious damage they cause to flower quality (Quiñones et al., 2020), but relatively little damage was evident in the outstanding cultivars.

The differences in floral quality that were determined and fixed among the different outstanding cultivars evaluated are consistent with the findings in the initial stimulation (Sathyanarayana, 2021), such that it is feasible to generate new gladiolus cultivars from gamma irradiation with ^{60}Co whose characteristics are fixed and superior to the progenitor variety. In the 100% of outstanding cultivars were not true-to-type. In this sense, Pereira (2019) mentions that the processes of introduction and adaptation of new species and varieties are being intensified and focused on new cultivars and hybrids, whose market value is higher than the parental varieties.

In this study, the optimal floral quality improvements were achieved in the outstanding cultivar of Blanca Borrega produced using 80 Gy. We concur with Anne and Hee (2020), who indicate that recommendations of the optimal dose of gamma radiation for improvement programs should be determined at the species level, since each crop will react or adapt differently to the induction due to their morphology or hereditary background.

Conclusions

The plants obtained from the third-generation descendants of the Blanca Borrega gladiolus cultivar irradiated at 80 Gy expressed fixed quality parameters that are superior to the parental variety in terms of larger combined height of the stem and flower spike, formation of more flower buds, and larger flower size, which places them in Class I of the UN/ECE standards, making it a cultivar with favorable esthetic characteristics.

Author Contribution

EPDJ: Wrote the article, carried out the field experiment on gladiolus production, and acquired and analyzed the data. **JRSP:** Supervised the project, helped to develop the written draft (revision and editing), provided the space for the experiment. **ACV:** Writing and revision. **OFM:** Revision and editing. **AEAV:** Assisted in the establishment of the field experiment, writing, and data acquisition. **LDP:** Data acquisition, support in preparation of the materials to establish the experiment.

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