

Original Research Article

Studies of Phenotypic and genotypic variation for morphological traits in saffron (*Crocus sativus* L.)

ABSTRACT

Aims: The "Saffron (*Crocus sativus* L.)" germplasm was evaluated to collect data on phenotypic and genotypic variability for morphological features. Genetic divergence among selected lines was thoroughly investigated with the purpose of identifying elite divergent features that demonstrated economic improvements for morphological qualities as well as their contribution to yield components.

Study design: The material for study comprised of 140 saffron germplasm lines collected from different saffron growing areas of Kashmir and abroad viz., Afghanistan, Iran. The pedigree details of all the 140 corm samples were recorded. Saffron corms weighing 5g to 16g were planted in Augmented Block Design with a row length of 3m, width 2m and inter and intra-row spacing of 20 and 10 cms, respectively for daughter corm production under annual planting cycle.

Place and Duration of Study: A study on genetic divergence among selected lines of saffron was conducted at Advanced Research Station for Saffron and Seed Spices (ARSSSS), Dusso Konibal, Pampore, SKUAST-Kashmir during cropping season 2017-18.

Methodology: Observations were recorded on 10 randomly selected and tagged competitive plants from each accessions for 15 morphological traits viz., number of flowers corm⁻¹, number of days to 50% flowering, fresh flower weight corm⁻¹, inner tepal length, outer tepal length, inner tepal width, outer tepal width, anther length, anther width, style length, stigma length, fresh pistil weight, dry pistil weight, leaf length, number of leaves corm⁻¹. **Results:** Significant variations among populations were observed for all the traits, number of flowers corm⁻¹ (0.90-1.98), fresh pistil weight (31.0- 69.46 mg), stigma length (2.55-4.18 cm), leaf length (16.12-37.10 cm), number of leaves corm⁻¹ (6.00-11.33), fresh flower weight corm⁻¹(1.80-14.31 mg) indicating presence of high level of variability and therefore imply considerable scope for saffron improvement through clonal selection.

Conclusion: Estimates of phenotypic variation were higher than equivalent estimates of genotypic variance, indicating that the environment has an impact on the expression of the characteristics investigated. The diversity found in saffron germplasm suggests that saffron has a lot of room for development in terms of morphological features. Our findings contribute to a better understanding of the genetic variations in this species' for vegetative and yield-related traits. However, in order to accurately characterize their performance, they must be evaluated at multiple locations over time. Therefore divergence studies are critical for determining the level of variability and the potential for its future use in breeding programme.

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Keywords: *Crocus sativus* L., cluster, correlation, divergence, genetic variability
Abbreviation:

1. INTRODUCTION

Saffron (*Crocus sativus* L.) a perennial herb belongs to family *Iridaceae* is one of the most expensive spices in the world and is popularly known as the “Golden Condiment”. Dried stigmas of saffron flowers compose the most expensive spice which has been valuable since time immemorial for its odoriferous, coloring and medicinal properties (Plessner *et al.*, 1989). The Kashmir saffron is famous across the world for its high crocin content and rich aroma; it commands a higher price than saffron from Spain or Iran. In India it is a legendary crop cultivated on well drained karewa soils of Kashmir and Kishtwar, where agro-climatic conditions are conducive for its quantitative and qualitative growth and development. It grows at an elevation of 1500-2000 m amsl. Photoperiod and temperature exerts a profound influence on the flowering of saffron. Saffron production in the globe is estimated to be around 300 tons per year (Ahmad *et al.*, 2013). The primary saffron producing countries are Iran, India, Spain, and Greece, with Iran covering the most territory and generating roughly 88 percent of global saffron production. Despite having the world's second-largest land area, India produces only about 7% of total global output (Kaloo *et al.*, 2014). The reason may be the use of traditional practices for saffron cultivation which ignore the importance of optimum resource management and also lack of quality planting material has led to poor performance in terms of the yield, quality and low Benefit Cost ratio. Saffron is solely grown in Jammu & Kashmir, India's only saffron-producing state. Spain is the world's third greatest producer; with 600 ha of land and an average yield of 8.33 kg/ha, the highest in the world. With intensive production processes, top saffron-growing countries like Iran, Spain, and Greece are able to reach higher production and productivity than we are, posing a serious threat to our saffron business as imports rise year after year.

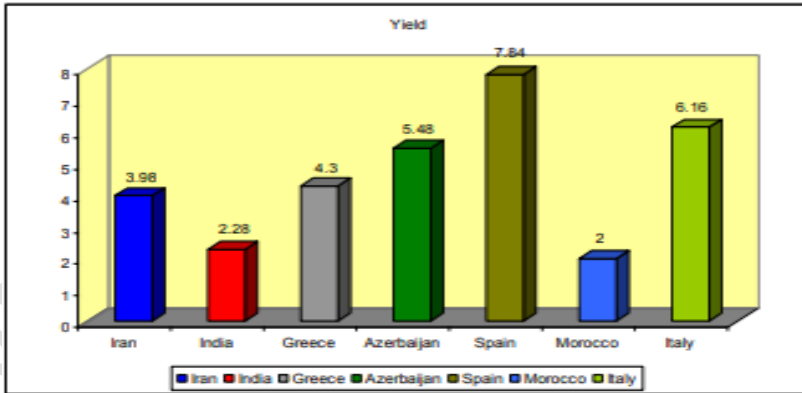


Image 1 : Saffron business as imports from different countries [..]

Source: Tantray *et al.*, 2017

To make it globally competitive and remunerative to growers, there is a need to expand production by bringing more land under cultivation and double average productivity by adopting an intense production method, efficient processing, and marketing. Saffron farming covers 3715 hectares in J&K, with annual yield and productivity of 13.3 MT and 3.0–4.0 kg/ha, respectively (Zulfikar Majid, 2021). Saffron is largely grown in four districts in J&K (Pulwama, Budgam, Srinagar, and Kishtwar), with an 86 percent saffron agricultural system at the Pampore heritage site covering 3200 hectares. Pampore, as a peri-urban location, is vulnerable to

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commercialization and colonization; consequently, expanding saffron cultivation to new prospective and non-traditional areas of J&K will ensure the saffron farming system's long-term viability. This would help to boost J&K's overall saffron production in order to meet the national demand of 100 M.T., as well as provide livelihood security to the state's moderately poor farmers. Prospect of saffron genetic improvement is through clonal selection from the available germplasm. Identification of elite genotypes with distinct superiority in quality and yield attributes can be used as a source for further improvement. Development of varieties from the identified germplasm exhibiting high yielding potential and quality will enhance the production and productivity of saffron to reduce the burden of costs on the import of priced commodity and improving the socio-economic status of the stakeholders associated with the production, processing and value chain of this important commercial crop

2. MATERIAL AND METHODS

The present investigation was carried out at Advanced Research Station for Saffron and Seed Spices (ARSSSS), Dusso Konibal, Pampore, during cropping season 2017-18., a constituent Research Station of Sher-e-Kashmir University of Agricultural Sciences and Technology Kashmir. The experimental site is located at 34°N latitude, 74°E longitude at an altitude of 1650m amsl. The material for study comprised of 140 saffron germplasm lines collected from different saffron growing areas of Kashmir and abroad viz., Afghanistan, Iran. The pedigree details of all the 140 corm samples were recorded. Saffron corms weighing 5g to 16g were planted in Augmented Block Design with a row length of 3m, width 2m and inter and intra-row spacing of 20 and 10 cms, respectively for daughter corm production under annual planting cycle. Recommended package of practice from SKUAST- Kashmir was followed for nutrition and intercultural operations in the crop planted. Observations were recorded on 10 randomly selected plants and tagged competitive plants from each line for all the traits during the period of experimentation.

2.1 Morphological traits studied:

[Number of flowers corm⁻¹, number of days to 50% flowering, fresh flower weight corm⁻¹ (mg), inner tepal length (cm), outer tepal length (cm), inner tepal width (cm), outer tepal width (cm), anther length (cm), anther width (mm), style length (cm), stigma length (cm), fresh pistil weight (mg), dry pistil weight (mg), leaf length (cm), number of leaves corm⁻¹ line⁻¹].

Mean values for all the characters were estimated for analysis of variance (Verma *et al.* 1987; Singh and Chaudhary, 1985) and character association at genotypic and phenotypic level (Al Jibouri, 1958).

3. RESULTS AND DISCUSSION

Genetic variability assists a great deal in detecting the range of genetic diversity for various traits in a population (Singh *et al.*, 2004). Components of phenotypic and genotypic variability indicated that a wide range of variability existed for all the traits studied shown in (Table 2, Pie chart-1, Fig. 4 & 5). Outer tepal length ranged from (3.13-4.55cm) with a mean value of (4.25cm), inner tepal length (3.46-3.96cm), with a mean value of (3.69cm), tepal width (3.45-3.95cm) with a mean value of (3.70cm), inner tepal width (1.55-2.03cm) with a mean value of (1.84cm), stigma length (2.55-4.18cm) with a mean value of (3.60cm), style length (2.34-7.35cm) with a mean value of (4.31cm), leaf length (16.12-37.10cm) with a mean value of (27.73cm), number of leaves corm⁻¹ (6.00-11.33) with a mean value of (8.93), number of flowers corm⁻¹ (4.00-35.33) with a mean value of (15.33), fresh flower weight corm⁻¹ (1.80-14.31g) with a mean value of (7.23g), fresh pistil weight (104.84-1207.38mg) with a mean value of (483.91mg), dry pistil weight (25.95-976.25mg) with a mean value of (114.71mg), anther length (1.34-2.37cm) with a mean value of (1.90cm), anther width (1.26-3.74mm) with a mean value of (2.40mm) and 50% flowering

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(68.66-76.66) with a mean value of (73.10). Results are in conformity with the reports of Sheikh *et al* (2014), Latto and Dhar (1999), Zargar (1999), Gohill (1999), Zargar (2002) and Makhdoomi *et al.* (2010) as they observed same results and reported wide range of variability exists in the natural population of saffron as indicated by the magnitude of *per se* performance, phenotypic and genotypic coefficient of variation, implying considerable scope for saffron improvement through clonal selection. The study suggests that there is an ample scope for saffron genetic improvement through selection of superior genotypes from the heterogeneous saffron populations. For floral attributes viz, outer tepal length, inner tepal length, outer tepal width, inner tepal width, anther length, anther width indicates less range of variability. The estimates of phenotypic variances were higher than the corresponding estimates of genotypic variances thereby revealing a strong influence of environment in the expression of the traits studied. *Per se* performance of genotypes under evaluation revealed a gross fresh pistil weight of 40.24mg per corm from 1.21 flowers corm⁻¹ resulting in 3 kg laccha per hectare with planting density of 5 lakh corms per hectare showing an increase of 25% over state average. Estimates of phenotypic and genotypic correlation coefficient among the characters have been found useful in planning and evaluating breeding programme (Johnson *et al.*, 1955; Al-Jibouri *et al.*, 1958). Genotypic correlation coefficient provide a measure of genetic association among the characters and gives an indication of characters that could be useful as to identify more important ones during a selection programme. At phenotypic and genotypic level, dry pistil weight (economic product) exhibited a significant positive correlation with all the traits. The results clearly reveal a scope for simultaneous improvements of this important trait through selection. Interrelationship among various floral, vegetative and yield contributing traits was observed to be significant both at genotypic and phenotypic levels. Yield is influenced by environmental conditions and is a complex mode for inheritance and low heritability. However, most of the yield components which naturally leads to use of some other trait that is highly correlated with yield and has a much higher heritability through selection of the best progenies for more reliability. In this study, to assess the phenotypic and genotypic relationships between studied traits, correlation coefficients based on phenotypic and genotypic values were calculated (Table 1, Fig. 1 & 2). Results showed that the saffron yield had positive and significant phenotypic and genotypic correlations with all traits. These findings are in conformity with (Gresta *et al.*, 2009). Therefore, any increase in the yield components improved saffron yield directly and indirectly. It was notable in this study that in most cases the genotypic correlation coefficients were larger than the phenotypic correlation coefficients. This finding is in agreement with the results of previous studies (Singh *et al* 2003, 2004; Bayat *et al.*, 2016). Saffron under temperate conditions of Kashmir Valley reported wide spectrum of variability for floral & vegetative attributes and the results implied a great scope for saffron improvement. Flower size, number of flowers per corm and saffron recovery per flower were observed to help as selection index for increasing saffron yield. Valley exhibited highest range of variability in saffron germplasm. From natural population flowers completely devoid of style and anthers, some flowers with 4 and 5 stigmas were observed. The presence of higher number of stigmas per flower results from physiological or developmental irregularities leading to 4-5 stigmas. These results are in conformity with (Nehvi *et al.* 2003, 2004 and 2006). The phenotypic and genotypic variations between different saffron ecotypes and the phenotypic/genotypic relationships between yield and yield components of saffron were measured such as: Fresh pistil Weight, Dry pistil Weight and Stigma Length. The results showed that genetic variances were much higher than phenotypic variances for most of the traits. And also these traits show highest genetic diversity. Results of the correlation coefficients showed that the phenotypic correlations were higher than the genotypic correlations for almost all of the traits like number of flowers corm⁻¹ (0.62), fresh flower weight (0.89g) and fresh pistil weight (0.91g) had the highest genotypic correlation with dry pistil weight. In general, with the purpose of the study and assessments to genotypic correlation coefficients, genetic parameters, we can conclude that traits like, number of flowers corm⁻¹, fresh flower weight, fresh pistil weight were the most effective traits and had the highest positive

impacts on the saffron yield. Therefore, with the phenotypic selection of saffron ecotypes in respect of these traits, the saffron yield can be increased and these findings are in agreement with the results of previous studies of (Bayat *et al.* 2016; Ahmed *et al.* 2012). They reported that with regard to positive and significant genotypic correlation coefficients and high positive direct effects, the selection might be based on these two characters and must be focused on most effective traits for the direct improvement of yield.

Table 1. Estimates of Phenotypic variance ($\delta^2 p$), genotypic variance ($\delta^2 g$), phenotypic coefficient of variation (PCV), Genotypic coefficient of variation (GCV) for morphological traits of Saffron (*Crocus sativus* L.) year 2017-2018

Comment [IGKA10]: Method employed to estimate phenotypic and genotypic variance should be described in the Material and methods section.

| Characters | Phenotypic variance ($\delta^2 P$) | Genotypic variance ($\delta^2 g$) | Phenotypic coefficient of variation (PCV) | Genotypic coefficient of variation (GCV) |
|--|--------------------------------------|-------------------------------------|---|--|
| Outer tepal length (cm) (OTL) | 0.015 | 0.058 | 2.88 | 5.65 |
| Inner tepal length (cm) (ITL) | 0.013 | 0.015 | 3.04 | 3.10 |
| Outer tepal width (cm) (OTW) | 0.013 | 0.014 | 3.11 | 3.15 |
| Inner tepal width (cm) (ITW) | 0.012 | 0.013 | 5.97 | 6.08 |
| Stigma length (cm) (SL) | 0.18 | 0.25 | 12.60 | 11.92 |
| Style length (cm) (STL) | 0.51 | 0.51 | 16.57 | 16.59 |
| Leaf length (cm) (LL) | 11.59 | 12.69 | 12.27 | 12.84 |
| Number of leaves corm ⁻¹ line ⁻¹ (L/C/L) | 0.95 | 2.971 | 10.72 | 19.28 |
| Number of flowers corm ⁻¹ line ⁻¹ (F/C/L) | 31.83 | 33.663 | 36.79 | 37.83 |
| Fresh Flower weight corm ⁻¹ line ⁻¹ (FW/C/L) | 9.055 | 9.353 | 41.61 | 42.29 |
| Fresh pistil weight (g) (FPW) | 47967.17 | 48544.88 | 45.25 | 45.53 |
| Dry pistil weight (g) (DPW) | 5556.44 | 10101.17 | 87.61 | 64.97 |
| Anther length (cm) (AL) | 0.092 | 0.092 | 15.92 | 15.95 |
| Anther width (mm) (AW) | 0.33 | 0.360 | 24.07 | 25.06 |
| 50% flowering (50% F) | 2.29 | 4.680 | 2.29 | 2.95 |

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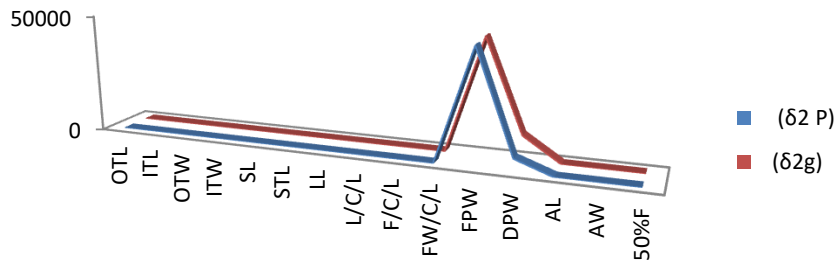


Fig. 1. Estimates of $\delta^2 p$ & $\delta^2 g$ for morphological traits

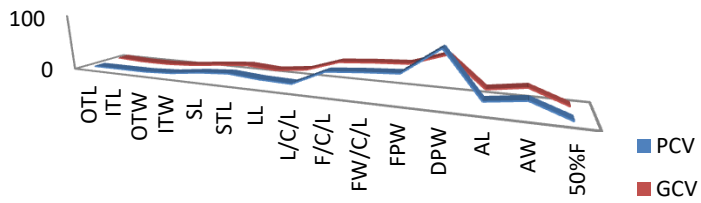


fig1 . Estimates of PCV & GCV for morphological traits



Fig.2 Saffron flower clearly depicting leaves, tepals, anther and stigma

Table 2. Magnitude of variability for different morphological traits in saffron (*Crocus sativus* L.).

| Characters | Range | Mean | C. V. | S.E | C.D. @5% |
|---|--------------------|--------|-------|-------|-------------|
| Outer tepal length (cm) (OTL) | 3.13-4.55 | 4.25 | 4.85 | 0.11 | 0.33 |
| Inner tepal length (cm) (ITL) | 3.46-3.96 | 3.69 | 0.55 | 0.01 | 0.03 |
| Outer tepal width (cm) (OTW) | 3.45-3.95 | 3.70 | 0.48 | 0.02 | 0.02 |
| Inner tepal width (cm) (ITW) | 1.55-2.03 | 1.84 | 1.14 | 0.01 | 0.03 |
| Stigma length (cm) (SL) | 2.55-4.18 | 3.60 | 4.08 | 0.08 | 0.23 |
| Style length (cm) (STL) | 2.34-7.35 | 4.31 | 0.70 | 0.02 | 0.04 |
| Leaf length (cm) (LL) | 16.12-37.10 | 27.73 | 3.77 | 0.60 | 1.68 |
| Number of leaves corm ⁻¹ line ⁻¹ (L/C/L) | 6.00-11.33 | 8.93 | 16.02 | 0.82 | 2.30 |
| Number of flowers corm ⁻¹ line ⁻¹ (F/C/L) | 4.00-35.33 | 15.33 | 8.81 | 0.78 | 2.17 |
| Fresh Flower weight corm ⁻¹ line ⁻¹ (FW/C/L) | 1.80-14.31 | 7.23 | 7.55 | 0.31 | 0.87 |
| Fresh pistil weight (g) (FPW) | 104.84- 1207.38 | 83.91 | 4.96 | 13.87 | 38.63 |
| Dry pistil weight (g) (DPW) | 25.95- 976.25 | 114.71 | 58.76 | 38.92 | 108.35 |
| Anther length (cm) (AL) | 1.34-2.37 | 1.90 | 1.01 | 0.01 | 0.03 |
| Anther Width (cm) (AW) | 1.26-3.74 | 2.40 | 6.97 | 0.09 | 0.26 |
| 50% flowering (50% F) | 68.66-76.66 | 73.10 | 1.87 | 0.78 | 2.19 |

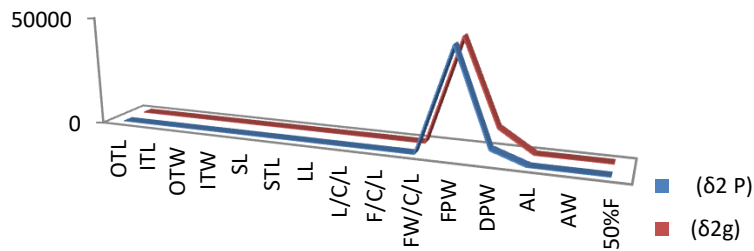


chart 1 . Estimates of $\delta^2 p$ & $\delta^2 g$ for morphological traits

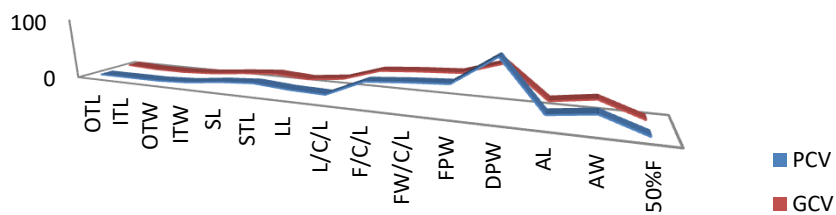


chart 2. Estimates of PCV & GCV for morphological traits

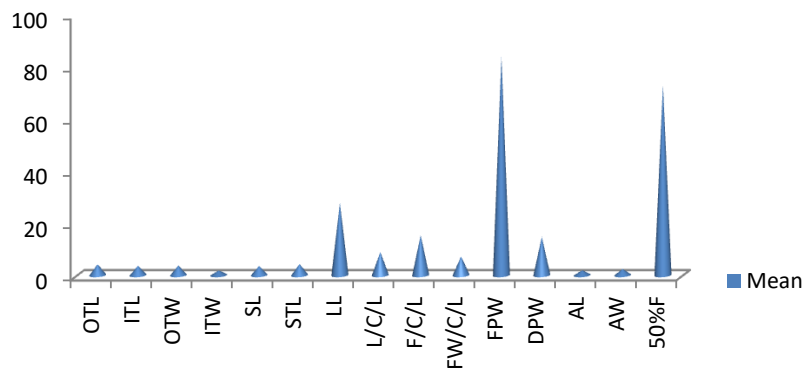


Fig. 3 Mean for magnitude of variability for different morphological traits

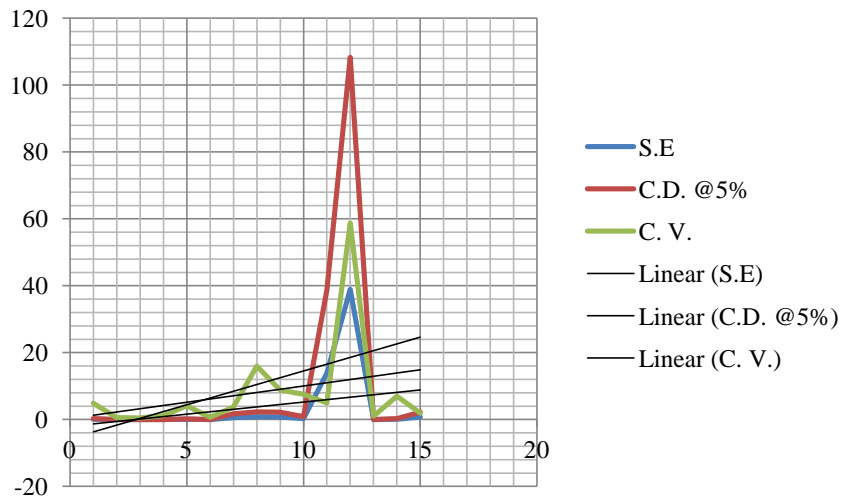


Fig. 4 Magnitude of variability for different morphological traits



Fig. 5 Layout of Research trial at ARSSSS, SKUAST-K Pampore



Fig. 6 Randomly selected and tagged saffron flower for evaluation

Based on the results of the investigation, wide range of variability exists in the natural population of saffron as indicated by the magnitude of performance, phenotypic and genotypic coefficient of variation, implying considerable scope for saffron improvement through clonal selection. Number of flowers corm⁻¹ and stigma length are the important traits for which due emphasis should be given while selecting for both quality and yield. The percent contribution of floral and vegetative attributes towards divergence in saffron germplasm revealed strong influence of fresh pistil weight followed by fresh flower weight corm⁻¹ and dry pistil weight. The main goal of this study was to find out the variability present in available germplasm and identification of elite genetic resource showing distinct superiority in certain traits can act as a source for further improvement and development of high yielding lines which will boost the production and productivity of saffron and can be beneficial to improve the socio-economic well being of the people associated with this important commercial crop.

Ethics statement

This article does not contain any human and animal subjects for experiments.

Data availability statement

The data that support the findings of this study are available from the corresponding author on request.

ETHICAL APPROVAL (WHERE EVER APPLICABLE)

This article does not contain any human and animal subjects for experiments.

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Comment [IGKA11]: References must be in the order that they appear in the text. Every reference referred in the text must also present in the reference list and vice versa

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