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Performance Evaluation of Snapdragon (*Antirrhinum majus* L.) Cultivars in the Dry Temperate Climate of Northern Balochistan

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Abstract: Snapdragon (*Antirrhinum majus* L.) is an ornamental plant widely grown as a cut flower worldwide because of its aesthetic appeal and adaptability to diverse climatic conditions. This study evaluated the performance of various *Antirrhinum* cultivars under the dry temperate climatic conditions of northern Balochistan, Pakistan. Three varieties—Sonnet, Shower, and Majus - and four cultivars - Yellow, White, Pink, and Purple were selected for field trials. The study examined morphological parameters, such as including plant height, number of leaves, leaf area, and number of branches, along with reproductive parameters such as the number of flowers and seeds. Seed germination tests were conducted under controlled conditions to determine germination rates and efficiency. The results showed significant variations among the cultivars in terms of growth, flowering, and germination. The findings indicated that *A. majus* can be successfully grown in dry temperate climates, offering potential for expanding the diversity of cut flowers in Pakistan's floriculture industry. The study highlights the effect of environmental factors such as temperature and photoperiod on plant development, contributing to the optimization of *A. majus* cultivation in regions with similar climatic conditions.

Keywords: Snapdragon, ornamental plant, growth, seed germination, Balochistan

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Introduction

Snapdragon (*Antirrhinum majus* L.) is a perennial, winter flowering plants, belongs to family Plantiginaceae. It is an herbaceous annual flowering plant which is originated in the Mediterranean region (Oyama and Baum. 2004). Later on, it has been introduced to different areas around the world. The Snapdragon is grown as a cut flower worldwide and it is estimated that, there are more than 20,000 cultivars are grown as commercial cut flowers worldwide (Ahmad. et al., 2020). *A. majus* is extensively used as an ornamental plant and is one of the model species in genetic science (Mateu-Andres and De Pacol, 2005). Snapdragons are known as 'cool season' or 'low temperature' crops (Miller, 1962). However, lowering temperature from 25 to 5 °C increased the flowering time in Snapdragons (Maginnes & Langhans, 1961). Plants at 21°C required 84 days for initiation and 109 days for the anthesis, whereas plants at 4.5°C required 124 days for initiation and 148 days for the anthesis (Maginnes & Langhans, 1961). On the other hand, fresh weight, number of flowers, number of leaves, stem and inflorescence length increased as the temperature was lowered from 25 to 10 °C (Maginnes & Langhans, 1961).

This plant used as a cut flower due to its showy petals. Flower petals are characterized by a variation in morphological characteristics, manifested in a variety of shapes, sizes and a series of colors. It is thought that this diversity develops as an adaptation to biotic pollinators, especially insects (Glover, 2011). *A. majus* when grown in warm regions exhibit a perennial behavior, however it is mostly grown as a winter annual, and used in flowering beds, mainly as short cultivars, or as a green background of flower beds, as tall varieties (Ball, 1991). Moreover, seed germination, growth and flowering of *Antirrhinum* are greatly influenced by various environmental conditions. The optimum temperature required for growth decreases with crop age, while seedlings require 20ºC night temperature. Plants near to flowering grow best at 13 ºC night temperature. Higher temperature adversely affects growth and flower quality (Bhargava, et al., 2016). Originally, Snapdragon is a summer flowering perennial in Mediterranean region. However, with the passage of time different hybrids were introduced which flower even in winter. Initially, Snapdragons were used only in landscape parks and gardens for flowering beds or borders. Recently, Snapdragon cultivars are classified into four different response groups because of their growth and flowering response in relation to temperature and day length (Ball, 1991). Recently, Snapdragon has become very popular in different gardens around the world and there is a high demand for this ornamental plant as cut flower. Therefore, the production of Snapdragon plant has been increased in recent years (Çelikel et al., 2010).

It is suggested that temperature photoperiod also plays an important role to determine the rate of growth and development in plants (El-Keblawy et al., 2015.). Temperature has a direct influence on the rate of many chemical reactions, including respiration that is the process responsible for growth and development of plants and photosynthesis. It showed that to have different effects on the flowering and budding time of genotypically different inbred lines of *Antirrhinum* sp. and most of the cultivars a temperature of 25 °C almost halved the flowering time compared to a 12 °C temperature (Edwards & Goldenberg, 1976). However, different plant sizes or plant growth stages were behavior in relation with optimum temperatures (Miller, 1962). Moreover, it is observed that, as the size of Snapdragons increased, the optimum temperature for dry weight accumulation decreased. Ethnobotanically, Snapdragon is also considered an important plant, flowers and leaves of Snapdragon have been used as traditional herbal medicine for treating several symptoms and diseases, including watery eyes, gum scurvy, hemorrhoids, ulcers, liver disorder, and tumors (Al-Snafi, 2015). The flowers of Snapdragon are among the most popular edible flowers and frequently introduced in different preparations of foods and drinks, such as salad, desserts, soups, teas, and liquors, for decorative and flavor-enhancing purposes (Rop et al., 2012).

Despite rich uses of the flower in medicinal and food products, only a few of studies have reported its antioxidant, antimicrobial, hemolytic, and wound-healing activities (Al-Snafi, 2015).

Although *A. majus* is among one of the major flowers of this plant are grown for its wide range of uses in the world, unfortunately trend of *Antirrhinum* growing has not yet been established in Pakistan. Pakistan only produced roses, gladiolus and tuberose as cut flower (Shafique et al., 2011). The study was conducted to increase the diversity of cut flowers in Pakistan and checked the efficiency of *Antirrhinum* cultivars at different times of the year. The seeds of different *Antirrhinum* cultivars were imported from the USA. Moreover, checked their field performance as cut flower under dry temperate climatic conditions of northern Balochistan.

Materials and Methods

Snapdragon Seed Collection

Three varieties i.e., Sonnet, Shower, Majus and four cultivars, Yellow, White, Pink, and Purple were collected from Directorate of Floriculture Department, (Agriculture Research Institute) Quetta in 2021. These seeds were transferred to Agriculture Plant Protection Lab, Agriculture Research Institute Quetta for further study.

Field Experiments

The field experiment was conducted at the Agriculture Research Institute (ARI) Sariab Road Quetta during growing season of 2021. The environmental conditions of Quetta are described as dry temperate zone with freezing temperatures during winter and mild weather in summer. The soil type described acidic with lower pH, and low organic content.

The following parameters were studied which are subdivided into morphological and reproductive parameters.

Morphological Parameters: The following parameters were measured weekly until the final harvest.

(i) Plant height, (ii) Number of leaves, (iii) Leaf area (leaf length x leaf width) and (iv) Number of branches.

Reproductive Parameters: The following reproductive parameters will be measured weekly when flower clusters appeared until the final harvest. (1) Number of flowers, (ii) Number of seeds.

Seed Germination Test

Twenty seeds of each variety were placed in a Petri dish with double-layered Whatman N°1 filter paper moistened with 10 ml of distilled water were used for germination test and stored at 20-25ºC in a germination. There were three replicates for each variety and cultivars were used for this experiment. Germination counts were made every day for 21 days or until all seeds germinated. Seeds was considered germinated when the tip of the radicle (2 mm) had grown free of the seed. The experimental design was described as Completely Randomized Design (CRD) with three replicates.

Environmental Data

The local environmental data were obtained from ARI, Quetta for experimental seasons. The environmental data were included relative humidity, maximum and minimum temperature and precipitation.

Soil and Water Analysis of Experimental Fields

The soil and water quality of both experimental fields were analyzed at the Directorate of Soil Fertility Research Centre, ARI Quetta.

Germination Index (GI)

The germination parameters used in this experiment are as follows:

(a) Final Germination Percentage (FGP): The FGP defined as the number of seeds germinated of an *Antirrhinum* variety during four days multiplied by 100. The higher FGP value indicates the greater seed germination of an *Antirrhinum* variety.

(b) Mean Germination Time (MGT): MGT defined as follows

$MGT = \Sigma f.x./\Sigma f$

Where f = Seeds germinated on day x

It is described that the lower the MGT, the faster the seeds of *Antirrhinum* variety germinated.

(c) First day of Germination (FDG): Day on which the first seed germination of an *Antirrhinum* variety occurred. Lower FDG indicates less dormancy of seed in an *Antirrhinum* variety.

(d) Last Day of Germination (LDG): The day on which the last seed germination event occurred in an

Antirrhinum variety. It is described that lower LDG values indicate the faster ending of germination.

(e) Coefficient of Velocity of Germination (CVG): It is defined as follows:

CVG =N1 +N2+…..+ Nx/100 x N1T1+….+ NxTx

Where N = Number of seeds germinated each day

T = Number of days from seed germinated corresponding to N

The CVG is described as an indicator of rapidity of seed germination in *Antirrhinum* varieties. Similarly, CVG increases when the number of germinated seed increases and the days (Time) required for germination decreases. The maximum CVG is 100 when all seeds germinated on the first day.

(f) Germination Rate Index (GRI/day): Germination Rate Index defined as follows:

GRI = G1/1 +G2/2…. + Gx/x

Where G1 = Germination percentage multiplied by 100 at the first day after incubating seeds in an oven.

G2 = Germination percentage multiplied by 100 at the second day after incubating seeds in an oven.

The higher GRI percentage indicates the higher germination rate in an *Antirrhinum* seed variety.

(g) Germination Index (GI): Germination Index described as follows:

GI = GI= (4 x n1) + (3 x n2) …… + (1 x n4)

Where n1, n2… n4 = Number of germinated seeds on the first, second and subsequent days until the final day. However, 4, 3 …1 are weights given to the number of germinated seeds on the first, second, and final days respectively. From this model it is postulated that maximum GI obtained when a seed germinated on the first day first compared with the subsequent days. Therefore, the less dormant seeds of *Antirrhinum* varieties showed higher GI values compared with those which showed higher dormancy tendencies.

(h) Time Spread of Germination (TSG day): It is defined as the time in days between first and last germination events occurring in an *Antirrhinum* seed variety. The higher TSG indicates greater differences in germination tendencies between 'fast' and 'slow' germinating *Antirrhinum* varieties.

Statistical Analysis

The effects of *A. majus* varieties on morphological and reproductive parameters were statistically analyzed by using modified analysis of variance (ANOVA) procedure in which heterogeneity of variances and lack of independence over time (from the first week of emergence to final week of yield harvested) were taken into consideration. For statistical analysis temporal repeated measures of individual *A. majus* varieties were used with the help of SPSS® version 16 (IBM® Inc.). The modified univariate ANOVA was used in a way that time effects plus all interactions to the terms of ordinary the ANOVA model along with the REPEATED statement of the GLM procedure (SPSS® version 16). The difference in mean value were calculated by using LSD (Least Significant Differences) at $P < 0.05$ with the help of SPSS® version 16. The graphs were constructed with the help of Sigma Plot® version 2000 (Sigma® Inc.).

Results and Discussion

Statistical Analysis of Seed Germination

The effect of innate seed dormancy on three Snapdragon seed varieties (Sonnet, Shower and Majus) and four cultivars (Yellow, White, Pink and Purple) was studied. The results of univariate ANOVA showed that there were no significant differences found among three varieties ($P < 0.138$) and cultivars ($P < 0.154$) of Snapdragon (Table 1). Similarly, the interaction between cultivars and varieties also showed non-significant differences ($P < 0.865$). It is mostly due to uniformity that prevailed among cultivars and varieties of Snapdragon. Although the effect of different temperature regime did not study in this experiment, but the results of experiments conducted by Silva et al. (2013) showed that effect of temperature regime significantly affected the seed germination of *A. viridis*.

Moreover, the results of temporal effects on seed germination revealed that there was a significant effect of time on seed germination of different varieties and cultivars of Snapdragon ($P < 0.001$, Table 1). The temporal repeated measures ANOVA is a comparatively advanced analysis of variance in which the effect of time on seed germination taken into consideration. Therefore, to adjust these effects G-G (Greenhouse-Geisser) and H-F (Huynh-Feldt) must be adjusted. In G-G (Greenhouse-Geisser) and H-F (Huynh-Feldt) the number of degrees of freedom of the F-test for time-related effects are reduced in order to take the autocorrelation and heteroscedasticity over time into account. Therefore, the adjusted values of G-G and H-F Epsilon are separately measured in Temporal Repeated Measures ANOVA are as follows: G-G = Greenhouse-Geisser Epsilon = 0.455 H-F = Huynh-Feldt Epsilon = 0.812 (The G-G and H-F Epsilon can be used to adjust the degrees of freedom for the averaged tests of significance). This test is used to correct for violation in the within subject effect factor. Within the subject degree of freedom is adjusted into 1 ($P < 0.001$, Table 1 & 2). The Epsilon values (G-G= 0.455 and H-F= 0.812) are the results of Mauchly's Test of Sphericity, where, tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix (Footnote, Table 1). It is defined as used to be adjust the degrees of freedom for the averaged tests of Significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table (Dutilleul, 1998). Furthermore, the within the subject effects of Time interaction with Variety also showed non-significant effects ($P < 0.568$) and similar trends observed in case of their adjusted values carried out by G-G (0.964) and H-F (0.994). Similarly, the interaction between Time and Cultivar also showed non-significant difference and same goes in case of interaction between Time x Variety x Cultivar (Table 2).

The results of LSD Test are presented in Figures 1, and 2. Temporal effect on seed germination of three Snapdragon varieties revealed that "Shower" comparatively higher rate of seed germination (18.16 ± 0.34) compared with Sonnet (17.33 ± 0.39) and Majus (17.50±0.31). However, these differences statistically were non-significant (Figure 1). Similarly, cultivars yellow (17.88±0.26), white (17.66±0.33), Pink (17.00±0.40) and Purple (18.11±0.56) were also showed non-significant differences (Figure 1).

Table 1. Univariate ANOVA for seed germination index for three Snapdragon varieties (Sonnet, Shower and Majus) and four cultivars (Yellow, White, Pink and Purple).

Source	Df	Sum of Squares	Mean Square	F	Significance
Variety	2	0.467	0.233	2.154	0.138
Cultivar	3	0.622	0.207	1.915	0.154
Variety*Cultivar	6	1.711	0.285	2.632	0.865
Error	24	2.600	0.108		0.042

Table 2. Summary of temporal repeated measure ANOVA for seed germination index for three Snapdragon varieties (Sonnet, Shower and Majus) and four cultivars (Yellow, White, Pink and Purple).

Source	DF[1]	F-value	Probability	Adjusted Pr>F	
				G-G[2]	**H-F**
(a) Between subject effects					
Variety	2	2.154	0.138	---	---
Cultivar	3	1.915	0.154	---	---
Variety*Cultivar	6	2.632	0.042	---	---
Error	24	------	------	---	---
(b) Within subject effects					

Time (Days)	1	0.00	0.001	0.001	0.001
Time*Variety	2	0.58	0.568	0.964	0.994
Time*Cultivar	3	3.752	0.24	0.184	0.127
Time*Variety*Cultivar	6	2.31	0.067	0.263	0.209
Error	24	---	---		

1DF = degrees of freedom
2In G-G (Greenhouse-Geisser) and H-F (Huynh-Feldt)
Mauchly's test of sphericity,
G-G = Greenhouse-Geisser Epsilon = 0.455
H-F = Huynh-Feldt Epsilon = 0.812

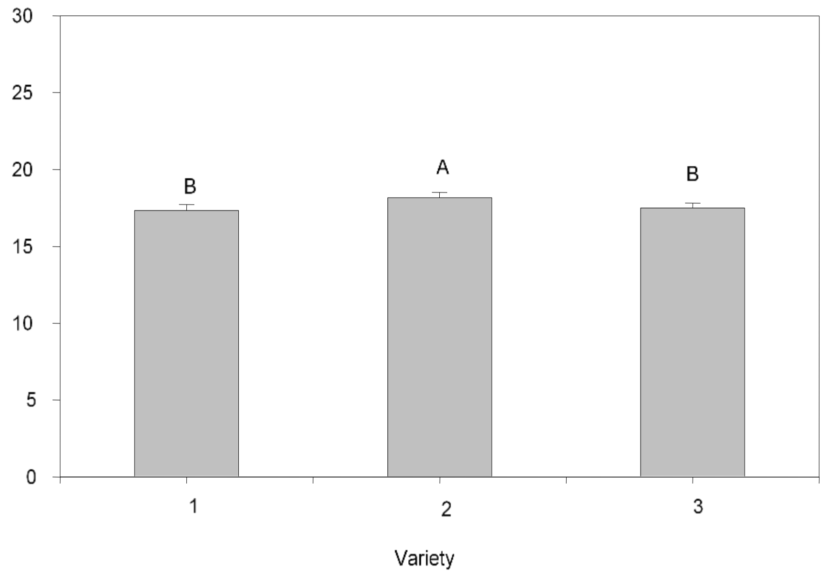

Figure 1. Seed germination (%) for three Snapdragon varieties (Sonnet, Shower, Majus). The arrows on the bar represent SE. The alphabets on the bar showed LSD ($p < 0.05$).

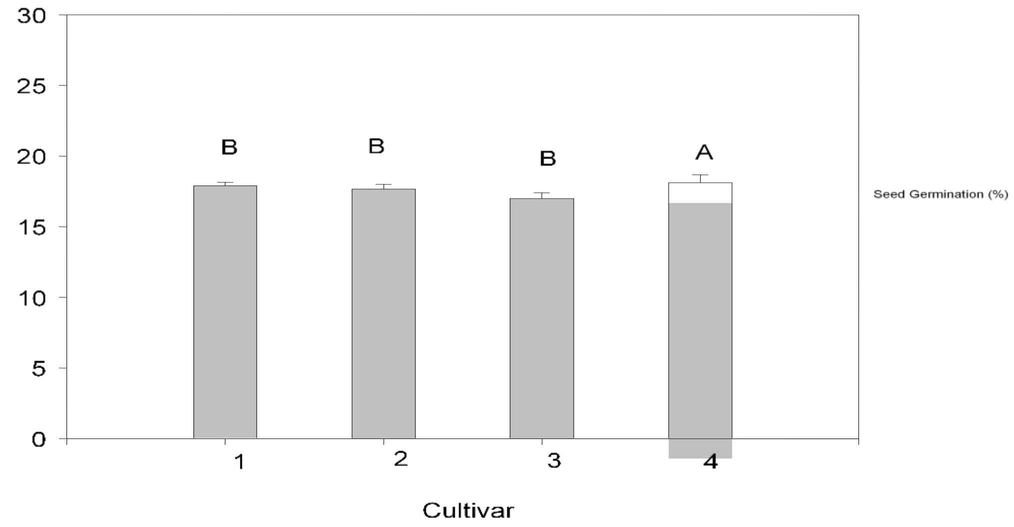

Figure 2. Seed germination (%) for four Snapdragon cultivars (Yellow, White, Pink and Purple). The arrows on the bar represent SE. The alphabets on the bar showed LSD ($p < 0.05$)

Seed Germination Index (SGI)

The result of SGI describes the effect of different parameters on seed germination (Kader, 2005). The results revealed a wide variation between germination data founded on the time spread of germination as well as its final percentage (Figure 3 & 4). The Final Germination Percentage (FGP), which reflects the final percentage of germination showed that the germination percentage appeared uniformly among three Snapdragon seed varieties. For instance, Snapdragon variety "Sonnet" showed 87.08 ± 1.78, Shower 87.50 ± 1.56 and Majus 87.50 ±1.56 (Figure 3). Similarly, the FGP of four cultivars of Snapdragon are as follows: Yellow showed 88.88 ±1.61, White 88.33±1.66, Pink 84.44±1.75 and Purple 91.11±2.46 (Figure 3). In general, there was a homogeneity prevailed among all varieties and cultivars, however, cultivar Purple showed highest FGP (91.11±2.46) compared with Sonnet which showed (87.08 ± 1.78).

The First Day of Germination (FDG) is described as the day on which the first germination event occurred (Kader, 2005). The results of FDG for three Snapdragon variety are as follows: Sonnet showed 4.91 ± 0.14, while Shower 4.75 ± 0.31and Majus 4.83 ±0.11. Moreover, the FDG of four cultivars of Snapdragon are as follows: Yellow showed 5.00 ± 0.00, White 4.77 ± 0.14, Pink 4.88 ± 0.20 and Purple 4.66 ± 0.16 (Figure 3 & 4). Based on these results it is observed that cultivar Yellow showed highest FDG (5.00 ± 0.00) compared with Shower (4.75 ± 0.3). Similar trend also observed in case of FDG, where, homogeneity prevailed among all varieties and cultivars.

The Last Day of Germination (LDG) is described as the day on which the last germination event occurred (Kader, 2005). The results of LDG for three Snapdragon varieties are as follows: Sonnet showed 9.83 ± 0.11, while Shower 9.91 ± 0.08 and Majus 9.66 ± 0.14. Furthermore, the LDG of four cultivars of Snapdragon are as follows: Yellow showed 10.00 ± 0.00, White 10.00 ± 0.00, Pink 9.66 ± 0.16 and Purple 9.55 ± 0.17 (Figure 3 & 4). Based on these results, it is observed that cultivar Yellow showed highest LDG (10.00 ± 0.00) compared with Purple (9.55 ± 0.17). These results revealed similar trend of homogeneity as observed in previous traits of germination indices.

The Coefficient of Velocity of Germination (CVG) is described as the day on which the number of seeds germinated per day (Kader, 2005). The results of CVG for three Snapdragon varieties are as follows: Sonnet showed 21.74 ± 0.88, while Shower 23.35 ± 0.74 and Majus 21.83 ± 0.91. Moreover, the CVG of four cultivars of Snapdragon are as follows: Yellow showed 23.53 ± 0.61, White 22.51 ± 0.86, Pink 20.25 ± 1.02 and Purple

22.94 ± 1.13 (Figure 3 & 4). Based on these results it is observed that cultivar Yellow showed the highest CVG (23.53 ± 0.61) compared with Pink (20.25 ± 1.02). Similar trend also observed in case of CVG, where, a homogeneity prevailed among all varieties and cultivars.

The Germination Rate Index (GRI) described is calculated based on the percentage of germination per day. The results of GRI for three Snapdragon varieties are as follows: Sonnet showed 2.53 ± 0.08, while Shower 2.72 ± 0.08 and Majus 2.61 ± 0.06. Besides, the GRI of four cultivars of Snapdragon are as follows: Yellow showed 2.58 ± 0.04, White 2.59 ± 0.06, Pink 2.57 ± 0.10 and Purple 2.74 ± 0.13 (Figure 3 & 4). Based on these results, it is observed that cultivar Purple showed highest GRI (2.74 ± 0.13) compared with Sonnet (2.53 ± 0.08). Similar trend also observed in case of GRI, where, a homogeneity prevailed among all varieties and cultivars.

The results of Germination Index (GI) for three Snapdragon varieties are as follows: Sonnet showed 65.75 ± 2.83, although Shower 71.58 ± 2.54, and Majus 68.83 ± 2.21. Furthermore, the GI of four cultivars of Snapdragon are as follows: Yellow showed 66.22 ± 1.51, White 67.22 ± 1.85, Pink 68.33 ± 3.44 and Purple 73.11 ± 4.17 (Figure 3 & 4). Based on these results it is detected that cultivar Purple showed highest GI (73.11 ± 4.17) compared with Sonnet (65.75 ± 2.83). Parallel trend also detected in case of GI, where, homogeneity prevailed among all varieties and cultivars.

Based on the Time Spread of Germination (TSG) were studied among three Snapdragon seed varieties. It was observed that Sonnet showed 4.91 ± 0.14, while Shower showed 5.16 ± 0.11 and Majus showed 4.83± 0.11. Moreover, the TSG of four cultivars of Snapdragon are as follows: Yellow showed 5.00 ± 0.00, White 5.22 ± 0.14, Pink 4.77 ± 0.14 and Purple 4.88 ± 0.20 (Figs. 3 and 4). Based on these results it was observed that cultivar White showed highest TSG (5.22 ± 0.14) compared with Pink (4.77 ± 0.14). Equivalent trend also detected in case of TSG, where; homogeneity prevailed among all varieties and cultivars.

The result of Mean Germination of Day (MGD) for three Snapdragon varieties are as follows: Sonnet showed 7.21 ± 0.10 while Shower showed 7.06 ± 0.07 and Majus showed 7.06 ± 0.11. Additionally, the MGD of four cultivars of Snapdragon are as follows: Yellow showed 7.29 ± 0.05, White showed 7.19 ± 0.07, Pink showed 6.98 ± 0.16 and Purple 6.98 ± 0.12 (Figure 3 & 4). Based on these results it was observed that cultivar Yellow showed highest MGD (7.29 ± 0.05) compared with Purple (6.98 ± 0.12). Equivalent trend was also observed in case of MGD, where; homogeneity prevailed among all varieties and cultivars.

Based on the result obtained with the help of different germination models, it is clear that all varieties and cultivars followed the same trends which confirms the assumption that despite their morphological heterogeneity, their genetic behavior is the same. Similarly, the seed dormancy among all these traits behaved similarly in a newly introduced environmental conditions. However, these results were obtained in a limited time scale and more research is required to observe the actual behavior of these traits.

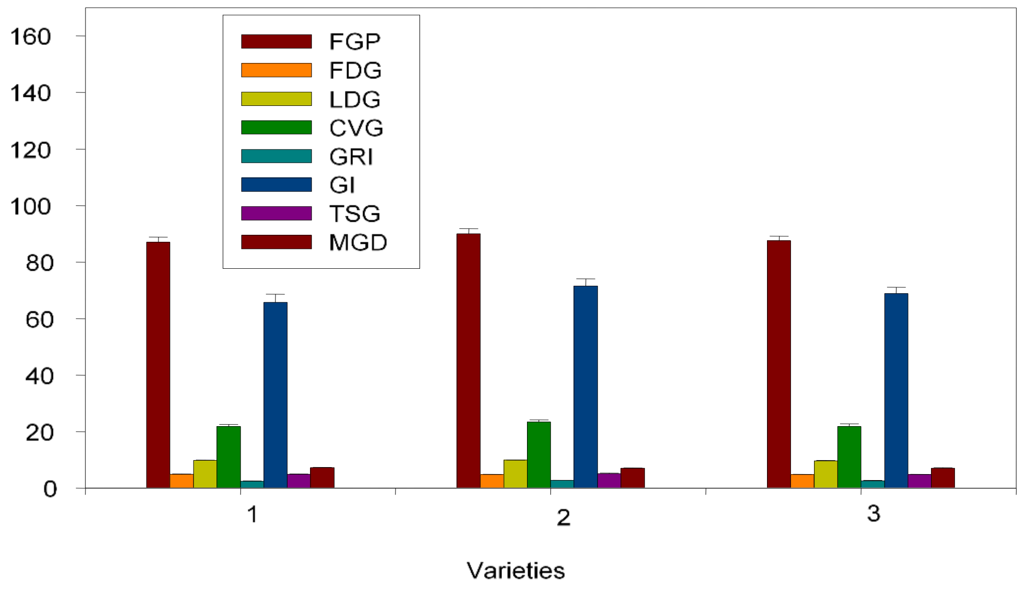

Figure 3. Germination parameters i.e., FGP (Final Germination Percentage), FDG (First Day of Germination), LDG (Last Day of Germination), CVG (Coefficient of Velocity of Germination), GRI (Germination Rate Index), GI (Germination Index), TSG (Time Spread of Germination) and MGD (Mean Germination Time) for three Snapdragon (Sonnet, Shower and Majus). The arrows on the bars represent the standard error.

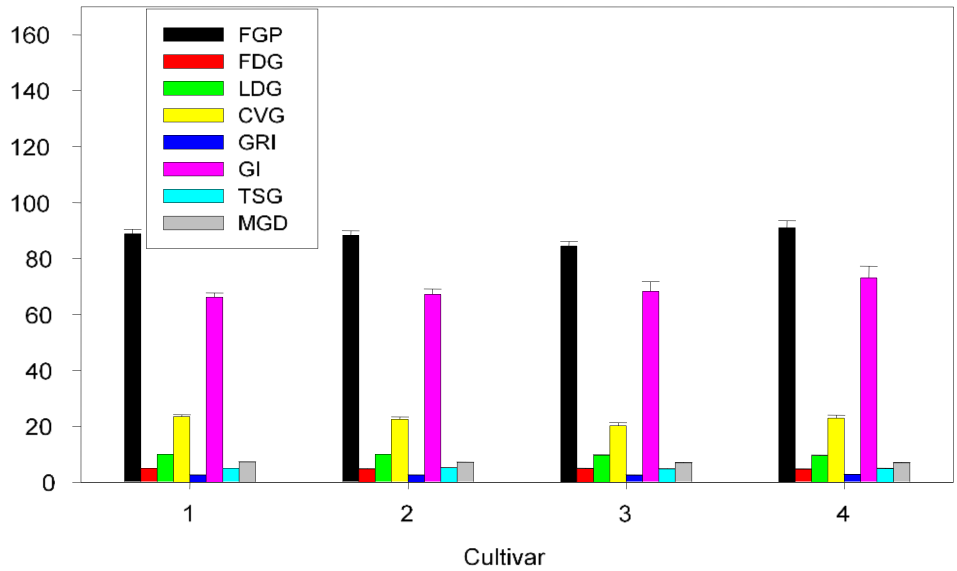

Figure 4. Germination Parameters i.e., FGP (Final Germination Percentage), FDG (First Day of Germination), LDG (Last Day of Germination), CVG (Coefficient of Velocity of Germination), GRI (Germination Rate Index), GI (Germination Index), TSG (Time Spread of Germination) and MGD (Mean Germination Time) for four Snapdragon cultivar (Yellow, White, Pink and Purple). The arrows on the bars represent the standard error.

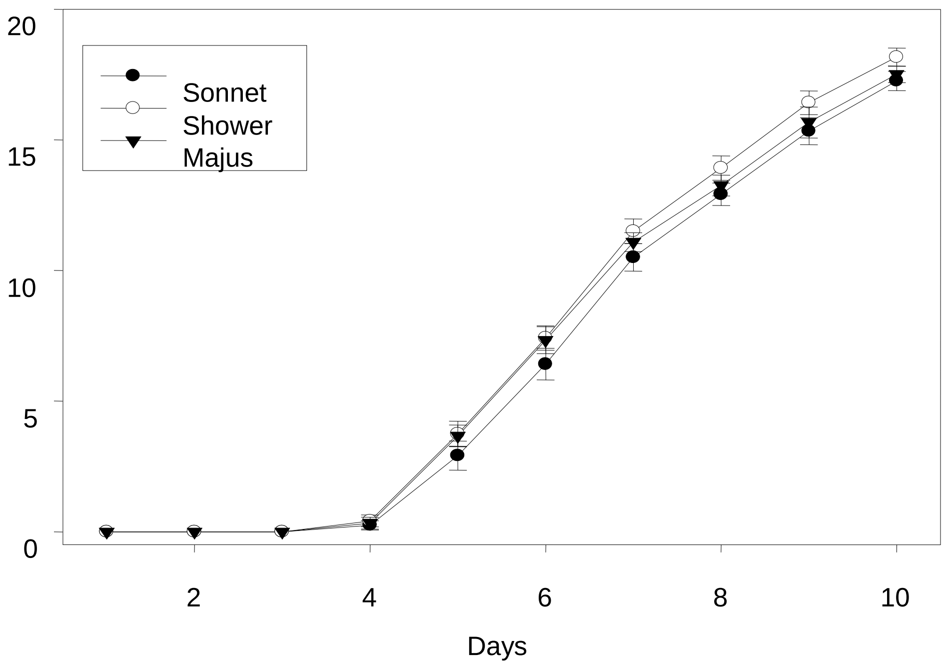

Figure 5. Cumulative Germination Index for three Snapdragon Varieties (Sonnet Shower, and Majus) for ten days. Arrows on dots are representing SE.

Conclusion

The study provides valuable insights into the adaptability and performance of *A. majus* cultivars under the dry temperate conditions of northern Balochistan. The results confirm that Snapdragon can be successfully cultivated in this region, with significant variations in morphological and reproductive traits among different varieties and cultivars. The influence of environmental factors, particularly temperature and photoperiod, plays a critical role in determining the growth and flowering patterns of Snapdragon. The findings suggest that introducing Snapdragon as a cut flower crop in Pakistan can enhance the diversity of the floriculture sector, offering economic benefits and aesthetic value. Future research should focus on optimizing cultivation practices, including irrigation management and soil fertility enhancement, to further improve the yield and quality of Snapdragon flowers in arid and semi-arid regions.

Additional Information and Declarations

Authors' Contribution: Authors declare that they have contributed equally to the manuscript.
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