



BİLİM-TEKNOLOJİ-YENİLİK EKOSİSTEMİ DERGİSİ

JOURNAL OF SCIENCE-TECHNOLOGY-INNOVATION ECOSYSTEM

E-ISSN : 2757-6140

Cilt | Volume:6

Sayı | Issue **: 1**

Yıl | Year: 2025



JOURNAL OF SCIENCE-TECHNOLOGY-INNOVATION ECOSYSTEM BİLİM-TEKNOLOJİ-YENİLİK EKOSİSTEMİ DERGİSİ

JSTIE 2025, 6(1)

Bilim-Teknoloji-Yenilik Ekosistemi Dergisi (BİTYED) yılda İki kez (Haziran ve Aralık) yayınlanan uluslararası veri indeksleri tarafından taranan hakemli bir dergidir. Gönderilen makaleler ilk olarak editörler ve yazı kurulunca bilimsel anlatım ve yazım kuralları yönünden incelenir. Daha sonra uygun bulunan makaleler alanında bilimsel çalışmaları ile tanınmış iki ayrı hakeme gönderilir. Hakemlerin kararları doğrultusunda makale yayımlanıp yayımlanmaz kararı alınır.

Bilim-Teknoloji-Yenilik Ekosistemi Dergisi'nde yayınlanan makalelerde fikirler yalnızca yazar(lar)ına aittir. Dergi sahibini, yayıncıyı ve editörleri bağlamaz. Bu sayıda yer alan tüm çalışmalar başvuru anında ve yayın öncesi olmak üzere iki kez **iThenticate** uygulaması aracılığıyla benzerlik taramasından geçirilmiştir.



Journal of Science-Technology-Innovation Ecosystem (JSTIE) offers free, immediate, and unrestricted access to peer reviewed research and scholarly work. Users are allowed to read, download, copy, distributed, print, search, or link to the full texts of the articles, or use them for any other lawful purpose, without asking prior permission from the publisher or the author.



Articles published in the Journal of Science-Technology-Innovation Ecosystem are Open-Access, distributed under the terms and conditions of the Creative Commons Attribution (CC BY 4.0) License. All rights to articles published in this journal are reserved and archived by the Journal of Science-Technology-Innovation Ecosystem, Çanakkale Onsekiz Mart University-TÜRKİYE.

Bu dergide yer alan makaleler 'Creative Commons Attribution (CC BY 4.0) Lisansı' ile lisanslanmıştır.

Bilim-Teknoloji-Yenilik Ekosistemi Dergisi (BİTYED) Çanakkale Onsekiz Mart Üniversitesi, Bilim ve Teknoloji Uygulama ve Araştırma Merkezi (ÇOBİLTUM) Terzioğlu Kampüsü, 17100 – Çanakkale – TÜRKİYE Telefon: +90 (286) 218 00 18 Dahili: 24006, Fax: +90(286) 218 19 48 Web: http://bityed.dergi.comu.edu.tr / E-mail: bityek@comu.edu.tr

ISSN: 2757-6140 (Online)

JOURNAL OF SCIENCE-TECHNOLOGY-INNOVATION ECOSYSTEM BİLİM-TEKNOLOJİ-YENİLİK EKOSİSTEMİ DERGİSİ

Volume 6 • Issue 1 • Year 2025 / Cilt 6 • Sayı 1 • Yıl 2025

Sahibi / Owner

Prof. Dr. Ramazan Cüneyt ERENOĞLU Çanakkale Onsekiz Mart Üniversitesi Rektörü

Baş Editör / Editor-in-Chief

Doç. Dr. Fırat ALATÜRK Bilim ve Teknoloji Uygulama ve Araştırma Merkezi

Editörler / Editors

Prof. Dr. Sermet KOYUNCU Doç. Dr. Ayça AYDOĞDU EMİR Doç. Dr. Emre ÖZELKAN Dr. Öğr. Üyesi Baboo ALİ Dr. Öğr. Üyesi Fatih SEZER Dr. Öğr. Üyesi Savaş GÜRDAL

Onursal Editor / Honorary Editor Prof. Dr. Ahmet GÖKKUŞ

Alan Editörleri / Associate Editors

Prof. Dr. Deniz Anıl ODABAŞI Prof. Dr. Derya SÜRGİT Prof. Dr. Mehmet Seckin ADAY Prof. Dr. Sibel MENTEŞE Doç. Dr. Ali KARANFİL Doç. Dr. Cemil TÖLÜ Doç. Dr. Melis İNALPULAT Doç. Dr. Muhittin KARAMAN Doç. Dr. Şahin KÖK Dr. Öğr. Üyesi Abdul HADİ Dr. Öğr. Üyesi Emin YAKAR Dr. Öğr. Üyesi Enis ARSLAN Dr. Öğr. Üyesi Gizem AKSU Dr. Öğr. Üyesi M. Burak BÜYÜKCAN Dr. Öğr. Üyesi Mehmet Ali GÜNDOĞDU Dr. Öğr. Üyesi Sefa AKSU Dr. Duygu ALGAN Dr. Uğur SARI

JSTIE 2025, 6(1)

Uluslararası Editorler Kurulu / International Editorial Board

Prof. Dr. Cedomir RADOVİC - Institue for Animal Husbandry, Belgrade-Serbia
Prof. Dr. Daniele BRUNO - University of Insubria, Varese Italy
Prof. Dr. Marcela Andreata KOREN - Krizevci University of Applied Sciences, Croatia
Prof. Dr. Mariyana IVANOVA - University of Agribusiness and Rural Development, Bulgaria
Prof. Dr. Tatjana JELEN - Krizevci University of Applied Sciences, Croatia
Assoc. Prof. Dr. Aynur HASHİMOVA - Sumgait State University, Azerbaijan
Assoc. Prof. Dr. Haneef Ur REHMAN - University of Turbat (UoT) Kech Balochistan, Pakistan
Assist. Prof. Dr. Asmat ULLAH - Kasetsart University Bangkok, Thailand
Assist. Prof. Dr. Muhammad Sharif BUZDAR - Balochistan Agriculture College Quetta, Pakistan

Teknik Editörler / Technical Editors

Doç. Dr. Ali KARANFİL - Çanakkale Onsekiz Mart Üniversitesi Dr. Öğr. Üyesi Sefa AKSU - Çanakkale Onsekiz Mart Üniversitesi

Dil Editörleri / Language Editors

Dr. Abdul HADİ Dr. Duygu ALGAN Dr. Uğur SARI

Yazım Editörleri / Copy Editors

Doç. Dr. Şahin KÖK - Çanakkale Onsekiz Mart Üniversitesi Dr. Öğr. Üyesi Mehmet Ali GÜNDOĞDU - Çanakkale Onsekiz Mart Üniversitesi

İstatistik Editörleri / Statistical Editors

Dr. Öğr. Üyesi Aykut OR - Çanakkale Onsekiz Mart Üniversitesi Dr. Öğr. Üyesi Zeynep GÖKKUŞ - Kastamonu Üniversitesi

Mizanpaj Editörleri / Layout Editors

Doç. Dr. Melis İNALPULAT - Çanakkale Onsekiz Mart Üniversitesi Ece COŞKUN - Doktora Öğrencisi - Çanakkale Onsekiz Mart Üniversitesi Hakan NAR - Doktora Öğrencisi - Çanakkale Onsekiz Mart Üniversitesi

Yazı İşleri / Secretariat

Dr. Öğr. Üyesi Baboo ALİ Zir. Yük. Müh. Hatice Simay SARI

Bilim Kurulu / Scientific Board

Prof. Dr. Ali KOÇ - Eskişehir Osmangazi Üniversitesi Prof. Dr. Cem ÖZKAN - Ankara Üniversitesi Prof. Dr. Dinçay KÖKSAL - Çanakkale Onsekiz Mart Üniversitesi Prof. Dr. Hüseyin ÇAVUŞ - Çanakkale Onsekiz Mart Üniversitesi Prof. Dr. İlhan ÇELİK - Samsun Üniversitesi Prof. Dr. İskender TİRYAKİ - Canakkale Onsekiz Mart Üniversitesi Prof. Dr. Kemal Melih TAŞKIN - Çanakkale Onsekiz Mart Üniversitesi Prof. Dr. M. Kerim GÜLLAP - Atatürk Üniversitesi, Erzurum Prof. Dr. Mustafa KIZILŞİMŞEK - Kahramanmaraş Sütçü İmam Üniversitesi Prof. Dr. Mustafa TAN - Atatürk Üniversitesi, Erzurum Prof. Dr. Ramazan ÇAKMAKÇI - Çanakkale Onsekiz Mart Üniversitesi Prof. Dr. Songül ÇAKMAKÇI - Atatürk Üniversitesi, Erzurum Prof. Dr. Tolga BEKLER - Canakkale Onsekiz Mart Üniversitesi Doç. Dr. Alper SAĞLIK - Çanakkale Onsekiz Mart Üniversitesi Doç. Dr. Erkan BİL - Çanakkale Onsekiz Mart Üniversitesi Doç. Dr. Önder GÜRSOY - Sivas Cumhuriyet Üniversitesi Doc. Dr. Sercan KARAV - Canakkale Onsekiz Mart Üniversitesi Doç. Dr. Uğur ŞİMŞEK - Iğdır Üniversitesi Dr. Öğr. Üyesi Aliye Aslı SONSUZ - İstanbul Medipol Üniversitesi Dr. Öğr. Üyesi Hülya HANOĞLU ORAL - Muş Alparslan Üniversitesi



JSTIE 2025, 6(1)

The Journal of Science-Technology-Innovation Ecosystem is indexed by the following data indices. Bilim-Teknoloji-Yenilik Ekosistemi Dergisi aşağıdaki veri indeksleri tarafından taranmaktadır.



JSTIE 2025, 6(1)

Certificates of Indexing / İndeks Sertifikaları







JSTIE: MID1732025

2025, 6(1): 29-39

e-ISSN: 2757-6140

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

Mehboob Ahmed^{1,2}, Shahid Ali³, Shaheen Ijaz⁴, Abdul Hameed Baloch¹, Haneef Ur Rehman⁵

¹Lasbela University of Agriculture, Water Marine Sciences, Faculty of Agriculture, Horticulture Department, Uthal Balochistan, Pakistan

²Government of Balochistan, Agriculture Extension Department, Turbat Balochistan, Pakistan

³Government of Balochistan, Department of Agriculture, Quetta Balochistan, Pakistan

⁴Balochistan Agriculture Research Institute, Directorate of Floriculture, Quetta Balochistan, Pakistan

⁵University of Turbat, Department of Natural and Basic Sciences, Turbat Balochistan, Pakistan

Article History Received: 05/03/2025

Accepted: 05/05/2025 Published: 22/04/2025 Research Article 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.

Abstract: Snapdragon (Antirrhinum majus L.) is an ornamental plant widely grown as a

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

Correspondence (Sorumlu yazar): haneef.baloch@uot.edu.pk

Citation (Alinti): Ahmed, M., Baloch, A. H., Ijaz, S., Ali, S., & Rehman, H. U. (2025). Performance evaluation of snapdragon (*Antirrhinum majus* L.) cultivars in the dry temperate climate of Northern Balochistan. *Journal of Science-Technology-Innovation Ecosystem*, 6(1), 29-39.



TIE: MID1732025 2025, 6(1): 29-39	
-----------------------------------	--

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 20°C night temperature. Plants near to flowering grow best at 13 °C 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 (Celikel 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 20-25°C 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:

 $GI = GI = (4 \text{ x } n1) + (3 \text{ x } n2) \dots + (1 \text{ x } n4)$

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 \pm 0.34) compared with Sonnet (17.33 \pm 0.39) and Majus (17.50 \pm 0.31). However, these differences statistically were non-significant (Figure 1). Similarly, cultivars yellow (17.88 \pm 0.26), white (17.66 \pm 0.33), Pink (17.00 \pm 0.40) and Purple (18.11 \pm 0.56) were also showed non-significant differences (Figure 1).

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

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 \pm 1.78, Shower 87.50 \pm 1.56 and Majus 87.50 \pm 1.56 (Figure 3). Similarly, the FGP of four cultivars of Snapdragon are as follows: Yellow showed 88.88 \pm 1.61, White 88.33 \pm 1.66, Pink 84.44 \pm 1.75 and Purple 91.11 \pm 2.46 (Figure 3). In general, there was a homogeneity prevailed among all varieties and cultivars, however, cultivar Purple showed highest FGP (91.11 \pm 2.46) compared with Sonnet which showed (87.08 \pm 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 ± 0.31 and 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 \pm 2.83, although Shower 71.58 \pm 2.54, and Majus 68.83 \pm 2.21. Furthermore, the GI of four cultivars of Snapdragon are as follows: Yellow showed 66.22 \pm 1.51, White 67.22 \pm 1.85, Pink 68.33 \pm 3.44 and Purple 73.11 \pm 4.17 (Figure 3 & 4). Based on these results it is detected that cultivar Purple showed highest GI (73.11 \pm 4.17) compared with Sonnet (65.75 \pm 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.
 Conflict of Interests: The authors of the manuscript declare that they have no conflict of interest.
 Copyright: 2025 Ahmed et al.
 Academic Editor: Dr. Duygu ALGAN
 Layout Editor: Dr. Baboo Ali

This work is licensed under a Creative Commons Attribution CC-BY 4.0 International License.

References

- Al-Snafi, A. E. (2015). The pharmacological importance of Antirrhinum majus-A review. Asian Journal of Pharm Science & Technology, 5 (4), 313-320.
- Ahmad, A., Ahmad, I., & Ferdosi, M. F. H. (2020). Indigenous soilless substrate compositions affect growth, yield and quality of cut Antirrhinum majus. Sarhad Journal of Agriculture, 36(2), 586-592.

Ball, V. (1991). Ball Red Book: Greenhouse Growing, 15" edition. Geo. J. Ball Publishing, Chicago, Illinois. 605-609.

- Bhargava, B., Gupta, Y.C, & Sharma, P. (2016). Performance of Snapdragon (Antirrhinum majus L.) under protected and open field conditions in Himachal Pradesh. Proceedings of the national academy of sciences, India section B: Biological sciences, 86(1), 65-69.
- Çelikel, F. G., Cevallos, J. C., & Reid, M. S. (2010). Temperature, ethylene and the postharvest performance of cut Snapdragons (*Antirrhinum majus* L.). Scientia Horticulturae, 125(3), 429-433.
- Dutilleul, P. (1998). Incorporating scale in study design and data analysis. In: *Scale Issues in Ecology*. (Peterson D.L. & Parker, V.T. Eds.) New York, Columbia University Press NY-387-425.
- El-Keblawy, A., Bhatt, A., & Gairola, S. (2015). Storage on maternal plants affects light and temperature requirements during germination in two small seeded halophytes in the Arabian deserts. *Pakistan Journal of Botany*, 47(5), 1701-1708.
- Edwards, K. J. R. & Goldenberg, J. B. (1976). A temperature effect on the expression of genotypic differences in flowering induction in *Antirrhinum majus*. *Annals of Botany*, 40,1277-83.
- Glover, B. J. (2011). Pollinator attraction: the importance of looking good and smelling nice. *Current Biology*, 21(9), R307-R309.
- Kader, M. A. (2005). A comparison of seed germination calculation formulae and the associated interpretation of resulting data. *Journal and Proceeding of the Royal Society of New South Wales*, 138, 65-75.
- Mateu-Andres, I., & De Paco, L. (2005). Allozymic differentiation of the *Antirrhinum majus* and *A. siculum* species groups. *Annals of Botany*, 95(3), 465-473.
- Maginnes, E. A. & Langhans, R. W. (1961). The effect of photoperiod and temperature on initiation and flowering of Snapdragon (*Antirrhinum majus*-variety Jackpot) Proc. of the American Society. *For Hort. Sci.*, 77, 600-607.
- Miller, R. O. (1962). Variations in optimum temperatures of Snapdragons depending on plant size. In: Proc. of the American Society. *For Hort. Sci.*, 81, 535-4Check the page number
- Rop, O., Mlcek, J., Jurikova, T., Neugebauerova, J., & Vabkova, J. (2012). Edible flowers-a new promising source of mineral elements in human nutrition. *Molecules*, 17(6), 6672-6683.
- Shafique, A., Maqbool, Muhammad, Nawaz, M. A., & Ahmed, W. A. Q. A. R. (2011). Performance of various Snapdragon (*Antirrhinum majus* L.) cultivars as cut flower in Punjab, Pakistan. *Pakistan Journal of Botany*, 43(2), 1003-1010.
- Silva. B. P., Alves, P. L. C. A., & Nepomucenol, M. P. (2013). Relative competitiveness between Industrial tomato and slender Amaranth. *Journal of Agriculture Science* 5(4), 103-111.
- Oyama, R. K., & Baum, D. A. (2004). Phylogenetic relationships of North American Antirrhinum (Veronicaceae). American Journal of Botany, 91(6), 918-925.