Altitude-Dependent Growth and Yield Characteristics in Petunia (*Petunia* × *hybrida* Vilm.): A Comparative Study of Varietal Responses

ABSTRACT

A study was conducted during the 2020-2021 growing season to evaluate the effects of different altitudinal rages on the growth and yield characteristics of six Petunia varieties: 'Red Chief', 'Star Mix', 'White', 'Pendula', 'N/C Mix' and 'Alderman'. The research was carried out across three experimental sites in Himachal Pradesh, Indi, Representing diverse altitudes: Khaltoo Experimental Farm (1060m amsl) of Department of Seed Science and Technology, the Experimental Farm (1276m amsl) of Department of Floriculture and Landscape Architecture, Dr. Yashwant Singh Parmar University of Horticulture and Forestry Nauni, Solan and the Experimental Farm (468m amsl) of Regional Horticultural Research and Training Station, Dhaulkuan, District Sirmaur (HP). The 'White' variety performed better in growth and yield attributes of petunia at different altitudinal range. The study systematically investigated how variations in altitudes affected critical growth and yield parameters, including plant height, flowering time, branch number and overall ornamental performance. Of the six varieties assessed, 'White' consistently demonstrated superior performance in terms of growth vigour and yield attributes across all the altitudinal range. The result also revealed that plant grown at mid-altitude range(1276 m amsl) at the Department of Floriculture and Landscape Architecture's Experimental Farm showed the most favourable growth and yield outcomes.

Keywords: Petunia, altitudinal range, different varieties, yield, growth

INTRODUCTION

The annual plant (*Petunia* × *hybrida* Vilm.), belonging to the Solanaceae family, holds the distinction of being recognized as the first bedding plant developed for ornamental use. This genus encompasses 25 species including the widely cultivated synthetic garden species *Petunia* × *hybrid* (Stehmann et al. 2009). The latter is a product of hybridization that occurred during historical times, originating from two wild species, *Petunia axillaris* and *Petunia violacea* as noted by Selaru (2008).Petunias are celebrated for their funnel shaped flowers which serve as the foundation for extensive horticultural advancements (Knapp, 2002). Through the efforts of skilled hybridizers, numerous variations have been developed, expanding the aesthetic appeal of this plant. These variations include both single and double bloom, featuring petals with distinctive characteristics such as fringed or wavy edges. Additionally, petunia flowers are available in a range of captivating patterns, including stripes, speckles and bordered designs, as well as hues of mauve and other vibrant color. These diverse prized for their versatility and visual impact in landscapes and containers alike (Toma, 2009). Garden petunias

are compact, herbaceous plants that grow to a height of 25-50 cm. they exhibit a sprawling or decumbent growth habit and are characterized by their pubescent, somewhat sticky foliage. These plants are known for producing large, strikingly beautiful flowers in an extensive array of colors (Ganga *et al*., 2011).

The increasing establishment of urban green spaces has highlighted the demand for a broader variety of floral plants to support diverse landscape development initiatives. Among these, Petunia hybrid has emerged as a popular choice for urban landscaping owing to its vibrant aesthetic and adaptability. It is widely utilized in both professional setting such as public parks and commercial spaces and informal context including home gardens and community landscapes. The continuous pursuit of novelty by end users, including homeowners, landscaper and urban planners creates a dynamic but challenging environment for ornamental plant breeding and use. Although a hundreds of new flower crop varieties are introduced each year across the globe, many fail to achieve long terms popularity. This phenomenon is largely driven by the desire for fresh aesthetic, unique colour palettes or innovative plant forms which quickly make existing varieties feel outdated.

MATERIALS AND METHODS

This study was carried out from December, 2020 to June, 2021 to evaluate the performance of six petunia varieties across three distinct altitudinal ranges. The chosen locations were Khaltoo Experimental Farm, Department of Seed Science and Technology (latitude of 30º51'7" N and longitude 77°10'56" E.), Floriculture Farm, Department of Floriculture and Landscape Architecture (latitude of 30°51'0" N and longitude of 77°11'0" E) and Dhaulakuan farm, Regional Horticulture Research and Training Station (latitude of 30°30'20" N and longitude 77°20'30" E), Dr. Yashwant Singh Parmar University of Horticulture and Forestry Nauni Solan. A Randomized Complete Block Design (factorial) with four replication and 18 treatment combination (variety × location) was employed to ensure robust experimental accuracy. The trials were carried out under open-field conditions. Land preparation including thorough plowing to a depth of 30 cm followed by the manual removal of stones, pebbles and other debris. cleaned by removing stones, pebbles and other unwanted material manually. Raised beds of size 1.0 m × 1.0 m × 0.15 m (Length × Breadth × Height) were constructed and properly leveled for uniformity across the experimental plots. These fields corresponded to the targeted altitudinal ranges labeled AR-I, AR-II and AR-III allowing for a comparative assessment of how altitude impacts petunia growth and ornamental traits. Throughout the study standard agronomical practices were adhered to ensuring optimal growing conditions for the petunia varieties. This methodological approach aimed to generate reliable data on the interaction between cultivar performance and environmental factors associated with varying altitudes.

List 1 : Treatment Details with their symbol

Altitudinal Ranges	
Khaltoo Farm	**: AR-I**

Floriculture Farm	:	**AR-II**
Dhaulakuan Farm	:	**AR-III**

Varieties		
Red Chief	:	$\mathbf{V_1}$
White	:	$\mathbf{V_2}$
Star Mix	:	$\mathbf{V_3}$
Pendula	:	$\mathbf{V_4}$
N/C Mix	:	$\mathbf{V_5}$
Alderman	:	$\mathbf{V_6}$

RESULTS AND DISCUSSION

The analyzed data recorded on number of days taken to first flowering of six varieties of petunia grown under three selected altitudinal ranges at the experimental Farm of Khaltoo (1060 m amsl), Floriculture Farm (1276 m amsl) and Dhaulakuan Farm (468m amsl) are presented in the Table-1. The results indicate that there is a significant influence by different altitudinal ranges and varieties on first flowering. Among the varieties cultivated at the AR-I (i.e. Khaltoo Farm) conditions, shortest time period for advent of first flowering (68.58 days) was recorded in the plants of var. 'Star Mix' and maximum time for first flowering (87.79 days) was there in 'White' variety. Similarly, the 'Star mix' variety recored shortest period of first flowering *viz.,* 72.52 and 64.57days at Floriculture farm and Dhaulakuan farm, respectively. The interaction, varieties × altitudinal ranges took significantly minimum number of days (64.57 days) for first flowering in the interaction, V_3× AR-III i.e. cultivation of Star Mix variety of petunia at the Dhaulakuan Farm.These results are in line with the Erwin *et al.*, 1997 and Howe and Waters, 1992).

The another parameter, plant height was influenced significantly by the altitudinal ranges and varieties tested as well as their interactive effects. The 'White' variety recorded considerably maximum plant height viz.,52.47, 57.77 and 53.26 cm at Khaltoo, floriculture and Dhaulakuan farm, respectively. The higher values for plant height in var.'White' at all the selected farms may be due to its superior genetic makeup. Among different ranges, maximum plant height was observed in AR-II (Floriculture Farm) which may be due to the fact that this very experimental farm might have supplied favourable environmental factors more efficiently in comparison to other altitudinal ranges (locations), the said result can get the support of work under taken in petunia by Drummond *et al*., (2015) and Nguyen *et al*., (2021).

The data recorded for number of flowers produced in every plant of six varieties of petunia grown under three selected altitudinal ranges revealed that 'White' variety has been produced significantly maximum number of flower per plant i.e. 137.33 at AR-I, 146.24 at AR-II and 130.23 at AR-III among the rest of variety in all three altitude range. A higher number of flowers per plant may be due to the result of exuberant vegetative growth before to flowering and the availability of favourable climate conditions

during flowering, which in response led to enhanced photosynthesis. The said result can get the support of work undertaken in petunia by Kelly et al. (2007) and Talang et al. (2019).

The analyzed data of number of branches revealed that white variety has recorded maximum number of branches viz., 26 and 19 when grown in Khaltoo and Floriculture farm, respectively. Whereas in Dhaulakuan farm (AR-III) maximum number of branches per plant (18.00) was counted in the plants of var. 'N/C Mix' and found to be statistically similar to number of branches in plants of var. 'White'(16.00). The interaction of varieties × altitudinal ranges had exhibited significantly maximum number of branches (26.00) per plant in the interaction, V_2 × AR-I i.e. cultivation of White variety of petunia at the Khaltoo Farm. The variation observed in number of branches per plant may be due to some inherent traits as well fluctuations in climatic condition. These results are similar with the findings already obtained in petunia by Griesbach (2007) and Nguyen *et al*. (2021).

Table 1: Effect of various altitudinal range and varieties on growth parameters of petunia

Altitudinal ranges / Varieties	Days taken to first flowering			Plant Height (cm)			No. of flowers/plant			No. of branches/plant		
	AR-I	**AR-II**	**AR-III**	**AR-I**	**AR-II**	**AR-III**	**AR-I**	**AR-II**	**AR-III**	**AR-I**	**AR-II**	**AR-III**
Red chief (V_1)	71.70	81.33	68.20	49.33	41.67	47.03	91.33	96.45	87.22	17.00	15.02	15.00
White (V_2)	87.79	88.58	81.77	52.47	57.77	53.26	137.33	146.24	130.23	26.00	19.00	16.00
Star mix (V_3)	68.58	72.52	64.57	47.14	38.66	43.10	70.31	76.58	64.82	13.03	16.00	14.00
Pendula (V_4)	83.33	85.69	76.07	49.17	52.61	52.42	120.33	127.34	113.23	21.00	17.00	14.01
N/C mix (V_5)	71.51	76.49	67.05	50.93	43.21	45.58	84.56	93.48	75.60	16.00	14.01	18.00
Alderman (V_6)	76.77	83.29	73.22	46.03	45.77	49.59	100.04	103.24	88.60	19.00	17.00	13.00
$CD_{0.05}$	2.84	1.97	1.96	0.89	0.93	1.08	1.25	0.32	1.58	2.12	1.88	2.87
$CD_{0.05}$												
Varieties:	1.21			0.51			0.83			1.43		
Altitudinal ranges:	0.86			0.36			0.58			1.09		
Varieties × Altitudinal Ranges:	2.10			0.89			1.43			2.67		

Note : AR-1 (Khaltoo farm), AR-II (Floriculture farm), AR-III (Dhaulakuan farm)

The data on number of capsules produced per plant in six varieties of petunia grown under three selected altitudinal ranges at the experimental Farm of Khaltoo (1060 m amsl), Floriculture Farm (1276 m amsl) and Dhaulakuan Farm (468m amsl) are presented in the Table-2. Among the varieties cultivated at the AR-I (Khaltoo Farm) conditions, significantly maximum number of capsules (107.23) per plant was found in var. 'White' and was minimum (54.90) in var. 'Star Mix'. Similarly, the plants of var. 'White' have also produced significantly highest number of capsules in weather condition of AR-II and AR-III. The data recorded on capsule length revealed that the effects of varieties, altitudinal ranges and their interactive influences were found to be non-significant.

The experimental results of capsule yield per plant indicates that altitudinal ranges and varieties significantly influenced the yield of capsule per plant. Among the varieties evaluated at AR-I, AR-II and AR-III location, the white variety recorded 3.53, 7.29 and 6.17 g weight of capsule, respectively. The interaction, varieties × altitudinal ranges gave significantly maximum capsule yield (7.29 g) per plant in the interaction, V_2× AR-II i.e. cultivation of White variety of petunia at the Floriculture Farm. Capsules yield per plant is a very important character that signifies the yield of capsules produced in a plant and seed yield produced in each plant too. The variation in the yield of capsules among altitudinal ranges and varieties might be due to the effect of environment and genetic makeup of the varieties. The results capsule yield per plant get the support from the earlier work done in petunia by Griesbach (2007) and Warner (2020).

The findings of the capsule yield per plot of three different altitudinal ranges showed in Table-2. Among the varieties cultivated at the AR-I (Khaltoo Farm) conditions could produce significantly highest capsule yield per plot (102.48 g) in var. 'White' and lowest yield per plot (56.48 g) in the plants of var. 'Star Mix'. Likewise, in Floriculture farm (AR-II) the 'white' variety recorded considerably maximum yield of capsule (116.64 g) per plot as compared to other variety.

Table 2: Effect of various altitudinal range and varieties on Yieldattributes of petunia

Altitudinal ranges / Varieties	No. of capsule/plant			Capsule length (cm)			Capsule yield per plant (g)			Capsule yield per plot (g)		
	AR-I	AR-II	AR-III	AR-I	AR-II	AR-III	AR-I	AR-II	AR-III	AR-I	AR-II	AR-III
Red chief (V_1)	71.33	76.45	67.22	1.04	1.07	1.06	4.28	4.44	4.14	68.48	71.00	66.16
White (V_2)	107.23	116.14	100.13	1.04	1.20	1.13	6.41	7.29	6.17	102.48	116.64	98.76
Star mix (V_3)	54.90	61.37	49.14	1.06	1.03	1.09	3.53	3.35	3.05	56.48	53.52	48.76
Pendula (V_4)	94.15	101.16	87.05	1.03	1.01	1.08	5.77	6.35	5.48	92.28	101.56	87.68
N/C mix (V_5)	66.11	75.03	57.15	0.98	1.04	1.06	4.16	4.42	3.60	66.56	70.72	57.60
Alderman (V_6)	75.44	82.28	67.66	1.02	1.05	1.03	4.41	5.16	4.19	70.52	82.60	66.96
$CD_{0.05}$	0.28	0.26	0.28	NS	NS	NS	0.35	0.25	0.25	5.63	4.03	3.96
$CD_{0.05}$												
Varieties:0.13					NS			0.15			2.40	
Altitudinal ranges:0.09					NS			0.11			1.70	
Varieties × Altitudinal Ranges: 0.22					NS			0.26			4.16	

Note : AR-1 (Khaltoo farm), AR-II (Floriculture farm), AR-III (Dhaulakuan farm)

CONCLUSION

The findings of this study revealed significant impacts o growth and yield attributes on the performance of six evaluated petunia varieties. The results highlighted a strong influence of varietal and environmental factors, particularly the specific altitudinal conditions on the ornamental and physiological trait of the plants.

Among the varieties, 'White' demonstrated superior performance across various parameters including earlier flowering, greater plant height, a high number of branches and enhanced yield attributes. These traits make 'White' a particularly desirable choice for both ornamental and landscaping purposes, emphasizing its adaptability and vigour under varying conditions.

The environmental conditions at AR-II (Floriculture Farm, Department of Floriculture and Landscape Architecture) provided the most favorable results for petunia growth and yield. This mi-altitude range (1276 m amsl) appeared to offer optimal conditions such as temperature, soil quality and possible light exposure which are critical for petunia development. The superior performance of varieties at this location suggest that altitude specific microclimate significantly influence the overall growth dynamics of petunias, underscoring the importance of site selection in ornamental horticulture.

The study emphasizes the need for integrating environmental factors, such as altitude with varietal selection to optimize the growth and ornamental appeal of petunias. These findings contribute valuable insights for breeders, horticulturists and landscapers aiming to achieve high quality floral displays and maximize yield in different geographical settings.

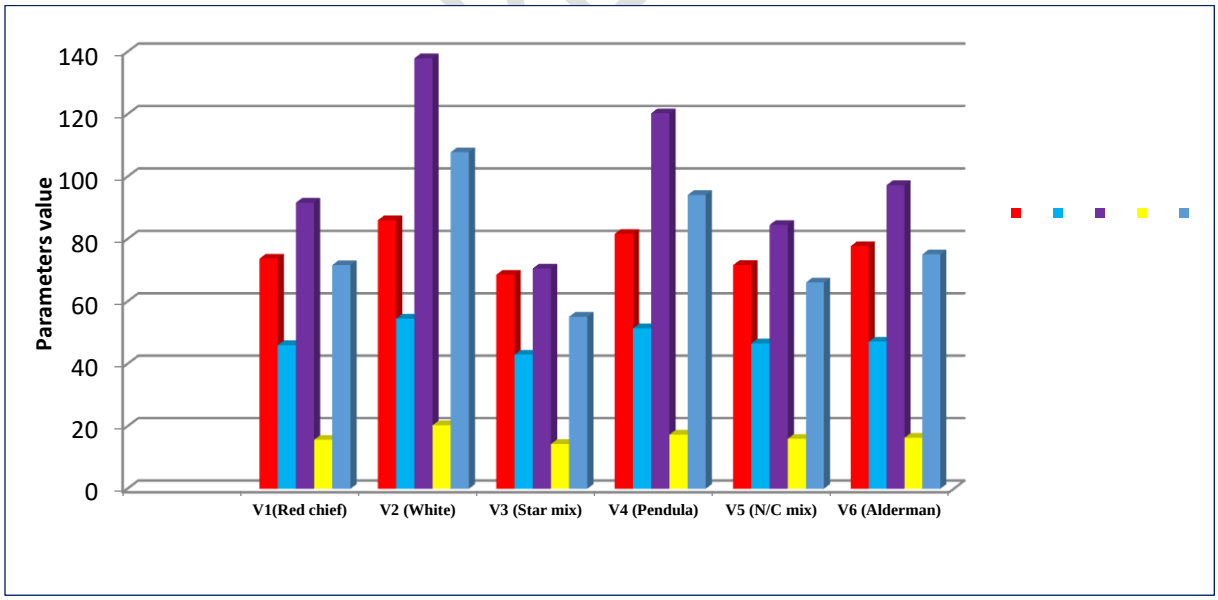

Fig.1 Mean performance of different varieties of petunia

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models,etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology i.e. ChatGPT.

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