PHENOLOGICAL DEVELOPMENT OF GLADIOLUS BASED ON HEAT UNIT REQUIREMENT

Thesis

Submitted to the Punjab Agricultural University
in partial fulfillment of the requirements
for the degree of

INTEGRATED MASTER OF SCIENCE (HONS.)
in
BOTANY
(Minor Subject: Biochemistry)

By

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2021

CERTIFICATE-I

This is to certify that the thesis entitled, **"Phenological development of gladiolus based on heat unit requirement"** submitted for the degree of **5-year Integrated M.Sc. (Hons.) Programme,** in the subject of **Botany** (Minor subject: **Biochemistry**) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Ravijot Kaur (L-2016-BS-67-IM)** under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE–II

This is to certify that the thesis entitled, **"Phenological development of gladiolus based on heat unit requirement"**submitted by **Ravijot Kaur** (**L-2016-BS-67-IM**) to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirement for the degree of **5-year Integrated M.Sc. (Hons.) Programme,** in the subject of **Botany** (Minor subject: **Biochemistry**) has been approved by the Student's Advisory Committee along with the External Examiner after an oral examination on the same.

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ACKNOWLEDGEMENT

As an unwavering and unshakable believer in his supreme existence, I, First and foremost, thank the master of my soul, ***'Waheguru, The Almighty'****, for showering his immense blessings on me and helping me throughout the period of my study.*

I would like to express my sincere and deepest gratitude to my thesis and research advisor, ***Dr Shalini Jhanji,*** *Plant Physiologist, Department of Floriculture and Landscaping for the continuous support, patience, motivation and immense guidance during my M.Sc. study and research. Without her continuous inspiration, it would have not been possible to complete this study. Her ideas and concepts had a remarkable influence on my entire work and helped me realise the power of critical reasoning. I have been extremely lucky to have an advisor who cared so much about my work, and who responded to my queries so promptly. I could not have imagined having a better advisor and mentor for my post graduate programme.*

My sincere thanks go to Dr KK Dhatt, Principal Scientist cum Head, Department of Floriculture and Landscaping; Dr Navjyot Kaur, Plant Physiologist, Department of Plant Breeding and Genetics; Dr Gagandeep Kaur Chahal, Assistant Professor, Department of Botany and Dr Satvir Kaur Grewal, Senoir Biochemist, Department of Biochemistry, members of my advisory committee for their priceless and inexpressible help and encouragement during the course of my research work.

I owe a debt of gratitude to the Head of Department of Botany and Head of Department of Floriculture and Landscaping for providing me with all the facilities and their immense support.

I dedicate this milestone to my family for their unflagging love and support throughout the life. I have no words to express my venerations towards my grandparents and parents, who made me see this world, my ever replenishing source of strength and encouragement, for their prayers and loving emotions during my entire span of life. I am happy to acknowledge the shadow support and moral upliftment showered upon me by my brother ***Harshdeep Singh****.*

It's my fortune to gratefully acknowledge the support of some special individuals : Eena Di, Manisha Di, Himani Di, Jaspreet Bajwa, Damanpreet, Amandeep, Gurleen, Jaismeen, Simran Minhas, Himani, Sandeep and Steffy for their love, care and support. I convey special thanks to ***Gurpreet Sidhu****. I cannot list all the names here, but they were always in my mind.*

I express my appreciation for the cooperation and help I received from Ved Parkash (Fieldman), Ramchandar, Mr. Anand (Lab Assistant) of the Department of Floriculture and Landscaping and Mr. Ashok Kumar of the Department of Botany.

Finally, I thank all who in one way or another contributed in the compilation of this thesis.

Place

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Date

Title of the Thesis	:	Phenological development of gladiolus based on heat unit requirement
Name of the Student and Admission No.	:	Ravijot Kaur (L-2016-BS-67-IM)
Major Subject	:	Botany
Degree to be Awarded	:	Integrated M.Sc. (Hons.)
Name and Designation of Major Advisor	:	Dr. Shalini Jhanji Plant Physiologist
Year of award of Degree	:	2021
Total Pages of Thesis	:	100 + VITA
Name of University	:	Punjab Agricultural University, Ludhiana- 141 004, Punjab, India

ABSTRACT

The present investigation entitled "Phenological development of gladiolus based on heat unit requirement" was undertaken in the field area of the Department of Floriculture and Landscaping, Punjab Agricultural University, Ludhiana, during 2020-2021. Corms of five gladiolus varieties namely Punjab Glad 3, Punjab Lemon Delight, CPG, Punjab Glance and White Prosperity were planted at 30 days interval from 28th September to 28th December and agrometeorological indices viz. Growing Degree Days (GDD), Heat Thermal Units (HTU), Photothermal Units (PTU) and Effective Night Temperature (ENT) were calculated. Punjab Glance took least number of days to blooming and plant senescence and accumulated minimum agrometeorological indices whereas, CPG recorded maximum number of days to blooming and plant senescence and accumulated maximum agrometeorological indices under all planting dates. Phenological model describing the detailed developmental stages and requirement of agrometeorological indices for each stage for gladiolus varieties was prepared by using Schwab's developmental staging system. Minimum (98.57) days to blooming were recorded under September planting followed by October (104.75), November (111.93) and December (117.05). Punjab Glance recorded maximum sprouting of corms (100%) whereas minimum was recorded in CPG (81.66%). Morpho-physiological characters like maximum plant height (106.07 cm), number of leaves/plant (8.02), spike length (95.41 cm), number of florets/spike (14.21), floret size (8.78 cm), leaf area (446.74 cm^2), dry matter accumulation at full spike senescence (28.14 g), corm diameter (5.16 cm) and weight of spike (48.16 g) were recorded in Punjab Glad 3 and maximum number of corms/plant (2.33), number of cormels/plant (47.17) and corm weight (35.99 g) were recorded in Punjab Glance under September planting. Postharvest quality parameters viz. minimum number of days for basal floret to open (1.30 days) in White Prosperity, maximum size of fully expanded floret (8.50 cm), number of florets opened at one time (6.33), water absorbed/spike (79.50 ml), vase life (9.06 days), percent opening of florets (79.5%), minimum loss in physiological weight (26.73%) and change in pH (0.1) in Punjab Glad 3 were observed under September planting. Regression analysis indicated a significant positive correlation between days to blooming, days to harvest corms and number of days to phenostage. Maximum correlation coefficient for days to blooming was observed with vegetative and spike emergence stages. Whereas, maximum correlation coefficient for days to corm harvest was observed with reproductive stages. Schwab's staging system along with regression equations could be used to predict days to blooming so that planting could be done accordingly to get spikes near the desired date.

Keywords: Gladiolus, Phenological development, Agrometeorological indices, Planting dates, Schwab's staging model, Regression model

Signature of Major Advisor **Signature of the Student**

ਖੋਜ ਗ੍ਰੰਥ ਦਾ ਸਿਰਲੇਖ	:	ਹੀਟ ਯੂਨਿਟ ਦੀ ਲੋੜ ਤੇ ਅਧਾਰਿਤ ਗਲੈਡੀਓਲਸ ਦਾ ਫੀਨੋਲੌਜੀਕਲ ਵਿਕਾਸ
ਵਿਦਿਆਰਥੀ ਦਾ ਨਾਂ ਅਤੇ ਦਾਖ਼ਲਾ ਨੰਬਰ	:	ਰਵੀਜੋਤ ਕੌਰ (ਐੱਲ-2016-ਬੀਐੱਸ-67-ਆਈਐੱਮ)
ਪ੍ਰਮੁੱਖ ਵਿਸ਼ਾ	:	ਬੌਟਨੀ
ਸਹਿਯੋਗੀ ਵਿਸ਼ਾ	:	ਜੀਵ ਰਸਾਇਣ
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ਡਿਗਰੀ	:	ਇੰਟੀਗ੍ਰੇਟਿਡ ਮਾਸਟਰ ਆਫ਼ ਸਾਇੰਸ (ਆਨਰਜ਼)
ਡਿਗਰੀ ਮਿਲਣ ਦਾ ਸਾਲ	:	2021
ਖੋਜ ਪੱਤਰ ਵਿੱਚ ਕੁੱਲ ਪੰਨੇ	:	100 + ਵੀਟਾ
ਯੂਨੀਵਰਸਿਟੀ ਦਾ ਨਾਮ	:	ਪੰਜਾਬ ਖੇਤੀਬਾੜੀ ਯੂਨੀਵਰਸਿਟੀ, ਲੁਧਿਆਣਾ-141 004, ਪੰਜਾਬ, ਭਾਰਤ।

ਸਾਰ ਅੰਸ਼

ਪੰਜਾਬ ਐਗਰੀਕਲਚਰਲ ਯੂਨੀਵਰਸਿਟੀ, ਲੁਧਿਆਣਾ ਦੇ ਫਲੋਰੀਕਲਚਰ ਅਤੇ ਲੈਂਡਸਕੇਪਿੰਗ ਵਿਭਾਗ ਦੇ ਫੀਲਡ ਏਰੀਏ ਵਿੱਚ 2020-2021 ਦੌਰਾਨ 'ਹੀਟ ਯੂਨਿਟ ਦੀ ਲੋੜ ਤੇ ਆਧਾਰਿਤ ਗਲੈਡੀਓਲਸ ਦਾ ਫੀਨੋਲੌਜੀਕਲ ਵਿਕਾਸ' ਸਿਰਲੇਖ ਵਾਲੀ ਮੌਜੂਦਾ ਜਾਂਚ ਕੀਤੀ ਗਈ ਸੀ। ਪੰਜ ਗਲੈਡੀਓਲਸ ਕਿਸਮਾਂ ਜਿਵੇਂ ਕਿ ਪੰਜਾਬ ਗਲੈਡ 3, ਪੰਜਾਬ ਲੈਮਨ ਡੀਲਾਇਟ, ਸੀ ਪੀ ਜੀ, ਪੰਜਾਬ ਗਲੈਂਸ ਅਤੇ ਵਾਈਟ ਪ੍ਰੋਸਪੈਰਟੀ, 28 ਸਤੰਬਰ ਤੋਂ 28 ਦਸੰਬਰ ਤੱਕ 30 ਦਿਨਾਂ ਦੇ ਅੰਤਰਾਲ ਤੇ ਲਗਾਈਆਂ ਗਈਆਂ ਸਨ ਅਤੇ ਖੇਤੀ ਮੌਸਮੀ ਸੂਚਕਾਂਕ ਜਿਵੇਂ ਕਿ ਵਧ ਰਹੇ ਡਿਗਰੀ ਦਿਨ (ਜੀ ਡੀ ਡੀ) ਹੀਟ ਥਰਮਲ ਯੂਨਿਟਸ (ਏਚ ਟੀ ਯੂ), ਫੋਟੋਥਰਮਲ ਯੂਨਿਟਸ (ਪੀ ਟੀ ਯੂ) ਅਤੇ ਪ੍ਰਭਾਵੀ ਰਾਤ ਦੇ ਤਾਪਮਾਨ (ਈ ਏਨ ਟੀ) ਦੀ ਗਣਨਾ ਕੀਤੀ ਗਈ ਸੀ। ਪੰਜਾਬ ਗਲੈਂਸ ਨੇ ਫੁੱਲ ਖਿੜਨ ਅਤੇ ਮੁਰਝਾਉਣ ਵਿੱਚ ਸਭ ਤੋਂ ਘੱਟ ਦਿਨ ਲਏ ਅਤੇ ਘੱਟ ਖੇਤੀ ਮੌਸਮੀ ਸੂਚਕਾਂਕ ਇਕੱਠੇ ਕੀਤੇ। ਜਦੋਂ ਕਿ ਸੀ ਪੀ ਜੀ ਨੇ ਪੌਦੇ ਲਗਾਉਣ ਦੀਆਂ ਸਾਰੀਆਂ ਤਾਰੀਖਾਂ ਦੇ ਤਹਿਤ ਫੁੱਲ ਖਿੜਨ ਅਤੇ ਮੁਰਝਾਉਣ ਵਿੱਚ ਸਭ ਤੋਂ ਵੱਧ ਦਿਨ ਰਿਕਾਰਡ ਕੀਤੇ ਅਤੇ ਖੇਤੀ ਮੌਸਮੀ ਸੂਚਕਾਂਕ ਇਕੱਠੇ ਕੀਤੇ। ਗਲੈਡੀਓਲਸ ਕਿਸਮਾਂ ਦੇ ਹਰੇਕ ਪੜਾਅ ਲਈ ਵਿਸਤ੍ਰਿਤ ਵਿਕਾਸ ਦੇ ਪੜਾਵਾਂ ਅਤੇ ਖੇਤੀ ਮੌਸਮੀ ਸੂਚਕਾਂਕਾਂ ਦੀ ਜ਼ਰੂਰਤ ਦਾ ਵਰਨਣ ਕਰਨ ਵਾਲਾ ਫੀਨੋਲੌਜੀਕਲ ਮਾਡਲ ਸ਼ਵਾਬ ਦੀ ਵਿਕਾਸ ਸੰਬੰਧੀ ਸਟੇਜਿੰਗ ਪ੍ਰਣਾਲੀ ਦੀ ਵਰਤੋਂ ਕਰਕੇ ਤਿਆਰ ਕੀਤਾ ਗਿਆ। ਸਭ ਤੋਂ ਘੱਟ ਫੁੱਲ ਖਿੜਨ ਦੇ ਦਿਨ (98.57) ਸਤੰਬਰ ਵਿੱਚ ਪਾਏ ਗਏ, ਇਸ ਤੋਂ ਬਾਅਦ ਅਕਤੂਬਰ (104.75), ਨਵੰਬਰ (111.93) ਅਤੇ ਦਸੰਬਰ (117.05) ਵਿੱਚ ਦਰਜ ਕੀਤੇ ਗਏ। ਪੰਜਾਬ ਗਲੈਂਸ ਨੇ ਵੱਧ ਤੋਂ ਵੱਧ ਫੁੱਟਣ ਦੀ ਦਰ (100%) ਦਰਜ ਕੀਤੇ ਜਦੋਂ ਕਿ ਸੀ ਪੀ ਜੀ (81.65%) ਵਿੱਚ ਸਭ ਤੋਂ ਘੱਟ ਦਰ ਦਰਜ ਕੀਤੀ ਗਈ। ਮੋਰਫੋ-ਫਿਜੀਓਲੋਜੀਕਲ ਕਰੈਕਟਰ ਜਿਵੇਂ ਕਿ ਪੌਦਿਆਂ ਦੀ ਲੰਬਾਈ (106.07 ਸੈ.ਮੀ.), ਪੱਤੇ ਪ੍ਰਤੀ ਪੌਦਾ (8.02), ਡੰਡੀ ਦੀ ਲੰਬਾਈ (95.41 ਸੈ.ਮੀ.), ਫੁੱਲਾਂ ਦੀ ਗਿਣਤੀ/ਡੰਡੀ (14.21), ਫੁੱਲਾਂ ਦਾ ਆਕਾਰ (8.78 ਸੈ.ਮੀ.), ਪੱਤਾ ਖੇਤਰ ਪ੍ਰਤੀ ਪੌਦਾ (446.74 ਸੈ.ਮੀ.^{2}), ਸੁੱਕੀ ਡੰਡੀ ਦਾ ਭਾਰ (28.14 ਗ੍ਰਾਮ) ਗੰਢੇ ਦਾ ਵਿਆਸ (5.16 ਸੈ.ਮੀ.) ਅਤੇ ਡੰਡੀ ਦਾ ਭਾਰ (48.16 ਗ੍ਰਾਮ) ਪੰਜਾਬ ਗਲੇਡ 3 ਵਿੱਚ ਦਰਜ ਕੀਤਾ ਗਿਆ ਅਤੇ ਵੱਧ ਤੋਂ ਵੱਧ ਗੰਢੇ/ਪੌਦਾ (2.33) ਗੰਢੀਆਂ/ਪੌਦਾ ਦੀ ਸੰਖਿਆ (47.17) ਅਤੇ ਗੰਢੇ ਦਾ ਵਜ਼ਨ (35.99 ਗ੍ਰਾਮ) ਸਤੰਬਰ ਦੀ ਬਿਜਾਈ ਅਧੀਨ ਪੰਜਾਬ ਗਲੈਂਸ ਵਿੱਚ ਦਰਜ ਕੀਤਾ ਗਿਆ। ਤੁੜਾਈ ਉਪਰੰਤ ਗੁਣਵੱਤਾ ਮਾਪਦੰਡਾਂ ਜਿਵੇਂ ਕਿ ਬੇਸਲ ਫਲੋਰਟ ਦੇ ਖੁੱਲਣ ਲਈ ਘੱਟ-ਘੱਟ ਦਿਨਾਂ ਦੀ ਸੰਖਿਆ (130 ਦਿਨ) ਵਾਈਟ ਪ੍ਰੋਸਪੈਰਿਟੀ ਵਿੱਚ ਸੀ, ਪੂਰੀ ਤਰ੍ਹਾਂ ਫੈਲੇ ਫੁੱਲਾਂ ਦਾ ਵੱਧ ਤੋਂ ਵੱਧ ਆਕਾਰ (8.50 ਸੈ.ਮੀ.), ਇੱਕ ਸਮੇਂ ਖੁੱਲ੍ਹੇ ਫੁੱਲਾਂ ਦੀ ਗਿਣਤੀ (6.33), ਪ੍ਰਤੀ ਡੰਡੀ ਪਾਣੀ ਸੋਖਣਾ (79.50 ਮਿ.ਮੀ.), ਫੁੱਲਦਾਨ ਦਾ ਜੀਵਨ (9.06 ਦਿਨ), ਫੁੱਲਾਂ ਦੇ ਖੁੱਲਣ ਦਾ ਪ੍ਰਤੀਸ਼ਤ (79.5%), ਡੰਡੀ ਦੇ ਭਾਰ ਵਿੱਚ ਘੱਟੋ ਘੱਟ ਘਾਟਾ (26.73%) ਅਤੇ ਪੀ ਐੱਚ ਵਿੱਚ ਤਬਦੀਲੀ (0.1) ਸਤੰਬਰ ਦੀ ਬਿਜਾਈ ਦੇ ਤਹਿਤ ਪੰਜਾਬ ਗਲੈਡ 3 ਵਿੱਚ ਦੇਖੀ ਗਈ। ਰਿਗਰੈਸ਼ਨ ਵਿਸ਼ਲੇਸ਼ਣ ਨੇ ਫੁੱਲ ਖਿੜਨ ਦੇ ਦਿਨ, ਗੰਢਿਆਂ ਦੀ ਹਾਰਵੇਸਟਿੰਗ ਦੇ ਦਿਨਾਂ ਅਤੇ ਫਿਨੋਸਟੇਜ ਦੇ ਦਿਨਾਂ ਦੀ ਗਿਣਤੀ ਦੇ ਵਿਚਕਾਰ ਇੱਕ ਮਹੱਤਵਪੂਰਨ ਸਕਾਰਾਤਮਕ ਸੰਬੰਧ ਦਾ ਸੰਕੇਤ ਦਿੱਤਾ। ਫੁੱਲਾਂ ਦੇ ਖਿੜਨ ਦੇ ਦਿਨਾਂ ਲਈ ਵੱਧ ਤੋਂ ਵੱਧ ਸਹਿਸੰਪਰਕ ਗੁਣਾਂਕ ਬਨਸਪਤੀ ਅਤੇ ਡੰਡੀ ਦੇ ਉਭਾਰ ਦੇ ਪੜਾਵਾਂ ਨਾਲ ਦੇਖਿਆ ਗਿਆ । ਜਦੋਂ ਕਿ ਪ੍ਰਜਨਨ ਦੇ ਪੜਾਵਾਂ ਦਾ ਅਧਿਕਤਮ ਸਹਿ ਸੰਪਰਕ ਗੁਣਾਂਕ ਗੰਢਿਆਂ ਦੀ ਹਰਵੈਸਟਿੰਗ ਨਾਲ ਦੇਖਿਆ ਗਿਆ। ਰਿਗਰੈਸ਼ਨ ਸਮੀਕਰਨਾਂ ਦੇ ਨਾਲ ਸ਼ਵਾਬ ਦੀ ਸਟੇਜਿੰਗ ਪ੍ਰਣਾਲੀ ਦੀ ਵਰਤੋਂ ਫੁੱਲ ਖਿੜਨ ਦੇ ਦਿਨਾਂ ਦੀ ਭਵਿੱਖਬਾਣੀ ਕਰਨ ਲਈ ਕੀਤੀ ਜਾ ਸਕਦੀ ਹੈ ਤਾਂ ਜੋ ਲੋੜੀਂਦੀ ਮਿਤੀ ਦੇ ਨੇੜੇ ਡੰਡੀਆਂ ਪ੍ਰਾਪਤ ਕਰਨ ਲਈ ਬਿਜਾਈ ਕੀਤੀ ਜਾ ਸਕੇ।

ਮੁੱਖ ਸ਼ਬਦ: ਗਲੈਡੀਓਲਸ, ਫੀਨੋਲੌਜੀਕਲ ਵਿਕਾਸ, ਖੇਤੀ ਮੌਸਮੀ ਸੂਚਕਾਂਕ, ਗੰਢੇ ਲਗਾਉਣ ਦੀਆਂ ਤਰੀਕਾਂ, ਸ਼ਵਾਬ ਦਾ ਸਟੇਜਿੰਗ ਮਾਡਲ, ਰਿਗਰੈਸ਼ਨ ਮਾਡਲ

ਮੁੱਖ ਸਲਾਹਕਾਰ ਦੇ ਹਸਤਾਖਰ **ਵਿੱਦਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ**

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CHAPTER I

INTRODUCTION

Gladiolus grandiflorus (also called gladiola) is an important cut flower native to South Africa and belongs to monocotyledonous family Iridaceae. There are more than 100 wild species of Gladiolus mainly occurring in the regions of Mediterranean and South Africa (Tombolato *et al* 2005, Riaz *et al* 2010). In addition to cut flower, gladiolus is used for flower beddings in gardens. Gladiolus is popularly known as "Xiphium" because in Greek Xiphos means sword and "Sword Lily" due to its sword shaped, longitudinally grooved leaves; and is also called "Queen of bulbous flowers" as its spikes exist in many forms, colour combinations, attractive shapes with excellent shelf life (Bushman 1990). Major gladiolus producing countries are the United States, Netherlands, France, Bulgaria, Italy, India and Israel (Vasanthakumar *et al* 2015).

Gladiolus is an herbaceous plant bearing underground stems called corms which give rise to sword shaped foliage bearing terminal inflorescence known as spike. It's spikes are ready to harvest after 60 to 100 days of planting depending upon the cultivar and time of year (Fatihullah and Bostan 2018). The herbaceous stem has linear and narrow leaves with flattened sides. It is commercially propagated through corms and cormels which are produced after full bloom as the food material is transported downwards to increase their size (Hartmann *et al* 1981). A bud develops on the upper surface of daughter corm from where a new plant grows. Corm is a food storing underground stem and it maintains the plant during dormancy phase until growth resumes after spring rain begins (Fatihullah and Boston 2018). Corm is covered by thin, old, dry and papery leaves called husks. Corm usually sprouts within a week after planting. The filiform roots start emerging from the base of the corm (Schwab *et al* 2015). Gladiolus corms are harvested six to eight weeks after flowering (Ahmed *et al* 2002).

The study of plant development is called phenology (Hodges 1991). The plant development generally includes cell differentiation, initiation and appearance of an organ and may extend throughout the plant life including senescence (Wilhelm and McMaster 1995). Appearance of an organ is the developmental stage while developmental phase is defined as the time interval between two stages (Streck *et al* 2003). Phenology is basically the study of periodic plant life cycle events and influence of these events to different environmental factors like temperature (low and high), moisture etc. (Meier *et al* 2009).

Determination of developmental events in plant life cycle and their assembly in proper sequence could result in phenological or developmental scale with stages designating those events (Schwab *et al* 2015). The dates of different developmental events in life cycle are recorded under different climatic conditions to prepare phenological scale. Data from

phenological studies can provide evidence of the effects of climate change on species and help in assessing the impact of future changes in climate (Dhyani *et al* 2010). Thus, phenology combines ecology with meteorology. The phenological scale consists of four main parts: the name of the developmental phases, the name of the developmental stages within each developmental phase, a code (may be a number, a set of letters or a combination of letters and numbers) and description of each developmental stage (Zadoks *et al* 1974, Counce *et al* 2000).

Most of crop modeling efforts have been devoted to cereal crops, and only a few for ornamental crops (Gary *et al* 1998). However, there are many applications of ornamental crop models, including assisting growers in planning the timing of management practices and to predict flowering time (Uhlmann *et al* 2017). In floral crops, there are phenological scales for Rosa sp. (Meier *et al* 2009), *Zinnia elegans* (Gonclaves *et al* 2008), Saffron (Lopez-Corcoles *et al* 2015) and Gladiolus (Schwab *et al* 2015). Extended BBCH scale proposed by Hack *et al* (1992) is global coding system commonly used to integrate phenological studies (Yasmin and Nehvi 2018). But staging system of Schwab *et al* (2015) is easier for end users such as growers and extension agents than a system coded only with numbers such as the Zadoks' scale and the BBCH system (Yasmin and Nehvi 2018). The codes for staging system for Gladiolus consists of a letter and a number, where letter represents the phase of development (V = vegetative, R = reproductive) and number represent the developmental stage (V1, where V represents vegetative phase and 1 is for first leaf) (Schwab *et al* 2015).

The increasing aesthetic sense, changing lifestyle and celebration of festivals like Christmas, Valentine's day, Mother's day etc. has created a year around demand of cut flowers especially gladiolus as it forms an integral part of bouquets and floral arrangements. The year around or early or late flower production in gladiolus would result in steady supply of spikes at remunerative prices in the market. The regulation of plant growth and development depends upon genetic and environmental factors (Setiyono *et al* 2007, 2010). The main environmental factors affecting development includes temperature, humidity, photoperiod etc. Therefore, the planting date plays an important role in regulating the developmental cycle, quality of spikes and scheduling of harvest (Schwab *et al* 2017). The harvest date of cut flowers on commemorative dates is very important for regulation of market supply according to consumer's demands.

Temperature plays a very important role in gladiolus production by affecting shoot emergence, flower initiation, appearance of spike and flowering. Environmental factors have quantitative as well as qualitative effects on flowering. Stress conditions either blast individual florets or blast the whole inflorescence. The extent to which damage occur depends on the severity and duration of unfavorable conditions (Kadam *et al* 2013). Variations in temperature can adversely affect the speed, percentage and uniformity in shoot emergence,

leaf area and flower development (Muttoni *et al* 2017). Mitigating strategies for farmers to cope with climate change and maintain gladiolus production include adjusting the optimal planting date (Becker *et al* 2021).

To predict plant development for management decisions, people often use calendars. But sometimes calendar days can be misleading. For each developmental stage, plants require specific amount of heat and light. There are different agrometeorological indices like Growing Degree Days (GDD), Photothermal Units (PTU) etc. that are used to determine the requirement of heat or light for a particular developmental phase and constitute "thermal calendar". The GDD predicts the time of stages in plant development using developmental thresholds. Plant development stops below and above lower developmental threshold temperature or base temperature and upper threshold temperature respectively (Miller *et al* 2018). Several Brazilian authors have determined the basic temperature (Tb) and thermal requirements as a sum of degree days (DD) for many crops. For annual crops, the base temperature varies between 4 and 14˚C (Pedro Junior *et al* 2004). Considering some perennial crops, it was concluded that they have a base temperature of 10˚C (Sentelhas *et al* 1995). In ornamental plants, the variation in the base temperature is higher (between 1.5 and 14˚C), depending on the species (Boschi *et al* 2004). The developmental cycle of gladiolus has three cardinal temperatures; Tb and TB represent the temperatures below and above which plant development is absent or negligible, respectively, and Tot is the temperature at which the rate of plant development is at the maximum (Bonhomme 2000). Knowledge of lower temperature limits for plant development and their thermal requirements, is a useful tool for producers when it comes to scheduling sowing and harvesting seasons (Pascale and Damario 2004). A change in optimal temperature during its vegetative or reproductive growth adversely affects the onset and duration of phenophases and yield of a crop. To achieve a high yield, it is important to know the exact duration of development stages in a particular environment and their association with yield determinants (Sidhu and Raj 2018).

Gladiolus is grown in many tropical, sub-tropical and temperate regions of the world (Ahmad *et al* 2011). In plains, gladiolus produce beautiful spikes from December to March and in hilly areas of India from June to September (Nagar *et al* 2018). In the plains, gladiolus is grown from September/October to mid-February when temperature ranges from 10-18˚C. Hisar's semi-arid climate provides a suitable environment for growing cut flowers in winter from November to February (Singh *et al* 2019). Both high and low temperature affects the crop. For ornamental crops grown in open field, temperature changes can result in significant losses as the market requires flowering to occur within a short time frame to meet market demand (Munir *et al* 2015). The detailed studies on phenology of gladiolus and regulation of its production using agrometeorological indices are scarce. Keeping in view, the commercial significance of gladiolus, its year around demand, changing climatic conditions and paucity of

research on phenological development in gladiolus, the study was planned to understand the influence of temperature on development of different gladiolus varieties for their off season production to achieve following objectives:

i. To study morpho-physiological parameters of different phenophases of gladiolus varieties under different planting conditions

ii. To study heat unit requirement of different phenophases during gladiolus development

CHAPTER II

REVIEW OF LITERATURE

Flowers symbolize peace, purity, beauty, love and compassion. Gladiolus is one of the few plants, which produce pleasant cut flowers with long spikes (Fatihullah and Boston 2018), hence it is in great market demand. The better understanding of gladiola phenology has the potential to improve flower quality and minimize environmental effects on commercial production systems. The information pertaining to "Phenological development of Gladiolus based on heat unit requirement" has been reviewed in this chapter under the following headings:

2.1 Phenological Growth Models

2.2 Effect of Planting Dates on Phenological Development

2.3 Effect of Temperature on Phenological Development

2.4 Agrometeorological Indices

2.1 Phenological Growth Models

Accurate prediction of crop phenology is a key requirement for crop development models. The following are the phenological models proposed by different scientist:

1. **Decimal coding system:** Most plants and crops had no uniform code for describing their growth phases until the early 1990s. Zadoks *et al* (1974) published the first decimal code, which aimed to standardize the description of phenological development stages for similar cereal crops by utilizing the same codes. In cereal crops, ten growth stages were considered for phenology model i.e. germination (0), seed growth (1), tillering (2), elongation of stem (3), booting (4), emergence of inflorescence (5), anthesis (6), milk development (7), dough development (8) and ripening (9) (Zadocks *et al* 1974).

For several other agricultural crops, phenological scales have been proposed viz. maize (Hanway 1966) and rice (Counce *et al* 2000). Some fruit crops also have developmental scales such as olive tree (Sanz-Cortes *et al* 2002), persimmon tree (Garcia-Carbonell *et al* 2002) and mango tree (Delgado *et al* 2011).

2. **Extended BBCH Scale:** BBCH (Biologische Bundesanstalt, Bundessortenamt and Chemische Industrie) scale was proposed by Bleiholder *et al* (1989) and the extended BBCH scale was proposed by Hack *et al* (1992). Since then, the extended BBCH-scale has become a widely used coding system for phenology in agricultural, horticultural, environmental, meteorology, and climatic investigations all around the world (Meier *et al* 2009). Plants' whole growth cycle was subdivided into ten distinct and easily distinguished longer-term developmental phases. These ten principal growth stages alone are not sufficient to define exactly application or evaluation dates, since they always describe time spans in the course of development of a plant. Therefore, secondary stages

are utilized when precise dates or stages in the plant's development are required. Secondary growth stages are defined as short developmental steps characteristic of the respective plant species, which are passed successively during the respective principal growth stage. They are also coded by using a second digit with figures from 0 to 9 (Lopez-Corcoles *et al* 2015).

Extended BBCH scale divided rose morphogenesis into ten growth stages: seed germination (0), leaf development (1), formation of basal side shoots (2), shoot growth of branches (3), harvest of vegetative plant (4), emergence of inflorescence (5), flowering (6), fruit development (7), ripening of fruit and seed (8) and dormancy (9) (Meier *et al* 2009).

Saffron spice is obtained from dried stigmas of *Crocus sativus* L. plant and it is appreciated because of its colouring, flavouring and aroma capacity (Carmona *et al* 2006). It is the most expensive world-wide spice and thus it has been called "the red gold" (Poggi 2009). The extended BBCH-scale proposed for saffron plant considers 6 out of the 10 principal growth stages, Sprouting (Stage 0), Leaf development (Stage 1), Development of replacement corms (Stage 4), Appearance of flower cataphylls (Stage 5), Flowering (Stage 6) and Plant senescence (Stage 9). Some stages of the extended BBCH scale, such as BBCH stage 2 (related to the formation of side shoots or tillering) do not apply to saffron plant and must be omitted (Lopez-Corcoles H *et al* 2015).

Phenological stages considered for the development of Zinnia 'Profusion Cherry' were:- 0: sowing of seeds not yet germinated; 1: sprouted seeds (seedling emergence); 2: seedlings with first pair of true leaves; 3: seedlings with second pair of true leaves; 4: seedlings with apical bud visible, measuring 2 mm approximately; 5: plants with first flower opened; 6: plants with 50% of the flowers opened; 7: plants with 90% of the flowers opened, and 8: plants with senescent flowers (Gonçalves *et al* 2015).

According to the extended BBCH scale using three-digit numerical system, Kishore (2017) defined codes and phenological stages of Indian gooseberry (Aonla). A total of 8 principal growth stages, viz., bud development (Stage 0), leaf development (1), shoot development (3), reproductive development (5), flowering (6), fruit development (7), fruit maturation (8) and senescence (9) and 43 secondary growth stages have been described. The phenological developmental stages of plants and their BBCH coding system are used in agricultural and horticultural science and practice, botanical sciences, meteorology and climate science as well as agricultural insurance, each with their own varying individual objectives.

3. **Staging System:** Counce *et al* (2000) proposed rice developmental staging system which was divided into three main phases of development: seedling, vegetative, and reproductive. Seedling development consisted of four growth stages: unimbibed seed (S0), radicle and coleoptile emergence from the seed (S1, S2), and prophyll emergence

from the coleoptile (S3). Vegetative development consisted of stages V1, V2 . . . .VN; N being equal to the final number of leaves with collars on the main stem. Reproductive development consists of 10 growth stages based on discrete morphological criteria: panicle initiation (R0), panicle differentiation (R1), flag leaf collar formation (R2), panicle exertion (R3), anthesis (R4), grain length and width expansion (R5), grain depth expansion (R6), grain dry down (R7), single grain maturity (R8), and complete panicle maturity (R9). Rice research results and producer practices can be communicated more easily if a uniform system for expressing rice development can be used to determine stage of growth in an objective, unequivocal manner.

Schwab *et al* (2015) created an easy-to-use staging system for describing the development of gladiola that relies on simple, visual and non-destructive criteria. The developmental cycle of gladiolus is divided into following four developmental phases: dormancy, sprouting, vegetative and reproductive phases and covered 20 growth stages of gladiolus under four phases. In gladiolus, corm remains dormant in dormancy phase due to the presence of growth inhibitors such as ABA (Abscisic acid). Application of growth regulators or cold storage of corms at 5°C broke corm dormancy (Castro *et al* 1970). Dormancy allowed the corm to survive under adverse field conditions, such as cold temperatures and low soil moisture. The developmental stages that were identified during the dormancy phase and during the sprouting phases are coded as S stages: S0 = dormant corm, S1 = appearance of roots, S2.1 = first sheath, S2.2 = second sheath and S2.3 = third sheath. Vegetative phase is coded as V stages: VE = emergence of the sheaths above ground, V1 = first leaf, V2 = second leaf, Vn = nth leaf and VF = flag leaf. The developmental stages during the reproductive phases are coded as R stages: R1 = heading, R2 = blooming, R3 = onset of flowering, R4 = end of anthesis, R5 = end of florets senescence and R6 = plant senescence (leaves and floret axis are brown) (Schwab *et al* 2015).

The Gladiolus development model, named PhenoGlad, was divided into three main phases based on the developmental scale proposed by Schwab *et al* (2015): corms sprouting phase, from planting (PL) until emergence (VE), vegetative phase, from VE until heading (R1.0) and reproductive phase, from R1.0 until the end of florets senescence (R5). During the vegetative phase, leaf appearance starts at VE and stops when the crop reaches R1 (Uhlmann *et al* 2017).

Based on Schwab's staging system, Yasmin and Nehvi (2018) create a staging system for describing the development of saffron. The ontogenesis of Kashmir saffron (*Crocus sativus* L.) spread over 6 developmental phases i.e., corm dormancy, flower ontogenesis, bud sprouting, reproductive, vegetative and plant senescence under temperate conditions of Kashmir. During dormancy (S0) saffron corms apparently show neither morphological change nor external growth and the apex looks like a resting bud with

protective cataphylls. During flower ontogenesis (FO), there was increase in size of the apex followed by the formation of leaf primordial (FO.1). In succession the formation of stamen primordia (FO.2), leaf primordia development is at the base of meristem (FO.3) and the formation of gynoecium (FO.4) is observed. Flower ontogenesis is followed by bud sprouting (BS). Reproductive developmental stages are denoted as R stages. The flowering stage starts when the sprout (usually composed of three sheaths) emerges from the soil surface. Flowering (sprout are visible above ground and saffron flower are within the sheath, R.1), blooming (unopened flowers with floral organs enclosed by the tepals, R.2), anthesis (opened tepals with visible stigma and anthers, R.3) and flower senescence (when the tepals dehydrate and falls on the ground, R.4) are major developmental stages. Vegetative developmental stages are designated as V stages. There are four stages within the vegetative phase: VE.1 (leaves from the apicular bud region are first visible above ground and leaves grow at 20% of final length), VE.2 (development of corm, lateral bud and terminal bud contractile roots), VE.3 (formation of replacement corms) and VE.4 (leaf and corm development completed). Plant senescence VE.5, when leaves show signs of prominent senescence.

To date, only a few floral crops have phenological or developmental scales. But as we know that phenological studies are important for understanding the influence of climate dynamics on vegetative growth, flowering and fruiting on plants and can be used in many scientific subjects, such as Agronomy, Botany and Plant Biology, but also Climatology as a result of the current global interest in climate change monitoring. Therefore, it's important to create phenological scales for other floral crops also.

2.2 Effect of Planting Dates on Phenological Development

Different planting dates enabled to study the influence of altered weather conditions on the growth for evaluation of varieties for early or late plantings. This screening regulates the supply chain to the market and adds to the beauty of landscape in case of ornamental crops. Planting dates have an impact on the quality of gladiolus spikes (Zubair *et al* 2006). Planning harvest time is critical for flower crops and models can be useful tools for defining the planting dates for different cultivars to be ready for harvesting at the right time. For example, PhenoGlad might be used to identify locations and seasons where the risk of injury from low and high temperatures was low (agricultural zoning). Another use of PhenoGlad was to forecast the best planting date for cultivars with various developmental cycles in order to harvest spikes for sale around certain holidays (Uhlmann *et al* 2017).

Under Punjab conditions, study was conducted to investigate the effect of five environments i.e. 10th October, 25th October, 10th November, 25th November and 10th December, 2011 on growth and floral characters of twelve gladiolus genotypes. Gladiolus planted in October and first week of November gave better results in terms of growth and floral characteristics in all genotypes (Thakur *et al* 2015). Under 10th October

planting, the minimum days to corm sprouting (10.38 days) and the longest spike length (81.20 cm) were recorded. The floret size (8.62 cm) and number of florets per spike (13.57) were maximum under 10th November planting. The plant developed better root system and luxuriant growth by quantities of photosynthates under favourable conditions whereas, in late planting, plant establishment and growth was poor due to low temperature in December.

A field experiment was conducted during winter season to study the effect of planting dates and varieties on growth and quality on Gladiolus (*Gladiolus hybridus* Hort.) under sub-humid zone of Rajasthan. The study had 15 treatment combinations of five varieties (V1- African Star, V2- Hunting Song, V3- Legend, V4- Pusa Srijana and V5- Snow Princess) and three planting dates (D1- 10th October, D2- 25th October and D3- 9th November). The treatment V2D1 (Hunting Song + 10th October planting) recorded the maximum plant height (116.10 cm), highest number of leaves per plant (8.77), main stem diameter (1.50 cm), number of florets per spike (15.8), spike length (91.80 cm), rachis length (57.90 cm), floret diameter (10.04 cm), vase life of spike (13 days), while the maximum leaf length (64.20 cm), leaf width (4.96 cm) in V5D3. The maximum number of leaves per plant in October planting of gladiolus indicated that plants acquired maximum efficiency for development due to ideal conditions (Nagar 2016). Spike emergence is dependent upon the food reserves in the plant that could be related to growth rate of plant regarding accumulation of carbohydrates for slipping (Kumar and Yadav 2005).

The effect of three planting dates 5th October, 15th October and 5th November on five cultivars viz. Nova Lux, White Prosperity, Rose Supreme, American Beauty and Big Time Supreme was studied by Kumar *et al* (2017). Minimum days taken to sprouting of corms (9.65 days), maximum plant height (77.84 cm), number of leaves (8.70 per plant) were recorded under 5th November while minimum days taken to spike emergence (68.48 days) and basal florets opening (79.04 days) and maximum length of spike (64.02 cm), number of florets per spike (13.42), length of florets (11.04 cm), maximum vase life (8.25 days) were recorded under 15th October planting. It was concluded that the planting date 15th October to 5th November gave better results with respect to vegetative and flowering characters.

From July 15 to October 15, corms of seven gladiolus cultivars, including Anglia, Punjab Lemon Delight, Alexander the Great, CPG, Punjab Glance, Sylvia and Novalux were planted at 15-day intervals. 15th July and 15th August planting took the maximum time to sprout i.e. 20.11 and 20.74 days, respectively, while 15th October planting took the minimum time (10.90 days). Early plantings i.e. 15th July, 1st August and 15th August had plant heights of 71.70, 79.34 and 79.59 cm respectively, which were comparatively less than late plantings. Under 15th October planting, the maximum number of corms and cormels (1.63 and 18.88, respectively) were recorded. Maximum size of corms and cormels (4.05 cm and 1.93 cm) and weight of corms (43.85 g) were also recorded under 15th October planting.

Increase in corm production during October followed by September, was attributed to partitioning of more photosynthates towards underground sinks due to low temperature (Chaudhary 2017).

Effect of planting dates and mulching on growth and flowering of tuberose (*Polianthes tuberosa* L.) cv. Sikkim Selection was studied. The experiment had 12 treatment combinations with three planting dates i.e. 20th May, 15th June and 10th July along with 3 mulching materials. Amongst various interactions, crop planted on 20th May with black plastic mulch showed best results in various growth and flowering parameters like early sprouting of bulb, spike emergence, maximum spike length, rachis length, number of florets per spike, fresh weight of spike, duration of flowering and largest sized bulbs. Based on the findings, 20th May planting and black plastic mulch were found to be best treatments (Vaid *et al* 2019). In tuberose, higher number of leaves in early planting attributed to optimum time of planting and nutrient for growth of plant (Bhattacharjee *et al* 1979). In early plantings of tuberose, increase in spike and rachis length was because of cell division, cell elongation and longer days during spike/rachis formation stage. The increased synthesis of amino acids, chlorophyll and better carbohydrate transformation, resulted into better rachis length and ultimately produced more florets per spike (Meena *et al* 2018).

Effect of planting time and growing conditions on sprouting and growth of gladiolus cultivar American Beauty was studied in Precision Farming Development Center of Department of Horticulture, CCS Haryana Agriculture University, Hisar. Maximum percentage of sprouting of corms (99.32%), number of leaves per plant (8.81), leaf area (105.97cm^2) and plant height (106.12 cm) was observed in 15th October planting. Whereas, minimum percentage of sprouting of corms (71.75%), number of leaves (6.95), leaf area (88.20 cm^2), and plant height (92.12 cm) were recorded under 15th December planting (Singh *et al* 2019). Better performance of the genotype under 15th October planting for the sprouting and vegetative growth characters may be attributed to prevalence of optimum temperature for plant growth and development. However, minimum number of days required for corm sprouting (11.77 days), spike initiation (105.5 days), basal floret opening (119 days), last floret opening (127.3 days) were observed in 15th October planting. Whereas, maximum number of days taken to sprouting of corms (18.75 days), spike initiation (114.4 days), basal floret opening (126.8 days), last floret opening (134.6 days) were recorded under 15th December planting. Reduction in time requirement by genotype for the above floral characters may be attributed to the fact that cultivar had a early exposure to congenial climatic conditions as compared to late planting during which temperature was low (Singh *et al* 2019).

A delay in the optimum planting date to harvest gladiola for All Souls' Day in future climate scenarios was attributed to an increase in minimum and maximum temperature in all regions of the state of Rio Grande do Sul, Southern Brazil, which led to an increase in

developmental rate and a decrease in length of the developmental cycle (Adil *et al* 2013; Schwab *et al* 2015). Ornamental crops, such as *Antirrhinum majus* L. (Munir *et al* 2004, Munir *et al* 2015), *Celosia argentea* L. and *Impatiens walleriana* Hook. F. (Pramuk and Runkle 2005), *Brunonia australis* and *Calandrinia sp.* (Cave *et al* 2013), *Salvia splendens* and *Tagetes patula* (Moccaldi and Runkle 2007), *Chysanthemum morifolium* (Larsen and Persson 1999), 18 species of annual bedding plants (Blanchard and Runkle 2011) and *Petunia hybrida* (Blanchard *et al* 2011) present a similar response to rising temperature.

Temperature fluctuations may result in significant losses for ornamental crops cultivated in open fields, as the market requires flowering to occur within a short time frame to fulfill market demand (Munir *et al* 2015). The increase in emission of greenhouse gas (GHG) into the atmosphere is a key contributor to the rise in global surface temperature. The IPCC's Assessment Report Five (AR5) provided the climate change scenarios utilized in the study to examine climate change effects on gladiola in Southern Brazil. RCP2.6, RCP4.5, and RCP8.5 (RCP stands for Representative Concentration Pathway) scenarios were chosen to depict optimistic, moderate, and pessimistic GHG emissions, respectively. The HadGEM-ES global ocean atmosphere model was used to create climate scenarios (Jones *et al* 2011). Temperature rise and CO_2 concentration estimates until 2100 are 1.7°C and 421 ppm for the RCP2.6 scenario, 2.6°C and 538 ppm for the RCP4.5 scenario and 4.8°C and 936 ppm for the RCP8.5 scenario (IPCC 2013). In RCP8.5 scenario, minimum and maximum air temperatures are higher than the crop's optimum temperature, resulting in the largest positive anomalies (+ 55 days) in this region's optimal planting date. This means that growers should plant gladiola corms nearly two months later in the future than they currently do (Becker *et al* 2021). In addition to the influence on developmental rate, numerous studies have linked increased temperature to a decline in ornamental crop quality, because faster crop development results in fewer flower buds, smaller flower size and lower plant biomass (Blanchard *et al* 2011, Vaid *et al* 2014). A shorter developmental cycle in crops such as soybean (Rio *et al* 2015), potato (Wang *et al* 2015b) and wheat (Wang *et al* 2015a) resulted in a shorter leaf development period, resulting in a lesser quantity of radiation intercepted and, as a result, a lower crop yield.

2.3 Effect of Temperature on Phenological Development

Both genetic and environmental (biotic and abiotic) factors affect crop phenology (Setiyono *et al* 2007, 2010). Air temperature is the most important abiotic factor that influences gladiolus phenology in the field (Shillo and Halevy 1976a, Streck *et al* 2012). Although photoperiod may affect development, but gladiolus is considered as a facultative short-day plant (Shillo and Halevy 1976b).

Effect of different growth temperature regimes was studied on morphological and flowering characters of two gladiolus cultivars viz. Snow Princess and American Beauty.

Temperature treatments were maintained 20/18, 26/22 or 30/26°C (Day/ Night) with 14 h light and 60–65 % relative humidity in the growth chambers. 30/26 °C temperature was found with lowest days for corm sprouting. However, sprouting percentage of corms was 100 % under all the treatments in both the cultivars. Temperature did not affect the corms sprouting percentage but the days required for sprouting reduced as temperature increased (Kadam *et al* 2013).

To determine the cardinal temperatures for the planting-emergence phase of gladiolus, Muttoni *et al* (2017) conducted an experiment with 12 temperature treatments (5°C, 7°C, 10°C, 13°C, 16°C, 18°C, 20°C, 22°C, 25°C, 30°C, 33°C and 35°C). The increase in temperature increased the respiration rate considerably between 0 and 30°C, and that enhanced the sprouting. Temperatures higher than optimum declined the emergence rate of gladiolus corms because the enzymes responsible for respiration became inactive. Elevated temperatures also decreased the cell membrane stability, causing alterations in the composition and structure, resulting in ion loss. The ruptured membranes also inhibited respiration and photosynthesis as both processes relied on the enzymes and electron carriers bound to the membranes (Taiz and Zeiger 2006). For gladiolus planting-emergence phase, cardinal temperatures are 5°C, 22.5°C and 35°C for base, optimum and maximum temperatures, respectively (Muttoni *et al* 2017). Callejas *et al* (2014) reported that respiration, photosynthesis, growth and developmental rates are dependent on temperature. Therefore, it is vitally important to know the optimum temperature at which these processes are not adversely affected.

Each developmental phase has its own set of cardinal temperatures. Tb = 5 °C (Shillo and Simchon 1973), Topt = 25 °C and TB = 35 °C were the cardinal temperatures during the sprouting phase (Uhlmann *et al* 2017). Tb = 2 °C (Shillo and Halevy 1976a), Topt = 27 °C (International Flower Bulb Centre 2011) and TB = 45 °C were the cardinal temperatures for the vegetative phase (Shillo and Halevy 1976a, International Flower Bulb Centre, 2011). Tb = 6 °C (Burg 2004), Topt = 25 °C (International Flower Bulb Centre 2011) and TB = 42 °C were the cardinal temperatures for the reproductive phase (heading and blooming sub-phases) (Shillo and Halevy 1976a, International Flower Bulb Centre 2011). Uhlmann *et al* (2017) reported that in gladiolus emergence did not occur even at 35°C. During October to November the average temperature ranges between 24.8-19.4°C which is optimum for corm sprouting (Arora and Sandhu 1987).

In case of reproductive propagation plant parts like sugarcane sticks, sprouting which is a biological process draws energy from the breakdown of reserves via the respiratory cycle. At temperatures below 5°C, potato (*Solanum tuberosum*), showed a decline in the respiratory rates, with lower rate of tuber sprouting (Taiz and Zaiger 2006). Bonhomme (2000) reported that at very low temperature specific enzymes are insufficiently flexible and; therefore, unable

to effectively perform in a reaction.

During early growth, well developed root system is extremely important for the growth and development of wheat (McMaster *et al* 2003). Under late sowing, crown root initiation took more time as compared with that in early sown crop. Numerous studies have shown that environmental factors like temperature affect crown root growth (Chmielewski and Rotzer 2002, Wang *et al* 2008). Crown roots are more sensitive to the range of temperature occurring during the early growth. Crown root initiation depends on mobilization of seed reserves. The 25 °C temperature may increase enzymes activity for the mobilization of seed reserves and thus enhanced crown root initiation (Sattar *et al* 2015).

Specific temperature is required for the conversion of vegetative meristem into the reproductive otherwise meristem is aborted (Kadam *et al* 2013). The number of spikes per plant was not significantly affected by the temperature. But as the temperature increased from treatment T2 (26/24 °C) to T3 (30/26 °C), emergence of spike was completely absent. The failure of spike emergence at higher temperature may be due to the meristem abortion. Maximum duration of flowering on spike (5.67 day) was found in control (20/18 °C). The duration of flowering reduced as temperature increased. More sunlight, affable temperature, nutrient uptake in presence of water and carbon dioxide increased the rate of photosynthesis which improved C:N ratio and florigen synthesis and resulted in early initiation of spike emergence (Meena *et al* 2018).

In rice, when temperature dropped from 24°C to 21°C a sharp decrease in days to heading occurred. A temperature drop by 1 °C led to 13-day delay in heading. When the temperature increased above 24 °C, days to heading decreased to 91 days at 27 °C and to 86 days at 30 °C. A temperature rise of 1 °C above 24 °C shortened the number of days to heading by less than 2 days (Parthasarathi *et al* 2013).

Gladiolus flowered more rapidly under warm temperature apart from photoperiod. Under short day lengths, flower blasting is more prevalent indicating that the corm is a sink for assimilates, while under long day lengths, flowers grow and develop fully resulting in inflorescence becoming a sink for assimilates (Halevy 1985). Low temperature resulted in flower blasting while warm temperature hastens the growth in gladiolus (Armitage 1993).

Low temperature increased the number of days to inflorescence formation in gladiolus (McCalla *et al* 2011). Plants developed during the warmest months had shorter length of vegetative and reproductive stages when the air temperature varied from 1.2-36.3°C while during autumn and winter when the air temperature varied from -1.1-31.7°C plants had longer length of all the developmental stages (Schwab *et al* 2015). The gladiolus developmental cycle was short when planting occurred during periods of higher air temperatures and long when planting occurred in low air temperature periods (Schwab *et al* 2018).

The vase life of gladiolus, which lasts from R3 to R4 developmental stages, is an essential feature for customers. With an average error of one day, PhenoGlad was able to simulate the vase life. The model can be used to predict the rate at which florets open under lower temperatures. For example, the anticipated time from R3 (first open floret) to R4 (last open floret) at 8 °C is 62 days, whereas the projected duration at 10 °C is 31 days (Uhlmann *et al* 2017).

Volatile oils are obtained from the flowers, leaves, fruits, seeds and roots of plants. Rose is the most popular and most important among all volatile oil plants grown in Turkey (*Rosa damascena* Mill.). Oil rose is a perennial plant with an active growing period of about 120 days depending on the phenological periods (Baydar and Kazaz 2013). Temperature and humidity are among the most important factors with impact on flowering intensity of oil rose (Yucel *et al* 2018). Volatile oil content decreased when night time temperatures dropped below 5°C or when day time temperatures exceeded 20°C (Baydar and Baydar, 2005, Sangwan *et al* 2001).

Extreme temperatures (low and high) can cause damage to Gladiolus vegetative and reproductive parts (Shillo and Halevy 1976a). Freezing temperatures during the vegetative phase cause leaf injury whereas during reproductive phase cause severe corolla damage. Leaves are more tolerant to high temperature (36-40 °C) (Shillo and Halevy 1976a, International Flower Bulb Centre 2011) than florets, which can be injured at temperatures above 25 °C (International Flower Bulb Centre 2011).

Uhlmann *et al* (2017) reported injuries due to low and high temperature on Gladiolus in PhenoGlad as follows: if the minimum temperature is lower than -2 °C during at least three days in a row, from DVS (Developmental stage) = 0 (VE) to DVS = 2.0 (R5) then the crop is killed by frost. If the minimum temperature is lower than or equal to -2 °C during one day or if -2 °C$\leq$ Tmin $\leq$ 3 °C during 3 days in a row, then the spike is killed by frost but leaves are only injured slightly (patchy whitening and burning). Heat injury in PhenoGlad is considered when the maximum temperature is greater than or equal to 34 °C during three consecutive days during the reproductive phase (from R1 to R5). The model warns the user about a severe burning of petals and sepals if the simulation ends at R2 (harvest point). The warning is about severe burning and the possibility that the 3 or 4 topmost florets on the spike will not open if the simulation stops at R5 (end of flowering). From DVS = 0 to DVS = 2, if the maximum temperature is higher than 48 °C, the crop reaches the upper lethal temperature (Shillo and Halevy 1976a) and dies from heat.

The study "Assessing climate change effects on gladiola in southern Brazil" has practical implications for future climate scenarios in southern Brazil. Future temperatures will be more damaging to florets, lowering the quality of spikes, particularly throughout the growing season for harvest on All Souls' Day. The results of the study underlined the

necessity of research about the effect of shade screens on minimizing damage from high temperatures to gladiola flower stems (Becker *et al* 2021). During the summer months in southern Spain, the usage of screens reduced the frequency of burnt peppers (López-Marin *et al* 2011). Another option might come from breeding initiatives aimed at developing gladiola cultivars that are more tolerant to high temperatures (Becker *et al* 2021). Gladiola producers from major producing countries like Bulgaria, the United States and India have studied the effects of climate change on agricultural crops, but not on gladiola (Alexandrov and Hoogenbom 2000, Fei *et al* 2017, Srivastava *et al* 2010). Therefore, the effects of climate change on gladiola as well as mitigation measures have been proven to give useful information to these nations (Becker *et al* 2021).

2.4 Agrometeorological Indices

Plants have a definite temperature requirement before they attain certain phenological stage. Agrometeorological indices [Growing Degree Days (GDD), Heliothermal Units (HTU), Photothermal Units (PTU) and Photothermal Index (PTI)] represent different forms of accumulated temperature above a base level, which in turn affect thermal unit requirements during the vegetative and reproductive growth periods (Ram *et al* 2016, Hou *et al* 2014). Crop heat unit (CHU) or thermal time or growing degree days is a temperature response of development that differs between day and night. The French scientist Rene A. F. de Réaumur introduced GDD idea almost 300 years ago, in 1700. Growing degree days is a way of assigning a heat value to each day (Parthasarathi *et al* 2013). Though accumulation of degree-days for each development stage is relatively constant and independent of sowing date, crop variety may modify it considerably (Ram *et al* 2012). Each developmental stage has its own total heat requirement. Development can be estimated by accumulating degree days between high and low temperature thresholds throughout the season. It is tough to predict plant growth based on the calendar time because temperature may vary greatly from year to year. Instead, growing degree days based on actual temperatures are a simple and accurate way to predict the time span of plant growth stage (Sattar *et al* 2015). Phenological development from seedling to maturity is related to accumulation of heat or temperature units above a base temperature below which no growth occurs (Sidhu and Raj 2018). Grain yield of cereal crops was affected by seasonal temperature change mainly through phenological development processes. Late sowing of wheat reduced the heat unit requirements for different phenological stages which ultimately shortened the duration of phenology (Sikder 2009).

The growing degree day requirements and yield performance of durum wheat sown at two dates (1 and 30 November) were evaluated. In timely sown crop (1 November) all agrometeorological parameters i.e. GDD, HTU, PTU and PTI were higher as compared to late sown (30 November). The GDD requirements of timely sown wheat were 171°C day and 292°C day higher in comparison to late sown for earing and maturity growth stages,

respectively. However, from sowing to maturity growth periods under timely sown conditions, a significant increase of 1503°C day hours for HTU and 2802°C day hours for PTU was recorded. The higher phenothermal index of timely sown wheat suggested longer growing period of each phenophase resulting in more accumulation of thermal units both at flowering and maturity stages, which resulted in higher yield attributes and grain yield (Ram *et al* 2016). The availability of ideal climatic conditions for crop growth and development may improve photosynthate accumulation from source to sink which might be ascribed to the greater value of yield attributing factors and yield in case of early planting over delayed sowing (Ram *et al* 2012). Wardlaw and Wringley (1994) found that each 1°C increase in ambient temperature above 15°C during grain filling reduced grain yield by 3-4 percent. The increased 1000-grain weight of timely sown crop might be due to more number of days taken to earing and physiological maturity. Longer is the duration of the grain filling stage, more is the translocation of photoassimilates to developing grains and higher will be the test weight (Ram *et al* 2016). When sowing was delayed, the wheat crop was subjected to sub-optimal temperatures at establishment and supra-optimal temperatures during reproductive periods, resulting in forced maturity and reduction in grain yield (Sardana *et al* 1999).

To investigate the link between growing degree days, yield, and yield components, five sunflower hybrids (Super-25, Parsun-1, SMH-9706, Award and Hysun-33) were sown on ten planting dates both during autumn and spring. The spring sunflower was sown in January and February (low temperature) and grew vegetatively in February and March (low to medium temperature) before entering the reproductive stage. The reproductive stage developed in May (high temperature), then it matured and was harvested in June/July (high temperature). In contrast to spring, autumn crop was sown during the hot and humid months of July and August. Its germination and early vegetative growth underwent high to medium temperature of August and September before entering into reproductive stage. The reproductive period of autumn crop started at a medium temperature of October. It matured and was harvested under low temperature of November. So, when sunflowers were grown in the spring and autumn, two opposing sets of environmental circumstances persisted from germination to maturity. Crops planted in the early part of the year, Feb-April, experienced lower temperatures during early phases and took longer to complete their life cycle, resulting in higher 100 seed weight, whereas crops planted later in the year, July-August, experienced higher temperatures during early phases and completed their life cycle quickly, resulting in lower 100 seed weight (Qadir *et al* 2007). Singh *et al* (1999) also found that February sowing produced the highest seed yield and yield component values, followed by January sowing. According to Sur and Sharma (1999), delayed planting during autumn season lowered yields because the late planted crop encountered lower temperatures during the seed filling phase.

Kumar *et al* (2010) performed a field experiment at the Institute of Himalayan Bioresource Technology, (CSIR) Palampur (HP), India in 2007 and 2008 to investigate the performance of wild marigold (*Tagetes minuta*) under various temperature regimes throughout the crop growing season. For different dates of planting the crop, agroclimatic indices such as relative temperature disparity (RTD), growth degree days (GDD), heliothermal units (HTU) and photothermal units (PTU) were calculated. The results of the study indicated that early (Feburary) sown crop had a longer crop span (224 days) than the late (June) sown crop (102 days) from planting to harvesting. From planting to harvest, the average GDD accumulation ranged from 1378 to 2518°C days, HTU from 6781 to 15706°C days hour and PTU from 17400 to 33052°C days hour. During both years, there were significant positive relationships between total oil yield and temperature difference and day length. This suggested that temperature, day length, and sunshine hours all have an impact on the oil yield of tagetes. More sunshine hours during the reproductive period may have aided photosynthate transfer to the sink and resulted in more oil synthesis.

Dhatt and Jhanji (2021) used agro-meteorological indices to evaluate gladiolus varieties for off-season planting. Corms of five gladiolus varieties, Punjab Glance, Punjab Lemon Delight, Novalux, Rose Supreme and Alexander the Great were planted at six different times: 5th July, 20th July, 5th August, 20th August, 5th September and 20th September. In Northern plains, the normal planting of gladiolus is done in October - November and flowering occurs in December - January depending on variety. During October-November when the crop is in the vegetative phase, the temperature varies between 26-30°C, but as the temperature drops in December-January, coupled with the rise in photoperiod, the crop begins to bloom. When the crop was planted in July-August, the temperature was higher, but the plants accumulated those heat units and developed vegetatively, producing shorter spikes because the requirements for reproductive development of low temperature and photoperiod were not fulfilled. The normal planted crop accumulated fewer heat units and shorter days with fewer bright sunshine hours but was able to use them efficiently for spike production, whereas the early planted gladiolus accumulated higher heat units and longer days with more bright sunshine hours but was unable to use them efficiently for spike production. The varieties under study accumulated more heat units but still produce spikes of comparable quality depicts the thermo tolerant characteristic of these varieties that could be used further in breeding programmes for development of varieties that could efficiently channelize their accumulated heat units for spike production. This will enable the farmers to get the short duration varieties that could be planted in months of July and August and will bloom in September with good quality spikes.

Correlation between cumulative growing degree days, cumulative heliothermal units and cumulative photothermal units for various phenophases showed that onset of phenophases

depends more on temperature than on sunshine hours and day length (Singh *et al* 1990). These GDD's were used to assess the suitability of a region: for production of a particular crop, to determine growth stages of crops, assess best time of fertilizer, herbicide etc. The GDD accumulated during day was basically for production of biomass and at night for flower production (Parthasarathi *et al* 2013). Predictive accuracy of CHU in crop growth is 67-91% (vegetative phenostage) and 90-95% (reproductive phenostage) (Parthasarathi *et al* 2013).

In the light of above literature, it was planned to study the heat unit requirement of different phenophases of gladiolus to regulate flower production and evaluate varieties for early and late plantings.

CHAPTER III

MATERIALS AND METHODS

The study entitled "Phenological development of gladiolus based on heat unit requirement" was conducted during 2020-21. The experiment was conducted at the Research Farm of Department of Floriculture and Landscaping, Punjab Agricultural University, Ludhiana. A brief account of the materials and methods used and experimental practices followed in the study are given in this chapter.

3.1 Location and Climate

Ludhiana is situated at the latitude of 30.91° N and longitude of 75.48° E and the mean height above the sea level is 247 m. This place is characterized by typical sub-tropical climate with hot and dry summer during April to June followed by hot and humid monsoon during July to mid-September and cold winters during December and January. The area experiences an average rainfall of 700 mm during monsoon season.

3.2 Soil Characteristics

The soil used to raise the crop had sandy loam texture and alkaline nature with pH 8.3.

3.3 Plan of work

The following experiment was conducted in the present study:

i) **Name of the experiment:** Evaluation of gladiolus varieties for morpho-physiological parameters and heat unit requirement of different phenophases under different planting dates

ii) **Location and place of work:** The corms of gladiolus varieties were grown in the Field Area of the Department of Floriculture and Landscaping for phenological, morpho-physiological and postharvest quality parameters. The studies were conducted in the Laboratories of the Department of Floriculture and Landscaping and Department of Botany, Punjab Agricultural University, Ludhiana.

iii) **Methodology**

Varieties: 5, Punjab Glad 3 (V_1), Punjab Lemon Delight (V_2), CPG (V_3), Punjab Glance (V_4) and White Prosperity (V_5)

Planting dates: 4, 28th September (D_1), 28th October (D_2), 28th November (D_3) and 28th December (D_4)

No. of treatments: $5 \times 4 = 20$

Design of experiment: Split plot design

Number of replications per treatment: 3

Total number of plots: $20 \times 3 = 60$

The corms of all varieties were soaked overnight in water and then treated with

bavistin (0.1%) for half an hour as a protective measure against fungus. The treated corms were dried in shade and de-husked before planting in the field. The corms of five different varieties were planted on four planting dates viz. 28th September (D_1), 28th October (D_2), 28th November (D_3) and 28th December (D_4). All recommended cultural practices were followed to raise the crop.

iv) Observations

Following observations pertaining to phenophases, morpho-physiological and postharvest quality parameters and agrometeorological indices were recorded:

I. Different phenophases of Gladiolus: Schwab *et al* (2015) proposed staging system for phenological development of gladiolus. The developmental cycle of gladiolus is divided into four developmental phases: dormancy, sprouting, vegetative and reproductive phases and covered 20 growth stages of gladiolus under four phases. Five plants from each replication were selected and tagged for different phenological observations i.e. from sprouting to plant senescence. The days taken to following stages from planting were recorded:

(i) Sprouting (S1): After planting corm, the first sheath grew from the apex and was visible at the top of the corm pushing up the husks. Sheath continued its growth through the husks and then the second sheath was visible at the top of the corm. Sprouting was recorded when third sheath was visible at the top of the corm.

(ii) Vegetative:

(a) Shoot emergence (VE): When shoot was first visible above the ground.

(b) First leaf (V1): First true leaf tip was visible at the shoot whorl.

(c) Second leaf (V2): Second true leaf tip was visible at the shoot whorl.

(d) Third leaf (V3): Third true leaf tip was visible at the shoot whorl.

(e) nth leaf (Vn): nth true leaf tip was visible at the shoot whorl.

(f) Flag leaf (VF): Last leaf tip was visible at the shoot whorl.

(iii) Reproductive:

(a) Heading

- **Spike emergence initiation (R1.0):** This stage was recorded when spike tip was first visible at the shoot whorl.
- **Half spike emergence (R1.1):** This stage was recorded when half of the spike emerged. The tip of the spike was leveled with the tip of the last leaf.
- **Complete spike emergence (R1.2):** This stage was recorded when whole spike emerged. The peduncle of the spike was visible. After complete spike emergence, the rachis elongated and florets grew apart.

(b) Blooming (R2): When first three florets at the bottom of the spike showed the colour of the florets.

(c) Anthesis

- **Initiation of anthesis (R3):** When the corolla of the first floret at the bottom on the spike was opened with visible anthers.
- **Half of anthesis (R3.4):** The corolla of the floret located at the middle portion of the spike was opened with visible anthers.
- **Complete anthesis (R4):** The corolla of the last uppermost floret on the spike was opened with visible anthers.

(d) Senescence:

- **Beginning of floret senescence (R3.5):** First floret at the bottom of the spike started senescence i.e. corolla of the first floret got wilted.
- **Half florets senescence (R3.6):** Floret at the middle of the spike started senescence.
- **End of floret senescence (R5):** Last uppermost floret on the spike senesced. Tepals of all florets wilted.
- **Plant senescence (R6):** This stage was recorded when above ground parts of the plant i.e. leaves and floral axis were brown (wilted).

II. Morpho-physiological Parameters:

(a) **Per cent Sprouting:** After the completion of sprouting, the number of corms sprouted were counted from each replication and per cent sprouting was calculated as:

$$\text{Per cent sprouting} = \frac{\text{No. of corms sprouted}}{\text{Total no. of corms sown}} \times 100$$

(b) **Plant height (cm):** Plant height was measured from ground level to the tip of the spike with the help of a scale and expressed in centimeters.

(c) **Number of leaves/plant (cm^2):** Number of leaves per plant was recorded by counting the total number of leaves at initiation of spike emergence.

(d) **Leaf area/plant:** Leaf area of each leaf was calculated by multiplying the length (L) and width (W) by a constant factor i.e., 0.664.

Leaf area (LA) of each leaf = $0.664 \times L \times W$

Leaf area per plant = $LA_1 + LA_2 + \ldots\ldots + LA_n$

Where,

LA_1 = Leaf area of first leaf

LA_2 = Leaf area of second leaf

LA_n = Leaf area of n^{th} leaf

(e) **Dry matter accumulation:** Dry weight of whole plant on oven dry weight basis was recorded at stages: spike emergence initiation and full spike senescence.

(f) **Spike length (cm):** Spike length from the base of second pair of leaves to the tip of spike was measured and expressed in centimeters.

(g) **Number of florets per spike:** Total number of florets on the spike was calculated.

(h) **Floret size (cm):** Diameter of the floret was measured and expressed in centimeters.

(i) **Weight of spike (g):** Spike weight was recorded by weighing the spike after harvesting and weight was expressed in grams.

(j) **Number of corms per plant:** Number of corms produced per plant was recorded.

(k) **Number of cormels per plant:** Cormels produced per plant were counted from selected plants.

(l) **Corm weight (g):** The harvested corms from selected plants were weighed and their weight was expressed in grams.

(m) **Corm diameter (cm):** Equatorial diameter from nine plants was recorded using vernier calipers and the average corm diameter was expressed in centimeters.

III. **Postharvest Quality Parameters:**

Spikes were harvested at tight bud stage and immediately put in flasks containing distilled water. Following observations pertaining to postharvest keeping quality of spikes were recorded:

(a) **Days to opening of the basal floret in vase:** The number of days taken by the basal floret of the spikes to open while placed in vase containing distilled water was recorded.

(b) **Size of fully expanded floret (2nd floret from base):** The maximum diameter of the 2nd fully opened floret from the base was measured in cm and expressed as floret size.

(c) **Maximum number of florets open at one time:** The total number of open florets was recorded daily and maximum number of florets opened at one time was recorded as the total number of open florets till the basal floret showed wilting signs.

(d) **Per cent opening of florets:** Per cent opening of florets was calculated using the following formula:

$$\text{Per cent opening of florets} = \frac{\text{Total no. of florets open}}{\text{Total no. of florets}} \times 100$$

(e) **Vase life:** Vase life was measured in days from the day of opening of one basal floret till when there were five open florets on the spike and in case of spike where less than five florets showed opening, wilting of the basal floret was taken as criterion for the termination of vase life.

(f) **Change in pH of the vase solutions:** The change in pH was measured in terms of difference in pH of distilled water before keeping the spikes in it (initial) and pH of distilled water containing spikes at the end of vase life (final).

Change in pH = Final pH - Initial pH

(g) **Total water absorbed per spike (ml):** Total volume of water absorbed by the spike till the end of vase life was measured in ml and expressed as water absorbed per spike.

(h) Physiological loss in weight (%) at the end of vase life: The difference between initial weight and weight of spikes at the end of vase life was recorded and loss in physiological weight of spikes was calculated by following formula:

$$\text{Physiological loss in weight (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

IV. Agrometeorological Indices:

Following indices were calculated:

(a) Heat Units or Growing Degree Days (GDD)

(Cross and Zuber 1972)

$$GDD = n\frac{(T_{max} + T_{min})}{2} - T_b$$

Where,

n = Number of days in between two successive phenological stages

T_{max} = Maximum temperature (˚C) of the day

T_{min} = Minimum temperature (˚C) of the day

T_b = Base temperature below which leaf appearance rate reached zero (considered $T_b = 5$˚C) (Cross and Zuber 1972)

(b) Photothermal Units (PTU)

(Baker *et al* 1986)

$$PTU = n\frac{(T_{max} + T_{min})}{2} \text{ x } L_i$$

Where,

L_i = Day length (actual bright day light hours)

(c) Heliothermal Units (HTU)

(Chakravartty and Sastry 1985)

$$HTU = n\frac{(T_{max} + T_{min})}{2} - T_b \text{ x SS}$$

Where,

SS = Sunshine hours

(d) Phyllochron Index (PI)

(Haun 1973)

It is the time interval between appearance of successive leaf on the main shoot.

(e) Effective night temperature (ENT)

$$ENT = \frac{\left[T_{min}\left(\frac{T_{max} + T_{min}}{2}\right)\right]}{2}$$

The data of agrometeorological parameters viz. temperature, day length and sunshine hours for the period between September 2020 and August 2021 was attained from School of

Agricultural Meteorology, PAU, Ludhiana.

STATISTICAL ANALYSIS

The experiment was carried out in split plot design with three replications. Two way analysis of variance was used for data analysis. Mean comparison to calculate significant difference between treatments were performed using CD at 0.05 level of probability. Data was subjected to statistical analysis (ANOVA) using SPSS software.

CHAPTER IV

RESULTS AND DISCUSSION

The present study entitled "Phenological development of gladiolus based on heat unit requirement" was carried out to evaluate the effect of different planting dates on phenological development, morpho-physiological and postharvest quality parameters of gladiolus and correlate the performance of gladiolus varieties to temperature and photoperiod prevailing under different planting dates. The results of present investigation are presented and discussed under following heading:

Experiment: Evaluation of gladiolus varieties for morpho-physiological parameters and heat unit requirement of different phenophases under different planting conditions

4.1 Relationship between Phenological Development and Thermal and Photothermal Units of different gladiolus varieties under different planting dates

4.2 Influence of dates of planting on morpho-physiological parameters of different gladiolus varieties

4.3 Effect of dates of planting on vase life of different gladiolus varieties

4.1 Relationship between Phenological Development and Thermal and Photothermal Units

4.1.1 Sprouting (S1)

The data on sprouting of corms of different gladiolus varieties under different planting dates is presented in Table 4.1. A significant difference in number of days, GDD, HTU and ENT taken for sprouting of corms was observed under different dates of planting. The data revealed that all gladiolus varieties took minimum days to sprouting under September planting (12.07 days). The planting done in October took 14.81 days to sprout which was at par with November planting. However, the maximum time for corm sprouting was observed when planting was done in December (24.55 days). GDD, HTU and ENT required for sprouting of corms were maximum in September planting i.e. 256°C day, 30700°C day hr and 3076°C respectively followed by October and November plantings. The minimum GDD (157°C day), HTU (7415°C day hr) and ENT (1114°C) were required under December planting. A non-significant difference in PTU required for sprouting of corms was observed under different planting dates.

A significant difference in number of days, GDD, HTU, PTU and ENT taken for sprouting of corms was observed in different varieties. Among five varieties evaluated, it was observed that Punjab Glad 3 sprouted at the earliest of all the varieties and took 16.11 days. Punjab Lemon Delight took 16.29 days which was at par with Punjab Glance and White Prosperity. Maximum number of days for sprouting of corms was taken by CPG (18.79 days). Punjab Glad 3 took minimum GDD (190°C day), HTU (15669°C day hr), PTU (31899°C day

Table 4.1: Number of days and agrometeorological indices accumulated by gladiolus varieties for sprouting of corms under different dates of planting

S.No.	Treatment	DAS	GDD (°C day)	HTU (°C day hr)	PTU (°C day hr)	ENT (°C)
Dates of planting (D)						
1.	**D_1 (28 Sep.)**	12.07^{C}	256^{A}	30700^{A}	37539	3076^{A}
2.	**D_2 (28 Oct.)**	14.81^{B}	218^{B}	19993^{B}	36244	1580^{B}
3.	**D_3 (28 Nov.)**	16.54^{B}	187^{C}	18425^{B}	32096	1354^{BC}
4.	**D_4 (28 Dec.)**	24.55^{A}	157^{D}	7415^{C}	40602	11147^{C}
	CD (5%)	2.26	28.71	6630	NS	288
Varieties (V)						
1.	**V_1 (Punjab Glad 3)**	16.11^{B}	190^{B}	15669^{B}	31899^{B}	1630^{B}
2.	**V_2 (Punjab Lemon Delight)**	16.29^{AB}	201^{AB}	19256^{AB}	34731^{AB}	1765^{AB}
3.	**V_3 (CPG)**	18.79^{A}	228^{A}	23844^{A}	44634^{A}	2002^{A}
4.	**V_4 (Punjab Glance)**	16.48^{AB}	201^{AB}	18253^{AB}	34585^{AB}	1754^{AB}
5.	**V_5 (White Prosperity)**	17.29^{AB}	203^{AB}	18644^{AB}	37251^{AB}	1754^{AB}
	CD (5%)	2.57	34.63	6934	11650	332
D×V						
1.	**D_1V_1**	10.28^{h}	216^{bcdef}	21662^{bcde}	26248^{c}	2625^{b}
2.	**D_1V_2**	12.28^{fgh}	259^{ab}	30978^{ab}	37756^{abc}	3109^{ab}
3.	**D_1V_3**	14.50^{efgh}	308^{a}	42825^{a}	52953^{ab}	3671^{a}
4.	**D_1V_4**	11.67^{gh}	245^{abcd}	28494^{bc}	34738^{abc}	2948^{b}
5.	**D_1V_5**	11.67^{gh}	252^{abc}	29541^{ab}	35998^{abc}	3026^{ab}
6.	**D_2V_1**	13.44^{efgh}	199^{bcdefg}	17085^{bcdef}	29326^{c}	1440^{cd}
7.	**D_2V_2**	16.42^{cdefg}	240^{abcde}	23358^{bcd}	43585^{abc}	1748^{c}
8.	**D_2V_3**	16.00^{defg}	235^{bcdef}	22763^{bcd}	42018^{abc}	1694^{c}
9.	**D_2V_4**	15.89^{defg}	230^{bcdef}	21950^{bcde}	41195^{abc}	1679^{c}
10.	**D_2V_5**	12.33^{fgh}	185^{cdefgh}	14811^{cdef}	25094^{c}	1341^{cd}
11.	**D_3V_1**	14.17^{efgh}	172^{efgh}	15249^{cdef}	25042^{c}	1245^{cd}
12.	**D_3V_2**	16.83^{cdef}	180^{defgh}	18576^{bcde}	31930^{bc}	1291^{cd}
13.	**D_3V_3**	18.50^{cde}	201^{bcdef}	21380^{bcde}	38101^{abc}	1462^{cd}
14.	**D_3V_4**	16.89^{cdef}	195^{bcdefg}	18350^{bcde}	33368^{abc}	1426^{cd}
15.	**D_3V_5**	16.33^{defg}	187^{cdefgh}	18570^{bcde}	32037^{bc}	1346^{cd}
16.	**D_4V_1**	26.58^{ab}	171^{fgh}	8682^{ef}	46978^{abc}	1211^{cd}
17.	**D_4V_2**	19.67^{cd}	125^{h}	4113^{f}	25654^{c}	913^{d}
18.	**D_4V_3**	26.17^{ab}	168^{fgh}	8407^{f}	45464^{abc}	1181^{cd}
19.	**D_4V_4**	21.50^{bc}	132^{gh}	4219^{f}	29038^{c}	965^{d}
20.	**D_4V_5**	28.83^{a}	187^{cdefgh}	11654^{def}	55874^{a}	1302.0^{cd}
	CD (5%)	5.15	69.27	13870	23300	665

hr) and ENT (1630°C) whereas CPG took maximum GDD (228°C day), HTU (23844°C day hr), PTU (44634°C day hr) and ENT (2002°C) for sprouting of corms.

The interaction between planting dates and varieties for days taken, GDD, HTU, PTU and ENT requirement for corm sprouting varied significantly. Punjab Glad 3 took minimum 10.28 days to sprout when planted on 28th September followed by 13.44 days under October planting which was at par with November planting (14.17 days). Under September planting all the varieties took minimum days to sprout as compared to other planting dates. White Prosperity took maximum time to sprout when planted on 28th December (28.83 days). CPG under September planting took maximum GDD (308°C day), HTU (42825°C day hr) and ENT (3671°C) whereas White Prosperity required maximum PTU (55874°C day hr) under December planting. All the varieties under September planting required maximum GDD, HTU and ENT.

The results of the study revealed that all the varieties took comparatively less time and more energy units for corm sprouting under early plantings while significant delay was noticed under late plantings. This indicated that apart from genetic makeup, the sprouting of corms was affected by prevailing temperature at the time of planting. Uhlmann *et al* (2017) reported that optimum temperature for corm sprouting was 25°C. The reason for late sprouting under late sown condition may be due to downfall in temperature which started decreasing from beginning of November. Singh *et al* (2019) also reported similar results, where corms planted on 15th October took minimum number of days for sprouting under both growing conditions (open field and shade net) and increased with late planting (15th December). It was observed that CPG took more time to sprout irrespective of planting dates that may be due to its genetic makeup. The genotypic differences among varieties could have led to different hormonal levels especially of GA and ABA that controlled the extent of dormancy and in turn the time required for sprouting of corms. Due to change in temperature, sunshine hours and day length with planting dates the change was observed in required GDD, HTU, PTU and ENT for sprouting of corms.

4.1.2 Shoot Emergence (VE)

A significant difference in number of days, GDD, HTU, PTU and ENT taken for shoot emergence was observed under different dates of planting whereas, non-significant difference was observed for varieties (Table 4.2). Data on dates of planting showed that September planting took minimum number of days for shoot emergence i.e. 15.24 days followed by October (17.99) and November (20.71) whereas December planting took maximum number of days to shoot emergence i.e. 29.47 days. The number of days taken up by the crop to shoot emergence increased with each delay in planting from D_1 to D_4. The accumulated GDD, HTU and ENT were maximum under D_1 i.e., 323°C day, 47,536°C day hr and 3826°C respectively and minimum under late planting (D_4) i.e., 192 °C day, 13,899°C

Table 4.2: Number of days and agrometeorological indices accumulated by gladiolus varieties for shoot emergence under different dates of planting

S.No.	Treatment	DAS	GDD (°C day)	HTU (°C day hr)	PTU (°C day hr)	ENT (°C)
Dates of planting (D)						
1.	**D_1 (28 Sep.)**	15.24^{D}	323^{A}	47536^{A}	58826^{A}	3826^{A}
2.	**D_2 (28 Oct.)**	17.99^{C}	258^{B}	27845^{B}	51234^{AB}	1865^{B}
3.	**D_3 (28 Nov.)**	20.71^{B}	213^{C}	24086^{B}	44861^{B}	1540^{B}
4.	**D_4 (28 Dec.)**	29.47^{A}	192^{C}	13899^{C}	59329^{A}	1303^{C}
	CD (5%)	1.38	24.56	7298	10109	249
Varieties (V)						
1.	**V_1 (Punjab Glad 3)**	20.19	232^{B}	24255	48701	1973^{B}
2.	**V_2 (Punjab Lemon Delight)**	20.31	244^{AB}	28816	51941	2128^{AB}
3.	**V_3 (CPG)**	22.21	266^{A}	32877	61412	2320^{A}
4.	**V_4 (Punjab Glance)**	20.13	239^{AB}	26457	49602	2084^{AB}
5.	**V_5 (White Prosperity)**	21.42	251^{AB}	29302	56156	2163^{AB}
	CD (5%)	NS	33.62	NS	NS	307
D×V						
1.	**D_1V_1**	12.87^{j}	273^{bcd}	33715^{bcd}	41115^{c}	3278^{c}
2.	**D_1V_2**	15.72^{hij}	328^{ab}	49099^{ab}	60669^{abc}	3880^{abc}
3.	**D_1V_3**	17.50^{efghij}	371^{a}	60299^{a}	75582^{a}	4353^{a}
4.	**D_1V_4**	14.78^{ij}	314^{abc}	45914^{abc}	56684^{abc}	3720^{bc}
5.	**D_1V_5**	15.33^{hij}	329^{ab}	48652^{ab}	60079^{abc}	3901^{ab}
6.	**D_2V_1**	16.19^{ghij}	235^{de}	23453^{defg}	41216^{c}	1695^{def}
7.	**D_2V_2**	19.97^{defgh}	277^{bcd}	34201^{bcd}	61443^{abc}	1982^{d}
8.	**D_2V_3**	18.67^{efghi}	270^{bcd}	29350^{cde}	56157^{abc}	1980^{d}
9.	**D_2V_4**	18.47^{fghij}	261^{cde}	28172^{de}	52265^{abc}	1889^{d}
10.	**D_2V_5**	16.67^{fghij}	245^{de}	24051^{defg}	45092^{c}	1781^{de}
11.	**D_3V_1**	18.94^{efghi}	205^{ef}	20644^{defg}	39262^{c}	1499^{def}
12.	**D_3V_2**	21.22^{def}	216^{def}	24983^{def}	46551^{bc}	1553^{def}
13.	**D_3V_3**	21.67^{cde}	219^{def}	26417^{de}	48146^{bc}	1559^{def}
14.	**D_3V_4**	21.05^{def}	212^{def}	23123^{defg}	44209^{c}	1542^{def}
15.	**D_3V_5**	20.67^{defg}	216^{def}	25261^{def}	46138^{c}	1548^{def}
16.	**D_4V_1**	32.78^{a}	215^{def}	19206^{defg}	73213^{ab}	1422^{def}
17.	**D_4V_2**	24.33^{cd}	155^{f}	6983^{g}	39102^{c}	1098^{f}
18.	**D_4V_3**	31.00^{ab}	204^{ef}	15444^{efg}	65761^{abc}	1389^{def}
19.	**D_4V_4**	26.25^{bc}	168^{f}	8618^{fg}	45251^{c}	1185^{ef}
20.	**D_4V_5**	33.00^{a}	215^{def}	19243^{defg}	73316^{ab}	1422^{def}
	CD (5%)	5.09	67.25	17528	27928	615

day hr and 1303°C respectively. Accumulated HTU and ENT of October planting were at par with November planting. September and December planting accumulated maximum photo thermal units i.e., 58826°C day hr and 59329°C day hr respectively for shoot emergence due to more daylength.

The interaction between planting dates and varieties for days after planting, GDD, HTU, PTU and ENT requirement for shoot emergence varied significantly. It was found that Punjab Glad 3 took minimum days for shoot emergence i.e., 12.87 days under September planting followed by October (16.19 days) and November (18.94 days) plantings. However, White Prosperity took maximum number of days for shoot emergence when planted on 28th December i.e, 33 days which was at par with Punjab Glad 3 (32.78 days). For shoot emergence, CPG under September planting accumulated maximum GDD (371°C day), HTU (60299°C day hr), PTU (75582°C day hr) and ENT (4353°C) whereas, Punjab Lemon Delight under December planting accumulated minimum GDD (155°C day), HTU (6983°C day hr), PTU (39102°C day hr) and ENT (1098°C).

All the varieties took comparatively less time for shoot emergence under early plantings while significant delay was noticed under late plantings. It could be accounted to the early sprouting of corms in early plantings. The required GDD, HTU and ENT for shoot emergence were maximum for early plantings whereas with delay in planting the requirement for energy units decreased. Ram *et al* (2016) also reported that in timely sown wheat crop (1 November) all agrometeorological parameters were higher as compared to late sown (30 November).

4.1.3 Flag Leaf Development (VF)

Data presented in Table 4.3 shows that significant variation existed among planting dates as well as varieties in context to days taken for leaf development. The data revealed that minimum number of days for flag leaf development were recorded in September planting (75.03 days) followed by October (81.99 days) planting which was at par with November (86.06 days) planting. December planting took maximum number of days for flag leaf development i.e. 94.12 days. The difference among planting dates could be attributed to the fact that under short day conditions which prevailed during leaf development in early plantings and favourable temperature during these months allowed early leaf development as compared to delayed leaf development in late plantings. Accumulated GDD and ENT were maximum i.e., 1163°C day and 10493°C respectively in September planting followed by December planting. Maximum HTU were noted in September planting (608527°C day hr) which were at par with December planting (584601°C day hr). Maximum PTUs were recorded in January (1158843°C day hr) planting because day length started increasing after December.

Table 4.3: Number of days and agrometeorological indices accumulated by gladiolus varieties for flag leaf development under different dates of planting

S.No.	Treatment	DAS	GDD (°C day)	HTU (°C day hr)	PTU (°C day hr)	ENT (°C)
Dates of planting (D)						
1.	**D_1 (28 Sep.)**	75.03^{C}	1163^{A}	608527^{A}	954108^{B}	10493^{A}
2.	**D_2 (28 Oct.)**	81.99^{B}	812^{C}	314864^{B}	693545^{C}	5660^{C}
3.	**D_3 (28 Nov.)**	86.06^{B}	734^{D}	311379^{B}	668328^{C}	4881^{D}
4.	**D_4 (28 Dec.)**	94.12^{A}	1096^{B}	584601^{A}	1158843^{A}	9064^{B}
	CD (5%)	5.07	65.89	70152	120841	579
Varieties (V)						
1.	**V_1 (Punjab Glad 3)**	84.17^{BC}	958^{B}	457182^{B}	872477^{BC}	7621^{B}
2.	**V_2 (Punjab Lemon Delight)**	81.05^{CD}	915^{C}	419186^{BC}	801336^{C}	7229^{C}
3.	**V_3 (CPG)**	93.12^{A}	1054^{A}	560348^{A}	1066413^{A}	8363^{A}
4.	**V_4 (Punjab Glance)**	77.82^{D}	868^{D}	377296^{C}	719795^{D}	6803^{D}
5.	**V_5 (White Prosperity)**	85.34^{B}	963^{B}	460202^{B}	883509^{B}	7606^{B}
	CD (5%)	3.99	42.84	42014	78816	346
D×V						
1.	**D_1V_1**	75.91^{ghij}	1182^{abc}	617250^{cd}	972712^{cd}	10668^{ab}
2.	**D_1V_2**	73.11^{hij}	1152^{bcd}	588271^{cd}	917634^{cde}	10442^{ab}
3.	**D_1V_3**	84.67^{gef}	1233^{ab}	709855^{ab}	1137457^{b}	10914^{a}
4.	**D_1V_4**	71.28^{ij}	1131^{cd}	570610^{cd}	882329^{de}	10266^{abc}
5.	**D_1V_5**	70.22^{j}	1118^{cd}	556649^{cd}	860408^{de}	10173^{bc}
6.	**D_2V_1**	78.43^{fghij}	786^{fgh}	292951^{gh}	637584^{hi}	5515^{gh}
7.	**D_2V_2**	79.11^{efghi}	794^{fgh}	304421^{fgh}	654988^{fghi}	5535^{gh}
8.	**D_2V_3**	90.00^{bcd}	866^{ef}	352919^{efg}	811120^{defg}	6016^{g}
9.	**D_2V_4**	75.92^{ghij}	774^{gh}	287390^{gh}	609199^{hi}	5425^{gh}
10.	**D_2V_5**	86.50^{cde}	838^{efg}	336638^{efgh}	754834^{efgh}	5808^{g}
11.	**D_3V_1**	85.33^{def}	717^{hi}	288857^{gh}	640502^{ghi}	4740^{hi}
12.	**D_3V_2**	80.33^{efgh}	657^{i}	246023^{h}	550018^{i}	4254^{i}
13.	**D_3V_3**	94.67^{abc}	853^{efg}	416344^{e}	850467^{de}	5826^{g}
14.	**D_3V_4**	80.00^{efghi}	655^{i}	249319^{h}	550264^{i}	4272^{i}
15.	**D_3V_5**	90.00^{bcd}	789^{fgh}	356352^{efg}	750389^{efgh}	5313^{gh}
16.	**D_4V_1**	97.03^{ab}	1146^{bcd}	629671^{bc}	1239108^{b}	9561^{cd}
17.	**D_4V_2**	91.67^{bcd}	1056^{d}	538030^{d}	1082336^{bc}	8685^{e}
18.	**D_4V_3**	103.17^{a}	1264^{a}	762274^{a}	1466608^{a}	10695^{ab}
19.	**D_4V_4**	84.09^{defg}	911^{e}	401864^{ef}	837388^{def}	7250^{f}
20.	**D_4V_5**	94.67^{bc}	1105^{cd}	591167^{cd}	1168406^{b}	9130^{de}
	CD (5%)	7.98	85.68	84027	157633	692

Amongst varieties evaluated, it was found that Punjab Glance was earliest and took 77.82 days for flag leaf development followed by Punjab Lemon Delight (81.05 days). The maximum time for flag leaf development was recorded in CPG (93.12 days). The difference among the varieties was attributed to the varietal variation (Kumari *et al* 2001). For flag leaf development, lowest agrometeorological parameters i.e. GDD (868°C day), HTU (377296°C day hr), PTU (719795°C day hr) and ENT (6803°C day) were recorded in Punjab Glance whereas the highest GDD (1054°C day), HTU (560348°C day hr), PTU (1066413°C day hr) and ENT (8363°C) were recorded in CPG.

The results with respect to interaction effects between planting dates and varieties showed that number of days taken for flag leaf development increased with delay in planting time in all the varieties. CPG planted on 28th December took maximum time (103.17 days) for flag leaf development. Whereas, early plantings took less number of days for flag leaf development in all the varieties with White Prosperity planted on 28th September recording minimum time (70.22 days) for flag leaf development. Early development of flag leaf could be due to optimum time of planting, favourable environmental conditions like temperature, light etc.

Similar results were found by Nagar *et al* (2018), who reported best growth behaviour per plant under early plantation of gladiolus (10th October). CPG took maximum GDD (1264°C day), HTU (762274°C day hr) and PTU (1466608°C day hr) under December planting and maximum ENT (10914°C) under September planting. Whereas, Punjab Lemon Delight under November planting took minimum agrometeorological parameters i.e. GDD (657°C day), HTU (246023°C day hr), PTU (550018°C day hr) and ENT (4254°C) for flag leaf development.

4.1.4 Initiation of Spike Emergence (R1.0)

Data pertaining to initiation of spike emergence is presented in Table 4.4. The initiation of spike emergence was significantly influenced by planting dates, varieties and their interactions. The data revealed that minimum time for initiation of spike emergence was recorded under September planting (84.39 days). The plants took 90.15 days for spike emergence initiation when planted on 28th October which was statistically at par with November planting. The planting done on 28th December resulted in maximum time taken for spike emergence initiation (102.65 days). The indices viz. GDD, HTU and ENT required for spike emergence initiation in September planting were at par with those required in December planting. Maximum PTUs were accumulated in December planting i.e. 1473460°C day hr whereas minimum PTUs were accumulated in October planting (816030°C day hr) which was at par with November planting (844409°C day hr).

Among varieties evaluated, Punjab Glance was the earliest and took 85.06 days for

Table 4.4: Number of days and agrometeorological indices accumulated by gladiolus varieties for initiation of spike emergence under different dates of planting

S. No.	Treatment	DAS	GDD (°C day)	HTU (°C day hr)	PTU (°C day hr)	ENT (°C)
			Dates of planting (D)			
1.	**D_1 (28 Sep.)**	84.39^{C}	1239^{A}	699313^{A}	1135206^{B}	11033^{A}
2.	**D_2 (28 Oct.)**	90.15^{B}	868^{B}	364537^{B}	816030^{C}	5986^{B}
3.	**D_3 (28 Nov.)**	93.58^{B}	846^{B}	411598^{B}	844409^{C}	5831^{B}
4.	**D_4 (28 Dec.)**	102.65^{A}	1264^{A}	765234^{A}	1473460^{A}	10786^{A}
	CD (5%)	5.03	71	73231	127358	652
			Varieties (V)			
1.	**V_1 (Punjab Glad 3)**	93.06^{B}	1056^{B}	567094^{B}	1073065^{B}	8417^{B}
2.	**V_2 (Punjab Lemon Delight)**	90.51^{B}	1036^{B}	536615^{B}	1023770^{B}	8290^{B}
3.	**V_3 (CPG)**	102.37^{A}	1173^{A}	694750^{A}	1317239^{A}	9434^{A}
4.	**V_4 (Punjab Glance)**	85.06^{C}	960^{C}	456202^{C}	877799^{C}	7602^{C}
5.	**V_5 (White Prosperity)**	92.46^{B}	1047^{B}	546191^{B}	1044510^{B}	8302^{B}
	CD (5%)	3.64	55	56374	101683	526
			D×V			
1.	**D_1V_1**	87.14^{hi}	1250^{bc}	731022^{bcde}	1172783^{cd}	11068^{bc}
2.	**D_1V_2**	77.72^{j}	1197^{cd}	632657^{efg}	1009604^{defg}	10790^{bc}
3.	**D_1V_3**	97.33^{bcdef}	1321^{b}	814691^{bc}	1383950^{b}	11500^{b}
4.	**D_1V_4**	77.75^{j}	1203^{c}	640350^{defg}	1018513^{defg}	10835^{bc}
5.	**D_1V_5**	82.00^{ij}	1225^{bc}	677846^{def}	1091180^{de}	10970^{bc}
6.	**D_2V_1**	88.22^{ghi}	851^{fghi}	344384^{ijk}	779786^{hi}	5903^{efg}
7.	**D_2V_2**	90.53^{fgh}	869^{fghi}	358744^{ijk}	816823^{ghi}	6012^{efg}
8.	**D_2V_3**	98.00^{bcde}	930^{fg}	436673^{hij}	953875^{defgh}	6321^{ef}
9.	**D_2V_4**	81.83^{ij}	807^{hi}	307675^{k}	685872^{i}	5637^{fg}
10.	**D_2V_5**	92.17^{defgh}	880^{fgh}	375210^{ijk}	843792^{fghi}	6057^{efg}
11.	**D_3V_1**	91.89^{defgh}	814^{ghi}	376038^{ijk}	787117^{hi}	5539^{fg}
12.	**D_3V_2**	91.22^{efgh}	818^{ghi}	392870^{ijk}	805107^{ghi}	5634^{fg}
13.	**D_3V_3**	101.67^{bc}	972^{ef}	530184^{gh}	1050286^{def}	6926^{e}
14.	**D_3V_4**	87.44^{hi}	751^{i}	321600^{jk}	691234^{i}	5016^{g}
15.	**D_3V_5**	95.67^{cdefg}	875^{fgh}	437297^{hi}	888302^{efghi}	6039^{efg}
16.	**D_4V_1**	105.00^{b}	1308^{bc}	816934^{b}	1552572^{b}	11159^{bc}
17.	**D_4V_2**	102.55^{bc}	1260^{bc}	762190^{bcd}	1463545^{b}	10723^{bc}
18.	**D_4V_3**	112.50^{a}	1468^{a}	997452^{a}	1880844^{a}	12989^{a}
19.	**D_4V_4**	93.20^{defgh}	1078^{de}	555181^{fgh}	1115577^{d}	8919^{d}
20.	**D_4V_5**	100.00^{bcd}	1207^{bc}	694410^{cde}	1354763^{bc}	10141^{c}
	CD (5%)	7.29	110	112749	203366	1053

spike emergence initiation. Punjab Lemon Delight took 90.51 days which was at par with Punjab Glad 3 and White Prosperity. Maximum number of days for initiation of spike emergence were taken by CPG (102.37 days). Minimum agrometeorological indices i.e. GDD (960°C day), HTU (456202°C day hr), PTU (877799°C day hr) and ENT (7602°C) were accumulated by Punjab Glance whereas maximum GDD (1173°C day), HTU (694750°C day hr), PTU (1317239°C day hr) and ENT (9434°C) were accumulated by CPG. Agrometeorological indices accumulated by Punjab Glad 3, Punjab Lemon Delight and White Prosperity were at par with each other.

Interaction studies between planting dates and varieties revealed that the number of days taken for initiation of spike emergence increased with delay in planting in all the varieties. Early planting took less number of days for spike emergence initiation in all the varieties with September planting recording minimum time (84.39 days) for spike emergence initiation.

Among all the varieties, Punjab Lemon Delight (77.72 days) and Punjab Glance (77.75 days) under September planting emerged spikes at the earliest. The days taken to spike emergence initiation were maximum in CPG (112.50 days) under December planting. Time taken for spike emergence initiation under all planting dates was more in CPG as compared to all other varieties evaluated indicating its longer duration. It took 97.33, 98.00, 101.67 and 112.50 days under September, October, November and December plantings, respectively. Concomitant to the days, accumulation of all agrometeorological indices i.e. GDD (1468°C day), HTU (997452°C day hr), PTU (1880844°C day hr) and ENT (12989°C) were maximum in CPG under December planting. Whereas, Punjab Glance accumulated minimum GDD (751°C day), PTU (691234°C day hr) and ENT (5016°C) under November planting and minimum HTU (307675°C day hr) under October planting.

The time taken for initiation of spike emergence was least in timely planting. This could be explained as in timely planting, growth and flowering period coincided with short days which led to earliness in flowering. Photoperiod induction is perceived by young expanding leaves and after sufficient exposure to the required photoperiod, there is no reversal effect even fluctuations in day light hours occur (Taiz and Zeiger 2006). The plants of December planting passed through long day lengths and experienced relatively higher temperature in March, so there was delay in initiation of spike emergence. High temperature delayed the meristem transition to reproductive state and rates of floret initiation and differentiation (Whealy *et al* 1987). Similar results were also obtained by Singh *et al* (2019) who observed that early planting i.e. 15th October (105.5 days) needed a significantly short period of time for spike emergence compared to those planted on 15th December (114.5 days).

4.1.5 Half Spike Emergence (R1.1)

A significant difference in number of days, GDD, HTU, PTU and ENT taken for half

Table 4.5: Number of days and agrometeorological indices accumulated by gladiolus varieties for half spike emergence under different dates of planting

S. No.	Treatment	DAS	GDD (°C day)	HTU (°C day hr)	PTU (°C day hr)	ENT (°C)
Dates of planting (D)						
1.	**D_1 (28 Sep.)**	89.58^{C}	1269^{B}	743932^{B}	1229184^{B}	11202^{A}
2.	**D_2 (28 Oct.)**	94.48^{B}	901^{C}	402153^{D}	890407^{C}	6167^{B}
3.	**D_3 (28 Nov.)**	97.79^{B}	911^{C}	472702^{C}	954255^{C}	6410^{B}
4.	**D_4 (28 Dec.)**	106.96^{A}	1348^{A}	860350^{A}	1642821^{A}	11663^{A}
	CD (5%)	4.52	67.11	63242	114545	620
Varieties (V)						
1.	**V_1 (Punjab Glad 3)**	97.65^{B}	1112^{B}	632055^{B}	1190262^{B}	8904^{B}
2.	**V_2 (Punjab Lemon Delight)**	94.45^{B}	1085^{B}	588607^{B}	1122992^{B}	8709^{B}
3.	**V_3 (CPG)**	107.54^{A}	1235^{A}	762680^{A}	1460217^{A}	10006^{A}
4.	**V_4 (Punjab Glance)**	88.94^{C}	1002^{C}	501322^{C}	961083^{C}	7949^{C}
5.	**V_5 (White Prosperity)**	97.44^{B}	1102^{B}	614258^{B}	1161279^{B}	8734^{B}
	CD (5%)	3.62	55.79	59170	104967	530
D×V						
1.	**D_1V_1**	91.33^{hij}	1277^{cde}	773766^{cd}	1253615^{d}	11173^{c}
2.	**D_1V_2**	81.00^{k}	1218^{de}	665209^{def}	1072885^{ef}	10948^{c}
3.	**D_1V_3**	103.83^{bcd}	1361^{bc}	854244^{bc}	1513352^{c}	11793^{bc}
4.	**D_1V_4**	82.14^{k}	1221^{de}	668992^{def}	1083025^{def}	10958^{c}
5.	**D_1V_5**	89.61^{ij}	1267^{cde}	757448^{cde}	1223042^{de}	11137^{c}
6.	**D_2V_1**	93.58^{ghi}	890^{hi}	385387^{ijk}	864686^{fg}	6102^{fg}
7.	**D_2V_2**	94.83^{ghi}	902^{hi}	398456^{hijk}	889819^{fg}	6169^{fg}
8.	**D_2V_3**	103.67^{bcde}	983^{gh}	497686^{ghi}	1068870^{def}	6638^{ef}
9.	**D_2V_4**	84.50^{jk}	824^{i}	320643^{k}	722811^{g}	5740^{fg}
10.	**D_2V_5**	95.83^{fghi}	908^{hi}	408596^{hijk}	905849^{fg}	6186^{fg}
11.	**D_3V_1**	95.31^{ghi}	864^{hi}	427023^{hijk}	867787^{fg}	5931^{fg}
12.	**D_3V_2**	95.89^{efghi}	887^{hi}	455510^{hij}	924133^{fg}	6230^{fg}
13.	**D_3V_3**	105.33^{bcd}	1038^{fg}	589790^{fg}	1167413^{de}	7633^{e}
14.	**D_3V_4**	91.44^{hij}	807^{i}	371748^{jk}	778542^{g}	5448^{g}
15.	**D_3V_5**	101.00^{cdefg}	960^{gh}	519438^{gh}	1033399^{ef}	6808^{ef}
16.	**D_4V_1**	110.36^{ab}	1419^{b}	942043^{b}	1774961^{b}	12408^{b}
17.	**D_4V_2**	106.11^{bc}	1332^{bcd}	835251^{bc}	1605132^{bc}	11490^{bc}
18.	**D_4V_3**	117.33^{a}	1558^{a}	1109002^{a}	2091232^{a}	13960^{a}
19.	**D_4V_4**	97.69^{defgh}	1157^{ef}	643904^{ef}	1259955^{d}	9651^{d}
20.	**D_4V_5**	103.33^{bcdef}	1273^{cde}	771549^{cd}	1482826^{c}	10805^{c}
	CD (5%)	7.25	111.60	118339	209933	1060

spike emergence was observed under different dates of planting (Table 4.5). The data revealed that all gladiolus varieties took minimum number of days for half spike emergence under September planting (89.58 days). The planting done on 28th October took 94.48 days for half spike emergence which was at par with November planting. However, the maximum time for half spike emergence was observed when planting was done in December (106.96 days). The accumulated GDD (1348°C day), HTU (860350°C day hr), PTU (1642821°C day hr) and ENT (11663°C) were maximum under December planting. Minimum GDD (901°C day), PTU (890407°C day hr) and ENT (6167°C) were accumulated under October planting which were at par with November planting. Minimum HTU was accumulated in October planting (402153°C day hr) followed by November planting (472702°C day hr).

Irrespective of planting date, a significant difference in number of days, GDD, HTU, PTU and ENT taken for half spike emergence was observed among the varieties. Among all varieties, Punjab Glance took minimum number of days (88.94 days), GDD (1002°C day), HTU (501322°C day hr), PTU (961083°C day hr) and ENT (7949°C) whereas; CPG took maximum number of days (107.54 days), GDD (1235°C day), HTU (762680°C day hr), PTU (1460217°C day hr) and ENT (10006°C). Punjab Glad 3, Punjab Lemon Delight and White Prosperity were at par with each other for ENT required for half spike emergence.

The data presented in Table 4.5 for interaction showed significant variation in days taken for half spike emergence in different varieties under different planting dates. Number of days taken for half spike emergence increased with delay in planting time in all the varieties with December planting recording maximum time for half spike emergence. CPG took maximum number of days, GDD (1558°C day), HTU (1109002°C day hr), PTU (2091232°C day hr) and ENT (13960°C) under December planting. Punjab Lemon Delight took minimum (81 days) number of days for half spike emergence under September planting which was at with Punjab Glance which took 82.14 days under same planting. Punjab Glance took minimum GDD (807°C day) and ENT (5448°C) under November planting and minimum HTU (320643°C day hr) and PTU (722811°C day hr) under October planting.

The results of the study revealed that all the varieties took comparatively lesser time for half spike emergence under their early plantings which is concomitant to early initiation of spike emergence in early plantings.

4.1.6 Full Spike Emergence (R1.2)

The data in Table 4.6 reveals significant differences for full spike emergence under different planting dates, varieties and their interactions. Among the dates of planting 28th September planting resulted in minimum number of days (93.60 days) taken for full spike emergence followed by October planting which took 98.63 days. December planting took maximum number of days for full spike emergence i.e. 111.38 days. December planting accumulated maximum agrometeorological indices whereas minimum were accumulated

Table 4.6: Number of days and agrometeorological indices accumulated by gladiolus varieties for full spike emergence under different dates of planting

S. No.	Treatment	DAS	GDD (°C day)	HTU (°C day hr)	PTU (°C day hr)	ENT (°C)
Dates of planting (D)						
1.	**D_1 (28 Sep.)**	93.60^{D}	1290^{B}	775440^{B}	1302052^{B}	11314^{B}
2.	**D_2 (28 Oct.)**	98.63^{C}	936^{C}	442491^{D}	965615^{D}	6353^{D}
3.	**D_3 (28 Nov.)**	103.14^{B}	999^{C}	555608^{C}	113324^{C}	7238^{C}
4.	**D_4 (28 Dec.)**	111.38^{A}	1439^{A}	972090^{A}	1836447^{A}	12644^{A}
	CD (5%)	4.15	77.45	77833	140943	774
Varieties (V)						
1.	**V_1 (Punjab Glad 3)**	102.35^{B}	1167^{B}	695400^{B}	1312632^{B}	9365^{B}
2.	**V_2 (Punjab Lemon Delight)**	98.33^{C}	1133^{B}	647606^{B}	1224447^{B}	9138^{B}
3.	**V_3 (CPG)**	113.21^{A}	1320^{A}	858542^{A}	1646643^{A}	10812^{A}
4.	**V_4 (Punjab Glance)**	92.03^{D}	1039^{C}	542591^{C}	1034328^{C}	8251^{C}
5.	**V_5 (White Prosperity)**	102.51^{B}	1169^{B}	687897^{B}	1303748^{B}	9370^{B}
	CD (5%)	3.59	57.75	58037	110028	556
D×V						
1.	**D_1V_1**	96.08^{f}	1298^{de}	803227^{de}	1336415^{fg}	11291^{cde}
2.	**D_1V_2**	83.61^{g}	1229^{efg}	689133^{efg}	1111675^{hij}	10993^{de}
3.	**D_1V_3**	106.83^{de}	1382^{cd}	869124^{cd}	1578566^{cde}	11963^{cd}
4.	**D_1V_4**	85.61^{g}	1240^{ef}	713129^{ef}	1146790^{ghij}	11030^{de}
5.	**D_1V_5**	95.89^{f}	1298^{de}	802585^{de}	1336814^{fg}	11293^{cde}
6.	**D_2V_1**	99.25^{f}	936^{klm}	442613^{ij}	966297^{jkl}	6325^{hi}
7.	**D_2V_2**	98.56^{f}	926^{klm}	433689^{ij}	946709^{jkl}	6269^{hi}
8.	**D_2V_3**	109.33^{bcd}	1039^{jk}	560859^{gh}	1190057^{ghi}	6992^{gh}
9.	**D_2V_4**	86.83^{g}	841^{m}	332028j	758428^{l}	5852^{i}
10.	**D_2V_5**	99.17^{f}	936^{klm}	443265^{ij}	966584^{jkl}	6328^{hi}
11.	**D_3V_1**	99.47^{f}	928^{klm}	494691^{hi}	978046^{ijkl}	6442^{hi}
12.	**D_3V_2**	100.50^{ef}	959^{jkl}	520453^{hi}	1053669^{hij}	6941^{gh}
13.	**D_3V_3**	114.33^{bc}	1191^{efghi}	735165^{e}	1471920^{def}	9121^{f}
14.	**D_3V_4**	94.72^{f}	854^{lm}	417454^{ij}	852255^{kl}	5835^{i}
15.	**D_3V_5**	106.67^{de}	1061^{j}	610278^{fgh}	1210730^{gh}	7849^{g}
16.	**D_4V_1**	114.61^{b}	1506^{b}	1041070^{b}	1969769^{b}	13403^{b}
17.	**D_4V_2**	110.67^{bcd}	1417^{bc}	947150^{bc}	1785737^{bc}	12348^{bc}
18.	**D_4V_3**	122.33^{a}	1667^{a}	1269018^{a}	2346028^{a}	15171^{a}
19.	**D_4V_4**	100.98^{ef}	1221^{efgh}	707752^{ef}	1379837^{efg}	10288^{e}
20.	**D_4V_5**	108.33^{bcd}	1382^{cd}	895462^{cd}	1700863^{cd}	12009^{c}
	CD (5%)	7.18	115.49	116075	220057	1060

under October planting.

The data on varieties revealed that minimum number of days (92.03 days), GDD (1039°C day), HTU (542591°C day hr), PTU (1034328°C day hr) and ENT (8251°C) were taken by Punjab Glance whereas; CPG took maximum number of days (113.21 days), GDD (1320°C day), HTU (858542°C day hr), PTU (1646643°C day hr) and ENT (10812°C). Punjab Lemon Delight was at par with Punjab Glad 3 and White Prosperity for agrometeorological indices required for full spike emergence.

The results relating to interaction effects between planting dates and varieties showed that days taken for full spike increased with delay in planting. All the varieties under December planting took more time for full spike emergence with CPG showing maximum number of days i.e. 122.33 days. Punjab Lemon Delight under September planting took minimum number of days for full spike emergence which were at par with Punjab Glance under September and October planting. CPG accumulated maximum agrometeorological indices under December planting whereas Punjab Glance accumulated minimum agrometeorological indices under October planting.

Varieties planted under early plantings initiated early spike emergence and half spike emergence, thereby leading to earliness in full spike emergence too.

4.1.7 Blooming (R2)

Data enumerated in Table 4.7 showed that days taken from planting to blooming differed significantly with different planting dates and varieties. Among different planting dates, earliest blooming in 98.57 days was observed under September planting followed by October planting which took 104.75 days. On the other hand, blooming was found to be delayed during November (111.93 days) and December planting (117.05 days). Maximum GDD (1561°C day), PTU (2102487°C day hr) and ENT (14029°C) were accumulated under December planting whereas maximum HTU (814453) were accumulated under September planting. Punjab Glance took minimum number of days (98.19 days), GDD (1114°C day), HTU (632685°C day hr), PTU (1186055°C day hr) and ENT (8848°C) for blooming. Whereas, CPG took maximum number of days (118.58 days), GDD (1405°C day), HTU (962380°C day hr), PTU (1846341°C day hr) and ENT (11681°C) for blooming.

The interaction between planting dates and varieties revealed that days, GDD, HTU, PTU and ENT taken for blooming varied significantly. Punjab Lemon Delight took minimum (86.77 days) days to reach blooming under September planting which was at par with Punjab Glance (88.86 days) whereas, CPG took maximum days i.e. 126 days under December planting.

Accumulation of all agrometeorological indices i.e. GDD (1762°C day), HTU (1381463°C day hr), PTU (2566359°C day hr) and ENT (16458°C) were maximum in CPG under December planting. Whereas, Punjab Glance accumulated minimum

Table 4.7: Number of days and agrometeorological indices accumulated by gladiolus varieties for blooming under different dates of planting

S. No.	Treatment	DAS	GDD (°C day)	HTU (°C day hr)	PTU (°C day hr)	ENT (°C)
Dates of planting (D)						
1.	**D_1 (28 Sep.)**	98.57^{D}	1326^{B}	814453^{A}	1407841^{B}	11565^{B}
2.	**D_2 (28 Oct.)**	104.75^{C}	993^{D}	508761^{B}	1090789^{C}	6714^{D}
3.	**D_3 (28 Nov.)**	111.93^{B}	1150^{C}	711300^{D}	1408483^{B}	8712^{C}
4.	**D_4 (28 Dec.)**	117.05^{A}	1561^{A}	1122043^{C}	2102487^{A}	14029^{A}
	CD (5%)	4.75	76.58	87173	155965	766
Varieties (V)						
1.	**V_1 (Punjab Glad 3)**	109.88^{B}	1282^{B}	813560^{B}	1552187^{B}	10484^{B}
2.	**V_2 (Punjab Lemon Delight)**	103.68^{C}	1221^{B}	747086^{B}	1407553^{C}	10006^{B}
3.	**V_3 (CPG)**	118.58^{A}	1405^{A}	962380^{A}	1846341^{A}	11681^{A}
4.	**V_4 (Punjab Glance)**	98.19^{D}	1114^{C}	632685^{C}	1186055^{D}	8848^{C}
5.	**V_5 (White Prosperity)**	110.04^{B}	1267^{B}	789983^{B}	1519863^{BC}	10257^{B}
	CD (5%)	3.81	63.88	69782	127705	619
D×V						
1.	**D_1V_1**	102.22^{fghi}	1355^{de}	843920^{efg}	1482112^{ef}	11769^{d}
2.	**D_1V_2**	86.77^{j}	1247^{ef}	725766^{fgh}	1165930^{hij}	11055^{d}
3.	**D_1V_3**	111.33^{de}	1407^{cd}	898548^{de}	1674730^{de}	12113^{cd}
4.	**D_1V_4**	88.86^{j}	1264^{ef}	752315^{fgh}	1211060^{ghij}	11119^{d}
5.	**D_1V_5**	103.67^{fghi}	1358^{de}	851718^{efg}	1505373^{ef}	11769^{d}
6.	**D_2V_1**	102.56^{fghi}	967^{ijk}	481592^{jk}	1033754^{ij}	6517^{g}
7.	**D_2V_2**	101.64^{ghi}	958^{jk}	468942^{jk}	1014453^{j}	6471^{g}
8.	**D_2V_3**	112.67^{cde}	1079^{ghij}	604464^{hij}	1278047^{fgh}	7315^{fg}
9.	**D_2V_4**	97.56^{i}	922^{k}	427065^{k}	936722^{j}	6262^{g}
10.	**D_2V_5**	109.33^{def}	1039^{hijk}	561741^{ijk}	1190967^{ghi}	7003^{fg}
11.	**D_3V_1**	114.27^{cde}	1187^{fg}	728199^{fgh}	1458601^{efg}	9075^{e}
12.	**D_3V_2**	108.75^{efg}	1103^{ghi}	664404^{hi}	1328443^{fgh}	8323^{ef}
13.	**D_3V_3**	124.33^{ab}	1371^{cde}	965048^{de}	1866226^{cd}	10837^{d}
14.	**D_3V_4**	99.47^{hi}	927^{k}	490478^{jk}	975378^{j}	6495^{g}
15.	**D_3V_5**	112.83^{cde}	1163^{fgh}	708370^{ghi}	1413768^{efgh}	8832^{e}
16.	**D_4V_1**	120.47^{abc}	1618^{b}	1200531^{b}	2234282^{b}	14574^{b}
17.	**D_4V_2**	117.56^{bcd}	1573^{b}	1129235^{bc}	2121386^{bc}	14175^{b}
18.	**D_4V_3**	126.00^{a}	1762^{a}	1381463^{a}	2566359^{a}	16458^{a}
19.	**D_4V_4**	106.89^{efgh}	1343^{de}	860884^{ef}	1621060^{de}	11517^{d}
20.	**D_4V_5**	114.33^{cde}	1507^{bc}	1038104^{cd}	1969346^{c}	13423^{bc}
	CD (5%)	7.62	127.76	139564	255410	1238

agrometeorological indices i.e. GDD (922°C day), HTU (427065°C day hr), PTU (936722°C day hr) and ENT (6262°C) under October planting.

The plants of December planting took more time for full spike emergence. Hence, they took more time for blooming also. Minimum days to reach blooming was recorded in September planting. Temperature is considered as a major factor that influences number of days to flowering in gladiolus. The late planted corms being exposed to lower temperatures as compared to early planted corms showed delayed flower initiation in plants. Roh and Joung (2004) found that in *Ornithogalum arabicum* flower initiation took place under wide range of temperatures i.e. from 2°C to 30°C. He found that initiation was slow at 2°C and 30°C but relatively faster at 20°C mild temperature. Prasanna *et al* (2016) also witnessed earlier appearance of flower buds for Kharif season (July planting) as compared to winter season (October planting) in Asiatic lily hybrids.

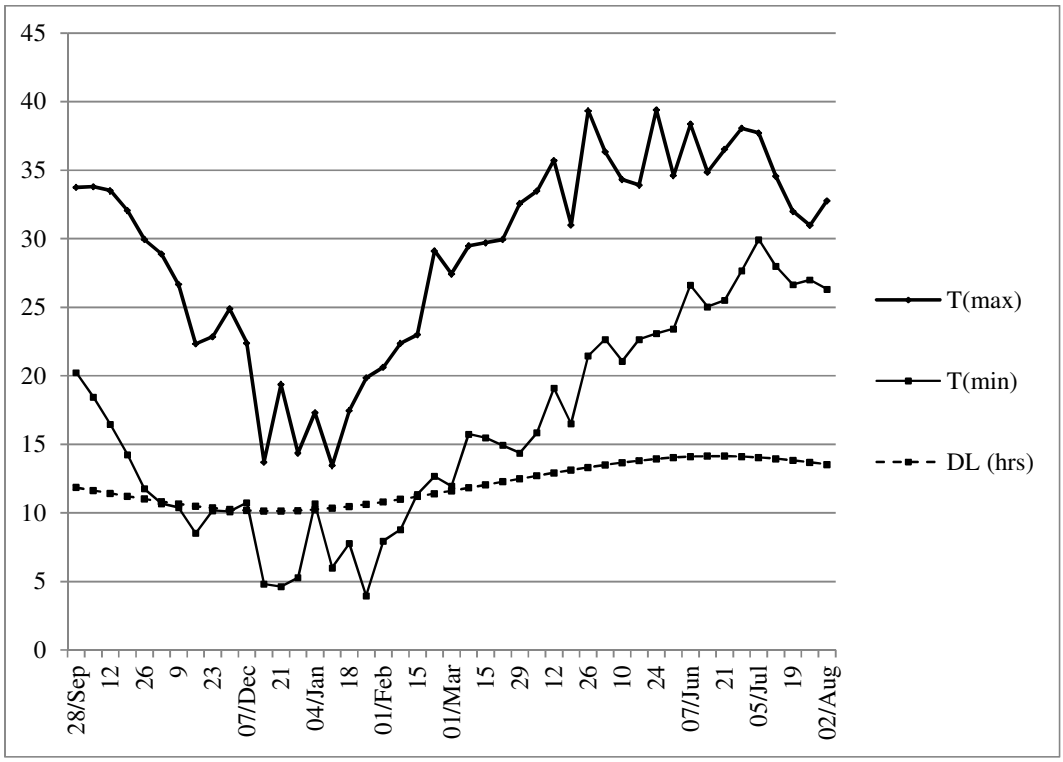

Fig. 1: Graphical representation of environmental conditions i.e. maximum temperature, minimum temperature and daylength of experimental site during the study period (2020-2021)

It is evident from the data that earliest blooming in 98.57 days was observed under September planting followed by October planting which took 104.75 days. On the other hand, blooming was found to be delayed during November (111.93 days) and December (117.05 days) planting. The planting carried out in September produced flowers in starting of January, October planting in mid-January, November planting in mid-March and December planting in April. The prevailing maximum and minimum temperature from initiation of spike emergence

to blooming were 18.9°C and 7.12°C, 15.9°C and 6.5°C and 20.6°C and 7.96°C under September, October and November planting, respectively. Whereas, December planted corms faced 34.4°C maximum and 17.4°C minimum temperatures from spike emergence to blooming stage. Moreover, September and October planted corms experienced short days for three months i.e. November, December and January followed by November planted crop which experienced short days for two months i.e. December and January. December planted corms experienced minimum short day conditions i.e. of only one month in January. It could be concluded that comparatively lower temperature and short day conditions under early planting might have resulted in fewer number of days to reach blooming, whereas, higher temperature and long day conditions under late planting resulted in more number of days to reach blooming stage. The results are in conformity with Laurie *et al* (1979) and Dhatt and Jhanji (2021).

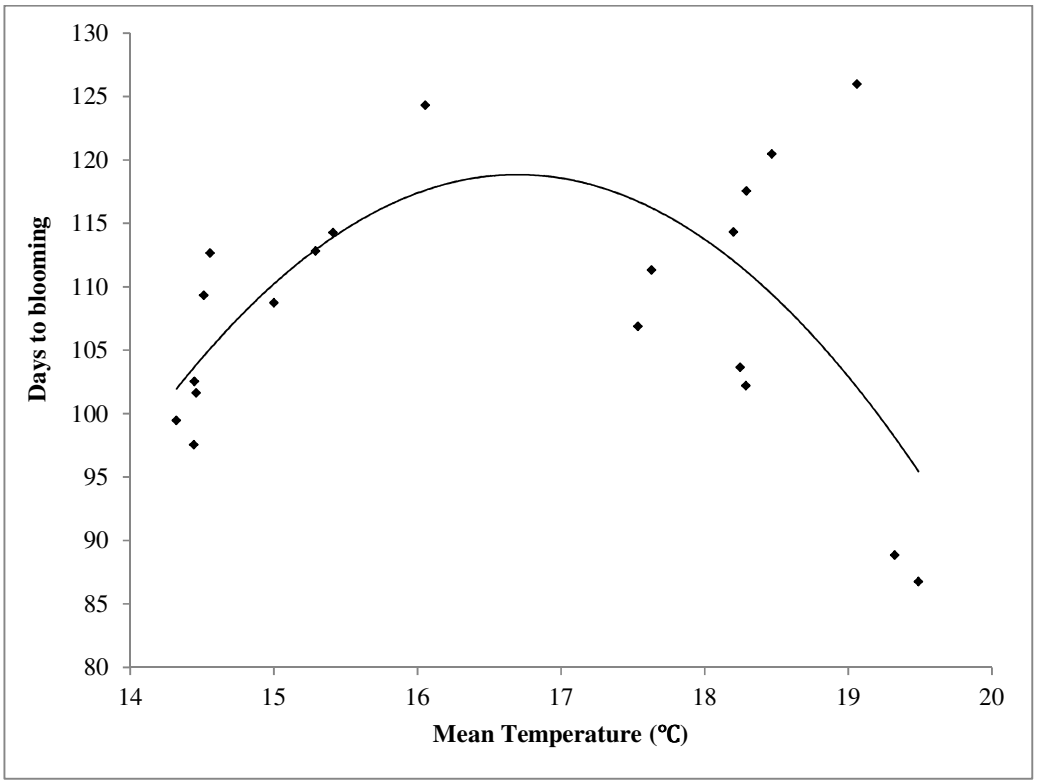

Fig 2. Effect of temperature on Bloomimg

The relationship between temperature and days to blooming is presented in Fig 2. When temperature ranged between 14-16°C (low temperature), number of days taken to blooming were 97-113 days and these were very close to those evident from the parabolic curve i.e. 102-117 days. As temperature started increasing, the number of days taken to blooming also increased. From curve, predictable maximum number of days taken to blooming were 118 days corresponding to 16.5-17°C temperature range. Whereas, recorded maximum number of days to blooming were 124 days corresponding to 16°C. The increase in

temperature i.e. from 17-19.5°C (high temperature) decreased the number of days taken to blooming. From curve, estimated number of days to blooming were 95-117 days whereas, observed ranged from 87-125 days. It could be concluded that with rise in temperature predicted and recorded number of days to blooming decreased from 102 to 95 and 97 to 87 respectively. The results are in conformity with McCalla *et al* (2011), low temperature increased the number of days to inflorescence formation in gladiolus.

4.1.8 Initiation of Anthesis (R3)

The data on days, GDD, HTU, PTU and ENT taken for initiation of anthesis as influenced by planting dates, varieties and their interactions is presented in Table 4.8.

Number of days, GDD, HTU, PTU and ENT taken for initiation of anthesis was significantly affected by planting dates. December planting recorded the highest number of days for initiation of anthesis (121.23 days). Minimum number of days for initiation of anthesis were taken by September planting i.e. 101.20 days. Late plantings accumulated more agrometeorological indices as compared to early plantings. December planting accumulated maximum agrometeorological indices i.e. GDD (1659°C day), HTU (1246824°C day hr), PTU (2335560°C day hr) and ENT (15251°C) whereas, October planting accumulated minimum of all agrometeorological indices i.e. GDD (1015°C day), HTU (533904°C day hr), PTU (1137768°C day hr) and ENT (6862°C).

The data on days, GDD, HTU, PTU and ENT for the parameter differed significantly in varieties with Punjab Glance recording minimum number of days (101.40 days), GDD (1165°C day), HTU (683760°C day hr), PTU (1285968°C day hr) and ENT (9357°C) for initiation of anthesis followed by Punjab Lemon Delight (106.69 days). White Prosperity was at par with Punjab Glad 3. CPG took maximum number of days (123.00 days), GDD (1486°C day), HTU (1063392°C day hr), PTU (2045784°C day hr) and ENT (12637°C) for initiation of anthesis. The significant variation among the varieties could be attributed to the individual genetic makeup that could have been further influenced by the climatic conditions.

The data pertaining to interactions between planting dates and varieties showed significant differences. CPG under December planting took maximum number of days (133.00 days) and accumulated highest agrometeorological indices i.e., GDD (1942°C day), HTU (1613448°C day hr), PTU (3023640°C day hr) and ENT (18951°C). Punjab Lemon Delight took minimum (88.61 days) number of days for initiation of anthesis under September planting which was at par with Punjab Glance (90.67 days). Punjab Glance took minimum agrometeorological indices i.e. GDD (940°C day), HTU (447528°C day hr), PTU (974856°C day hr) and ENT (6371°C) under October planting for initiation of anthesis.

Analysis of data revealed that all the varieties with delay in planting took more number of days for initiation of anthesis. Early plantings took less number of days and accumulated less agrometeorological indices for initiation of anthesis as compared to late

Table 4.8: Number of days and agrometeorological indices accumulated by gladiolus varieties for initiation of anthesis under different dates of planting

S. No.	Treatment	DAS	GDD (°C day)	HTU (°C day hr)	PTU (°C day hr)	ENT (°C)
Dates of planting (D)						
1	**D_1 (28 Sep.)**	101.20^{D}	1343^{B}	833976^{B}	1462488^{B}	11673^{B}
2	**D_2 (28 Oct.)**	106.87^{C}	1015^{D}	533904^{C}	1137768^{C}	6862^{D}
3	**D_3 (28 Nov.)**	116.70^{B}	1232^{C}	800832^{B}	1574232^{B}	9491^{C}
4	**D_4 (28 Dec.)**	121.23^{A}	1659^{A}	1246824^{A}	2335560^{A}	15251^{A}
	CD (5%)	2.98	51	61968	112920	578
Varieties (V)						
1	**V_1 (Punjab Glad 3)**	113.24^{B}	1335^{B}	877416^{B}	1675944^{B}	11037^{B}
2	**V_2 (Punjab Lemon Delight)**	106.69^{C}	1264^{C}	804072^{C}	1505424^{C}	10394^{C}
3	**V_3 (CPG)**	123.00^{A}	1486^{A}	1063392^{A}	2045784^{A}	12637^{A}
4	**V_4 (Punjab Glance)**	101.40^{D}	1165^{D}	683760^{D}	1285968^{D}	9357^{D}
5	**V_5 (White Prosperity)**	113.17^{B}	1311^{BC}	840792^{BC}	1624488^{BC}	10672^{BC}
	CD (5%)	3.66	61	69576	129960	621
D×V						
1	**D_1V_1**	105.57^{ij}	1376^{efg}	865680^{efg}	1553040^{def}	11926^{de}
2	**D_1V_2**	88.61^{k}	1261^{gh}	748512^{gh}	1204680^{hij}	11111^{ef}
3	**D_1V_3**	113.83^{defgh}	1419^{e}	909792^{ef}	1719096^{de}	12191^{de}
4	**D_1V_4**	90.67^{k}	1275^{fgh}	770952^{fgh}	1247544^{ghi}	11165^{e}
5	**D_1V_5**	107.33^{hi}	1385^{ef}	874968^{efg}	1588128^{def}	11971^{de}
6	**D_2V_1**	104.25^{ij}	982^{l}	501936^{j}	1066848^{ij}	6609^{h}
7	**D_2V_2**	103.75^{ij}	977^{l}	491592^{j}	1055112^{ij}	6587^{h}
8	**D_2V_3**	115.83^{defg}	1117^{ijk}	647184^{hi}	1360272^{fgh}	7607^{h}
9	**D_2V_4**	99.50^{j}	940^{l}	447528^{j}	974856^{j}	6371^{h}
10	**D_2V_5**	111.00^{fghi}	1058^{jkl}	581352^{ij}	1231776^{ghi}	7137^{h}
11	**D_3V_1**	119.39^{cde}	1271^{fgh}	820824^{efg}	1639008^{de}	9874^{fg}
12	**D_3V_2**	113.42^{efgh}	1172^{hij}	747720^{gh}	1463136^{efg}	8886^{g}
13	**D_3V_3**	129.33^{ab}	1466^{de}	1083120^{d}	2080104^{c}	11798^{de}
14	**D_3V_4**	105.03^{ij}	1024^{kl}	579744^{ij}	1145424^{hij}	7445^{h}
15	**D_3V_5**	116.33^{defg}	1226^{hi}	772776^{fgh}	1543512^{def}	9451^{g}
16	**D_4V_1**	123.75^{bc}	1710^{b}	1321248^{b}	2444856^{b}	15739^{b}
17	**D_4V_2**	121.00^{cd}	1646^{bc}	1228464^{bc}	2298768^{bc}	14991^{bc}
18	**D_4V_3**	133.00^{a}	1942^{a}	1613448^{a}	3023640^{a}	18951^{a}
19	**D_4V_4**	110.40^{ghi}	1421^{e}	936816^{e}	1776048^{d}	12447^{d}
20	**D_4V_5**	118.00^{cdef}	1575^{cd}	1134144^{cd}	2134488^{c}	14127^{c}
	CD (5%)	7.32	122	139152	259944	1244

plantings. This may be due to favourable environmental conditions prevailing during the development of plants of early plantings. Plants of late planting experienced high temperature during the month of April and May and hence they accumulated more agrometeorological indices but due to high temperature their growth and development was affected. Early plantings produced better growth and initiated early spike emergence which coincided with favourable environmental conditions leading to early initiation of anthesis (Pavani 2009). Similar results were obtained by Sheikh and John (2005) in gladiolus under Jammu and Kashmir conditions and Tirkey *et al* (2018) under Chhattisgarh Plains.

4.1.9 Half Anthesis (R3.4)

The number of days, GDD, HTU, PTU and ENT taken for half of anthesis differed significantly due to planting dates, varieties and their interactions (Table 4.9). Among the planting dates investigated, number of days taken for half anthesis were minimum for September planting (103.89 days) followed by October planting (109.71 days). Delay in half anthesis was observed in December planting (125.4 days). Minimum agrometeorological indices i.e., GDD (1049°C day), HTU (574056°C day hr), PTU (1210896°C day hr) and ENT (7096°C) were accumulated in October planting whereas maximum i.e. GDD (1752°C day), HTU (1372512°C day hr), PTU (2564040°C day hr) and ENT (16410°C) were accumulated in December planting.

The data on varieties showed that Punjab Glance took significantly least days (105.08 days), minimum GDD (1220°C day), HTU (744144°C day hr), PTU (1404240°C day hr) and ENT (9907°C) for half anthesis followed by Punjab Lemon Delight. Whereas, CPG took maximum number of days (126.96), GDD (1556°C day), HTU (1165824°C day hr), PTU (2230272°C day hr) and ENT (13385°C) for half anthesis.

The data related to interaction between planting dates and varieties showed that there was increase in number of days taken for half anthesis from September to December planting. CPG took maximum number of days i.e. 139 days for half anthesis under December planting whereas; the same variety took 116.83 days for half anthesis under September planting. Punjab Lemon Delight took minimum number of days (90.78 days) for half anthesis under September planting which was at par with Punjab Glance (92.69 days). Minimum agrometeorological indices i.e. GDD (960°C day), HTU (475512°C day hr), PTU (1019904°C day hr) and ENT (6469°C) were accumulated by Punjab Glance under October planting.

Varieties planted under early plantings had early spike emergence and initiation of anthesis thereby leading to earliness in half of anthesis too. The results are in conformity with Pavani (2009).

Table 4.9: Number of days and agrometeorological indices accumulated by gladiolus varieties for half anthesis under different dates of planting

S. No.	Treatment	DAS	GDD (°C day)	HTU (°C day hr)	PTU (°C day hr)	ENT (°C)
Dates of planting (D)						
1	**D_1 (28 Sep.)**	103.89^{D}	1360^{B}	857184^{B}	1519032^{C}	11765^{B}
2	**D_2 (28 Oct.)**	109.71^{C}	1049^{C}	574056^{C}	1210896^{D}	7096^{D}
3	**D_3 (28 Nov.)**	121.36^{B}	1316^{B}	900912^{B}	1753728^{B}	10348^{C}
4	**D_4 (28 Dec.)**	125.4^{A}	1752^{A}	1372512^{A}	2564040^{A}	16410^{A}
	CD (5%)	3.14	56	61968	131064	664
Varieties (V)						
1	**V_1 (Punjab Glad 3)**	117.32^{B}	1398^{B}	954240^{B}	1825200^{B}	11709^{B}
2	**V_2 (Punjab Lemon Delight)**	109.83^{C}	1312^{C}	864600^{C}	1613088^{C}	10866^{C}
3	**V_3 (CPG)**	126.96^{A}	1556^{A}	1165824^{A}	2230272^{A}	13385^{A}
4	**V_4 (Punjab Glance)**	105.08^{D}	1220^{D}	744144^{D}	1404240^{D}	9907^{D}
5	**V_5 (White Prosperity)**	116.28^{B}	1359^{BC}	902040^{BC}	1736832^{BC}	11156^{BC}
	CD (5%)	3.48	61	83472	139128	636
D×V						
1	**D_1V_1**	108.82^{hij}	1392^{fgh}	884688^{fg}	1618272^{fg}	12023^{ef}
2	**D_1V_2**	90.78^{k}	1275^{hij}	770952^{ghi}	1247544^{hij}	11165^{efg}
3	**D_1V_3**	116.83^{efg}	1444^{def}	948552^{ef}	1799496^{ef}	12339^{def}
4	**D_1V_4**	92.69^{k}	1284^{ghij}	783816^{ghi}	1277856^{hij}	11209^{efg}
5	**D_1V_5**	110.33^{ghi}	1403^{efg}	897888^{fg}	1652016^{fg}	12091^{ef}
6	**D_2V_1**	108.67^{hij}	1032^{lm}	554688^{jkl}	1175064^{ij}	6945^{jk}
7	**D_2V_2**	106.33^{ij}	1007^{lm}	528552^{kl}	1119912^{ij}	6767^{jk}
8	**D_2V_3**	118.67^{def}	1162^{jk}	704280^{hij}	1455696^{gh}	7966^{ij}
9	**D_2V_4**	101.89^{j}	960^{m}	475512^{l}	1019904j	6469^{k}
10	**D_2V_5**	113.00^{fghi}	1082^{kl}	607272^{jkl}	1283952^{hij}	7332^{ijk}
11	**D_3V_1**	124.89^{cd}	1381^{fgh}	967128^{ef}	1878624^{ef}	11031^{fg}
12	**D_3V_2**	118.19^{def}	1257^{ij}	840192^{fgh}	1636344^{fg}	9745^{h}
13	**D_3V_3**	133.33^{ab}	1536^{d}	1187544^{cd}	2250936^{cd}	12473^{de}
14	**D_3V_4**	110.28^{ghi}	1116^{kl}	663552^{ijk}	1318776^{hi}	8361^{i}
15	**D_3V_5**	120.11^{cde}	1292^{ghi}	846144^{fgh}	1683936^{fg}	10129^{gh}
16	**D_4V_1**	126.89^{bc}	1788^{b}	1410432^{b}	2628864^{b}	16839^{b}
17	**D_4V_2**	124.00^{cd}	1710^{bc}	1318704^{bc}	2448552^{bc}	15786^{bc}
18	**D_4V_3**	139.00^{a}	2082^{a}	1822896^{a}	3414960^{a}	20764^{a}
19	**D_4V_4**	115.47^{efgh}	1521^{de}	1053720^{de}	2000424^{de}	13589^{d}
20	**D_4V_5**	121.67^{cde}	1659^{c}	125664^{c}	2327472^{c}	15074^{c}
	CD (5%)	6.95	122	167400	278256	1273

4.1.10 Full Anthesis (R4)

The data in Table 4.10 reveals significant differences for full anthesis under different planting dates, varieties and their interactions. Among the dates of planting, September planting resulted in minimum number of days (107.72 days) taken for full anthesis followed by October planting which took 113.68 days. December planting took maximum number of days for full anthesis i.e. 129.21 days which was at par with November planting (126.45 days). December planting accumulated maximum agrometeorological indices whereas minimum were accumulated under October planting.

The data on varieties revealed that minimum number of days (109.75 days), GDD (1286°C day), HTU (825024°C day hr), PTU (1557024°C day hr) and ENT (10511°C) were taken by Punjab Glance whereas; CPG took maximum number of days (130.92 days), GDD (1624°C day), HTU (1262304°C day hr), PTU (2408160°C day hr) and ENT (14112°C). Punjab Glance was at par with Punjab Lemon Delight and White Prosperity was at par with Punjab Glad 3 for number of days taken for full anthesis.

The results pertaining to interaction between planting dates and varieties showed that days taken for full anthesis increased with delay in planting. All the varieties under December planting took more time for full anthesis with CPG showing maximum number of days i.e. 142.33 days. Punjab Lemon Delight took minimum number of days (93.17 days) for full anthesis which were at par with Punjab Glance (96.28 days). CPG accumulated maximum agrometeorological indices under December planting whereas Punjab Glance accumulated minimum agrometeorological indices under October planting.

Varieties planted under early plantings had early spike emergence, initiation of anthesis and half anthesis thereby leading to earliness in full anthesis too.

4.1.11 Spike Senescence Initiation (R3.5)

A significant difference in number of days, GDD, HTU and ENT taken for initiation of spike senescence was observed under different dates of planting (Table 4.11). The data reveals that all varieties took minimum days to start senescence under September planting (105.14 days). The planting done on October took 111.28 days to start senescence. However, the maximum time for starting of spike senescence was observed when planting was done on 28th December (126.71 days) which was at par with November planting. Minimum GDD, HTU, PTU and ENT were required to start anthesis in October planting i.e. 1065°C day, 591168°C day hr, 1244520°C day hr and 7211°C respectively. The maximum GDD (1782°C day), HTU (1409832°C day hr), PTU (2634720°C day hr) and ENT (16798°C) were required under December planting. Early start of spike senescence in early plantings may be due to earliness in all floral characters i.e. early initiation of spike emergence and anthesis.

A significant difference in number of days, GDD, HTU, PTU and ENT taken for starting of spike senescence was observed in different varieties. Among five varieties

Table 4.10: Number of days and agrometeorological indices accumulated by gladiolus varieties for full anthesis under different dates of planting

S. No.	Treatment	DAS	GDD (°C day)	HTU (°C day hr)	PTU (°C dayhr)	ENT (°C)
Dates of planting (D)						
1	**D_1 (28 Sep.)**	107.72^{C}	1382^{B}	884184^{C}	1600920^{C}	11907^{B}
2	**D_2 (28 Oct.)**	113.68^{B}	1097^{C}	630696^{D}	1316328^{D}	7470^{C}
3	**D_3 (28 Nov.)**	126.45^{A}	1413^{B}	1025784^{B}	1971936^{B}	11322^{B}
4	**D_4 (28 Dec.)**	129.21^{A}	1841^{A}	1492776^{A}	2785896^{A}	17527^{A}
	CD (5%)	3.34	61	80832	140256	774
Varieties (V)						
1	**V_1 (Punjab Glad 3)**	121.55^{B}	1465^{B}	1036560^{B}	1991232^{B}	12408^{B}
2	**V_2 (Punjab Lemon Delight)**	113.21^{C}	1368^{C}	933336^{C}	1743456^{C}	11478^{C}
3	**V_3 (CPG)**	130.92^{A}	1624^{A}	1262304^{A}	2408160^{A}	14112^{A}
4	**V_4 (Punjab Glance)**	109.75^{C}	1286^{D}	825024^{D}	1557024^{D}	10511^{D}
5	**V_5 (White Prosperity)**	120.89^{B}	1424^{BC}	984576^{BC}	1893984^{B}	11773^{BC}
	CD (5%)	3.49	63	69576	148488	650
D×V						
1	**D_1V_1**	112.31^{ghi}	1411^{ef}	903144^{ghij}	1690200^{ghi}	12142^{ghi}
2	**D_1V_2**	93.17^{j}	1286^{efg}	788160^{hijk}	1288704^{klm}	11217^{hij}
3	**D_1V_3**	120.17^{ef}	1469^{e}	977736^{fg}	1881600^{fg}	12522^{fg}
4	**D_1V_4**	96.28^{j}	1300^{fg}	804528^{hijk}	1342272^{klm}	11299^{ghij}
5	**D_1V_5**	116.67^{fg}	1445^{e}	947280^{fghi}	1800864^{fghi}	12354^{gh}
6	**D_2V_1**	112.33^{ghi}	1074^{ij}	598488^{lmn}	1265688^{lmn}	7260^{mn}
7	**D_2V_2**	109.42^{hi}	1036^{ij}	557904^{mn}	1182504^{mn}	6965^{n}
8	**D_2V_3**	122.67^{def}	1219^{gh}	780456^{ijk}	1582296^{hijk}	8443^{lm}
9	**D_2V_4**	105.67^{i}	1000^{j}	518880^{n}	1105584^{n}	6730^{n}
10	**D_2V_5**	118.33^{efg}	1158^{hi}	697704^{klm}	1445520^{jklm}	7950^{mn}
11	**D_3V_1**	130.14^{bc}	1472^{e}	1091184^{ef}	2094864^{ef}	11856^{ghij}
12	**D_3V_2**	122.83^{def}	1347^{efg}	955776^{fgh}	1833432^{fgh}	10681^{jk}
13	**D_3V_3**	138.50^{a}	1653^{d}	1359552^{cd}	2535360^{cd}	13738^{ef}
14	**D_3V_4**	116.22^{fgh}	1220^{gh}	764616^{jkl}	1530840^{ijkl}	9393^{kl}
15	**D_3V_5**	124.56^{bcde}	1374^{ef}	957720^{fgh}	1865184^{fgh}	10941^{ij}
16	**D_4V_1**	131.42^{b}	1901^{b}	1553376^{b}	2914128^{b}	18373^{b}
17	**D_4V_2**	127.44^{bcd}	1804^{bc}	1431480^{bc}	2669160^{bc}	17049^{c}
18	**D_4V_3**	142.33^{a}	2155^{a}	1931424^{a}	3632424^{a}	21747^{a}
19	**D_4V_4**	120.85^{def}	1624^{d}	1212072^{de}	2249376^{de}	14621^{de}
20	**D_4V_5**	124.00^{cde}	1718^{cd}	1335576^{cd}	2464368^{cd}	15847^{cd}
	CD (5%)	6.99	127	151080	297000	1301

Table 4.11: Number of days and agrometeorological indices accumulated by gladiolus varieties for initiation of spike senescence under different dates of planting

S. No.	Treatment	DAS	GDD (°C day)	HTU (°C day hr)	PTU (°C day hr)	ENT (°C)
Dates of planting (D)						
1	**D_1 (28 Sep.)**	105.14^{C}	$1,367^{B}$	864624^{C}	1543296^{C}	$11,810^{B}$
2	**D_2 (28 Oct.)**	111.28^{B}	$1,065^{C}$	591168^{D}	1244520^{D}	$7,211^{D}$
3	**D_3 (28 Nov.)**	123.31^{A}	$1,353^{B}$	947208^{B}	1833336^{B}	$10,699^{C}$
4	**D_4 (28 Dec.)**	126.71^{A}	$1,782^{A}$	1409832^{A}	2634720^{A}	$16,798^{A}$
	CD (5%)	3.92	64	77304	151320	713
Varieties (V)						
1	**V_1 (Punjab Glad 3)**	118.31^{B}	$1,414^{B}$	971208^{B}	1861920^{B}	$11,890^{B}$
2	**V_2 (Punjab Lemon Delight)**	111.63^{C}	$1,341^{C}$	900408^{C}	1680792^{C}	$11,178^{C}$
3	**V_3 (CPG)**	128.13^{A}	$1,573^{A}$	1190280^{A}	2268960^{A}	$13,531^{A}$
4	**V_4 (Punjab Glance)**	107.11^{D}	$1,244^{D}$	768216^{D}	1458288^{D}	$10,120^{D}$
5	**V_5 (White Prosperity)**	117.88^{B}	$1,386^{BC}$	935928^{BC}	1799832^{C}	$11,428^{BC}$
	CD (5%)	3.33	54	68520	127200	568
D×V						
1	**D_1V_1**	109^{jk}	$1,394^{fgh}$	882936^{ef}	1625664^{efg}	$12,041^{ef}$
2	**D_1V_2**	92.39^{l}	$1,282^{ijk}$	781152^{fg}	1271256^{hijk}	$11,195^{fg}$
3	**D_1V_3**	117.83^{efgh}	$1,451^{ef}$	954696^{de}	1818048^{de}	$12,398^{e}$
4	**D_1V_4**	94.81^{l}	$1,292^{hij}$	794592^{fg}	1311624^{hijk}	$11,246^{fg}$
5	**D_1V_5**	111.67^{hij}	$1,414^{fg}$	909792^{ef}	1689864^{efg}	$12,169^{ef}$
6	**D_2V_1**	109.92^{ijk}	$1,044^{mn}$	565248^{ij}	1199064^{ijk}	$7,026^{ij}$
7	**D_2V_2**	107.81^{jk}	$1,018^{mn}$	540480^{j}	1143552^{jk}	$6,842^{j}$
8	**D_2V_3**	120.50^{defg}	$1,185^{jkl}$	728736^{gh}	1503288^{fgh}	$8,159^{hi}$
9	**D_2V_4**	103.83^{k}	977^{n}	494760^{j}	1055592^{k}	$6,563^{j}$
10	**D_2V_5**	114.33^{ghij}	$1,100^{lm}$	626640^{hij}	1321128^{hij}	$7,463^{ij}$
11	**D_3V_1**	125.58^{cd}	$1,387^{fghi}$	976560^{de}	1892208^{de}	$11,081^{fg}$
12	**D_3V_2**	120.08^{defg}	$1,297^{ghij}$	888024^{ef}	1720584^{ef}	$10,127^{g}$
13	**D_3V_3**	135.33^{ab}	$1,584^{d}$	1264392^{c}	2367504^{c}	$12,931^{de}$
14	**D_3V_4**	113.36^{hij}	$1,170^{kl}$	709248^{ghi}	1423320^{ghi}	$8,906^{h}$
15	**D_3V_5**	122.17^{cdef}	$1,328^{ghi}$	897768^{ef}	1763040^{ef}	$10,449^{g}$
16	**D_4V_1**	128.72^{bc}	$1,830^{b}$	1460088^{b}	2730816^{b}	$17,412^{b}$
17	**D_4V_2**	126.22^{cd}	$1,769^{bc}$	1391928^{bc}	2587800^{bc}	$16,548^{bc}$
18	**D_4V_3**	138.83^{a}	$2,073^{a}$	1813344^{a}	3387024^{a}	$20,635^{a}$
19	**D_4V_4**	116.45^{fghi}	$1,538^{de}$	1074264^{d}	2042616^{d}	$13,763^{d}$
20	**D_4V_5**	123.33^{cde}	$1,702^{c}$	1309536^{c}	2425296^{c}	$15,632^{c}$
	CD (5%)	6.67	109	137040	254448	1136

evaluated, it was observed that spikes of Punjab Glance senescenced at the earliest of all the varieties and took 107.11 days followed by Punjab Lemon Delight which took 111.63 days. White Prosperity was at par with Punjab Glad 3. Maximum number of days for starting of spike senescence was taken by CPG (128.13 days). Punjab Glance took minimum GDD (1244°C day), HTU (768216°C day hr), PTU (1458288°C day hr) and ENT (10120°C) whereas CPG took maximum GDD (1573°C day), HTU (1190280°C day hr), PTU (2268960°C day hr) and ENT (13531°C) for starting of spike senescence. Varietal differences may be due to genetic makeup.

The data presented in Table 4.11 for interaction between planting dates and varieties and GDD, HTU, PTU, ENT requirement for starting of spike senescence varied significantly. Punjab Lemon Delight took minimum 92.39 days to start spike senescence which was at par with Punjab Glance under September planting (94.81 days). Punjab Glance took minimum agrometeorological indices to start spike senescence under October planting. Under September planting all the varieties took minimum days to start spike senescence as compared to other planting dates. CPG took maximum time (138.83 days), GDD (2073°C day), HTU (1813344°C day hr), PTU (3387024°C day hr) and ENT (20635°C) when planted under December planting.

The results of the study revealed that all the varieties took comparatively less time for initiation of spike senescence under early plantings while significant delay was noticed under late plantings which may be due to overall late development of all phenostages in late plantings.

4.1.12 Half Spike Senescence (R3.6)

Data presented in Table 4.12 shows that significant variation existed among planting dates as well as varieties in context to days taken for half spike senescence. The data revealed that minimum number of days for half spike senescence were recorded in September planting (108.43 days) followed by October planting (114.88 days). December planting took maximum number of days for half spike senescence i.e. 130.75 days which was at par with November planting (127.98 days). Accumulated agrometeorological indices were minimum under October planting whereas maximum accumulation of all agrometeorological indices were noted in December.

Amongst varieties evaluated, it was found that Punjab Glance was earliest and took 110.95 days for half spike senescence followed by Punjab Lemon Delight (115.28 days). The maximum time for half spike senescence was recorded in CPG (131.88 days). The difference among the varieties was attributed to the varietal variation (Kumari *et al* 2001). For half spike senescence, least agrometeorological parameters i.e. GDD (1301°C day), HTU (839040°C day hr), PTU (1588368°C day hr) and ENT (10647°C) were recorded in Punjab Glance under October planting whereas the highest GDD (1638°C day), HTU (1287528°C day hr), PTU

Table 4.12: Number of days and agrometeorological indices accumulated by gladiolus varieties for half spike senescence under different dates of planting

S. No.	Treatment	DAS	GDD (°C day)	HTU (°C day hr)	PTU (°C day hr)	ENT (°C)
Dates of planting (D)						
1	**D_1 (28 Sep.)**	108.43^{C}	$1,387^{B}$	891768^{C}	1614264^{C}	$11,927^{B}$
2	**D_2 (28 Oct.)**	114.88^{B}	$1,112^{C}$	644808^{D}	1346328^{D}	$7,577^{C}$
3	**D_3 (28 Nov.)**	127.98^{A}	$1,441^{B}$	1059120^{B}	2031048^{B}	$11,587^{B}$
4	**D_4 (28 Dec.)**	130.75^{A}	$1,879^{A}$	1542552^{A}	2880120^{A}	$18,055^{A}$
	CD (5%)	3.40	54	76488	130488	572
Varieties (V)						
1	**V_1 (Punjab Glad 3)**	122.49^{B}	$1,480^{B}$	1054776^{B}	2024424^{B}	$12,552^{B}$
2	**V_2 (Punjab Lemon Delight)**	115.28^{C}	$1,404^{C}$	974472^{C}	1825992^{C}	$11,876^{C}$
3	**V_3 (CPG)**	131.88^{A}	$1,638^{A}$	1287528^{A}	2445360^{A}	$14,243^{A}$
4	**V_4 (Punjab Glance)**	110.95^{D}	$1,301^{D}$	839040^{D}	1588368^{D}	$10,647^{D}$
5	**V_5 (White Prosperity)**	121.94^{B}	$1,450^{BC}$	1017000^{BC}	1955544^{BC}	$12,113^{BC}$
	CD (5%)	3.19	54	74088	130968	562
D×V						
1	**D_1V_1**	111.89^{jkl}	$1,409^{ef}$	898704^{ghi}	1682136^{ij}	$12,129^{fgh}$
2	**D_1V_2**	94.44^{m}	$1,291^{gh}$	792792^{ij}	1306512^{m}	$11,243^{gh}$
3	**D_1V_3**	122.00^{fgh}	$1,482^{e}$	1005024^{fg}	1924080^{ghi}	$12,572^{ef}$
4	**D_1V_4**	97.31^{m}	$1,310^{fgh}$	813216^{hij}	1365816^{klm}	$11,381^{gh}$
5	**D_1V_5**	116.50^{hijk}	$1,441^{e}$	949104^{gh}	1792752^{hij}	$12,308^{g}$
6	**D_2V_1**	115.00^{ijk}	$1,107^{jk}$	633288^{k}	1337592^{lm}	$7,534^{jk}$
7	**D_2V_2**	111.25^{kl}	$1,060^{jk}$	582456^{k}	1233984^{m}	$7,159^{k}$
8	**D_2V_3**	123.67^{efg}	$1,236^{hi}$	800472^{hij}	1615344^{jk}	$8,575^{ij}$
9	**D_2V_4**	107.50^{l}	$1,019^{k}$	538272^{k}	1144992^{m}	$6,858^{k}$
10	**D_2V_5**	117.00^{hijk}	$1,136^{ij}$	669504^{jk}	1399632^{klm}	$7,758^{jk}$
11	**D_3V_1**	131.17^{cd}	$1,492^{e}$	1118280^{ef}	2141256^{fg}	$12,053^{fgh}$
12	**D_3V_2**	125.22^{def}	$1,393^{efg}$	1005888^{fg}	1926240^{ghi}	$11,102^{h}$
13	**D_3V_3**	138.17^{ab}	$1,645^{d}$	1352448^{cd}	2516352^{de}	$13,655^{de}$
14	**D_3V_4**	118.06^{ghij}	$1,249^{h}$	793440^{ij}	1590672^{jkl}	$9,684^{i}$
15	**D_3V_5**	127.28^{cdef}	$1,424^{e}$	1025568^{fg}	1980744^{gh}	$11,440^{fgh}$
16	**D_4V_1**	131.92^{bc}	$1,910^{b}$	1568832^{b}	2936664^{b}	$18,494^{b}$
17	**D_4V_2**	130.22^{cde}	$1,872^{bc}$	1516752^{b}	2837280^{bc}	$18,002^{bc}$
18	**D_4V_3**	143.67^{a}	$2,188^{a}$	1992120^{a}	3725616^{a}	$22,171^{a}$
19	**D_4V_4**	120.93^{fghi}	$1,626^{d}$	1211232^{de}	2251968^{ef}	$14,664^{d}$
20	**D_4V_5**	127.00^{cdef}	$1,797^{c}$	1423824^{bc}	2649072^{cd}	$16,947^{c}$
	CD (5%)	6.38	108	148200	261984	1125

(2445360°C day hr) and ENT (14243°C) were recorded in CPG under December planting.

The results with respect to interaction effects between planting dates and varieties showed that number of days taken for half spike senescence increased with delay in planting time in all the varieties with December planting recording maximum time. Whereas, early plantings took less number of days for half spike senescence in all the varieties with September planting recording minimum time. CPG took maximum time (143.67 days), GDD (2188°C day), HTU (1992120°C day hr), PTU (3725616°C day hr) and ENT (22171°C) under December planting. Whereas, Punjab Glance under October planting accumulated minimum agrometeorological parameters i.e. GDD (1019°C day), HTU (538272°C day hr), PTU (1144992°C day hr) and ENT (6858°C).

Varieties planted under early plantings initiated early spike senescence, thereby leading to earliness in half spike senescence.

4.1.13 Full Spike Senescence (R5)

Data pertaining to full spike senescence is presented in Table 4.13. Spike senescence was significantly influenced by planting dates, varieties and their interactions. The data revealed that minimum time for full spike senescence was recorded in September planting (112.51 days). The planting done on 28th December took maximum time for full spike senescence (136.05 days). Maximum agrometeorological indices were accumulated in December planting whereas minimum were accumulated in October planting as plants of October planting experienced low temperature of November, December, January and February.

Amongst varieties evaluated, Punjab Glance took 115.62 days for full spike senescence which was at par with Punjab Lemon Delight (118.90 days). Maximum number of days for full spike senescence from planting was taken by CPG (135.50 days). Minimum agrometeorological indices i.e. GDD (1384°C day), HTU (935376°C day hr), PTU (1776480°C day hr) and ENT (11543°C) were accumulated by Punjab Glance whereas maximum GDD (1702°C day), HTU (1392216°C day hr), PTU (2624904°C day hr) and ENT (14940°C) were accumulated by CPG.

Interaction studies between planting dates and varieties showed that the number of days taken for full spike senescence increased with delay in planting time in all the varieties with December planting recording maximum time. Among all the varieties, the minimum days taken to full spike senescence was observed in Punjab Lemon Delight (97.22 days) under September planting which was at par with Punjab Glance (101.61 days) under same planting. Time taken for full spike senescence under all planting dates was more in CPG as compared to all other varieties evaluated. It took 125, 127.17, 141.50 and 148.33 days under September, October, November and December plantings, respectively. Accumulation of all agrometeorological indices i.e. GDD (2301°C day), HTU (2195064°C day hr), PTU

Table 4.13: Number of days and agrometeorological indices accumulated by gladiolus varieties for full spike senescence under different dates of planting

S. No.	Treatment	DAS	GDD (°C day)	HTU (°C day hr)	PTU (°C day hr)	ENT (°C)
Dates of planting (D)						
1	**D_1 (28 Sep.)**	112.51^{D}	$1,417^{C}$	$9,32,952^{C}$	$17,10,408^{C}$	$12,122^{B}$
2	**D_2 (28 Oct.)**	119.26^{C}	$1,170^{D}$	$7,17,456^{D}$	$14,73,216^{D}$	$8,039^{C}$
3	**D_3 (28 Nov.)**	132.15^{B}	$1,525^{B}$	$11,70,600^{B}$	$22,28,808^{B}$	$12,449^{B}$
4	**D_4 (28 Dec.)**	136.05^{A}	$2,006^{A}$	$17,23,056^{A}$	$32,21,712^{A}$	$19,743^{A}$
	CD (5%)	1.94	44	70,728	1,16,016	553
Varieties (V)						
1	**V_1 (Punjab Glad 3)**	127.52^{B}	$1,562^{B}$	1173312^{B}	2244096^{B}	$13,441^{B}$
2	**V_2 (Punjab Lemon Delight)**	118.90^{C}	$1,458^{C}$	1038192^{C}	1959000^{C}	$12,433^{C}$
3	**V_3 (CPG)**	135.50^{A}	$1,702^{A}$	1392216^{A}	2624904^{A}	$14,940^{A}$
4	**V_4 (Punjab Glance)**	115.62^{C}	$1,384^{D}$	935376^{D}	1776480^{D}	$11,543^{D}$
5	**V_5 (White Prosperity)**	127.42^{B}	$1,542^{B}$	1140984^{B}	2188200^{B}	$13,084^{BC}$
	CD (5%)	3.38	63	95640	166560	728
D×V						
1	**D_1V_1**	116.69^{ijk}	$1,443^{fg}$	942504^{hijk}	1792320^{ijkl}	$12,336^{fg}$
2	**D_1V_2**	97.22^{l}	$1,310^{h}$	811608^{klm}	1366104^{no}	$11,386^{gh}$
3	**D_1V_3**	125.00^{gh}	$1,501^{ef}$	1054872^{ghi}	1997400^{hij}	$12,625^{fg}$
4	**D_1V_4**	101.61^{l}	$1,347^{gh}$	839208^{jkl}	1464744^{mno}	$11,689^{fgh}$
5	**D_1V_5**	122.00^{hij}	$1,485^{ef}$	1016592^{ghij}	1931472^{hijk}	$12,574^{fg}$
6	**D_2V_1**	118.65^{ijk}	$1,152^{ij}$	685440^{lmn}	1434384^{mno}	$7,879^{ij}$
7	**D_2V_2**	114.61^{k}	$1,100^{j}$	626832^{mn}	1321512^{no}	$7,465^{j}$
8	**D_2V_3**	127.17^{efgh}	$1,285^{h}$	874800^{ijkl}	1729584^{jklm}	$8,968^{i}$
9	**D_2V_4**	111.89^{k}	$1,068^{j}$	591816^{n}	1251480^{o}	$7,221^{j}$
10	**D_2V_5**	124.00^{ghi}	$1,243^{hi}$	808440^{klm}	1629168^{klmn}	$8,660^{ij}$
11	**D_3V_1**	135.61^{bcd}	$1,584^{e}$	1264392^{ef}	2367504^{fg}	$12,931^{f}$
12	**D_3V_2**	130.97^{def}	$1,496^{ef}$	1132752^{fg}	2169576^{gh}	$12,188^{fgh}$
13	**D_3V_3**	141.50^{b}	$1,719^{d}$	1444104^{de}	2703552^{de}	$14,521^{e}$
14	**D_3V_4**	123.33^{ghi}	$1,358^{gh}$	930552^{hijk}	1823784^{ijk}	$10,812^{h}$
15	**D_3V_5**	129.33^{defg}	$1,466^{efg}$	1081176^{fgh}	2079600^{ghi}	$11,794^{fgh}$
16	**D_4V_1**	139.11^{bc}	$2,071^{b}$	1800912^{b}	3382200^{b}	$20,617^{b}$
17	**D_4V_2**	132.78^{cde}	$1,924^{c}$	1581576^{cd}	2978808^{cd}	$18,695^{c}$
18	**D_4V_3**	148.33^{a}	$2,301^{a}$	2195064^{a}	4069080^{a}	$23,646^{a}$
19	**D_4V_4**	125.67^{fgh}	$1,762^{d}$	1379952^{e}	2565888^{ef}	$16,448^{d}$
20	**D_4V_5**	134.33^{cd}	$1,972^{bc}$	1657752^{bc}	3112584^{bc}	$19,308^{bc}$
	CD (5%)	6.77	127	191280	333120	1457

(4069080°C day hr) and ENT (23646°C) was maximum in CPG under December planting. Whereas, Punjab Glance accumulated minimum GDD (1068°C day), HTU (591816°C day hr), PTU (1251480°C day hr), and ENT (7221°C) under October planting.

4.1.14 Plant Senescence (R6)

Data enumerated in Table 4.14 shows that days taken from planting to plant senescence differed significantly due to different planting dates and varieties. Among different planting dates, plant senescence occurred in 176.03 days under September planting followed by October planting (191.90 days). On the other hand, plant senescence was delayed during December planting (209.53 days), as plants experienced low temperature during early growth stages which influenced overall growth and development of plants. Maximum agrometeorological indices were accumulated under December planting whereas minimum were accumulated under September planting because September planting experienced low temperature during overall development as compared to December planting which experienced high temperature during later developmental stages. Punjab Glance took minimum number of days (184.52 days) and agrometeorological indices i.e. GDD (2732°C day), HTU (3311832°C day hr), PTU (6039336°C day hr) and ENT (28100°C) from planting to plant senescence. Whereas, CPG took maximum number of days (205.42 days) and agrometeorological indices i.e. GDD (3198°C day), HTU (4277568°C day hr), PTU (7885488°C day hr) and ENT (34387°C) from planting to plant senescence.

Data presented in Table 4.14 for interaction between planting dates and varieties reveals that days, GDD, HTU, PTU and ENT taken from planting to plant senescence varied significantly. Punjab Glance took minimum days (160.58 days) to reach plant senescence under September planting which was at par with Punjab Lemon Delight (161.72 days) whereas, CPG took maximum time i.e. 219 days under December planting. CPG accumulated maximum agrometeorological indices i.e. GDD (4134°C day), HTU (6033312°C day hr), PTU (11389200°C day hr) and ENT (52752°C) under December planting. Whereas, Punjab Glance and Punjab Lemon Delight were at par to each other in accumulating minimum agrometeorological indices under September planting.

The results of the study revealed that all the varieties took comparatively less time from planting to plant senescence under early plantings while significant delay was noticed under late plantings which may be due to overall late development of all phenostages in late plantings. Late planting experienced low temperature (19.7°C) during early developmental stages, so there growth was affected/reduced. But as temperature (32.7°C) and day length increased during later stages of development, plants accumulated more heat and light in less time and crop planted four months later took only 33 more days than early planted crop to reach plant senescence. Similar results were found by Qadir *et al* (2007) who reported sunflower hybrids planted during early part of the year, Feb-April, passed through lower

Table 4.14: Number of days and agrometeorological indices accumulated by gladiolus varieties for plant senescence under different dates of planting

S. No.	Treatment	DAS	GDD (°C day)	HTU (°C day hr)	PTU (°C day hr)	ENT (°C)
Dates of planting (D)						
1	**D_1 (28 Sep.)**	176.03^{D}	2217^{D}	2388432^{D}	4293336^{D}	18705^{D}
2	**D_2 (28 Oct.)**	191.90^{C}	2558^{C}	2972688^{C}	5537136^{C}	22791^{C}
3	**D_3 (28 Nov.)**	200.21^{B}	3127^{B}	4096152^{B}	7465536^{B}	33725^{B}
4	**D_4 (28 Dec.)**	209.53^{A}	3898^{A}	5548704^{A}	10237200^{A}	48900^{A}
	CD (5%)	6.51	155	348408	642696	2378
Varieties (V)						
1	**V_1 (Punjab Glad 3)**	196.64^{B}	$2,992^{B}$	3816840^{B}	7025328^{B}	$31,573^{B}$
2	**V_2 (Punjab Lemon Delight)**	189.27^{C}	$2,846^{C}$	3552912^{C}	6514152^{C}	$29,828^{C}$
3	**V_3 (CPG)**	205.42^{A}	$3,198^{A}$	4277568^{A}	7885488^{A}	$34,387^{A}$
4	**V_4 (Punjab Glance)**	184.52^{D}	$2,732^{D}$	3311832^{D}	6039336^{D}	$28,100^{D}$
5	**V_5 (White Prosperity)**	196.24^{B}	$2,983^{B}$	3798384^{B}	6952200^{B}	$31,263^{B}$
	CD (5%)	4.56	100	218664	402816	1434
D×V						
1	**D_1V_1**	180.50^{h}	$2,286^{h}$	2480544^{i}	4501512^{h}	$19,349^{h}$
2	**D_1V_2**	161.72^{i}	$1,956^{i}$	1906392^{j}	3404976^{i}	$16,079^{i}$
3	**D_1V_3**	193.50^{def}	$2,532^{fg}$	3040992^{efgh}	5399352^{fg}	$21,779^{gh}$
4	**D_1V_4**	160.58^{i}	$1,958^{i}$	1885440^{j}	3424632^{i}	$16,274^{i}$
5	**D_1V_5**	183.83^{gh}	$2,352^{gh}$	2628816^{hi}	4736208^{gh}	$20,045^{h}$
6	**D_2V_1**	191.52^{efg}	$2,547^{fg}$	2937792^{fghi}	5477736^{fg}	$22,657^{gh}$
7	**D_2V_2**	187.72^{fgh}	$2,455^{gh}$	2785224^{ghi}	5162280^{gh}	$21,383^{h}$
8	**D_2V_3**	198.50^{cde}	$2,716^{ef}$	3263376^{ef}	6111696^{f}	$24,905^{g}$
9	**D_2V_4**	184.78^{fgh}	$2,387^{gh}$	2666136^{hi}	4933224^{gh}	$20,456^{h}$
10	**D_2V_5**	197.00^{cde}	$2,688^{ef}$	3210936^{efg}	6000696^{f}	$24,556^{g}$
11	**D_3V_1**	204.17^{bc}	$3,219^{cd}$	4261080^{d}	7818600^{e}	$35,090^{e}$
12	**D_3V_2**	198.31^{cde}	$3,079^{d}$	3989112^{d}	7272168^{e}	$33,020^{e}$
13	**D_3V_3**	210.67^{ab}	$3,409^{c}$	4772544^{c}	8641656^{d}	$38,111^{d}$
14	**D_3V_4**	189.44^{efgh}	$2,844^{e}$	3470832^{e}	6319032^{f}	$29,384^{f}$
15	**D_3V_5**	198.44^{cde}	$3,083^{d}$	3987216^{d}	7276272^{e}	$33,020^{e}$
16	**D_4V_1**	210.36^{ab}	$3,915^{b}$	5587920^{b}	10303464^{b}	$49,197^{b}$
17	**D_4V_2**	209.33^{b}	$3,894^{b}$	5530944^{b}	10217160^{bc}	$48,831^{bc}$
18	**D_4V_3**	219.00^{a}	$4,134^{a}$	6033312^{a}	11389200^{a}	$52,752^{a}$
19	**D_4V_4**	203.27^{bcd}	$3,740^{b}$	5224896^{bc}	9480408^{cd}	$46,287^{c}$
20	**D_4V_5**	205.67^{bc}	$3,808^{b}$	5366496^{b}	9795672^{bc}	$47,433^{bc}$
	CD (5%)	9.11	200	437328	805608	2868

temperature during early phases and completed their life cycle taking longer period whereas, hybrids planted during the later part of the year, July-August, had higher temperature during the early phases and completed their life cycle rapidly.

4.1.15 Phyllochron Index (PI)

The relationship between development of leaf and phyllochrons after emergence (time interval between the appearance of successive leaves) in gladiolus varieties under different planting dates was worked out and is presented in Fig. 3. The X- axis showed the number of leaves. On Y-axis phyllochrons after emergence is plotted which represents the days between appearance of successive leaves.

The number of days taken for each leaf development by Punjab Glad 3, Punjab Lemon Delight, CPG, Punjab Glance and White Prosperity increased with delay in planting with September planting showing minimum and December planting showing maximum number of days. Maximum difference in phyllochron index due to planting date was observed in White Prosperity while minimum was observed in Punjab Lemon Delight. The seventh leaf in Punjab Glad 3 and fifth leaf in Punjab Glance and White Prosperity did not emerge out under October, November and December planting. Similarly, fifth leaf in Punjab Lemon Delight and CPG did not emerge out in crop for December planting. Early emergence of each leaf and higher number of leaves in early planting could be attributed to optimum time of planting that led to pronounced vegetative growth. The variation in number of leaves per plant among the varieties might be due to genotype influence on phenotypic expression of general vigour of plants (Nagar *et al* 2018).

4.2 Influence of date of planting on morpho-physiological parameters of different gladiolus varieties

a) Per cent sprouting (%)

A non-significant difference in per cent sprouting of corms was observed under different planting dates. Whereas, a significant difference was observed in per cent sprouting of corms due to varieties and interaction between planting dates and varieties (Table 4.15).

The corms of Punjab Glance recorded maximum sprouting per cent of corms (100%) followed by Punjab Glad 3 (95%) which was at par with Punjab Lemon Delight (93.33%). Minimum per cent sprouting of corms was observed in CPG (81.66%).

The data in respect to the interaction studies between planting dates and varieties showed that corm sprouting was 100% in Punjab Glance under all planting dates. Punjab Glad 3 showed 100% corm sprouting under September and November planting, Punjab Lemon Delight under November and December and White Prosperity under October and December planting. In CPG, maximum per cent sprouting i.e. 93.33% was observed under September planting and minimum corm sprouting (66.66%) under December planting.

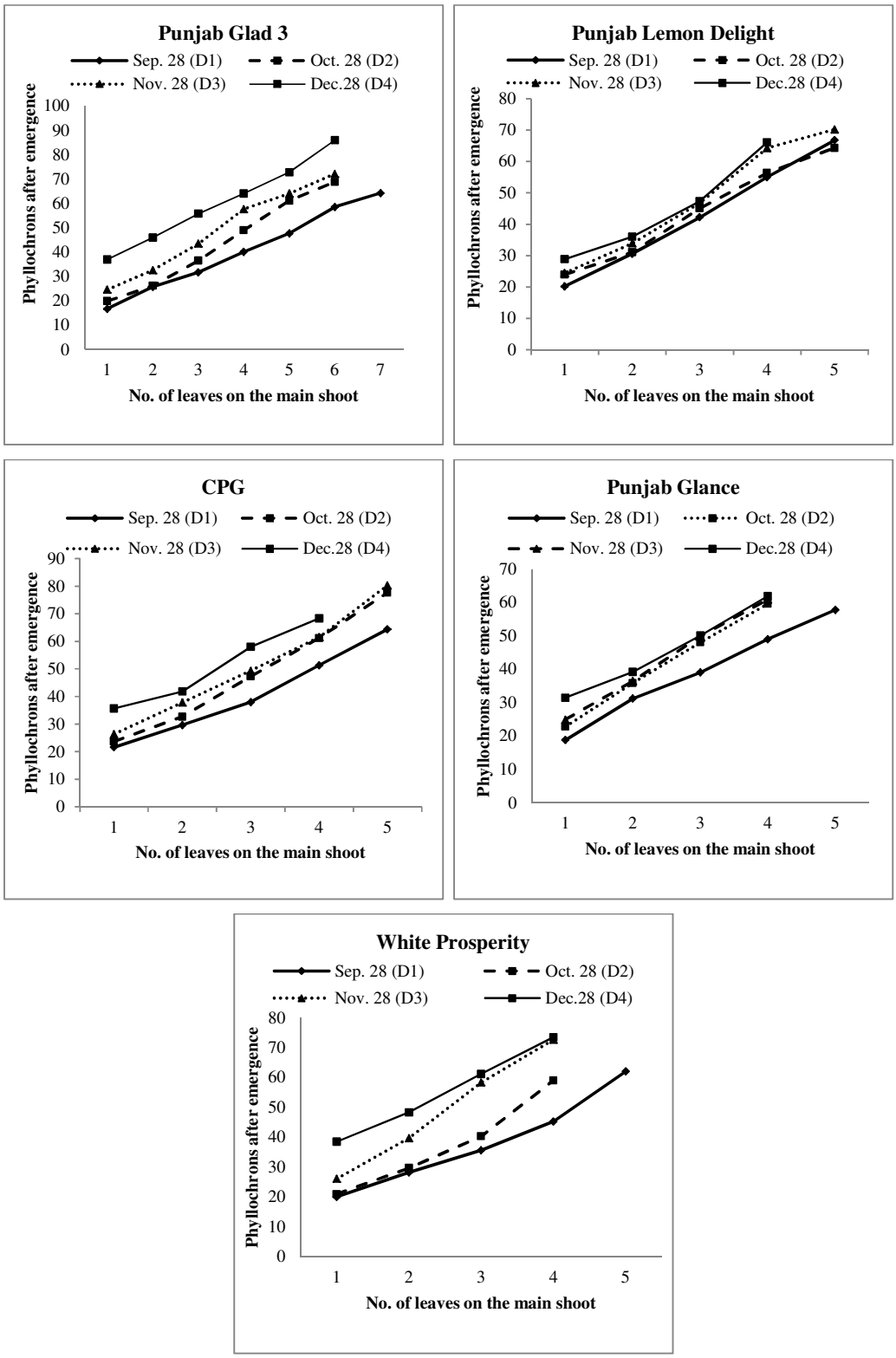

Fig 3. Relationship between development of leaf and phyllochron after emergence in gladiolus varieties under different dates of planting

Table 4.15: Influence of date of planting on per cent sprouting of corms of different varieties

Planting Date (D)	Varieties (V)					
	Punjab Glad 3	Punjab Lemon Delight	CPG	Punjab Glance	White Prosperity	Mean
D_1 (28 Sep.)	100.00^{a}	80.00^{bcd}	93.33^{ab}	100.00^{a}	73.33^{cd}	89.33^{A}
D_2 (28 Oct.)	86.66^{abc}	93.33^{ab}	80.00^{bcd}	100.00^{a}	100.00^{a}	92.00^{A}
D_3 (28 Nov.)	100.00^{a}	100.00^{a}	86.66^{abc}	100.00^{a}	86.66^{abc}	94.66^{A}
D_4 (28 Dec.)	93.33^{ab}	100.00^{a}	66.66^{d}	100.00^{a}	100.00^{a}	92.00^{A}
Mean	95.00^{AB}	93.33^{AB}	81.66^{C}	100.00^{A}	90.00^{B}	
C.D. (5%)	D = 11.91;		V = 7.59;		D × V = 15.18	

The results revealed that per cent corm sprouting was not affected by different planting dates and temperature but varied due to varieties. Kadam *et al* (2013) reported similar results in two gladiolus cultivars viz. Snow Princess and American Beauty grown under different temperature regimes. Under all temperature treatments, both the cultivars showed 100% sprouting of corms indicating that temperature did not affect the corms sprouting but the days required for sprouting reduced as temperature increased. This is in concomitant to our findings as depicted in Table 4.1: Number of days and agrometeorological indices accumulated by gladiolus varieties for sprouting of corms under different dates of planting.

b) Plant Height (cm)

Plant height was significantly influenced by planting dates, varieties and their interactions and is presented in the Table 4.16.

Data on dates of planting showed that plant height decreased with delay in planting. Maximum plant height i.e. 84.16 cm was recorded under September planting followed by October (82.69 cm). Minimum plant height i.e. 78.58 cm was recorded under December planting.

Among the varieties, the maximum plant height was recorded in Punjab Glad 3 (102.68 cm) followed by Punjab Glance (81.19 cm) and White Prosperity (77.24 cm). On the other hand, the shortest plants of 73.51 cm height were recorded in CPG.

The interaction between planting dates and varieties revealed that maximum plant height in all varieties was recorded under September planting. In the present study, maximum plant height of 106.07 cm was recorded in Punjab Glad 3 under September planting. The plants of Punjab Glad 3 were tallest and CPG were shortest under all planting dates.

Table 4.16: Influence of date of planting on plant height of different varieties

Planting Date (D)	Varieties (V)					
	Punjab Glad 3	**Punjab Lemon Delight**	**CPG**	**Punjab Glance**	**White Prosperity**	**Mean**
D_1 (28 Sep.)	106.07^{a}	76.19^{j}	75.02^{k}	84.03^{e}	79.54^{h}	84.168^{A}
D_2 (28 Oct.)	104.06^{b}	75.18^{k}	74.35^{l}	81.52^{f}	78.37^{i}	82.696^{B}
D_3 (28 Nov.)	101.72^{c}	73.85^{m}	73.68^{m}	80.85^{g}	76.53^{j}	81.326^{C}
D_4 (28 Dec.)	98.88^{d}	70.17^{o}	71.00^{n}	78.34^{i}	74.52^{l}	78.583^{D}
Mean	102.68^{A}	73.58^{D}	73.51^{E}	81.19^{B}	77.24^{C}	
C.D. (5%)	**D = 0.16;**			**V = 0.17;**		**D × V = 0.34**

The results revealed that comparatively shorter plants were recorded under late plantings as compared to early planting of September. Maximum plant height in September planting may be attributed to ideal temperature during plant growth which was neither too high nor too low. Variation in plant height under different dates of planting may be due to better root system and luxuriant growth which resulted large quantity of photosynthates under favourable condition (Nagar *et al* 2018). Muhammad *et al* (2013) observed strong correlation between plant height and temperature and reported maximum plant height under 10^{th} September planting in gladiolus under Peshawar conditions. This could be accounted as under low light intensities, auxins synthesised were less subjected to photo-oxidation and photo destruction leading to taller plants (Arteca 1997).

c) Number of leaves per plant

The data on number of leaves per plant as influenced by planting dates, varieties and their interactions are presented in Table 4.17.

The data revealed that number of leaves reduced with delay in planting. The plants of September (6.64) and October (6.30) planting had more number of leaves per plant as compared to November (5.96) and December (5.63) planting.

Among the varieties, maximum number of leaves per plant were produced by Punjab Glad 3 (7.45) followed by CPG (6.17) which was at par with Punjab Lemon Delight (6.12). Minimum number of leaves per plant were produced by Punjab Glance (5.44) which was at par with White Prosperity (5.49).

The data regarding the interaction effects revealed that Punjab Glad 3 under September planting produced highest number of leaves (8.02). Number of leaves per plant produced by CPG (6.62) was at par with Punjab Lemon Delight (6.55) under September planting. Punjab Glance (5.01) and White Prosperity (5.01) under December planting had least number of leaves.

Table 4.17: Influence of date of planting on number of leaves per plant of different varieties

Planting Date (D)	Varieties (V)					
	Punjab Glad 3	Punjab Lemon Delight	CPG	Punjab Glance	White Prosperity	Mean
D_1 (28 Sep.)	8.02^{a}	6.55^{d}	6.62^{d}	6.02^{fg}	6.02^{fg}	6.64^{A}
D_2 (28 Oct.)	7.52^{b}	6.33^{def}	6.42^{de}	5.52^{hi}	5.72^{gh}	6.30^{B}
D_3 (28 Nov.)	7.22^{bc}	6.02^{fg}	6.12^{ef}	5.21^{ij}	5.21^{ij}	5.96^{C}
D_4 (28 Dec.)	7.02^{c}	5.60^{h}	5.52^{hi}	5.01^{j}	5.01^{j}	5.63^{D}
Mean	7.45^{A}	6.12^{B}	6.17^{B}	5.44^{C}	5.49^{C}	
C.D. (5%)	D = 0.11;			V = 0.20;		D × V = 0.40

Higher number of leaves in early planting could be attributed to optimum time of planting that led to pronounced vegetative growth. The variation in number of leaves per plant among the varieties might be due to genotype influence on phenotypic expression of general vigour of plants (Nagar *et al* 2018).

d) Leaf area per plant ($cm^{2)}$

Data regarding leaf area per plant revealed significant differences for planting dates, varieties and their interactions (Table 4.18).

September planting recorded maximum leaf area (278.44 cm^2) followed by October (245.37 cm^2), November (223.10 cm^2) and December (199.00 cm^2).

Table 4.18: Influence of date of planting on leaf area per plant of different varieties

Planting Date (D)	Varieties (V)					
	Punjab Glad 3	Punjab Lemon Delight	CPG	Punjab Glance	White Prosperity	Mean
D_1 (28 Sep.)	446.74^{a}	239.18^{cdefg}	195.22^{efgh}	256.00^{c}	255.08^{cd}	278.44^{A}
D_2 (28 Oct.)	397.30^{a}	200.43^{cdefgh}	186.46^{fgh}	198.31^{efgh}	244.36^{cde}	245.37^{B}
D_3 (28 Nov.)	337.83^{b}	186.66^{fgh}	150.21^{hi}	199.13^{defgh}	241.68^{cdef}	223.10^{B}
D_4 (28 Dec.)	321.14^{b}	177.95^{hi}	121.51^{i}	184.22^{gh}	190.18^{efgh}	199.00^{C}
Mean	375.75^{A}	201.05^{C}	163.35^{D}	209.4^{BC}	232.83^{B}	
C.D. (5%)	D = 23.93;			V = 28.50;		D × V = 57.00

Among the varieties, significantly maximum leaf area was recorded in Punjab Glad 3 (375.75 cm^2) followed by White Prosperity (232.83 cm^2). Whereas, minimum leaf area was recorded in CPG i.e. 163.35 cm^2.

With regards to interaction effects between planting dates and varieties, it was observed that leaf area decreased with delay in planting from September to December in all the varieties. Punjab Glad 3 produced maximum leaf area under September planting (446.74 cm^2) which was at par with October planting (397.30 cm^2). CPG produced minimum leaf area (121.51 cm^2) under December planting which was at par with its November planting (150.21 cm^2) and December planting of Punjab Lemon Delight (177.95 cm^2).

The maximum leaf area in September planting may be due to the reason that in early plantings favourable temperatures might have promoted more uptake of nutrients in initial stages of plant growth thereby leading to maximum leaf area. Singh *et al* (2019) also recorded maximum leaf area under 15th October planting and minimum under 15th December in gladiolus cv. American Beauty. Similar decrease in leaf area of gladiolus varieties was obtained by Pavani (2009) by delay in planting from 15th September to 15th December.

e) Dry matter accumulation at spike initiation stage (g)

Dry matter accumulation at spike initiation stage was significantly influenced by planting dates, varieties and their interactions and is presented in the Table 4.19.

The data pertaining to dates of planting showed that dry matter accumulation at spike initiation decreased with delay in planting. Maximum dry matter (17.66 g) was accumulated by plants under September planting followed by October planting (11.22 g) and minimum dry matter i.e. 8.25 g was accumulated under December planting.

Table 4.19: Influence of date of planting on dry matter accumulation at spike initiation stage of different varieties

Planting Date (D)	Varieties (V)					
	Punjab Glad 3	**Punjab Lemon Delight**	**CPG**	**Punjab Glance**	**White Prosperity**	**Mean**
D_1 (28 Sep.)	21.29^{a}	18.09^{bc}	11.11^{ef}	18.81^{b}	19.00^{b}	17.66^{A}
D_2 (28 Oct.)	16.10^{c}	9.48^{fgh}	7.93^{hi}	10.74^{fg}	11.87^{de}	11.22^{B}
D_3 (28 Nov.)	13.49^{d}	8.41^{hi}	4.83^{j}	9.423^{fgh}	10.74^{efg}	9.37^{C}
D_4 (28 Dec.)	11.66^{de}	9.06^{fgh}	4.76^{j}	6.81^{ij}	8.96^{gh}	8.25^{D}
Mean	15.63^{A}	11.26^{C}	7.16^{D}	11.44^{C}	12.64^{B}	
C.D. (5%)	**D = 0.91;**		**V = 1.04;**		**D × V = 2.09**	

Among the varieties, the maximum dry matter accumulation at spike initiation was recorded in Punjab Glad 3 (15.63 g) followed by White Prosperity (12.64 g). The dry matter accumulated by Punjab Glance (11.44 g) was at par with Punjab Lemon Delight (11.26 g). On the other hand, minimum dry matter accumulation i.e. 7.16 g cm was recorded in CPG.

The interaction between planting dates and varieties revealed that maximum dry

matter accumulation at spike initiation stage i.e. 21.29 g was recorded in Punjab Glad 3 under September planting followed by 19 g in White Prosperity under same planting. Minimum dry matter accumulation at spike initiation stage was in CPG under November (4.83 g) and December (4.76 g) plantings.

Dry matter accumulation at full spike senescence stage (g)

Dry matter accumulation at full spike senescence stage was significantly influenced by planting dates, varieties and their interactions and is presented in the Table 4.20.

Table 4.20: Influence of date of planting on dry matter accumulation at full spike senescence stage of different varieties

Planting Date (D)	Varieties (V)					
	Punjab Glad 3	**Punjab Lemon Delight**	**CPG**	**Punjab Glance**	**White Prosperity**	**Mean**
D_1 (28 Sep.)	28.14^{a}	20.08^{cde}	14.66^{efgh}	22.21^{bcd}	27.85^{ab}	22.59^{A}
D_2 (28 Oct.)	25.27^{abc}	17.31^{defg}	8.98^{hi}	15.63^{efg}	19.30^{def}	17.30^{B}
D_3 (28 Nov.)	22.97^{abcd}	13.00^{gh}	8.63^{hi}	13.957^{efgh}	14.24^{efgh}	14.56^{B}
D_4 (28 Dec.)	13.30^{fgh}	12.92^{gh}	5.97^{i}	11.29^{ghi}	12.63^{gh}	11.22^{C}
Mean	22.42^{A}	15.83^{B}	9.56^{C}	15.77^{B}	18.50^{B}	
C.D. (5%)	**D = 3.12;**		**V = 2.96;**		**D × V = 5.93**	

The data pertaining to dates of planting showed that dry matter accumulation at full spike senescence stage decreased with delay in planting. Maximum dry matter accumulation of 22.59 g at full spike senescence stage was recorded under September planting followed by October planting (17.30g) which was at par with November planting (14.56 g). Minimum dry matter accumulation (11.22 g) at full spike senescence stage was recorded under December planting.

Among the varieties, the maximum dry matter accumulation was recorded in Punjab Glad 3 (22.42 g) followed by White Prosperity (18.50 g) which was at par with Punjab Lemon Delight (15.83 g) and Punjab Glance (15.77 g). On the other hand, minimum dry matter accumulation (9.56 g) was recorded in CPG.

The interaction between planting dates and varieties revealed that maximum dry matter accumulation i.e. 28.14 g was recorded in Punjab Glad 3 under September planting. Minimum dry matter accumulation was recorded in CPG under December planting (5.97 g). The plants of all varieties under September planting received optimum climatic conditions required for gladiolus growth resulting in maximum dry matter accumulation at both stages. The similar decrease in dry matter with delay in planting was observed by Pavani (2009) in gladiolus varieties planted under different planting dates from 15th September to 15th

December.

f) Spike Length (cm)

The data pertaining to spike length showed significant differences for planting dates, varieties and their interactions as depicted in Table 4.21.

The data on dates of planting showed that September planting produced longest spikes (75.82 cm) followed by October (73.56 cm), November (71.17 cm) and December planting (68.12 cm).

Among the varieties, significantly longer spikes were produced by Punjab Glad 3 (91.69 cm) followed by Punjab Glance (71.18 cm), Punjab Lemon Delight (67.58 cm) and White Prosperity (65.39 cm). CPG produced spikes with shortest spike length of 65.01 cm.

Table 4.21: Influence of date of planting on spike length of different varieties

Planting Date (D)	Varieties (V)					
	Punjab Glad 3	**Punjab Lemon Delight**	**CPG**	**Punjab Glance**	**White Prosperity**	**Mean**
D_1 (28 Sep.)	95.41^{a}	70.46^{g}	68.78^{i}	74.82^{e}	69.63^{h}	75.82^{A}
D_2 (28 Oct.)	93.51^{b}	69.12^{i}	65.26^{k}	73.15^{f}	66.77^{j}	73.56^{B}
D_3 (28 Nov.)	90.37^{c}	66.99^{j}	63.75^{m}	69.96^{h}	64.76^{l}	71.17^{C}
D_4 (28 Dec.)	87.47^{d}	63.75^{m}	62.24^{n}	66.77^{j}	60.40^{o}	68.12^{D}
Mean	91.69^{A}	67.58^{C}	65.01^{E}	71.18^{B}	65.39^{D}	
C.D. (5%)	**D = 0.13;**			**V = 0.19;**		**D × V = 0.38**

With regards to interaction effects between planting dates and varieties, spike length decreased with delay in planting time from September to December in all the varieties. Punjab Glad 3 produced longest spikes of 95.41 cm under September planting whereas White Prosperity produced shortest spikes of 60.40 cm under December planting.

The results of the study revealed that planting time significantly influenced the spike length. The spike length increased under September planting and decreased significantly under December planting. The results are in conformity with Thakur *et al* (2015) who reported maximum spike length in gladiolus under 10^{th} October planting and minimum spike length under 10^{th} December planting. The better spike length may be attributed to the prevalence of favorable environmental conditions at the time of early planting. The plant develops better root system and luxuriant growth by quantities of photosynthates under favourable environmental conditions whereas, in late planting plant establishment and growth is poor due to low temperature in December. Present study also showed a wide range of variation for spike length among the varieties. Such a wide variation for this character could also be accounted due to genetic nature (Singh *et al* 2000).

g) Number of florets per spike

Number of florets per spike was significantly influenced by planting dates, varieties and their interactions and is presented in the Table 4.22.

Table 4.22: Influence of date of planting on number of florets per spike of different varieties

Planting Date (D)	Varieties (V)					
	Punjab Glad 3	**Punjab Lemon Delight**	**CPG**	**Punjab Glance**	**White Prosperity**	**Mean**
D_1 (28 Sep.)	14.21^{a}	10.03^{e}	9.53^{f}	11.03^{d}	10.03^{e}	10.97^{A}
D_2 (28 Oct.)	12.87^{b}	9.03^{h}	9.23^{g}	10.03^{e}	8.53^{i}	9.94^{B}
D_3 (28 Nov.)	11.54^{c}	8.32^{j}	8.02^{k}	8.53^{i}	8.02^{k}	8.89^{C}
D_4 (28 Dec.)	10.03^{e}	7.22^{m}	6.52^{o}	7.52^{l}	7.02^{n}	7.66^{D}
Mean	12.16^{A}	8.65^{C}	8.32^{E}	9.28^{B}	8.40^{D}	
C.D. (5%)	**D = 0.10;**		**V = 0.05;**		**D × V = 0.10**	

Data on dates of planting showed that number of florets per spike decreased with delay in planting. Maximum number of florets per spike i.e. 10.97 was recorded in plants under September planting followed by October planting (9.94). Minimum number of florets per spike i.e. 7.66 was recorded under December planting.

Among the varieties, the maximum number of florets per spike was recorded in Punjab Glad 3 (12.16) followed by Punjab Glance (9.28) and Punjab Lemon Delight (8.65). On the other hand, minimum number of florets per spike i.e. 8.32 was recorded in CPG.

The interaction between planting dates and varieties revealed that maximum number of florets per spike i.e. 14.21 was recorded in Punjab Glad 3 under September planting followed by 12.87 and 11.54 under October and November plantings, respectively. Minimum number of florets per spike was recorded in CPG under December planting (6.52).

Maximum number of florets per spike under September and October plantings may be due to optimum conditions of light and temperature prevailing during the growth of plants. Whereas, there was less number of florets per spike in late planting which might be due to reduced plant height and spike length. The production of more number of florets per spike is a genetic character and is also influenced to a large extent by the environmental factors particularly light (Sivasamy and Dadlani 1999). The spike length and rachis length are the two main factors influencing number of florets per spike directly (Anuradha *et al* 2000). Thakur *et al* (2015) also recorded more number of florets per spike in gladiolus varieties which were taller and having longest spike under October and November plantings.

h) Floret Size (cm)

Data regarding floret size had shown significant differences for planting dates, varieties and their interactions (Table 4.23).

Table 4.23: Influence of date of planting on floret size of different varieties

Planting Date (D)	Varieties (V)					
	Punjab Glad 3	**Punjab Lemon Delight**	**CPG**	**Punjab Glance**	**White Prosperity**	**Mean**
D_1 (28 Sep.)	8.78^{a}	7.63^{i}	8.32^{e}	8.02^{g}	8.53^{c}	8.26^{A}
D_2 (28 Oct.)	8.61^{b}	7.60^{i}	8.02^{g}	7.52^{j}	8.02^{g}	7.95^{B}
D_3 (28 Nov.)	8.44^{d}	7.44^{k}	7.02^{n}	7.32^{m}	7.82^{h}	7.61^{C}
D_4 (28 Dec.)	8.15^{f}	7.39^{l}	6.02^{p}	6.92^{o}	7.52^{j}	7.20^{D}
Mean	8.49^{A}	7.52^{C}	7.34^{E}	7.45^{D}	7.97^{B}	
C.D. (5%)	**D = 0.02;**			**V = 0.01;**		**D × V = 0.02**

The data on dates of planting showed that September planting recorded maximum floret size (8.26 cm) followed by October planting (7.95 cm) while the minimum floret size i.e. 7.20 cm was recorded in December planting.

Among the varieties, significantly large sized florets were recorded in Punjab Glad 3 (8.49 cm) followed by White Prosperity (7.97 cm), Punjab Lemon Delight (7.52 cm), Punjab Glance (7.45 cm) and CPG (7.34cm).

With regards to interaction effects between planting dates and varieties, floret size decreased with delay in planting time from September to December in all the varieties. Punjab Glad 3 produced large sized florets i.e. 8.78 cm under September planting whereas CPG produced small sized florets i.e. 60.40 cm under December planting.

Favorable growing conditions with mild temperature, high relative humidity and low rate of evaporation prevailing during the crop period might have become favorable for bigger size of florets in September and October plantings. Bigger sized florets were recorded by Nagar *et al* (2018) in gladiolus under 10^{th} October planting. Thakur *et al* (2015) also reported decrease in floret size with delay in planting to December.

i) Weight of spike (g)

Weight of spike was significantly influenced by planting dates, varieties and their interactions and is presented in the Table 4.24.

Data on dates of planting showed that weight of spike decreased with delay in planting. Maximum weight of spike i.e. 34.71 g was recorded in plants under September planting followed by October planting (31.90 g). Minimum spike weight (25.88 g) was recorded in plants under December planting.

Table 4.24: Influence of date of planting on weight of spike of different varieties

Planting Date (D)	Varieties (V)					
	Punjab Glad 3	**Punjab Lemon Delight**	**CPG**	**Punjab Glance**	**White Prosperity**	**Mean**
D_1 (28 Sep.)	48.16^{a}	29.097^{i}	31.103^{g}	30.1^{h}	35.117^{e}	34.715^{A}
D_2 (28 Oct.)	44.147^{b}	28.093^{j}	27.09^{k}	28.093^{j}	32.107^{f}	31.906^{B}
D_3 (28 Nov.)	41.137^{c}	25.083^{m}	24.08^{n}	25.083^{m}	30.1^{h}	29.097^{C}
D_4 (28 Dec.)	38.127^{d}	23.077^{o}	20.067^{q}	22.073^{p}	26.087^{l}	25.886^{D}
Mean	42.89^{A}	26.33^{C}	25.58^{D}	26.33^{C}	30.85^{B}	
C.D. (5%)	**D = 0.49;**		**V = 0.39;**		**D × V = 0.79**	

Among the varieties, maximum spike weight was recorded in Punjab Glad 3 (42.89 g) followed by White Prosperity (30.85 g). Weight of spike of Punjab Lemon Delight (26.33 g) was at par with Punjab Glance (26.33 g). On the other hand, minimum spike weight i.e. 25.58 g was recorded in CPG.

The interaction between planting dates and varieties revealed that maximum spike weight of 48.16 g was recorded in Punjab Glad 3 under September planting followed by 44.14 g in same variety under October planting. Weight of spike of Punjab Lemon Delight was at par with weight of spike of Punjab Glance under October and November plantings. Minimum weight of spike was recorded in CPG under December planting i.e. 20.06 g.

The spike weight was maximum for Punjab Glad 3 under September planting and minimum for CPG under December planting. Plants of Punjab Glad 3 under September planting had maximum leaf area while the minimum leaf area was recorded by plants of CPG under December planting. More spike weight under early planting may be due to the reason that by the time spike was produced the plants have already completed their growth and development and the photosynthates produced in excess of their requirement were translocated to the sink which was developing spike. Results are in conformity with Pavani (2009) who reported more nutrient uptake in the early planting dates which helped in better translocation of material thereby resulting in more spike weight. Whereas, in late planting due to less photosynthetic activity, less translocation of food material was there, leading to less spike weight.

j) Number of corms per plant

The data on number of corms per plant as influenced by planting dates, varieties and their interactions are presented in Table 4.25.

Table 4.25: Influence of date of planting on number of corms per plant of different varieties

Planting Date (D)	Varieties (V)					
	Punjab Glad 3	Punjab Lemon Delight	CPG	Punjab Glance	White Prosperity	Mean
D_1 (28 Sep.)	1.33^{c}	1.50^{bc}	1.16^{c}	2.33^{a}	1.55^{bc}	1.57^{A}
D_2 (28 Oct.)	1.33^{c}	1.33^{c}	1.11^{c}	2.11^{ab}	1.44^{bc}	1.46^{AB}
D_3 (28 Nov.)	1.16^{c}	1.33^{c}	1.00^{c}	1.33^{c}	1.33^{c}	1.23^{BC}
D_4 (28 Dec.)	1.11^{c}	1.16^{c}	1.00^{c}	1.16^{c}	1.22^{c}	1.13^{C}
Mean	1.23^{B}	1.33^{B}	1.06^{B}	1.73^{A}	1.39^{AB}	
C.D. (5%)	D = 0.25;		V = 0.35;		D × V = 0.70	

The data pertaining to dates of planting revealed that September planting produced more number of corms per plant (1.57) as compared to December planting (1.13). The number of corms produced under October planting (1.46) is at par with number of corms produced per plant under November planting (1.23).

Among the varieties, maximum number of corms per plant were produced by Punjab Glance (1.73) followed by White Prosperity (1.39). The number of corms per plant produced by Punjab Lemon Delight was 1.33 which was at par with Punjab Glad 3 (1.23) and CPG (1.06).

The data regarding the interaction effects revealed that more number of corms per plant were produced by Punjab Glance under September planting. Punjab Glance produced maximum number of corms per plant irrespective of planting dates as compared to other varieties. Minimum number of corms per plant i.e. 1 corm per plant was produced by CPG under November and December planting. Number of corms per plant produced by all the varieties under November and December plantings were at par to each other.

Increment in corm production during early planting in the present study might be attributed by partitioning of more photosynthates towards the underground sinks caused by the low temperature. The results are in conformity with Sudhakar and Kumar (2014). Kumar *et al* (2017) also found that more number of daughter corms per plant were obtained from 20th October planting, whereas delay (5 November) in planting resulted in decrease in daughter corms per plant.

k) Number of cormels per plant

Data regarding number of cormels per plant had shown significant differences for planting dates, varieties and their interactions (Table 4.26).

Table 4.26: Influence of date of planting on number of cormels per plant of different varieties

Planting Date (D)	Varieties (V)					
	Punjab Glad 3	Punjab Lemon Delight	CPG	Punjab Glance	White Prosperity	Mean
D_1 (28 Sep.)	42.85^{b}	32.89^{e}	25.91^{h}	47.17^{a}	31.45^{f}	36.05^{A}
D_2 (28 Oct.)	37.87^{d}	25.91^{h}	19.93^{k}	39.86^{c}	24.91^{i}	29.70^{B}
D_3 (28 Nov.)	32.89^{e}	21.92^{j}	15.94^{m}	32.89^{e}	18.93^{l}	24.51^{C}
D_4 (28 Dec.)	24.91^{i}	19.93^{k}	9.96^{o}	26.91^{g}	14.95^{n}	19.33^{D}
Mean	34.63^{B}	25.16^{C}	17.94^{E}	36.71^{A}	22.56^{D}	
C.D. (5%)	**D = 0.36;**		**V = 0.17;**		**D × V = 0.34**	

The data on dates of planting showed that September planting recorded maximum number of cormels per plant (36.05) followed by October planting (29.70) while the minimum number of cormels per plant i.e. 19.33 was recorded in December planting.

Among the varieties, significantly highest number of cormels per plant were produced by Punjab Glance (36.71) followed by Punjab Glad 3 (34.63), Punjab Lemon Delight (25.16), White Prosperity (22.56) and CPG (17.94).

With regards to interaction effects between planting dates and varieties, number of cormels per plant decreased with delay in planting from September to December in all the varieties. Punjab Glance produced maximum number of cormels per plant i.e. 47.17 under September planting followed by Punjab Glad 3 (42.85) under same planting. Whereas, CPG produced minimum number of cormels per plant i.e. 9.96 under December planting.

According to Khanna and Gill (1983), cormel production in gladiolus is mainly dependent on varieties. Whereas, Banker and Mukhopadhyay (1980) reported that cormel production is highly affected by day length and temperature. Short days during and after flowering enhanced the cormel production while long days reduced it. Because under short day conditions underground parts become sink due to low temperature. In the present study, planting done on 28th September passed through short day conditions during and after flowering as compared to planting on 28th December that might be the reason for increased number of cormels per plant under September planting. Similar decrease in cormel production per plant with delay in planting was observed by Pavani (2009) in gladiolus varieties planted under different planting dates.

l) Corm weight (g)

Corm weight was significantly influenced by planting dates, varieties and their interactions and is presented in the Table 4.27.

Table 4.27: Influence of date of planting on corm weight of different varieties

Planting Date (D)	Varieties (V)					
	Punjab Glad 3	**Punjab Lemon Delight**	**CPG**	**Punjab Glance**	**White Prosperity**	**Mean**
D_1 (28 Sep.)	34.10^{b}	31.00^{e}	33.06^{c}	35.99^{a}	29.96^{f}	32.82^{A}
D_2 (28 Oct.)	31.00^{e}	28.93^{g}	31.00^{e}	33.06^{c}	28.93^{g}	30.58^{B}
D_3 (28 Nov.)	26.86^{h}	25.83^{i}	28.93^{g}	32.03^{d}	26.86^{h}	28.10^{C}
D_4 (28 Dec.)	26.00^{i}	22.73^{k}	25.83^{i}	28.93^{g}	24.80^{j}	25.66^{D}
Mean	29.49^{C}	27.12^{E}	29.70^{B}	32.50^{A}	27.64^{D}	
C.D. (5%)	**D = 0.62;**			**V = 0.18;**		**D × V = 0.37**

The corm weight decreased with delay in planting from September to December. Maximum corm weight i.e. 32.82 g was recorded in plants under September planting followed by October (30.58 g), November (28.10 g) and December (25.66 g).

Among the varieties, maximum corm weight was recorded in Punjab Glance (32.50 g) followed by CPG (29.70 g) and Punjab Glad 3 (29.49 g). On the other hand, minimum corm weight i.e. 27.12 g was recorded in Punjab Lemon Delight.

The data presented in Table for interaction between planting dates and varieties revealed that maximum corm weight in all the varieties was recorded under early planting. In the present study, maximum corm weight of 35.99 g was recorded in Punjab Glance under September planting followed by 34.1 g in Punjab Glad 3 under same planting. Minimum corm weight was recorded in Punjab Lemon Delight under December planting i.e. 22.73 g followed by White Prosperity (24.80 g) under same late planting.

In spite of better growth of aerial parts in Punjab Glad 3, the less weight of corms may be attributed to the environmental factors which favoured flower production at the expense of corm production due to utilization of available photosynthates. Similar results were found by Sivasamy and Dadlani (1999) in Peter Pears. CPG recorded less leaf area, spike length, number of florets per spike and more corm weight as compared to Punjab Glad 3 which might be due to more photosynthates partitioning to underground parts than to the floral parts. The lowest corm weight in late plantings might be due to prevalence of high temperatures after flowering. Roy (1988) noticed that the corm did not attain appreciable size due to high respiration rate under high temperatures. Ferdousi *et al* (2018) obtained maximum weight of corm per plant with planting done on 25th October, while comparatively less weight was recorded in 25th November planting in Sylhet region, Bangladesh.

m) Corm Diameter (cm)

Corm diameter was significantly influenced by planting dates, varieties and their

interactions and the data is presented in the Table 4.28.

The corm diameter decreased with delay in planting. Maximum corm diameter (4.75 cm) was recorded in plants under September planting followed by October planting (4.66 cm). Minimum corm diameter i.e. 3.50 cm was recorded in plants under December planting.

Table 4.28: Influence of date of planting on corm diameter of different varieties

Planting Date (D)	Varieties (V)					
	Punjab Glad 3	**Punjab Lemon Delight**	**CPG**	**Punjab Glance**	**White Prosperity**	**Mean**
D_1 (28 Sep.)	5.16^{a}	4.81^{d}	4.19^{g}	4.68^{e}	4.94^{bc}	4.75^{A}
D_2 (28 Oct.)	4.98^{b}	4.78^{d}	4.19^{g}	4.45^{f}	4.89^{c}	4.66^{B}
D_3 (28 Nov.)	4.92^{bc}	3.68^{i}	3.10^{l}	3.59^{j}	3.81^{h}	3.82^{C}
D_4 (28 Dec.)	3.72^{i}	3.59^{j}	2.97^{m}	3.46^{k}	3.76^{hi}	3.50^{D}
Mean	4.69^{A}	4.21^{C}	3.61^{E}	4.05^{D}	4.35^{B}	
C.D. (5%)	**D = 0.06;**		**V = 0.02;**			**D × V = 0.04**

Among the varieties, the maximum corm diameter was recorded in Punjab Glad 3 (4.69 cm) followed by White Prosperity (4.35 cm) and Punjab Lemon Delight (4.21 cm). On the other hand, minimum corm diameter i.e. 3.61 cm was recorded in CPG.

The interaction between planting dates and varieties revealed that maximum corm diameter i.e. 5.16 cm was recorded in Punjab Glad 3 under September planting followed by 4.98 cm in same variety under October planting. Minimum corm diameter was recorded in CPG under December planting (2.97 cm).

In all varieties, maximum corm diameter was observed in early plantings, which might be due to healthy plant production at that time which ultimately accumulated more photosynthates, in downward sink that led to increase in corm size (Kumar *et al* 2017).

4.3 Effect of dates of planting on vase life of different gladiolus varieties

a) Days to opening of basal floret

The number of days taken for the basal floret to open in vase for gladiolus varieties planted at different dates and their interaction is presented in Table 4.29.

Planting dates had significant influence on number of days taken for basal floret to open. September planting recorded minimum (1.27 days) number of days for basal floret to open in vase followed by October (1.68 days) and November (2..02 days) plantings. Spikes obtained from December planting took maximum (2.22 days) number of days for basal floret to open in vase.

Among the varieties evaluated significantly least number of days were recorded for White Prosperity (1.53 days) followed by CPG (1.58 days). Maximum number of days for the

parameter was recorded by Punjab Glad 3 (2.04 days).

Table 4.29: Influence of date of planting on days to opening of basal floret of different varieties

Planting Date (D)	Varieties (V)					
	Punjab Glad 3	**Punjab Lemon Delight**	**CPG**	**Punjab Glance**	**White Prosperity**	**Mean**
D_1 (28 Sep.)	1.60^{g}	1.03^{k}	1.03^{k}	1.40^{i}	1.30^{j}	1.27^{D}
D_2 (28 Oct.)	1.80^{e}	1.60^{g}	1.50^{h}	1.80^{e}	1.70^{f}	1.68^{C}
D_3 (28 Nov.)	2.23^{b}	2.00^{d}	1.80^{e}	2.10^{c}	2.00^{d}	2.02^{B}
D_4 (28 Dec.)	2.53^{a}	2.10^{c}	2.00^{d}	2.23^{b}	2.23^{b}	2.22^{A}
Mean	2.04^{A}	1.88^{B}	1.58^{D}	1.68^{C}	1.53^{E}	
C.D. (5%)	**D = 0.04;**			**V = 0.02;**		**D × V = 0.04**

The data of interaction between planting dates and varieties revealed that Punjab Lemon Delight and CPG under September planting took minimum (1.03 days) days for basal floret to open in vase whereas, Punjab Glad 3 under December planting took maximum (2.53 days) number of days for basal floret to open.

Delay in basal floret opening in vase with delay in planting may be due to comparatively high temperature during reproductive growth period of plants of late plantings. Uhlmann *et al* (2017) reported injuries due to low and high temperature on Gladiolus in PhenoGlad model, heat injury in PhenoGlad during reproductive phase warns user about burning of petals and sepals and risk that the florets on the spike do not open.

b) Size of fully expanded floret (cm)

Data regarding size of fully expanded floret had shown significant differences for planting dates, varieties and their interactions (Table 4.30).

The data on dates of planting showed that September planting recorded maximum size of fully expanded floret (7.84 cm) followed by 28th October (7.54 cm) and 28th November (6.93 cm) planting. Minimum size of fully expanded floret i.e. 6.50 cm was recorded in December planting.

Among the varieties, significantly large sized fully expanded floret was recorded in Punjab Glad 3 (7.85 cm) followed by White Prosperity (7.40 cm), Punjab Glance (7.05 cm) and Punjab Lemon Delight (6.90 cm). Whereas, small size of fully expanded floret was recorded in CPG i.e. 6.8 cm.

With regards to interaction effects between planting dates and varieties, Punjab Glad 3 recorded large size of fully expanded floret i.e. 8.50 cm under September planting whereas Punjab Glance recorded small size of fully expanded floret i.e. 6 cm under December

planting.

Table 4.30: Influence of date of planting on size of fully expanded floret of different varieties

Planting Date (D)	Varieties (V)					
	Punjab Glad 3	**Punjab Lemon Delight**	**CPG**	**Punjab Glance**	**White Prosperity**	**Mean**
D_1 (28 Sep.)	8.50^{a}	8.13^{b}	7.50^{f}	7.60^{e}	7.50^{f}	7.84^{A}
D_2 (28 Oct.)	8.06^{c}	7.80^{d}	7.33^{h}	7.40^{g}	7.10^{i}	7.54^{B}
D_3 (28 Nov.)	7.76^{d}	7.00^{j}	6.90^{k}	6.20^{o}	6.80^{l}	6.93^{C}
D_4 (28 Dec.)	7.10^{i}	6.70^{m}	6.50^{n}	6.00^{p}	6.20^{o}	6.50^{D}
Mean	7.85^{A}	6.90^{D}	6.80^{E}	7.05^{C}	7.40^{B}	
C.D. (5%)	**D = 0.02;**			**V = 0.02;**		**D × V = 0.05**

Favorable growing conditions prevailing during the crop period might have become responsible for bigger size of fully expanded floret in September and October plantings. Thakur *et al* (2015) also reported decrease in floret size with delay (10^{th} December) in planting.

c) Maximum florets open at one time

Maximum number of florets remained open at one time was significantly influenced by planting dates, varieties and their interaction (Table 4.31).

Table 4.31: Influence of date of planting on maximum florets open at one time of different varieties

Planting Date (D)	Varieties (V)					
	Punjab Glad 3	**Punjab Lemon Delight**	**CPG**	**Punjab Glance**	**White Prosperity**	**Mean**
D_1 (28 Sep.)	6.33^{a}	5.33^{bcd}	5.00^{cde}	5.66^{abc}	6.00^{ab}	5.66^{A}
D_2 (28 Oct.)	6.00^{ab}	5.00^{cde}	4.66^{def}	5.66^{abc}	5.66^{abc}	5.40^{AB}
D_3 (28 Nov.)	5.33^{bcd}	4.66^{def}	4.33^{ef}	5.00^{cde}	5.66^{abc}	5.00^{BC}
D_4 (28 Dec.)	5.33^{bcd}	4.33^{ef}	4.33^{ef}	5.00^{cde}	4.00^{f}	4.60^{C}
Mean	5.75^{A}	4.83^{B}	4.58^{B}	5.33^{A}	5.33^{A}	
C.D. (5%)	**D= 0.50;**			**V = 0.45;**		**D× V = 0.91**

Among the planting dates, September planting resulted in maximum number of florets opened at one time (5.66) followed by October (5.40) and November (5.00) planting. Minimum number of florets (4.60) opened at one time in December planting.

Punjab Glad 3 recorded significantly maximum number of florets opened at a time (5.75) which was at par with Punjab Glance and White Prosperity. Minimum number of florets opened at a time (4.58) was recorded in CPG which was at par with Punjab Lemon Delight (4.83).

In the interaction studies between planting dates and varieties, Punjab Glad 3 recorded significantly maximum number of florets opened at one time (6.33) under September planting. Punjab Glance and White Prosperity were at par with each other under October planting. White Prosperity recorded minimum number of florets opened at one time (4.00) under December planting.

Maximum number of florets remained open at one time in early plantings can be attributed to favorable environmental conditions that result in accumulation of more amount of carbohydrates during vegetative growth period. These carbohydrates might have resulted in maintenance of freshness of florets and thereby more number of opened florets. The results are in conformity with Namita (2005) who studied the effect of different chemical formulations on vase life of gladiolus cv. Jacksonville Gold and observed that Sucrose + $Al_2(SO_{4)3}$.$16H_2O$ resulted in maximum vase life and number of florets opened at one time. Sucrose provided energy and helped in maintenance of turgidity of florets.

d) Per cent floret opening

Data regarding per cent opening of florets had shown significant differences for planting dates, varieties and their interactions (Table 4.32).

Table 4.32: Influence of date of planting on percent floret opening of different varieties

Planting Date (D)	Varieties (V)					
	Punjab Glad 3	**Punjab Lemon Delight**	**CPG**	**Punjab Glance**	**White Prosperity**	**Mean**
D_1 (28 Sep.)	79.5^{a}	72.5^{abc}	69.267^{abcdef}	74.267^{ab}	69.8^{abcde}	73.067^{A}
D_2 (28 Oct.)	77.6^{a}	$68.333^{abcdefg}$	62.233^{cdefgh}	71.033^{abcd}	$63.433^{bcdefgh}$	68.527^{A}
D_3 (28 Nov.)	70.567^{abcde}	58.9^{efghi}	55.567^{hi}	59.733^{defghi}	57.5^{fghi}	60.453^{B}
D_4 (28 Dec.)	69.633^{abcde}	49.5^{i}	48.533^{i}	57.067^{ghi}	53.333^{hi}	55.613^{B}
Mean	74.32^{A}	62.30^{BC}	58.90^{C}	65.52^{B}	61.01^{BC}	
C.D. (5%)	**D = 4.92;**		**V = 6.00;**		**D × V = 12.00**	

The planting on 28th September recorded maximum per cent opening of florets (73.06%) which was at par with 28th October (68.52%) planting. Minimum per cent opening of florets i.e. 55.61 % was recorded in December planting which was at par with November (60.45%) planting.

Among the varieties significantly maximum per cent opening of florets was recorded

in Punjab Glad 3 (74.32%) followed by Punjab Glance (65.52%). Per cent opening of florets in Punjab Lemon Delight (62.30%) was at par with White Prosperity (61.01%). Minimum per cent opening of florets was recorded in CPG (58.90%).

With regards to interaction effects between planting dates and varieties, Punjab Glad 3 recorded maximum per cent opening of florets i.e. 79.50% under September planting which was at par with per cent opening of florets in same variety under October (77.6%) planting. Whereas, CPG recorded minimum (48.53%) per cent opening of florets which was at par with Punjab Lemon Delight (49.5%) under December planting.

Decrease in per cent opening of florets might be due to decrease in water absorption, reduction in accumulation of carbohydrates under late plantings and hence loss of turgidity. The results are in conformity with Namita (2005). The opening of florets on the spike is also genetically determined and considerable variations occur among the varieties (Bhattacharjee and De 2006).

e) Vase life

Data regarding vase life had shown significant differences for planting dates, varieties and their interactions (Table 4.33).

Table 4.33: Influence of date of planting on vase life of different varieties

Planting Date (D)	Varieties (V)					
	Punjab Glad 3	**Punjab Lemon Delight**	**CPG**	**Punjab Glance**	**White Prosperity**	**Mean**
D_1 (28 Sep.)	9.06^{a}	8.56^{d}	8.03^{f}	8.86^{b}	8.73^{c}	8.65^{A}
D_2 (28 Oct.)	8.56^{d}	8.03^{f}	7.36^{h}	8.36^{e}	8.03^{f}	8.07^{B}
D_3 (28 Nov.)	7.56^{g}	6.73^{j}	6.63^{k}	7.26^{h}	6.96^{i}	7.03^{C}
D_4 (28 Dec.)	7.06^{i}	6.33^{m}	6.03^{n}	6.53^{k}	6.43^{l}	6.48^{D}
Mean	8.06^{A}	7.41^{D}	7.01^{E}	7.75^{B}	7.54^{C}	
C.D. (5%)	**D = 0.13;**			**V = 0.02;**		**D × V = 0.05**

The data on dates of planting showed that 28th September planting recorded significantly maximum vase life (8.65 days) followed by 28th October (8.07 days) and 28th November (7.03 days) planting. Minimum vase life i.e. 6.48 days was recorded in December planting.

Among the varieties, significantly maximum vase life was recorded in Punjab Glad 3 (8.06 days) followed by Punjab Glance (7.75 days), White Prosperity (7.54 days) and Punjab Lemon Delight (7.41 days). Minimum vase life was recorded in CPG (7.01 days).

With regards to interaction effects between planting dates and varieties, Punjab Glad 3 recorded significantly maximum vase life i.e. 9.06 days under September planting whereas

CPG recorded minimum vase life (6.03 days) under December planting.

The spikes harvested from September planting recorded maximum vase life. In the plants of late plantings, the flower initiation and development were confronted with high temperature during April. A tremendous heat along with longer day periods caused a reduction in growth quality and vase life of gladiolus drastically (Pavani 2009). Temperature plays a crucial role in determining the vase life of flowers as it influences the metabolism of flowers regulating their senescence (Dhatt and Jhanji 2021). Low temperature lower the rate of cell metabolism thus, delays the respiration rate, ethylene action, pathogen attack and ultimately senescence (Faraji *et al* 2011). Variations in vase life among the varieties may be attributed to differential accumulation of carbohydrates due to varied leaf production (Pavani 2009).

f) Change in pH of the vase solution

Data regarding change in pH of vase solution had shown significant differences for planting dates, varieties and their interactions (Table 4.34).

Table 4.34: Influence of date of planting on change in pH of vase solution of different varieties

Planting Date (D)	Varieties (V)					
	Punjab Glad 3	**Punjab Lemon Delight**	**CPG**	**Punjab Glance**	**White Prosperity**	**Mean**
D_1 (28 Sep.)	0.100^{h}	0.306^{f}	0.406^{e}	0.203^{g}	0.306^{f}	0.264^{D}
D_2 (28 Oct.)	0.203^{g}	0.406^{e}	0.510^{d}	0.306^{f}	0.406^{e}	0.366^{C}
D_3 (28 Nov.)	0.306^{f}	0.510^{d}	0.710^{b}	0.510^{d}	0.610^{c}	0.529^{B}
D_4 (28 Dec.)	0.510^{d}	0.813^{a}	0.8133^{a}	0.710^{b}	0.710^{b}	0.711^{A}
Mean	0.280^{D}	0.509^{B}	0.610^{A}	0.432^{C}	0.508^{B}	
C.D. (5%)	**$D = 5.69 \times 10^{-3}$;**		**$V = 2.63 \times 10^{-3}$;**		**$D \times V = 5.26 \times 10^{-3}$**	

The data on dates of planting showed that 28th December planting recorded maximum change in pH (0.71) whereas minimum change in pH i.e. 0.26 was recorded in September planting.

Among the varieties significantly maximum change in pH was recorded in CPG (0.61). Punjab Lemon Delight and White Prosperity were at par to each other for change in pH. Minimum change in pH was recorded in Punjab Glad 3 (0.28).

With regards to interaction effects between planting dates and varieties, Punjab Glad 3 recorded minimum change in pH i.e. 0.1 under September planting whereas CPG recorded maximum change in pH (0.81) under December planting.

Change in pH increases (acidic to basic) whereas water absorbed per spike decreases

with delay in planting. Spikes of September planting absorbed maximum amount of water and there was minimum change in pH of distilled water which may be due to less bacterial growth. Bacterial growth in vase solutions can lead to stem vasculature blockage causing petal and leaf wilt, bent neck or similar water stress related symptoms that reduces vase life (Carlson 2014). Acidic pH prevented and slowed down bacterial growth, ensured proper water uptake and delayed senescence (Hussen and Yassin 2013).

g) Water absorbed per spike (ml)

Water absorbed by spikes of gladiolus varieties planted at different dates and their interaction is presented in Table 4.35.

Table 4.35: Influence of date of planting on water absorbed per spike of different varieties

Planting Date (D)	Varieties (V)					
	Punjab Glad 3	**Punjab Lemon Delight**	**CPG**	**Punjab Glance**	**White Prosperity**	**Mean**
D_1 (28 Sep.)	79.50^{a}	72.50^{abc}	69.26^{abcdef}	74.26^{ab}	69.80^{abcde}	73.06^{A}
D_2 (28 Oct.)	77.60^{a}	$68.33^{abcdefg}$	62.23^{cdefgh}	71.03^{abcd}	$63.43^{bcdefgh}$	68.52^{A}
D_3 (28 Nov.)	70.56^{abcde}	58.90^{efghi}	55.56^{hi}	59.73^{defghi}	57.50^{fghi}	60.45^{B}
D_4 (28 Dec.)	69.63^{abcde}	49.50^{i}	48.53^{i}	57.06^{ghi}	53.33^{hi}	55.61^{B}
Mean	74.32^{A}	62.30^{BC}	58.90^{C}	65.52^{B}	61.01^{BC}	
C.D. (5%)	**D = 4.92;**		**V = 6.00;**		**D× V = 12.00**	

Planting dates had significant influence on absorption of water by spikes of gladiolus. September planting recorded maximum water uptake (73.06 ml) which was at par with October (68.52 ml) planting. Spikes obtained from December planting absorbed minimum water per spike (55.61 ml) and it was at par with November planting (60.45 ml).

Among the varieties evaluated, Punjab Glad 3 absorbed maximum water per spike (74.32 ml) followed by Punjab Glance (65.52 ml). Punjab Lemon Delight and White Prosperity were at par with each other for the parameter. CPG absorbed minimum i.e. 58.90 ml of water per spike.

The data on interaction between planting dates and varieties revealed that Punjab Glad 3 under September planting absorbed significantly maximum water per spike (79.50 ml) whereas, CPG under December planting absorbed minimum water per spike (48.53 ml) which was at par with Punjab Lemon Delight (49.5 ml) under same planting.

Maximum water absorbed per spike in early plantings might be due to increased floret opening. Increased floret opening could be attributed to accumulation of more amount of carbohydrates during vegetative growth period due to favorable environmental conditions.

Kaur (2013) also observed that increased water absorption by gladiolus spikes treated with sugars was due to increased floret opening which required considerable amount of water for their growth. Yamanda *et al* (2007) suggested that sugar accumulation in the cells reduced petal water potential and promoted water uptake.

h) Physiological loss in weight (%)

Physiological loss in weight was significantly influenced by planting dates, varieties and their interaction (Table 4.36).

Table 4.36: Influence of date of planting on physiological loss in weight of different varieties

Planting Date (D)	Varieties (V)					
	Punjab Glad 3	**Punjab Lemon Delight**	**CPG**	**Punjab Glance**	**White Prosperity**	**Mean**
D_1 (28 Sep.)	26.73^{n}	35.63^{j}	36.63^{i}	31.70^{l}	34.66^{k}	33.07^{D}
D_2 (28 Oct.)	29.70^{m}	37.60^{h}	38.63^{f}	35.03^{k}	38.20^{g}	35.83^{C}
D_3 (28 Nov.)	34.66^{k}	40.56^{d}	42.06^{bc}	38.63^{fg}	39.90^{e}	39.16^{B}
D_4 (28 Dec.)	38.63^{fg}	42.56^{b}	44.56^{a}	40.56^{d}	41.96^{c}	41.66^{A}
Mean	32.43^{E}	39.09^{B}	40.47^{A}	36.48^{D}	38.68^{C}	
C.D. (5%)	**D = 0.42;**		**V = 0.15;**		**D × V = 0.30**	

Among the four planting dates, December planting resulted in maximum (41.66%) loss in physiological weight followed by November (39.16%) and October (35.83%) planting. Minimum loss in physiological weight (33.07%) was recorded in September planting.. Data regarding effect of varieties showed that CPG recorded significantly maximum (40.47%) loss in physiological weight whereas minimum loss in physiological weight (32.43%) was recorded in Punjab Glad 3.

In the interaction studies between planting dates and varieties, Punjab Glad 3 recorded minimum loss in physiological weight (26.73%) under September planting. CPG recorded maximum loss in physiological weight (44.56%) under December planting.

Physiological loss in weight increased with delay in planting which might be due to decreased or retarded growth because in the plants of late plantings, high temperature along with longer day periods caused a reduction in growth quality and vase life of gladiolus. Spikes produced by late plantings are of low quality as compared to early plantings.

4.4 Schwab's developmental staging system for Gladiolus

Schwab's model for gladiolus varieties Punjab Glad 3, Punjab Lemon Delight, CPG, Punjab Glance and White Prosperity are presented in Table 4.37, 4.38, 4.39, 4.40 and 4.41 respectively. In this model each developmental phase is further divided into developmental

stages and days, GDD, HTU, PTU and ENT accumulated under four planting dates for each developmental stage were calculated.

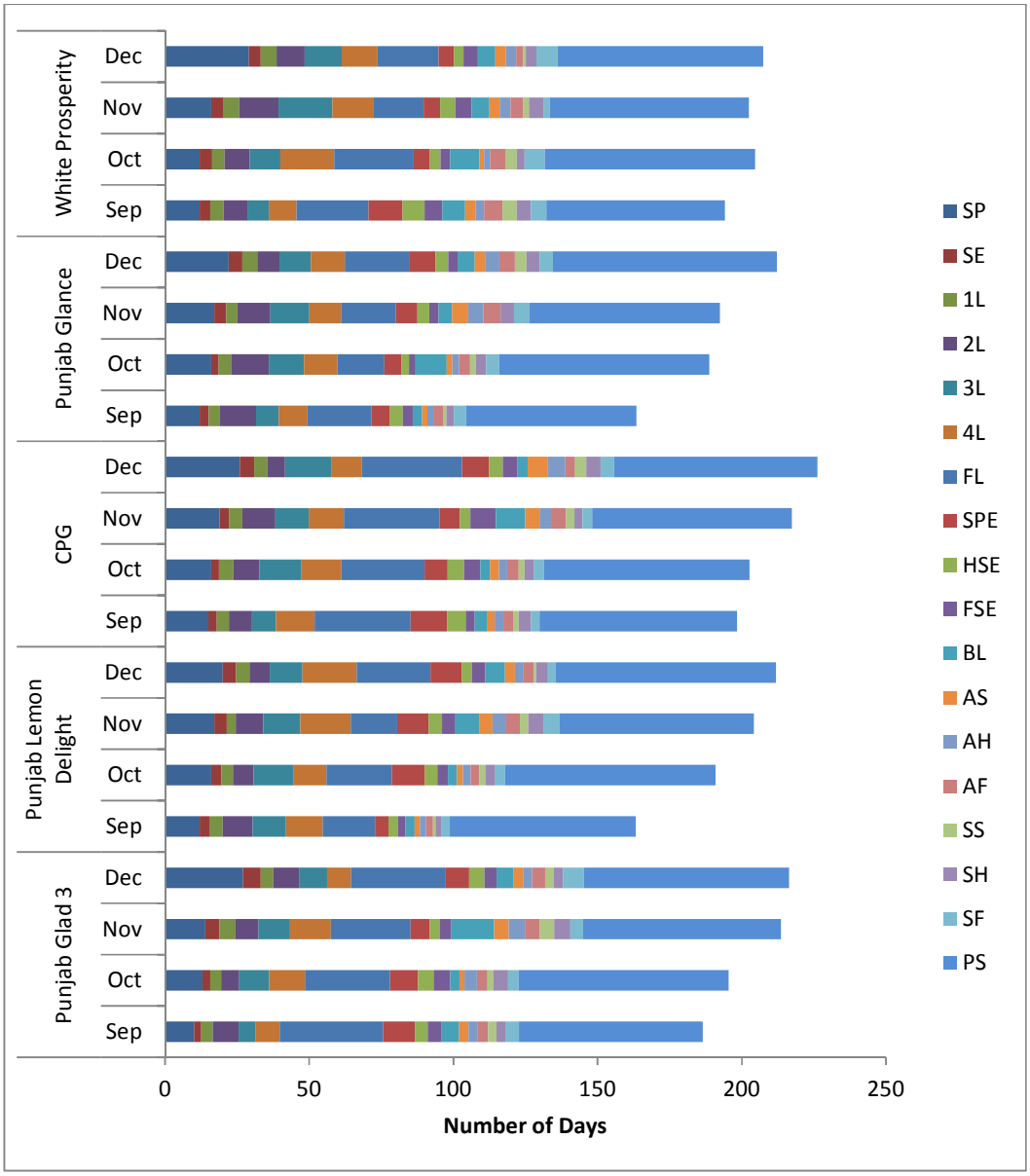

Fig 4. Graphical presentation of Gladiolus varieties phenology under different dates of planting

Table 4.37: Developmental staging system for Punjab Glad 3

	Days				GDD				HTU				PTU				ENT			
	Sep	**Oct**	**Nov**	**Dec**	**Sep**	**Oct**	**Nov**	**Dec**	**Sep**	**Oct**	**Nov**	**Dec**	**Sep**	**Oct**	**Nov**	**Dec**	**Sep**	**Oct**	**Nov**	**Dec**
S1	10.28	13.44	14.17	26.58	216.87	199.18	172.90	171.42	21663	17085	15249	8682	26248	29326	25043	46979	2625	1440	1245	1211
Vegetative phase																				
VE	12.87	16.19	18.94	32.78	273.37	235.90	205.40	215.75	33715	23454	20645	19207	41115	41216	39262	73214	3278	1695	1500	1423
V1	16.77	19.89	24.61	37.03	350.03	285.32	231.53	247.23	54554	30013	32273	29185	67908	60630	57750	94358	4119	2083	1607	1552
V2	25.78	26.23	32.61	46.00	527.28	350.72	277.93	337.63	122264	53747	49227	60998	156840	98052	91822	163166	5831	2508	1802	2131
V3	31.78	36.53	43.50	55.83	628.42	468.99	363.05	454.03	168252	102588	68612	108417	229092	182012	160462	269072	6690	3321	2477	3024
V4	40.11	49.03	57.72	64.08	753.72	593.26	448.98	577.63	244773	164979	100560	182224	343700	305095	263839	397342	7597	4272	3019	4015
V5	47.75	61.12	64.08	72.83	825.00	676.00	494.00	707.00	309044	234865	133276	266911	436603	430229	325092	550552	8288	4685	3212	5224
V6	58.58	68.87	72.19	86.03	974.00	710.00	566.00	951.00	408607	256757	184712	427391	627937	502432	421338	900454	9147	4888	3638	7670
V7	64.25	-	-	-	1042.00	-	-	-	482218	-	-	-	736433	-	-	-	9614	-	-	-
VF	75.92	78.43	85.33	97.03	1182.01	786.58	717.85	1146.77	617251	292952	288857	629672	972713	637585	640503	1239108	10668	5515	4741	9561
Reproductive phase																				
R1.0	87.14	88.22	91.89	105.00	1250.88	851.81	814.92	1308.83	731022	344384	376039	816935	1172783	779786	787118	1552572	11069	5903	5540	11160
R1.1	91.33	93.58	95.31	110.36	1277.14	890.13	864.70	1419.23	773766	385387	427024	942043	1253615	864686	867787	1774961	11174	6102	5932	12409
R1.2	96.08	99.25	99.47	114.61	1298.64	936.23	928.70	1506.80	803228	442614	494692	1041070	1336415	966298	978046	1969769	11291	6326	6442	13403
R2	102.22	102.56	114.28	120.47	1355.26	967.38	1187.52	1618.03	843920	481592	728199	1200531	1482112	1033754	1458601	2234282	11769	6517	9076	14574
R3	105.57	104.25	119.39	123.75	1376.79	982.24	1271.03	1710.20	865685	501943	820826	1321250	1553062	1066858	1639015	2444875	11926	6609	9874	15740
R3.4	108.82	108.67	124.89	126.89	1392.36	1032.66	1381.58	1788.63	884706	554707	967148	1410449	1618278	1175074	1878625	2628872	12024	6945	11032	16839
R4	112.31	112.33	130.14	131.42	1411.93	1074.36	1472.23	1901.63	903162	598505	1091204	1553377	1690221	1265703	2094873	2914135	12142	7260	11856	18374
R3.5	109.00	109.92	125.58	128.72	1394.26	1043.99	1387.23	1829.78	882943	565242	976552	1460092	1625655	1199058	1892196	2730810	12041	7026	11081	17412
R3.6	111.89	115.00	131.17	131.92	1409.33	1107.26	1491.57	1910.40	898699	633286	1118287	1568833	1682126	1337602	2141255	2936665	12129	7534	12053	18494
R5	116.69	118.65	135.61	139.11	1442.73	1151.56	1583.73	2071.28	942516	685442	1264396	1800920	1792316	1434386	2367496	3382190	12336	7879	12931	20617
R6	180.50	191.52	204.17	210.36	2285.73	2546.86	3219.47	3915.02	2480554	2937803	4261077	5587916	4501508	5477744	7818602	10303474	19349	22657	35090	49197

Table 4.38: Developmental staging system for Punjab Lemon Delight

	Days				GDD				HTU				PTU				ENT			
	Sep	**Oct**	**Nov**	**Dec**	**Sep**	**Oct**	**Nov**	**Dec**	**Sep**	**Oct**	**Nov**	**Dec**	**Sep**	**Oct**	**Nov**	**Dec**	**Sep**	**Oct**	**Nov**	**Dec**
S1	12.28	16.42	16.83	19.67	259.23	240.67	180.97	125.38	30978	23359	18576	4114	37756	43586	31931	25654	3110	1748	1291	913
Vegetative phase																				
VE	15.72	19.97	21.22	24.33	328.63	272.87	216.07	155.85	49099	34202	24984	6983	60670	61443	46552	39102	3881	1982	1554	1098
V1	20.22	23.94	24.44	28.89	422.15	326.69	231.53	188.28	80672	45923	32273	10630	101000	86417	57750	55696	4845	2361	1607	1329
V2	30.61	31.06	33.89	36.06	604.82	401.29	283.57	237.43	159284	73915	51382	26709	213634	133567	97291	87993	6476	2866	1830	1493
V3	42.22	45.06	46.81	47.33	773.92	575.33	377.27	348.90	257466	152312	74633	65107	376160	270862	180156	173196	7745	4135	2548	2211
V4	55.00	56.39	64.28	66.11	936.35	642.69	501.93	611.08	390683	206206	136305	206063	586981	376652	334160	448097	8868	4548	3309	4415
V5	66.78	64.33	70.25	-	1065.00	686.00	549.00	-	509137	244863	169331	-	774574	457505	396751	-	9751	4738	3542	-
V6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
V7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
VF	73.11	79.11	80.33	91.67	1152.94	794.13	657.30	1056.02	588271	304422	246024	538031	917635	654988	550019	1082704	10443	5535	4255	8685
Reproductive phase																				
R1.0	77.72	90.53	91.22	102.56	1197.18	869.11	818.48	1260.07	632658	358745	392871	762191	1009604	816824	805108	1463545	10790	6013	5635	10723
R1.1	81.00	94.83	95.89	106.11	1218.94	902.19	887.15	1332.20	665209	398456	455511	835252	1072885	889820	924133	1605132	10949	6169	6230	11490
R1.2	83.61	98.56	100.50	110.67	1229.78	926.36	959.58	1417.70	689133	433689	520453	947150	1111675	946709	1053669	1785737	10993	6269	6942	12349
R2	86.78	101.64	108.75	117.56	1247.74	958.99	1103.97	1573.33	725767	468942	664404	1129235	1165929	1014453	1328443	2121386	11055	6472	8323	14175
R3	88.61	103.75	113.42	121.00	1261.88	977.29	1172.67	1646.13	748520	491593	747741	1228482	1204687	1055113	1463155	2298786	11111	6588	8887	14991
R3.4	90.78	106.33	118.19	124.00	1275.31	1007.03	1257.12	1710.68	770972	528574	840198	1318714	1247547	1119926	1636354	2448563	11165	6767	9746	15787
R4	93.17	109.42	122.83	127.44	1286.28	1036.03	1347.22	1804.60	788177	557923	955781	1431483	1288718	1182518	1833434	2669176	11218	6966	10682	17049
R3.5	92.39	107.81	120.08	126.22	1281.74	1017.79	1297.30	1768.77	781158	540469	888036	1391925	1271252	1143547	1720587	2587795	11195	6842	10127	16548
R3.6	94.44	111.25	125.22	130.22	1290.84	1059.74	1392.68	1871.77	792788	582454	1005885	1516744	1306507	1233995	1926235	2837274	11243	7159	11102	18002
R5	97.22	114.61	130.97	132.78	1309.88	1099.76	1496.02	1924.47	811610	626833	1132743	1581582	1366096	1321500	2169567	2978816	11386	7465	12188	18695
R6	161.72	187.72	198.31	209.33	1956.06	2454.66	3079.38	3894.28	1906388	2785222	3989112	5530948	3404964	5162269	7272160	10217173	16079	21383	33020	48831

Table 4.39: Developmental staging system for CPG

	Days				GDD				HTU				PTU				ENT			
	Sep	**Oct**	**Nov**	**Dec**	**Sep**	**Oct**	**Nov**	**Dec**	**Sep**	**Oct**	**Nov**	**Dec**	**Sep**	**Oct**	**Nov**	**Dec**	**Sep**	**Oct**	**Nov**	**Dec**
S1	14.50	16.00	18.50	26.17	308.67	235.07	201.50	168.08	42826	22764	21381	8408	52954	42018	38102	45465	3672	1695	1462	1182
Vegetative phase																				
VE	17.50	18.67	21.67	31.00	371.20	270.83	219.23	204.62	60299	29350	26417	15445	75583	56158	48146	65761	4354	1981	1560	1389
V1	21.67	23.67	26.33	35.67	454.18	323.92	246.17	237.43	92038	46034	37491	26709	114606	83571	66339	87993	5160	2308	1665	1493
V2	29.67	32.67	37.83	41.83	595.08	425.59	313.28	294.97	153112	83230	58055	44899	204596	150048	120839	128933	6410	3020	2057	1868
V3	38.00	47.33	49.33	58.00	721.63	593.66	392.52	486.00	226891	163388	78481	123999	319482	296196	197015	300093	7359	4267	2661	3277
V4	51.33	61.17	61.50	68.33	896.52	671.73	474.85	645.83	355880	231484	118206	227499	526490	428223	297927	476563	8592	4669	3135	4618
V5	64.33	77.67	80.33	-	1042.00	783.00	652.00	-	482218	292021	243028	-	736433	626361	542777	-	9614	5493	4209	-
V6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
V7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
VF	84.67	90.00	94.67	103.17	1233.84	866.71	853.80	1264.93	709856	352919	416344	762275	1137457	811121	850467	1466608	10915	6016	5827	10695
Reproductive phase																				
R1.0	97.33	98.00	101.67	112.50	1321.06	930.61	972.00	1468.37	814692	436674	530184	997452	1383950	953876	1050286	1880844	11501	6321	6926	12990
R1.1	103.83	103.67	105.33	117.33	1361.34	983.43	1038.70	1558.70	854244	497686	589791	1109002	1513352	1068870	1167413	2091232	11793	6639	7634	13961
R1.2	106.83	109.33	114.33	122.33	1382.23	1039.49	1191.85	1667.18	869125	560860	735165	1269018	1578566	1190057	1471920	2346028	11963	6992	9122	15171
R2	111.33	112.67	124.33	126.00	1407.19	1079.74	1371.82	1762.53	898548	604464	965048	1381463	1674730	1278047	1866226	2566359	12114	7315	10837	16458
R3	113.83	115.83	129.33	133.00	1419.86	1117.64	1466.47	1942.65	909809	647198	1083132	1613467	1719106	1360278	2080112	3023639	12192	7607	11798	18951
R3.4	116.83	118.67	133.33	139.00	1444.66	1162.86	1536.13	2082.40	948564	704293	1187563	1822901	1799506	1455702	2250943	3414970	12339	7966	12473	20764
R4	120.17	122.67	138.50	142.33	1469.86	1219.44	1653.03	2155.63	977737	780478	1359573	1931441	1882560	1582310	2535373	3632438	12522	8444	13738	21747
R3.5	117.83	120.50	135.33	138.83	1451.33	1184.59	1583.73	2073.47	954689	728729	1264396	1813350	1818045	1503296	2367496	3387034	12398	8159	12931	20635
R3.6	122.00	123.67	138.17	143.67	1481.89	1235.81	1645.43	2187.70	1005033	800484	1352436	1992126	1924082	1615354	2516350	3725612	12572	8575	13655	22171
R5	125.00	127.17	141.50	148.33	1501.43	1285.33	1719.27	2301.32	1054864	874805	1444100	2195063	1997397	1729573	2703548	4069069	12625	8968	14521	23646
R6	193.50	198.50	210.67	219.00	2531.98	2715.59	3409.47	4133.85	3040994	3263383	4772544	6033299	5399350	6111689	8641651	11389212	21779	24905	38111	52752

Table 4.40: Developmental staging system for Punjab Glance

	Days				GDD				HTU				PTU				ENT			
	Sep	**Oct**	**Nov**	**Dec**	**Sep**	**Oct**	**Nov**	**Dec**	**Sep**	**Oct**	**Nov**	**Dec**	**Sep**	**Oct**	**Nov**	**Dec**	**Sep**	**Oct**	**Nov**	**Dec**
S1	11.67	15.89	16.89	21.50	245.20	230.83	195.63	132.62	28494	21951	18350	4219	34738	41196	33369	29039	2948	1679	1427	965
Vegetative phase																				
VE	14.78	18.47	21.04	26.25	314.60	261.00	212.80	168.88	45915	28172	23123	8618	56684	52265	44210	45252	3720	1889	1543	1185
V1	18.78	22.78	24.93	31.50	388.32	314.42	232.23	206.87	69677	42439	32463	16361	86614	78214	57667	67528	4488	2254	1614	1394
V2	31.25	35.89	36.47	39.22	617.92	462.66	295.67	271.40	164119	98332	54551	34983	221345	178921	108478	110229	6609	3313	1901	1736
V3	39.06	48.04	49.89	50.08	733.62	600.36	398.92	384.28	231656	164792	81638	78918	325747	301193	204838	204931	7456	4334	2703	2485
V4	49.06	59.62	60.94	61.94	864.25	665.49	472.47	541.42	322277	226007	114751	161295	479285	412480	294577	361589	8380	4639	3143	3720
V5	57.81	-	-	-	962.00	-	-	-	403492	-	-	-	610196	-	-	-	9044	-	-	-
V6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
V7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
VF	71.28	75.92	80.00	84.09	1131.14	774.28	655.70	911.08	570611	287390	249320	401865	882330	609199	550265	837388	10266	5426	4272	7251
Reproductive phase																				
R1.0	77.75	81.83	87.44	93.20	1203.31	807.98	751.07	1078.20	640351	307675	321601	555182	1018513	685872	691234	1115576	10836	5638	5017	8919
R1.1	82.14	84.50	91.44	97.69	1221.11	824.41	807.22	1157.95	668992	320643	371748	643905	1083025	722812	778543	1259955	10958	5740	5449	9652
R1.2	85.61	86.83	94.72	100.98	1240.71	841.78	854.07	1221.17	713130	332029	417454	707752	1146790	758428	852256	1379837	11031	5852	5835	10289
R2	88.86	97.56	99.47	106.89	1264.08	922.58	927.87	1343.80	752315	427065	490478	860885	1211060	936722	975378	1621060	11120	6263	6495	11518
R3	90.67	99.50	105.03	110.40	1275.31	940.41	1024.25	1421.60	770972	447534	579767	936834	1247547	974873	1145429	1776052	11165	6371	7445	12448
R3.4	92.69	101.89	110.28	115.47	1284.18	960.34	1116.18	1521.63	783835	475533	663556	1053741	1277866	1019922	1318794	2000428	11210	6469	8361	13589
R4	96.28	105.67	116.22	120.84	1300.08	1000.39	1220.62	1624.18	804548	518890	764640	1212081	1342286	1105601	1530849	2249386	11299	6730	9394	14622
R3.5	94.81	103.83	113.36	116.44	1291.61	976.86	1170.12	1538.37	794584	494753	709239	1074259	1311626	1055584	1423326	2042619	11246	6563	8906	13763
R3.6	97.31	107.50	118.06	120.93	1309.68	1018.81	1249.42	1625.70	813204	538276	793451	1211221	1365825	1145000	1590677	2251959	11381	6858	9684	14664
R5	101.61	111.89	123.33	125.67	1347.21	1067.61	1357.62	1762.03	839218	591804	930544	1379951	1464740	1251477	1823774	2565885	11689	7221	10812	16448
R6	160.58	184.78	189.44	203.27	1958.28	2386.93	2843.88	3739.62	1885440	2666141	3470840	5224888	3424641	4933234	6319041	9480407	16274	20455	29384	46287

Table 4.41: Developmental staging system for White Prosperity

	Days				GDD				HTU				PTU				ENT			
	Sep	**Oct**	**Nov**	**Dec**	**Sep**	**Oct**	**Nov**	**Dec**	**Sep**	**Oct**	**Nov**	**Dec**	**Sep**	**Oct**	**Nov**	**Dec**	**Sep**	**Oct**	**Nov**	**Dec**
S1	11.67	12.33	16.33	28.83	252.17	185.07	187.80	187.78	29542	14811	18571	11654	35999	25095	32037	55874	3027	1341	1346	1302
Vegetative phase																				
VE	15.33	16.67	20.67	33.00	329.57	245.35	216.40	215.90	48653	24051	25262	19243	60079	45092	46138	73316	3901	1781	1549	1422
V1	20.00	21.00	26.11	38.50	422.68	300.98	245.13	263.47	80306	34678	36283	33647	100161	68371	66003	105431	4854	2203	1666	1671
V2	28.22	29.67	39.67	48.33	568.28	389.99	334.10	359.73	139956	70207	62408	69110	183993	125236	136493	182139	6196	2758	2241	2286
V3	35.67	40.33	58.33	61.17	689.62	519.96	454.90	533.98	203581	125875	109719	152217	281528	223986	275508	348702	7143	3711	3014	3674
V4	45.28	59.00	72.67	73.50	824.37	661.56	575.33	732.27	287994	220130	190717	282601	419877	410259	435090	583043	8099	4630	3682	5491
V5	62.00	-	-	-	1020.00	-	-	-	455013	-	-	-	699856	-	-	-	9490	-	-	-
V6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
V7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
VF	70.22	86.50	90.00	94.67	1118.61	838.51	789.37	1105.90	556650	336639	356352	591167	860409	754834	750390	1168406	10173	5808	5313	9130
Reproductive phase																				
R1.0	82.00	92.17	95.67	100.00	1225.41	880.93	875.32	1207.73	677847	375211	437297	694411	1091181	843792	888303	1354763	10970	6057	6040	10141
R1.1	89.61	95.83	101.00	103.33	1267.51	908.74	960.55	1273.53	757449	408597	519438	771549	1223042	905850	1033399	1482826	11137	6187	6809	10805
R1.2	95.89	99.17	106.67	108.33	1298.98	936.16	1061.22	1382.90	802585	443265	610278	895462	1336814	966584	1210730	1700863	11293	6329	7850	12009
R2	103.67	109.33	112.83	114.33	1358.31	1039.96	1163.18	1507.53	851719	561741	708371	1038104	1505373	1190967	1413768	1969345	11770	7003	8832	13423
R3	107.33	111.00	116.33	118.00	1385.39	1058.69	1226.83	1575.87	874969	581362	772777	1134150	1588142	1231789	1543534	2134492	11972	7138	9452	14128
R3.4	110.33	113.00	120.11	121.67	1403.39	1082.78	1292.67	1659.00	897908	607286	846162	1256817	1652016	1283958	1683958	2327476	12091	7332	10130	15074
R4	116.67	118.33	124.56	124.00	1445.29	1158.06	1374.73	1718.90	947296	697710	957739	1335585	1800865	1445524	1865186	2464387	12355	7950	10942	15848
R3.5	111.67	114.33	122.17	123.33	1414.19	1099.63	1328.15	1701.80	909789	626631	897769	1309529	1689852	1321138	1763029	2425295	12169	7463	10449	15632
R3.6	116.50	117.00	127.28	127.00	1441.09	1136.21	1424.45	1797.30	949100	669509	1025570	1423821	1792745	1399632	1980737	2649070	12308	7758	11440	16947
R5	122.00	124.00	129.33	134.33	1484.58	1243.36	1465.97	1972.12	1016590	808433	1081181	1657761	1931483	1629175	2079596	3112591	12574	8660	11794	19308
R6	183.83	197.00	198.44	205.67	2352.43	2687.99	3083.45	3807.65	2628822	3210941	3987217	5366507	4736202	6000702	7276278	9795660	20045	24556	33020	47433

4.5 Regression Equations:

The regression equations in gladiolus are discussed under the following headings:

1. Number of days to phenostage and days to blooming
2. Number of days to phenostage and days to corm harvest

1. Number of days to phenostage and days to blooming:

Linear regression equations indicating days to blooming (x) based on the number of days taken for achieving particular growth stage (y) for Punjab Glad 3, Punjab Lemon Delight, CPG, Punjab Glance and White Prosperity are presented in table 4.42, 4.43, 4.44, 4.45 and 4.46 respectively. Regression analysis indicated a significant positive correlation between days to blooming and number of days to phenostage. The highest correlation coefficient was obtained with number of days taken to different vegetative growth stages i.e. sprouting (r^2 = 0.99) in Punjab Glance, shoot emergence (r^2 = 0.99) in Punjab Lemon Delight, leaf development (r^2 = 0.93) in Punjab Glad 3, initiation of spike emergence (r^2 = 0.99) in White Prosperity and full spike emergence (r^2 = 0.84) in CPG. From these regression equations one can predict the days to blooming if the number of days to reach the particular stage is known.

Table 4.42: Relationship between number of days to different phenostages (y) and days to blooming (x) in Punjab Glad 3

Growth stages	Regression Equation	r^2
Sprouting	y = 0.683x - 58.933	0.7361
Shoot emergence	y = 0.8744x - 75.888	0.8119
Leaf development	y = 1.0111x - 26.927	0.9311
Initiation of spike emergence	y = 0.8291x + 1.962	0.8277
Half spike emergence	y = 0.8305x + 6.39	0.7524
Full spike emergence	y = 0.7706x + 17.677	0.6976

Table 4.43: Relationship between number of days to different phenostages (y) and days to blooming (x) in Punjab Lemon Delight

Growth stages	Regression Equation	r^2
Sprouting	y = 0.2295x - 7.3362	0.9731
Shoot emergence	y = 0.2715x - 7.6536	0.9924
Leaf development	y = 0.5523x + 24.167	0.871
Initiation of spike emergence	y = 0.7579x + 12.444	0.9551
Half spike emergence	y = 0.775x + 14.637	0.9674
Full spike emergence	y = 0.8431x + 11.498	0.9779

Table 4.44: Relationship between number of days to different phenostages (y) and days to blooming (x) in CPG

Growth stages	Regression Equation	r^2
Sprouting	y = 0.5631x - 47.801	0.7261
Shoot emergence	y = 0.6565x - 55.425	0.7091
Leaf development	y = 0.9069x - 14.111	0.8234
Initiation of spike emergence	y = 0.7485x + 13.861	0.7014
Half spike emergence	y = 0.6186x + 34.389	0.5459
Full spike emergence	y = 0.7991x + 18.72	0.8414

Table 4.45: Relationship between number of days to different phenostages (y) and days to blooming (x) in Punjab Glance

Growth stages	Regression Equation	r^2
Sprouting	y = 0.5412x - 36.285	0.9888
Shoot emergence	y = 0.6368x - 41.949	0.9601
Leaf development	y = 0.7252x + 7.1136	0.9591
Initiation of spike emergence	y = 0.8717x + 0.0694	0.9232
Half spike emergence	y = 0.8785x + 3.2891	0.8559
Full spike emergence	y = 0.8707x + 7.1389	0.8044

Table 4.46: Relationship between number of days to different phenostages (y) and days to blooming (x) in White Prosperity

Growth stages	Regression Equation	r^2
Sprouting	y = 1.2838x - 123.29	0.5974
Shoot emergence	y = 1.3357x - 124.85	0.6336
Leaf development	y = 2.1928x - 154.77	0.9799
Initiation of spike emergence	y = 1.5954x - 82.239	0.9943
Half spike emergence	y = 1.2625x - 40.797	0.9883
Full spike emergence	y = 1.1783x - 26.514	0.9021

2. Number of days to phenostage and days to corm harvest

Linear regression equations indicating days to harvest corms (x) based on the number of days taken for achieving particular growth stages (y) for Punjab Glad 3, Punjab Lemon Delight, CPG, Punjab Glance and White Prosperity is presented in table 4.47, 4.48, 4.49, 4.50 and 4.51 respectively. Regression analysis indicated a significant positive correlation between days to harvest corms and number of days to a phenostage in all the five varieties. The highest correlation coefficient was obtained with number of days taken to different reproductive growth stages such as initiation of spike emergence (r^2 = 0.99) in White Prosperity, blooming

(r^2 = 0.99) in Punjab Lemon Delight and Punjab Glance, half spike senescence (r^2 = 0.93) in Punjab Glad 3 and full spike senescence (r^2 = 0.98) in CPG. From the regression equations one can predict the days to corm harvest if the number of days to reach the particular stage is known.

Table 4.47: Relationship between number of days to different phenostages (y) and days to corm harvest (x) in Punjab Glad 3

Phenostages	Regression equation	r^2
Sprouting	y = 0.4394x - 70.12	0.6758
Shoot emergence	y = 0.5611x - 89.918	0.7415
Leaf development	y = 0.6473x - 42.861	0.8464
Initiation of spike emergence	y = 0.5118x - 7.3755	0.6996
Half spike emergence	y = 0.5189x - 4.1916	0.6515
Full spike emergence	y = 0.4889x + 6.4134	0.6227
Blooming	y = 0.6336x - 14.455	0.8903
Anthesis start	y = 0.6732x - 18.885	0.8511
Anthesis half	y = 0.6913x - 18.36	0.873
Anthesis full	y = 0.7413x - 23.925	0.87
Senescence start	y = 0.7303x - 25.008	0.9056
Senescence half	y = 0.7553x - 25.743	0.9275
Senescence full	y = 0.8221x - 33.826	0.9237

Table 4.48: Relationship between number of days to different phenostages (y) and days to corm harvest (x) in Punjab Lemon Delight

Phenostages	Regression equation	r^2
Sprouting	y = 0.1454x - 11.152	0.9649
Shoot emergence	y = 0.1717x - 12.092	0.9794
Leaf development	y = 0.3405x + 16.779	0.8173
Initiation of spike emergence	y = 0.4771x + 0.4514	0.9343
Half spike emergence	y = 0.4903x + 1.9223	0.9556
Full spike emergence	y = 0.5343x - 2.5234	0.9696
Blooming	y = 0.6309x - 15.407	0.994
Anthesis start	y = 0.6769x - 21.073	0.9929
Anthesis half	y = 0.7087x - 23.936	0.9864
Anthesis full	y = 0.741x - 26.643	0.9792
Senescence start	y = 0.7206x - 24.397	0.9846
Senescence half	y = 0.7722x - 30.476	0.9795
Senescence full	y = 0.7896x - 30.134	0.9568

Table 4.49: Relationship between number of days to different phenostages (y) and days to corm harvest (x) in CPG

Phenostages	Regression equation	r^2
Sprouting	y = 0.4175x - 66.79	0.8942
Shoot emergence	y = 0.4871x - 77.651	0.8748
Leaf development	y = 0.6562x - 41.396	0.9661
Initiation of spike emergence	y = 0.5539x - 11.184	0.8608
Half spike emergence	y = 0.4775x + 9.6632	0.7287
Full spike emergence	y = 0.5725x - 4.1467	0.9678
Blooming	y = 0.6304x - 10.656	0.9368
Anthesis start	y = 0.8015x - 41.314	0.9654
Anthesis half	y = 0.9179x - 61.206	0.9773
Anthesis full	y = 0.9287x - 59.476	0.9613
Senescence start	y = 0.8764x - 51.539	0.9616
Senescence half	y = 0.8998x - 52.575	0.9757
Senescence full	y = 0.9517x - 59.597	0.9857

Table 4.50: Relationship between number of days to different phenostages (y) and days to corm harvest (x) in Punjab Glance

Phenostages	Regression equation	r^2
Sprouting	y = 0.2214x - 24.243	0.9642
Shoot emergence	y = 0.2592x - 27.548	0.9271
Leaf development	y = 0.2984x + 22.923	0.9465
Initiation of spike emergence	y = 0.3555x + 19.639	0.8955
Half spike emergence	y = 0.3555x + 23.534	0.8171
Full spike emergence	y = 0.3509x + 27.479	0.7615
Blooming	y = 0.4112x + 22.532	0.9874
Anthesis start	y = 0.4644x + 15.952	0.9741
Anthesis half	y = 0.5412x + 5.5098	0.9438
Anthesis full	y = 0.5889x + 1.4015	0.9186
Senescence start	y = 0.5238x + 10.728	0.9154
Senescence half	y = 0.5745x + 5.2389	0.9118
Senescence full	y = 0.588x + 7.431	0.8975

Table 4.51: Relationship between number of days to different phenostages (y) and days to corm harvest (x) in White Prosperity

Phenostages	Regression equation	r^2
Sprouting	y = 0.6678x - 113.43	0.5968
Shoot emergence	y = 0.6951x - 114.65	0.6335
Leaf development	y = 1.1421x - 138.23	0.9814
Initiation of spike emergence	y = 0.8242x - 68.874	0.9797
Half spike emergence	y = 0.6294x - 25.756	0.9068
Full spike emergence	y = 0.5631x - 7.7196	0.7607
Blooming	y = 0.4961x + 12.935	0.9308
Anthesis start	y = 0.4848x + 18.269	0.8303
Anthesis half	y = 0.5109x + 16.259	0.7406
Anthesis full	y = 0.3441x + 53.524	0.6353
Senescence start	y = 0.5294x + 14.237	0.7191
Senescence half	y = 0.4789x + 28.201	0.5406
Senescence full	y = 0.5224x + 25.155	0.7514

CHAPTER-V

SUMMARY

The present study entitled "Phenological development of Gladiolus based on heat unit requirement" was conducted at the Research Farm of the Department of Floriculture and Landscaping and Laboratories of Department of Floriculture and Landscaping and Department of Botany, Punjab Agricultural University, Ludhiana during the year 2020-2021. The growth and phenological development are primarily determined by temperature and photoperiodic conditions experienced by the crop during its life cycle. The most scientific and exact way of assessing and quantifying the effects of temperature and photoperiod on plant growth and development is obtained by making the application of heat unit which showed that plants have a definite temperature requirement to pass through a certain growth phenophase. Keeping in view the importance of temperature and photoperiod, the present experiment was conducted to study the effect of four planting dates on phenological development, morpho-physiological characters and vase life of five different gladiolus varieties. The corms of five gladiolus varieties i.e. Punjab Glad 3, Punjab Lemon Delight, CPG, Punjab Glance and White Prosperity were planted on four different planting dates viz. 28th September, 28th October, 28th November and 28th December. The experiment was laid out in Split Plot Design with three replications and ten plants per replication. The corms were planted at 30 × 20 cm and standard package of practices was followed to raise the crop.

Summary of results obtained from the experiment is as under:

- Minimum days to sprouting (12.07 days), shoot emergence (15.24 days), flag leaf development (75.03 days), initiation of spike emergence (84.39 days), half spike emergence (89.58 days), full spike emergence (93.60 days), blooming (98.57 days), initiation of anthesis (101.20 days), half of anthesis (103.89 days), anthesis full (107.72 days), initiation of senescence (105.14 days), half of senescence (108.43 days), full senescence (112.51 days) and plant senescence (176.03 days) were taken by corms planted under September i.e. early planting. Whereas, corms planted under December i.e. late planting took maximum days to sprouting (24.55 days), shoot emergence (29.47 days), flag leaf development (94.12 days), initiation of spike emergence (102.65 days), half spike emergence (106.96 days), full spike emergence (111.38 days), blooming (117.05 days), initiation of anthesis (121.23 days), half of anthesis (125.40 days), anthesis full (129.21 days), initiation of senescence (126.71 days), half of senescence (130.75 days), full senescence (136.05 days) and plant senescence (209.53 days).
- Punjab Glance took minimum days to sprouting (16.11 days), flag leaf development (77.82 days), initiation of spike emergence (85.06 days), half spike emergence (88.94 days), full spike emergence (92.03 days), blooming (98.19 days), initiation of anthesis

(101.40 days), half of anthesis (105.08 days), anthesis full (109.75 days), initiation of senescence (107.11 days), half of senescence (110.95 days), full senescence (115.62 days) and plant senescence (184.52 days). Whereas, CPG took maximum days to sprouting (18.79 days), flag leaf development (93.12 days), initiation of spike emergence (102.37 days), half spike emergence (107.54 days), full spike emergence (113.21 days), blooming (118.58 days), initiation of anthesis (123 days), half of anthesis (126.96 days), anthesis full (130.92 days), initiation of senescence (128.13 days), half of senescence (131.88 days), full senescence (135.50 days) and plant senescence (205.42 days).

- GDD, HTU and ENT required for sprouting of corms were maximum in September planting i.e. 256 °C day, 30700°C day hr and 3076 °C respectively whereas, minimum GDD (157°C day), HTU (7415°C day hr) and ENT (1114°C) were required under December planting. For flag leaf development, accumulated GDD, HTU and ENT were maximum i.e., 1163°C day, 608527°C day hr and 10493°C respectively in September planting whereas, minimum were accumulated under November planting. Accumulation of more agrometeorological indices under early planting i.e. September resulted in better vegetative growth. This vegetative growth helped in early full spike emergence with less number of days taken to blooming i.e. commercial harvest stage in gladiolus.
- Minimum GDD for half spike emergence (901°C day), blooming (993°C day), initiation of anthesis (1015°C day), half of anthesis (1049°C day), anthesis full (1097°C day), initiation of senescence (1065°C day), half of senescence (1112°C day), full senescence (1170°C day) were accumulated under October planting whereas for plant senescence (2217°C day) accumulated under September planting.
- October planting accumulated minimum HTU for half spike emergence (402153°C day hr), blooming (508761°C day hr), initiation of anthesis (533904°C day hr), half of anthesis (574056°C day hr), anthesis full (630696°C day hr), initiation of senescence (591168°C day hr), half of senescence (644808°C day hr), full senescence (717456°C day hr) whereas for plant senescence minimum HTU (2388432°C day hr) were accumulated under September planting.
- Minimum PTU for half spike emergence (890407°C day hr), blooming (1090789°C day hr), initiation of anthesis (1137768°C day hr), half of anthesis (1210896°C day hr), anthesis full (1316328°C day hr), initiation of senescence (1244520°C day hr), half of senescence (1346328°C day hr), full senescence (1473216°C day hr) were accumulated under October planting whereas for plant senescence (4293336°C day hr) accumulated under September planting.
- October planting accumulated minimum ENT for half spike emergence (6167°C), blooming (6714°C), initiation of anthesis (6862°C), half of anthesis (7096°C), anthesis

full (7470°C), initiation of senescence (7211°C), half of senescence (7577°C), full senescence (8039°C) whereas for plant senescence minimum ENT (18705°C) were accumulated under September planting.

- The planting carried out in September produced flowers in the starting of January (after 3 months), October planting in mid-January (after 2.5 months), November planting in mid-March (after 3.5 months) and December planting in April (after 4 months).
- GDD, HTU, PTU and ENT required for sprouting of corms were minimum in Punjab Glad 3 i.e. 190 °C day, 15669°C day hr, 31899°C day hr and 1630°C respectively whereas, maximum GDD (228°C day), HTU (23844°C day hr), PTU (44634 °C day hr) and ENT (2002°C) were required by CPG. For flag leaf development, accumulated GDD, HTU, PTU and ENT were maximum i.e., 1054°C day, 560348°C day hr, 1066413°C day hr and 8363°C respectively in CPG.
- Minimum GDD for initiation of spike emergence (960°C day), half spike emergence (1002°C day), full spike emergence (1039°C day), blooming (1114°C day), initiation of anthesis (1165°C day), half of anthesis (1220°C day), anthesis full (1286°C day), initiation of senescence (1244°C day), half of senescence (1301°C day), full senescence (1384°C day) and plant senescence (2732°C day) were accumulated by Punjab Glance.
- Punjab Glance accumulated minimum HTU for initiation of spike emergence (456202°C day hr), half spike emergence (501322°C day hr), full spike emergence (542591°C day hr), blooming (632685°C day hr), initiation of anthesis (683760°C day hr), half of anthesis (744144°C day hr), anthesis full (825024°C day hr), initiation of senescence (768216°C day hr), half of senescence (839040°C day hr), full senescence (935376°C day hr) and plant senescence (3311832°C day hr).
- Minimum PTU for initiation of spike emergence (877799°C day hr), half spike emergence (961083°C day hr), full spike emergence (1034328°C day hr), blooming (1186055°C day hr), initiation of anthesis (1285968°C day hr), half of anthesis (1404240°C day hr), anthesis full (1557024°C day hr), initiation of senescence (1458288°C day hr), half of senescence (1588368°C day hr), full senescence (1776480°C day hr) and plant senescence (6039336°C day hr) were accumulated by Punjab Glance.
- Punjab Glance accumulated minimum ENT for initiation of spike emergence (7602°C), half spike emergence (7949°C), full spike emergence (8251°C), blooming (8848°C), initiation of anthesis (9357°C), half of anthesis (9907°C), anthesis full (10511°C), initiation of senescence (10120°C), half of senescence (10647°C), full senescence (11543°C) and plant senescence (28100°C).
- Phyllochron Index was used to relate days required for the appearance of particular number of leaves on the main shoot. Maximum difference in phyllochron index due to

planting date was observed in White Prosperity while minimum was observed in Punjab Lemon Delight. With delay in planting dates there was decrease in appearance of number of leaves per plant. Seventh leaf in Punjab Glad 3, fifth in Punjab Glance, White Prosperity, Punjab Lemon Delight and CPG did not emerge out.

- A non-significant difference in per cent sprouting of corms was observed under different planting dates. The corms of Punjab Glance recorded maximum sprouting percent of corms (100%). Minimum per cent sprouting of corms was observed in CPG (81.66%).
- Morpho-physiological characters like maximum plant height (106.07 cm), number of leaves per plant (8.02), spike length (95.41 cm), number of florets per spike (14.21), floret size (8.78 cm), leaf area (446.74 cm^2), dry matter accumulation at full spike senescence (28.14 g), corm diameter (5.16 cm) and weight of spike (48.16 g) were recorded in Punjab Glad 3 under September planting. Whereas, maximum number of corms per plant (2.33), number of cormels per plant (47.17) and corm weight (35.99 g) were recorded in Punjab Glance under September planting.
- Best postharvest quality parameters viz. minimum number of days for basal floret to open i.e., 1.30 days in White Prosperity, maximum size of fully expanded floret (8.50 cm), number of florets opened at one time (6.33), water absorbed per spike (79.50 ml), vase life (9.06 days), percent opening of florets (79.5 %), minimum loss in physiological weight (26.73 %) and change in pH (0.1) in Punjab Glad 3 were observed under September planting.
- Comparatively low temperature and short day conditions during vegetative and reproductive growth stages resulted in better morpho-physiological parameters like maximum plant height, number of leaves per plant, dry matter accumulation per plant, number of florets per spike, weight of spike, production of corms and cormels and postharvest quality parameters like minimum days to basal floret open, maximum size of fully expanded floret, maximum vase life, maximum per cent opening of floret etc. under September planting whereas, high temperature and long day conditions during December planting retarded vegetative and reproductive growth and hence affects morpho-physiological and postharvest quality parameters.
- Punjab Glance responded best under all planting dates, even with delay in planting the quality of spikes did not affected much whereas, with delay in planting CPG affected the most and produced spikes of low quality.
- Phenological model describing the detailed developmental stages and requirement of agrometeorological indices for each stage for gladiolus varieties was prepared by using Schwab's developmental staging system.
- Regression analysis indicated a significant positive correlation between days to blooming,

days to harvest corms and number of days to phenostage. Maximum correlation coefficient for days to blooming was observed with vegetative and spike emergence stages. Whereas, maximum correlation coefficient for days to corm harvest was observed with reproductive stages. From the regression equation one can predict the days to blooming and corm harvest if the number of days to reach the particular stage is known.

These results indicated that September planting i.e. early planting is best suited for all gladiolus varieties evaluated, as plants under this planting completed their phenological development in less time with accumulation of less agrometeoroligcal indices but utilizing these agrometeorological indices effectively for spike and corm and cormels production as compared to late i.e. December planting which took more time and agrometeorolgical indices but was unable to use them effectively for spike and corm and cormels production. Moreover, best of all morpho-physiological and postharvest quality parameters were also observed under September planting due to optimum environmental conditions. Schwab's staging system along with regression equations could be used to predict days to blooming so that planting should be done accordingly to get spikes on occasions like Christmas, New Year etc.

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