Journal of Agrometeorology

ISSN : 0972-1665 (print), 2583-2980 (online)
Vol. No. 24 (4) : 353-358 (December- 2022)

https://journal.agrimetassociation.org/index.php/jam

Research Paper

Evaluation of PhenoGlad model on the phenological development of gladiolus varieties under subtropical conditions of Punjab

SHALINI JHANJI[1*] and RAVIJOT KAUR[2]

[1]Department of Floriculture and Landscaping, Punjab Agricultural University, Ludhiana-141004, Punjab, India
[2]Department of Botany, Punjab Agricultural University, Ludhiana-141004, Punjab, India
[*]Corresponding author email: shalinijhanji@pau.edu

ABSTRACT

Gladiolus (*Gladiolus grandiflorus* Hort.) is a commercially important open field crop, cultivated for elegant spikes. The development rate is dependent upon temperature so planting date is crucial factor to regulate flower production around the specific days. The present investigation was to validate the application of PhenoGlad model on different varieties grown in Punjab, India so that it could be used as a management tool for meeting market requirements. Five varieties of gladiolus with different developmental cycles were procured from Department of Floriculture and Landscaping, PAU, Ludhiana and planted at monthly interval from September to December at the research farm of Department of Floriculture and Landscaping, PAU, Ludhiana. Punjab Lemon Delight and Punjab Glance took minimum days to reach phenostages whereas Punjab Glad 3 and CPG took maximum days and White Prosperity took intermediate days under all planting dates. Observed days to reach a particular phenostage in our results was close to simulated days under October planting for Punjab Lemon Delight, Punjab Glance and White Prosperity and November planting for Punjab Glad 3 and CPG. Thus, these results validated the use of PhenoGlad model to simulate flowering time of different varieties to regulate the market demand.

Keywords: Gladiolus, planting dates, crop simulation, PhenoGlad model

Gladiolus (*Gladiolus grandiflorus* Hort.), an important bulbous crop with elegant spikes, occupies important position among cut flowers in domestic as well as international market (Schwab *et al.,* 2015). The development and selection of suitable genotypes is an important factor that determines successful cultivation of gladiolus under different agro-climatic conditions. Phenology describes the morphological changes that come during plant development (Santilli *et al.,* 2021). Phenotype in addition to the genetic makeup is greatly influenced by environmental conditions as well as interaction between genotype and environment (Thakur *et al.,* 2015). Air temperature is the most important environmental factor that influences gladiolus phenology in the field.

The planting of crop at different dates enables to study the influence of altered weather conditions on growth and development of crop and evaluation of varieties for off season production. The climatic parameters viz., temperature and light intensity are important factors that influence gladiolus development and different planting dates provide altered temperature and light intensities. Further, planting date regulates growth and quality of gladiolus as different phenophases viz., days to sprouting, sprouting percentage, days to the 6-leaf stage etc are correlated with air temperature (Dhatt and Jhanji, 2021).

Crop simulation models are simplified representations of complicated mechanisms that drive crop growth and development during the growing season. These models depict the plant processes using mathematical functions that include genetic and environmental factors which influence biological processes (Prusinkiewick, 2004). The relationship between temperature and crop growth rate is linked either linearly or non-linearly (Streck *et al.,* 2008). The non-linear method was used to incorporate genetic and environmental factors in the Wang and Engel wheat model and PhenoGlad model (Uhlmann *et al.*, 2017). When flower crop is grown in an open field, like gladiola, crop models are excellent tools for arranging planting dates and estimating flowering time based on historical daily weather data (Vaid *et al.,* 2014). The crop modelling has been done drastically for grain crops but very few for ornamental crops.

The long term responses of crops to climate change are going to alter the planting time of a crop not only for off season but also for in season production. So, simulation model will enable

Article info - DOI: *https://doi.org/10.54386/jam.v24i4.1633*
Received: 21 April 2022; Accepted: 21 September 2022; Published online : 1 December 2022

the growers to select a variety for particular planting time to have flowering on desired date. The PhenoGlad model of gladiolus simulates the phenostages based on maximum and minimum air temperature. This model could enable the regulation of market demand of spikes. Keeping in view, the importance of gladiolus as cut flower, influence of temperature on its flowering, performance of PhenoGlad model as crop simulation model, therefore, the objective of the study was to validate the 'PhenoGlad' model to predict days taken to reach a particular phenostage through development of phenological models for gladiolus varieties with different developmental cycle is fitted into the model or not.

MATERIALS AND METHODS

Five cultivars of gladiolus grown by commercial farmers and representative of the wide range of colours *viz.* Punjab Lemon Delight and Punjab Glance with early developmental cycle, White Prosperity with intermediate developmental cycle and Punjab Glad 3 and CPG with late developmental cycle were planted at monthly interval from September to December during the year 2020-21. Early cultivars have development cycle from 69 to 121 days whereas late cultivars have development cycle from 85 to 148 days (Becker *et al*., 2021). This cultivar x planting dates experiment provided a rich data set for parameterizing and evaluating the gladiolus model.

The experimental design was split plot design with three replications. In each planting, 15 plants of each cultivar were tagged (five plants per replication) to record number of days taken to phenostages proposed by Schwab *et al.,* (2015) from planting: shoot emergence (VE), first leaf (V1), second leaf(V2), third leaf (V3), fourth leaf (V4), n^{th} leaf (Vn), flag leaf (VF), complete spike emergence (R1.2), blooming (R2), initiation of anthesis (R3), half of anthesis (R3.4), complete anthesis (R4), beginning of floret senescence (R3.5), half florets senescence (R3.6) and end of floret senescence (R5).

Version 1.1 of the gladiolus PhenoGlad Model (available for free download at http://coral.ufsm.br/phenoglad/) proposed by Uhlmann *et al*., (2017) was used to validate the application of this model on different varieties grown in Punjab, India. Input data for running the PhenoGlad model were daily minimum and maximum air temperature, which were used to calculate the daily mean temperature that in turn was used in a nonlinear model by Wang and Engel (1998) to simulate the daily rate of gladiolus development. The daily temperature was attained from School of Agricultural Meteorology, PAU, Ludhiana. Simulated days (obtained from PhenoGlad Model) and observed days for each phenostage of different gladiolus cultivars under different planting dates were plotted on graphs and analysed for model validation. RMSE (Root Mean Square Error) and MAE (Mean Absolute Error) were calculated as follows:

$RMSE = [\Sigma(Si-Oi)^2/n]^{0.5}$

Where, S_i = Simulated day for phenostage (Version 1.1 of the gladiolus PhenoGlad Model)

O_i = Observed day for phenostages and

n = total number of observations

$MAE = 1/n\ (\Sigma\ |Oi-Si|)$

RESULTS AND DISCUSSION

Different planting dates enabled to study the influence of altered weather conditions on the growth and 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 in order to harvest spikes for sale around certain holidays. Planting dates × varieties is important to test the PhenoGlad in simulating the timing of developmental stages under conditions different from the parameterization environments (Uhlmann *et al.,* 2017).

The figures were worked out to compare simulated (1.1 version of PhenoGlad model) versus observed days after planting (DAP) for the data of different phenostages for each gladiolus variety planted under different dates to validate the model for sub-tropical grown cultivars under different planting time.

Performance of early developmental cycle varieties

Punjab Lemon Delight and Punjab Glance came under early developmental cycle group as they took lesser number of days to complete developmental cycle i.e. to reach R5 stage. For Punjab Lemon Delight, under September planting observed days taken to shoot emergence (13 days), flag leaf development (73 days), full spike emergence (83 days), blooming (86 days), initiation of anthesis (88 days) and initiation of spike senescence (92 days) were more as compared to simulated days for a particular phenostage .When planting was done in October, observed days taken to shoot emergence (15 days), first leaf (18 days), second leaf (25 days), third leaf (34 days) and fourth leaf (45 days) were more as compared to simulated days. But when it comes to reproductive growth stages like full spike emergence (88 days), blooming (101 days), initiation of anthesis (103 days), initiation of senescence (107 days), full anthesis (109 days) and complete spike senescence (114 days) observed days completely coincides with the simulated ones. Whereas, in November and December plantings, observed days to shoot emergence and vegetative growth stages coincides with the simulated ones but observed days to reproductive stages were more as compared to simulated ones. Thus, it could be interpreted that October planting is best suited for Punjab Lemon Delight.

Observed days for shoot emergence (14 days), flag leaf development (68 days), complete spike emergence (74 days), blooming (85 days), initiation of anthesis (90 days) and initiation of spike senescence (94 days) for Punjab Glance under September planting were higher than simulated days for the phenostages. When crop was planted in October, the number of days for shoot emergence (11 days), first leaf (16 days), second leaf (25 days), third leaf (34 days), fourth leaf (41 days) and observed days for reproductive developmental stages such as full spike emergence (86 days), blooming (98 days), initiation of anthesis (100 days) and initiation of senescence (103 days) were close to simulated days. Observed days to shoot emergence, vegetative developmental stages and reproductive developmental stages were exactly same as predicted by PhenoGlad model for November planting. In December planting, observed days to shoot emergence and vegetative growth stages were less as compared to simulated days but when it comes to reproductive stages, observed days exceeded the simulated ones.

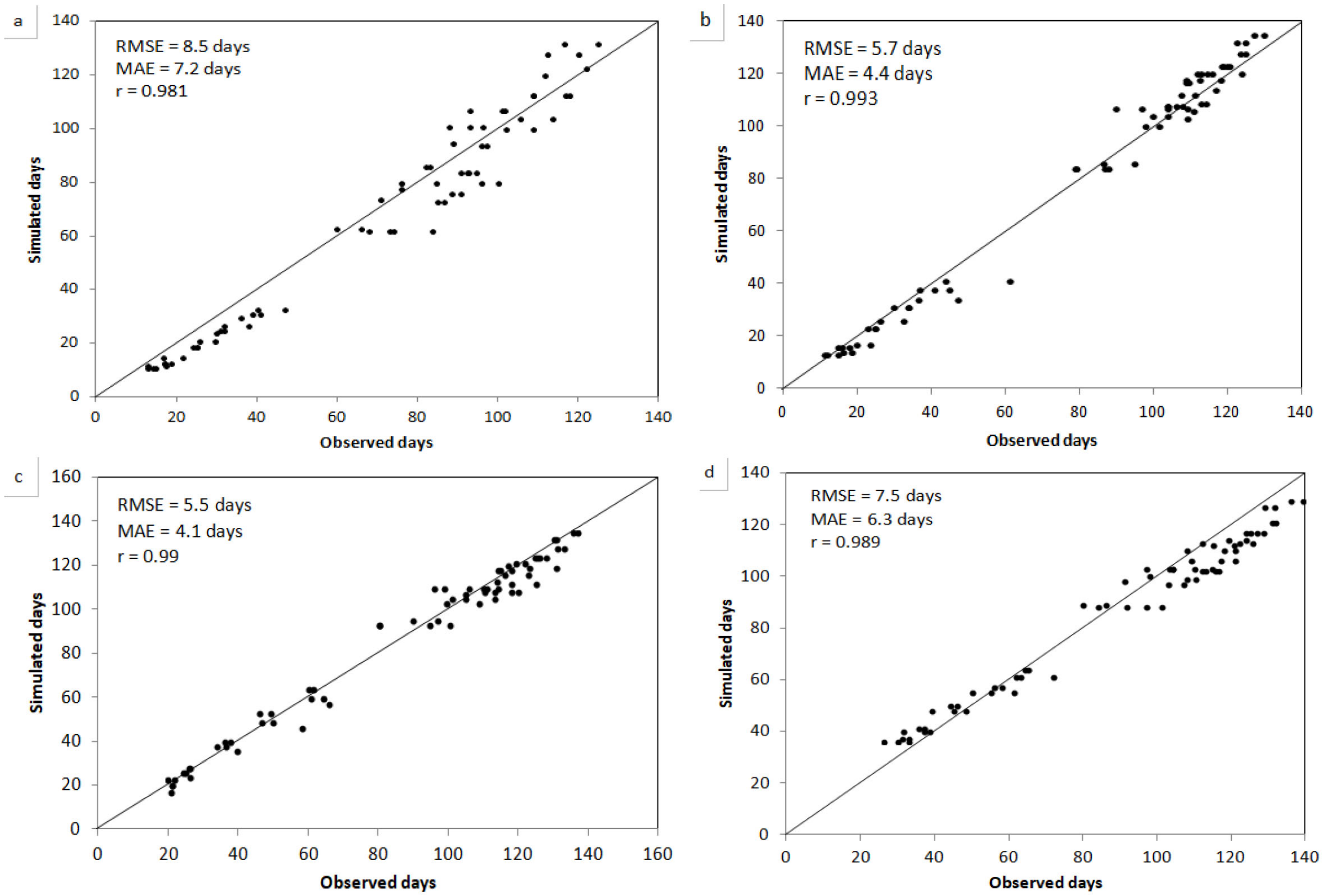

Fig. 1: The simulated versus observed days after planting (DAP) with the PhenoGlad model for different phenostages under different planting dates [(a) September planting, (b) October planting, (c) November planting and (d) December planting]. Varieties are pooled. The solid line is the 1:1 line. Inserts are RMSE = Root Mean Square Error, MAE = Mean Absolute Error and r= coefficient of correlation.

So, according to PhenoGlad model, the ideal planting date for the Punjab Glance is October and November as under both these months observed reproductive growth and blooming stage i.e. commercially important harvest point of the crop showed best matches with simulated ones.

Performance of intermediate developmental cycle varieties

Under September planting, the observed days for shoot emergence, vegetative and reproductive developmental stages did not coincide much with the simulated ones. However, the number of days for shoot emergence (12 days), flag leaf development (86 days), full spike emergence (95 days), blooming (109 days), beginning of anthesis (111 days), initiation of spike senescence (114 days), complete anthesis (118 days) and complete spike senescence (124 days) were close to simulated days under October planting. Under November and December planting, observed days to shoot emergence, vegetative development stages and reproductive developmental stages coincides with simulated days. Therefore, ideal planting date for White Prosperity according to PhenoGlad model is October, as observed phenostages coincides best with simulated ones during this month.

The early and intermediate developmental cycle cultivars have their development more affected with higher temperature in October-November when their vegetative season is at peak or very low temperature in December-January when their flowering is at peak. The delay in planting will force them to low temperature during vegetative stages and hence low developmental rate and with this delay the spike harvesting will coincide with higher temperature in February. Moreover, gladiolus is considered as facultative short-day plant (Uhlmann *et al.*, 2017). Therefore, heat along with longer day period might cause reduction in growth, quality and vase life of gladiolus drastically (Nagar *et al*., 2018). Thus, planting of cultivars with these developmental cycles could be delayed up to October. The results pertaining to our studies also revealed that the planting of Punjab Glance, Punjab Lemon Delight and White Prosperity with early and intermediate developmental cycle could be delayed up to October as observed days to different phenostages coincided to simulated days under October planting.

Performance of late developmental cycle varieties

Punjab Glad 3 and CPG came under late developmental cycle group as they took greater number of days to reach R5 stage. For Punjab Glad 3, under September and October plantings observed days for phenostages were close to simulated ones with RMSE values of 8.3 and 5.2 days, respectively. But when the crop was planted in November, observed days for shoot emergence (20 days),

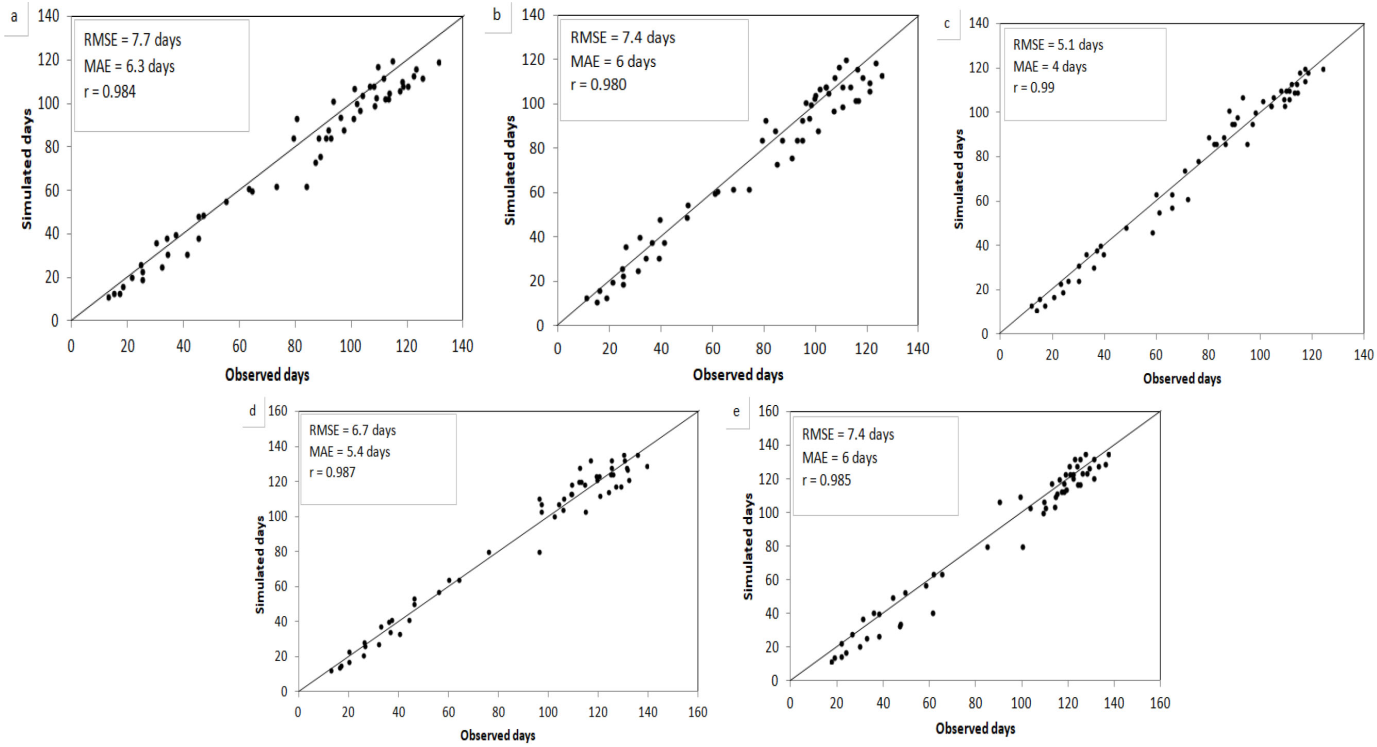

Fig. 2: The simulated versus observed days after planting (DAP) with the PhenoGlad model for different phenostages of gladiolus varieties [(a) Punjab Lemon Delight, (b) Punjab Glance, (c) White Prosperity, (d) Punjab Glad 3 and (e) CPG]. Dates of planting are pooled. The solid line is the 1:1 line. Inserts are RMSE = Root Mean Square Error, MAE = Mean Absolute Error and r= coefficient of correlation.

flag leaf development (96 days), full spike emergence (106 days), blooming (114 days), beginning of anthesis (119 days), initiation of spike senescence (125 days), complete anthesis (130 days) and complete spike senescence (135 days) coincides with number of days simulated by PhenoGlad model with RMSE value of 4.9 days. Under December planting, observed days to shoot emergence and vegetative development stages were same as simulated through model but the number of days recorded to reach each reproductive phenostages were more than simulated. The November planting could be considered as the best time to plant Punjab Glad 3. For CPG, under September and October planting, observed days taken to shoot emergence and vegetative developmental stages were higher than simulated days whereas, for reproductive developmental stages observed days were higher than simulated ones in September planting and lower than simulated in October planting. Moreover, both these plantings have higher RMSE values i.e. 9.3 days for September and 9.4 days for October planting. Under November planting, observed days taken to shoot emergence (21 days), flag leaf (99 days), full spike emergence (114 days), blooming (118 days), beginning of anthesis (122 days), initiation of spike senescence (128 days), complete anthesis (131 days) and complete spike senescence (137 days) coincides completely with simulated ones. In December planting, observed days to shoot emergence, vegetative growth stages and reproductive stages were more as compared to simulated ones. Therefore, from simulated PhenoGlad model, it could be observed that November planting is best suited for CPG.

The late developmental cycle cultivars require more days to reach harvest stage so planting such cultivars in September-October lead to exposure to low temperature during November-December i.e., as they have longer developmental cycle, their vegetative development slows down during these months and as temperature increases in early spring, they hasten development and comes to bloom. So, if these cultivars are planted in November -December, their vegetative phase will be exposed to higher temperature during vegetative development that will hasten their growth and they will bloom in early spring. If their planting is delayed further, there is increase in minimum and maximum temperature, which leads to an increase in developmental rate and a decrease in length of the developmental cycle (Adil *et al.,* 2013). As developmental cycle of Punjab Glad 3 and CPG is shortened, flowering will take less number of days but now the flowering will coincide with higher temperature during early summer i.e. April leading to reduction in flower quality and postharvest life (Becker *et al*., 2021). So, planting of Punjab Glad 3 and CPG could be delayed up to November.

Performance of gladiolus under different planting dates

The model was validated for different planting dates irrespective of varieties (Fig. 1). High degree of correlation coefficient (r ≥ 0.98) between simulated days and observed days revealed that PhenoGlad model could be used to predict days to reach a particular phenostage for different varieties over different planting dates. The RMSE varied from 5.5 days for November planting to 8.5 days for September planting. This revealed that irrespective of variety, observed days to reach a particular phenostage in November planting could be predicted from simulated days with a variation of 5.5 days whereas corresponding values for September , October and December plantings were 8.5, 5.7 and 7.5 days respectively. These results indicated that October and November plantings to be better than other plantings.

Performance of different varieties

The model was also validated for different varieties irrespective of planting dates (Fig. 2). The graphs depict linear relationship with high correlation coefficient (≥ 0.98) between observed days and simulated days for all varieties. This revealed that the phenostages of all the varieties under study could be predicted from PhenoGlad model over a wide range of planting time. Among the varieties, White Prosperity had least RMSE of 5.1 days i.e. the observed days to reach a particular phenostage could be predicted from simulated ones from model with a variation of just 5 days. The corresponding prediction for a particular phenostage in Punjab Lemon Delight, Punjab Glance, CPG and Punjab Glad 3 were 7.7, 7.4, 6.7 and 7.4 days respectively.

PhenoGlad showed good performance among varieties and planting dates as revealed from low RMSE values (Fig. 1 &2). The value of RMSE varied from 5-8 days when pooled for varieties under different planting dates and from 4-6 days for varieties when pooled for planting dates. This much variation has also been recorded in prediction of phenostages with other models like 5–6 days for winter wheat (Streck et al., 2003) with Wang and Engle model, 7 days for potato (Streck et al . 2007), 4.3-10.9 days for rice (Streck et al . 2011). The error of 5-6 days in prediction of any phenostage could be accepted in gladiolus. If the model predicts harvestable spikes 4-8 days before market demand, the farmer can store spikes at 4-5 ºC for 10-15days as low temperature will slow down the flower opening (Jhanji and Dhatt 2022).

CONCLUSION

PhenoGlad model was used to simulate developmental stages of gladiolus varieties with different developmental cycles under different planting dates. It was found efficient in predicting the number of days taken to reach phenostages, best planting time for the variety and categorization of varieties as early, intermediate and late development cycle as observed days to reach a phenostage coincided with simulated ones. The results came out with recommendation for growers/farmers to plant Punjab Glance, Punjab Lemon Delight and White Prosperity up to October as in November or December i.e. delay in planting will slow down vegetative development rate, which in turn will delay flowering period, which will then coincide with high temperatures leading to poor flower quality. The Punjab Glad 3 and CPG cultivars could be planted up to November, but further delay will reduce flower quality and post-harvest life due to increased risk of heat damage. This model can further be used to simulate other gladiolus varieties as data input requirements are only minimum and maximum temperature, variety and planting or shoot emergence date.

Conflict of Interest Statement: The author(s) declare(s) that there is no conflict of interest.

Disclaimer: The contents, opinions, and views expressed in the research article published in the Journal of Agrometeorology are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

Publisher's Note: The periodical remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

REFERENCES

Adil, M., Ahmad, W., Ahmad, K.S., Shafi, J., Shehzad, M.A., Sarwar, M.A., Salman, M., Ghani, M.I. and Iqabal, M. (2013). Effect of different planting dates on growth and development of Gladiolus grandiflorus under the ecological conditions of Faisalabad, Pakistan. *Univ. J. Agric. Res.,* 1: 110-17.

Becker, C.C., Streck, N.K., Uhlmann, L.O., Cera, J.C., Ferraz, S.E.T., Silveira, W.B., Balest, D.S. and Ferreira da Silva, L. (2021). Assessing climate change effects on gladiola in Southern Brazil. *Sci. Agric.,* 78: e20180275. doi: https://doi.org/10.1590/1678-992X-2018-0275

Dhatt, K.K. and Jhanji, S. (2021). Evaluating gladiolus varieties for off-season planting using agro-meteorological indices. *J. Agrometeorol.,* 23: 46-53. doi: https://doi.org/10.54386/jam.v23i1.87

Jhanji, S. and Dhatt, K.K. (2022). Unravelling physiological and biochemical attributes influencing post harvest quality of gladiolus spikes after packaging and low temperature storage. *Indian J. Exp. Biol.,* 60 (1): 41-48.

Nagar, K.K., Mishra, A. and Patil, S.S. (2018). Studies on effect of planting dates and varieties on growth and quality in gladiolus (*Gladiolus hybridus* Hort.) under sub- humid zone of Rajasthan. *Univ. J. Agric. Res.,* 6: 160-164. doi: 10.13189/ujar.2018.060503

Prusinkiewick, P. (2004). Modeling plant growth and development. *Curr. Opin. Plant Biol.*, 7: 79–83.

Santilli, M., Bas-Nahas, S.S. and Medrano, N. (2021). Freesia crop (*Freesia x hybrida*) phenological growth stages according to the BBCH scale. *Rev. Agron. Noroeste Argent.,* 41(1): 15-25.

Schwab, N.T., Streck, N.A., Becker, C.C., Langner, J.A., Uhlmann, L.O. and Ribeiro, B.S.M. R. (2015). A phenological scale for the development of Gladiolus. *Ann. Appl. Biol.,* 166: 496–507. doi: https://doi.org/10.1111/aab.12198

Streck, N.A., Weiss, A., Xue, Q. and Baezinger, P.S. (2003). Improving predictions of developmental stages in winter wheat: a modified Wang and Engel model. *Agric. For. Meteorol.,* 115: 139–157. doi: http://dx.doi.org/10.1016/S0168- 1923(02)00228-9

Streck, N.A., Paula de, F.L.M., Bisognin, D.A., Heldwein, A.B. and Dellai, J. (2007). Simulating the development of field grown potato (*Solanum tuberosum* L.). *Agric. For. Meteorol.,* 142: 1-11.

Streck, N.A., Bosco, L.C. and Lago, I. (2008). Simulating leaf appearance in rice. *Agron J.*, 100: 490–501. doi: https://

doi.org/10.2134/agronj2007.0156

Streck, N.A., Lago, I., Oliveira, F.B., Heldwein, A.B., Avila, L.A. and Bosco, L.C. (2011). Modeling the development of cultivated rice and weedy red rice. *T. Asabe.,* 54: 371–384. doi: http://dx.doi.org/10.13031/2013.36234

Thakur, T., Dhatt, K.K. and Ahmed, S. (2015). Effect of planting time on growth and flowering of Gladiolus. *Int. J. Curr. Res. Aca. Rev.,* 3: 145-52.

Uhlmann, L.O., Streck, N.A., Becker, C.C., Schwab, N.T., Benedetti, R.P., Charao, A.S., Ribeiro, B.S.M.R, Silveira, W.B., Backes, F.A.A.L., Alberto, C.M., Muttoni, M., Paula, G.M., Tomiozzo, R., Bosco, L.C. and Becker, D. (2017). PhenoGlad: A model for stimulating development in Gladiolus. *European J. Agron.,* 82:33-49. doi: https://doi.org/10.1016/j.eja.2016.10.001

Vaid, T.M., Runkle, E.S. and Frantz, J.M. (2014). Mean daily temperature regulates plant quality attributes of annual ornamental plants. *Hort. Sci.,* 49: 574-580. doi: https://doi.org/10.21273/HORTSCI.49.5.574

Wang, E. and Engel, T. (1998). Simulation of phenological development of wheat crops. *Agric. Syst.*, 58: 1–24. doi: https://doi.org/10.1016/S0308-521X(98)00028-6

Zubair, M., Wazir, F.K., Akhtar, S. and Ayub, G. (2006). Planting dates affect floral characteristics of gladiolus under the soil and climatic conditions of Peshawar. *Pak. J. Biol. Sci.,* 9: 1669-1676.