



Photoperiod, Plant Growth Regulators and Nutrient Responses in Chrysanthemum in Relation to Flowering

*Aparna A S and Amal Pious

Department of Agricultural Microbiology, Kerala Agricultural University,
Vellayani-695522, Kerala, India

*Corresponding Author's email: aparnaas152002@gmail.com

Chrysanthemum (*Chrysanthemum × morifolium* Ramat.) is an economically important ornamental crop cultivated for cut flowers, potted plants and garden displays. Its commercial value depends on flowering time, flower number, size, colour, stem quality and uniformity. Flowering is controlled by interactions between genotype and environmental and management factors. Among these, photoperiod is a primary signal, while plant growth regulators (PGRs), mineral nutrition and temperature influence the transition to flowering and subsequent flower development. Understanding these responses allows the growers to schedule flowering, improve market quality and use inputs more efficiently.

Photoperiodic Response and Flowering

Most commercial chrysanthemum cultivars are short-day plants: they initiate flowers when the uninterrupted dark period is sufficiently long. In practice, growers commonly maintain long days during vegetative growth to build plant size, then provide short days to induce flowering. The critical daylength and the number of inductive cycles differ among cultivars, so a schedule suitable for one variety may not give the same response in another. The plant must also attain a developmentally competent stage before it responds fully to short days. Night length is often more important than day length alone. A brief exposure to light during the dark period, known as a night break, can inhibit flowering, particularly when red light is used. This response is associated with phytochrome signalling and the plant's circadian system. Higuchi et al. (2012) showed that the effect of a night break depended on light quality and on the spectrum supplied during the preceding photoperiod. Thus, red, blue and far-red light cannot be treated as interchangeable signals. Modern LED studies show that flowering responses are more complex than a simple short-day/long-day classification. SharathKumar et al. (2021) found that blue-light extension could permit floral initiation and development under particular controlled-environment conditions, whereas similar extensions after natural solar light did not produce the same outcome. This indicates that the spectral composition of the main photoperiod, timing of supplementary light and growing environment interact. A 2025 study of seven cultivars also reported differences between obligate and facultative short-day responses, confirming substantial genotypic variation in flowering time and quality. Photoperiod also interacts with temperature. Temperature affects the rate of floral development and can influence the time from floral initiation to anthesis. Munir (2023), using different photoperiods, shading levels and temperatures, examined these effects through photo-thermal models. Therefore, flowering schedules should be based on cultivar-specific responses and local growing conditions rather than photoperiod alone.

Plant Growth Regulators and Flowering

Plant growth regulators modify plant architecture and developmental processes and may be used to improve the appearance and timing of chrysanthemum flowering. Their effects depend on compound, concentration, cultivar, application stage and growing conditions. PGRs should

therefore be selected using locally validated recommendations rather than assuming that one treatment is suitable for all cultivars.

Gibberellins

Gibberellins (GAs) regulate stem elongation and can participate in the transition to reproductive growth. In chrysanthemum, the relationship between GA signalling and flowering is not simply a matter of increasing or decreasing stem growth. Dong et al. (2017) investigated a chrysanthemum mutant capable of flowering under long days and showed that GA signalling was required for flowering under both short- and long-day conditions in their experimental system. The study highlights the role of hormone signalling in the flowering pathway, while also showing that photoperiod and genotype remain important. Excessive stem elongation, however, may reduce the compactness and commercial quality required in potted plants.

Growth retardants

Growth retardants such as paclobutrazol are used in ornamental production to limit excessive elongation and produce compact plants. By interfering with gibberellin biosynthesis, paclobutrazol generally reduces internode extension and plant height. Depending on dose and timing, it may also affect branching, flower development and the interval to flowering. The desirable outcome is a balanced plant with strong stems and well-distributed flowers, not simply the shortest possible plant. Excessive application can suppress growth and compromise flower size or overall quality; cultivar-specific trials are therefore essential.

Other hormonal signals

Auxins, cytokinins, abscisic acid and ethylene-related pathways can influence branching, bud development, senescence and responses to environmental stress. Their effects are often indirect and interact with carbohydrate availability and photoperiodic signalling. The florigen–antiflorigen system is particularly relevant: flowering-promoting and flowering-inhibiting signals help translate daylength information into developmental responses. Oda (2014) reviewed this balance and its importance in commercial photoperiodic control. Hormonal treatments should be interpreted within this wider network rather than as isolated triggers of flowering.

Nutrient Responses in Relation to Flowering

Adequate mineral nutrition is required for leaf area development, photosynthesis, assimilate production, bud formation and flower growth. Nitrogen (N), phosphorus (P) and potassium (K) are particularly important, but the optimum balance changes with cultivar, growth stage, substrate and production system. Nutrient management should support vegetative establishment first and reproductive growth later, while avoiding excessive fertilisation.

Nitrogen

Nitrogen is essential for chlorophyll, amino acids, proteins and enzymes. Adequate N supports leaf development and photosynthetic capacity, providing carbohydrates for developing buds and flowers. Nitrogen deficiency can result in pale leaves, reduced growth and fewer or smaller flowers. Conversely, excessive N may promote soft, lush vegetative growth, delay or reduce flowering quality, and increase susceptibility to some production problems. The goal is balanced N supply rather than maximum application.

Phosphorus

Phosphorus contributes to energy transfer, nucleic acids, membrane function and root development. Sufficient P supports establishment and the metabolic activity required during bud development. However, additional P beyond crop requirements does not automatically advance flowering or increase flower number. Soil or substrate testing and consideration of nutrient interactions are preferable to routine high-P applications.

Potassium

Potassium regulates stomatal function, enzyme activity, osmotic balance and the movement of assimilates. It supports water relations and can contribute to flower size, stem strength and postharvest quality. Jiang et al. (2024) compared different NPK fertilisation levels in Chrysanthemum morifolium and reported that balanced nutrition improved several vegetative traits, while a high-potassium treatment increased flower size and yield relative to the balanced

treatment under their experimental conditions. This result should not be interpreted as a universal recommendation: the response depends on the starting nutrient status, cultivar and treatment design. Calcium, magnesium, sulphur and micronutrients also contribute to healthy flowering. Calcium supports cell-wall integrity, magnesium is central to chlorophyll, and sulphur is required for sulphur-containing amino acids. Iron, boron, zinc and other micronutrients are needed in small quantities for chlorophyll formation, enzyme function and normal reproductive development. Deficiency or imbalance can reduce plant vigour and flower quality, but unnecessary supplementation can cause toxicity or nutrient antagonism.

Integrated Management for Improved Flowering

Photoperiod, PGRs and nutrition should be managed as interacting factors. A practical programme begins with cultivar selection and a healthy, uniform planting material. During vegetative growth, an appropriate long-day regime can encourage canopy development where required. Once plants reach the cultivar-specific competent stage, short-day conditions are used to induce flowering, ensuring that the dark period is not unintentionally interrupted by light. Temperature, shading and light spectrum should be monitored because they can modify the response. Nutrient supply should be adjusted to growth stage and based, where possible, on soil or substrate analysis. Adequate nutrition supports leaf area and bud development, while excessive nitrogen should be avoided near the reproductive phase. PGRs may be considered where plant height, branching or uniformity requires correction, but only with suitable product labels and locally tested rates. Records of cultivar, planting date, photoperiod, temperature, nutrient inputs, PGR treatment, days to visible bud, days to anthesis, flower number and flower size help identify the most reliable combination. The main principle is balance: photoperiod provides a key flowering signal, hormones regulate developmental and architectural responses, and nutrients supply the resources needed to produce marketable flowers. Since cultivar differences are substantial, small replicated trials are useful before adopting a production schedule at commercial scale.

Conclusion

Flowering in chrysanthemum is governed by an interaction between photoperiod, temperature, hormonal regulation and mineral nutrition. Short days with uninterrupted nights induce flowering in most commercial cultivars, although responses vary by genotype and light spectrum. Gibberellin signalling contributes to flowering and stem growth, while growth retardants such as paclobutrazol can improve compactness when carefully managed. Balanced NPK nutrition supports plant development, bud formation and flower quality; neither excessive fertilisation nor indiscriminate PGR use guarantees better flowering. Cultivar-specific photoperiod schedules, stage-based nutrition and evidence-based PGR use offer the most reliable route to uniform, high-quality chrysanthemum flowers.

References

1. Dong, B., Deng, Y., Wang, H., Gao, R., Stephen, G. K., Chen, S., Jiang, J., & Chen, F. (2017). Gibberellic acid signaling is required to induce flowering of chrysanthemums grown under both short and long days. *International Journal of Molecular Sciences*, 18(6), 1259. <https://doi.org/10.3390/ijms18061259>
2. Higuchi, Y., Sumitomo, K., Oda, A., Shimizu, H., & Hisamatsu, T. (2012). Day light quality affects the night-break response in the short-day plant chrysanthemum, suggesting differential phytochrome-mediated regulation of flowering. *Journal of Plant Physiology*, 169(18), 1789–1796. <https://doi.org/10.1016/j.jplph.2012.07.003>
3. Jiang, K., Peng, S., Yin, Z., Li, X., Xie, L., Shen, M., Li, D., & Gao, J. (2024). Effects of N, P, K nutrition levels on the growth, flowering attributes and functional components in *Chrysanthemum morifolium*. *Horticulturae*, 10(3), 226. <https://doi.org/10.3390/horticulturae10030226>

4. Munir, M. (2023). Application of photo-thermal models to quantify flowering time and development response of Chrysanthemum (*Chrysanthemum × morifolium* Ramat.). *Journal of Applied Horticulture*, 25(3), 230–237. <https://doi.org/10.37855/jah.2023.v25i03.41>
5. Oda, A. (2014). Florigen and antiflorigen determine the flowering in chrysanthemum. *Journal of the Japanese Society for Horticultural Science / relevant society journal feature article*, 49(1), 34–40. https://doi.org/10.18978/jscrp.49.1_34
6. SharathKumar, M., Heuvelink, E., Marcelis, L. F. M., & van Ieperen, W. (2021). Floral induction in the short-day plant chrysanthemum under blue and red extended long-days. *Frontiers in Plant Science*, 11, 610041. <https://doi.org/10.3389/fpls.2020.610041>
7. Chrysanthemum photoperiod study (2025). Flowering characteristics and expression patterns of key genes in response to photoperiod in different chrysanthemum varieties. *Horticulturae*, 11(1), 5. <https://doi.org/10.3390/horticulturae11010005>