AGRI MAGAZINE
(International E-Magazine for Agricultural Articles)
Volume: 03, Issue: 06 (June, 2026)
Available online at http://www.agrimagazine.in

Bolting as a Managed Resource – Leveraging Garlic Scapes for Pest Regulation and Edge Effects

Aakansha Porswal[1], *Vishant Gahlout[2], Kusum[3] and Sanyam Munaula[4]
[1]Research Scholar, Department of Forestry, VCSG UUHF, College of Forestry, Ranichauri, Tehri, Uttarakhand, India
[2]Research Scholar, Department of Genetics & Plant Breeding, CCS University, Kisan PG College, Simbhaoli, Hapur, U.P, India
[3]Guest Faculty, Horticulture (Fruit Science), College of Forestry, VCSG UUHF, Ranichauri, Tehri Garhwal, Uttarakhand, India
[4]Assistant Professor, Department of Forestry, VCSG UUHF, College of Forestry, Ranichauri, Tehri, Uttarakhand, India
*Corresponding Author's email: vishantgahlot52@gmail.com

Bolting in garlic (*Allium sativum* L.) represents a critical developmental transition in which the plant shifts from vegetative bulb production to reproductive inflorescence development, characterized by scape elongation and flower formation (Kamenetsky *et al*., 2004). This phenomenon is particularly important in agroforestry systems, where garlic is frequently integrated with other crops to enhance productivity and ecosystem services (Björklund *et al*., 2018). Bolting directly influences garlic's marketability and yield, as scapes (flower stems) represent an important horticultural product, while uncontrolled bolting can compromise bulb quality and size (Wu *et al*., 2016). Understanding the mechanisms underlying garlic bolting is essential for developing integrated management strategies that optimize both bulb and scape production within diverse agroforestry systems, particularly where multiple cropping patterns and microclimatic variations are common.

Environmental Factors Regulating Bolting and Scape Initiation

Temperature and photoperiod are the primary environmental determinants of bolting initiation in garlic, acting through complex interactions (Kamenetsky *et al*., 2004). Low temperature exposure, particularly during the dormancy period following harvest and storage, is crucial for vernalization of garlic bulbs, which subsequently enables bolting when plants are exposed to appropriate growing conditions (Michael *et al*., 2020). The critical finding that long cold exposure (approximately 12 weeks at 4°C) is a major cue for meristem transition highlights the importance of winter conditions in temperate agroforestry systems (Michael *et al*., 2020).

Photoperiod exerts differential effects on various stages of garlic's reproductive development (Kamenetsky *et al*., 2004). Research demonstrates that shorter photoperiods (8-10 hours) combined with lower temperatures (10°C) promote the highest flowering incidence across diverse garlic clones, whereas long photoperiods (16 hours) at elevated temperatures (18°C) significantly reduce bolting capacity (Pooler and Simon, 1993). The interaction between temperature and photoperiod is particularly nuanced: while higher temperatures (20°C or 25°C) combined with longer photoperiods (14 hours) significantly enhance bolting and accelerate inflorescence development, moderate continuous exposure to moderate temperatures paradoxically results in poor flowering outcomes (Wu *et al*., 2016). This counterintuitive response suggests that garlic requires specific temperature transitions rather than constant conditions to successfully complete reproductive development.

Physiological and Molecular Mechanisms of Floral Transition

At the molecular level, garlic's bolting process involves coordinated changes in gene expression and phytohormone dynamics that regulate the meristem transition from the vegetative to reproductive phase. Comparative transcriptome analyses reveal that vernalization activates approximately 14,000 differentially expressed genes, with circadian clock processes playing a central integrative role in translating low-temperature signals into reproductive development (Michael *et al*., 2020). Circadian rhythm appears to serve as a critical orchestrator, coordinating signals from the vernalization pathway with later photoperiodic responses to ensure proper developmental timing. Phytohormone levels shift dramatically during bolting, with methyl jasmonate (MeJA) and abscisic acid (ABA) showing inverse relationships to temperature conditions (Wu *et al*., 2016). Endogenous gibberellic acid levels are particularly important for bolting initiation and bulbing, as these hormones stimulate both scape elongation and bulb development (Wu *et al*., 2016). The integrated transcriptome catalogue of fertile garlic reveals that orthologues of key flowering genes such as FLOWERING LOCUS T (FT) and related proteins are differentially expressed not only in reproductive tissues but also in leaves and bulbs, (Kamenetsky *et al*., 2015) suggesting these genes coordinate both flowering & bulbing processes through shared signaling pathways.

Cultivar Variation and Fertility Considerations in Bolting

Significant genetic variation exists among garlic accessions regarding their capacity to bolt and produce fertile flowers (Pooler and Simon, 1993). Clone-specific responses to environmental conditions are pronounced: while some accessions (such as clone R81) flower readily under all conditions tested, others demonstrate strong dependence on specific temperature and photoperiod combinations (Pooler and Simon, 1993). This cultivar-specific variation reflects garlic's history as a vegetatively propagated crop with high phenotypic plasticity and environmental adaptation capacity, making different clones suitable for distinct agroecological conditions. Recent achievements in fertility restoration have enabled systematic evaluation of reproductive traits across diverse garlic germplasm. Among 47 accessions evaluated, only 19 demonstrated adequate seed production capacity, with significant variation in flowering timing, stigma position, anther morphology, and umbel characteristics. The proportion of plants producing seed ranged from 1.5 to 48.5% within accessions, indicating substantial phenotypic plasticity influenced by local growing environments (Jenderek and Hannan, 2004). For agroforestry applications, this variation offers opportunities to select cultivars well-suited to specific intercropping arrangements and microenvironmental conditions created by tree canopies and diverse crop arrangements.

Bolting Management within Integrated Agroforestry Systems

Integration of garlic into agroforestry and intercropping systems requires careful consideration of how companion crops and modified microenvironments affect bolting (Maitra *et al*., 2021). Intercropping systems that combine garlic with other crops can alter microclimate characteristics, including light availability and temperature, which directly impact bolting responses (*Yousefi et al*., 2024). The effectiveness of such diversified systems in managing plant development depends on selecting appropriate spatial arrangements and component crop combinations that create favorable microclimatic conditions for the target bolting phenotype. Nutrient management practices substantially influence bolting behavior, with nitrogen fertilization showing complex relationships to scape initiation (Ionescu *et al*., 2016). Research on related Allium crops demonstrates that nutrient balance affects developmental timing and reproductive capacity (Wu *et al*., 2016). In integrated nutrient management approaches increasingly promoted in sustainable agroforestry, (Paramesh *et al*., 2023) careful calibration of nutrient inputs can support both bulb development and controlled bolting. Climate-smart agriculture practices, including hedgerow planting and perennial crop-based agroforestry systems, (Tadesse *et al*., 2021) offer frameworks for managing garlic production while maintaining soil health and ecosystem services essential for long-term sustainability.

Adaptation to Climate Change and Future Perspectives

As climate patterns shift toward warmer springs and altered precipitation regimes, garlic's photoperiod and temperature-dependent bolting mechanisms face novel challenges in temperate agroforestry systems. Phenological responsiveness varies substantially among crop species and plant populations based on their evolutionary history and local adaptation (Gerst *et al*., 2017). Modern garlic breeding programs increasingly prioritize development of cultivars with stable bolting characteristics across diverse environmental conditions while restoring sexual fertility where desirable (Parreño *et al*., 2023). Integration of genomic selection technology and chromosome-scale genome assemblies now enables identification of genes underlying bolting timing, scape quality, and bulbing efficiency. Future agroforestry systems will benefit from targeted cultivation of garlic cultivars matched to specific environmental niches created by tree-based intercropping (Gautam *et al*., 2017). The integration of indigenous knowledge regarding cultivar-specific requirements with modern genomic approaches offers promising pathways for developing resilient garlic production systems. Additionally, chemical manipulation of flowering through external application of flower-inducing compounds (Ionescu *et al*., 2016) represents an emerging tool that could complement environmental management strategies in agroforestry contexts where natural cues are modified by canopy shade and microclimate alteration.

Conclusion

Bolting in garlic represents a complex developmental process controlled by vernalization, temperature, photoperiod, and internal phytohormone signaling, with substantial genetic variation among cultivars offering opportunities for agroforestry system optimization. Success in integrating garlic into diversified agroforestry systems requires understanding these regulatory mechanisms and selecting appropriate cultivars and management practices tailored to specific environmental contexts. Continued research into molecular mechanisms of bolting, combined with participatory approaches that incorporate local knowledge, will enable the development of more productive, resilient, and sustainable garlic production systems that contribute to food security while enhancing ecosystem services in agroforestry landscapes.

References

1. Björklund, J., Eksvärd, K., and Schaffer, C. (2019). Exploring the potential of edible forest gardens: experiences from a participatory action research project in Sweden. *Agroforestry Systems*, ***93***(3), 1107-1118.
2. Gautam, D. K., Bajracharya, R. M., and Sitaula, B. K. (2017). Effects of biochar and farm yard manure on soil properties and crop growth in an agroforestry system in the Himalaya. *Sustainable Agriculture Research*, ***6***(4), 74-82.
3. Gerst, K. L., Rossington, N. L., and Mazer, S. J. (2017). Phenological responsiveness to climate differs among four species of Quercus in North America. *Journal of Ecology*, ***105***(6), 1610-1622.
4. Ionescu, I. A., Møller, B. L., and Sánchez-Pérez, R. (2017). Chemical control of flowering time. *Journal of Experimental Botany*, ***68***(3), 369-382.
5. Jenderek, M. M., and Hannan, R. M. (2004). Variation in reproductive characteristics and seed production in the USDA garlic germplasm collection. *HortScience*, ***39***(3), 485-488.
6. Kamenetsky, R., Faigenboim, A., Shemesh Mayer, E., Ben Michael, T., Gershberg, C., Kimhi, S., Esquira, I., Shalom, S. R., Eshel, D., Rabinowitch, H., and Sherman, A. (2015). Integrated transcriptome catalogue and organ-specific profiling of gene expression in fertile garlic (*Allium sativum* L.). *Bmc Genomics*, ***16***(1), 12.
7. Kamenetsky, R., Shafir, I. L., Zemah, H., Barzilay, A., and Rabinowitch, H. D. (2004). Environmental control of garlic growth and florogenesis. *Journal of the American Society for Horticultural Science*, ***129***(2), 144-151.
8. Maitra, S., Hossain, A., Brestic, M., Skalicky, M., Ondrisik, P., Gitari, H., Brahmachari, K., Shankar, T., Bhadra, P., Palai, J. B., Jena, J., Bhattacharya, U., Duvvada, S. K., Sagar,

L., and Sairam, M. (2021). Intercropping—A low input agricultural strategy for food and environmental security. *Agronomy*, ***11***(2), 343.

9. Ben Michael, T. E., Faigenboim, A., Shemesh-Mayer, E., Forer, I., Gershberg, C., Shafran, H., Rabinowitch, H. D., and Kamenetsky-Goldstein, R. (2020). Crosstalk in the darkness: bulb vernalization activates meristem transition via circadian rhythm and photoperiodic pathway. *BMC plant biology*, ***20***(1), 77.
10. Paramesh, V., Mohan Kumar, R., Rajanna, G. A., Gowda, S., Nath, A. J., Madival, Y., Jinger, D., Bhat, S., and Toraskar, S. (2023). Integrated nutrient management for improving crop yields, soil properties, and reducing greenhouse gas emissions. *Frontiers in Sustainable Food Systems*, ***7***, 1173258.
11. Parreño, R., Rodríguez-Alcocer, E., Martínez-Guardiola, C., Carrasco, L., Castillo, P., Arbona, V., Jover-Gil, S., and Candela, H. (2023). Turning garlic into a modern crop: State of the art and perspectives. *Plants*, ***12***(6), 1212.
12. Pooler, M. R., and Simon, P. W. (1993). Garlic flowering in response to clone, photoperiod, growth temperature, and cold storage. *HortScience*, ***28***(11), 1085-1086.
13. Tadesse, M., Simane, B., Abera, W., Tamene, L., Ambaw, G., Recha, J. W., Mekonnen, K., Demeke, G., Nigussie, A., and Solomon, D. (2021). The effect of climate-smart agriculture on soil fertility, crop yield, and soil carbon in southern ethiopia. *Sustainability*, ***13***(8), 4515.
14. Wu, C., Wang, M., Cheng, Z., and Meng, H. (2016). Response of garlic (*Allium sativum* L.) bolting and bulbing to temperature and photoperiod treatments. *Biology Open*, ***5***(4), 507-518.
15. Yousefi, M., Marja, R., Barmettler, E., Six, J., Dray, A., and Ghazoul, J. (2024). The effectiveness of intercropping and agri-environmental schemes on ecosystem service of biological pest control: a meta-analysis. *Agronomy for Sustainable Development*, ***44***(2), 15.