4.2 Post-harvest and dehydration techniques

Post-harvest quality is particularly important in gomphrena because the crop is extensively marketed as a dried ornamental flower. Modern dehydration technologies aim to preserve flower colour, shape, texture, and structural integrity while minimizing shrinkage during drying. Among available techniques, hot-air oven drying at 50 °C-55 °C consistently produces superior colour retention and flower quality compared with traditional air drying (Akbar and Sahare, 2024). Embedding flowers in silica gel during drying further improves dehydration efficiency by minimizing moisture loss-induced deformation and preserving flower diameter, colour intensity, and fresh appearance. Although these techniques substantially improve product quality, commercial adoption depends on drying costs, energy requirements, and processing capacity.

4.3 Genetic and morphological improvements

Genetic improvement of gomphrena has increasingly relied on morphological evaluation and molecular characterization to identify superior breeding materials. Variability studies involving diverse genotypes have revealed substantial differences in vegetative growth, flowering behaviour, flower weight, branch number, and flower stalk length. High heritability estimates for these traits indicate that they can be effectively improved through selection, thereby providing opportunities for developing superior cultivars adapted to different production environments.

Molecular marker technologies have further strengthened breeding programmes by enabling accurate characterization of germplasm diversity. Inter-simple sequence repeat (ISSR) markers have detected approximately 67.76% polymorphism among gomphrena genotypes, demonstrating considerable genetic diversity for breeding improved cultivars with enhanced productivity, flower quality, and stress tolerance (Kumar et al., 2023).

4.4 Value addition and extraction

The commercial value of gomphrena extends beyond ornamental use because its flowers contain biologically active compounds with applications in food, pharmaceutical, and cosmetic industries. Recent advances in extraction technologies have focused on improving the recovery of natural pigments, particularly betacyanins, while maintaining their antioxidant activity. Ultrasonic-assisted extraction has proven more efficient than conventional extraction methods by improving pigment recovery, extraction efficiency, and product quality, making the extracts suitable for natural food colourants and functional food products such as cookies (Roriz et al., 2020).

Chemical profiling studies have also demonstrated that gomphrena flowers are rich sources of flavonoids, phenolic compounds, and other antioxidants possessing antimicrobial, anti-inflammatory, and enzyme inhibitory properties (Tang et al., 2022). These findings further expand the industrial potential of gomphrena beyond ornamental horticulture.

4.5 PGR innovation

Plant growth regulators have become valuable tools for improving vegetative growth, flowering, and post-harvest quality in gomphrena. Gibberellic acid (GA_3) promotes cell elongation, stem growth, and flower initiation by stimulating cell division and internode elongation, thereby increasing plant height, flower size, and marketable yield. Application of GA_3 at 150 ppm has been reported to provide optimum improvement in growth, flower yield, and post-harvest longevity (Sahoo, 2021). Likewise, NAA at 200 ppm accelerates flowering and prolongs the flowering period, whereas higher concentrations of maleic hydrazide reduce plant height by suppressing vegetative growth. Appropriate selection of plant growth regulators should therefore consider cultivar characteristics, production objectives, and environmental conditions to maximize productivity and flower quality.

4.6 High density planting

High-density planting (HDP) of *Gomphrena globosa* (globe amaranth) in greenhouses is an intensive production technique used to maximize the yield of cut flowers or potted plants per unit area. It focuses on utilizing vertical