

6.2 Nutritional regulation and functional feed application

Nutritional regulation has become more important because forage shortages are increasingly common, and supplemental feeding is now a routine management input during dearth or stressful production periods (Ricigliano et al., 2022; Bogaert et al., 2025). Reviews indicate that artificial feeding can serve as an alternative to migration and help maintain colony parameters well enough to benefit from the next floral-rich season, although no universally accepted balanced commercial diet yet exists (Paray et al., 2020). Experimental feeding studies show that diet composition strongly affects colony performance. In commercial colonies under extended forage dearth, artificial feed improved colony performance and health, and pollen-containing diets produced the largest colonies and the heaviest bees (Ricigliano et al., 2022). Other trials likewise found that soybean-enriched pollen substitute diets increased brood area, bee strength, foraging efficiency, and honey yield relative to control feeding (Ullah et al., 2021).

Current evidence also suggests that feed quality depends on specific nutrient balance rather than crude protein content alone. In one commercial study, diet macronutrient content was not correlated with colony size or health biomarkers, whereas essential amino acid deficiencies relative to leucine were associated with lower bee weight and smaller colonies. This supports a shift from generic supplementation toward functional feed design based on bioactive nutrient requirements and operation-specific goals (Ricigliano et al., 2022). Newer work indicates that nutritionally complete pollen-replacing diets can support brood production for much longer than standard commercial feeds when natural pollen is absent. A complete diet supported continuous brood production from May to October, whereas colonies on a commercial diet declined sharply in brood production after 36 days and died out. The same study identified isofucosterol as a critical micronutrient, because omitting it significantly reduced brood production and caused adult neuromuscular dysfunction (Bogaert et al., 2025).

6.3 Genetic improvement and queen bee management

Genetic improvement is increasingly treated as a practical management technology because it supports colony productivity, health, and adaptation while preserving locally suitable bee stocks (Maucourt et al., 2021). Modern breeding programs rely on breeding value estimation because environmental conditions strongly mask colony phenotype, so queen selection must separate hereditary merit from apiary effects.

Long-term breeding data show that this approach can improve commercially relevant traits. In a Canadian selection program, progress averaged 0.63 kg per year for honey production and 164 brood cells per year for spring development (Maucourt et al., 2021). Large-scale European breeding data similarly indicate considerable gains in honey yield and other desirable traits after the adoption of BLUP-based evaluation, without increased inbreeding coefficients.

Queen management is central to translating genetic gain into field performance because breeding success depends on accurate selection, standardized testing, and mating control. Standard methods emphasize that ranking queens by breeding value is the basis for improvement, and that controlled mating remains a major challenge because queens naturally mate with many drones over long distances. Queen and drone rearing, artificial insemination, and controlled mating stations therefore remain major tools for adapting colonies to changing environments, pests, and production demands.

Genomic tools now extend this framework by improving selection accuracy and supporting diversity management. Large-scale genomic prediction increased breeding value accuracy for honey yield compared with pedigree-based evaluation, and routine queen genotyping can also verify subspecies identity and monitor genetic diversity within breeding populations (Bernstein et al., 2022). Even so, evidence for molecular selection remains stronger for productivity and workability traits than for disease-related traits, so phenotypic testing still needs to be paired with genetic data across diverse environments.

7 Case Studies: Seasonal Management Practices in Commercial Honey Production

7.1 Spring management for maximizing acacia honey production

In acacia-based systems, spring management is most effective when colony buildup is completed before the short major bloom, because acacia often serves as the primary honey source and rewards strong colonies entering