

link between potassium supply and legume physiological performance. Field evidence from common bean further showed that crops responded strongly to combined phosphorus and potassium fertilization, reaching grain yields up to 3,600 kg/ha and requiring calibration of both nutrients even where soil tests suggested relatively high availability. However, potassium effects in *Canavalia* appear to be more pronounced in reproductive traits than in early vegetative growth. In jack bean, potassium source and timing did not significantly affect plant height, leaf number, or productive branches, although the study identified flower and pod drop as a major production constraint and recommended further work on potassium management during the generative phase (Eklems et al., 2025). Consistent with this, cowpea achieved its highest nodulation and grain yield when inoculation was combined with both phosphorus and potassium, showing that potassium is most effective when integrated with other nutrient and biological inputs rather than applied in isolation (Emmanuel et al., 2020).

3.3 Organic fertilizers and integrated nutrient management strategies

Integrated nutrient management generally outperforms sole reliance on mineral fertilizers because it improves nutrient availability, root-rhizosphere function, and fertilizer-use efficiency. In faba bean, the combined application of organic and inorganic fertilizers produced the highest yield when organic nitrogen accounted for about half of total nitrogen, and this treatment also increased seed nitrogen accumulation and nitrogen harvest efficiency (Liu et al., 2023). Similarly, French bean studies report broad agreement that integrated plant nutrient systems are superior to exclusive chemical-input strategies for sustaining production and soil health. The mechanism behind this advantage is that organic inputs create a more favorable rhizosphere for nodulation and nutrient assimilation while mineral inputs provide readily available nutrients during periods of rapid demand. In faba bean, the 50% organic treatment increased total nodule number by 52.5%, fresh nodule weight by 55.8%, and nitrate reductase activity by 70.7%, while integrated nutrient use in French bean was associated with higher growth and better yield attributes than unfertilized controls (Liu et al., 2023). This mechanism is highly relevant to sword bean, whose growth depends on balancing external nutrient supply with its inherent biological nitrogen-fixing capacity.

Recent legume research also supports combining organic amendments, inoculation, and moderate phosphorus rather than increasing single-input rates alone. In haricot bean, the sole and combined application of vermicompost, phosphorus, and *Rhizobium* significantly improved growth, yield, and nitrogen fixation, and the combination of 30 kg P/ha with 5 t vermicompos/ha gave the highest yield among tested treatments. Long-term practical recommendations from vegetable legumes point in the same direction, with integrated nutrient management treatments combining inorganic fertilizer with vermicompost producing the highest plant height, pod number, and yield under acidic soil conditions (Changkiri et al., 2023). For sword bean, integrated strategies are especially promising because they can reduce overdependence on mineral nitrogen while improving phosphorus availability and biological nutrient capture. Research on root-focused nutrient management in French bean argues that sustainable production requires combining chemical, organic, and biofertilizer sources, and that biofertilizers with organic manure enhance root biomass and nutrient absorption. Sword bean studies also show that mycorrhizal inoculation increased nitrogen uptake and that phosphorus uptake depended on its interaction with rock phosphate, supporting the view that coordinated nutrient and biological management is more effective than single-factor fertilization.

4 Effects of Water Management and Environmental Conditions on Sword Bean Growth

4.1 Responses of sword bean growth to water availability

Water availability strongly regulates legume growth, and sword bean is expected to follow the general pattern seen across related species in which water deficit suppresses vegetative development, photosynthetic function, and final productivity. In grain legumes, drought reduces leaf area, shoot and root growth, chlorophyll content, stomatal conductance, CO₂ influx, nutrient uptake, and water-use efficiency, while severe stress also causes stunted growth and damage to the photosynthetic apparatus (Khatun et al., 2021). Because sword bean is managed for vigorous canopy growth and prolonged reproductive development, these drought-driven reductions in assimilatory capacity are likely to translate directly into lower biomass accumulation and weaker yield formation