

and biological nitrogen fixation, while response size varies with species, soil organic carbon, and soil pH, indicating that management recommendations must be adapted to local conditions rather than generalized (Muoni et al., 2022). Parallel evidence from grain legumes shows that crop performance is also influenced by sowing density, irrigation, fertilization, tillage, and inoculation strategy, and that these factors interact with genotype and developmental stage to determine both yield and crop quality (Karavidas et al., 2022).

The available sword bean literature already points to several management-sensitive growth responses that justify dedicated study. Climatic adaptation is one major issue: sword bean tolerates drought better than many legumes but does not tolerate waterlogging, prolonged low temperatures during flowering reduce growth, and low light reduces flower and pod number; in cooler regions, transplanting may be needed to compensate for a shorter growing season. Experimental work also shows that management alters crop performance in more specific ways: moderate urea application changed forage quality more than biomass production, suggesting partial replacement of fertilizer N by biological fixation, while vesicular-arbuscular mycorrhiza and rock phosphate improved nutrient uptake pathways, especially nitrogen and phosphorus acquisition.

Research on sword bean growth has progressed, but it remains fragmented and much less developed than work on major legumes. Existing studies have examined seed production in non-native environments, forage production under nitrogen fertilization, nutrient uptake under mycorrhiza and phosphate application, and seed maturation physiology. These studies show, for example, that early cultivars can produce well-germinating seed under Polish conditions whereas late cultivars fail to mature fully, and that physiological seed maturity occurs around 80 days after anthesis with maximum germination and seed vigor at that stage. Even so, the crop remains underutilized and comparatively overlooked despite the recognized protein potential of *Canavalia* species and their possible contribution to future food strategies.

Against this background, the objective of a study on the growth characteristics of sword bean under different management practices is clear. A focused experiment can help determine how key agronomic variables influence vegetative growth, biomass accumulation, reproductive development, and yield formation in this species, while also clarifying which management combinations best express its potential under specific production conditions. Such work is needed because legume responses to management are often species- and environment-dependent, and because broader reviews show that improved agronomic practice, together with breeding and adaptation to stress conditions, is central to making legumes more productive and sustainable in modern agriculture.

2 Growth Characteristics and Physiological Development of Sword Bean

2.1 Morphological characteristics and growth dynamics

Sword bean is a vigorous climbing legume with a pronounced vegetative habit, and its morphology helps explain its adaptation to diverse tropical production systems. It is described as a perennial climbing plant with stems that can reach about 3-10 m, while its leaves are trifoliate and relatively large, supporting an expansive canopy during vegetative development. Broader agronomic descriptions likewise characterize sword bean as a tropical legume with favorable agronomic features and distinct morphological attributes, indicating that vegetative growth is one of its defining biological strengths .

Growth dynamics in sword bean show both species-level regularity and substantial genotypic variation. Field characterization of 20 genotypes found clear variation in days to germination, pod size, pod weight, and seed weight, with germination ranging from 3 to 6 days and pod length from 16.45 to 32.87 cm, which indicates that early establishment and subsequent structural development are strongly genotype-dependent (Debbarma et al., 2023). Quantitative growth analysis also showed that whole-plant weight increased early after sowing, leaf area expanded markedly after 50 days, and the reddish type expressed stronger early growth than the white type because specific leaf area, leaf area ratio, and leaf weight ratio were higher in the initial stage.

2.2 Photosynthetic characteristics and biomass accumulation

Sword bean appears to have strong biomass-forming ability because of its capacity to build large vegetative structures and convert intercepted radiation into dry matter. Agronomic work describes the crop as rapidly