

5.2 Effects of tillage and soil management practices

Tillage affects legume growth mainly through its effects on soil structure, aeration, moisture, temperature, and microbial activity, all of which influence nodulation and nitrogen fixation. Conservation tillage often improves soil quality and biological processes by preserving structure and microbial diversity, but its effects on performance are not universally positive because reduced tillage can also lower pH or increase compaction under some conditions. Across legume systems, conservation tillage tends to enhance nodulation and nitrogen fixation by improving soil moisture retention and microbial biomass. Residue retention strengthens this effect by conserving soil moisture, lowering soil temperature, and improving seed emergence, suggesting that sword bean growth may benefit most where reduced tillage is combined with mulch or retained residues rather than implemented alone (Virk et al., 2024).

However, field yield responses to tillage remain context-dependent. A three-year legume experiment found that no-till gave lower average yields (2.24 t/ha) than standard tillage (2.58 t/ha) and deep tillage (2.62 t/ha), and deep tillage also reduced soil stiffness and improved seed nitrogen content. Mediterranean evidence likewise notes contradictory year-to-year responses between conventional and conservation tillage, partly because plowing can improve drainage and spring warming in poorly drained soils, which may favor early crop growth in some environments. These mixed results indicate that the best soil management system for sword bean will depend on local constraints rather than ideology. Where moisture conservation, erosion control, and long-term soil biological quality are priorities, reduced tillage is likely advantageous, but where compaction or slow warming restricts establishment, some soil loosening may still be necessary (Virk et al., 2024). This is consistent with broader rotation evidence showing that tillage interacts with residue management and soil properties, so cultivation systems should be designed as integrated packages rather than as single isolated practices (Zhao et al., 2022).

5.3 Effects of intercropping and rotation systems

Intercropping and rotation improve legume-based systems by increasing biodiversity in space or time, which enhances soil fertility, pest regulation, and input efficiency while sustaining productivity (Liu et al., 2023). In global synthesis, legume-based rotations increased the main crop yield by 20% on average, and the benefits were strongest in low-input, low-diversity systems, which is highly relevant to sword bean as a multipurpose legume suited to sustainable production (Zhao et al., 2022).

Intercropping benefits arise partly from complementary resource capture. Vertical stratification reduces competition for light and nutrients, row and strip arrangements improve sunlight interception and resource distribution, and effective spatial design can raise yields by 10%~20% in intercrop systems (Akchaya et al., 2025). A broader meta-analysis also found that cereal-grain legume intercrops had higher yield stability than sole legume crops, with lower yield variation than the respective monocultures, indicating that sword bean intercropping could improve system reliability as well as mean output.

Rotation effects are not uniform, because the identity of the legume species, background fertility, and fertilization regime all shape the strength of the legacy effect on following crops (Zhao et al., 2022). In a seven-year field experiment, legume inclusion increased subsequent wheat yield by 52% without fertilization and 26% with fertilization, while also improving yield stability, resilience, and topsoil multifunctionality, showing that legume rotations can strengthen both productivity and soil performance over time (Liu et al., 2023).

At the same time, intercrops can impose early competition if species combinations or root interactions are poorly matched. Some systems showed a 15%~20% reduction in legume shoot dry matter during early growth, which means sword bean mixtures will require careful choice of companion crop, row arrangement, and planting density (Akchaya et al., 2025). Overall, the evidence favors intercropping and rotation as effective cultivation strategies for sword bean, especially when designed to exploit complementarity, reduce external inputs, and match local soil and climate conditions (Liu et al., 2023).

6 Case Study: Evaluation of Sword Bean Growth under Integrated Management Practices

6.1 Experimental design and management treatments