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DESAFIOS BIOTECNOLÓGICOS EM *CANNABIS SATIVA* L.: MICROPROPAGAÇÃO, QUALIDADE FITOSSANITÁRIA E CONSERVAÇÃO DE GERMOPLASMA

BIOTECHNOLOGICAL CHALLENGES IN *CANNABIS SATIVA* L.: MICROPROPAGATION, PHYTOSANITARY QUALITY, AND GERMPLASM CONSERVATION

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RESUMO

A produção comercial de *Cannabis sativa* L. enfrenta gargalos relacionados à sua produção em larga escala, qualidade fitossanitária e conservação de germoplasma. Os métodos convencionais de propagação vegetativa, ainda amplamente empregados, apresentam limitações para garantir materiais livres de patógenos, comprometendo a qualidade e a sustentabilidade da cadeia produtiva. A busca de informações científicas sobre os avanços gerados nos últimos anos com relação ao emprego de ferramentas biotecnológicas, estratégias fitossanitárias e técnicas de conservação de germoplasma aplicadas a essa espécie possibilitam identificar padrões, lacunas metodológicas e oportunidades para acelerar a transição do setor para práticas mais sustentáveis. Assim, procedeu-se uma busca bibliográfica nas bases *PubMed*, *Web of Science*, *Scopus* e *Google Scholar*, utilizando os descritores *Cannabis*, *Hemp*, *Plant tissue culture* e *micropropagation*. Do conjunto inicial de 169 trabalhos, 25 atenderam aos critérios de rigor e relevância temática, priorizando artigos originais em inglês publicados em periódicos de alto impacto. Os estudos convergiram ao indicar um cenário de baixa replicabilidade experimental. A espécie é classificada como recalcitrante para regeneração *de novo*, com respostas morfogenéticas influenciadas pelo genótipo, fato que compromete a universalização de protocolos. Apesar disso, avanços recentes relacionados a adoção da formulação nutritiva DKW, a suplementação de gluconato de cálcio no meio de cultura, ao emprego de micropropagação fotoautotrófica e o resfriamento basal do meio têm se mostrado estratégias eficazes para reduzir a hiperhidricidade, o distúrbio fisiológico mais recorrente nos cultivos *in vitro* da espécie. Com relação à qualidade fitossanitária de matrizes, a combinação entre as técnicas de cultura de meristemas e termoterapia se configura como a abordagem mais promissora para a eliminação de fitopatógenos importantes, tais como o hop latent viroid (HLVd, *Cocadviroid latenshumuli*), embora a eficácia varie amplamente entre cultivares. Para conservação de germoplasma, técnicas de criopreservação baseadas nas metodologias de vitrificação podem ser funcionalmente aplicadas, ainda que as taxas de regeneração pós-descongelamento também variem conforme o genótipo. O avanço sustentável da canabicultura brasileira depende da superação desses gargalos e da consolidação de

marcos regulatórios alinhados com a realidade produtiva do país. Protocolos padronizados, monitoramento molecular da estabilidade genética, combinações terapêuticas de limpeza de patógenos e o estabelecimento de bancos de germoplasma criopreservados surgem como prioridades estratégicas. Nesse contexto, a cultura de tecidos ocupa posição basilar na cadeia produtiva, oferecendo soluções robustas para a produção sustentável de material certificado, com qualidade genética, sanitária e farmacológica.

Palavras-chave: Biotecnologia Vegetal; Recursos Genéticos Vegetais; Propagação *in vitro*; Fitossanidade; Conservação.

ABSTRACT

Commercial production of *Cannabis sativa* L. faces bottlenecks related to large-scale production, phytosanitary quality, and germplasm conservation. Conventional methods of vegetative propagation, still widely employed, present limitations in ensuring pathogen-free materials, compromising the quality and sustainability of the production chain. The search for scientific information on advances generated in recent years regarding the use of biotechnological tools, phytosanitary strategies, and germplasm conservation techniques applied to this species enables the identification of patterns, methodological gaps, and opportunities to accelerate the transition of the sector toward more sustainable practices. Thus, a bibliographic search was conducted in the PubMed, Web of Science, Scopus, and Google Scholar databases using the descriptors Cannabis, hemp, plant tissue culture, and micropropagation. From the initial set of 169 records, 25 met the criteria of rigor and thematic relevance, prioritizing original articles in English published in high-impact journals. The studies converged in indicating a scenario of low experimental replicability. The species is classified as recalcitrant for *de novo* regeneration, with morphogenetic responses influenced by genotype, a factor that

compromises the universalization of protocols. Despite this, recent advances related to the adoption of the DKW nutrient formulation, the supplementation of calcium gluconate in the culture medium, the use of photoautotrophic micropropagation, and basal medium cooling have proven to be effective strategies to reduce hyperhydricity, the most recurrent physiological disorder in the *in vitro* culture of the species. Regarding the phytosanitary quality of stock plants, the combination of meristem culture and thermotherapy stands out as the most promising approach for the elimination of important phytopathogens, such as hop latent viroid (HLVd, *Cocadviroid latenshumuli*), although efficacy varies widely among cultivars. For germplasm conservation, cryopreservation techniques based on vitrification methodologies can be functionally applied, although post-thaw regeneration rates also vary according to genotype. The sustainable advancement of Brazilian cannabis cultivation depends on overcoming these bottlenecks and consolidating regulatory frameworks aligned with the country's production reality. Standardized protocols, molecular monitoring of genetic stability, combined pathogen-cleaning strategies, and the establishment of cryopreserved germplasm banks emerge as strategic priorities. In this context, plant tissue culture occupies a central position in the production chain, offering robust solutions for the sustainable production of certified material with genetic, sanitary, and pharmacological quality.

Keywords: Plant Biotechnology; Plant Genetic Resources; *In vitro* Propagation; Phytosanitary Quality; Conservation.

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