

Agronomic use of *biol* and its effects on soil quality and plant growth: A narrative synthesis with bibliometric analysis

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Supplementary material

SUPPLEMENTARY FILE S1 – Review Protocol

S1.1. Title of the Review

Agronomic Use of Biol and Its Effects on Soil Quality and Plant Growth: A Narrative Synthesis with Bibliometric Analysis

S1.2. Objectives

General Objective

To synthesize the scientific evidence (2000–2025) on the agronomic use of *biol*, its physicochemical and microbiological characteristics, and its effects on soil quality, germination and crop growth, using a narrative approach supported by a systematized search and bibliometric analysis.

Specific Objectives

1. To characterize the reported composition of *biol* (pH, EC, nutrients, microbial load).
2. To evaluate the effects of *biol* on soil physicochemical and biological properties.
3. To assess crop responses to *biol* application (germination, root development, biomass and yield).
4. To compare *biol* with chemical fertilizers in agronomic and environmental terms.
5. To identify bibliometric patterns and thematic clusters using VOSviewer based on an expanded corpus of studies on *biol* and liquid organic amendments.

S1.3. Research Questions

1. What physicochemical and microbiological properties of *biol* are reported in the literature?
2. How does *biol* affect soil quality indicators?
3. What effects does *biol* have on germination and plant growth?
4. How does *biol* compare with chemical fertilizers in terms of crop performance and soil quality?
5. What are the dominant thematic clusters and trends in research on *biol* and liquid organic amendments?

S1.4. Eligibility Criteria

Inclusion Criteria

- Original research articles.
- Experimental studies using *biol* or liquid effluents from anaerobic digestion (digestate, biogas effluent, liquid organic fertilizer) for agronomic purposes.
- Studies evaluating soil, crop or plant responses (germination, growth, yield, soil properties, microbial or enzymatic activity).
- Publications between 2000–2025.
- Articles in English, Spanish or Portuguese.
- Full text accessible (open access or institutional access).

Exclusion Criteria

- Reviews, theses, editorials, opinion pieces, conference abstracts without full papers.
- Biomedical, clinical or aquaculture studies not related to crops or soils.
- Studies focused exclusively on reactor design, energy production or wastewater treatment without agronomic/soil variables.
- Articles where “*biol*”, digestate or liquid organic fertilizer is mentioned but not experimentally evaluated.
- No full text available after a reasonable search.



S1.5. Information Sources and Search Strategy

Databases Searched

- Scopus
- SpringerLink
- PubMed
- SciELO

Additionally, targeted searches and citation chasing (backward and forward) were performed to identify key studies not captured by the initial search strings, especially in SciELO and regionally relevant journals.

Search Period

2000–2025

Boolean Search String (Scopus / SpringerLink / PubMed)

("biol" OR "liquid organic fertilizer" OR "digestate" OR "biogas effluent")

AND ("soil quality" OR "soil properties" OR "soil nutrients" OR "soil fertility")

AND ("crop growth" OR "plant growth" OR "Zea mays" OR "agricultural sustainability")

Alternative simplified strings (SciELO / testing)

- biol AND suelo AND cultivo
- digestate AND soil AND crop

These were complemented by manual identification of key journals and citation chasing.

S1.6. Search Output by Database

String-based search summary

- After merging Scopus (54) and SpringerLink (249): 303 records.
- After de-duplication: 295 unique records (N_string_total = 295).
- After title/abstract screening: 42 potentially eligible studies.
- After full-text reading: 15 included studies from the string-based search.

Database table

Database	Initial Records	After Database Filters*	After De-duplication	Eligible at Abstract Level	Included in Final Review**
Scopus	134	54	–	–	–
SpringerLink	5,074	249	–	–	–
PubMed	70	0	–	0	0
SciELO	0	0	–	0	0

* Filters for publication type, subject area and, when possible, open-access status.

** The detailed distribution of included studies by source is discussed in the main text.

Manual / targeted records

Source	Manually Identified	Included
Scopus (targeted search)	15	15
SciELO & regional journals	16	7

Final datasets

- From string-based searches: 15 studies
- From manual / targeted inclusion: 22 studies
- N_final_review = 37 studies (evidence synthesis)
- Expanded corpus for bibliometric analysis (VOSviewer): 64 articles

- o 42 records that reached full-text assessment in the automated pathway
- o 22 studies included from manual / regional searches

S1.7. Study Selection Procedure

1. Import of records from all databases into Zotero.
2. Application of database-level filters.
3. Merging + de-duplication → 295 unique string-based records.
4. Addition of 31 manual/targeted records and duplicate checking.
5. Title/abstract screening using inclusion/exclusion criteria → 42 potentially eligible studies.
6. Full-text reading for all potentially eligible studies.
7. Final selection for the evidence synthesis:
 - o 15 studies from the string-based (automated) search.
 - o 22 studies from manual/targeted searches.
 - o N_final_review = 37 studies.
8. Definition of the expanded corpus for bibliometric analysis:
 - o 42 articles that reached full-text assessment in the automated pathway.
 - o 22 included studies from the manual pathway.
 - o N_bibliometric = 64 articles.
9. Documentation of the process via a PRISMA-style flowchart (Fig. S1-1).

S1.8. PRISMA Flow Diagram (Figure 2 in the main article)

In the main article, Figure 2 presents a PRISMA-inspired flow diagram showing:

- Records identified from databases (Scopus, SpringerLink, PubMed, SciELO).
- Additional records from manual searches and citation chasing.
- 295 records after de-duplication.
- Records excluded at screening (title/abstract) and full-text levels.
- Final set for evidence synthesis: 15 string-based + 22 manual = 37 studies.
- Expanded corpus used exclusively for bibliometric mapping: 64 articles (42 + 22).

S1.9. Data Extraction Process

For each study included in the evidence synthesis:

- Bibliographic data (authors, year, country).
- Crop species and production system.
- Type and origin of *biol*.
- Fermentation substrates.
- Physicochemical parameters.
- Microbiological indicators.
- Experimental design.
- Soil indicators.
- Plant parameters.
- Comparisons with chemical fertilizers.
- Key findings and limitations.

S1.10. Quality Assessment Criteria

Assessed aspects:

- Clarity and completeness of methods.
- Transparency in *biol* preparation.
- Adequacy of experimental design.
- Statistical robustness.

- Reporting of biol composition and microbiology.
- Agronomic relevance.
- Potential sources of bias and missing information.

S1.11. Bibliometric Analysis Protocol

Software: VOSviewer 1.6.x

Steps:

1. Compilation of keywords from the 64-article bibliometric corpus (37 studies included in the review + 27 additional thematically related papers on liquid organic amendments and biodigester-derived effluents).
2. Cleaning, harmonization and normalization of author keywords.
3. Selection of the final set of terms (≈ 58).
4. Construction of the co-occurrence matrix.
5. Generation of network, overlay and cluster maps.

Expected clusters:

1. Organic amendments and waste management.
2. Soil quality and biogeochemical processes.
3. Crop response and productivity.

S1.12. Synthesis of Evidence

Narrative synthesis structured into:

- Soil-focused effects.
- Plant-focused effects.
- Comparisons with chemical fertilizers.
- Identification of critical research gaps.

S1.13. Limitations of the Protocol

- Heterogeneous methodologies across studies.
- Limited standardization in biol characterization.
- SciELO string-based search retrieved no records, although relevant articles were identified through manual searching.
- Heterogeneity constrains the implementation of a formal meta-analysis.
- Possible under-representation of non-indexed local studies.

S1.14. Ethical Considerations

No human or animal research was directly involved in this review.

S1.15. Registration

Internal documentation only (not registered in public repositories).