Supplementary File S1

Search strategy for the critical narrative review

Moniliophthora roreri in Cacao: An Evidence-Calibrated Synthesis from Population Biology and Molecular Pathogenicity to Epidemiology and Adaptive Disease Management

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1 Review scope and evidence horizon

This supplement describes the structured manual search and evidence-appraisal approach used for the critical narrative review of *Moniliophthora roreri* and frosty pod rot of cacao. The objective was mechanistic integration across heterogeneous biological and applied domains, rather than exhaustive retrieval or quantitative pooling. The search cutoff was 20 August 2026, with no strict lower publication-date limit. Publications in English, Spanish and Portuguese were considered, and recent primary research received particular attention.

Scopus, Web of Science Core Collection and PubMed/MEDLINE were supplemented by Google Scholar, backward and forward citation tracking, and relevant technical and official phytosanitary sources. Core terms were combined with the eight thematic groups in Appendix A of the manuscript.

2 Interpretation of the search strings

The database-specific strings in Section 4 are documented retrospective reconstructions from the term groups in Appendix A of the manuscript. They are not verbatim, timestamped historical query logs. Exact run dates, interface settings and filters were not systematically archived. No new search or retrieval totals are represented by these reconstructions.

Search results overlapped across sources and were assembled iteratively. Counts of retrieved, de-duplicated, screened and excluded records were not prospectively registered; they cannot be reconstructed from the final bibliography alone. No PRISMA record-flow diagram, pooled effect estimate or inter-reviewer agreement statistic is claimed.

2a Source and claim traceability

Table S1 maps all 69 included references to their design, material, finding used, citing location, evidence scope and principal inferential limit. Table S2 links evidence-sensitive claims to current reference numbers, calibration and a proposed decisive future test. Table S3 provides an author-proposed phenotyping reporting template, which is non-validated and non-mandatory.

3 Databases, screening and eligibility

Database and source roles are described below. The table below summarises the contribution of each source to the search process.

Source	Role
Scopus	Primary multidisciplinary coverage of plant pathology, mycology, molecular biology and agricultural literature.
Web of Science Core Collection	Parallel bibliographic coverage and forward citation tracking.
PubMed and MEDLINE	Complementary molecular, genomic and diagnostic literature.
Google Scholar	Additional discovery and cross-checking of academic, technical and official sources. Retrieval does not imply eligibility of all grey literature.
Citation tracking	Backward reference-list checks and forward citation checks from key studies.
Technical and phytosanitary sources	Official status, quarantine and surveillance information, and retrievable technical protocols and catalogues.

3a Screening and resolution of disagreements

Title and abstract screening was followed by full-text assessment. Y.Y.P.-R. and L.A.R.-P. screened independently. Disagreements about inclusion or claim calibration were resolved by discussion and, when consensus was not reached, by A.J.-O., as described in Section 2 of the manuscript.

3b General inclusion and exclusion criteria

Eligible sources provided original data, an authoritative synthesis, or an official phytosanitary or methodological document directly relevant to one or more review domains. Comparative or methodological sources from other pathosystems were eligible when needed to interpret a specific FPR question and were explicitly labelled as context or analogy.

Sources were excluded when they duplicated already included data, lacked sufficient methodological description to judge the inference, were conference abstracts or non-peer-reviewed reports without retrievable data, or addressed another cacao pathogen without an explicit comparative purpose. Official documents and retrievable technical protocols were eligible exceptions to the non-peer-reviewed-report exclusion. Ineligible extrapolations were corrected at claim level; a comparative source was not excluded simply because it lacked M. roreri validation.

4 Search strings by thematic domain

Taxonomy and reproductive biology

Representative terms (Appendix A, Table A1): taxonomy; phylogeny; Moniliophthora; basidiomycete; mating type; sporogenesis; conidia.

Scopus

TITLE-ABS-KEY("Moniliophthora roreri" OR "frosty pod rot") AND TITLE-ABS-KEY(taxonomy OR phylogeny OR Moniliophthora OR basidiomycete OR "mating type" OR sporogenesis OR conidia)

Web of Science Core Collection

TS=("Moniliophthora roreri" OR "frosty pod rot") AND TS=(taxonomy OR phylogeny OR Moniliophthora OR basidiomycete OR "mating type" OR sporogenesis OR conidia)

PubMed/MEDLINE

("Moniliophthora roreri"[Title/Abstract] OR "frosty pod rot"[Title/Abstract]) AND (taxonomy[Title/Abstract] OR phylogeny[Title/Abstract] OR Moniliophthora[Title/Abstract] OR basidiomycete[Title/Abstract] OR "mating type"[Title/Abstract] OR sporogenesis[Title/Abstract] OR conidia[Title/Abstract])

Population genetics and genomics

Representative terms (Appendix A, Table A1): population structure; clonality; SSR; SNP; AFLP; ISSR; genome; structural variation; founder effect.

Scopus

TITLE-ABS-KEY("Moniliophthora roreri" OR "frosty pod rot") AND TITLE-ABS-KEY("population structure" OR clonality OR SSR OR SNP OR AFLP OR ISSR OR genome OR "structural variation" OR "founder effect")

Web of Science Core Collection

TS=("Moniliophthora roreri" OR "frosty pod rot") AND TS=("population structure" OR clonality OR SSR OR SNP OR AFLP OR ISSR OR genome OR "structural variation" OR "founder effect")

PubMed/MEDLINE

("Moniliophthora roreri"[Title/Abstract] OR "frosty pod rot"[Title/Abstract]) AND ("population structure"[Title/Abstract] OR clonality[Title/Abstract] OR SSR[Title/Abstract] OR SNP[Title/Abstract] OR AFLP[Title/Abstract] OR ISSR[Title/Abstract] OR genome[Title/Abstract] OR "structural variation"[Title/Abstract] OR "founder effect"[Title/Abstract])

Molecular pathogenicity

Representative terms (Appendix A, Table A1): secretome; effector; CAZyme; transcriptome; gene expression; biotrophy; necrotrophy.

Scopus

TITLE-ABS-KEY("Moniliophthora roreri" OR "frosty pod rot") AND TITLE-ABS-KEY(secretome OR effector OR CAZyme OR transcriptome OR "gene expression" OR biotrophy OR necrotrophy)

Web of Science Core Collection

TS=("Moniliophthora roreri" OR "frosty pod rot") AND TS=(secretome OR effector OR CAZyme OR transcriptome OR "gene expression" OR biotrophy OR necrotrophy)

PubMed/MEDLINE

("Moniliophthora roreri"[Title/Abstract] OR "frosty pod rot"[Title/Abstract]) AND (secretome[Title/Abstract] OR effector[Title/Abstract] OR CAZyme[Title/Abstract] OR transcriptome[Title/Abstract] OR "gene expression"[Title/Abstract] OR biotrophy[Title/Abstract] OR necrotrophy[Title/Abstract])

Diagnostics

Representative terms (Appendix A, Table A1): PCR; qPCR; LAMP; RPA; biosensor; molecular detection; spore trap.

Scopus

TITLE-ABS-KEY("Moniliophthora roreri" OR "frosty pod rot") AND TITLE-ABS-KEY(PCR OR qPCR OR LAMP OR RPA OR biosensor OR "molecular detection" OR "spore trap")

Web of Science Core Collection

TS=("Moniliophthora roreri" OR "frosty pod rot") AND TS=(PCR OR qPCR OR LAMP OR RPA OR biosensor OR "molecular detection" OR "spore trap")

PubMed/MEDLINE

("Moniliophthora roreri"[Title/Abstract] OR "frosty pod rot"[Title/Abstract]) AND (PCR[Title/Abstract] OR qPCR[Title/Abstract] OR LAMP[Title/Abstract] OR RPA[Title/Abstract] OR biosensor[Title/Abstract] OR "molecular detection"[Title/Abstract] OR "spore trap"[Title/Abstract])

Epidemiology

Representative terms (Appendix A, Table A1): disease progress; dispersal; climate suitability; inoculum; sporulation; incidence.

Scopus

TITLE-ABS-KEY("Moniliophthora roreri" OR "frosty pod rot") AND TITLE-ABS-KEY("disease progress" OR dispersal OR "climate suitability" OR inoculum OR sporulation OR incidence)

Web of Science Core Collection

TS=("Moniliophthora roreri" OR "frosty pod rot") AND TS=("disease progress" OR dispersal OR "climate suitability" OR inoculum OR sporulation OR incidence)

PubMed/MEDLINE

("Moniliophthora roreri"[Title/Abstract] OR "frosty pod rot"[Title/Abstract]) AND ("disease progress"[Title/Abstract] OR dispersal[Title/Abstract] OR "climate suitability"[Title/Abstract] OR inoculum[Title/Abstract] OR sporulation[Title/Abstract] OR incidence[Title/Abstract])

Resistance and breeding

Representative terms (Appendix A, Table A1): QTL; GWAS; genomic prediction; clone; resistance; tolerance.

Scopus

TITLE-ABS-KEY("Moniliophthora roreri" OR "frosty pod rot") AND TITLE-ABS-KEY(QTL OR GWAS OR "genomic prediction" OR clone OR resistance OR tolerance)

Web of Science Core Collection

TS=("Moniliophthora roreri" OR "frosty pod rot") AND TS=(QTL OR GWAS OR "genomic prediction" OR clone OR resistance OR tolerance)

PubMed/MEDLINE

("Moniliophthora roreri"[Title/Abstract] OR "frosty pod rot"[Title/Abstract]) AND (QTL[Title/Abstract] OR GWAS[Title/Abstract] OR "genomic prediction"[Title/Abstract] OR clone[Title/Abstract] OR resistance[Title/Abstract] OR tolerance[Title/Abstract])

Biological control

Representative terms (Appendix A, Table A1): Trichoderma; endophyte; antagonist; biocontrol; microbiome.

Scopus

TITLE-ABS-KEY("Moniliophthora roreri" OR "frosty pod rot") AND TITLE-ABS-KEY(Trichoderma OR endophyte OR antagonist OR biocontrol OR microbiome)

Web of Science Core Collection

TS=("Moniliophthora roreri" OR "frosty pod rot") AND TS=(Trichoderma OR endophyte OR antagonist OR biocontrol OR microbiome)

PubMed/MEDLINE

("Moniliophthora roreri"[Title/Abstract] OR "frosty pod rot"[Title/Abstract]) AND (Trichoderma[Title/Abstract] OR endophyte[Title/Abstract] OR antagonist[Title/Abstract] OR biocontrol[Title/Abstract] OR microbiome[Title/Abstract])

Integrated disease management

Representative terms (Appendix A, Table A1): sanitation; fungicide; integrated management; cultural control.

Scopus

TITLE-ABS-KEY("Moniliophthora roreri" OR "frosty pod rot") AND TITLE-ABS-KEY(sanitation OR fungicide OR "integrated management" OR "cultural control")

Web of Science Core Collection

TS=("Moniliophthora roreri" OR "frosty pod rot") AND TS=(sanitation OR fungicide OR "integrated management" OR "cultural control")

PubMed/MEDLINE

("Moniliophthora roreri"[Title/Abstract] OR "frosty pod rot"[Title/Abstract]) AND (sanitation[Title/Abstract] OR fungicide[Title/Abstract] OR "integrated management"[Title/Abstract] OR "cultural control"[Title/Abstract])

5 Domain-specific eligibility and appraisal

The following operational criteria apply the general eligibility rules to each domain. They guide interpretation of included evidence rather than constitute a validated numerical quality score.

Taxonomy and reproductive biology

Include phylogenetic, morphological, cytological and mating-locus evidence relevant to species placement or reproductive mode. Retain superseded interpretations for historical context. Distinguish asexual sporogenesis and mating potential from demonstrated realised sex, and examine the scope of recombination tests.

Population genetics and genomics

Include marker surveys, genome resources and comparative or demographic studies bearing on diversity, structure, clonality or expansion. Appraise sample size, geographical coverage, marker resolution, clone correction and correspondence between datasets. Methodological sources supply tests, not M. roreri population results.

Molecular pathogenicity

Include genomic, expression, physiological and functional studies relevant to infection or host response. Separate predicted repertoire, expression, heterologous activity, recombinant host activity and pathogen-side genetic causation. Evaluate stage, host background, replication, controls and biomass confounding.

Diagnostics

Include assay development or validation in M. roreri and explicitly relevant comparative technologies. Appraise target specificity, matrices, controls, detection limits and external validation. Distinguish DNA detection from viability, infection competence and operational readiness.

Epidemiology

Include natural-infection cohorts, environmental studies, distribution or process models, dispersal evidence and official status documents. Appraise temporal origin, host cohorts, environmental lags and validation. Comparative dispersal and host-suitability models cannot establish direct FPR dispersal or realised disease risk.

Resistance and breeding

Include inoculation trials, QTL and association studies, genomic prediction and retrievable deployment records. Appraise host and isolate coverage, pod stage, replication, environmental exposure and transferability. Natural-incidence differences alone cannot establish resistance independently of disease escape.

Biological control

Include antagonism, agent, formulation, community and field studies relevant to FPR. Appraise ecological context, host dependence, persistence, controls and endpoints. In vitro inhibition does not establish field control; community association is distinct from community manipulation.

Integrated disease management

Include sanitation, cultural, chemical, biological and integrated trials, with retrievable economic or modelling analyses. Appraise comparator, duration, site, scale, environmental context, disease, sporulation, yield, labour and costs. Retain local effects within their study context; no universal removal or spray interval is inferred.

6 Evidence inventory and calibration

The included evidence base contains 69 sources: 65 peer-reviewed journal articles, one edited reference volume [25], one official phytosanitary document [41] and two technical documents, a clone catalogue [58] and an inoculation protocol [68]. Thirty-four sources were published in 2020 or later and twenty-five in 2023 or later. These are counts of included sources, not records retrieved or screened.

Fifty-seven sources address M. roreri or the FPR pathosystem, including syntheses and technical documents. Twelve are comparative or methodological sources [18,19,33,36–40,44,45,47,69]. These scope labels do not imply that every FPR-specific source provides direct experimental evidence for every claim. Reference numbers refer to the current manuscript bibliography and Table S1.

6a Claim calibration

Term	Meaning for the stated claim
Demonstrated	Direct experimental or field evidence for the specified mechanism or outcome in M. roreri or the cacao–FPR system.
Supported	Convergence of independent or complementary evidence supporting the same conclusion.
Suggested	Association, restricted replication, comparative inference or surrogate-system evidence that increases plausibility without establishing causation.
Hypothesised	A biologically plausible proposition not directly tested in M. roreri, including proposed frameworks whose performance remains unvalidated.

6b Narrative synthesis and limits

Evidence was synthesised first within domains and then across domains to identify convergence, conflicting interpretations and unresolved causal links. No pooled effect-size analysis or formal study-design hierarchy was applied. Calibration concerns individual claims and retains the original biological, geographical and experimental scope of the cited evidence.

The review is not a registered systematic review or a PRISMA-equivalent retrieval process. Manual iterative searching and narrative selection remain potential sources of selection and interpretation bias. Source-level and claim-level traceability improve auditability without making retrieval exhaustive or retrospectively recovering missing search-history records.