Mycromist: A Pilot Greenhouse Study of an Integrated Biochar–Hydrogel–Microbial Amendment for Post-Fire Soil Restoration

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Abstract

We evaluated Mycromist, a biochar–polymer–microbial amendment, in a 54-day greenhouse pilot using soil from a controlled burn in Pleasanton, California. Fifteen boxes seeded with Bermuda grass (*Cynodon dactylon*) received no amendment or one of two complete formulations differing in polymer base (five boxes per treatment). Treated boxes received approximately 120 g once at the start. All boxes followed the same watering schedule. Descriptive analyses used available-box daily means, with 794 moisture readings across 53 observed days. Moisture-index slopes were −0.0647, −0.0346, and −0.0129 index units per day for control, formulation A, and formulation B, respectively; corresponding mean indices were 5.29, 5.54, and 5.63. Mean pH values were similar. Fertility-meter categories were summarized as ordinal observations rather than nutrient concentrations; coded daily means suggested declining control readings and comparatively stable treated readings, but their magnitude depends on the coding. Recorded group-level canopy heights were 8.6, 12.8, and 13.5 inches, respectively, giving descriptive contrasts of approximately 49% and 57%. No inferential treatment tests were performed. Microbial establishment, component interactions, and field performance were not measured. These preliminary observations motivate component-controlled experiments with laboratory soil assays and practical application rates.

Keywords: biochar; polymer soil amendment; microbial inoculants; fire-affected soil; greenhouse pilot; descriptive analysis.

1 Introduction

Fire can alter soil organic matter, nutrient pools, aggregation, microbial communities, and water repellency. The direction and magnitude of these changes depend on fire severity, soil properties, and subsequent environmental conditions [1, 2, 3, 4]. Consequently, soil collected from a controlled burn provides a relevant substrate for a pilot experiment but cannot automatically represent soils affected by high-severity wildfire.

Biochar, water-retaining polymers, and microbial inoculants offer potentially complementary approaches to soil amendment. Biochar can influence soil chemical and physical properties, hydrogels can modify water availability, and some microbial inoculants can influence plant nutrition and growth under suitable conditions [5, 6, 7, 8, 9, 10, 11, 12, 15, 16]. These functions provide a rationale for testing a combined formulation; they do not establish that the components will act synergistically or that introduced organisms will establish in a particular soil.

Mycromist is a student-developed granule combining a biochar-based carrier, a polymer base, and fungal and bacterial inoculants. This study evaluates two complete Mycromist formulations against untreated fire-affected soil in a small greenhouse experiment. Its contribution is a formulation-specific, longitudinal proof-of-concept comparison, rather than a claim that combining these amendment classes is unprecedented. We describe soil-meter trajectories and early vegetation observations over 54 days, while distinguishing measured outcomes from untested mechanisms and potential applications.

2 Related Work and Scope of the Contribution

2.1 Fire-affected soils

Reviews document substantial variation in the effects of fire on soil chemistry, belowground processes, water repellency, and aggregation [1, 2, 3, 4]. Such variation makes substrate characterization and replication across soils important for restoration research. The present experiment used homogenized soil from one controlled-burn site and did not measure burn severity, soil texture, organic carbon, or laboratory nutrient concentrations.

2.2 Biochar and water-retaining polymers

Biochar research describes possible changes in nutrient retention, soil structure, and microbial habitat [5, 6, 7]. A meta-analysis of crop productivity also emphasizes variation among soils and experimental conditions [8]. Amazonian terra preta informs the historical discussion of charcoal-rich fertile soils, but the term does not itself specify the composition or properties of a commercial carrier [5]. Here, "terra preta" is retained only as the material label recorded for the study's biochar-based carrier; its composition was not independently characterized.

Reviews of superabsorbent polymers describe their capacity to absorb water and their possible agricultural uses [9, 10]. Such material properties do not establish improved plant-available water or field performance for every polymer–soil combination. In this trial, moisture was measured with a field-meter index, rather than by gravimetric water content or a water-retention curve.

2.3 Microbial inoculants

Arbuscular mycorrhizal fungi (AMF) can contribute to plant nutrition and soil aggregation, while plant-growth-promoting bacteria and *Trichoderma* species have additional potential functions [11, 12, 13, 15, 16, 17, 18]. Restoration literature also considers AMF inoculation in degraded lands [14]. These studies motivate including inoculants in an experimental formulation, but their reported functions cannot be assumed to have occurred here. In particular, inclusion of a *Rhizobium*-labelled product does not demonstrate nitrogen fixation in Bermuda grass. Inoculant viability, root colonization, microbial abundance, nutrient cycling, and pathogen suppression were not assessed.

2.4 Specific research contribution

Combined amendments already form an established research area. A review of biochar co-applied with other amendments provides a relevant comparison and underscores the need to consider formulation and context [19]. We therefore make no priority claim for integrating biochar, polymers, and microbial inoculants. The narrower contribution is evaluation of the particular Mycromist preparations on controlled-burn soil, with repeated monitoring of treatment-level trajectories over 54 days. The untreated control permits a comparison of the complete formulations, but the absence

of component-only treatments prevents attribution to individual ingredients or demonstration of synergy.

3 Research Objectives

The exploratory questions were whether the complete formulations differed descriptively from untreated soil in (i) moisture-index trajectories, (ii) fertility-meter category trajectories, (iii) pH and temperature, and (iv) germination observations and final group-level canopy height. A secondary question was whether the two polymer-base formulations showed different descriptive patterns. No inferential tests were performed, and the experiment was not designed to establish component mechanisms. Because all boxes followed the same watering schedule, the study did not independently test drought-stress conditions or water-use efficiency.

4 Materials and Methods

4.1 Soil source

Soil was collected in July 2025 from a controlled-burn site in Pleasanton, California. The collection area was visibly charred and ash-laden. The soil was transported to the greenhouse, homogenized, and distributed in equal volumes among 15 boxes. Fire severity and baseline laboratory soil chemistry were not measured. Approximate untreated field-meter readings reported during the trial were pH 5.9 and moisture index 5.3; these are not pre-treatment laboratory characterizations. Texture, organic matter, cation-exchange capacity, and separate nitrogen, phosphorus, and potassium concentrations remain uncharacterized.

4.2 Site, design, and control

The trial took place in a greenhouse at Wallis Ranch Hills, Dublin, California. Fifteen plywood boxes, each $12 \times 12 \times 5$ inches, formed three groups of five: untreated control (C1–C5), Mycromist formulation A (A1–A5; Ecovia Gel), and formulation B (B1–B5; Ecovia Base). Bermuda grass (*Cynodon dactylon*) was seeded at approximately $1.2\,\mathrm{g\,ft^{-2}}$. The box was the experimental unit; repeated daily readings did not increase the number of independent experimental units beyond five per treatment.

Both treated groups received the complete formulation, and controls received no amendment. The A–B comparison concerns the two complete preparations differing in polymer base; it does not isolate a polymer mechanism or its interaction with the remaining ingredients. Random allocation of positions and rotation of boxes were not documented in the available study records. Possible position effects therefore remain a source of confounding.

4.3 Formulation and application

Each treated box received approximately 120 g of granules, mixed during preparation and applied once at the beginning of the trial. The preparation notes list a biochar-based carrier labelled "terra preta," an Ecovia polymer base, AMF-labelled material, and minor additions labelled *Rhizobium* sp. and *Trichoderma harzianum*. The study identifies formulation A with Ecovia Gel/AzuraGel and formulation B with Ecovia Base/AzuraBase. The recorded material description identifies A as a cross-linked γ-polyglutamic-acid material and B as a linear, non-cross-linked γ-polyglutamic-acid material. Accordingly, we use "polymer base" for the A–B comparison rather than assuming that



Figure 1: Experimental greenhouse setup showing boxes containing homogenized fire-affected soil before seeding.

both materials are structurally equivalent hydrogels. Material identities and specifications require confirmation against the supplied product documentation.

The nominal formulation comprised approximately 85% terra preta, 10% polymer base, 3% and 2% AMF-labelled inoculant materials, and 1% each of *Rhizobium* and *Trichoderma harzianum*. These proportions were rough preparation estimates rather than measured final mass fractions. Their approximate total of 102% therefore does not represent an exact mass balance, and the values have not been normalized or presented as precise dosing measurements. The recorded AMF names (*Rhizophagus intraradices/irregularis* and *Glomus intraradices*) still require confirmation against product labels and do not establish that two distinct taxa were used. Strain identities, individual ingredient masses, and inoculum densities were not independently verified; inoculant viability was not assayed. These gaps limit formulation reproducibility and mechanistic interpretation.

4.4 Watering and monitoring

All boxes followed the same watering schedule: approximately 1.5 cups daily during weeks 1–2, followed by 3 cups every two days. Cup measurements are retained as reported because a calibrated volume was not specified. The intended daily observations over 54 days were soil-moisture index (0–10 field-meter scale), soil temperature (°F), electronic-meter pH, and an ordinal fertility-meter category. Meter models, calibration records, sampling depth, measurement timing relative to watering, and greenhouse environmental logs were not available for verification. Light readings were also recorded, but their units and measurement protocol were not documented; they were not used as a quantitative outcome.

Germination was noted observationally. Final canopy height was recorded as one group-level average for each treatment; the underlying per-box heights were not available. The method used to calculate each group average was not described, so these values cannot estimate between-box variability.

4.5 Data completeness and processing

The planned sampling frame was $15 \times 54 = 810$ box-days. The exported measurement sheet contains 809 listed rows, including 15 rows marked N/A for all boxes on day 41; A2 on day 6 is absent. Thus, there are 794 box-days with at least one recorded soil-variable reading, rather than 809 valid observations. Day 41 was missed for all boxes. For C2–C4 on day 4, moisture values were recorded but temperature, pH, and fertility were marked X. These unavailable readings were excluded only from the affected variables, without imputation.

One pH entry (C3, day 20) is written as "5..8" and was excluded from numeric pH analysis rather than assigned a guessed correction. Five fertility labels are outside the study's coding key: H2 (B5, day 14), LH (A2, day 17), L-L2 (A3, day 18), H, (B5, day 22), and L? (C4, day 53). They were retained in the transcription but excluded from coded fertility summaries. The resulting usable counts are 794 for moisture, 791 for temperature, 790 for pH, and 786 for classified fertility (Table 1). Each treatment has an available daily summary on 53 days; the original calendar-day indices were retained in fitting temporal trends.

Table 1: Usable individual box-level readings after variable-specific exclusions. These repeated readings are not independent experimental replicates; each treatment contains five boxes. The planned count was 270 readings per treatment per variable.

Variable	Control	A	B	Total
Moisture index	265	264	265	794
Temperature	262	264	265	791
pH	261	264	265	790
Classified fertility	261	262	263	786

All soil-variable summaries in this revision were recalculated from the exported measurement sheet. Raw text entries were preserved alongside numeric fields in a transcription. Per-page box-row inventories were cross-checked with a second PDF text extractor, and pages containing unusual entries were visually inspected. The transcription, daily means, exclusion rules, and analysis script are included in the accompanying editable project.

4.6 Descriptive analysis and experimental units

For continuous variable x, let $I_{g,t}$ be the set of boxes in treatment g with an available numeric reading on day t. The treatment daily mean is

$$\bar{x}_{g,t} = \frac{1}{n_{g,t}} \sum_{i \in I_{g,t}} x_{i,t}, \qquad n_{g,t} = |I_{g,t}|. \tag{1}$$

The denominator is five only when all readings are available. The trial-wide treatment mean is the unweighted mean of its 53 available daily means, so each observed day receives equal weight. A least-squares line fitted against the actual calendar day yields an exploratory slope:

$$\bar{x}_{g,t} = \alpha_g + \beta_g t + e_{g,t}. \tag{2}$$

Here β_g describes change in the meter variable per calendar day over the shared watering regime. It is not a controlled drying-cycle rate, a mechanistic parameter, or a statistically tested treatment effect. Daily observations are repeated measurements and may be serially correlated. The independent experimental units are the boxes, with five assigned to each treatment. No p-values, confidence

intervals, or claims of statistical significance are reported. The slope summary displays one daily-series coefficient per treatment, without box-level points or error bars.

The fertility labels were coded using the study key: L1 → 1, L2 → 2, LM → 4, MM → 6, HM → 7, Low Much → 8, Middle Much → 9, and High Much → 10. The unusual "Much" labels are retained verbatim from the records. These are ordinal, study-specific codes with unequal gaps, not equal increments in fertility or measured N–P–K concentrations. Their correspondence to a manufacturer-defined scale has not been independently verified.

For consistency with the original analysis, the revised diagnostic time series uses the arithmetic mean of available fertility codes per treatment per day, not the median. This reproduces the direction and approximate magnitude of the original coded trends, but does not establish the exact operations used in the original code, which was not available. Code means are reported only as an exploratory pattern whose magnitude can change under a different coding. Numerical fertility slopes are omitted from the main results. Label frequencies are presented directly, and pooled medians are identified explicitly as medians of all classified box-day observations under the study ordering, rather than medians of daily means. Because label frequencies pool repeated readings, they are descriptive counts and are not used in an independent-samples significance test.

Recalculation used Python, pandas, and NumPy; figures used Matplotlib [20, 22]. The original manuscript also identified SciPy as an analysis tool [21]. Previously reported SDs and CVs are not retained because their aggregation basis could not be verified. No new inferential analysis was conducted.

5 Results

Five boxes were assigned to each treatment. The soil-variable results below use the variable-specific available counts in Table 1 and 53 daily summaries per treatment. Plant observations are retained as recorded group-level or qualitative observations.

5.1 Trial-wide summaries

Mean daily moisture indices over the trial were 5.29 for control, 5.54 for A, and 5.63 for B (Table 2). Mean pH values were similar (5.91, 5.85, and 5.83). Mean temperatures were 78.6, 79.3, and 79.1 °F. These small mean contrasts do not establish statistically distinct treatment responses, and position effects were not excluded. Under the study's fertility ordering, the pooled median class was LM for control and MM for A and B. This corrects the earlier statement that every treatment had median class MM.

Table 2: Recalculated soil-variable summaries and recorded canopy heights. Continuous-variable means are the unweighted means of 53 treatment daily means. Fertility medians pool all classified box-day readings under the study ordering and are descriptive. Canopy height is one recorded average per group, without per-box variability estimates.

Measurement	Control	A	B
Mean moisture index (0–10)	5.29	5.54	5.63
Mean pH	5.91	5.85	5.83
Mean soil temperature (°F)	78.6	79.3	79.1
Pooled median fertility category	LM	MM	MM
Final group-level canopy height (in)	8.6	12.8	13.5

5.2 Moisture-index trajectories

Recalculated treatment-level slopes were −0.0647 index units per day for control, −0.0346 for A, and −0.0129 for B (Table 4; Figs. 2 and 3). The descriptive A–control slope contrast was +0.0301 index units per day, and the B–control contrast was +0.0519. The updated values reflect the variable-specific exclusions and available-box daily means described in Methods. The trajectories are consistent with a slower decline in the moisture-meter index in the treated groups under the shared watering schedule. They do not establish a difference in volumetric water content, water-use efficiency, or plant-available water.

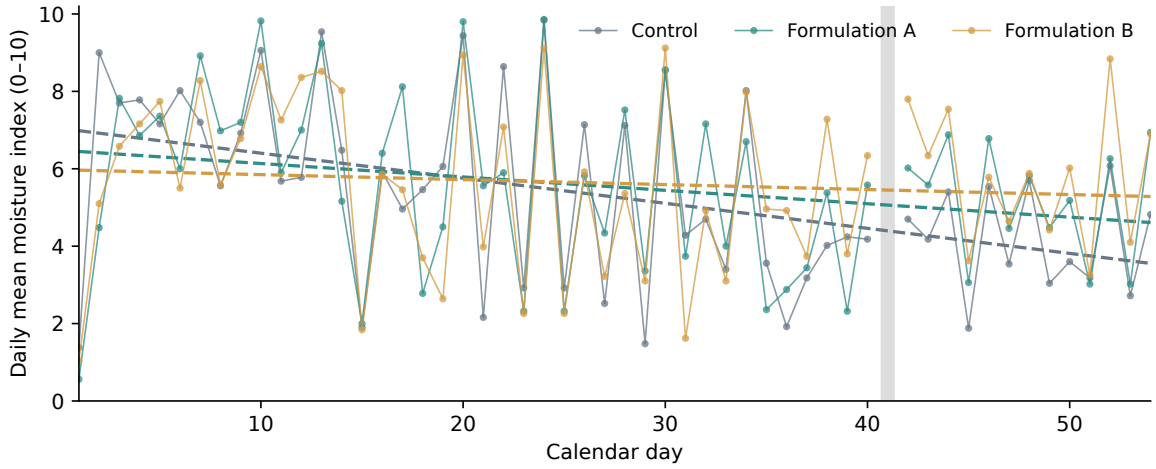


Figure 2: Treatment daily-mean moisture indices (points and thin lines) and descriptive least-squares trends (dashed lines). There are 53 observed days per treatment. Day 41 is missing and is not interpolated; actual calendar-day indices are used for fitting. A2 on day 6 is absent, so formulation A's daily mean on that day uses four boxes. Lines are visual guides, not confidence intervals.

5.3 Fertility-meter categories

The coded daily means showed a downward fitted direction for control and near-flat, slightly positive directions for A and B. This description is conditional on the study's unequal ordinal coding and is not a rate of nutrient change. Table 3 provides the actual classified-label frequencies; the most common label was LM in control and A, and MM in B. These summaries do not demonstrate improved N, P, or K concentrations or microbial nutrient cycling.

5.4 pH and temperature

Recalculated pH slopes were +0.0110, +0.0003, and +0.0054 pH units per day for control, A, and B. These summarize relative upward drift and do not demonstrate biological buffering. Trial-wide mean pH values remained similar and slightly acidic. An upward fitted trend alone does not show that control soil became alkaline or that nutrient availability deteriorated. No laboratory nutrient measurements were made. The temperature summaries likewise provide no basis for a treatment-specific thermal mechanism.

Table 3: Classified fertility-meter label counts across the trial. Labels are reproduced from the records and shown in the study's coding order. Counts pool repeated box readings; they are not independent biological replicates. Five unclear labels are excluded, in addition to unavailable readings.

Label	Control	A	B
L1	13	5	11
L2	45	44	43
LM	78	74	60
MM	59	49	72
HM	48	62	63
Low Much	13	24	9
Middle Much	4	4	4
High Much	1	0	1
Total classified readings	261	262	263

Table 4: Recalculated slopes fitted to treatment-level daily means against calendar day. Each entry is one descriptive series-level coefficient, not a mean of box-level coefficients. No inferential uncertainty is estimated. Numerical fertility slopes are omitted because the codes are ordinal with unequal spacing.

Variable	Control	A	B
Moisture index (index units/day)	−0.0647	−0.0346	−0.0129
pH (pH units/day)	+0.0110	+0.0003	+0.0054

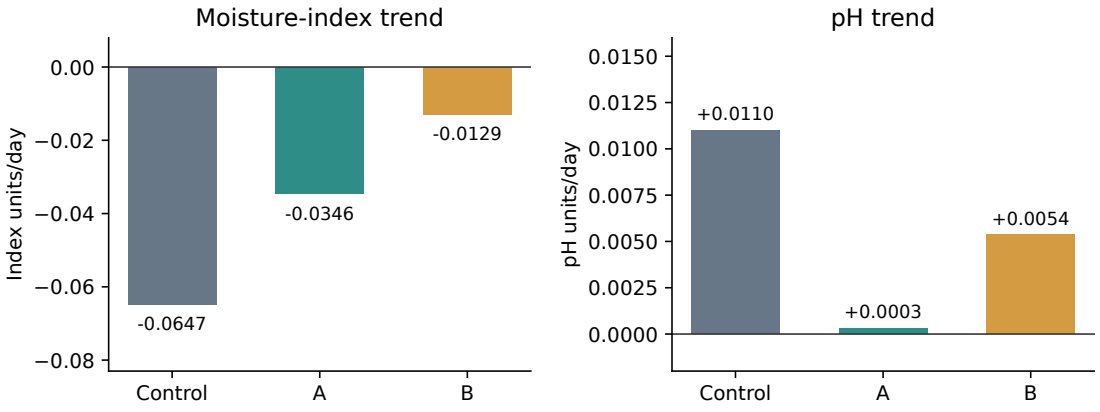


Figure 3: Recalculated slopes from treatment-level daily-mean series. Each bar corresponds to one descriptive coefficient, with no box-level points or error bars. This presentation resolves the discrepancy between the original treatment-level Methods and box-level slope figure.

5.5 Germination and canopy height

First germination was reported in A2 on day 6, in B boxes around days 8–9, and in controls around day 11. These observations do not constitute a complete replicated time-to-germination analysis. The final recorded group-level canopy-height averages were 8.6 inches for control, 12.8 inches for A, and 13.5 inches for B. Relative to the control value, the descriptive contrasts are $(12.8 - 8.6)/8.6 \times 100 \approx 49\%$ and $(13.5 - 8.6)/8.6 \times 100 \approx 57\%$. Because only one average per treatment was available, these percentages have no estimate of between-box variability and were not statistically tested. Figure 4 provides a representative photograph rather than quantitative evidence of a between-treatment canopy-density difference.

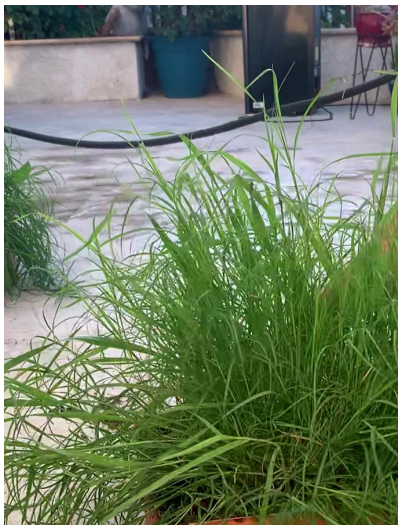


Figure 4: Representative formulation-B box at the end of the 54-day trial. The photograph illustrates observed vegetation growth but does not quantify comparative density, biomass, or restoration success.

6 Discussion

6.1 Observed patterns and strength of evidence

The clearest descriptive pattern is a difference in moisture-index trajectories despite modest differences in trial-wide means. Fertility-meter readings and pH also show potentially useful temporal patterns, but their interpretation is more limited. Treatment daily means can describe these trajectories, yet they do not preserve between-box variation or support inferential claims by themselves. Accordingly, the results identify patterns worth testing rather than confirming efficacy, superiority of one base, or the original hypotheses.

The complete formulations were compared with untreated soil, so any observed contrast concerns the amendment package under the conditions tested. It cannot identify whether biochar, polymer, inoculants, their interaction, or unmeasured experimental differences explain the pattern. Formulation B had the least negative recalculated moisture-index slope and the largest recorded group-level height, but these rankings do not establish that its polymer base is more effective.

6.2 Proposed mechanisms require direct testing

Water retention by polymer or carrier materials is one possible explanation for a less negative moisture-index trajectory. However, water balance, drainage, evapotranspiration, and plant-available water were not measured. Likewise, biochar-related chemical changes and microbial activity are possible explanations for pH or plant-growth patterns, but neither was isolated experimentally.

There is no direct evidence here for microbial establishment, mycorrhizal colonization, nitrogen fixation, pathogen suppression, or biological recovery. No claim is made that inoculants buffered pH or maintained nutrient cycling. The field fertility-meter signal may also vary with measurement conditions, so an association among moisture, pH, and fertility categories cannot establish a biological pathway. Testing these explanations requires verified inoculant identity and viability, root-colonization measurements, microbial assays, and laboratory soil chemistry, alongside component controls.

6.3 Potential applications and application-rate constraints

A granulated amendment could potentially be useful in restoration if its efficacy, handling, storage stability, ecological suitability, and cost are demonstrated. Broadcast or drone delivery remains a future engineering possibility, not an outcome of this trial. No application equipment, storage viability, erosion control, runoff reduction, cost saving, or field-scale performance was evaluated. Product-level biodegradation and environmental residue were also not measured, so the formulation cannot be described as leaving no synthetic residue on the basis of these data.

The container application rate is a substantial constraint: approximately 120 g per 1 ft^2 corresponds to 5,227 kg per acre, or approximately 12.9 t ha^{-1}. These are unit conversions of the experimental dose, not recommended field rates. No agronomically effective or economically feasible field dose was established. Dose-response experiments should precede claims of low-input deployment or scalability; lower rates cannot be assumed to preserve the observed greenhouse patterns.

6.4 Limitations and reproducibility priorities

This study used one controlled-burn soil source, one greenhouse setting, five boxes per treatment, and a 54-day observation window. It did not characterize fire severity, baseline soil chemistry, or representativeness of high-severity wildfire soils. Position effects, undocumented randomization and rotation, small containers, and the shared watering regime restrict causal interpretation and generalization.

The data audit resolves the record-count and aggregation descriptions, but several limitations remain. The formulation proportions are rough estimates, the AMF product identities and inoculum densities remain unverified, and the manufacturer's fertility-category ordering was not independently established. Five unusual fertility labels and one malformed pH entry were left unclassified or excluded rather than corrected by assumption. Although the analysis retains other variables from affected rows, variable-specific missingness may influence comparisons. The mean-based fertility diagnostic is sensitive to code spacing and cannot quantify nutrient change.

The sheet also records unequal light readings among boxes on some dates, but the units and measurement protocol were not documented. These observations reinforce the possibility of environmental or position confounding; the light column cannot establish a quantitative treatment effect or be used as a validated covariate in its present form.

Canopy height was available only at group level, and germination observations were incomplete for formal comparison. No biomass, root growth, soil aggregation, nutrient flux, microbial abundance, or colonization data were available. The lack of component-only and combination controls prevents

claims of component-specific efficacy or synergy. The descriptive approach does not estimate statistical uncertainty or establish whether differences exceed between-box and temporal variation.

7 Conclusion and Future Work

This small greenhouse pilot reports less negative moisture-index trajectories in two complete Mycromist formulations than in untreated controlled-burn soil, along with descriptive differences in germination timing and group-level final canopy height. Mean pH values were similar across groups; fertility categories differed descriptively but do not measure nutrient concentrations. These observations support further investigation of the specific preparations, but do not establish microbial recovery, nutrient cycling, component synergy, statistical efficacy, or field scalability.

A subsequent experiment should include verified ingredient doses and inoculant identities, randomized and blocked box placement, multiple soils and burn conditions, practical dose levels, and controls that separate the components. Per-box plant measurements, laboratory nutrient assays, water-balance measurements, and microbial-colonization assays would permit direct tests of the proposed mechanisms. Repeated-measures models should account for box-level replication and temporal dependence, with ordinal methods used for verified fertility categories. Field validation would then be needed before recommendations for post-fire restoration.

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Data and reproducibility statement

The exported box-level measurement sheet was used to reconstruct the soil-variable analysis. A transcription preserving original entries, the available-box daily means, variable-specific counts and exclusions, and the reanalysis script are included in the accompanying editable project. This statement does not imply public repository deposition. Product labels, preparation mass logs, the original analysis code, and per-box canopy-height measurements were not available for independent verification.

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