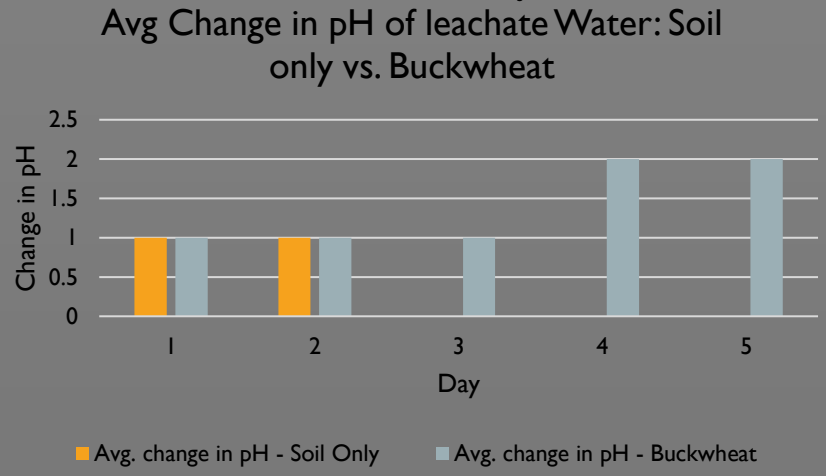
The Role of Fagopyrum Esculentum in Phytoremediation and Soil pH Stabilization

Research Question

If buckwheat was grown in soil contaminated with a dilute-water-soluble fertilizer, then it will reduce pH disturbance and keep soil pH closer to its original value than contaminated soil without buckwheat.

Data Analysis



Procedures

1. 10 identical pots with equal volumes of organic potting soil.
2. Undifferentiated amounts of water-soluble fertilizer was applied to each pot to simulate soil contamination.
3. Buckwheat seeds were planted in 5 pots ; 5 pots remained unplanted as controls.
4. Soil pH was measured at consistent intervals to contrast change

Conclusion

- From the data collected in this experiment, it can be concluded that the group of soil with buckwheat seeds were more efficient at stabilizing the pH of the soil than the group of soil without buckwheat seeds.

Foundations of Environmental Pollution

What is it ?

Environmental pollution is the presence of harmful contaminants, including physical, chemical, or biological agents, into natural ecosystems which disrupt ecological balance, weakening natural processes.

Soil Pollution

Soil acts a major reservoir for contaminants. Contamination can accumulate through run-off of industrial waste, mining operations, improper waste disposal, fertilizer overuse, etc.

Consequences

- Altered pH and chemical imbalance
- Reduced crop yield
- Depletion of soil nutrition
- Bioaccumulation of heavy metals in crops
- Groundwater contamination
- Decreased soil fertility
- Disruption of food webs

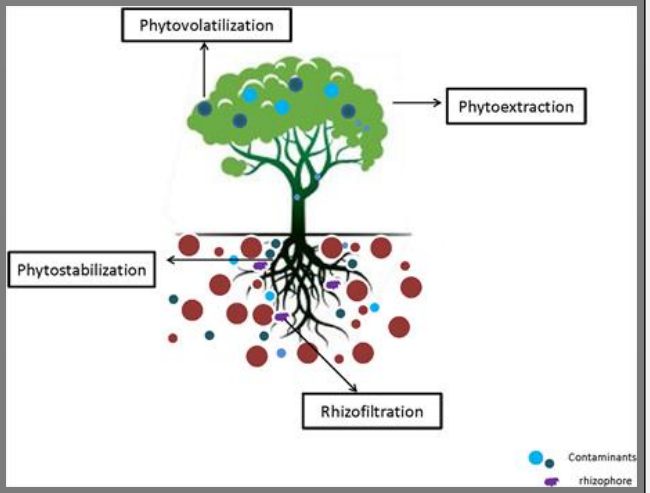
Biogeochemical Mechanisms of Phytoremediation

What is it?

Phytoremediation is a plant-based remediation strategy that uses plant physiological and biochemical processes to removed and/or stabilize environmental contaminants in soil or water.

Major Mechanisms

- **Phytoextraction:** Plants absorb pollutants through roots to relocate them into aboveground tissues, allowing for removal
- **Phytostabilization**: Plant roots immobilize contaminants through absorption or precipitation, reducing mobility to the pollutant
- **Phytovolitization:** Plants absorb contaminants from soil or water and chemically convert them into less toxic forms to be released
- **Rhizofiltration:** Roots absorb contaminants from aqueous environments



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The Rhizosphere Microbiome

What is it?

- The Rhizosphere is the area of soil surrounding the plant roots where there is exchange of nutrients, water and chemicals between roots and microbes.
- This zone contains fungi and bacteria that feed on the sugars, amino acids and organic acids released by the plant

Role of Microbes

- The microbes help to cycle nutrients (phosphorus, nitrogen, sulfur), making it easier for plant uptake
- Many bacteria and fungi in the rhizosphere can immobilize pollutants and reduce their toxicity, helping plants tolerate the stress

Research Question, Hypothesis, Variables, and Prediction

Research Question

Does the presence of Fagopyrum Esculentum reduce soil pH disturbance caused by fertilizer contamination in comparison to unplanted contaminated soil?

Hypothesis

If Fagopyrum Esculentum is planted in fertilizer-treated soil, then the soil will exhibit less disturbance caused by the fertilizer, resulting in soil pH values closer to the original measure compared to contaminated soil without plants.

Variables

Independent variable: Presence or absence of Fagopyrum Esculentum in polluted soil
Dependent variable: Soil pH over time, total pH change
Controlled variable: Soil type and volume, fertilizer concentration, watering amount and schedule, light exposure, temperature, pot size, and initial soil pH

Prediction

The unplanted fertilizer-contaminated pots will undergo more pH fluctuation and acidity than the pots planted with Fagopyrum Esculentum. The planted soil will demonstrate a smaller overall pH change due to root-mediated mitigation effects.

Materials and Experimental Design

Materials

- Buckwheat seeds
- 10 pots
- Organic potting mix
- PH up and down kit
- Soil pH meter
- pH test strips
- Distilled water
- 10 cups

Experimental Design

- pH measured between two groups – Soil only vs. Soil with Buckwheat
- 10 identical pots were filled with soil
- 5 pots with Buckwheat seeds, 5 pots with-out buckwheat seeds
- Trial 1: pH of soil of all 10 pots were measured every day for 7 days
- Trial 2: pH of leachate water was measured of all 10 pots every day for 5 days

Experimental Procedure

1

10 identical pots were filled with equal volumes of organic potting soil and watered with a uniform amount of fertilizer solution.

2

Altered

Un-altered

Buckwheat seeds were planted in 5 pots thus allowing 5 pots to remain unaltered, acting as controls.

3

Identical environmental variables were maintained including light exposure and watering schedules.

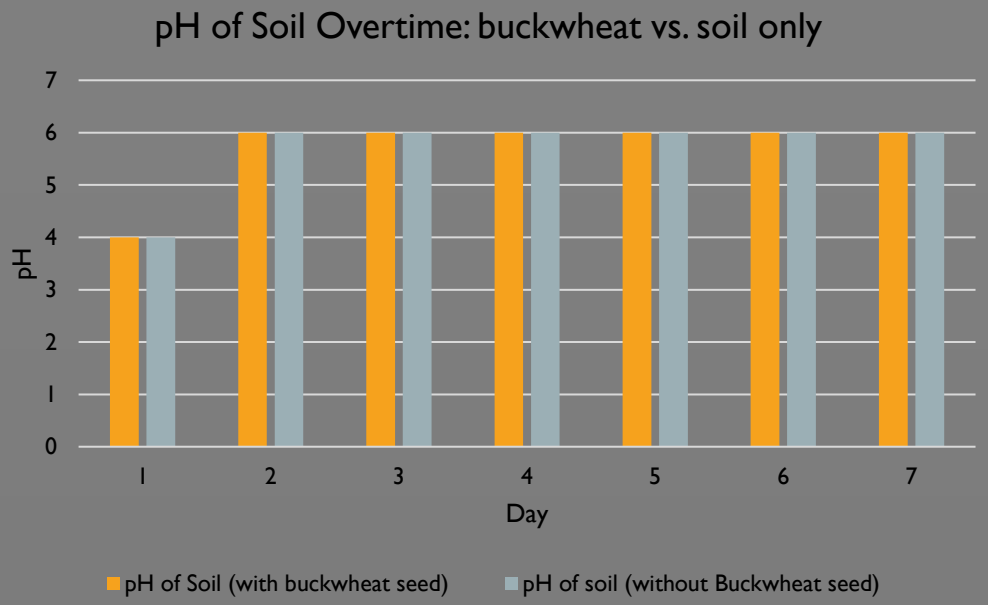
4

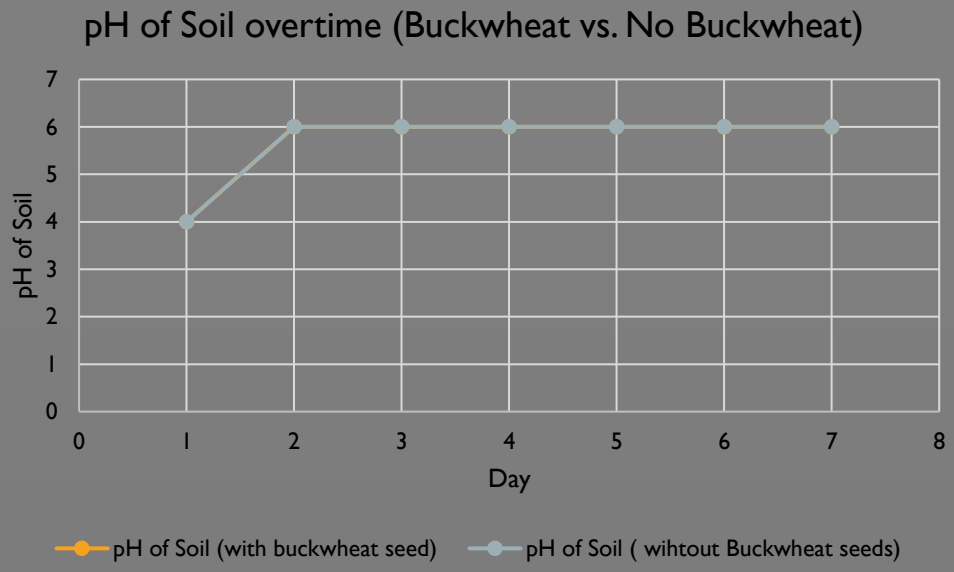
A pH meter was used to measure soil pH at regular intervals to detect change.

5

The collected pH data for both groups were analyzed using Excel graphs

Trial 1: Measurement of Soil pH over 7 days





The results of Trial 1 show that there is no differences in the pH of both groups. Both groups started with a soil pH of 4. There was a shift in pH for both groups on day 2. The shift was from 4 pH to 6 pH. From day 3 though day 7, there was no shift in the pH.

Trial 1 Claim/Evidence/Reasoning

Claim

- Buckwheat and soil only reduces pH disturbance of contaminated soil, keeping the pH of soil closer to a neutral pH level.

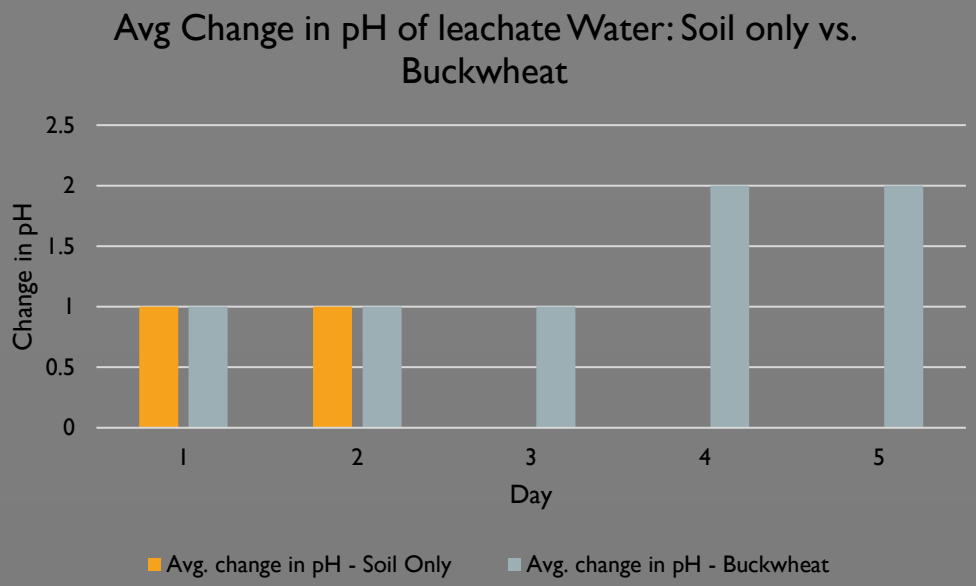
Evidence

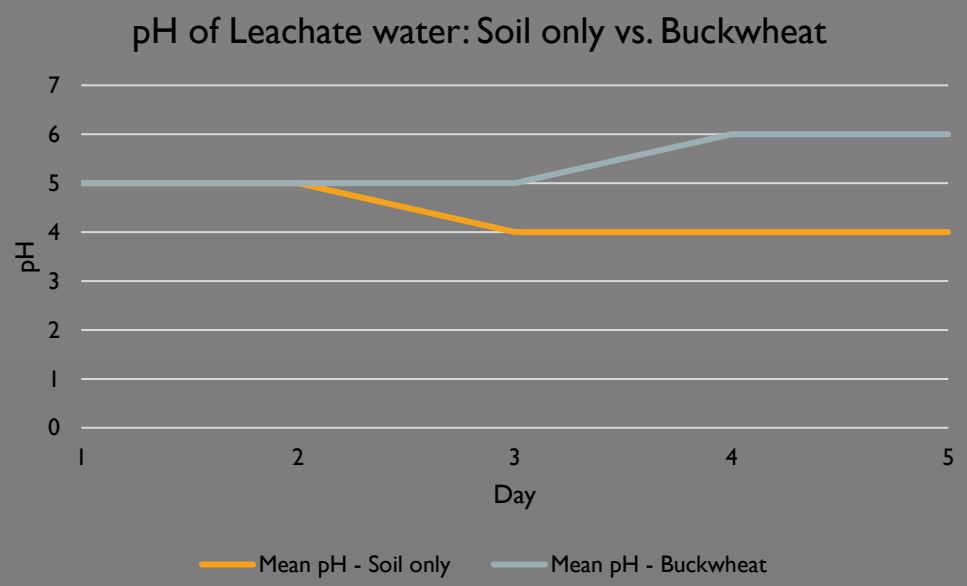
- Soil with Buckwheat showed an increase in pH from 4 to 6
- Soil only showed an increase in pH from 4 to 6
- In both groups (soil with buckwheat + soil only), the measure of pH increased from 4-6 on day 2

Reasoning

- The identical jump in pH form 4-6 in both treatments suggest a limitation in the measurement of pH rather than biological effects. The soil pH meter used does not provide precise readings in the acidic range. Small changes in the pH could have been rounded to the nearest whole number, making both groups appear to shift in the same way. Therefore, it cannot be concluded that the neutralization of the soil is from buckwheat alone.

Trial 2: The pH of Leachate Water





The results of trial 2 show that there is a difference in the change in pH between Soil only and Buckwheat. Graph 1 (left), shows that on day 4 and 5 the biggest difference in the change of pH was seen. Graph 2 (right), shows that throughout 5-day trial period, the mean pH of leachate water with Buckwheat was closer to neutral on day 3, 4, 5 compared to mean pH of leachate water without Buckwheat.

Trial 2 Claim/Evidence/Reasoning

Claim

- Buckwheat reduces pH disturbance in contaminated soil, keeping pH of leachate water closer to a neutral pH rather than soil without Buckwheat.

Evidence

- Soil with Buckwheat showed a mean leachate that remained 5-6 over 5 days
- Soil only showed a mean leachate that remained 5-4 over 5 days

Reasoning

- As the buckwheat roots grew over the 5 days, they released sugar, amino acids and organic acids that the fungi and bacteria in the rhizosphere zone were able to feed on. The activity between the Buckwheat roots and Rhizosphere microbiome reduced the soil's susceptibility to the contaminated water, keeping the leachate water of the soil with buckwheat more neutral than the leachate water of the soil without buckwheat.

Cumulative Data Analysis

Summary

- Trial : Over 7 days, the pH of soil was measured of 2 groups (Soil only-control + Soil with Buckwheat-experimental)
- Trial 2: Over 5 days, the pH of leachate water was measured of 2 groups (Soil only-control + Soil with Buckwheat-experimental)

Overall Trends

- Soil pH: Both groups showed a stabilization of pH on day 2 (pH of 6), however was unreliable due to meter limitation
- Leachate pH: Soil with Buckwheat stayed more stable; unplanted soil stayed more acidic

Conclusion

- Leachate pH data supports the hypothesis that Buckwheat stabilizes pH better than soil alone in contaminated soil.

Evaluation of Experimental Design and Data Reliability

Procedural Challenges

- Equipment Error (Trial 1): The initial 7-day trial revealed data that showed inconsistent pH readings due to fault in the pH meter used. This required full repetition of the experiment.
- Duration Constraint (Trial 2): The repeated trial was limited to 5 days. To ensure rhizosphere and soil buffering effects fully developed, it would have been ideal to have more time.
- Limited Access to Advanced Equipment: Limited access to laboratory-grade equipment restricted maximal precision and prevented the analysis of more complex factors like nutrient ion concentrations.

Interpretation and Reliability

The data supports the hypothesis that the presence of Fagopyrum Esculentum influence soil pH stability, though the information on the precise mechanism requires further investigation using more advanced technology.

- The tested amount of 10 total pots, 5 belonging to each group (planted vs. unplanted), increases confidence in data as it relies on multiple sources of evidence rather than just one
- The controlled variables minimized possible external interference
- The repeat of the trial corrected the instrumentation error

Future Directions, Real-World Application, and Influence

Future Experiments

- Increase sample size for more variation possibility in results
- Measure addition variables like soil nitrogen concentration
- Compare and use other cover crops than Fagopyrum Esculentum
- Conduct an experiment longer than 7 and 5 days to increase data collection

Applications

If this experiment was done at a larger scale, this research supports:

- Use of cover crops for pH stabilization
- Agricultural practices with increased sustainability
- Reduction of soil degradation caused by fertilizer
- Efficient, low-cost, and convenient soil remediation strategies
- Long-term land productivity

Impact

Phytoremediation using fast-growing plants like Fagopyrum Esculentum offers an accessible and sustainable approach to the mitigation of soil pollution whilst maintaining ecosystem productivity and health, further contributing to things like the food chain and crop yield.

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