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Screening of Hyper accumulating plants for grey water systems

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ABSTRACT
Environmental pollution presents a significant threat to both ecosystems and human health. Hyperaccumulator plants, which can absorb and tolerate high concentrations of toxic substances, offer a promising solution for mitigating this challenge. These plants have the ability to accumulate heavy metals, pesticides, and industrial contaminants, thereby reducing soil and water pollution. Utilizing hyperaccumulator plants for phytoremediation can help decontaminate polluted soils and groundwater, reduce the bioavailability of toxic substances, improve soil fertility, and enhance ecosystem health. Furthermore, this approach holds potential for developing cost-effective and sustainable remediation technologies. This study focuses on understanding the nutrient uptake mechanisms of hyperaccumulator plants within a hydroponic model. Key species studied include Brassica juncea, Sedum alfredii, Alpine pennycress, water hyacinth, and ferns, among others. A total of 20 plant species were evaluated for their unique phytoremediation capabilities. The primary objective is to investigate how these hyperaccumulating plants can serve as eco-friendly agents to improve water quality by removing heavy metals from industrial effluents. Preliminary findings suggest that the introduction of these plants into aquatic environments can significantly reduce metal concentrations, contributing to water purification. The results indicate varying levels of nutrient uptake efficiency among the species studied, with the order of effectiveness observed as follows: wheatgrass > mustard > cosmos > zinnia (white) > spinach > sunflower > zinnia (pink) > marigold > zinnia (yellow) > morning glory. These findings provide valuable insights into the potential application of hyperaccumulator plants in water purification and environmental remediation, offering a sustainable and innovative strategy for combating pollution.
Keywords: *Phytoremediation, wastewater management, hyperaccumulator plants, environmental remediation.*

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INTRODUCTION

In India, water pollution, water scarcity, and waste management represent significant challenges in both rural and urban regions. These issues are becoming increasingly critical due to the rising number of food industry establishments and small roadside vendors, a trend driven by rapid urbanization and high rates of unemployment. Many women and unemployed youth have opened roadside food stalls, where sanitary and healthy cooking practices are often not adhered to.

The treatment of grey water (waste water from kitchens and bathrooms) has become prohibitively expensive and inaccessible for such vendors, leading to the discharge of untreated grey water into the environment. This practice contributes to the proliferation of disease vectors like rodents and mosquitoes, exacerbating public health concerns such as dengue and malaria. Combined with the growing influx of population, India faces a severe social and environmental crisis.

To address these concerns, researchers are increasingly focused on integrating sanitation systems with agricultural practices. However, traditional wastewater reuse systems, such as those linking sanitation with crop production, are not feasible in urban settings, including schools, colleges, and apartment complexes, due to limited land availability for agriculture. In response, an innovative approach is being investigated that utilizes hydroponic systems to recover nutrients from grey water.

Preliminary screening studies have been conducted at St. Ann's College for Women, where hydroponic systems have been used over the past five years to produce both food and ornamental crops by recovering nutrients from canteen wastewater. In conventional hydroponics, plants are grown in soilless media, with external nutrient supplementation. Recognizing the potential of nutrient-rich kitchen wastewater, researchers are exploring its use as a resource for controlling pollution while simultaneously producing crops. Kitchen wastewater, with its high nutrient content, can otherwise contribute to odor and promote the growth of harmful algae blooms if left untreated.

To date, no extensive research has been conducted on using hydroponic systems for the treatment of kitchen wastewater, particularly for the dual purpose of house beautification through ornamental plants and the cultivation of hyper accumulating flowering plants and leafy vegetables. This emerging technology offers a promising solution for addressing both environmental and health challenges while supporting urban greening and food production.

MATERIAL AND METHODS

Description of Experimental set up:

The experimental set up (Figure:1) consists of growing trays, the experimental water for circulation in the setup, water pump with motor connected to it. The flow is constantly monitored in the lab. The setup is shown schematically as

Source of Waste water collection

Kitchen waste water of washed veggies and fruits and washed rice and grains were collected from college canteen. Growth Parameters were regularly measured to track the growth of the plants as well as the quality of wastewater used.

In this experiment, a total of 20 plant species (Figure:2) have been selected on the basis of their hyperaccumulation, comprising 10 varieties of flowers and 10 types of leaves.

- Mesembryanthemum
- Sunflower
- Zinnia orange
- Zinnia Yellow
- Morning glory
- African marigold
- French marigold
- Garden Cosmos
- Indian lotus
- Alyssum
- Lemongrass
- Thyme
- Fenugreek
- Spinach
- Mustard seeds
- Lettuce
- Coriander
- Wheatgrass
- Flax seeds

Plant Selection for Hydroponics

Commercially available hydroponic systems typically focus on cultivating fruits and vegetables using nutrients mixed with water. However, when assessing these systems for use with wastewater, caution is warranted. The plant parts—such as leaves, roots, and stems—may accumulate heavy metals due to direct contact with the wastewater, which raises concerns about food safety. Given the current study's focus on screening hyperaccumulating leafy green vegetables and ornamental plants using partially treated greywater (specifically kitchen wastewater), further research in this area is warranted.

Selected Plant for Study

Mesembry anthemum: *Mesembryanthemum*, commonly referred to as ice plants, belongs to the Aizoaceae family. These plants exhibit a distinctive appearance, resembling ice crystals. They are particularly efficient for the phytoextraction of chromium and cadmium contamination. As a halophytic coastal species, Mesembryanthemum can thrive in high-salinity environments, making it a viable alternative to traditional leafy greens such as spinach. Recent evaluations have confirmed that this plant is well-suited for cultivation within hydroponic systems utilizing kitchen wastewater, highlighting its potential as a hyperaccumulating plant in nutrient-rich, saline conditions. [1,2,3,4,5]

Sunflower (*Helianthus annuus*)

The sunflower, a member of the Asteraceae family, is an annual herbaceous plant known for its distinctive large blooms and robust growth. This species is recognized for its application in wastewater treatment through phytoremediation. Sunflowers act as coagulant adsorbents, effectively removing contaminants from polluted water. [6,7]

In addition to its functional uses in wastewater management, the sunflower is also valued for its oil production and ornamental qualities. Given its versatility and potential as a hyperaccumulator, the sunflower has been evaluated for its suitability in hydroponic systems utilizing kitchen wastewater. Research has involved testing various nutrient formulations and cultivation systems to optimize its performance in this context. [8-10,14]

Zinnia (*Zinnia elegans*) - Orange and Yellow

Zinnia elegans is a vibrant flowering plant that originates from Mexico, renowned for its striking orange and yellow blooms. This annual species produces either single or double flowers atop long stems, making it a favorite in gardens and as cut flowers. Zinnias flourish in sunny environments and are relatively low-maintenance, attracting butterflies and other pollinators. [11,12]

Morning Glory (*Ipomoea* spp.)

Morning glory is a climbing vine recognized for its heart-shaped leaves and trumpet-like flowers, which display a range of colors, including blue, purple, pink, and white. These plants are often cultivated on trellises, fences, or arbors, celebrated for their eye-catching flowers that bloom in the morning and close in the afternoon. Common species include Ipomoea purpurea and Ipomoea tricolor. [13]

African Marigold (*Tagetes erecta*)

African marigold, scientifically known as *Tagetes erecta*, is a tall variety of marigold characterized by its large, vibrant yellow to orange flowers. Often used for ornamental purposes, this annual plant is also significant in traditional ceremonies. It is believed to have pest-repelling qualities, making it a beneficial addition to gardens. [15]

French Marigold (*Tagetes patula*)

French marigold, or Tagetes patula, is a compact annual known for its colorful blooms, which come in shades of orange, red, and yellow. Similar to its African counterpart, this plant is popular for its vibrant flowers and ability to deter pests. French marigolds are frequently planted in vegetable gardens to protect crops from harmful insects. [16]

Garden Cosmos (*Cosmos bipinnatus*)

Cosmos bipinnatus is a flowering plant celebrated for its delicate, feathery leaves and daisy-like blooms in shades of pink, white, and purple. This annual plant is easy to cultivate and attracts pollinators, making it a favored choice in gardens. It blooms from summer through fall, providing continuous color [17,18].

Indian Lotus (*Nelumbo nucifera*)

The Indian lotus, scientifically known as Nelumbo nucifera, is an aquatic plant famous for its large, fragrant flowers that can be pink, white, or blue. Thriving in shallow waters, this plant holds cultural significance in many societies due to its beauty and symbolism. The seeds and rhizomes of the lotus are edible and nutritious. [19,20]

Alyssum (*Lobularia maritima*)

Alyssum, particularly Lobularia maritima, is a low-growing annual or perennial known for its clusters of small, fragrant flowers, typically white or purple. This plant is often utilized as ground cover or in rock gardens and is attractive to beneficial insects such as bees.

Lemongrass (*Cymbopogon citratus*)

Lemongrass is a tropical grass recognized for its distinct lemon flavor, widely used in culinary practices, especially in Asian cuisines. It grows in clumps and can reach heights of up to three feet. Additionally, lemongrass is known for its essential oils, which possess various medicinal properties. [21]

Thyme (*Thymus vulgaris*)

Thyme is a perennial herb that is native to Europe and Asia, featuring small aromatic leaves and tiny flowers. It is commonly used in cooking for its flavor and is also valued for its medicinal applications. This herb is drought-tolerant and thrives in well-drained soils. [22]

Fenugreek (*Trigonella foenum-graecum*)

Fenugreek is an annual herb prized for both its leaves and seeds, commonly used as a spice and in traditional medicine. The leaves are often incorporated into dishes, while the seeds are rich in protein and fiber. Fenugreek is recognized for its potential health benefits.

Spinach (*Spinacia oleracea*)

Spinach is a leafy green vegetable that forms rosettes and has tender leaves of varying sizes. Known for its high nutritional value, spinach is rich in vitamins A, C, and K, as well as iron and calcium. It is frequently used in salads, cooked dishes, and smoothies.

Mustard Seeds (*Brassica* spp.)

Mustard seeds are small round seeds derived from various mustard plants, primarily from the Brassica and Sinapis genera. These seeds are used in cooking, for making condiments, and for oil extraction. The most common varieties include yellow (white), brown, and black mustard seeds.

Lettuce (*Lactuca sativa*)

Lettuce (*Lactuca sativa*) is a popular leafy green vegetable typically used in salads and sandwiches. It includes several varieties, such as romaine, iceberg, and butterhead, each with distinct textures and flavors. Lettuce is known for its crisp leaves and low-calorie content.

Coriander (*Coriandrum sativum*)

Coriander, or cilantro (*Coriandrum sativum*), is an herb with bright green, feathery leaves and small white or pink flowers. The fresh leaves are commonly used in culinary dishes, while the seeds are dried and serve as a spice in various cuisines, including Mexican, Indian, and Middle Eastern.

Wheatgrass (*Triticum aestivum*)

Wheatgrass, the young grass of the wheat plant (*Triticum aestivum*), is known for its rich content of vitamins, minerals, antioxidants, and chlorophyll. Often consumed as a juice or powder, it is popular for its health benefits and is frequently grown in home gardens and hydroponic systems.

Flax Seeds (*Linum usitatissimum*)

Flax seeds are derived from the flax plant (*Linum usitatissimum*) and are recognized for their high content of omega-3 fatty acids, fiber, and lignans. They can be consumed whole or ground and are often added to smoothies, cereals, and baked goods for their nutritional advantages.

RESULTS AND DISCUSSIONS

The results indicate that the ability to take up the excess nutrients present in the kitchen wastewater follows this order: Wheatgrass > Mustard > Cosmos (yellow) > Spinach > Sunflower > Zinnia (pink) > Zinnia (white) > Marigold. Out of the 11 species studied, all showed a positive result in absorbing nutrients present in the kitchen wastewater.

Plant growth in 20 species was observed over a time period of 15 days. The plants not mentioned here showed no signs of growth.

The pH, being the key factor, aids in biochemical reactions. The kitchen wastewater had a pH between 7-8, confirming that biochemical activity is present. As there were no additions of antibiotics, fertilizers, or nutrients, the unbiological activity was enhanced. High salt content may lead to unwanted biophysical reactions, which can generally be ignored in biological treatments.

The study indicates that significant results can be obtained even in the absence of fertilizers. All plants continued to grow throughout the study. The growth period from seedlings in the hydroponic system ranged between 13-15 days. The plant growth was observed only at low flow rates, and when the flow rate increased, it led to the inhibition of nutrient ion adsorption. Plant growth and survival depend on sunlight, pH, and the assimilation of nutrients in the plant-system. Nutrient solutions provided sufficient conditions for regrowth. Since the cultivated container size was small, further studies should focus on increasing container sizes.

Nutrient uptake by plants varies from species to species. They require macronutrients like nitrogen, phosphorus, and potassium, which play crucial roles. Water is essential for managing plant growth, photosynthesis, transpiration, and ventilation. Roots absorb nutrients through various mechanisms such as passive and facilitated diffusion, as well as active transport of biotic nutrients and enzymes.

In the study, two different varieties of Zinnia (Zinnia elegans) were examined. They exhibited variations even though they belong to the same classification. Further studies are needed to investigate all growth parameters comprehensively.

In this present study, the efficiency of ornamental plant systems in treating canteen wastewater was evaluated, marking a step towards addressing larger environmental challenges.

Figure 1: Hydroponics setup in lab

Figure 2: Seed bank

Table 1: Growth characteristics of plants

Plant Species	Shoot growth (in cm)	Root growth (in cm)	Time (days)
Wheatgrass	30.1	4.2	15
Mustard	13.5	2.5	13
Cosmos (yellow)	12.5	2.0	13
Zinnia (white)	10.2	1.5	13
Spinach	8.5	1.2	15
Sunflower	5.5	1.1	13
Zinnia (pink)	4	1.0	13
Coriander	3.0	1.0	15
Marigold (French)	1.4	0.5	13
Zinnia (yellow)	0.9	0.3	13
Morning glory	0.5	0.1	13

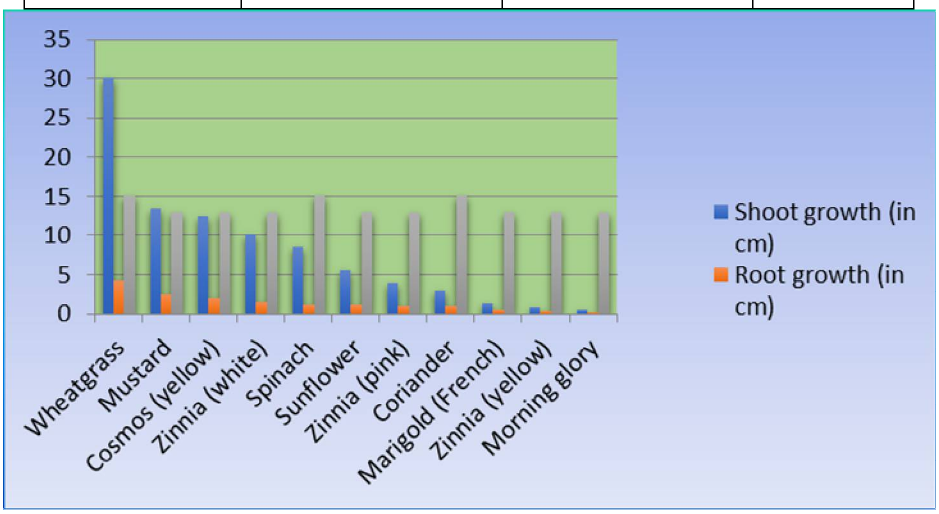

Fig 3: Growth characteristics of plants

Table 2: Showing Physicochemical parameters

Parameter	Kitchen wastewater	Normal Water
pH	7	7
D.O	14.6 mg/L	25 mg/L
EC	0.76 S	0.21 S
TDS	0.13 ppm	100 ppm
Temperature	25.9ºC	25.0ºC

CONCLUSION

Considering the commercialization of process, various parameters beyond stem growth and stem diameter need to be studied. The main advantage of this system is its significant reduction in nutrient contamination. It is an economical and sustainable alternative for decentralizing kitchen waste. This system not only enhances aesthetic value but also beautifies indoor environments. It has the potential for implementation in both rural and urban domestic areas. By mitigating degradation problems in both settings, it plays a vital role in conserving freshwater resources and enhancing environmental sustainability.

Providing guidance for self-sustainability in growing leafy vegetables and ornamental plants. Replicability of the process is possible.

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