Investigation of the Effects of Fly Ash-Enriched Soil on the Radish Growth Using a Multi-Attribute Decision-Making Method

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Background and Motivation

- Fly ash is a by-product stemming from coal combustion in many industries.
- The presence of fly ash in the soil can be used as a solution of waste management system.
- As a soil amendment ingredient, the impact of fly ash-enriched soil on plant growth requires a comprehensive evaluation and understanding.

Aim of This Investigation

- Optimized fly ash composition and the impacts of soil conditions on the radish plant growth in the delta clay-rich and the coastal sandy soil conditions.
- As an optimization method, we used a Multi-Attribute Decision-Making (MADM) method, which is called 'Multi-Objective Optimization on the Basis of Ratio Analysis' (MOORA) technique.
- Using this method, we find the best configuration or alternative for the radish plant growth in the delta clay-rich and the coastal sandy soil conditions.

Data Resources:

The radish plant growth data for the delta clay-rich and the coastal sandy soil conditions are publicly available through the resource [1]..

EXPERIMENTAL METHOD

- The experiment was performed in semi-controlled greenhouse conditions [1].
- There were 10 experimental formulae used for the experiment. They were 100% delta clay rich soil, 95% delta clay rich soil + 5% FA, 90% delta clay rich soil + 10% FA, 85% delta clay rich soil + 15% FA, 80% delta clay rich soil + 20% FA, 100% coastal sandy soil, 95% coastal sandy soil + 5%FA, 90% coastal sandy soil + 10%FA, 85% coastal sandy soil + 15%FA, and 80% coastal sandy soil + 20%FA.
- The plant germination rate (GR) was recorded at 2nd, 3rd, 4th, 5th, 6th, and 7th days after sowing.
- The plant height and number of leaves were collected at 11th, 21st, 31st, 41st, 51st, 61st, and 71st days after sowing.
- The fresh weight was measured by using an electronic balance (OHAUS PR4202, USA).
- Dry weight of tuber was determined after drying samples at 80 °C for three days in a drying chamber (BINDER, USA) until constant weight. Dry samples were weighed by the electronic balance (OHAUS STX-223, USA).

THEORY

The MOORA technique is widely used in process parameters optimization, materials selection, and system performance assessment. The method simultaneously incorporates both desirable and undesirable criteria by using a ratio system. It then converts a decision matrix into a ranking system based on the sample configuration.

In short, the method uses desirable and undesirable criteria or attributes simultaneously for developing ranking of the alternatives.

Normalize Decision Matrix Equation [2]:

$$x_{ij}^{*} = x_{ij} / \left[\sum_{i=1}^{m} x_{ij}^{2}\right]^{1/2}$$

Here, $j = 1, 2, \ldots, n$

$$x = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \cdots & \cdots & \cdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix}$$

Assessment Values Equation [2]:

$$y_i = \sum_{j=1}^{g} w_j x_{ij}^{*} - \sum_{j=g+1}^{n} w_j x_{ij}^{*}$$

Here, $j = 1, 2, \ldots, n$

The weight (w) is determined by the Shannon Entropy Weight method.

Performance Indices or Project Outcomes (p_{ij}) Equation [3]:

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}$$

Entropy (E_j) Measurement Equation [3]:

$$E_j = -k \sum_{i=1}^{m} p_{ij} \ln p_{ij}$$

Here, $k = \frac{1}{\ln(m)}$

Entropy-Based Weight Equation [3]:

$$w_j = \frac{1 - E_j}{\sum_{j=1}^{n} (1 - E_j)}$$

RESULT & DISCUSSION

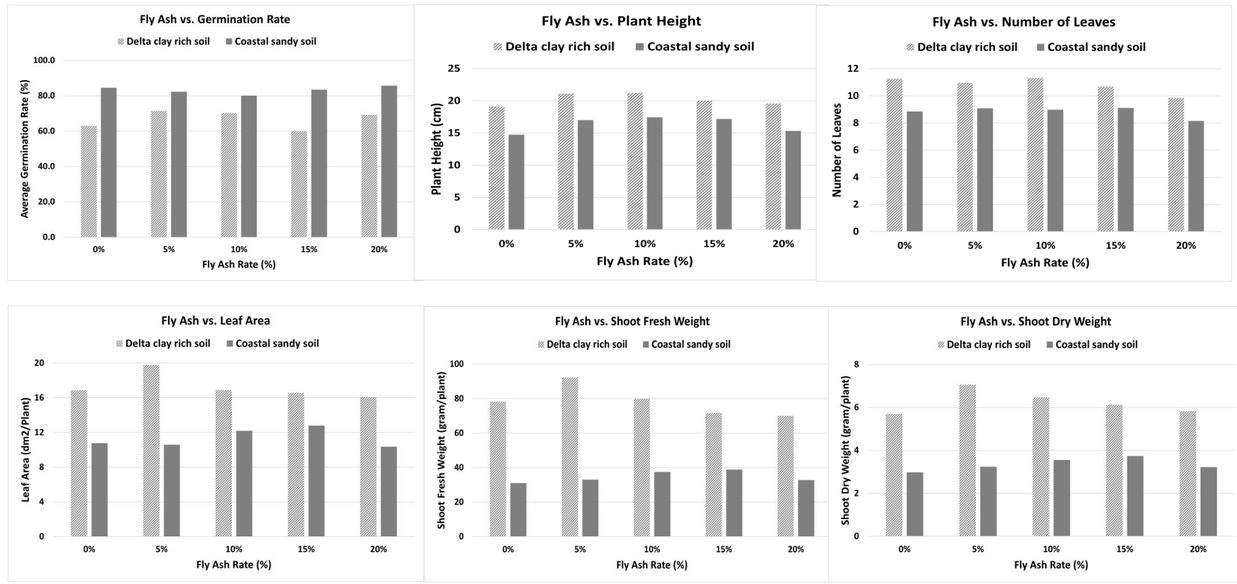

Figure: Average germination rate, GR (%), plant height (cm), number of leaves, leaf area (dm2/plant), and shoot fresh and dry weight are plotted against the fly ash rate (%). GR is taken as an average over 7 days after sowing, and plant height and number of leaves are averaged over 11 - 71 days with 10 days interval..

Soil Type	Attributes	Beneficial	Beneficial	Beneficial	Non-beneficial	Non-beneficial	Non-beneficial
Delta clay rich soil	FA Rate (%)	GR (%)	Plant Height (cm)	Leaves Number	Leaf Area (cm2)	Fresh Weight (g)	Dry Weight (g)
Alternative 1 (A1)	0%	62.857	19.123	11.257	1687.300	78.320	5.698
Alternative 2 (A2)	5%	71.429	21.129	10.957	1977.400	92.326	7.058
Alternative 3 (A3)	10%	70.286	21.214	11.314	1689.400	79.832	6.472
Alternative 4 (A4)	15%	60.000	20.031	10.686	1655.700	71.662	6.119
Alternative 5 (A5)	20%	69.143	19.589	9.843	1609.400	69.974	5.823
m = 5							
Weight (w)		0.15093	0.05570	0.08177	0.18193	0.32801	0.20170

Soil Type	Attributes	Beneficial	Beneficial	Beneficial	Non-beneficial	Non-beneficial	Non-beneficial
Coastal sandy soil	FA Rate (%)	GR (%)	Plant Height (cm)	Leaves Number	Leaf Area (cm2)	Fresh Weight (g)	Dry Weight (g)
Alternative 1 (A1)	0%	84.571	14.751	8.857	1077.300	31.012	2.976
Alternative 2 (A2)	5%	82.286	17.011	9.079	1059.400	32.996	3.237
Alternative 3 (A3)	10%	80.000	17.449	8.986	1219.500	37.454	3.550
Alternative 4 (A4)	15%	83.429	17.197	9.114	1279.100	38.886	3.737
Alternative 5 (A5)	20%	85.714	15.326	8.157	1036.600	32.762	3.224
m = 5							
Weight (w)		0.02019	0.16268	0.05821	0.25814	0.27062	0.23014

Table: Decision matrix development containing all beneficial and non-beneficial attributes for MOORA analysis. There are five (5) alternatives (As) represented as A1, A2, A3, A4, and A5.

Soil Type: Delta clay rich soil

Alternatives	FA Rate (%)	Assessment Estimation	Rank Evaluation
A1	0%	-0.18239	3
A2	5%	-0.23162	5
A3	10%	-0.18620	4
A4	15%	-0.17828	2
A5	20%	-0.16285	1

Soil Type: Coastal sandy soil

Alternatives	FA Rate (%)	Assessment Estimation	Rank Evaluation
A1	0%	-0.20777	1
A2	5%	-0.21043	2
A3	10%	-0.25037	4
A4	15%	-0.26750	5
A5	20%	-0.21673	3

Table: Rank assessment values are presented by 'Rank Evaluation' for the delta clay-rich soil and the coastal sandy soil. The assessment values were determined using the MOORA analysis method based on the decision matrix shown in the tables above for both soil types.

CONCLUSION

- The MOORA method configured a rank based on beneficial and non-beneficial attributes.
- The best configurations for the delta clay-rich and coastal sandy soil are a fly ash rate of 20% and 0%, respectively.
- The least alternatives for the delta clay-rich and coastal sandy soil are a fly ash rate of 5% and 15%, respectively.
- The results indicate the necessity of further study for a better understanding of the phenomena of radish plant growth in different soil types.

REFERENCE

[1] Nguyen, Van Loc, & Duc Huy Nguyen. Data in Brief 53, 110234 (2024)..
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[3] Wu, J., Sun, J., Liang, L., & Zha, Y, Expert Systems with Applications, 38(5), 5162-5165 (2011).

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