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Evaluation of the impact of slash on physico-chemical properties of soil under mustard cultivation grown in sandy loam soil

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Abstract
The present study elucidates the impact of SLASH-a matrix comprising sewage sludge, fly ash and lime on physic-chemical dynamics of soil of mustard crop (*Brassica juncea L.*). A randomized block design with thirteen treatments (0-60%) combined with the Recommended Dose of Fertilizer was employed to determine the threshold at which agronomic benefits are maximized. Comprehensive analysis of soil physical parameters and chemical attributes were conducted. Results demonstrated that moderate SLASH incorporation (20%-30%) significantly improved soil structural integrity, enhanced moisture retention capacity, and elevated nutrient bioavailability owing to increased organic carbon and ash derived mineral inputs Conversely, higher SLASH levels (>40%) adversely affected crop performance and soil fertility, likely owing to nutrient imbalance and potential accumulation of undesirable elements. The findings indicates that SLASH, when applied within optimal threshold, constitute a viable and sustainable soil amendment capable of improving soil health and mustard productivity, while emphasizing the necessity for regulated application to mitigate potential environmental risk.

Keywords: Slash, fly ash, sewage sludge, phytotoxic

Introduction

The rapid increase in industrial and municipal waste generation, particularly fly ash and sewage sludge, has intensified the demand for sustainable and environmentally sound waste-management strategies. When co-stabilized with lime, these residues form a composite soil amendment known as SLASH, which has demonstrated potential for improving soil quality through enhanced soil structure, nutrient enrichment, and pH buffering capacity. Fly ash contributes essential mineral constituents and improves soil aeration and moisture retention, while sewage sludge serves as a valuable source of organic carbon and plant-available nutrients, including nitrogen (N), phosphorus (P), and potassium (K).

However, both sewage sludge and fly ash may also contain potentially harmful constituents which can adversely affect soil health and crop performance when applied at excessive or unregulated rates. Therefore, evaluating the safe and optimal application levels of SLASH is crucial for its effective use as an agricultural amendment. Mustard (*Brassica juncea* L.), a major oilseed crop with moderate tolerance to metal stress, provides an appropriate model crop for assessing both agronomic benefits and potential environmental risks.

The present study aims to evaluate the effects of graded SLASH application levels on soil physico-chemical properties, and to determine an optimal and environmentally safe SLASH dose that enhances soil quality without inducing adverse effects.

Experimental Methodology

The present investigation was conducted as a field experiment at the Nursery of Environmental Science, Sam Higginbottom Institute of Agriculture, Technology and Sciences (SHUATS), Prayagraj, during the Rabi season. The experiment was arranged in a Randomized Block Design (RBD) comprising thirteen treatments with three replications.

Fly ash utilized in the study was procured from IFFCO Phulpur, while the sewage sludge was sourced from the Sewage Treatment Plant (STP), Naini, Prayagraj. The constituents of SLASH fly ash, sewage sludge, and lime were accurately weighed, thoroughly homogenized, and incorporated into the soil according to the predefined treatment combinations.

SLASH possesses the beneficial characteristics of both sewage sludge and fly ash, contributing positively to soil fertility. It is prepared by blending 60% fly ash, 30% sewage sludge, and 10% lime on a dry matter basis. The effectiveness and quality of SLASH depend on maintaining these components in appropriate and standardized proportions.

All treatment mixtures were applied uniformly, and the experimental layout ensured randomization within each replication to minimize experimental error. The study consisted of three replications (R_1, R_2, R_3) and thirteen SLASH treatment levels, ranging from 0% to 60%.

Details of Treatment Combination

Treatment	Combinations
T_0	0% Slash + RDF (Control)
T_1	5% Slash + RDF
T_2	10% Slash + RDF
T_3	15% Slash + RDF
T_4	20% Slash + RDF
T_5	25% Slash + RDF
T_6	30% Slash + RDF
T_7	35% Slash + RDF
T_8	40% Slash + RDF
T_9	45% Slash + RDF
T_{10}	50% Slash + RDF
T_{11}	55% Slash + RDF
T_{12}	60% Slash + RDF

Statistical Analysis

The experiment was directed in RBD design having thirteen treatments with three replications. For testing of the hypothesis, the ANOVA table was used.

Results and Discussions

The interactive use of SLASH along with RDF had considerable effects on the physical characteristics of soil in the two years and in the pooled analysis. The bulk density of the soil gradually declined with the level of SLASH to the lowest point in T_{12} (60% SLASH + RDF) and this made soil have better structure because of the addition of organic matter and enhancement of aggregation. Conversely, the density of the particles had relatively small changes between treatments, which is an indication that the natural mineral composition of soil was not significantly changed as a result of incorporation of SLASH. As expected, the pore space of the soil made an apparent upsurge with the increased application of SLASH with T_{12} always showing the highest pore space, which is an indication of better aeration and porosity of the soil due to organic amendments.

Table 1: Effect of SLASH + RDF on Soil Physical Properties

Treatment	Bulk Density (mg m^{-3})	Particle Density (mg m^{-3})	Pore Space (%)
T_0	1.30	2.65	50.55
T_1	1.29	2.65	50.55
T_2	1.28	2.65	52.15
T_3	1.27	2.64	53.30
T_4	1.26	2.65	54.10
T_5	1.25	2.64	54.80
T_6	1.31	2.65	53.20
T_7	1.28	2.64	53.40
T_8	1.24	2.63	55.60
T_9	1.27	2.64	53.30
T_{10}	1.25	2.64	53.40
T_{11}	1.23	2.63	53.70
T_{12}	1.21	2.62	53.90

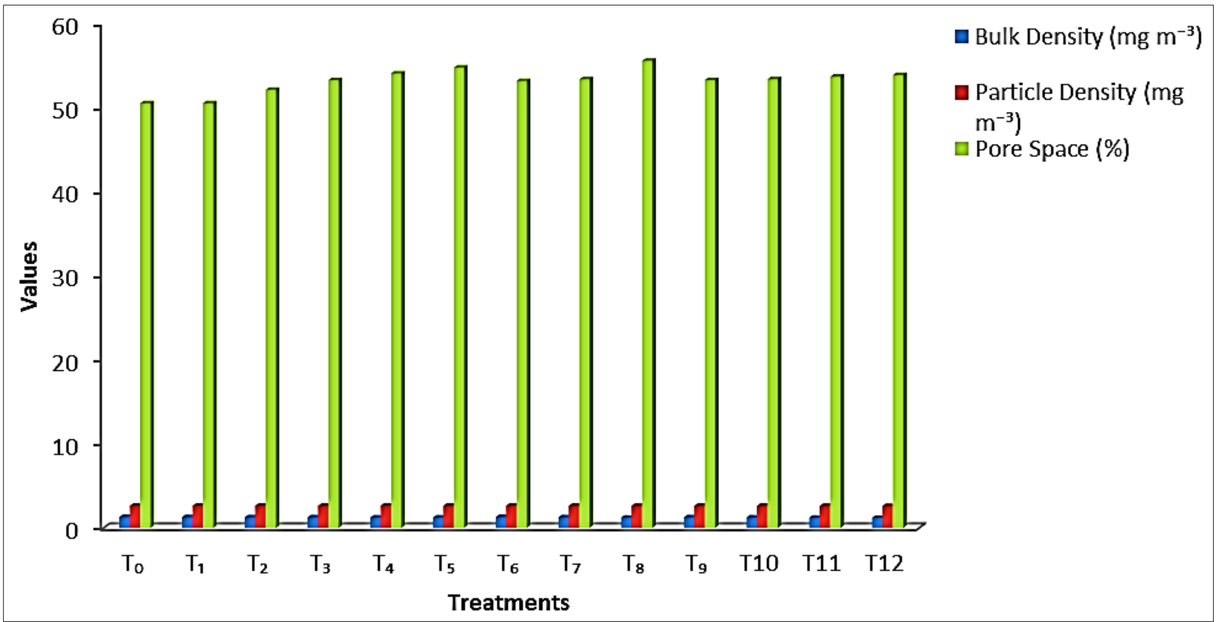

Fig 1: Effect of SLASH + RDF on Soil Physical Properties

Chemical properties of soil were also very sensitive to changes in the treatment. The pH of soil was neutral to slightly alkaline with the highest pH being T_8 and the lowest being T_8 between seasons and pooled data. The range of electrical conductivity in all treatments was non-saline, but T_9 was always the highest EC with lower values maintained under T_4, T_5, T_6. Application of SLASH significantly enhanced soil organic carbon content, especially at T_1 and T_4 in the soil, which was good evidence of better carbon sequestration and accumulation of organic matter but the lowest SOC was recorded at T_5.

Availability of the nutrients had treatment-specific trends.

Optimum availability of nitrogen was achieved in T_4, and this result demonstrated the synergistic interaction between moderate levels of SLASH and RDF in the availability of nitrogen where T_5 always registered the lowest nitrogen status. The highest values of available phosphorus were at T_8 and the lowest values were in the control treatment indicating that higher SLASH inputs enhanced P mobilization. Conversely, the amount of potassium in the available treatment was the highest in the control treatment (T_0), and it reduced significantly when the levels of SLASH were high, especially T_5. Sulphur content was found to be available in large amounts at T_8 and T_5, and the lower levels were obtained at T_3, T_0 and T_{12}. In general, the findings show that the use of SLASH, especially in moderate and high concentrations, was able to significantly alter the physical state of soil, organic carbon and nutrient availability of soil, but with some differences in the responses to individual nutrients.

Table 2: Effect of SLASH + RDF on Soil Chemical Properties

Treatment	pH	EC (dS m^{-1})	SOC (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Available S (mg kg^{-1})
T_0	7.46	0.118	0.29	64.45	19.68	314.60	2.89
T_1	7.76	0.063	0.50	94.05	28.32	240.78	2.91
T_2	7.56	0.084	0.48	84.78	19.88	295.55	2.89
T_3	7.96	0.086	0.36	73.75	19.98	240.78	2.37
T_4	7.56	0.062	0.50	103.25	24.60	197.05	2.94
T_5	7.56	0.060	0.26	54.63	28.95	120.42	3.53
T_6	7.66	0.063	0.36	74.62	24.60	218.88	2.90
T_7	7.76	0.450	0.36	73.75	24.60	284.58	2.90
T_8	7.06	0.136	0.29	58.99	32.10	197.05	3.83
T_9	8.45	0.089	0.36	73.75	24.60	207.97	2.94
T_{10}	7.56	0.075	0.43	88.50	20.05	218.88	2.37
T_{11}	7.66	0.078	0.29	61.47	20.20	207.97	2.35
T_{12}	7.96	0.071	0.29	64.45	19.88	197.05	2.89

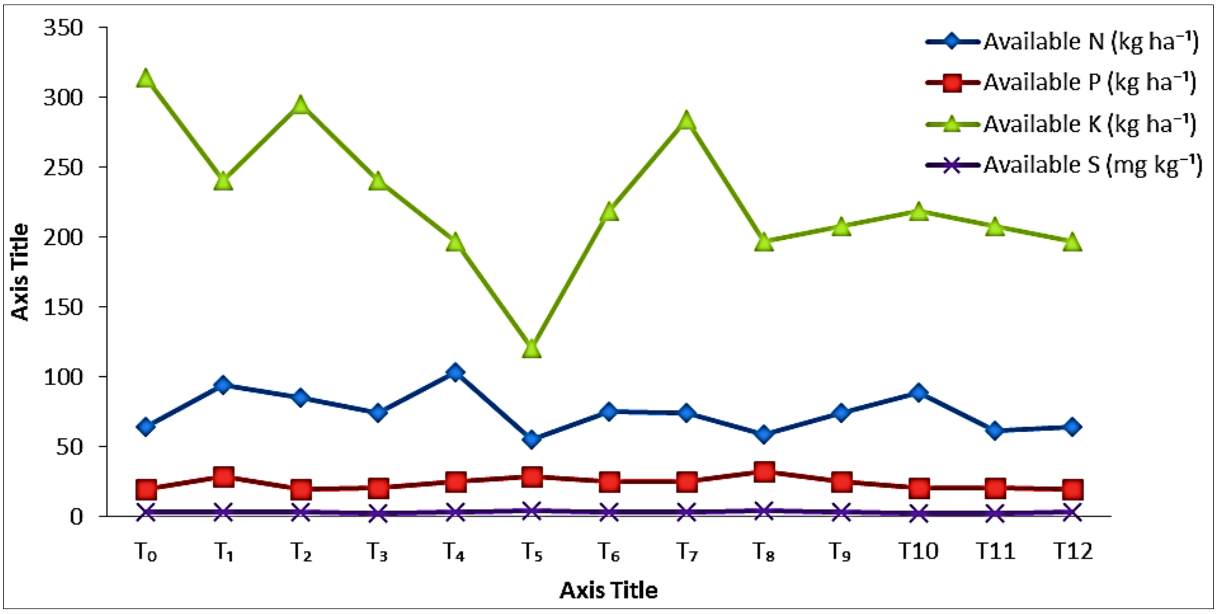

Fig 2: Effect of SLASH + RDF on Soil Chemical Properties

Conclusion

The present investigation clearly demonstrated that incorporation of SLASH along with recommended fertilizer doses had a pronounced and beneficial effect on soil physical and chemical properties over the two years of study. Bulk density decreased progressively with increasing levels of SLASH application, while pore space showed a corresponding increase, indicating improvement in soil structure, aggregation, and aeration. Particle density remained largely unaffected across treatments, suggesting that soil mineral composition was stable and changes were primarily driven by organic matter dynamics.

Among chemical properties, soil organic carbon and available nutrients (N, P, K, and S) were significantly influenced by treatment variations. SLASH incorporation substantially enhanced soil organic carbon content compared to the control, reflecting improved carbon sequestration and soil health. Available nitrogen and phosphorus showed marked improvement under SLASH-amended treatments, attributed to enhanced mineralization and increased nutrient solubilization through organic acid production. Available sulphur also increased considerably with higher SLASH levels, indicating the importance of organic residues as a source of secondary nutrients.

In contrast, available potassium showed a relatively declining trend under higher SLASH treatments, possibly due to greater crop uptake and leaching losses, emphasizing the need for balanced potassium management under residue-based nutrient strategies.

Overall, treatments integrating SLASH with recommended fertilizer doses—particularly T_4 and T_8—proved most effective in improving soil quality and nutrient availability.

The study highlights that judicious use of crop residues such as SLASH can play a vital role in sustainable soil management by improving soil physical conditions, enhancing nutrient cycling, and maintaining long-term soil fertility in sandy loam soils. Adoption of such integrated nutrient management practices can therefore contribute significantly to sustainable crop production and soil health improvement.

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