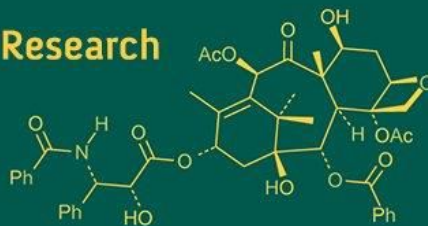
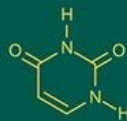
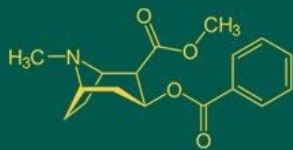


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Probiotic-assisted bioconversion of agro-waste into organic liquid NPK fertilizer: Fermentation dynamics and efficacy evaluation on paddy under pot and field conditions

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Abstract

Using factorial combination of nitrogen (poultry litter, greengram flour, groundnut cake), phosphorus (rock phosphate, PROM, bone meal) and potassium-rich (potassium humate, wood ash, pressmud) agro-residues, a total of 27 treatments were developed along with two controls (absolute and chemical). Probiotic strains including *Lactobacillus* spp. and *Saccharomyces* spp (extracted from milk and bread) were subjected to co-fermentation with *Azospirillum*, phosphate-solubilizing bacteria (PSB), and potassium-mobilizing bacteria under aerobic conditions for 30 days at optimum temperature of $30 \pm 2^\circ\text{C}$ and pH 6.5-7.5. The formulation containing groundnut cake + rock phosphate + potassium humate recorded the highest NPK content of 15% along with the presence of important metabolites like indole-3-acetic acid (IAA), gibberellic acid, cellulase and phosphatase.

Through a three-month rice cycle of field evaluation, the treatment (T_{21}) containing 50% organic NPK liquid fertilizer along with 50% RDF observed to significantly enhanced the height of the plant (90.6 cm), tillering (15 tillers/plant) and grains (125 grains/panicle) as compared to control and chemical fertilizer alone. Using agro-waste will definitely valorise crop production in a sustainable way by reducing the dependency on chemical inputs.

Keywords: Agro-waste management, organic NPK fertilizer, probiotics, rice (*Oryza sativa*), sustainable agriculture, biofertilizer efficacy

Introduction

Large quantities of agro waste are generated like poultry litter, groundnut cake, greengram flour, rock phosphate, pressmud, wood ash, etc. If not properly disposed, it causes environmental pollution, greenhouse-gas emission and soil degradation. While these residues are abandoned, they still have favourable compositions in macronutrients (N, P, K) and organic materials for sustainable valorization. Low-cost agro-by products can be converted into organic liquid NPK fertilizer which can reduce pollution, promote circular bio-economy and provide an alternative to conventional fertilizers.

Inorganic fertilizers are used to improve soil fertility but intensive inorganic fertilizer usage in agriculture causes so many health problems and unrecoverable environmental pollution.^[1] On the other hand, use of organic fertilizers results in increased soil organic matter, reduced erosion, better water infiltration and aeration, higher soil biological activity as the materials decompose in soil, and increased yields after the year of application (residual effects)^[2]. During the fermentation process of organic sources, microorganisms can also decompose organic matter and produce many nutrients such as nitrogen, phosphorus, and potassium that crops can absorb^[3].

Integrated consumption of organic manures and chemical fertilizers has the potential to provide greater sustainability in crop production, maintain improve soil fertility, and enhance the efficiency of growth, yield and nutrients uptake of rice cultivars^[4].

Synergistic combination of waste biomass and plant-growth-stimulating microorganisms creates bioorganic fertilizers that reduce dependence on primary raw materials and synthetic fertilizers. They may alleviate issues such as the dispersal of antibiotic resistance and the persistence of recalcitrant residues in current compost and AD-based fertilizers, reducing soil

pollution and enhancing crop yield, and soil health [5]

The study uses probiotics to convert agro waste into a liquid fertilizer with higher NPK. *Lactobacillus* species in addition to *Saccharomyces* species, which is isolated from milk and bread, plus confirmed with 16S rRNA sequencing, mixed with *Azospirillum*, phosphate solubilizing bacteria, and potassium mobilizing bacteria obtained from Tamil Nadu Agricultural University.

This microbial consortium not only helps dissolve nutrients but also helps microbes produce metabolites in aerobic fermentation during a 30 days period at 30 °C and pH 7.0 in sterilized molasses medium along with coconut milk, curd, seaweed gel and gibberellic acid.

The fermentation produced a liquid full of nutrients-it holds NPK in even amounts as well as good metabolites like IAA, gibberellic acid, cellulase as well as phosphatase. The best mixture, which had groundnut cake, rock phosphate in addition to potassium humate, reached 15% NPK. It also contained many bioactive metabolites.

Materials and Methods

Collection and Pre-treatment of Agro-waste Materials

Agro waste materials and agro residues rich in NPK such as poultry litter, greengram flour, groundnut cake, rock phosphate, prom, bone meal, Potassium humate, wood ash, pressmud were collected and sun dried to reduce moisture content. Then the wastes and residues were pulverized to pass through a 2 mm sieve (Fig. 1). 27 formulations using these agro wastes were made and fermentation proceeds.

12 g of each substrate was weighed and added to 600 mL of a sterilized fermentation molasses medium within a 1 L flask. The medium was composed of molasses (30 g), peptone (1g), yeast extract (1g) per L of water and sterilized at 121 °C for 20 minutes to eliminate contaminants prior to inoculation (Fig. 2).

Isolation and Maintenance of Microbial Strains

Probiotic strains used in the study *Lactobacillus* and *Saccharomyces* were isolated from milk and bread respectively (Fig.3) (Fig. 4) and subjected to biochemical characterization and 16s rna and ITS sequencing. The cultures were maintained separately in selective media. de Man Rogosa and Sharpe (MRS) broth for *Lactobacillus* and Yeast Peptone broth for *Saccharomyces*.

Azospirillum, Phosphobacteria *Bacillus megaterium* and potash bacteria were also obtained from TNAU, Coimbatore and maintained in selective media. NFB (Nitrogen free bromothymol malate broth) for *Azospirillum*, Pikovaskya broth for phosphobacteria and GYC (Glucose Yeast Extract Calcium carbonate) media for potash bacteria were made and cultures were inoculated and maintained under controlled conditions.

Fermentation Protocol

To the fermentation media in 1 Litre flasks coconut milk 20 mL, coconut water 10 mL, curd 5 mL, seaweed gel 5 mL and gibberellic acid 0.01% were added. 1 ml of all the five microbial strains were inoculated. The temperature and pH was maintained 30°C and 7.0 throughout the fermentation process.

Aerobic fermentation was maintained by covering the flasks with cotton plug and avoiding external contamination [6]. Fermentation carried out over one month period. During that time, the flasks were shaken twice a week for well

distribution of organic sources and microbes.

Nutrient and Biochemical Characterization of Liquid Fertilizer

The NPK content of the fermentation liquid was tested after 30 days after filtration of the liquid from the solid components.

- Nitrogen was estimated by kjeldahl method involving digestion, distillation, neutralization and titration with HCl
- Phosphorus (P) was determined by spectrophotometry by absorbance of the molybdenum blue solution at a specific wavelength, typically in the range of 600-900 nm.
- Potassium (K) was Determined by flame photometry method.

Pot Culture Experiment and Field trails

Pot culture experiments was carried out in the Pot culture yard of Faculty of Agriculture, Annamalai University. Surface sterilized paddy seeds were sown in 10 kg pots filled with clam loam soil. The experimental set up is Completely Randomized Design (CRD). 27 factorial combinations along with 50% RDF taken as 27 treatments. With these a control and inorganic fertilizer treatment also carried out. Totally 29 treatments were carried out. Treatment details given in Table 1. The liquid organic fertilizer was foliar sprayed and applied in soil at three growth stages 15, 30 and 45 days after transplanting. Growth parameters like plant height, number of tillers per plant and chlorophyll content was measured at 60 days after transplanting (DAT).

Field trail was conducted in Kottapakathuvveli region of Villupuram District in 30 cents area. Randomized Block Design experimental setup was carried out for 29 treatments and 3 replications with plot size 5 x 2 and spacing 20 cm x 10 cm. The organic liquid fertilizer was foliar sprayed and applied in soil at critical growth stages. Mean value of Plant growth parameters like plant height, number of tillers per plant, grain yield, 1000 grain weight was recorded at 120 days after transplanting.

Results and Discussion

Characterization of *Lactobacillus* and *Saccharomyces* strains

16S rRNA and ITS sequencing for *Lactobacillus* and *Saccharomyces* were compared to those of known sequences using BLAST and the GenBank database. Sequence phylogenetic analysis revealed that *Lactobacillus* LF1 was closely related to 12 known strains of *Limosilactobacillus fermentum* (Fig. 5) and *Saccharomyces* SCB-1 was closely related to and 10 known strains of *Saccharomyces boulardii* (Fig. 6).

Nutrient Composition of Fermented Liquid Formulations

The NPK content of all the 27 formulation was tested by standard techniques and among them the formulation containing groundnut cake + rock phosphate + potassium humate recorded the highest NPK of 15% (N-4.5%, P-5%, K-5.5%) (Table. 2). Microbial fermentation of nitrogen rich groundnut cake was previously studied to support higher nitrogen release [7]. Rock phosphate fermentation in the presence of phosphobacteria was also studied for phosphate

solubilization [8]. Potassium humate provided slow release of K complemented by potassium mobilizing microbes. These findings are similar with [9], who reported that the insoluble K and structural inaccessible forms of K complexes are mobilized and solubilized due to the excretion of a wide range of organic acids by microbes.

Phytohormone and Enzyme Production

Indole 3 acetic acid and Gibberellic acid in the formulation of groundnut cake + rock phosphate + potassium humate which contains 15% NPK were tested using High Performance Liquid Chromatography (HPLC) while Cellulase and Phosphatase activity were tested by Bradford Protein estimation method.

The results obtained shows that IAA, 28.6 µg/mL, GA₃, 19.3 µg/mL, Cellulase 4.8 IU/mL and Phosphatase 3.6 IU/mL were recorded in that specific formulation. The presence of probiotics contributes to IAA and gibberellin production [10].

Plant Growth Performance in Pot Culture and Field Trails

Plant Growth parameters of Paddy (*Oryza Sativa*) ADT-37 at pot culture and Field Trails were carried out at 60 and 120 days after transplanting respectively (Fig. 7) (Fig. 8). Results showed that Treatment T₂₁ (the formulation containing groundnut cake + rock phosphate + potassium humate + 50% RDF) recorded the highest plant height 89.4 cm, 14.4 tillers per plant and Chlorophyll content (SPAD value 47.9) in pot culture studies (Table 3) and also T₂₁ recorded maximum values of plant height, number of productive tillers per plant and 1000 grain weight in field studies compared with control and inorganic fertilizer treatment (Table 4).

Soil Health and Microbial Response

Soil from 29 pots were analysed after harvesting of paddy for available NPK, organic carbon and microbial population. Results favoured T₂₁ treatment (50% organic + 50% RDF) that produces 0.48% available NPK, 0.68% organic carbon and 2.17 x 10⁶ CFU/g of soil. These results were significantly higher compared to inorganic treatment and control (Table 5). Thus, the diverse microbial population promote better soil health and organic matter content.



Fig 1: Collection of Nine different Agro residues rich in N, P & K



Fig 2: Fermentation of Agro residues in Sterilized Molasses Medium



Fig 3: Isolation of Probiotic Strain *Lactobacillus*



Fig 4: Isolation of Probiotic Strains *Saccharomyces*

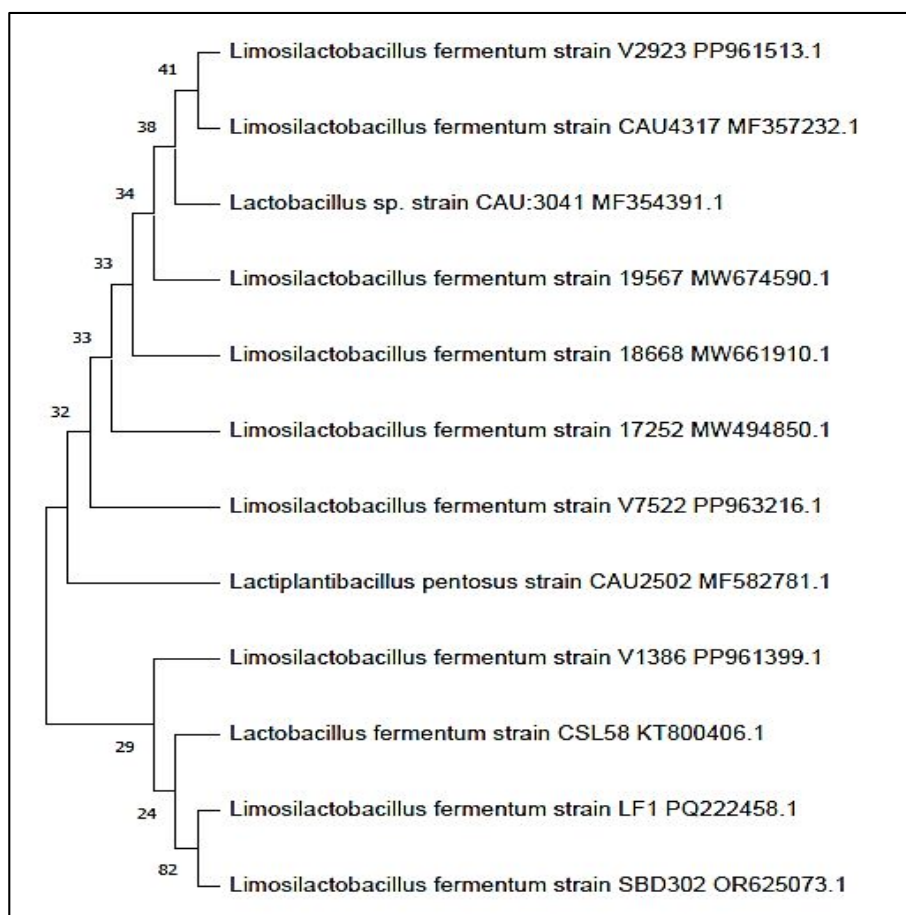


Fig 5: Phylogenetic tree of *Lactobacillus* LF1 Strain

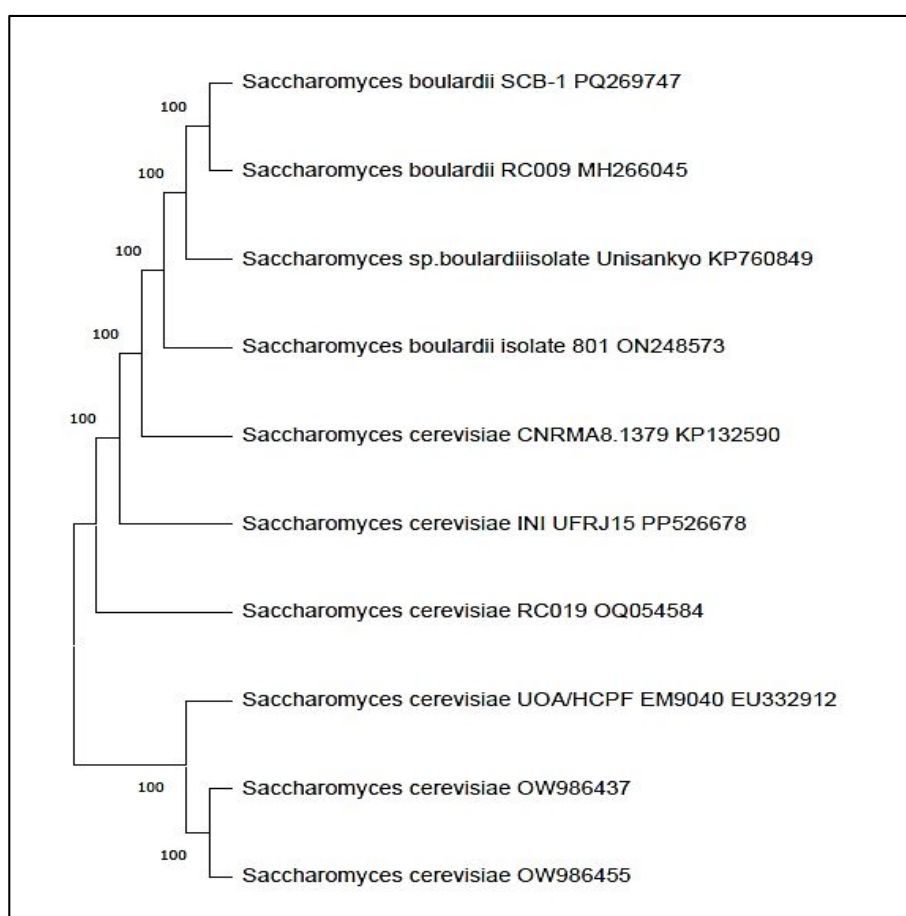


Fig 6: Phylogenetic Tree of *Saccharomyces* SCB-1 Strain



Fig 7: Plant Growth parameters on paddy under pot culture @ 60 DAT



Fig 8: Plant growth Parameters on paddy under field conditions @ 120 DAT

Table 1: Treatment Details

T ₁	Control
T ₂	RDF
T ₃	Poultry Litter + Rock Phosphate + Potassium Humate + 50% RDF NPK
T ₄	Poultry Litter+ Rock Phosphate + Wood Ash + 50% RDF NPK
T ₅	Poultry Litter+ Rock Phosphate + Pressmud + 50% RDF NPK
T ₆	Poultry Litter+ Prom + Potassium Humate + 50% RDF NPK
T ₇	Poultry Litter+ Prom + Wood Ash + 50% RDF NPK
T ₈	Poultry Litter+ Prom + Pressmud + 50% RDF NPK
T ₉	Poultry Litter+ Bone Meal + Potassium Humate + 50% RDF NPK
T ₁₀	Poultry Litter+ Bone Meal + Wood Ash + 50% RDF NPK
T ₁₁	Poultry Litter+ Bone Meal + Pressmud + 50% RDF NPK
T ₁₂	Greengram Flour + Rock Phosphate + Potassium Humate + 50% RDF NPK
T ₁₃	Greengram Flour + Rock Phosphate + Wood Ash + 50% RDF NPK
T ₁₄	Greengram Flour + Rock Phosphate + Pressmud + 50% RDF NPK
T ₁₅	Greengram Flour + Prom + Potassium Humate + 50% RDF NPK
T ₁₆	Greengram Flour + Prom + Wood Ash + 50% RDF NPK
T ₁₇	Greengram Flour + Prom + Pressmud + 50% RDF NPK
T ₁₈	Greengram Flour + Bone Meal + Potassium Humate + 50% RDF NPK
T ₁₉	Greengram Flour + Bone Meal + Wood Ash + 50% RDF NPK
T ₂₀	Greengram Flour + Bone Meal + Pressmud + 50% RDF NPK
T ₂₁	Groundnut Cake + Rock Phosphate + Potassium Humate + 50% RDF NPK
T ₂₂	Groundnut Cake + Rock Phosphate + Wood Ash + 50% RDF NPK
T ₂₃	Groundnut Cake + Rock Phosphate + Pressmud + 50% RDF NPK
T ₂₄	Groundnut Cake + Prom + Potassium Humate + 50% RDF NPK
T ₂₅	Groundnut Cake + Prom + Wood Ash + 50% RDF NPK
T ₂₆	Groundnut Cake + Prom + Pressmud + 50% RDF NPK
T ₂₇	Groundnut Cake + Bone Meal + Potassium Humate + 50% RDF NPK
T ₂₈	Groundnut Cake + Bone Meal + Wood Ash + 50% RDF NPK
T ₂₉	Groundnut Cake + Bone Meal + Pressmud + 50% RDF NPK

Table 2: NPK % of the different fermented organic liquid fertilizer formulations

S. No	Treatment Combination	N%	P%	K%	Total NPK %
1	Poultry Litter + Rock Phosphate + Potassium Humate	3.2	5.3	5.6	14.1
2	Poultry Litter+ Rock Phosphate + Wood Ash	3	5.4	6.1	14.5
3	Poultry Litter+ Rock Phosphate + Pressmud	3.4	5.5	4.6	13.5
4	Poultry Litter+ Prom + Potassium Humate	3.4	4.8	5.7	13.9
5	Poultry Litter+ Prom + Wood Ash	3.2	4.9	6.2	14.3
6	Poultry Litter+ Prom + Pressmud	3.6	5	4.7	13.3
7	Poultry Litter+ Bone Meal + Potassium Humate	4.1	4.1	5.8	14
8	Poultry Litter+ Bone Meal + Wood Ash	3.9	4.2	6.3	14.4
9	Poultry Litter+ Bone Meal + Pressmud	4.3	4.3	4.8	13.4
10	Greengram Flour + Rock Phosphate + Potassium Humate	3.9	4.6	5.2	13.7
11	Greengram Flour + Rock Phosphate + Wood Ash	3.7	4.7	5.7	14.1
12	Greengram Flour + Rock Phosphate + Pressmud	4.1	4.8	4.2	13.1
13	Greengram Flour + Prom + Potassium Humate	4.1	4.1	5.3	13.5
14	Greengram Flour + Prom + Wood Ash	3.9	4.2	5.8	13.9
15	Greengram Flour + Prom + Pressmud	4.3	4.3	4.3	12.9
16	Greengram Flour + Bone Meal + Potassium Humate	4.8	3.4	5.4	13.6
17	Greengram Flour + Bone Meal + Wood Ash	4.6	3.5	5.9	14
18	Greengram Flour + Bone Meal + Pressmud	5	3.6	4.4	13
19	Groundnut Cake + Rock Phosphate + Potassium Humate	4.5	5	5.5	15
20	Groundnut Cake + Rock Phosphate + Wood Ash	4.3	4.9	5.6	14.8
21	Groundnut Cake + Rock Phosphate + Pressmud	4.7	5.2	4.5	14.4
22	Groundnut Cake + Prom + Potassium Humate	4.7	4.5	5.5	14.7
23	Groundnut Cake + Prom + Wood Ash	4.5	4.6	5.7	14.8
24	Groundnut Cake + Prom + Pressmud	4.9	4.7	4.6	14.2
25	Groundnut Cake + Bone Meal + Potassium Humate	5.3	3.8	5.6	14.7
26	Groundnut Cake + Bone Meal + Wood Ash	5.1	3.9	5.6	14.6
27	Groundnut Cake + Bone Meal + Pressmud	5.6	4	4.7	14.3

Table 3: Growth Performance of Paddy (ADT 37) at 60 DAT under Different Fertilizer Treatments in Pot Culture Experiment

S. No	Treatment Combination	Plant Ht (cm)	Tillers per Plant	SPAD (Chlorophyll)
1	Control	62.9	8.2	32.4
2	RDF	80.5	12.5	42.2
3	Poultry Litter + Rock Phosphate + Potassium Humate + 50% RDF NPK	77.2	12.1	41.2
4	Poultry Litter+ Rock Phosphate + Wood Ash + 50% RDF NPK	85.7	13.8	45.9
5	Poultry Litter+ Rock Phosphate + Pressmud + 50% RDF NPK	82.7	13.2	44.1
6	Poultry Litter+ Prom + Potassium Humate + 50% RDF NPK	80.3	12.9	42.9
7	Poultry Litter+ Prom + Wood Ash + 50% RDF NPK	74.1	11.8	39.3
8	Poultry Litter+ Prom + Pressmud + 50% RDF NPK	73.7	11.5	39.3
9	Poultry Litter+ Bone Meal + Potassium Humate + 50% RDF NPK	72.5	11.3	38.5
10	Poultry Litter+ Bone Meal + Wood Ash + 50% RDF NPK	84.7	13.3	45.4
11	Poultry Litter+ Bone Meal + Pressmud + 50% RDF NPK	80.6	12.6	43.2
12	Greengram Flour + Rock Phosphate + Potassium Humate + 50% RDF NPK	83.8	13	45
13	Greengram Flour + Rock Phosphate + Wood Ash + 50% RDF NPK	72.4	11.2	38.8
14	Greengram Flour + Rock Phosphate + Pressmud + 50% RDF NPK	82.5	12.9	44.5
15	Greengram Flour + Prom + Potassium Humate + 50% RDF NPK	78.3	12.3	42
16	Greengram Flour + Prom + Wood Ash + 50% RDF NPK	68.2	10.6	36.5
17	Greengram Flour + Prom + Pressmud + 50% RDF NPK	68.7	11.2	36.5
18	Greengram Flour + Bone Meal + Potassium Humate + 50% RDF NPK	65.6	10.8	34.9
19	Greengram Flour + Bone Meal + Wood Ash + 50% RDF NPK	84.4	13.7	44.8
20	Greengram Flour + Bone Meal + Pressmud + 50% RDF NPK	78.9	12.9	41.9
21	Groundnut Cake + Rock Phosphate + Potassium Humate + 50% RDF NPK	89.4	14.4	47.9
22	Groundnut Cake + Rock Phosphate + Wood Ash + 50% RDF NPK	87.1	13.8	47.2
23	Groundnut Cake + Rock Phosphate + Pressmud + 50% RDF NPK	85.6	13.6	46.1
24	Groundnut Cake + Prom + Potassium Humate + 50% RDF NPK	80.6	12.8	43.5
25	Groundnut Cake + Prom + Wood Ash + 50% RDF NPK	76.7	12.1	41
26	Groundnut Cake + Prom + Pressmud + 50% RDF NPK	76.7	11.9	41.1
27	Groundnut Cake + Bone Meal + Potassium Humate + 50% RDF NPK	73.6	11.3	39.5
28	Groundnut Cake + Bone Meal + Wood Ash + 50% RDF NPK	86.5	13.5	46.7
29	Groundnut Cake + Bone Meal + Pressmud + 50% RDF NPK	81	12.7	43.8

Table 4: Estimation of Ideal Growth Parameters of Paddy Under Field Conditions

Tr. No.	Treatment Description	Plant Ht (cm)	Productive Tillers/Plant	Panicle Length (cm)	Grains/ Panicle	1000- Grain Weight (g)
T ₁	Control	68	9.4	19	83	20.7
T ₂	RDF	81.6	13.9	24.7	119	25.6
T ₃	Poultry Litter + Rock Phosphate + Potassium Humate + 50% RDF NPK	84.3	12.9	23.5	114	24.1
T ₄	Poultry Litter+ Rock Phosphate + Wood Ash + 50% RDF NPK	82.9	13	23	112	23.8
T ₅	Poultry Litter+ Rock Phosphate + Pressmud + 50% RDF NPK	82.4	12.9	22.8	110	23.6
T ₆	Poultry Litter+ Prom + Potassium Humate + 50% RDF NPK	83.3	13.1	23.1	113	23.9
T ₇	Poultry Litter+ Prom + Wood Ash + 50% RDF NPK	82	12.8	22.6	109	23.4
T ₈	Poultry Litter+ Prom + Pressmud + 50% RDF NPK	80.7	12.3	22.3	107	23.2
T ₉	Poultry Litter+ Bone Meal + Potassium Humate + 50% RDF NPK	82.8	12.8	22.8	112	23.7
T ₁₀	Poultry Litter+ Bone Meal + Wood Ash + 50% RDF NPK	81.6	12.5	22.7	108	23.7
T ₁₁	Poultry Litter+ Bone Meal + Pressmud + 50% RDF NPK	80.5	12.3	22.5	106	23.4
T ₁₂	Greengram Flour + Rock Phosphate + Potassium Humate + 50% RDF NPK	84	12.7	23.6	113	24.1
T ₁₃	Greengram Flour + Rock Phosphate + Wood Ash + 50% RDF NPK	82.1	12.4	23	110	23.7
T ₁₄	Greengram Flour + Rock Phosphate + Pressmud + 50% RDF NPK	80.8	12.2	22.7	108	23.5
T ₁₅	Greengram Flour + Prom + Potassium Humate + 50% RDF NPK	82.9	12.7	23	112	23.8
T ₁₆	Greengram Flour + Prom + Wood Ash + 50% RDF NPK	81	12.3	22.6	109	23.3
T ₁₇	Greengram Flour + Prom + Pressmud + 50% RDF NPK	80.3	12.7	22.1	106	23.1
T ₁₈	Greengram Flour + Bone Meal + Potassium Humate + 50% RDF NPK	82.9	13.2	22.8	111	23.6
T ₁₉	Greengram Flour + Bone Meal + Wood Ash + 50% RDF NPK	81.6	12.9	22.5	108	23.3
T ₂₀	Greengram Flour + Bone Meal + Pressmud + 50% RDF NPK	80.6	12.7	22.1	105	22.9
T ₂₁	Groundnut Cake + Rock Phosphate + Potassium Humate + 50% RDF NPK	90.6	15	25.5	125	25.3
T ₂₂	Groundnut Cake + Rock Phosphate + Wood Ash + 50% RDF NPK	89	14.1	24.8	121	24.9
T ₂₃	Groundnut Cake + Rock Phosphate + Pressmud + 50% RDF NPK	87.3	13.7	24.3	118	24.6
T ₂₄	Groundnut Cake + Prom + Potassium Humate + 50% RDF NPK	88.6	14.2	25	122	25.1
T ₂₅	Groundnut Cake + Prom + Wood Ash + 50% RDF NPK	87.3	13.8	24.4	119	24.7
T ₂₆	Groundnut Cake + Prom + Pressmud + 50% RDF NPK	86.5	13.4	24.2	116	24.5
T ₂₇	Groundnut Cake + Bone Meal + Potassium Humate + 50% RDF NPK	88.3	13.9	24.8	121	25.1
T ₂₈	Groundnut Cake + Bone Meal + Wood Ash + 50% RDF NPK	87	13.5	24.3	117	24.6
T ₂₉	Groundnut Cake + Bone Meal + Pressmud + 50% RDF NPK	85.3	13.2	23.9	115	24.3

Table 5: Post-Harvest Estimation of Available NPK, Organic Carbon, and Microbial Population under Different Nutrient Management Treatments

Tr. No.	Treatment Description	Available NPK (%)	Organic Carbon (%)	Microbial Population (CFU/g)
T ₁	Control	0.26	0.41	1.10×10^6
T ₂	RDF	0.33	0.44	1.49×10^6
T ₃	Poultry Litter + Rock Phosphate + Potassium Humate + 50% RDF NPK	0.4	0.47	1.50×10^6
T ₄	Poultry Litter+ Rock Phosphate + Wood Ash + 50% RDF NPK	0.39	0.46	1.53×10^6
T ₅	Poultry Litter+ Rock Phosphate + Pressmud + 50% RDF NPK	0.38	0.45	1.54×10^6
T ₆	Poultry Litter+ Prom + Potassium Humate + 50% RDF NPK	0.4	0.48	1.60×10^6
T ₇	Poultry Litter+ Prom + Wood Ash + 50% RDF NPK	0.39	0.47	1.59×10^6
T ₈	Poultry Litter+ Prom + Pressmud + 50% RDF NPK	0.37	0.45	1.53×10^6
T ₉	Poultry Litter+ Bone Meal + Potassium Humate + 50% RDF NPK	0.39	0.46	1.58×10^6
T ₁₀	Poultry Litter+ Bone Meal + Wood Ash + 50% RDF NPK	0.38	0.45	1.56×10^6
T ₁₁	Poultry Litter+ Bone Meal + Pressmud + 50% RDF NPK	0.34	0.44	1.53×10^6
T ₁₂	Greengram Flour + Rock Phosphate + Potassium Humate + 50% RDF NPK	0.37	0.47	1.61×10^6
T ₁₃	Greengram Flour + Rock Phosphate + Wood Ash + 50% RDF NPK	0.36	0.46	1.58×10^6
T ₁₄	Greengram Flour + Rock Phosphate + Pressmud + 50% RDF NPK	0.34	0.45	1.57×10^6
T ₁₅	Greengram Flour + Prom + Potassium Humate + 50% RDF NPK	0.37	0.48	1.63×10^6
T ₁₆	Greengram Flour + Prom + Wood Ash + 50% RDF NPK	0.36	0.47	1.61×10^6
T ₁₇	Greengram Flour + Prom + Pressmud + 50% RDF NPK	0.34	0.45	1.55×10^6
T ₁₈	Greengram Flour + Bone Meal + Potassium Humate + 50% RDF NPK	0.37	0.49	1.64×10^6
T ₁₉	Greengram Flour + Bone Meal + Wood Ash + 50% RDF NPK	0.36	0.47	1.63×10^6
T ₂₀	Greengram Flour + Bone Meal + Pressmud + 50% RDF NPK	0.41	0.45	1.61×10^6
T ₂₁	Groundnut Cake + Rock Phosphate + Potassium Humate + 50% RDF NPK	0.48	0.68	2.17×10^6
T ₂₂	Groundnut Cake + Rock Phosphate + Wood Ash + 50% RDF NPK	0.46	0.64	2.11×10^6
T ₂₃	Groundnut Cake + Rock Phosphate + Pressmud + 50% RDF NPK	0.45	0.62	1.95×10^6
T ₂₄	Groundnut Cake + Prom + Potassium Humate + 50% RDF NPK	0.47	0.66	2.00×10^6
T ₂₅	Groundnut Cake + Prom + Wood Ash + 50% RDF NPK	0.45	0.63	1.94×10^6
T ₂₆	Groundnut Cake + Prom + Pressmud + 50% RDF NPK	0.39	0.61	1.89×10^6
T ₂₇	Groundnut Cake + Bone Meal + Potassium Humate + 50% RDF NPK	0.41	0.65	2.09×10^6
T ₂₈	Groundnut Cake + Bone Meal + Wood Ash + 50% RDF NPK	0.4	0.63	1.87×10^6
T ₂₉	Groundnut Cake + Bone Meal + Pressmud + 50% RDF NPK	0.39	0.61	1.92×10^6

Conclusion

The current research offers scientific knowledge on the feasibility in exploiting probiotic-assisted fermentation as a green technique for upscaling NPK liquification from agro-waste. The combination of groundnut cake, rock phosphate and potash humate was found to be the best among 27 combinations tested for obtaining high plant nutrients (15% NPK) and also enriched with microbial metabolites (IAA, gibberellic acid, cellulase, phosphatase).

Field and pot experiments on the paddy (var. ADT 37) was reported that T₂₁ significantly improved plant growth, tillering, and grain yield at least similar to full chemical fertilizer application. Furthermore, its application benefited soil health after harvest by improving soil organic carbon and microbial biomass, confirming the potential long-term agronomic advantages.

The treatment T₂₁ (50% organic + 50% recommended chemical fertilizers) recorded the maximum yield which proves the suitability of these formulations in Integrated Nutrient Management (INM) systems. Considering the increasing soil deterioration and dependence on fertilizers, these biologically enhanced liquid fertilizers may offer a step toward more sustainable food systems.

References

- Sharma A, Chetani R. A review on the effect of organic and chemical fertilizers on plants. *International Journal of Research in Applied Science and Engineering Technology*. 2017;5(2):677-680.
- Gupta ARTI, Hussain NISREEN. A critical study on the use, application and effectiveness of organic and inorganic fertilizers. *Journal of Industrial Pollution Control*. 2014;30(2):191-194.
- Mengqi Z, Shi A, Ajmal M, Ye L, Awais M. Comprehensive review on agricultural waste utilization and high-temperature fermentation and composting. *Biomass Conversion and Biorefinery*. 2023;13(7):5445-5468.
- Ashrafi Esfahani A, Niknejad Y, Fallah H, Dastan S. Integrated management of organic manures and chemical fertilizers for enhancing paddy yield and the nutrient content of rice cultivars. *Communications in Soil Science and Plant Analysis*. 2019;50(5):570-585.
- Kiruba NJM, Saeid A. An insight into microbial inoculants for bioconversion of waste biomass into sustainable "bio-organic" fertilizers: a bibliometric analysis and systematic literature review. *International Journal of Molecular Sciences*. 2022;23(21):13049.
- Fikre FW. Organic liquid fertilizer production from sheep manure and onion peels and testing its effectiveness [dissertation/thesis]. [Place unknown]: [Publisher unknown]; 2019. [Page numbers not available].
- Duhan JS, Saharan P, Sadh PK. Effect of production parameters on release of phenolic content of peanut press cake fermented with *Aspergillus oryzae* and *A. awamori*. *International Journal of Pharmacy and Biological Sciences*. 2019;9(2):434-444.
- do Carmo TS, Moreira FS, Cabral BV, Dantas RC, de Resende MM, Cardoso VL, *et al.* Phosphorus recovery from phosphate rocks using phosphate-solubilizing bacteria. *Geomicrobiology Journal*. 2019;36(3):195-203.
- Bellaso PG, Ebo R, Pepania AKC, Yabo BB, Tabiolo CDL. Degradation of organic kitchen food wastes enhanced with probiotics. [Journal name, volume, issue, and page numbers not provided].
- Amrullah S, Amin M, Ali M. Converting husbandry waste into liquid organic fertilizer using probiotic consortiums (*Lactobacillus* sp., *Rhodopseudomonas* sp., *Actinomyces* sp., *Streptomyces* sp.). In: IOP Conference Series: Earth and Environmental Science. 2021 Feb;679(1):012001. IOP Publishing.