



RESEARCH ARTICLE

Effects of poultry manure and seaweed extract on growth and yield of rice (*Oryza sativa* L.)

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Abstract

The heavy use of chemical fertilisers for a long period of time deteriorates the soil quality and productivity of the crop. So, a field trial on “Effects of poultry manure and seaweed extract on growth and yield of rice (*Oryza sativa* L.)” was conducted during the kharif season (2024) at the Agri Farm, Lovely Professional University, Punjab to evaluate the effectiveness of poultry manure and seaweed extract on the growth and yield of rice. The field trial was structured in a split plot design with three replications; the main plots were poultry manure with four levels (0, 5, 10 and 15 t ha⁻¹) and the subplots were seaweed extract with four levels (0 %, 0.25 %, 0.75 % and 1 %), forming 16 treatment combinations and 48 plots. Results demonstrated that increasing levels of poultry manure significantly improved plant height, number of tillers, dry weight, panicle length and grain yield. The highest grain yield (6.33 t ha⁻¹) and harvest index (48.21 %) were noted with 15 t ha⁻¹ poultry manure (M₄). Among the seaweed extract treatments, 1 % foliar spray (S₄) produced the maximum grain yield (6.01 t ha⁻¹) and harvest index (48.22 %). The combined application of 15 t ha⁻¹ poultry manure + 1 % seaweed extract (M₄S₄) produced the maximum grain yield (7.19 t ha⁻¹). Thus, integrating poultry manure and seaweed extract proved to be a sustainable and eco-friendly practice for improving rice productivity.

Keywords: foliar spray; poultry manure; rice; seaweed extract; sustainable; yield

Introduction

Rice (*Oryza sativa* L.) is one of the most widely cultivated cereal crops worldwide and serves as a staple food for more than half of the global population (1). Rice is the predominant kharif crop as well as an important source of food security in India (2). However, excessive and prolonged usage of chemical fertilisers has led to issues such as nutrient imbalance, low soil fertility and environmental pollution (3). The application of organic manures and natural biostimulants has gained importance to overcome these problems.

Poultry manure contributes a substantial amount of nitrogen, phosphorus, potassium and micronutrients among the various sources of organics. It enhances the soil structure, increases microbial activity as well as provides nutrients to crops in a stable way. Several studies have reported that the application of poultry manure improves rice growth, increases the number of tillers, enhances yield attributes and ultimately increases grain yield. Therefore, poultry manure not only enriches the soil but also improves the productivity of crops. Seaweed extract is obtained from marine algae, which contain plant growth hormones like auxins, cytokinins and gibberellins as well as other useful nutrients like amino acids, vitamins and minerals. Foliar spraying of seaweed extract has been demonstrated to enhance photosynthesis, root development, nutrient absorption and stress resistance in crops. Earlier researchers mentioned that seaweed extract enhanced plant height, panicle growth and yield in rice (4).

Both poultry manure and seaweed extract are highly effective in improving the growth and productivity of rice. Poultry manure is used to enrich the soil, whereas seaweed extract is used to boost physiological processes. Their combined use can have a synergistic benefit of greater yield and greater soil health. Thus, the existing research was conducted to analyze the impact of poultry manure, as well as foliar seaweed extract on growth, yield parameters and productivity of rice in the Punjab environment.

Materials and Methods

The objective of the field trial was to evaluate how poultry manure and seaweed extract affected the growth and yield of rice in the kharif season (2024) under the influence of poultry manure and seaweed extract. The study area (Fig. 1) was situated at the Agri Farm, Lovely Professional University, Punjab (31°14'39.10"N, 75°41'51.67"E, 252 m mean sea level (MSL)). The weather in the area is hot, dry and subtropical with 760 to 800 mm rainfall each year. The temperature during the season was usually 25–35 °C. This mostly happens in the monsoon season. The experimental soil was sandy in texture and slightly alkaline (pH 8.02), determined using a glass electrode pH meter (5). It had low available nitrogen (150.26 kg ha⁻¹) determined by the alkaline potassium permanganate method (6), medium available phosphorus (11.64 kg ha⁻¹) determined by the Olsen method (7) using ammonium molybdate as a reagent. Available potassium (273.75 kg ha⁻¹) was determined using a flame photometer. Before

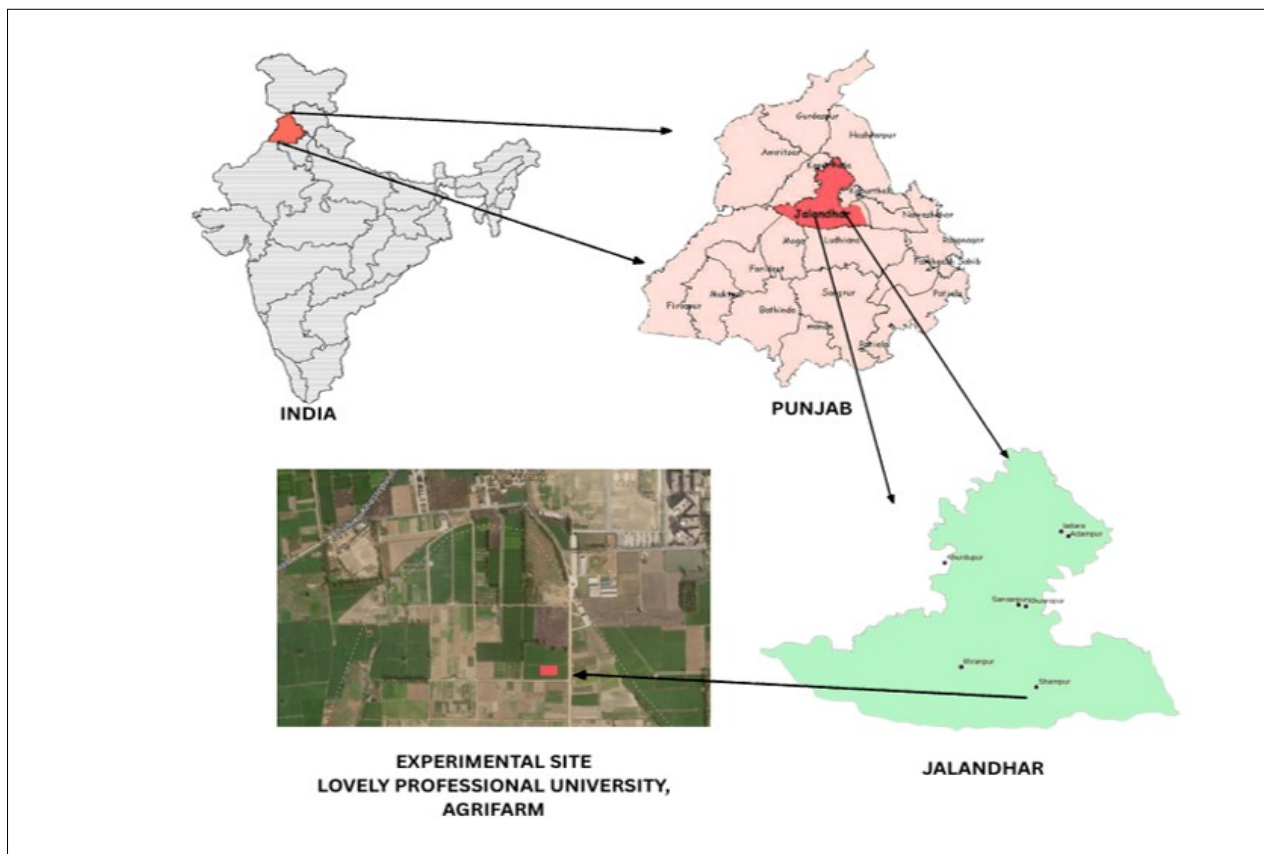


Fig. 1. Study area of the experiment.

sowing, a baseline soil sample (0–15 cm depth) was collected to carry out physicochemical analysis of the soil. Soil samples were collected at random from different locations of the experimental field using a soil auger. The samples were air-dried, ground and passed through a 2 mm sieve before being analysed.

A field trial was conducted using a split-plot design with three replications. The main plots consisted of four levels of poultry manure (PM): 0, 5, 10 and 15 t ha⁻¹. The subplots included four concentrations of seaweed extract: 0, 0.25, 0.75 and 1 %, forming a total of 16 treatment combinations and 48 plots. Each plot measured 5 m × 3 m. The test crop was rice (*Oryza sativa* L., variety Parimal), which was transplanted at 20 × 15 cm row spacing. The incorporation of poultry manure in the soil was done two weeks before transplantation. The poultry manure used in the experiment contained approximately 2.64 % N, 2.21 % P₂O₅ and 1.16 % K₂O. All plots received the recommended fertiliser dose of 120:60:40 kg N:P:K ha⁻¹. The application of nitrogen was done in three doses at the time of planting, tillering and at the beginning of panicle development. The 100 % natural seaweed extract from the brown macro algae (*Sargassum* sp.) available was diluted with water to prepare the required concentrations before foliar application. The required concentrations (0.25 %, 0.75 % and 1 %) were prepared by mixing the calculated quantity of seaweed extract with water and the solution was thoroughly mixed before spraying. Spraying of seaweed extract was done in the tiller stages and panicle initiation. The foliar spray was applied uniformly using a hand-operated knapsack sprayer during the morning hours. Standard agronomic practices for irrigation, weeding and plant protection were followed.

At various stages of crop development, growth and yield data were recorded. The plant heights were measured at 30, 60 and 90 days after transplanting (DAT) as well as at harvest. Dry

matter accumulation was determined by oven-drying plant samples at 70 °C until constant weight was reached. Number of tillers was counted at 30 and 60 DAT with effective tillers counted at harvest. The following yield attributes were also recorded: panicle length, grains per panicle, grain yield and straw yield.

Harvest index (%)

As per (8), the formula is

$$\text{Harvest index (\%)} = \frac{\text{Economical yield (q ha}^{-1}\text{)}}{\text{Biological yield (q ha}^{-1}\text{)}} \times 100 \quad \text{Eq. 1}$$

As per (9), the formula is

$$\text{Benefit cost ratio (B:C)} = \frac{\text{Net return}}{\text{Cost of cultivation}} \quad \text{Eq. 2}$$

All data were tabulated in tables and checked using analysis of variance (ANOVA) method given earlier (10). If the *F*-test showed a difference, the Critical Difference (CD) at the 5 % level was found. Microsoft Excel was used for analysing the data and Grapes Kau software was used to make graphs.

Results and Discussion

Effects of poultry manure and seaweed extract on growth attributes of rice

The application of different levels of poultry manure and seaweed extract significantly influenced all the parameters of rice growth (Table 1). The height of the plant (100.14 cm), the dry weight (37.57 g) and number of tillers per hill (10.78) were lowest in the control (M₁). The tallest plant height (108.87 cm), dry weight (50.18 g) and number of tillers per hill (15.97) were observed with the application of 15 t ha⁻¹ poultry manure (M₄). This may be

Table 1. Response of rice to poultry manure and seaweed extract in growth parameters

Treatment details	Plant height (cm) at harvest	Dry weight (g) at harvest	Number of tillers per hill
Main plots			
M ₁ : Control	100.14	37.57	10.78
M ₂ : 5 t ha ⁻¹ PM	102.05	41.81	11.88
M ₃ : 10 t ha ⁻¹ PM	104.77	46.32	13.75
M ₄ : 15 t ha ⁻¹ PM	108.87	50.18	15.97
SEd (±)	2.17	1.46	0.62
CD (P = 0.05)	5.31	3.57	1.53
Sub plots			
S ₁ : Control	100.94	40.00	11.56
S ₂ : 0.25 % SE	102.45	42.56	12.71
S ₃ : 0.75 % SE	105.30	45.18	13.10
S ₄ : 1 % SE	107.14	48.14	14.61
SEd (±)	1.78	0.80	0.47
CD (P = 0.05)	3.67	1.64	0.97
Interaction (M×S)			
SEd (±)	3.56	1.59	0.94
CD (P = 0.05)	7.34	3.28	1.93

attributed to the improved nutrient supply (N, P, K) from poultry manure which led to an increase in root growth and uptake efficiency of nutrients. The manure also improved the soil structure and microbial activity that contributed to the increase in the growth of the plants and biomass accumulation of the plant (11). Previous research has also reported similar enhancements in the growth of rice at increased poultry manure content, as better nutrient supply and improvement in soil microbial activity increased vegetative development and tiller formation. Similarly, under subplots seaweed extract levels, the lowest performance was observed in the control (S₁) with plant height (100.94 cm), dry weight (40.00 g) and number of tillers per hill (11.56) (Table 1), while 1 % seaweed extract (S₄) treatment produced the tallest plant height (107.14 cm), dry weight (48.14 g) and number of tillers per hill (14.61). The presence of plant growth regulators like auxins, cytokinins and gibberellins in seaweed extract stimulated the physiological activity and crop development. These findings agree with previous reports that seaweed-derived cytokinins stimulate tiller bud initiation and delay leaf senescence, thereby improving vegetative growth in cereal crops. The combined effect M₄S₄ (15 t ha⁻¹ poultry manure + 1 % seaweed extract) showed the best performance with plant height (114.62 cm), dry weight (53.77 g) and number of tillers per hill (18.92) as shown in Table 2, 3 and 4. The combined application had a synergistic effect, where poultry manure improved soil nutrient status and the seaweed extract enhanced nutrient absorption and physiological efficiency (12).

Effects of poultry manure and seaweed extract on yield attributes and yield of rice

The level of poultry manure and seaweed extract significantly affected the yield attributes and yield of rice (Table 5). The lowest values of effective tillers per hill (8.93), panicle length (25.89 cm), number of grains panicle⁻¹ (117.16), test weight (22.05 g), grain yield (4.00 t ha⁻¹) and straw yield (4.67 t ha⁻¹) and harvest index (44.05 %) were recorded in the control (M₁). However, using 15 t ha⁻¹ of poultry manure (M₄) produced the best results with higher values for effective tillers per hill (14.21), panicle length (33.06 cm), number of grains panicle⁻¹ (130.16), test weight (24.00 g), grain yield (6.33 t ha⁻¹), straw yield (6.90 t ha⁻¹) and harvest index (48.21 %). The high manure levels resulted in enhanced root mass, nutrient uptake and photosynthetic efficiency, that stimulated the growth and development of roots, nutrients and photosynthesis, which increased the production of assimilates and translocation of those to the developing grains (13). The magnitude of improvement recorded in the current study is similar to the previous results, which show that increased levels of poultry manure elevate the yield attributes under similar agro-climatic conditions.

Similarly, the lowest yield related attributes were recorded in the control (S₁) in terms of effective tillers per hill (9.95), panicle length (25.71 cm), number of grains per panicle (117.66), test weight (21.95 g), grain yield (3.95 t ha⁻¹), straw yield

Table 2. Interaction effects of poultry manure and seaweed extract on plant height of rice

Poultry manure	Seaweed extract	Plant height (cm) at harvest				
		S ₁	S ₂	S ₃	S ₄	Mean
M ₁ : Control		91.63	99.03	102.91	107.00	100.14
M ₂ : 5 t ha ⁻¹ PM		103.33	103.93	99.09	101.85	102.05
M ₃ : 10 t ha ⁻¹ PM		105.23	99.97	108.77	105.09	104.77
M ₄ : 15 t ha ⁻¹ PM		103.56	106.87	110.41	114.62	108.87
Mean		100.94	102.45	105.30	107.14	
				SEd (±)		CD (0.05)
S at same level of M				3.56		7.34
M at same or different level of S				3.77		7.88

Table 3. Interaction effects of poultry manure and seaweed extract on dry weight of rice

Poultry manure	Seaweed extract	Dry weight (g) at harvest				
		S ₁	S ₂	S ₃	S ₄	Mean
M ₁ : Control		33.05	36.20	40.43	40.58	37.57
M ₂ : 5 t ha ⁻¹ PM		35.69	39.56	41.27	50.73	41.81
M ₃ : 10 t ha ⁻¹ PM		45.11	45.78	46.93	47.46	46.32
M ₄ : 15 t ha ⁻¹ PM		46.15	48.69	52.09	53.77	50.18
Mean		40.00	42.56	45.18	48.14	
				SEd (±)		CD (0.05)
S at same level of M				1.59		3.29
M at same or different level of S				2.01		4.14

Table 4. Interaction effects of poultry manure and seaweed extract on number of tillers per hill of rice

Poultry manure	Seaweed extract		Number of tillers per hill (60 DAT)			
	S ₁	S ₂	S ₃	S ₄	Total	Mean
M ₁ : Control	10.21	10.54	10.42	11.92	43.10	10.78
M ₂ : 5 t ha ⁻¹ PM	10.72	11.89	11.62	13.31	47.54	11.88
M ₃ : 10 t ha ⁻¹ PM	14.04	12.79	13.90	14.29	55.02	13.75
M ₄ : 15 t ha ⁻¹ PM	12.87	15.63	16.47	18.92	63.89	15.97
Mean	11.96	12.71	13.10	14.61		
			SEd (±)		CD (0.05)	
S at same level of M			0.94		1.94	
M at same or different level of S			1.03		2.12	

Table 5. Response of rice to poultry manure and seaweed extract in yield parameters

Treatments details	Number of effective tillers per hill	Panicle length	Number of grain panicle ⁻¹	Test weight (g)	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Harvest index (%)
Main plots							
M ₁ : Control	8.93	25.89	117.16	22.05	4.00	4.67	44.05
M ₂ : 5 t ha ⁻¹ PM	10.19	27.77	120.34	22.19	4.61	5.48	46.16
M ₃ : 10 t ha ⁻¹ PM	11.44	30.63	122.20	22.49	5.59	6.53	47.14
M ₄ : 15 t ha ⁻¹ PM	14.21	33.06	130.16	24.00	6.33	6.90	48.21
SEd (±)	0.36	0.80	1.97	0.30	0.19	0.17	0.72
CD (P = 0.05)	0.89	1.96	4.82	0.74	0.45	0.43	1.76
Sub plots							
S ₁ : Control	9.95	25.71	117.66	21.95	3.95	5.52	44.98
S ₂ : 0.25 % SE	10.88	28.74	120.24	22.67	5.00	5.62	45.83
S ₃ : 0.75 % SE	11.66	30.40	123.83	22.70	5.57	6.18	46.54
S ₄ : 1 % SE	12.28	32.77	128.12	23.41	6.01	6.26	48.22
SEd (±):	0.37	0.84	2.08	0.29	0.12	0.16	0.48
CD (P = 0.05)	0.76	1.73	4.29	0.59	0.24	0.34	0.98
Interaction (M×S)							
SEd(±)	0.73	1.68	4.15	0.57	0.33	0.24	0.95
CD (P = 0.05)	1.52	3.46	8.57	1.18	0.67	0.49	1.97

(5.52 t ha⁻¹) and harvest index (44.98 %). In contrast, spraying 1 % of seaweed extract (S₄) produced the highest values of effective tillers per hill (12.28), panicle length (32.77 cm), grains panicle⁻¹ (128.12), test weight (23.41 g), grain yield (6.01 t ha⁻¹), straw yield (6.26 t ha⁻¹) and harvest index (48.22 %) (Table 5). This can be attributed to the fact that the seaweed extract contains natural plant growth regulators like auxin, gibberellins and cytokinins, which stimulated photosynthesis, enzyme activity and nutrient mobilisation that increased flowering, grain filling and productivity (14). These results agree with earlier reports which stated that seaweed extracts are natural biostimulants that enhance flowering, grain formation and productivity in cereal crops.

The greatest value in all parameters of yield was recorded in M₄S₄ (15 t ha⁻¹ poultry manure and 1 % seaweed extract) i.e., the number of effective tillers per hill (17.39), panicle length (37.66 cm), number of grains panicle⁻¹ (137.70), test weight (24.94 g), grain yield (7.19 t ha⁻¹), straw yield (7.37 t ha⁻¹) and harvest index (52.33 %) as shown in Table 6, 7, 8, 9, 10, 11 and 12. This synergistic response can be attributed to the enhancement of soil fertility through poultry manure as well as improvement of nutrient absorption and physiological productivity through seaweed extract. This

combined application of organic manure and biostimulant enhanced the availability of nutrients, assimilates and grain growth translocation resulting in a positive yield effect and sustainability in rice. These synergistic interactions of organic manure and seaweed-based biostimulants have also been reported in rice growth, which have been associated with the fact that nutrient utilisation efficiency and ultimately productivity are enhanced.

Benefit cost ratio

The increase in the application of poultry manure resulted in the highest grain yield as well as gross income among all the treatments, proving that it is an effective source of organic nutrients, which are essential in growing rice. But the benefit cost ratio was lower with the increase in poultry application dose due to the higher cost of cultivation from poultry manure. However, the highest benefit-cost ratio (1.94) was recorded with the application of seaweed extract at T₄ (i.e., SE 1 %) alone without poultry manure due to its lower input cost (Table 13). Therefore, poultry manure proved more effective for maximizing yield, while seaweed extract treatment was economically more efficient in terms of return per unit cost under the present experimental conditions.

Table 6. Interaction effects of poultry manure and seaweed extract on the number of effective tillers per hill of rice

Poultry manure	Seaweed extract		Number of effective tillers per hill			
	S ₁	S ₂	S ₃	S ₄	Total	Mean
M ₁ : Control	8.74	8.86	8.69	9.44	35.73	8.93
M ₂ : 5 t ha ⁻¹ PM	9.34	10.42	10.89	10.11	40.76	10.19
M ₃ : 10 t ha ⁻¹ PM	10.59	10.88	12.09	12.20	45.75	11.44
M ₄ : 15 t ha ⁻¹ PM	11.12	13.37	14.98	17.39	56.86	14.21
Mean	9.95	10.88	11.66	12.28		
			SEd (±)		CD (0.05)	
S at same level of M			0.73		1.52	
M at same or different level of S			0.73		1.51	

Table 7. Interaction effects of poultry manure and seaweed extract on panicle length (cm) of rice

Poultry manure Seaweed extract	Panicle length (cm)					
	S ₁	S ₂	S ₃	S ₄	Total	Mean
M ₁ : Control	24.04	24.09	25.29	30.12	103.54	25.89
M ₂ : 5 t ha ⁻¹ PM	23.28	28.90	29.82	29.09	111.09	27.77
M ₃ : 10 t ha ⁻¹ PM	29.07	28.42	30.81	34.20	122.51	30.63
M ₄ : 15 t ha ⁻¹ PM	26.43	32.46	35.67	37.66	132.22	33.06
Mean	25.71	28.47	30.40	32.77		
			SEd (±)		CD (0.05)	
S at same level of M			1.68		3.46	
M at same or different level of S			1.66		3.43	

Table 8. Interaction effects of poultry manure and seaweed extract on number of grain panicles⁻¹ of rice

Poultry manure Seaweed extract	Number of grain panicles ⁻¹					
	S ₁	S ₂	S ₃	S ₄	Total	Mean
M ₁ : Control	113.15	115.97	115.20	124.32	468.64	117.16
M ₂ : 5 t ha ⁻¹ PM	112.14	123.86	119.82	125.52	481.35	120.34
M ₃ : 10 t ha ⁻¹ PM	125.58	109.58	128.70	124.92	488.79	122.20
M ₄ : 15 t ha ⁻¹ PM	119.77	131.54	131.61	137.70	520.62	130.16
Mean	117.66	120.24	123.83	128.12		
			SEd (±)		CD (0.05)	
S at same level of M			4.15		8.57	
M at same or different level of S			4.10		8.46	

Table 9. Interaction effects of poultry manure and seaweed extract on test weight (g) of rice

Poultry manure Seaweed extract	Test weight (g)					
	S ₁	S ₂	S ₃	S ₄	Total	Mean
M ₁ : Control	21.69	22.20	22.49	21.80	88.18	22.05
M ₂ : 5 t ha ⁻¹ PM	21.67	22.39	21.48	23.21	88.76	22.19
M ₃ : 10 t ha ⁻¹ PM	22.15	21.83	22.30	23.68	89.96	22.49
M ₄ : 15 t ha ⁻¹ PM	22.29	24.24	24.54	24.94	96.02	24.00
Mean	21.95	22.67	22.70	23.41		
			SEd (±)		CD (0.05)	
S at same level of M			0.57		1.18	
M at same or different level of S			0.58		1.20	

Table 10. Interaction effects of poultry manure and seaweed extract on grain yield (t ha⁻¹) of rice

Poultry manure Seaweed extract	Grain yield (t ha ⁻¹)					
	S ₁	S ₂	S ₃	S ₄	Total	Mean
M ₁ : Control	3.26	3.60	4.09	5.06	16.01	4.00
M ₂ : 5 t ha ⁻¹ PM	3.16	4.15	5.48	5.66	18.45	4.61
M ₃ : 10 t ha ⁻¹ PM	4.46	5.97	5.81	6.11	22.36	5.59
M ₄ : 15 t ha ⁻¹ PM	4.93	6.29	6.90	7.19	25.31	6.33
Mean	3.95	5.00	5.57	6.01		
			SEd (±)		CD (0.05)	
S at same level of M			0.24		0.49	
M at same or different level of S			0.28		0.57	

Table 11. Interaction effects of poultry manure and seaweed extract on straw yield (t ha⁻¹) of rice

Poultry manure Seaweed extract	Straw yield (t ha ⁻¹)					
	S ₁	S ₂	S ₃	S ₄	Total	Mean
M ₁ : Control	4.37	4.42	4.68	5.20	18.67	4.67
M ₂ : 5 t ha ⁻¹ PM	5.00	4.62	6.11	6.21	21.93	5.48
M ₃ : 10 t ha ⁻¹ PM	6.15	6.47	6.55	6.94	26.12	6.53
M ₄ : 15 t ha ⁻¹ PM	6.56	6.96	6.71	7.37	27.59	6.90
Mean	5.52	5.62	6.18	6.26		
			SEd (±)		CD (0.05)	
S at same level of M			0.33		0.67	
M at same or different level of S			0.33		0.69	

Table 12. Interaction effects of poultry manure and seaweed extract on harvest index (%) of rice

Poultry manure Seaweed extract	Harvest Index (%)					
	S ₁	S ₂	S ₃	S ₄	Total	Mean
M ₁ : Control	40.67	44.86	44.79	45.90	176.22	44.05
M ₂ : 5 t ha ⁻¹ PM	45.66	46.33	46.00	46.66	184.65	46.16
M ₃ : 10 t ha ⁻¹ PM	46.30	46.89	47.39	48.00	188.58	47.14
M ₄ : 15 t ha ⁻¹ PM	47.30	45.22	48.00	52.33	192.86	48.21
Mean	44.98	45.83	46.54	48.22		
			SEd (±)		CD (0.05)	
S at same level of M			0.95		1.97	
M at same or different level of S			1.10		2.26	

Table 13. Benefit cost ratio and economic analysis of poultry manure and seaweed extract treatments in rice

S. No	Treatments	Cost of cultivation (₹ ha ⁻¹)	Gross return (₹ ha ⁻¹)	Net return (₹ ha ⁻¹)	B:C ratio
T1	Control	46,669.56	97,800	51,130.44	1.10
T2	0.25 % seaweed extract (SE)	46,771.56	1,08,000	61,228.44	1.31
T3	0.75 % seaweed extract	46,822.56	1,22,700	81,277.44	1.74
T4	1 % seaweed extract	46,873.56	1,51,800	90,826.44	1.94
T5	5 t ha ⁻¹ poultry manure (PM)	61,669.56	94,800	33,130.44	0.54
T6	5 t ha ⁻¹ PM + 0.25 % SE	61,771.56	1,24,500	62,728.44	1.02
T7	5 t ha ⁻¹ PM + 0.75 % SE	61,822.56	1,64,400	1,02,577.44	1.66
T8	5 t ha ⁻¹ PM + 1 % SE	61,873.56	1,69,800	1,07,926.44	1.74
T9	10 t ha ⁻¹ poultry manure	76,669.56	1,33,800	29,330.44	0.38
T10	10 t ha ⁻¹ PM + 0.25 % SE	76,771.56	1,79,100	1,02,328.44	1.33
T11	10 t ha ⁻¹ PM + 0.75 % SE	76,822.56	1,74,300	97,477.44	1.27
T12	10 t ha ⁻¹ PM + 1 % SE	76,873.56	1,83,300	1,06,426.44	1.38
T13	15 t ha ⁻¹ poultry manure	91,669.56	1,47,900	56,230.44	0.61
T14	15 t ha ⁻¹ PM + 0.25 % SE	91,771.56	1,88,700	96,928.44	1.06
T15	15 t ha ⁻¹ PM + 0.75 % SE	91,822.56	2,07,000	1,15,177.44	1.25
T16	15 t ha ⁻¹ PM + 1 % SE	91,873.56	2,15,700	1,23,826.44	1.35

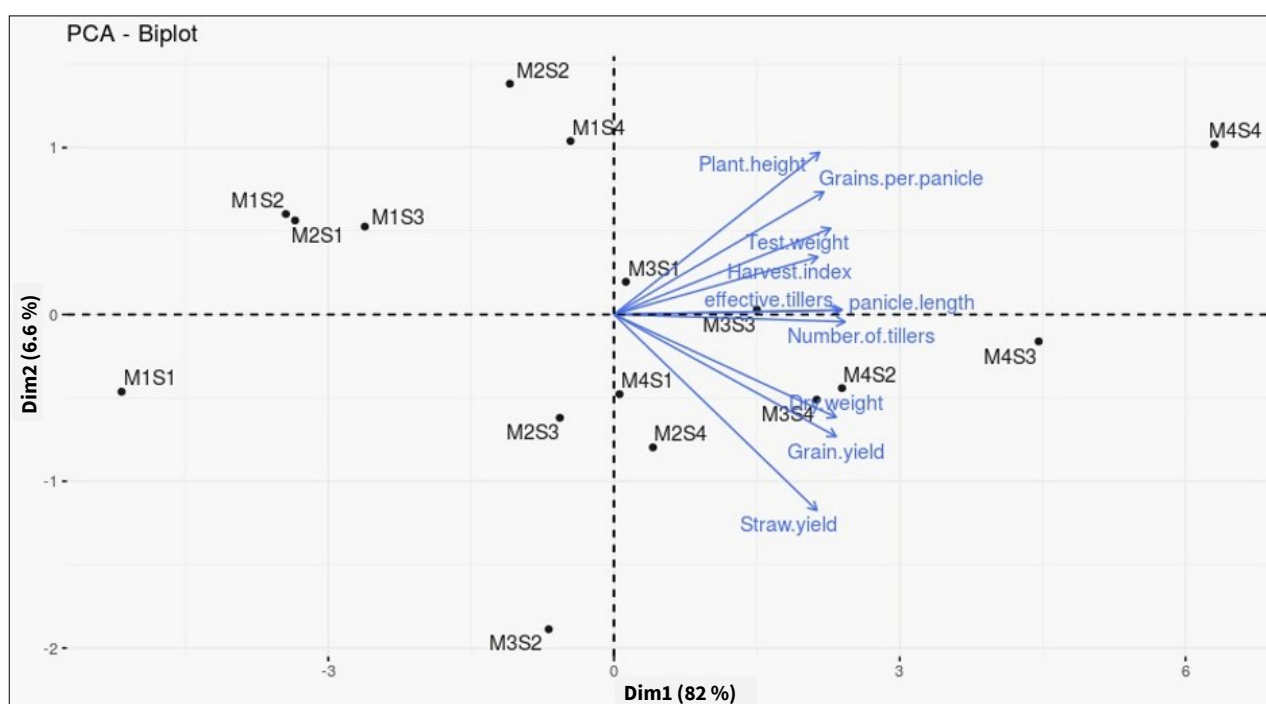
Principal component analysis (PCA)

It is clearly indicated in the PCA biplot (Fig. 2) that shows the relationship between all the treatments and the measured parameters. Dim1 has 78.1 % of total variation explained by it and the second dimension of data (Dim2) has 8.7 %, which altogether covers 86.8 % of the total variation in the data. The parameters that were represented by the blue arrows include plant height, panicle length, grain yield, grains per panicle, test weight, number of tillers and their effective ones, straw yield, dry weight and harvest index. The direction and the length of each arrow show the amount of variability attributed to each trait. Other parameters such as grain yield, grains per panicle, number of tillers and panicle length lead towards the same direction and indicated that they are positively correlated and they add in a similar manner as plant performance. Treatments located close to these vectors, particularly M₄S₃ and M₄S₄, are associated with higher values of yield and related traits. This clustering pattern clearly indicates that the integrated application of poultry manure and seaweed extract enhances multiple yield-contributing traits simultaneously, thereby resulting in superior overall crop performance under the given experimental conditions. M₁S₁ on the other hand is opposite and represents low yield parameter performance. Treatments (M₂S₁ and M₁S₄) are more connected with

plant height whereas M₃S₂ and M₂S₄ are more connected with dry weight, straw yield and harvest index. Because of the overall effect, the PCA biplot is useful to describe the difference between various treatments and highlights the parameters that contribute the most to the yield performance, which can be used to achieve the best treatment combination in future selection and improvement programs. This clustering also shows that treatments that are close to yield-related traits are more effective in improving crop productivity. Therefore, treatments M₄S₃ and M₄S₄ will be considered as the most efficient treatment combinations for improving rice growth and yield performance, while treatments located far from these traits show comparatively lower effectiveness.

Path analysis

The path analysis (Fig. 3) was performed in order to establish both direct and indirect effects of various yield-attributing traits on grain yield. The model clearly indicates that plant height acts as a fundamental trait influencing several morphological and yield parameters both directly and indirectly. Plant height positively affected the variables dry weight, number of tillers and effective tillers, which shows that taller plants tend to accumulate higher biomass and produce more productive tillers.


Fig. 2. PCA biplot showing the relationship between the treatments and the measured parameters.

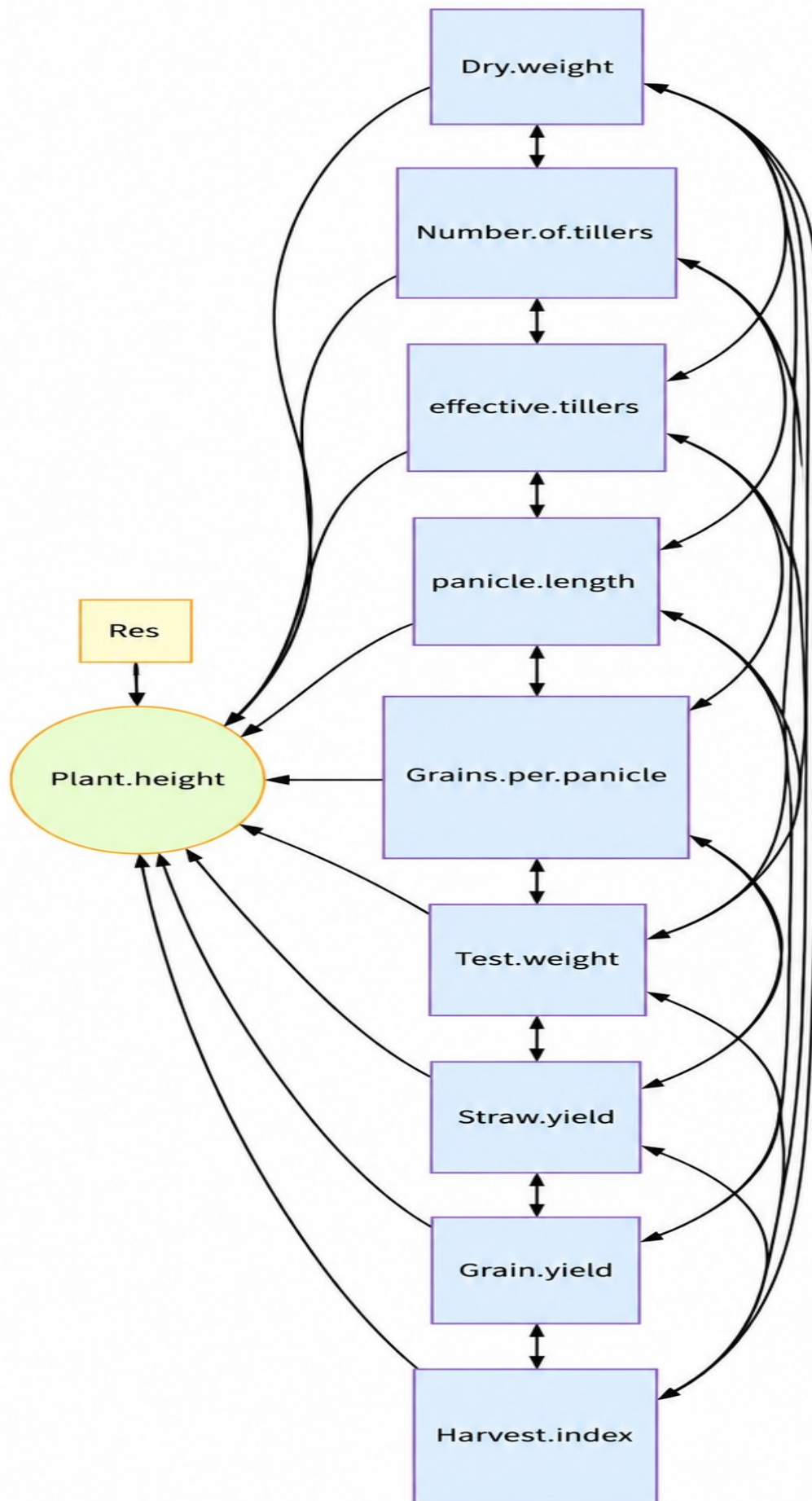


Fig. 3. Path analysis diagram showing direct and indirect effects of growth and yield attributes on grain yield of rice (*Oryza sativa* L.).

Moreover, plant height had moderate positive impacts on panicle length, straw yield, harvest index and test weight, which implies its relevance in the overall productivity of the plants.

Yield components such as the number of grains per panicle, had a beneficial impact on grain yield, with secondary effects on straw yield, test weight and harvest index. This implies that other processes such as the extent to which the panicle sets grains, the way the plant allocates biomass and the level of filling of the grains are the most significant factors to ensure a good output. Conversely, the height of plants had an indirect impact on grain yield owing to the fact that the taller the plants, the more the dry matter they produced, the more tillers and effective tillers and the greater the length of the panicles, which positively influenced the number of grains per panicle and straw yield.

The R^2 values of the endogenous variables indicated that a large proportion of their variability was explained by the model, suggesting a good overall fit. Hence, parameters such as grains per panicle, straw yield, test weight and harvest index should be given priority in selection programs for yield improvement, while plant height can be considered a foundational growth attribute with a continuous impact on productivity components.

Conclusion

The study clearly demonstrated that 15 t ha^{-1} poultry manure (M_4) was most effective in enhancing the overall growth and yield of rice among the main plot treatments. While 1 % seaweed extract (S_4) emerged as the best treatment for improving physiological efficiency and yield attributes among the subplot treatments. The combined application (M_4S_4) recorded the highest growth and grain yield (7.19 t ha^{-1}), indicating a strong synergistic effect. Although the increase in poultry manure produced higher yields, it had a lower benefit cost ratio due to the higher cost of cultivation. But seaweed extract application at 1 % without poultry manure showed the highest benefit cost ratio (1.94), making it more economically efficient. This combined effect M_4S_4 enhanced sustainable production of rice, as it enhanced production with less reliance on chemical inputs. So, further multi-location and long-term research are required to optimise the results.

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Authors' contributions

This research was a collaborative effort by MNR and KB, who jointly managed all aspects of this research, from conceptualizing the topic and designing the framework to collecting and analyzing the field data. B contributed to manuscript preparation and writing. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

References

1. FAO. Rice market monitor. Rome: Food and Agriculture Organization of the United Nations; 2021.
2. Kumar R, Sharma P, Singh V. Rice production and food security in India: a review. *Int J Agric Sci*. 2020;12(3):45–52.
3. Singh P, Sharma A, Kaur M. Impact of chemical fertilizers on soil health and crop productivity: a review. *J Environ Biol*. 2019;40(6):1201–8.
4. Verma P, Banwasi R, Srivastava LK, Naya N. Impact of poultry litter on yield and economic feasibility of rice under rice-wheat cropping system. *Biochem Cell Arch*. 2024;8(10):Part D. <https://doi.org/10.33545/26174693.2024.v8.i10d.2443>
5. Jackson ML. Soil chemical analysis. New Delhi: Prentice Hall of India Pvt Ltd; 1973. p. 498.
6. Subbaiah BV, Asija GL. A rapid procedure for the estimation of available nitrogen in soil. *Curr Sci*. 1956;25:258–60. <https://www.jstor.org/stable/24199419>
7. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Washington: United States Department of Agriculture; 1954.
8. Donald CM, Hamblin J. In search of yield. *J Aust Inst Agric Sci*. 1962;28:171–8.
9. Mukherjee S, Kumar S. Study on the cost of cultivation, returns and benefit-cost ratio of betel vine farmers in different farm groups in Bankura district, India. *Arch Curr Res Int*. 2024;24(5):671–81. <https://doi.org/10.9734/acri/2024/v24i5740>
10. Gomez KA, Gomez AA. Statistical procedures for agricultural research. 2nd ed. New York: John Wiley & Sons; 1984. <https://archive.org/details/statisticalproce00gome>
11. Ali M, Hassan S, Rehman A. Role of seaweed extract on growth and physiological attributes of rice. *J Plant Nutr*. 2023;46(5):812–23.
12. Chen Y, Zhang L, Wang X, Liu H. Effects of seaweed extracts on plant physiological growth and stress tolerance: a review. *J Plant Growth Regul*. 2022;41(3):1025–40.
13. Reddy BNK, Mehera B, Kumar P. Effect of poultry manure, vermicompost and zinc on growth and yield of rice. *Int J Plant Soil Sci*. 2023;35(12):46–50. <https://doi.org/10.9734/ijpss/2023/v35i122965>
14. Banjare L, Banwasi R, Jataw GK, Shrivastav LK. Effect of seaweed extract on yield and nutrient uptake of rice in a vertisol. *Pharma Innov J*. 2022;11(3):2193–8.

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