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Assessing the Role of Seaweed Extract, NPK consortia, and Urea Foliar Sprays on Rice (*Oryza sativa* L.) Production in an Inceptisol of Varanasi, Uttar Pradesh, India

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ABSTRACT

Rice (*Oryza sativa* L.) is a staple crop critical to global food security, yet sustaining high productivity requires integrated nutrient management strategies that enhance nutrient use efficiency while reducing environmental impacts. This study evaluated the effects of seaweed extract, NPK consortia, and urea foliar sprays on the growth, yield attributes, and nutrient uptake of rice along with chemical properties of post-harvest soil. A field experiment was conducted using a randomized complete block design with multiple treatment combinations, including recommended fertilizer practices, seaweed extract application, NPK consortia, and foliar urea sprays applied at key growth stages. Results indicated that it significantly improved plant growth and development compared to control and conventional fertilizer treatments. Yield components were also enhanced under combined treatments with better nutrient use efficiency and potential reduction in soil nutrient depletion.

Keywords Seaweed extract, NPK consortia, Urea, Productivity, Soil properties.

INTRODUCTION

Rice is a staple for over half of the world's population and occupies about 47 million hectares in India, contributing 135.75 MT to food grain production in 2022–23. High-yielding cultivars and intensive input use have increased yields over the past four decades. However, resource degradation and greenhouse gas emissions now threaten sustainability (Singh *et al.* 2017). Excessive chemical fertilizers have improved productivity but caused groundwater contamination, soil degradation (Srikanth *et al.* 2022), CH_4 and N_2O emissions and reduced microbial activity. Sole reliance on organic fertilizers has often reduced yields. To address this, researchers promote reducing synthetic inputs and increasing bio-based alternatives. Plant

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bio-stimulants—such as seaweed extracts, silicon, and beneficial microbes including AMF and N-fixing bacteria—enhance stress tolerance and nutrient efficiency. Seaweed extracts supply readily available nutrients and improve rice growth and yield. Declining factor productivity in India is also linked to micronutrient deficiencies. Bio-fertilizers, including NPK consortia, enhance nutrient availability and uptake (Meena 2020), while micronutrient-enriched sources improve elements like zinc (Chaubey *et al.* 2021). PGPR further support plant growth. Foliar urea application improves nutrient use efficiency and reduces emissions under waterlogged conditions (Pawar *et al.* 2017, Singh *et al.* 2022). This study evaluates the effects of seaweed extracts, NPK consortia, foliar urea spray, and varying mineral fertilizer levels on the growth and yield of transplanted rice.

MATERIALS AND METHODS

The study on seaweed extract, NPK consortia, and foliar urea in rice was conducted during *Kharif* 2022 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, located in the subtropical Indo-Gangetic plains on the left bank of the Ganga (25.256° N, 82.987° E; 76.6 m amsl). During the season, mean maximum temperatures ranged from 28.3–41°C (avg. 33.75°C) and minimum from 11.1–27.7°C (avg. 21.11°C). Total rainfall was 1310.2 mm, with a peak of 255.4 mm during 23–29 July (Week 30). Relative humidity ranged from 48–95% (morning) and 40–88% (minimum). T_1- Control (Absolute), T_2- RDF (100% NPK University Recommendation)(100% Urea, DAP, MOP), T_3-50% RDN (100% PK),T_4-T_2+Root Treatment (RT)/Seed Treatment (ST) with Bio-fertilizer NPK Consortia @ 10ml/litre water or10 ml/kg seed, T_5 - T_2+seaweed granules@10kg/acre (basal), T_6- T_2+sea weed liquid Two spray@5ml/litre (At Tillering and Pre-flowering stage), T_7 - T_2+ sea weed granule@10kg/acre (basal) + sea weed liquid Two sprays @5ml/litre water (At Tillering and Pre-flowering stage) ,T_8 -50% Urea*, 100% DAP & MOP +Pure Urea(Liquid) Two sprays@1% solution (At Tillering and Pre-flowering stage) , T_9-50% Urea*, 100% DAP & MOP + RT with Bio-fertilizer NPK Consortia +Pure Urea (Liquid)Two sprays @ 1% solution (At Tillering and Pre-flowering stage) , T_{10} -50% Urea*, 100% DAP & MOP + Pure Urea (Liquid) Two sprays @ 1%solution and seaweed liquid Two spray @ 5 ml/ litre (At Tillering and Pre-flowering stage), T_{11} -50% Urea*, 100% DAP & MOP +RT with Bio-fertilizer NPK Consortia +Pure Urea (Liquid) Two sprays @ 1% solution and seaweed liquid Two spray@5ml/ litre (At Tillering and Pre-flowering stage). Give the first top dressing of urea and replace the second top dressing with two foliar sprays of urea.

Eleven treatment combinations were evaluated in a randomized block design with three replications, using 3 × 2 m plots. The rice variety HUR-105 was grown. RDF (T_2) was applied @120:60:60 kg N:P:K ha^{-1} through urea, DAP, and MOP. In treatments with 50% urea (T_3, T_8, T_9, T_{10}, T_{11}), only the basal dose was applied, omitting splits. Seaweed extract ('Sagarika') and NPK consortia (IFFCO products) were used; liquid seaweed (@5 ml L^{-1}) and granular (10 kg $acre^{-1}$) were applied as foliar spray and soil application, respectively. NPK consortia (@10 ml L^{-1}) was applied as root treatment, and 1% urea as foliar spray. Soil samples (0–15 cm) were collected before sowing and after harvest, composited, air-dried, sieved (2 mm), and analyzed for pH and EC (Jackson, 1973), organic carbon (Walkley and Black 1934), available N (Subbiah and Asija 1956), P (Olsen *et al.* 1954), K (Jackson 1973), and micronutrients by DTPA (Lindsay and Norvell 1978). The soil was sandy clay loam, neutral (pH 7.64), non-saline (EC 0.26 dS m^{-1}), low in organic carbon (0.39%), and low in available N (125.2 kg ha^{-1}), P (10.23 kg ha^{-1}), and K (112 kg ha^{-1}).

RESULTS AND DISCUSSION

Growth parameters

The study assessed the effects of seaweed extract, urea, NPK consortia, and fertilizer levels on transplanted rice growth. Plants with 100% RDF (urea, DAP, MOP) showed better height, tillers, leaves, and chlorophyll than those with 50% urea, indicating the benefit of balanced nutrition (Table 1). At 60 and 90 DAT, T_7 (RDF + seaweed granule basal + two foliar sprays) produced the highest growth after seaweed application. At 30 DAT, T_2 recorded maximum plant height, followed by T_{11} and T_3, while T_7 remained su-

Table 1. Effect of seaweed extracts, NPK consortia and foliar spray of urea on growth parameters of rice.

Sl. No.	Plant height (cm)			No. tillers/hill			No. of leaves/hill			Chlorophyll content		
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
T_1	52.43	84.78	104.16	10.22	8.11	7.00	32.00	38.00	36.00	34.57	30.07	14.03
T_2	61.77	89.10	113.78	13.55	10.00	8.33	43.00	44.67	43.00	36.28	36.86	17.67
T_3	60.33	89.00	110.44	13.00	8.78	7.00	42.33	43.33	39.00	39.09	33.59	17.00
T_4	58.89	89.67	113.50	12.33	11.00	9.00	38.67	41.33	41.33	38.56	35.33	16.23
T5	59.28	91.33	114.67	13.00	10.78	8.67	38.00	42.67	44.00	35.66	36.10	15.00
T_6	56.67	91.67	113.89	10.56	10.00	8.00	33.33	42.00	43.00	41.05	37.19	16.37
T_7	55.78	92.56	114.89	12.45	12.56	9.33	37.33	46.00	46.67	37.75	38.82	16.70
T_8	55.67	88.08	111.34	12.45	9.78	7.67	37.67	41.33	42.33	37.80	31.29	16.67
T_9	56.33	86.44	110.45	11.00	11.00	8.00	34.67	41.00	41.67	38.01	34.12	15.10
T_{10}	56.44	86.56	110.78	11.67	10.22	8.00	37.00	41.67	40.00	36.74	31.41	18.57
T_{11}	61.13	87.22	111.66	14.44	12.56	8.00	44.33	43.33	43.00	36.04	33.16	20.80
SEm ±	**1.86**	**1.58**	**1.98**	**0.84**	**0.922**	**0.58**	**1.21**	**1.69**	**2.01**	**1.30**	**2.08**	**1.14**
CD at 5%	**5.37**	**4.54**	**5.70**	**2.43**	**2.66**	**1.68**	**3.49**	**4.87**	**5.80**	**3.76**	**5.99**	**3.29**

T_1- Control (Absolute), T_2- RDF (100% NPK University Recommendation) (100% Urea, DAP, MOP), T_3-50% RDN (100% PK), T_4-T_2+Root Treatment (RT)/Seed Treatment (ST) with Bio-fertilizer NPK Consortia @ 10ml/litre water or10ml/kg seed, T_5 - T2+sea-weed granules@10kg/acre (basal), T_6- T_2+sea weed liquid Two spray@5ml/litre (At Tillering and Pre-flowering stage), T_7 - T_2+sea weed granule@10kg/acre (basal)+sea weed liquid Two sprays @5ml/litre water (At Tillering and Pre-flowering stage) ,T_8 -50% Urea*, 100% DAP & MOP +Pure Urea (Liquid) Two sprays@1% solution (At Tillering and Pre-flowering stage) , T_9-50% Urea*, 100% DAP & MOP + RT with Bio-fertilizer NPK Consortia +Pure Urea (Liquid)Two sprays @ 1% solution (At Tillering and Pre-flowering stage) , T_{10} -50% Urea*, 100% DAP & MOP + Pure Urea (Liquid) Two sprays @ 1%solution and seaweed liquid Two spray @ 5 ml/litre (At Tillering and Pre-flowering stage), T_{11} -50% Urea*, 100% DAP & MOP +RT with Bio-fertilizer NPK Consortia +Pure Urea (Liquid) Two sprays @ 1% solution and seaweed liquid Two spray@ 5ml/litre (At Tillering and Pre-flowering stage).*Give first top dressing of urea; replace second top dressing of urea with two urea foliar spray.

Table 2. Effect of seaweed extracts, NPK consortia and foliar spray of urea on yield parameters of rice.

Sl. No.	Panicle length (cm)	No. of grains/panicle	Test weight (gm)	Grain yield (q/ha)	Straw yield (q/ha)	Biological Yield (q/ha)	Harvest Index (%)
T_1	19.48	135.67	22.73	40.12	59.79	99.91	40.16
T_2	22.27	148.67	24.10	57.57	74.07	131.64	43.61
T_3	21.28	140.33	23.75	46.79	62.13	108.92	43.14
T_4	21.83	145.67	23.40	58.79	72.93	131.72	44.81
T_5	21.95	155.00	24.25	58.82	73.29	132.12	44.60
T_6	22.33	149.33	24.43	59.53	73.90	133.44	44.64
T_7	22.46	158.67	24.63	62.68	77.18	139.86	44.81
T_8	20.92	148.00	23.97	52.68	67.24	119.91	43.93
T9	22.07	146.33	23.00	53.79	66.18	119.97	44.74
T_{10}	21.45	147.00	23.68	54.90	65.79	120.69	45.47
T_{11}	21.63	150.33	23.83	55.46	71.40	126.86	43.90
SEm ±	**0.58**	**4.55**	**0.38**	**3.68**	**4.01**	**5.32**	**2.47**
CD at 5%	**1.68**	**13.12**	**1.10**	**10.59**	**11.56**	**15.32**	**7.12**

T_1- Control (Absolute), T_2- RDF (100% NPK University Recommendation)(100% Urea, DAP, MOP), T_3-50% RDN (100% PK),T_4-T_2+Root Treatment (RT)/Seed Treatment (ST) with Bio-fertilizer NPK Consortia @ 10ml/litre water or10ml/kg seed, T_5 - T_2+ seaweed granules @10 kg/acre (basal), T_6- T_2+sea weed liquid Two spray@ 5ml/litre (At Tillering and Pre-flowering stage), T_7 - T_2+sea weed granule @10kg/acre (basal)+sea weed liquid Two sprays @5ml/litre water (At Tillering and Pre-flowering stage) ,T8 -50%Urea*, 100% DAP & MOP +Pure Urea(Liquid) Two sprays@1% solution (At Tillering and Pre-flowering stage) , T_9-50% Urea*, 100% DAP & MOP + RT with Bio-fertilizer NPK Consortia +Pure Urea (Liquid)Two sprays @ 1% solution (At Tillering and Pre-flowering stage) , T_{10}-50% Urea*, 100% DAP & MOP + Pure Urea (Liquid) Two sprays @ 1%solution and seaweed liquid Two spray @ 5 ml/litre (At Tillering and Pre-flowering stage), T_{11} -50% Urea*, 100% DAP & MOP +RT with Bio-fertilizer NPK Consortia +Pure Urea (Liquid) Two sprays @ 1% solution and seaweed liquid Two spray@5ml/litre (At Tillering and Pre-flowering stage).*Give first top dressing of urea; replace second top dressing of urea with two urea foliar spray.

Table 3. Effect of seaweed extracts, NPK consortia and foliar spray of urea on N, P and K content of grain and straw of rice.

Sl. No.	N content (%)		P content (%)		K content (%)		N uptake (kg/ha)		P uptake (kg/ha)		K uptake (kg/ha)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1	0.93	0.43	0.32	0.03	0.47	1.75	37.26	24.91	12.92	1.55	19.19	104.49
T_2	1.00	0.50	0.37	0.04	0.50	1.74	57.32	37.79	21.08	3.26	28.47	128.83
T_3	0.94	0.39	0.34	0.03	0.51	1.73	44.08	25.79	15.86	1.61	23.81	107.25
T_4	0.98	0.54	0.36	0.05	0.49	1.78	57.63	37.62	21.02	3.28	29.01	129.21
T_5	1.01	0.52	0.38	0.05	0.50	1.80	59.20	37.83	22.34	3.53	29.17	131.39
T_6	1.02	0.51	0.39	0.05	0.50	1.82	60.53	37.96	23.07	3.62	29.55	134.10
T_7	1.01	0.53	0.41	0.05	0.51	1.87	63.41	40.37	25.93	4.12	31.76	144.02
T_8	0.96	0.41	0.34	0.03	0.50	1.64	50.73	29.20	17.93	2.22	26.02	110.61
T9	0.97	0.43	0.33	0.03	0.49	1.80	52.38	29.75	18.11	2.23	26.76	118.82
T_{10}	0.97	0.45	0.35	0.04	0.51	1.82	53.43	30.03	19.19	2.40	27.92	119.89
T_{11}	1.03	0.48	0.37	0.04	0.51	1.81	57.04	35.63	20.35	3.03	28.15	128.77
SEm±	**0.03**	**0.01**	**0.02**	**0.00**	**0.02**	**0.02**	**3.70**	**2.00**	**1.90**	**0.24**	**2.17**	**6.49**
CD at 5%	**0.09**	**0.03**	**0.05**	**0.01**	**0.05**	**0.05**	**10.66**	**5.75**	**5.48**	**0.70**	**6.25**	**18.69**

T_1- Control (Absolute), T_2- RDF (100% NPK University Recommendation)(100% Urea, DAP, MOP), T_3-50% RDN (100% PK), T_4-T_2+Root Treatment (RT)/Seed Treatment (ST) with Bio-fertilizer NPK Consortia @ 10ml/litre water or10ml/kg seed, T_5 - T_2+sea-weed granules @10kg/acre (basal), T_6- T_2+sea weed liquid Two spray@5ml/litre (At Tillering and Pre-flowering stage), T_7 - T_2+ sea weed granule @10kg/acre (basal)+sea weed liquid Two sprays @5ml/litre water (At Tillering and Pre-flowering stage ,T_8 -50%Urea*, 100% DAP & MOP +Pure Urea(Liquid) Two sprays@1% solution (At Tillering and Pre-flowering stage) , T_9-50% Urea*, 100% DAP & MOP + RT with Bio-fertilizer NPK Consortia +Pure Urea (Liquid)Two sprays @ 1% solution (At Tillering and Pre-flowering stage) , T_{10} -50% Urea*, 100% DAP & MOP + Pure Urea (Liquid) Two sprays @ 1%solution and seaweed liquid Two spray @ 5 ml/litre (At Tillering and Pre-flowering stage), T_{11} -50% Urea*, 100% DAP & MOP +RT with Bio-fertilizer NPK Consortia +Pure Urea (Liquid) Two sprays @ 1% solution and seaweed liquid Two spray @ 5ml/litre (At Tillering and Pre-flowering stage).*Give first top dressing of urea; replace second top dressing of urea with two urea foliar spray.

Table 4. Effect of seaweed extracts, NPK consortia and foliar spray of urea on micronutrient content of grain and straw of rice.

Sl. No.	Cu content (ppm)		Zn content (ppm)		Mn content (ppm)		Fe content (ppm)		Cu uptake (g/kg)		Zn uptake (g/kg)		Mn uptake (g/kg)		Fe uptake (g/kg)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1	0.065	0.062	0.165	0.471	0.181	1.197	1.147	1.434	2.6	3.68	6.65	28.18	7.35	71.67	45.95	85.71
T_2	0.081	0.089	0.262	0.621	0.31	1.456	1.746	1.84	4.68	6.57	15.07	45.84	17.9	107.86	101	136.4
T_3	0.073	0.069	0.216	0.556	0.217	1.212	1.337	1.584	3.39	4.29	10.09	34.28	10.19	75.29	62.51	97.81
T_4	0.084	0.091	0.258	0.641	0.321	1.526	1.795	1.935	4.91	6.63	15.15	46.61	18.84	111.48	105.3	141.5
T_5	0.084	0.094	0.262	0.646	0.326	1.533	1.889	2.011	4.94	6.86	15.4	47.28	19.35	112.33	111.3	146.8
T_6	0.085	0.099	0.271	0.668	0.326	1.549	1.913	1.012	5.04	7.3	16.09	49.26	19.43	114.37	114	148.7
T_7	0.086	0.098	0.276	0.646	0.353	1.516	1.873	1.986	5.43	7.55	17.35	49.89	22.12	116.87	117.5	153.2
T_8	0.08	0.073	0.232	0.549	0.303	1.405	1.561	1.534	4.23	4.95	12.23	36.83	16	94.88	82.3	103.2
T_9	0.081	0.073	0.242	0.586	0.302	1.444	1.568	1.599	4.38	4.86	13.05	38.73	16.23	95.79	84.31	105.9
T_{10}	0.082	0.087	0.243	0.621	0.311	1.466	1.675	1.708	4.56	5.71	13.32	40.79	17.06	96.49	91.77	112.4
T_{11}	0.083	0.088	0.271	0.613	0.321	1.515	1.826	1.858	4.62	6.48	15.05	43.91	17.83	107.6	101.4	113
SEm±	**0.003**	**0.005**	**0.007**	**0.025**	**0.015**	**0.04**	**0.032**	**0.042**	**0.4**	**0.54**	**0.92**	**2.68**	**1.49**	**6.39**	**6.26**	**7.65**
CD at 5%	**0.009**	**0.013**	**0.021**	**0.073**	**0.042**	**0.114**	**0.091**	**0.122**	**1.15**	**1.55**	**2.66**	**7.71**	**4.29**	**18.41**	**18.02**	**22.05**

T_1- Control (Absolute), T_2- RDF (100% NPK University Recommendation) (100% Urea, DAP, MOP), T_3-50% RDN (100% PK),T_4-T_2+-Root Treatment (RT)/Seed Treatment (ST) with Bio-fertilizer NPK Consortia @ 10ml/litre water or10ml/kg seed, T_5 - T_2+ seaweed granules@10 kg/acre (basal), T_6- T_2+sea weed liquid Two spray@5ml/litre (At Tillering and Pre-flowering stage), T_7 - T_2+sea weed granule @10 kg/acre (basal)+sea weed liquid Two sprays @5ml/litre water (At Tillering and Pre-flowering stage) ,T_8 -50% Urea*, 100% DAP & MOP +Pure Urea (Liquid) Two sprays@1% solution (At Tillering and Pre-flowering stage) , T_9-50% Urea*, 100% DAP & MOP + RT with Bio-fertilizer NPK Consortia +Pure Urea (Liquid)Two sprays @ 1% solution (At Tillering and Pre-flowering stage) , T_{10} -50% Urea*, 100% DAP & MOP + Pure Urea (Liquid) Two sprays @ 1%solution and seaweed liquid Two spray @ 5 ml/litre (At Tillering and Pre-flowering stage), T_{11} -50% Urea*, 100% DAP & MOP +RT with Bio-fertilizer NPK Consortia +Pure Urea (Liquid) Two sprays @ 1% solution and seaweed liquid Two spray@5ml/litre (At Tillering and Pre-flowering stage).*Give first top dressing of urea; replace second top dressing of urea with two urea foliar spray.

Table 5. Effect of seaweed extracts, NPK consortia and foliar spray of urea on soil pH, EC and OC% and available N, P, K content in post-harvest soil.

Sl. No.	pH	EC (microS/m)	Organic Carbon (%)	Available Nitrogen (kg ha^{-1})	Available Phosphorus (kg ha^{-1})	Available Potassium (kg ha^{-1})
T_1	7.76	246.33	0.59	126.53	13.15	140.05
T_2	7.67	263.67	0.65	166.29	17.26	155.68
T_3	7.62	259.67	0.64	146.29	14.8	147.87
T_4	7.59	244	0.64	175.04	17.58	158.08
T_5	7.61	249	0.65	176.59	18.32	160.72
T_6	7.62	233	0.64	176.59	18.12	162.67
T_7	7.61	242	0.69	177.57	19.8	164.27
T_8	7.64	264	0.6	151.17	15.96	148.32
T_9	7.63	243	0.62	155.28	16.16	151.39
T_{10}	7.66	258	0.63	160.16	16.5	151.41
T_{11}	7.63	265.67	0.64	164.27	16.68	154.75
SEm±	0.04	11.76	0.02	10.83	0.98	5.87
CD at 5%	NS	NS	NS	31.19	2.82	NS

T_1- Control (Absolute), T_2- RDF (100% NPK University Recommendation) (100% Urea, DAP, MOP), T3-50% RDN (100% PK), T_4-T_2+Root Treatment(RT)/Seed Treatment (ST) with Bio-fertilizer NPK Consortia @ 10ml/litre water or10ml/kg seed, T_5 - T_2+ seaweed granules@10kg/acre (basal), T_6- T_2+sea weed liquid Two spray@5ml/litre (At Tillering and Pre-flowering stage), T_7 - T_2+sea weed granule @10 kg/acre (basal)+sea weed liquid Two sprays @5ml/litre water (At Tillering and Pre-flowering stage) ,T8 -50%Urea*, 100% DAP & MOP +Pure Urea (Liquid) Two sprays@1% solution (At Tillering and Pre-flowering stage) , T_9 50% Urea*, 100% DAP & MOP + RT with Bio-fertilizer NPK Consortia +Pure Urea (Liquid)Two sprays @ 1% solution (At Tillering and Pre-flowering stage) , T_{10} -50% Urea*, 100% DAP & MOP + Pure Urea (Liquid) Two sprays @ 1%solution and seaweed liquid Two spray @ 5 ml/litre (At Tillering and Pre-flowering stage), T_{11} -50% Urea*, 100% DAP & MOP +RT with Bio-fertilizer NPK Consortia +Pure Urea (Liquid) Two sprays @ 1% solution and seaweed liquid Two spray@5ml/litre (At Tillering and Pre-flowering stage).*Give first top dressing of urea; replace second top dressing of urea with two urea foliar spray.

perior at later stages with T_5 and T_6 often comparable. Tiller number decreased with age but stayed highest in T_7. Leaf count and chlorophyll were also greater under T_7 at 60 DAT, though chlorophyll declined with plant age. Treatments with 100% RDF (T_4–T_7) were generally comparable to T_2, and 50% urea treatments (T_8–T_{11}) also showed similar performance. Improved growth due to seaweed with RDF has been reported in several crops, attributed to growth hormones and bioactive compounds that enhance soil biological activity and dry matter production (Table 1).

Yield Attributes

At harvest, yield attributes including panicle length, grains per panicle, and 1000-grain weight were recorded (Table 2). Treatment T_7 (RDF + seaweed granule @ 10 kg acre^{-1} basal + two foliar sprays @ 5 ml L^{-1} at tillering and pre-flowering) produced the highest grains per panicle, followed by T_5 and T_6; all treatments except T_1 and T_3 were statistically at par with T_7. T_7 also recorded the maximum panicle length (others at par except T_1) and the highest test weight, followed by T_6 and T_5, while T_1 showed the lowest values (Table 2).

Grain and Straw yield (q ha^{-1})

Treatments with 50% urea (T_8–T_{11}) increased grain yield by 12.59%, 14.60%, 17.33%, and 18.53% (highest) over 50% urea alone (T_3: 46.79 q ha^{-1}) (Table 2). Under 100% RDF, T_7, T_6, T_5, and T_4 recorded yield increases of 8.87% (highest), 3.40%, 1.65%, and 2.11%, respectively, over sole RDF (T_2: 57.57 q ha^{-1}). Yields from 50% urea treatments were at par with T_2. Overall, the highest grain yield was obtained with T_7 (RDF + seaweed granule @10 kg acre^{-1} basal + two foliar sprays @5 ml L^{-1}), while the lowest was in control (T_1). Similarly, maximum straw yield was recorded in T_7 and minimum in T_1, with 50% urea treatments comparable to T_2. Increased grain and straw yield with seaweed extract plus RDF was also reported by Sharma *et al.* (2016). Yield enhancement is attributed to improved yield traits and stimulation of physiological processes by bio-stimulants. The highest harvest index (%) was observed in T_{10}, at par

Table 6. Effect of seaweed extracts, NPK consortia and foliar spray of urea on soil micronutrient content.

Sl. No.	Available Copper (ppm)	Available Zinc (ppm)	Available Manganese (ppm)	Available Iron (ppm)
T_1	0.176	0.191	1.175	4.552
T_2	0.196	0.285	1.398	6.189
T_3	0.185	0.219	1.231	5.094
T_4	0.205	0.309	1.467	6.435
T_5	0.211	0.309	1.507	6.48
T_6	0.207	0.320	1.518	6.558
T_7	0.222	0.329	1.553	6.634
T_8	0.193	0.263	1.315	5.639
T_9	0.197	0.270	1.342	5.633
T_{10}	0.2	0.294	1.395	5.87
T_{11}	0.205	0.311	1.46	6.317
SEm±	0.004	0.012	0.037	0.14
CD at 5%	0.012	0.035	0.107	0.413

T_1- Control (Absolute), T_2- RDF (100% NPK University Recommendation) (100% Urea, DAP, MOP), T_3-50% RDN (100% PK),T_4-T_2+Root Treatment (RT)/Seed Treatment (ST) with Bio-fertilizer NPK Consortia @ 10ml/litre water or10ml/kg seed, T_5 - T_2+seaweed granules@10kg/acre (basal), T_6- T_2+ sea weed liquid Two spray@5ml/litre (At Tillering and Pre-flowering stage), T_7 - T_2+sea weed granule@10 kg/acre (basal)+sea weed liquid Two sprays @5ml/litre water (At Tillering and Pre-flowering stage) ,T_8 -50% Urea*, 100% DAP & MOP +Pure Urea (Liquid) Two sprays@1% solution (At Tillering and Pre-flowering stage) , T_9-50% Urea*, 100% DAP & MOP + RT with Bio-fertilizer NPK Consortia +Pure Urea (Liquid)Two sprays @ 1% solution (At Tillering and Pre-flowering stage) , T_{10} -50% Urea*, 100% DAP & MOP + Pure Urea (Liquid) Two sprays @ 1%solution and seaweed liquid Two spray @ 5 ml/litre (At Tillering and Pre-flowering stage), T_{11} -50% Urea*, 100% DAP & MOP +RT with Bio-fertilizer NPK Consortia +Pure Urea (Liquid) Two sprays @ 1% solution and seaweed liquid Two spray@ 5 ml/litre (At Tillering and Pre-flowering stage).*Give first top dressing of urea; replace second top dressing of urea with two urea foliar spray.

with other treatments (Table 2).

Nutrient uptake (kg ha^{-1})

Data on nutrient uptake showed that treatment T_7 recorded significantly higher nitrogen, phosphorus, and potassium uptake in both grain (57.32, 25.93, 31.76 kg ha^{-1}) and straw (37.79, 4.124, 144.017 kg ha^{-1}, respectively) compared to 50% urea (T_3) and control (T_1) (Table 3). Among all treatments, T_7 (RDF + seaweed granule @10 kg acre^{-1} basal + two foliar sprays @5 ml L^{-1}) showed the highest N, P, and K uptake, while T_1 recorded the lowest. Nitrogen uptake in grain under 50% urea treatments (T_8–T_{11}) was at par with 100% RDF (T_2) and significantly higher than T_3. Similar findings were reported by Karmakar *et al.* (2023), and Singh *et al.* (2015). Enhanced nutrient uptake is attributed to improved soil biological activity and fertilizer use efficiency (Meena *et al*. 2016). Micronutrient (Fe, Cu, Zn, Mn) uptake by grain and straw followed a similar trend, with T_7 showing the highest values and T_1 the lowest (Table 4).

Physico-chemical status of the soil

The treatments and fertilizer levels had no significant effect on soil pH, electrical conductivity, or organic carbon (Table 5). However, residual available nitrogen and phosphorus were significantly influenced, with the highest values recorded in T_7 (RDF + seaweed granule @10 kg acre^{-1} basal + two foliar sprays @5 ml L^{-1}) and the lowest in control (T_1). Residual available potassium was not significantly affected, though the highest value was observed in T_7 and the lowest in T_1, consistent with findings by Karmakar *et al.* (2023), Singh *et al.* (2015), and Layek *et al.* (2018). Soil micronutrients (Fe, Cu, Zn, Mn) varied significantly among treatments, with T_7 showing the highest availability and T_1 the lowest (Table 6).

CONCLUSION

The study concludes that seaweed extract, NPK consortia, and foliar urea spray enhanced rice growth and yield, with T_7 (granular + foliar seaweed) showing the greatest improvement in yield and nutrient uptake. Treatments with 50% urea (T_8–T_{11}) achieved yields comparable to 100% RDF (T_2), indicating fertilizer savings by replacing split urea with foliar spray and bio-inputs. These results highlight the potential of bio-stimulants and bio-fertilizers as eco-friendly alternatives in rice cultivation.

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REFERENCES

Chaubey, Y., R. Meena, R. N. Meena, Y. V. Singh, A. Babu, & K. Meena, (2021), Effect of zinc and zinc-enriched compost on growth, yield and nutrient content in rice (*Oryza sativa* L.) in an Inceptisol of Varanasi, *Environment & Ecology,* 39(2), 342–345.

Jackson, M. L. (1973). Soil chemical analysis, Perntice Hall of India Pvt. Ltd., New Delhi, pp.183.

Karmakar, R., Meena, R., Meena, R. N., Verma, S. K., Meena, K., & Viveka, V. (2023). Growth, Yield and Cadmium Accumulation in Wheat Crop (*Triticum aestivum* L.) as Influenced by Nitrogenous Fertilizer in an Inceptisol of Varanasi, India. *Ecology, Environment and Conservation*, 29 (1), 356-360. http://doi.org/10.53550/EEC.2023.v29i01.052

Layek, J., Das, A., Idapuganti, R. G., Sarkar, D., Ghosh, A., Zodape, S. T. & Meena, R. S.(2018). Seaweed extract as organic bio-stimulant improves productivity and quality of rice in eastern Himalayas. *Journal of Applied Phycology,* 30, 547-558.

Lindsay, W. L., & Norvell, W. A. (1978). Development of a DTPA Soil Test for Zinc, Iron, Manganese, and Copper. *Soil Science Society of America Journal,* 42, 421-428.

Meena, R. (2020). Residual effect of rock phosphate enriched compost and inorganic fertilizers application on growth, yield and nutrient content of rice (*Oryza sativa* L.). *Environment and Ecology,* 38 (3A), 471-475.

Meena, R. N., Singh, R. K., Meena, R., & Singh, K. (2016). Effect of organic matter and soil-microbial community on physical, chemical and biological properties of soil. *Journal of Plant Development Sciences ,* 8(3), 137-141.

Olsen, S. R., Cole, C. W., Watanabe, F. S., & Dean, L. A. (1954). Estimation of available phosphorus in soil by extracting with Sodium Bicarbonate, USDA, Circular, 939. https://dn720703.ca.archive.org/0/items/estimationofavai939olse/estimationofavai939olse.pdf

Pawar, R., Singh, C. P., Singh, P. P., & Meena, R. (2017). Effect of Pre-Harvest Foliar Spray of Micronutrients on Chemical Properties of Mango Cv. Langra at Ambient Storage Conditions. *International Journal of Current Microbiology and Applied Sciences*, 6(4), 2557-2567.

Sharma, L., Banerjee M., Ghosh, A., & Malik, G. C. (2016). Economics of rice cultivation in the red and lateritic soil of eastern India. *International Journal of Bio Resource,* 2(3), 359-363.

Singh, P., Singh, Y. V., Singh, S. K., Raha, P., Singh, K., & Meena, R. (2022). Effect of Sewage Sludge Integration with Fertilizer on Growth Parameters of Rice-wheat Cropping System. *International Journal of Plant & Soil Science,* 34(22), 1477-1484.

Singh, P. P., Rashmi Pawar, & Meena, R. (2017). A Study of Nitrous oxide Emission from Rice Fields in Tarai Region of Uttarakhand, India. *International Journal of Current Microbiology and Applied Sciences,* 6(4), 423-430. doi: https://doi.org/10.20546/ijcmas.2017.604.048

Singh, S. K., Singh, M. K., Singh, C. S. & Pal, S. K. (2015). Effect of fertilizer level and seaweed sap on productivity and profit ability of rice (*Oryza sativa)*, *Indian Journal of Agronomy,* 60 (3), 69-74.

Srikanth, H., Kumari, K., & Meena, R. (2022). Contamination of groundwater with heavy metals and its impact on soil and plants—A review. *Ecology, Environment and Conservation.*

Subbiah, B. V., & Asija, G. L. (1956). A rapid procedure for the estimation of available nitrogen in soils. *Current Sciences,* 25, 259-260.

Walkley, A., & Black, C. A. (1934). Estimation of soil organic carbon by the chromic acid titration method. *Soil Science,* 37, 29-38.