Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(3): 247-253
Received: 12-03-2020
Accepted: 16-04-2020

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Effect of seaweed extracts on growth, yield and economics of *kharif* rice (*Oryza sativa* L.)

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DOI: https://doi.org/10.22271/phyto.2020.v9.i3d.11269

Abstract
A field experiment was redacted at Instructional Farm, BCKV, West Bengal, India during *kharif* (rainy) season of 2018 to evaluate the efficacy of seaweed extracts on growth, yield and economics of rice. The experiment was framed in RBD comprising 7 treatments (T_1- 100% RDF, T_2 -100% RDF + Biozyme granule @15 kg/ha, T_3 -100% RDF +Amaze-x granule @ 10 kg/ha, T_4 -75% RDF + Biozyme granule @ 15kg/ha, T_5 -75% RDF +Amaze-x granule @ 10 kg/ha, T_6 - 75% RDF + Biozyme granule @ 15 kg/ha + Proventus DS legacy spray @ 625ml/ha, T_7 -75% RDF +Amaze-x granule @10 kg/ha + Proventus DS legacy spray @ 625ml/ha), replicated thrice. Experimental findings revealed that highest growth and yield attributes of rice were observed under application of 75% RDF +Amaze-x granule @ 10 kg/ha + Proventus DS legacy spray @ 625 ml/ha (T_7). Maximum grain (3.90 t/ha) and straw (5.94 t/ha) yields of rice and high nutrient uptake (N: 91.45 kg/ha, P_2O_5: 11.49 kg/ha and K_2O: 190.74 kg/ha) were also ensured under treatment T_7. However, 75% RDF + Biozyme granule @ 15 kg/ha + Proventus DS legacy spray @ 625ml/ha (T_6) remained as second best option after T_7. Further, high economic viability was exhibited by both the treatment T_6 (BCR: 1.59) and T_7 (BCR: 1.58). Therefore, application of 75% RDF and Proventus DS legacy spray @ 625ml/ha along with either Biozyme granule @ 15 kg/ha or Amaze-x granule @ 10 kg/ha can be recommended for achieving best growth, yield and economics of *kharif* rice.

Keywords: Economics, growth, rice, seaweed extracts, yield

Introduction
Worldwide, rice (*Oryza sativa* L.) is appreciated for its high nutritional and caloric values. Being the staple food for more than half of the global population, rice cultivation needs urgent emphasise regarding its revamp in productivity. The concernment of uplifting rice productivity is more prominent under the scenarios of increasing food demand in response to consistent population growth as well as agricultural land shrinkage. Moreover, in the present context of changing climate, unsatisfactory performance of rice crop is a major challenge which needs to be addressed with competent agro-technological interventions. India is the largest producer of rice in terms of area (43.79 million ha) in the world with production of 112.91 million tonnes and productivity 2.58 t/ha in 2017-18 (Govt. of India, 2018). However, in order to cope up with the rapid population growth, the requirement of rice production by 2030 is estimated to be 160 million tonnes (Mishra *et al*., 2013) [24] which is not achievable through relying solely on green revolution based farming as it is gradually losing its hope due to excessive and unscientific exploitation of its broods (chemical fertilizers, pesticides, irrigation etc). Yield stagnation, sharp rise of input price, soil health deterioration and environmental footprints (Biswas *et al*., 2019) [3] are some pertinent issues associated with the use of chemical fertilizers and therefore, there is an urgent need for its partial replacement or complete paradigm shift towards modern biotechnological advances.

One such promising alternative of chemical fertilizers, which is gaining momentum at this hour is seaweed extract. Seaweeds are bio-stimulating substances (macroscopic, multi-cellular marine algae) naturally originated from coastal ecosystems. Among three major types of seaweeds (red, brown and green), brown (Phaeophyta) seaweeds are most commonly used in agriculture (Blunden and Gordon, 1986) [4]. *Ascophyllum nodosum* (L.), *Fucus spp.*, *Laminaria spp*., *Sargassum spp.*, and *Turbinaria* spp. are important brown seaweeds which are now being partially or totally used as alternatives of chemical fertilizers (Hong *et al.*, 2007; Ugarte *et al*., 2006) [13, 34]. Seaweed extracts contain phyto-hormones like auxins, gibberrelins, cytokinins and betaines (Crouch and van Staden, 1993) [6], enzymes, vitamins and hydrolysed proteins, polysaccharides, nutrients and trace elements (Fe, Cu, Zn, Co, Mo, Mn, and Ni) (Challen and Hemingway, 1965; Khan *et al*., 2009) [5, 18],

biologically active alginic acids, polyphenols, free amino acids etc which stimulate plant growth and help in alleviating various biotic and abiotic stresses. Besides, the organic substances produced from seaweed extracts are biodegradable, non-polluting, non-hazardous and eco-friendly in nature. Positive effects of seaweed extracts (either in solid or liquid form or in combination) on growth and yield of various field crops including rice have already been documented by many researchers around the globe. Considering all the facts in mind, the present experiment was planned to evaluate the effect of seaweed extracts on growth, yield and economics of rice (*Oryza sativa* L.) during rainy season.

Materials and Methods

The field experiment was carried out in Instructional Farm (22°93' N latitude, 88°53' E longitude and 9.75 m above mean sea level), Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal, India during rainy (*kharif*) season of 2018 to find out the effect of seaweed extracts on growth, yield and economics of rice. The soil of the experiment site (low land) belonged to inceptisol order and sandy loam in texture with pH of 7.17, organic carbon of 0.61%, available nitrogen of 192.37 kg/ha, available phosphorus of 41.23 kg/ha and available potassium of 188.74 kg/ha. The experiment was planned in randomized block design comprising seven treatments (T_1 – control or 100% recommended dose of fertilizers (RDF) i.e. 60:30:30 kg/ha N:P_2O_5:K_2O, T_2 -100% RDF + Biozyme granule @15 kg/ha, T_3 -100% RDF +Amaze-x granule @ 10 kg/ha, T_4 -75% RDF + Biozyme granule @ 15kg/ha, T_5 -75% RDF +Amaze-x granule @ 10 kg/ha, T_6 - 75% RDF + Biozyme granule @ 15 kg/ha + Proventus DS legacy spray @ 625ml/ha, T_7 -75% RDF +Amaze-x granule @10 kg/ha + Proventus DS legacy spray @ 625ml/ha), replicated thrice. Entire P_2O_5 and K_2O and 1/4th of total N were applied as basal through inorganic sources of fertilizers such as S.S.P., M.O.P. and Urea respectively while rest N was top dressed at tillering stage i.e. 30 days after transplanting (DAT) (1/2 of total N) and panicle initiation stage i.e. 60 DAT (1/4 of total N). Soil applications of Biozyme granule and Amaze-x granule and foliar spray of Proventus DS legacy were done at 15 and 45 DAT as per the treatments. Biozyme is a highly nutritious bio-stimulant as it contains organic nitrogen, proteins, amino acid, humic acid, carbohydrates, potassium, magnesium, calcium and traces of auxins, cytokinins, enzymes, betaines and vitamins etc and can be used in liquid and solid form, while Amaze-x is a silica based granule formulation. Both Biozyme and Amaze-x is prepared from brown seaweed *Ascophyllum nodosum*, while Proventus DS Legacy is prepared from brown seaweed 'Kelp' (*Laminaria* spp and *Saccharina latissima*). *Ascophyllum nodosum* is rich in cytokinins, auxin, hydrolyzed proteins, enzymes etc. (Kumar *et al.*, 2000) [19]. Nutritional compositions of *Ascophyllum nodosum* and *Laminaria* spp have been presented in Table 1 (Indergaard and Minsaas, 1991; Baardseth, 1970; Haug and Jensen, 1954; Gayral and Cossan, 1973, Jensen, 1956 a and b) [14, 1, 12, 8, 15, 16]. Rice variety 'IET-4786' was sown in nursery on 25th June, 2018 with the seed rate of 50 kg/ha and transplanted in main field on 27th July, 2018 at a spacing of 20 cm × 15 cm. Individual plot size was 7 m × 2 m. The crop was harvested on 5th November, 2018.

Table 1: Chemical composition of seaweeds *Ascophyllum nodosum and Laminaria* spp.

Parameter(s)	*Ascophyllum nodosum*	*Laminaria digitata*
Type	Brown	Brown
Water (%)	70-85	73-90
Ash	15-25	21-35
Alginic acid	15-30	20-45
Laminaren	0-10	0-18
Mannitol	5-10	4-16
Fucoidan	4-10	2-4
Carbohydrates	10	1-2
Protein	5-10	8-15
Fat	2-7	1-2
Tannins	2-10	1
Potassium	2-3	1.3-3.8
Sodium	3-4	0.9-2.2
Magnesium	0.5-0.9	0.5-0.8
Iodine	0.01-0.1	0.3-1.1

Observations recorded on growth attributes were plant height, leaf area index (LAI), dry matter accumulation, crop growth rate (CGR) at 30 days periodic interval and at harvest. Observations on yield attributes and yield included no. of panicles/m^2, panicle length, no. of filled grains/panicle, 1000-grain weight, grain yield, straw yield, harvest Index, % yield increase over control. Further, nutrient uptakes (N, P, K) of rice (grain, straw and total), residual soil fertility status (organic carbon, available N, P_2O_5 and K_2O) and soil microbial status (populations of bacteria, fungi and actinomycetes) at harvest were estimated. Soil microbial analysis was done by counting bacteria, fungi and actinomycetes on agar plates as number of viable cells per gram of soil through Tronton's agar medium, Martin-Rose Bengal Streptomycin agar medium and Jensen's agar medium respectively through serial dilution technique, pour plate method (Pramer and Schmidt, 1965) [30] followed by incubation at 28±1 °C. Organic carbon, available N, P_2O_5 and K_2O were estimated using the methods as prescribed by Walkley and Black (1934) [35], Nelson and Sommers (1980) [26], Olsen *et al.* (1954) [27] and Merwine and Peech (1951) [23] respectively. Data recorded from both field and laboratory were statistically analyzed by analysis of variance method (Panse and Sukhatme, 1985) [28] through OP-Stat online portal (Sheoran *et al*., 1998) [33] and comparison between treatment means was done using critical differences (CD) at 5% level of significance as prescribed by Gomez and Gomez (1984). Finally, production economics (total cost of cultivation, gross return, net return, benefit-cost ratio or BCR) of rice under different nutrient management options was chalked out.

Results and Discussion

Growth attributes

Experimental results revealed that nutrient management options although did not significantly influence growth attributes of rice at 30 DAT, variations on growth attributes became prominent afterwards (Table 2). At 30 DAT, however, maximum plant height (36.16 cm), LAI (2.01) and dry matter accumulation (DMA) (46.27 g/m^2) of rice were observed from applications of 100% RDF (T_1), 75% RDF +Amaze-x granule @10 kg/ha + Proventus DS legacy spray @ 625ml/ha (T_7) and 75% RDF +Amaze-x granule @ 10 kg/ha (T_5) respectively. It might be due to no competition among plants for resources and ample utilization of nutrients

irrespective of treatments. At 60 and 100 DAT, respectively the applications of 75% RDF + Biozyme granule @ 15 kg/ha + Proventus DS legacy spray @ 625 ml/ha (T_6) and 75% RDF +Amaze-x granule @10 kg/ha + Proventus DS legacy spray @ 625ml/ha (T_7) produced maximum plant height (79.53 cm and 93.33 cm), LAI (4.30 and 2.31) and DMA (469.69 g/m^2 and 934.15 g/m^2) and however, both those treatments remained statistically indifferent (Table 2). On a contrary, application of 100% RDF (T_1) exhibited lowest growth attributes (plant height: 70.46 cm and 80.33 cm, LAI: 3.83 and 1.97 and DMA: 332.76 g/m^2 and 734.63 g/m^2 at 60 and 100 DAT respectively). Similarly, highest crop growth rate (CGR) of rice at 30-60 DAT (14.24 g/m^2/day) and 60-100 DAT (12.66 g/m^2/day) intervals were noticed from applications of 75% RDF + Biozyme granule @ 15 kg/ha + Proventus DS legacy spray @ 625 ml/ha (T_6) and 75% RDF +Amaze-x granule @10 kg/ha + Proventus DS legacy spray @ 625ml/ha (T_7) respectively (Table 2). It might be due to the favorable effects of seaweed extracts to supply of growth promoting hormones, several nutrients and other bio-stimulating substances in readily available form. Gollan and Wright (2006) [9] also reported positive effects of seaweed extracts on cell division and thereby plant growth due to presence of growth promoting hormone auxin. Further, increased biomass accumulation and crop growth were noticed under integrated application of seaweed extracts and chemical fertilizers due to utilization of benefits of both (Lingakumar *et al.*, 2002; Kumari *et al*., 2011; El-Yazied *et al*., 2012 and Karanja *et al*., 2013) [21, 20, 7, 17].

Yield attributes and yield

Experimental results (Table 3) expressed that nutrient management options imparted statistically significant variations on yield attributes and yield of rice except panicle length and 1000-grain weight as they were mainly genetically governed. However, maximum panicle length (25.54 cm) and 1000-grain weight (21.86 g) of rice were found respectively under the applications of 75% RDF + Biozyme granule @ 15 kg/ha + Proventus DS legacy spray @ 625 ml/ha (T_6) and 75% RDF +Amaze-x granule @10 kg/ha + Proventus DS legacy spray @ 625ml/ha (T_7). Conversely, maximum no. of panicles/m^2 (304.59) and no. of filled grains/panicle (121.10) were found when respectively the applications of 75% RDF +Amaze-x granule @10 kg/ha + Proventus DS legacy spray @ 625ml/ha (T_7) and 75% RDF + Biozyme granule @ 15 kg/ha + Proventus DS legacy spray @ 625 ml/ha (T_6) were done. The higher number of panicles/m^2 obtained in Amaze-x or Biozyme granules and Proventus DS legacy spray along with 75% recommended doses of NPK fertilizers might be due to better utilization of resources in the plots receiving growth hormones, micronutrients, enzymes, proteins, vitamins etc through the addition of *Ascophyllum nodosum, Laminaria spp and Saccharina latissima* extracts. Further, higher chlorophyll content in leaves and light interception resulted from enlarged leaf area under integrated use of chemical fertilizers and seaweed extracts (Proventus DS legacy and Biozyme or Amaze-x) helped in increasing photosynthetic activity and thereby positively influencing translocation of photosynthates from leaves (source) to grain (sink). The result was in line with the findings of Mitra and Mandal (2012) [25] and Satapathy *et al*. (2014) [32]. Grain and straw yields of rice varied similarly as a reflection of growth and yield attributes. Maximum grain (3.90 t/ha) and straw (5.94 t/ha) yields of rice were obtained when 75% RDF +Amaze-x granule @10 kg/ha + Proventus DS legacy spray @ 625ml/ha (T_7) was applied which was closely followed by the application of 75% RDF + Biozyme granule @ 15 kg/ha + Proventus DS legacy spray @ 625 ml/ha (T_6) (grain yield: 3.87 t/ha and straw yield: 5.91 t/ha). However, both the treatments remained statistically similar to each other in terms of all the yield attributes and yield. High grain and straw yields under integrated use of seaweed extracts (Proventus DS legacy and Biozyme or Amaze-x) and chemical fertilizers were obtained due to their favorable impacts on yield attributes and dry matter production respectively. The result was in agreement with the findings of Bastia *et al*. (2013) [2] and Rathore *et al*. (2009) [31]. Khan *et al.* (2009) [18] also observed positive effects of phyto-hormones (betaines, cytokinins etc), minerals, vitamins, amino acids, enzymes etc present in seaweed extracts on grain and biological yields of several crops. Shortest panicle length (23.71 cm), minimum no. of panicles/m^2 (214.51), no. of filled grains/panicle (83.57), lowest grain (3.39 t/ha) and straw (5.17 t/ha) yields of rice were observed under application of 100% RDF (T_1) (Table 3). Percentage of yield increase over control (15.05%) was highest when 75% RDF +Amaze-x granule @10 kg/ha + Proventus DS legacy spray @ 625ml/ha (T_7) was applied, which was next followed by application of 75% RDF + Biozyme granule @ 15 kg/ha + Proventus DS legacy spray @ 625 ml/ha (T_6) (14.15%). As harvest index is a consequence of grain yield and biological yield, maximum harvest index (39.82) of rice was noticed under application of 75% RDF +Amaze-x granule @10 kg/ha (T_5), which was followed by application of 75% RDF + Biozyme granule @15 kg/ha (T_4) (39.68), 75% RDF +Amaze-x granule @10 kg/ha + Proventus DS legacy spray @ 625 ml/ha (T_7) (39.62), 100% RDF (T_1) (39.60), 100% RDF + Biozyme granule @15 kg/ha (T_2) (39.59), 75% RDF + Biozyme granule @15 kg/ha + Proventus DS legacy spray @ 625 ml/ha (T_6) (39.58) and 100% RDF +Amaze-x granule @10 kg/ha (T_3) (39.47) and all the treatments were statistically at par with each other except T_3.

Nutrient uptake

Results from Table 4 exhibited that nutrient uptake (N, P, K) of rice (grain and straw) varied significantly with nutrient management options. Highest uptakes of N (54.12 kg/ha) and K (27.12 kg/ha) of rice grain and N (37.33 kg/ha), P (4.78 kg/ha) and K (163.62 kg/ha) uptakes of rice straw were found under application of 75% RDF +Amaze-x granule @10 kg/ha + Proventus DS legacy spray @ 625ml/ha (T_7) which was next followed by application of 75% RDF + Biozyme granule @ 15 kg/ha + Proventus DS legacy spray @ 625 ml/ha (T_6) and both the treatments remained statistically similar to each other (Table 4). Highest P uptake (7.86 kg/ha) of rice grain, on the other hand, was noticed when 75% RDF + Biozyme granule @ 15 kg/ha + Proventus DS legacy spray @ 625 ml/ha (T_6) was applied. Lowest uptakes of P (4.05 kg/ha) and K (16.49 kg/ha) of rice grain and N (26.62 kg/ha) and K (146.63 kg/ha) uptakes of rice straw were observed under application of 100% RDF (T_1). Lowest N uptake (43.81 kg/ha) of rice grain and P uptake (2.24 kg/ha) of rice straw were however shown when 75% RDF + Biozyme granule @15 kg/ha (T_4) was applied. Accordingly, total nutrient uptake also varied under various nutrient management options. Highest total N (91.45 kg/ha) and K (190.74 kg/ha) uptakes of rice were noticed under application of 75% RDF +Amaze-x granule @10 kg/ha + Proventus DS legacy spray @ 625ml/ha (T_7), while highest total P uptake (12.52 kg/ha) of rice was found under application of 75% RDF + Biozyme

granule @ 15 kg/ha + Proventus DS legacy spray @ 625 ml/ha (T_6) and both the treatments remained statistically akin (Table 4). On a contrary, lowest total uptakes of N (70.82 kg/ha), P (7.06 kg/ha) and K (163.12 kg/ha) of rice were observed when 100% RDF (T_1) was applied. Biozyme and Amaze-x, extracts from the seaweed *Ascophyllum nodosum*, are the organic source of several primary nutrients (N, P and K), secondary nutrients (Ca and Mg); trace elements (Zn, Cu, Fe and Mn), beneficial elements (Ni and Na), bio-active substances etc and therefore, they proliferated root development, enhanced root to shoot ratio and thereby, helped the plants to take up nutrients from soil in balanced proportion. Besides, Mancuso *et al*. (2006) [22] reported improved stomatal nutrient uptake efficiency when foliar spray of seaweed extract was done. Pramanick *et al.* (2014) [29] also observed comparative increase of nutrient uptakes by seeds and stover of sesame under applications of *Kappaphyscus alvarezii* and *Gracilaria edulis* seaweed extracts at higher concentration (15%) along with 75% RDF over sole use of chemical fertilizers.

Residual soil fertility and microbial status

Alike the crop, nutrient management options also had marked influences on soil fertility and microbial status at harvest of rice. Residual organic carbon content and available P_2O_5 although did not vary significantly according to nutrient management options, marginal increases from initial level (before the experiment) were exhibited by all the treatments. Highest residual organic carbon (0.66%) and available P_2O_5 (47.11 kg/ha) of soil were however recorded by applications of 100% RDF + Biozyme granule @ 15 kg/ha (T_2) and 100% RDF (T_1) respectively (Table 5). Unlike organic carbon and available P_2O_5 of soil, nutrient management options exerted significant variations on available soil N and K_2O after harvest of rice. Highest residual available N (204.56 kg/ha) and K_2O (224.43 kg/ha) of soil were found from the plots treated with 100% RDF + Biozyme granule @ 15 kg/ha (T_2) which was statistically at par with treatments T_1, T_3, T_4, T_5 in terms of available N and with treatments T_1, T_3, T_5 in terms of available K_2O of soil after harvest of rice. It might be due to the less uptake of NPK leading to a substantial amount of left-over nutrients in the soil. Application of 75% RDF +Amaze-x granule @10 kg/ha + Proventus DS legacy spray @ 625ml/ha (T_7), on the other hand, provided lowest values of residual available N (183.71 kg/ha) and K_2O (193.27 kg/ha) of soil (Table 5). 25% substitution of RDF with seaweed extracts showed low residual soil fertility probably due to greater uptake of nutrients as well as less addition of inorganic nutrients to the soil. The overall enhancements of N, P_2O_5 and K_2O over the initial levels were higher where full dose of RDF either alone or along with supplementation through seaweed extracts were applied.

The soil microbial status at harvest of rice as shown in Table 6 expressed that nutrient management options did not exert significant variations on microbial population except bacteria. There was prolific increase of soil bacterial population when seaweed extracts were incorporated in nutrient management options. It might be due to improvement in activity and multiplication of bacteria upon consumption of organic substances added to the soil by seaweed extracts. Maximum bacterial population (200.2 CFU $\times 10^6$) was shown by application of 75% RDF +Amaze-x granule @ 10 kg/ha (T_5) which was however statistically at par with treatments T_4, T_6, T_7. Although fungi and actinomycetes populations remained statistically alike among the nutrient management options, highest fungi (2.52 CFU$\times 10^4$) and actinomycetes (70.1 CFU$\times 10^5$) populations were however recorded by applications of 75% RDF + Biozyme granule @ 15 kg/ha + Proventus DS legacy spray @ 625 ml/ha (T_6) and 100% RDF +Amaze-x granule @ 10 kg/ha (T_3) respectively (Table 6).

Economics

Economic analysis as shown in Table 7 indicated that integrated application of seaweed extracts and RDF increased the gross and net returns of rice cultivation as compared to sole RDF application or control (T_1). Among various nutrient management options, although application of 75% RDF +Amaze-x granule @10 kg/ha + Proventus DS legacy spray @ 625ml/ha (T_7) recorded highest gross return (Rs. 71,814/ha) due to best crop productivity, highest net return (Rs.26, 614/ha) of rice cultivation was however ensured by application of 75% RDF + Biozyme granule @ 15 kg/ha + Proventus DS legacy spray @ 625 ml/ha (T_6). This was due to relatively low cost of Biozyme than Amaze-x granule. Application of 100% RDF or control recorded lowest gross (Rs. 62,427/ha) and net (Rs. 19,340/ha) returns of rice cultivation due to lowest crop productivity. As a consequence of high monetary returns as well as low cost of cultivation, the maximum benefit-cost ratio (BCR) was realised under treatment T_6 (1.59) which was however very closely followed by treatment T_7 (1.58) (Table 7). Conversely, minimum BCR (1.44) was acquired by control or application of 100% RDF (T_1). The result corroborated the finding of Pramanick *et al.* (2014) [29] who reported that application of 75% RDF + *Kappaphyscus alvarezii* sap @15% to sesame crop produced significantly higher yield, nutrient uptake and net returns (Rs. 28650/ha) and BCR (1:99) over control (100% RDF).

Table 2: Effect of seaweed extracts on growth attributes of *kharif* rice

Treatment	Plant height (cm)			LAI			Dry matter accumulation (g/m^2)			CGR(g/m^2/day)	
	30 DAT	60 DAT	100 DAT	30 DAT	60 DAT	100 DAT	30 DAT	60 DAT	100 DAT	30-60 DAT	60-100 DAT
T_1- 100%RDF(Control) i.e. 60:30:30 kg/ha N:P_2O_5:K_2O	36.16	70.46	80.33	1.91	3.83	1.97	41.26	332.76	734.63	9.71	10.04
T_2 -100% RDF + Biozyme granule @ 15 kg/ha	32.93	73.89	89.66	1.96	4.19	2.23	39.73	385.83	876.56	11.53	12.26
T_3 -100% RDF +Amaze-x granule @ 10 kg/ha	33.93	75.26	91.40	1.97	4.27	2.26	43.36	449.26	883.81	13.53	10.86
T_4 -75% RDF + Biozyme granule @ 15 kg/ha	35.26	72.86	85.16	1.90	3.92	2.02	37.12	364.75	765.76	10.92	10.02
T_5 -75% RDF +Amaze-x granule @ 10 kg/ha	34.46	72.26	83.30	1.94	4.05	2.10	46.27	352.43	788.19	10.20	10.89
T_6 - 75% RDF + Biozyme granule @ 15 kg/ha + Proventus DS legacy spray @ 625 ml/ha	32.93	79.53	92.43	1.90	4.30	2.29	42.38	469.69	905.32	14.24	10.90
T_7 -75% RDF +Amaze-x granule @ 10 kg/ha + Proventus DS legacy spray @ 625 ml/ha	36.06	77.86	93.33	2.01	4.27	2.31	44.30	427.52	934.15	12.77	12.66
S.Em (±)	1.50	2.12	1.23	0.04	0.01	0.009	3.25	29.45	24.05	0.25	0.32
CD (*p=0.05*)	NS	6.50	3.78	NS	0.03	0.03	NS	90.38	73.82	0.75	0.96

Table 3: Effect of seaweed extracts on yield attributes and yield of *kharif* rice

Treatment	No. of panicles/m^2	Panicle length (cm)	No. of filled grains/ panicle	1000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest Index (%)	% yield increase over control
T_1- 100%RDF(Control) i.e. 60:30:30 kg/ha N:P_2O_5:K_2O	214.51	23.71	83.57	20.53	3.39	5.17	39.60	-
T_2 -100% RDF + Biozyme granule @ 15 kg/ha	276.84	24.68	106.69	20.33	3.71	5.66	39.59	9.38
T_3 -100% RDF +Amaze-x granule @ 10 kg/ha	286.11	24.23	110.21	21.70	3.77	5.78	39.47	11.21
T_4 -75% RDF + Biozyme granule @ 15 kg/ha	246.51	24.52	96.57	21.56	3.52	5.35	39.68	3.83
T_5 -75% RDF +Amaze-x granule @ 10 kg/ha	258.72	25.50	100.21	21.53	3.56	5.38	39.82	5.01
T_6 - 75% RDF + Biozyme granule @ 15 kg/ha + Proventus DS legacy spray @ 625 ml/ha	301.62	25.54	121.10	21.53	3.87	5.91	39.58	14.15
T_7 -75% RDF +Amaze-x granule @ 10 kg/ha + Proventus DS legacy spray @ 625 ml/ha	304.59	25.14	115.86	21.86	3.90	5.94	39.62	15.05
S.Em (±)	8.97	0.612	7.09	0.14	0.10	0.14	0.10	
CD (*p=0.05*)	27.45	NS	21.77	NS	0.29	0.43	0.31	

Table 4: Effect of seaweed extracts on nutrient uptakes of *kharif* rice

Treatment	Nutrients uptake of grain (kg/ha)			Nutrient uptake of straw (kg/ha)			Total uptake (kg/ha)		
	N	P	K	N	P	K	N	P	K
T_1- 100%RDF(Control) i.e. 60:30:30 kg/ha N:P_2O_5:K_2O	44.20	4.05	16.49	26.62	3.01	146.63	70.82	7.06	163.12
T_2 -100% RDF + Biozyme granule @ 15 kg/ha	50.55	6.59	21.94	31.74	2.52	159.29	82.29	9.11	181.23
T_3 -100% RDF +Amaze-x granule @ 10 kg/ha	52.76	7.27	24.50	33.01	3.28	154.15	85.76	10.55	178.65
T_4 -75% RDF + Biozyme granule @ 15 kg/ha	43.81	5.17	19.71	30.38	2.24	146.76	74.19	7.41	166.47
T_5 -75% RDF +Amaze-x granule @ 10 kg/ha	47.65	5.36	18.98	30.62	3.07	153.14	78.27	8.43	172.12
T_6 - 75% RDF + Biozyme granule @ 15 kg/ha + Proventus DS legacy spray @ 625 ml/ha	53.18	7.86	25.21	35.05	4.46	159.92	88.23	12.52	185.13
T_7 -75% RDF +Amaze-x granule @ 10 kg/ha + Proventus DS legacy spray @ 625 ml/ha	54.12	6.71	27.12	37.33	4.78	163.62	91.45	11.49	190.74
S.Em (±)	1.83	0.23	0.85	1.19	0.13	4.90	3.02	0.67	6.56
CD (*p=0.05*)	5.65	0.70	2.65	3.67	0.39	15.13	9.32	2.06	20.17

Table 5: Effect of seaweed extracts on soil fertility status after harvest of *kharif* rice

Treatment	Organic carbon (%)	Available N after harvest(kg/ha)	Available P_2O_5 after harvest(kg/ha)	Available K_2O after harvest(kg/ha)
T_1- 100%RDF(Control) i.e. 60:30:30 kg/ha N:P_2O_5:K_2O	0.62	196.41	47.11	217.76
T_2 -100% RDF + Biozyme granule @ 15 kg/ha	0.66	204.56	44.53	224.43
T_3 -100% RDF +Amaze-x granule @ 10 kg/ha	0.65	201.31	45.17	213.21
T_4 -75% RDF + Biozyme granule @ 15 kg/ha	0.64	190.27	46.68	204.57
T_5 -75% RDF +Amaze-x granule @ 10 kg/ha	0.64	195.39	45.84	209.13
T_6 - 75% RDF + Biozyme granule @ 15 kg/ha + Proventus DS legacy spray @ 625 ml/ha	0.63	186.84	42.77	198.68
T_7 -75% RDF +Amaze-x granule @ 10 kg/ha + Proventus DS legacy spray @ 625 ml/ha	0.62	183.71	43.29	193.27
S.Em (±)	0.02	5.14	1.83	5.53
CD (*p=0.05*)	NS	15.83	NS	17.04
Initial	0.61	192.37	41.23	188.74

Table 6: Effect of seaweed extracts on soil microbial status at harvest of *kharif* rice

Treatment	Microbial population		
	Total Bacteria (CFU×10^6)	Fungi (CFU×10^4)	Actinomycetes (CFU×10^5)
T_1- 100%RDF(Control) i.e. 60:30:30 kg/ha N:P_2O_5:K_2O	164.5	2.01	60.8
T_2 -100% RDF + Biozyme granule @ 15 kg/ha	180.6	2.42	68.5
T_3 -100% RDF +Amaze-x granule @ 10 kg/ha	172.9	2.15	70.1
T_4 -75% RDF + Biozyme granule @ 15 kg/ha	192.1	2.37	67.8
T_5 -75% RDF +Amaze-x granule @ 10 kg/ha	200.2	2.41	69.2
T_6 - 75% RDF + Biozyme granule @ 15 kg/ha + Proventus DS legacy spray @ 625 ml/ha	196.7	2.52	66.5
T_7 -75% RDF +Amaze-x granule @ 10 kg/ha + Proventus DS legacy spray @ 625 ml/ha	192.4	2.23	67.2
S.Em (±)	2.67	0.34	1.82
CD (*p=0.05*)	8.19	NS	NS

Table 7: Effect of seaweed extracts on production economics of *kharif* rice

Treatment	Total cost of cultivation (Rs/ha)	Gross return (Rs./ha)	Net return (Rs./ha)	BCR
T_1- 100%RDF(Control) i.e. 60:30:30 kg/ha N:P_2O_5:K_2O	43,087	62,427	19,340	1.44
T_2 -100% RDF + Biozyme granule @ 15 kg/ha	44,137	68,321	24,184	1.54

T_3 -100% RDF +Amaze-x granule @ 10 kg/ha	44,687	69,443	24,756	1.55
T_4 -75% RDF + Biozyme granule @ 15 kg/ha	43,407	64,810	21,403	1.50
T_5 -75% RDF +Amaze-x granule @ 10 kg/ha	43,957	65,528	21,571	1.49
T_6 - 75% RDF + Biozyme granule @ 15 kg/ha + Proventus DS legacy spray @ 625 ml/ha	44,657	71,271	26,614	1.59
T_7 -75% RDF +Amaze-x granule @ 10 kg/ha + Proventus DS legacy spray @ 625 ml/ha	45,207	71,814	26,607	1.58

Price of paddy: Rs.17.50/kg; straw:Rs.0.60/kg; Biozyme granule: Rs.70/kg; Amaze-x: Rs.160/kg; Proventus DS Legacy: Rs.100/100ml

Conclusion

Overall, the study confirms the efficacy of seaweed extracts *viz*. Biozyme, Amaze-x, Proventus DS legacy as substitutes or supplements to chemical fertilizers on performance of *kharif* rice. Based on experimental results, integrated use of 75% RDF and Proventus DS legacy spray @ 625ml/ha along with either Biozyme granule @ 15 kg/ha or Amaze-x granule @ 10 kg/ha at 15 and 45 DAT can be recommended to the farmers of new alluvial zone of West Bengal, India for realizing best growth, productivity and profitability of *kharif* rice.

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