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Bio efficacy of foliar applied biostimulants on nutrient uptake, yield and economics of rice (*Oryza sativa* L.) under lateritic soils of Konkan region

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Abstract
Enormous use of agrochemicals since green revolution had led to harmful effect on soil and environment as the whole. Considering this fact, currently agriculture is in need of sustainable innovations for improving production and productivity without disturbing environment. Keeping this view, the present investigation was planned to study the bioefficacy of different foliar applied biostimulants on nutrient uptake and yield in rice crop and to study economics of different treatments in rice crop under lateritic soils of Konkan region. The experiment was carried out at instructional farm of Department of Agronomy, College of Agriculture, Dapoli, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri, MH, India in *kharif*, 2021. Effect of foliar application different biostimulants namely SiLife, humic acid, triacontanol and vermiwash along with no foliar application as control treatment was studied on nutrient uptake and yield of rice. Positive effect and significant variations were observed among different biostimulants for nutrient uptake and yield. Biostimulant SiLife @ 0.4% (T_3) showed significantly higher uptake of nutrients and yield as compared to other treatments. It showed 22.96% and 18.91% higher grain and straw yield, respectively over control. While, treatment T_4 (humic acid @ 1%) showed higher monetary returns (₹ 15202.48 ha^{-1}) and B: C ratio (1.16) over all the other treatments.

Keywords: Biostimulants, rice, nutrient uptake, yield and economics etc.

1. Introduction
Rice (*Oryza sativa* L.) is considered as the principal staple food grain crop and counters for more than half of the worlds production and is extensively grown worldwide. It is cultivated on an area of 161.77 million hectares worldwide with production of 749.19 million metric tons in year 2021. In terms of rice production India ranks second (122.3 MMT) after China (209.61 MMT) (Anonymous, 2021a) [1]. In India, 45.07 million hectares area is covered by rice cultivation, producing of 122.27 million tons of rice with an average productivity of 2713 kg ha^{-1} (Anonymous, 2021a) [1]. In Maharashtra, rice is cultivated on 15.61 lakh hectares area producing 32.91 lakh tonnes rice with an average productivity of 2109 kg ha^{-1} in the year 2021-22. (Anonymous, 2021b) [2]. Konkan region of Maharashtra, has larger cultivated area under rice cultivation as compared to other regions with 3.57 lakh hectares area, producing 8.52 lakh tonnes of rice annually with an average productivity around 2386.01 kg ha^{-1} (Anonymous, 2021c) [3]. Rice is the most important staple food grain crop of the people in Konkan region.

Ever-increasing population is imposing tremendous pressure on producers to meet the growing demand of food and fibre. To meet this increasing demand, the use of chemical inputs to enhance production is crossing safe limits which is resulting in deleterious effect on soil and environment and consequently factor productivity is declining. The current scenario under such condition firmly highlights the need to adopt eco-friendly agricultural approaches for food production by considering the sustainability of both soil and environment. In this situation, use of plant biostimulants is of great importance to substitute the commercial chemical fertilizers.

Plant biostimulants are diverse substances and microorganisms that are obtained from natural sources and used in agriculture for stimulating plant growth, stress tolerance and improving quality (Calvo *et al.*, 2014) [6]. Among different plant biostimulants seaweed extract is a new generation of natural organic fertilizer containing highly effective nutrients, promotes growth and yield as well as enhance the resistant ability of many crops to biotic and abiotic stress.

Unlike chemical fertilizers, seaweed biostimulants are biodegradable, non-toxic, non-polluting and non-hazardous to humans and other living organisms. Humic substances are also widely used as plant biostimulants which are natural components of soil organic matter, derived from decomposed plant, animal and microbial residues. Its application results in enhanced root length and root biomass and thereby increasing root foraging capacity and enhancing nutrient use, consequently resulting in increased crop yield, hence reducing the use of synthetic fertilizers, and further losses to the environment (Jardin, 2015) [9]. Considering all the above facts, the present study was designed with the objective to study the effect of different biostimulants on nutrient uptake and yield of rice crop and to work out economics of different biostimulants in rice crop.

2. Material and Method

The present investigation was conducted at Instructional Farm, Department of Agronomy, College of Agriculture, Dapoli, Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli; Dist. Ratnagiri, Maharashtra, India during *Kharif*, 2021. The analytical work was done at research laboratory of Department of Agronomy. Geographically, the experimental plot (B - 42) is located in the subtropical region at 17°45’55” N latitude and 73°10’26” E longitude with 157.8 m elevation above mean sea level. Sub-tropical type of climate prevailed at the experimental site which was characterized by warm and humid atmosphere.

The soil of experimental plot was analysed initially to study various physico-chemical properties, which showed that it was sandy clay loam in texture, with high organic carbon (11.18 g kg^{-1}) and slightly acidic in reaction (pH 6.34) and was low in available nitrogen (259.80 kg ha^{-1}) and potassium (231.33 kg ha^{-1}) and medium in available phosphorous (11.50 kg ha^{-1}). The experiment was designed according to randomized block design with seven treatments and three replications. Rice variety Ratnagiri 1 was transplanted at the spacing of 20 cm × 15 cm. The gross plot size was 4.00 m × 4.50 m while the net plot size was 3.60 m × 3.90 m. Plant biostimulants were foliar applied thrice at different concentrations, each at 10-12 days after transplanting, panicle initiation stage and at milking/grain filling stage. Common RDF (100: 50: 50; N: P_2O_5: K_2O kg ha^{-1}) was applied to all the plots irrespective of the treatments. All the recommended agronomic practices were carried out uniformly for all the treatments as and when required. All together the experiment consist of 21 plots and the treatment details are given in Table 1.

Yield parameters [number of panicles $hill^{-1}$, panicle length (cm), weight of panicle (g), number of grains $panicle^{-1}$ and 1000 grain weight] were recorded at harvest from randomly selected five sample hills in each plot. The grain and straw yields and harvest index (HI) was recorded from each net plot area. Plant samples were oven dried, ground, sieved and analysed for total N by micro-Kjeldahl method (Tandon, 1993) [21], P by ammonium molybdate method (Tandon, 1993) [21] K by flame photometry (Tandon, 1993) [21]. Nutrient uptake was estimated by multiplying the N, P and K concentrations of grains and straw with their respective yield (kg ha^{-1}) and summing up the two values.

Table 1: Treatments details along with the symbols used

Treatments	Symbols used
Biostimulant (SiLife) foliar application @ 0.2%	T_1
Biostimulant (SiLife) foliar application @ 0.3%	T_2
Biostimulant (SiLife) foliar application @ 0.4%	T_3
Biostimulant (Humic Acid) foliar application @ 1%	T_4
Biostimulant (Triacontanol) foliar application @ 0.1%	T_5
Biostimulant (Vermiwash) foliar application @ 10%	T_6
Control (No foliar application)	T_7

The significance of the treatment difference was tested by variance ratio test (f value), critical difference (C.D.) at 5 per cent level of probability and was worked out for comparison and statistical interpretation of significance between treatments mean (Panse and Sukhatme, 1967) [17]. On the basis of the experimental findings the economics of different treatments was worked out. Gross returns (₹ ha^{-1}), net returns (₹ ha^{-1}) and B: C ratio was calculated for each treatment. For that the prevailing market prices of grain and straw were considered. Similarly, the cost of cultivation of the crop under the individual treatment was worked out by taking into account the cost of all inputs and the cost incurred for all the operations up to harvest. The net income was worked out by deducting the cost of cultivation from the gross returns and the B: C ratio for each treatment was worked out by dividing gross returns by cost of cultivation.

3. Result and Discussion

3.1 Yield attributes and yield

Experimental results (Table 2) expressed that various biostimulants imparted statistically significant variations on yield attributes and yield of rice except 1000-grain weight as it was mainly genetically governed. However, 1000 grain weight was numerically higher in treatment T_3 (SiLife @ 0.4%). Conversely, significantly higher number of panicles (9.13), length of panicle (21.15 cm), weight of panicle (2.91 g) and number of grains $panicle^{-1}$ (116.13) was recorded with application of SiLife @ 0.4% (T_3) which was followed treatments T_4 (humic acid @ 1%) and T_6 (vermiwash @ 10%) which were statistically at par with treatment T_3. The lowest yield attributes were recorded with the treatment T_7 (Control). The positive effect on yield attributes in rice crop might be due to efficient utilization of native as well as applied nutrients through roots and foliar application of biostimulants. Foliar application of seaweed extract based biostimulant (SiLife) recorded maximum yield attributes which might be due to presence of plant growth regulators, trace elements, vitamins and micronutrients in biostimulant which enhanced the yield attributing characters (Kavitha *et al*., 2008) [10]. Devi and Mani (2015) [8] reported that highest yield contributing characters were recorded with 100% RDF+15% *Kappaphycus alvarezii* sap which was followed by 100% RDF+15% *Gracilaria* sap. Layek *et al.* (2018) [14] stated that yield attributes significantly increased with application of seaweed extracts upto 10% concentration. The experimental findings of the present research are also in close agreement to those of Pramanick *et al*. (2014) [18], Banjare *et al*. (2022) [5], Deepana *et al*. (2021) [7], Zodape *et al*. (2010) [22] in green gram and Nayak *et al*. 2020 [15].

Table 2: Yield attributing characters and yield as influenced by different biostimulants

Treat.	No. of panicles hill^{-1}	No. of grains panicle^{-1}	Panicle length (cm)	Weight of panicle (g)	1000-grain weight (g)	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
T_1	7.13	76.20	17.79	2.46	29.74	4533.48	5562.20	10095.68	44.91
T_2	7.60	100.27	19.89	2.63	29.80	4681.86	5698.01	10379.87	45.10
T_3	9.33	116.13	21.15	2.91	29.88	4945.39	5908.83	10854.23	45.56
T_4	8.90	109.60	20.61	2.79	29.87	4902.66	5876.07	10778.73	45.48
T_5	7.20	80.00	18.40	2.56	29.79	4657.64	5709.88	10367.52	44.93
T_6	8.88	106.40	20.35	2.73	29.81	4883.67	5877.26	10760.92	45.38
T_7	6.97	75.07	16.46	2.32	29.58	4021.84	4969.14	8941.12	44.42
S.Em. (±)	0.17	3.40	0.34	0.09	0.23	55.90	54.95	109.57	0.14
C.D. at 5%	0.51	10.48	1.04	0.28	NS	172.24	169.32	337.60	NS

In the present investigation, grain, straw and ultimately biological yields of rice varied similarly as a reflection of the yield attributes (Fig. 1). Foliar application of different biostimulants showed positive effect on yield of rice when compared with control treatment. Maximum grain (4945.39 kg ha^{-1}), straw (5908.83 kg ha^{-1}) and biological (10854.23 kg ha^{-1}) yield of rice was obtained when biostimulant SiLife @ 0.4% (T_3) was foliar applied which was followed by application of humic acid @ 1% (T_4) with 4902.66 kg ha^{-1}, 5876.07 kg ha^{-1} and 10778.73 kg ha^{-1} grain, straw and biological yield, respectively and vermiwash @ 10% (T_6) with 4883.67 kg ha^{-1}, 5877.26 kg ha^{-1} and 10760.92 kg ha^{-1} grain, straw and biological yield, respectively. Also, foliar application of SiLife @ 0.4% showed higher harvest index (45.56%) over other treatments which was followed by application of humic acid @ 1% and vermiwash @ 10%. While lowest grain, straw and biological yield and harvest index was obtained with treatment T_7: control (no foliar application). Treatment T_3 (SiLife @ 0.4%) recorded 22.96% 18.91% and 21.39% more grain, straw and biological yield than control (T_7).

The improvement in yield due to application of biostimulant containing seaweed extract was might be due to presence of readily available nutrients like nitrogen, phosphorous, potash as well as trace minerals which helps in increasing yield (Kavitha *et al*., 2008) [10]. The higher value of grain yield of rice might be owing to greater availability of nutrients in the soil, improvement of soil environment leading to higher root proliferation resulting in better absorption of moisture and nutrients and ultimately ensuring higher grain yield (Kumari *et al*., 2013) [13]. It might be also due to better availability of plant nutrients throughout the growth period and particularly during the critical growth period of rice crop which resulted into better plant vigour and superior yield attributes (Arun *et al*., 2019) [4]. The results of present investigation are in close confirmation with those of Nayak *et al*. (2020) [15], Deepana *et al*. (2021) [7], Pramanick *et al*. 2014 [18], Devi and Mani (2015) [8] and Layek *et al*. (2018) [14] and Arun *et al*. (2019) [4].

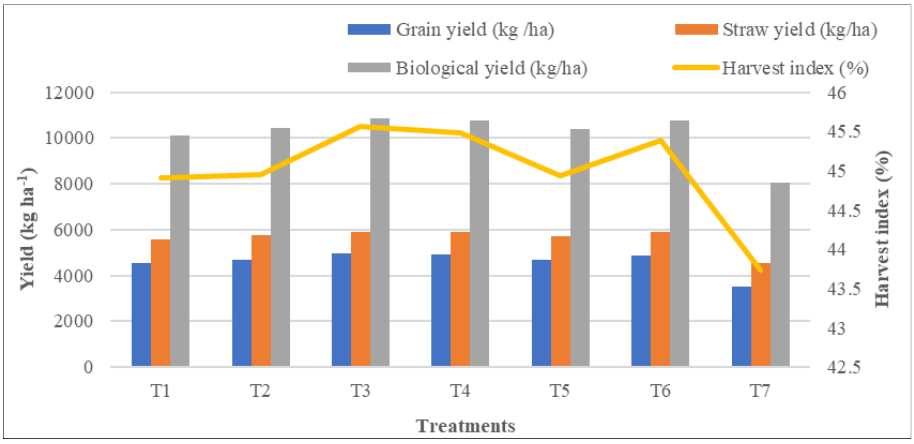

Fig 1: Grain yield, straw yield, biological yield (kg ha^{-1}) and harvest index (%) of rice as influenced by different treatments

3.2 Nutrient content and uptake

In the present investigation concentration of N, P and K in rice grain and straw differed significantly amongst treatments (Table 3). Significantly higher N (1.28% and 0.60% in grain and straw, respectively), P (0.323% and 0.203% in grain and straw, respectively) and K (0.35% and 1.11% in grain and straw, respectively) was observed in treatment T_3 (SiLife @ 0.4%) which was followed by treatments T_4 (humic acid @ 1%) and T_6 (vermiwash @ 10%).

Total N, P and K uptake was in linear association with grain yield and straw yield as shown in Table 3. Total nitrogen (98.45 kg ha^{-1}), phosphorus (28.00 kg ha^{-1}) and potassium (82.92 kg ha^{-1}) uptake in rice was higher when the crop was sprayed with 0.4% SiLife (T_3) as compared to other treatments. Treatments T_4 (humic acid @ 1%) and T_6 (vermiwash @ 10%) were statistically at par with treatment T_3 with regard to total N, P and K uptake. However, treatment T_7: control (no foliar application) showed lowest values of nutrient uptake. In the present study, with increase in N, P and K content in grain and straw, the uptake of these nutrients was also found to be higher in grain, straw as well as total biological produce; as uptake of a nutrient is a function of concentration of nutrient and yield per hectare. Higher values of nutrient uptake in treatment with seaweed extract based biostimulant might be due to the presence of several bioactive substances that are important for plants growth and vigour and they also can improve nutrient uptake from soil (Arun *et al*., 2019) [4]. Also, the biostimulants increases the efficiency of mineral fertilizers by decreasing leaching and other losses (Pramanik *et al*., 2020) [19]. Layek *et al*. (2018) [14] reported higher total N, P and K uptake with foliar application of 15% Kappaphycus alvarezii (K sap). Pramanick *et al*. (2014) [18] reported that the use of the seaweed extracts significantly increased N, P and K uptake by grains at higher concentrations (10% and above) and reached maximum at 15% seaweed extract compared with control. These results are in agreement to those previously reported by Nayak *et al*. (2020) [15], Pramanick *et al*. (2020) [18] and Singh *et al*. (2015) [20] in the rice crop.

Table 3: N, P and K content (%) in grain and straw and its total uptake (kg ha^{-1}) by rice crop as influenced by different treatments

Treat.	N content (%)		Total N uptake (kg ha^{-1})	P content (%)		Total P uptake (kg ha^{-1})	K content (%)		Total K uptake (kg ha^{-1})
	Grain	Straw		Grain	Straw		Grain	Straw	
T_1	1.16	0.52	81.16	0.257	0.186	21.949	0.33	1.00	70.62
T_2	1.19	0.54	86.65	0.280	0.198	24.462	0.33	1.08	77.16
T_3	1.28	0.60	98.45	0.323	0.203	28.006	0.35	1.11	82.92
T_4	1.25	0.59	95.52	0.307	0.202	26.903	0.35	1.10	81.29
T_5	1.19	0.53	85.59	0.267	0.192	23.393	0.33	1.07	76.56
T_6	1.24	0.58	94.96	0.300	0.201	26.477	0.34	1.09	80.53
T_7	1.15	0.49	62.69	0.247	0.176	16.663	0.32	0.91	52.42
S.Em. (±)	0.02	0.01	1.50	0.006	0.005	0.364	0.003	0.01	0.85
C.D. at 5%	0.05	0.04	4.62	0.02	0.01	1.12	0.01	0.03	2.63

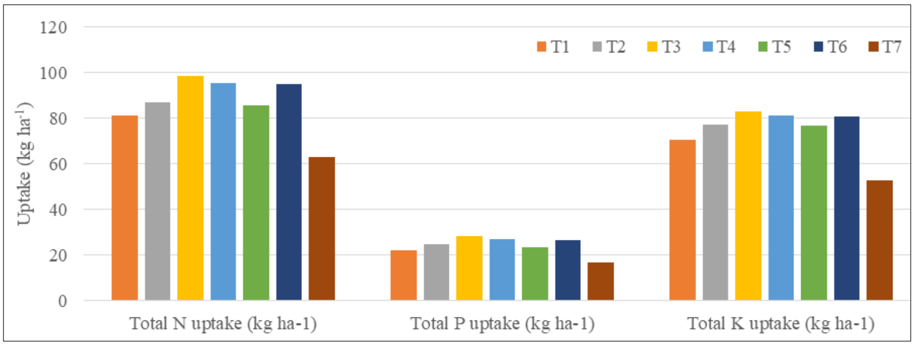

Fig 2: Total N, P and K uptake (kg ha^{-1}) by rice crop as influenced by different treatments

3.3 Economics

Economic analysis as shown in Table 4 indicated that foliar application of different biostimulants increased the gross and net returns of rice cultivation as compared to control *i.e.*, no foliar application (T_7). Among various biostimulant treatments, although application of SiLife @ 0.4% (T_3) recorded highest gross returns (₹ 110712.73 ha^{-1}) due to best crop productivity, highest net returns (₹ 15202.48 ha^{-1}) of rice cultivation was however ensured with foliar application of humic acid @ 1% (T_4). This was due to relatively low cost of humic acid as compared to biostimulant SiLife. Treatment T_7 control (no foliar application) recorded lowest gross (₹ 90446.58 ha^{-1}) and net (₹ -3972.70 ha^{-1}) 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 B: C ratio was realised under treatment T_4 (1.16) which was followed by treatment T_3 (1.14) and T_6 (1.14). Conversely, minimum B: C ratio (0.96) was acquired by control *i.e.*, no foliar application (T_7). The result corroborated the finding of Osman *et al*. (2013) [16], Kumar *et al*. (2016) [12] and Khan *et al*. (2019) [11].

Table 4: Economics of rice cultivation as influenced by different treatments based on input cost

Treatments	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B: C ratio
T_1: Biostimulant (SiLife) @ 0.2%	95859.28	101854.94	5995.66	1.06
T_2: Biostimulant (SiLife) @ 0.3%	96579.28	105073.12	8493.84	1.09
T_3: Biostimulant (SiLife) @ 0.4%	97299.28	110712.73	13413.45	1.14
T_4: Biostimulant (Humic acid) @ 1%	94599.28	109801.76	15202.48	1.16
T_5: Biostimulant (Triacontanol) @ 0.1%	94824.28	104633.00	9808.72	1.10
T_6: Biostimulant (Vermiwash) @ 10%	96399.28	109436.25	13036.97	1.14
T_7: Control (No foliar application)	94419.28	90446.58	-3972.70	0.96
S.Em. (±)	-	-	1210.36	-
C.D. at 5%	-	-	3729.50	-

Conclusion

On the basis of experimental findings, it may be concluded that foliar application of SiLife @ 0.4% resulted in higher yield attributes and yield. Also, it positively influences nutrient content in rice grain and straw and recorded higher total nutrient uptake by rice crop. However, economic analysis showed that though foliar application of SiLife @ 0.4% achieved higher gross returns, but the higher net returns and B: C ratio was obtained with foliar application of humic acid @ 1% due to lower cost of humic acid than SiLife.

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