Current Journal of Applied Science and Technology

36(2): 1-11, 2019; Article no.CJAST.49635
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Crop Growth and Productivity of Rainy Maize-garden Pea Copping Sequence as Influenced by *Kappaphycus* and *Gracilaria* Saps at Alluvial Soil of West Bengal, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2019/v36i230227
Editor(s):
(1) Dr. P. Senguttuvel, Indian Institute of Rice Research (Formerly Directorate of Rice Research), India.
Reviewers:
(1) Joseph Bandanaa, University of Ghana, Ghana.
(2) Florin Sala, Banat University of Agricultural Sciences and Veterinary, Romania.
Complete Peer review History: http://www.sdiarticle3.com/review-history/49635

Original Research Article

Received 14 April 2019
Accepted 25 June 2019
Published 04 July 2019

ABSTRACT

Aim: Cereal-legume cropping system has been proved to be one of the best alternatives for a productive as well as profitable farming in West Bengal. Maize is an important cereal crop which is widely grown during rainy (kharif) season throughout the State. While garden pea, a short duration winter (rabi) season vegetable, can easily fit in any existing cereal-legume cropping system. The present nutrient management strategies solely relay on NPK based chemical fertilizer application which results in the gradual deterioration in soil physical and chemical properties and stagnant crop yield. To maximize production level by spraying extracts of natural products that contain stimulants, is a strategic move to overcome the ill effects of the use of excessive doses of inorganic fertilizer.

Methodology: The present field experiment was conducted in Nadia district, West Bengal during rainy and winter season of 2016-17 and 2017-18 to assess the impact of seaweed extracts on crop growth and productivity under maize-garden pea cropping sequence. There were four concentrations of *Kappaphycus* seaweed sap (K-sap) (5.0 and 10%); two concentrations of GA3 free K-sap (5.0 and 10%); two concentrations of *Gracillaria* seaweed sap (G-sap) (5.0 and 10%) and a control [Recommended dose (RD) of NPK only].

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Results: Experimental results revealed that the foliar application of K-sap (10%) along with RD of NPK resulted in an impressive performance of both the crops in terms of growth (plant height, biomass, crop growth rate), yield attributes and yield, which was closely, followed G sap (10%). Throughout the growth period of garden pea, plants received recommended dose of fertilizer supplemented with K-sap at 10% concentration recorded significantly highest biomass production (56.94, 170.02 and 309.37 g m^{-2} respectively).
Conclusion: This may be concluded that the foliar application of 10% K-sap along with RD of NPK can be recommended for maize-garden pea cropping sequence.

Keywords: Seaweed; crop growth; yield; foliar nutrition.

1. INTRODUCTION

Global food demand in 2050 is projected to increase by at least 60 percent above 2006 levels, driven by population and income growth, as well as rapid urbanization. With the world gearing up to feed an estimated 9.6 billion hungry mouths by 2050, world's impending food crisis is becoming a major concern [1]. An approach for a cereal-legume cropping system proves one of the best options for a productive and sustained cropping system. Maize is an important cereal crop which is widely cultivated throughout the world and has the highest production amongst all the cereals [1]. In India, maize is grown predominantly in the rainy season with 85 percent of the total area under cultivation. Pulses are an important commodity group of crops that provide high-quality protein complementing cereal proteins for a pre-dominantly substantial vegetarian population of the country. In comparison to other vegetables, pulses are rich in protein which is less expensive than animal protein. Pea is the third most important pulse crop at global level, after bean and chickpea and third most popular winter pulse of India after chickpea and lentil [2]. Being a short duration crop, it can easily fit in any cereal-legume cropping system.

Owing to having a wide yield gaps of these two promising crops attributed to imbalanced fertilization as well as improper selection of nutrient sources, farmers are unable to harvest more causing their poor economical sustainability. Besides, excessive fertilization to get higher yield is not at all environmentally safe. Therefore, the efforts to maximize the absorption of nutrients by spraying extracts of natural products that contain stimulants, is a strategic move to overcome the ill effects of the use of excessive doses of inorganic fertilizer. In recent years, the extracts from naturally growing marine alga as a liquid fertilizer has been allowed for substitution in place of conventional synthetic fertilizer [3,4]. As these seaweed extracts contain macro and micro-nutrients as well as plant growth-promoting substances [5], thus seaweed extracts not only augment the yield but also the quality of crops. Seaweed extracts help in enhancing antioxidant properties and improving nutrient uptake from soil [6].

Both *Kappaphycus alvarezii* and *Gracilaria edulis* are tropical seaweeds that can be cultivated in seawater, under near-shore and off-shore conditions. Their sap is a green product with a low carbon footprint; cultivation in the sea does not require inputs from fossil fuels (fertilizers and pesticides). Large-scale commercial cultivation technologies have been developed for the two seaweeds, *Kappaphycu salvarezii* and *Gracilaria edulis* [7]. It is already established that foliar application of sap (liquid seaweed extract) of *K. alvarezii* and *G. edulis* has a significant positive impact on productivity and quality of many crops [8;9]. Given the facts, the present field experiment was conducted to assess the impact of foliar application of different seaweed extracts on growth and productivity of maize and garden pea cropping sequence.

2. MATERIALS AND METHODS

2.1 Experimental Site, Design and Treatment

This study was carried out at the research farm (situated at 22°57′ N latitude and 88°30′ E longitude at an altitude of 8 m above mean sea level) of Bidhan Chandra Krishi Viswavidyalaya, in West Bengal, India, during consecutive rainy and winter seasons (locally known as kharif and rabi season respectively) during 2016-17 and 2017-18. The experimental field had good irrigation facility as well as drainage. The soil type was typically Gangetic alluvium, falling under the New Alluvial Zone of India, with sandy clay loam in texture having good water holding capacity and with a moderate to high soil fertility status. The sand, silt and clay percentages of the soil were 54.7, 22.1 and 25.5%, respectively. Initial soil pH was 6.90 with an organic carbon content of 0.57%, while the available content of N, P_2O_5 and K_2O content was 226, 26.4 and 187 kg ha^{-1}, respectively. The climate of the experimental site is of sub-tropical humid type with an average annual rainfall of 1400 mm, mostly precipitated during June to September and the mean temperature ranges from 10.2°C to 40.4°C. The highest and lowest value of mean minimum temperature during the experimental period was 33.9ºC (July 2016) and 11.9ºC (January 2017) respectively. The rainfall was distributed throughout the monsoon season but, the highest rainfall received in the year 2016 was 464.3 mm in July followed by 227.3 mm in September.

The research was conducted in a randomized block design with 7 treatments replicated thrice. Size of the experimental plot was 6.0 m × 5.0 m. There were two concentrations of each *Kappaphycus* seaweed sap [K-sap], *Gracilaria* sap [G-sap] and GA_3 free *Kappaphycus* sap [K−GA_3 sap] (5% and 10%) and a control Recommended dose of fertilizer (RDF) i.e. 200: 60: 60 kg N, P_2O_5 and K_2O ha^{-1}, respectively [10] was given through urea (46% N), single super phosphate (16% P_2O_5), and muriate of potash (60% K_2O) for rainy season maize. An equal amount of total P and K fertilizers were applied to the soil prior to sowing in each plot. The N fertilizer was applied (as per treatment details) in three splits of 40% before sowing, 30% at 30 days after planting (DAP) at knee height stage and rest 30% at pre-tasseling stage. In case of garden pea recommended dose of fertilizer (RDF) i.e. 20: 60: 40 kg N, P_2O_5 and K_2O ha^{-1}, respectively [11] was given through urea (46% N), single super phosphate (16% P_2O_5), and muriate of potash (60% K_2O) as basal.

2.2 Extraction of Sap from Seaweed

Kappaphycus sp. and *Gracilaria sp.* ware cultivated in coastal area Tamil Nadu, India. The seaweeds are collected manually and washed with fresh water. After washing, the sap from *Kappaphycus sp.* and *Gracilaria sp.* were extracted mechanically by milling under ambient conditions. The resultant slurry obtained by a milling process was filtrated by centrifugation in order to obtain the seaweed sap (100% concentration) following which it was preserved as described by Pramanick et al. [3] and Eswaran et al. [7]. The obtained sap further diluted as per the treatment requirements. GA_3-free K-sap was prepared by methods as described by Prasad et al. [12]. The composition of sap (Table 1) used for the present study was from the same lot as that previously described by Layek et al. [13].

2.3 Field Management, Plant Measurements and Analysis

Crop growth rate, defined as the increase in dry weight of plant material per unit area of land per unit change of time [14], was calculated with the following formula:

Table 1. Composition of sea weed sap

Composition	Concentration	
	K Sap	G Sap
Indole acetic acid (mg/L)	23.36	8.67
Gibberelin GA3(mg/L)	27.87	–
Kinetin + Zeatin (mg/L)	31.91	3.13
Vitamin C (mg/100 g)	–	28.50
Thiamine (mg/L)	0.023	–
Ribloflavin (mg/L)	0.010	–
Nitrogen (mg/L)	30.00	–
Phosphorus (mg/L)	33.99	278.50
Potassium (mg/L)	1970.00	682.10
Sodium (mg/L)	510.00	1952.0
Calcium (mg/L)	460.11	352.00
Magnesium (mg/L)	581.20	311.0
Copper (mg/L)	0.30	0.04
Iron (mg/L)	10.59	12.67
Manganese (mg/L)	2.50	32.90
Zinc (mg/L)	0.62	0.63

Source: Layek et al. (2015)

$$\mathrm{CGR} = \frac{\mathrm{W_2} - \mathrm{W_1}}{\mathrm{t_2} - \mathrm{t_2}}\ \mathrm{gm^2 day^{-1}}$$

where,

W_1 = Initial dry weight per unit area at t_1 time
W_2 = Final dry weight per unit area at t_2 time

CGR was calculated for each treatment at an interval of 30 days in maize and rice and 20 days in greengram.

The harvest index was calculated by using the formula given by Donald [15].

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

To calculate system productivity of maize-garden pea cropping system, the yield of garden pea was converted into maize equivalent yield (t ha^{-1}) using the following equation as suggested by Parihar et al. [16].

Maize equivalent yield (t ha^(-1)) = (Garden pea yield (t ha^(-1)) × Market price of garden pea (US$ t^(-1)) / Minimum support price of maize (US$ t^(-1))

2.4 Statistical Analysis

The variance over the years was estimated for homogeneity of data by Bartlett's chi-square test. The effect of the years was non-significant and there were no significant interactions between treatments and years. Therefore, the data were pooled over the years and subjected to ANOVA by using the STAR Software version 2.0.1 [17]. Excel Software was used to draw graphs and figures.

3. RESULTS AND DISCUSSION

3.1 Growth of Crops in Cropping Sequence

The plant height of rainy season maize increased gradually with the growth stages (Table 2). The tallest plant (60.50 cm) at 30 DAS was registered with the application of G-sap 10 % with RD_{NPK} which was statistically at par with rest others except the treatment received GA_3 free K-sap (10 %) with RD_{NPK} and in control plot, but at later growth stages (60 and 90 DAS) the maximum plant height was noticed from the plants treated with K-sap 10% along with RD_{NPK} depicted a value of 139.50 cm and 200.32 cm respectively. The biomass production of rainy season maize at different growth stages varied significantly ($p \leq 0.05$). At 30 DAS, amongst all treatments, plants received K-sap 10 % with RD_{NPK} performed exceptionally good with a value of 133.65 g m^{-2} which was statistically at par to the treatment received RD_{NPK} supplemented with 5 % K-sap (130.45 g m^{-2}) (Table 2). At later growth stages (60 DAS and 90 DAS) treatment plot sprayed with K- sap 10 % + RD_{NPK} also results the maximum biomass production (502.05 g m^{-2} and 889.65 g m^{-2} respectively). In our study, plant height and dry matter accumulation were gradually increased with increasing application of seaweed extract. This is probably due to presence of growth promoting attributes in seaweed saps like carbohydrates [18], phenyl acetic acids [19], macro- and micro-elements [20; 21], and plant growth regulators like cytokinin [22] and gibberellins [23;24].

At 20 DAS, plant height of garden pea changed significantly ($p \leq 0.05$) with the changes in nutrient management options (Table 3). The most superior performance was exhibited from the plant treated with K-sap at 10% concentration with RD_{NPK}, depicted a value of 28.07 cm which was analogous to that of the plants received K sap without GA_3 at 10% concentration along with RD_{NPK} (27.85 cm). On the other hand, the most inferior performance was exhibited from the plants received only RD_{NPK} (45.03 cm). At later growth stages, the maximum plant height also recorded from the supplementary application of 10 % concentration of K-sap along with RD_{NPK}. The biomass production of garden pea at different growth stages varied significantly with the foliar application of varied seaweed treatments (Table 2). Throughout the growth period of garden pea, plants received recommended dose of fertilizer supplemented with K-sap at 10% concentration recorded significantly highest biomass production (56.94, 170.02 and 309.37 g m^{-2} respectively). Alternatively, biomass production from the control plots was discovered to be distinctively poor for entire growth period (Table 3). This result has a close agreement with the findings of [25], who opined that increasing concentration of *Kappaphycus*-sap along with RDF resulted in maximum plant height and dry matter accumulation. During experiment, treatment plot received *Gracillaria* Sap 10% + RD_{NPK}, was seen to perform an edge for leaf area index (LAI) of maize at 30 DAS over all the other treatments, statistically resembling treatments were K-sap at 10 % with RD_{NPK} (2.00), G-sap at 5% with RD_{NPK} (1.95), and K-sap 5% with RD_{NPK} (1.91) respectively. But at later growth stages (60 DAS and 90 DAS), the treatments received RD_{NPK} supplemented with K-sap 5 % and 10 % were statistically superior to control with LAI 3.65 and 4.99 respectively (Table 4).Gradual increment in plant height; dry matter accumulation and LAI with the application of increasing seaweed extract also reported by Pramanik et al. [25].

The crop growth rate (CGR) of maize at different growth stages changed significantly with the changes in nutritional management practices during investigation (Table 4). The treatment plots received 10% concentration of K-sap and G-sap along with RD_{NPK} exhibited the distinctively highest CGR (at 30-60 DAS and 60-90 DAS) depicting a value of 12.28 g m^{-2} day^{-1} and 13.13 g m^{-2} day^{-1} respectively, while the

Table 2. Effect of sea weed saps on plant height and biomass production of rainy *(kharif)* maize (pooled over two years)

Treatment	Plant height (cm)			Biomass production (g m^{-2})		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Kappaphycus sap 5% + RDF	59.25	130.35	191.27	130.45	463.73	826.85
Kappaphycus sap 10 % + RDF	58.50	139.50	200.32	133.65	502.05	889.65
Gracillaria sap 5% + RDF	57.50	132.15	193.50	120.85	426.45	780.25
Gracillaria sap 10% + RDF	60.50	134.55	196.15	122.45	442.45	836.45
K-GA_3 5% + RDF	58.85	132.95	187.65	111.25	397.65	741.25
K-GA_3 10% + RDF	54.00	137.45	191.00	112.29	416.85	751.25
Control (RDF)	53.50	126.75	185.60	103.05	384.05	702.85
SEm (±)	1.09	1.67	2.60	3.45	11.93	19.87
CD ($p \le 0.05$)	3.26	5.04	7.90	10.31	36.18	59.45

RDF (Recommended dose of fertilizer): N: P_2O_5: K_2O = 200:60:60 kg ha^{-1}

Table 3. Effect of sea weed saps on plant height and biomass production of winter (rabi*)* garden pea (pooled over two years)

Treatment	Plant height (cm)			Biomass production (g m^{-2})		
	20 DAS	40DAS	60 DAS	20 DAS	40 DAS	60 DAS
Kappaphycus sap 5% + RDF	21.51	47.63	56.87	51.07	127.01	245.36
Kappaphycus sap 10 % + RDF	28.07	52.05	61.53	56.94	170.02	309.37
Gracillaria sap 5% + RDF	23.68	45.85	55.75	48.84	138.27	261.62
Gracillaria sap 10% + RDF	25.15	47.25	56.63	52.98	156.51	284.86
K-GA_3 5% + RDF	26.17	46.22	54.50	49.74	127.07	235.42
K-GA_3 10% + RDF	27.85	49.28	59.73	54.12	163.84	289.19
Control (RDF)	19.82	45.03	51.45	46.18	122.78	226.13
SEm (±)	0.56	1.12	1.27	1.45	5.48	6.92
CD ($p \le 0.05$)	1.68	3.32	3.79	4.42	16.36	21.05

RDF (Recommended dose of fertilizer): N: P_2O_5: K_2O = 20:60:40 kg ha^{-1}

Table 4. Effect of sea weed saps on leaf area index (LAI) and crop growth rate (CGR) of rainy maize (pooled over two years)

Treatment	LAI			CGR (g m^{-2} day^{-1})	
	30 DAS	60DAS	90DAS	30-60 DAS	60-90 DAS
Kappaphycus sap 5% + RDF	1.91	3.65	4.76	11.11	12.10
Kappaphycus sap 10 % + RDF	2.00	3.57	4.99	12.28	12.92
Gracillaria sap 5% + RDF	1.95	3.40	4.50	10.19	11.79
Gracillaria sap 10% + RDF	2.03	3.58	4.85	10.67	13.13
K-GA_3 5% + RDF	1.62	3.15	4.17	9.55	11.45
K-GA_3 10% + RDF	1.67	3.28	4.35	10.15	11.15
Control (RDF)	1.56	3.03	4.00	9.37	10.63
SEm (±)	0.05	0.10	0.16	0.23	0.29
CD ($p \le 0.05$)	0.15	0.31	0.47	0.69	0.88

RDF (Recommended dose of fertilizer): N: P_2O_5: K_2O = 200:60:60 kg ha^{-1}

lowest was found under control plot (9.37 g m^{-2} day^{-1} and 10.6 3 g m^{-2} day^{-1} respectively) which did not show any considerable difference with the application of GA_3 free K-sap at 5% level of concentration with RD_{NPK} during entire growth duration. The seaweed saps contain GB/chlorine in substantial amounts [26] which are known to play a profound role in enhancing photosynthetic activity by maintaining higher levels of photosynthetic pigment [27] which results in a higher crop growth rate.

A distinguishable variation was recorded in the number of flowers $branch^{-1}$ of garden pea in maize –garden pea sequence during entire growth period in response to miscellaneous nutritional treatments (Table 5). Here also the treatment received K-sap at 10% concentration with RDF represented as superior by flowering in maximum number $branch^{-1}$ (3.17) over the other treatments at 20 DAS which was closely followed by the treatment sprayed with GA_3 free K-sap at 10% concentration along with RD_{NPK} (2.93). On the other hand, the lowest number of flowers $branch^{-1}$ were recorded in control plot (2.27) was closely followed by the performance of garden pea sprayed with 5% concentration of G-sap along with RD_{NPK} (2.30). The same trend was observed in subsequent growth stages.

Data presented in Table 5 revealed that, at 20-40 DAS growth duration the highest crop growth rate (CGR) (5.65 g m^{-2} day^{-1}) of garden pea was observed from the plots received K-sap 10 % with RD_{NPK} which was statistically at par (5.49 g m^{-2} day^{-1}) with the performance of GA_3 free K-sap at 10% concentration level along with RD_{NPK}. On the contrary, the least CGR (3.80 g m^{-2} day^{-1}) was illustrated by the application of RD_{NPK} supplemented with K-sap 5%. In case of later growth stage, supplementary spraying of K-sap at 10% concentration with RD_{NPK} was found to perform better (6.97 g m^{-2} day^{-1}) than all the other treatments. Similar finding was reported by [5] where the maximum crop growth rate was recorded with the application of *Kappaphycus* sap 15% along with RD_{NPK}. It probably due to enhancement of net photosynthetic rate and other gas exchange parameters by application of *Kappaphycus*-based sap formulations [26].

3.2 Yield of Crops in Cropping Sequence

The yield attributes of maize like number of cobs $plant^{-1}$, cob girth, numbers of kernel row^{-1} and grain weight cob^{-1} varied significantly with the application of foliar seaweed fertilization. The highest yield attributes of maize like number of cobs $plant^{-1}$ (2.21), cob girth (14.45 cm), numbers of kernel row^{-1} (24.03), grain weight cob^{-1} (97.17 g) and thereby grain yield (5.23 t/ha), stover yield (6.01 t ha^{-1}) and harvest index (46.54) recorded from the plots received foliar application of *Kappaphycus* extract at the rate of 10% along with RD_{NPK} (Table 6). But the number of the test weight of maize remained unchanged with application of different seaweed treatments (Table 6). The experimental results were in accordance with an earlier report by Layek et al. [13] where yield attributes and yield of maize were gradually increase with increasing the concentration of *Kappaphycus* sap. The number of kernels per row in the cob is an attribute that is determined in the early stages of the development in maize plants and the seaweed sap sprays may have favourably influenced it and eventually led to higher grain and stover yield over control (water spray).

Amongst the different yield attributing traits of garden pea, number of branches $plant^{-1}$, number of pods $branch^{-1}$, number of seeds pod^{-1} and 1000 seeds weight were found maximum from the plot received 10 % K-sap along with RD_{NPK}

Table 5. Effect of sea weed saps on flowers $branch^{-1}$ and crop growth rate (CGR) of winter garden pea (pooled over two years)

Treatment	Flowers $branch^{-1}$			CGR ($g/m^2/day$)	
	20 DAS	40DAS	60DAS	20-40 DAS	40-60 DAS
Kappaphycus sap 5% + RDF	2.50	4.63	4.93	3.80	5.92
Kappaphycus sap 10 % + RDF	3.17	5.63	6.03	5.65	6.97
Gracillaria sap 5% + RDF	2.30	4.25	4.50	4.47	6.17
Gracillaria sap 10% + RDF	2.67	4.90	5.07	5.18	6.42
K-GA_3 5% + RDF	2.53	4.20	4.77	3.87	5.42
K-GA_3 10% + RDF	2.93	4.72	5.03	5.49	6.27
Control (RDF)	2.27	3.97	4.20	3.83	5.17
SEm (±)	0.11	0.23	0.30	0.08	0.15
CD ($p \leq 0.05$)	0.32	0.68	0.91	0.24	0.44

RDF (Recommended dose of fertilizer): N: P_2O_5: K_2O = 20:60:40 kg ha^{-1}

Table 6. Effect of sea weed saps on yield and yield attributes of rainy maize (pooled over two years)

Treatment	Cobs plant^{-1}	Cob girth (cm)	Grains row^{-1}	Grain weight cob^{-1} (g)	Test wt. (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest Index (%)
Kappaphycus sap 5% + RDF	2.13	14.60	22.35	86.62	206.84	4.48	5.72	43.91
Kappaphycus sap 10 % + RDF	2.21	14.45	24.03	97.17	212.71	5.23	6.01	46.54
Gracillaria sap 5% + RDF	2.10	14.10	21.68	81.50	202.21	4.32	5.58	43.66
Gracillaria sap 10% + RDF	2.18	14.70	23.59	92.26	207.67	4.72	5.93	44.29
K-GA_3 5% + RDF	2.08	13.65	21.07	74.50	200.78	4.17	5.40	43.57
K-GA_3 10% + RDF	2.17	13.45	23.85	88.12	216.72	4.63	5.72	44.72
Control (RDF)	2.03	13.10	20.27	70.25	200.09	3.93	5.05	43.78
SEm (±)	0.03	0.17	0.58	3.13	8.33	0.15	0.16	-
CD ($p \leq 0.05$)	0.09	0.51	1.73	9.50	NS	0.48	0.43	-

RDF (Recommended dose of fertilizer): N: P_2O_5: K_2O = 200:60:60 kg ha^{-1}

Table 7. Effect of sea weed saps on yield and yield attributes of winter garden pea (pooled over two years)

Treatment	Branches plant^{-1}	Pods branch^{-1}	Seeds pod^{-1}	100 seed wt. (g)	Green pod yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest Index (%)
Kappaphycus sap 5% + RDF	4.63	3.85	4.30	43.32	6.79	2.98	69.53
Kappaphycus sap 10 % + RDF	5.17	3.97	4.79	44.48	7.83	3.20	70.97
Gracillaria sap 5% + RDF	4.19	3.68	4.45	43.63	6.65	3.13	68.00
Gracillaria sap 10% + RDF	5.03	3.82	4.54	44.24	7.50	3.49	68.24
K-GA_3 5% + RDF	4.37	3.80	4.35	44.00	6.70	2.96	69.36
K-GA_3 10% + RDF	5.05	3.93	4.38	44.25	7.25	3.31	68.63
Control (RDF)	4.07	3.45	4.03	43.88	6.59	3.16	67.58
SEm (±)	0.11	0.17	0.07	0.27	0.91	0.82	-
CD ($p \leq 0.05$)	0.32	NS	0.21	NS	0.57	0.25	-

RDF (Recommended dose of fertilizer): N: P_2O_5: K_2O = 20:60:40 kg ha^{-1}

Table 8. Effect of different nutritional treatments on economics of rainy maize-garden pea sequence

Treatment	System cost of cultivation**(Rs ha^{-1})	System returns (Rs ha^{-1})***		B:C ratio
		Gross returns	Net returns	
Kappaphycus sap 5% + RDF	1195.0	2716.7	1521.7	2.27
Kappaphycus sap 10 % + RDF	1221.3	3147.3	1926.0	2.58
Gracillaria sap 5% + RDF	1195.0	2645.3	1450.3	2.21
Gracillaria sap 10% + RDF	1221.3	2948.8	1727.5	2.41
K-GA_3 5% + RDF	1195.0	2623.7	1428.6	2.20
K-GA_3 10% + RDF	1221.3	2865.8	1644.5	2.35
Control (RDF)	1168.8	2541.6	1372.8	2.17

*Net return = Gross return–Total cost of production; Minimum support price for Maize \$227.5 t^{-1} and average market price for garden pea is \$250 t^{-1}; 1 US\$ = 60 INR (Indian rupees),**System cost of cultivation (Rs ha^{-1})= (Cost of cultivation of rainy maize + Cost of cultivation of garden pea), *** System Returns (Rs ha^{-1}) = (Return from rainy maize + Return from garden pea*

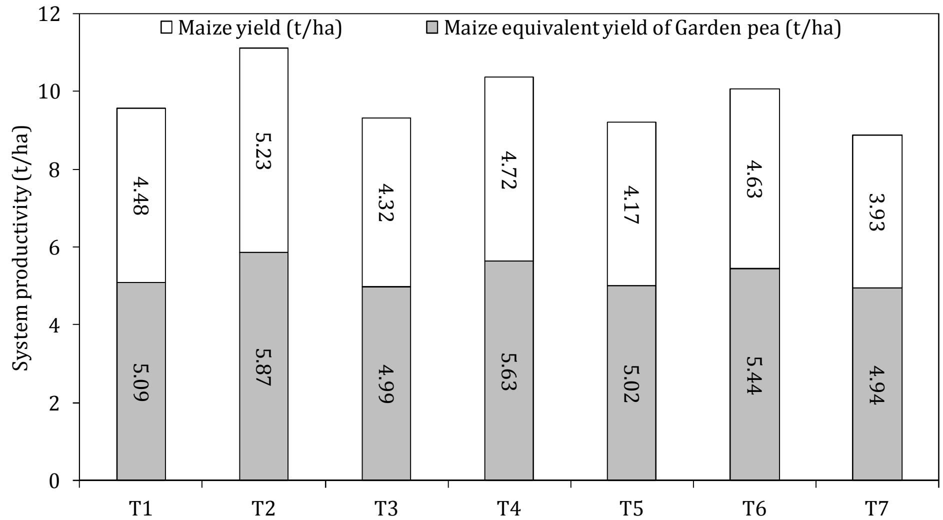

Fig. 1. System productivity of the winter maize - garden pea sequence

and ultimately plants from the same treatment recorded the highest green pod (7.83 t ha-1) (Table 7). Whereas the maximum stover yield (3.49 t ha-1) was observed from the plots in receiving G-sap at 10% concentration with RDNPK. In harmony to the present experiment, [5] also confirmed that application of K-sap at higher concentration helped to increase the yield and yield components pulse crop significantly. The beneficial effect of seaweed on growth and productivity on different crops has already been reported from different parts of the world such as wheat, tomato, greengram etc. [28;29;30;8]. Sea weed based products have capacity to enhance the activity of free radical trapping enzymes and antioxidant that protect the crop from cell wall damage by biotic and abiotic stress under uncontrolled field conditions [31]. Besides these, better nutrient mobilization, effective partitioning and translocation of photosynthates to the reproductive plant parts, enhancement of root length and volume, increase photosynthetic efficiency also reported by using seaweed based products [32].

3.3 System Productivity

The system productivity of the maize - garden pea sequence was substantially high (11.10 t ha-1) from the application of higher concentration of Kappaphycus sap along with RDNPK, which was closely followed by supplementary spraying of G-sap at 10% concentration with RDNPK, recorded 10.34 t ha-1. However, the lowest was observed from control plot (8.86 t ha-1) and was closely followed the performance of both 5% concentration of GA3 free Kappaphycus sap and Gracillaria Sap 5% along with RDNPK respectively (Fig. 1). The same trend was reported previously by Pramanick et al. [33] where utmost concentration of Kappaphycus sap along with 75% RDNPK resulted highest system productivity (30.25 t ha-1 year-1) in a cereal-legume cropping system. Being a wealthy source of versatile plant macro and micronutrients, phytohormones; amino acids; vitamins; stimulatory and antibiotic substances the liquid seaweed extract has a capacity to enhances overall plant growth, flowering, partitioning of photosynthates from vegetative parts to the developing grain, reduces chlorophyll degradation, disease occurrence etc. ultimately causing sound general plant growth and vigour, reflecting higher yield and superior quality of agricultural products.

4. CONCLUSION

Application of eco-friendly seaweed sap derived from marine algae, Kappaphycus and Gracilaria is capable enough to augment the growth and yield of the crop over conventional farmers' practice, thereby, it increased the system productivity and profitability. From this present study, foliar application of 10% *Kappaphycus* -sap along with RD of NPK can be recommended for rainy maize-garden pea cropping sequence as an eco-friendly sustainable nutrient management options for small and marginal farmers of the new alluvial zone of West Bengal.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. FAO (Food and Agriculture Organization of the United Nation), Maize Production Statistic (Rome: FAO); 2016.
Available:at:http://faostat.fao.org
2. Indian Agriculture. Performance and challenges, Report on State of Indian Agriculture 2015–16 (New Delhi, Government of India, Ministry of Agriculture and Cooperation; 2016.
3. Pramanick B, Brahmachari K, Mahapatra BS, Ghosh A, Ghosh D, Kar S. Growth, yield and quality improvement of potato tubers through the application of seaweed sap derived from the marine alga *Kappaphycus* alvarezii. J Appl Phycol. 2017;29(6):253–260.
4. Hong DD, Hien HM, Son PN. Seaweeds from Vietnam used for functional food, medicine and biofertilizer. J Appl Phycol. 2007;19:817–826.
5. Pramanick B, Brahmachari K, Ghosh A, Zodape ST. Effect of seaweed sap s derived from two marine algae *Kappaphycus* and Gracilaria on growth and yield improvement of Blackgram. Indian J Geo-Marine Sci. 2016;45(6):789-794.
6. Turan M, Köse C. Seaweed extracts improve copper uptake of grapevine. Acta Agr Scand B-S P. 2004;54(4):213–220.
7. Eswaran K, Ghosh PK, Siddhanta AK, Patolia JS, Periyasamy C, Mehta AS, Mody KH, Ramavat BK, Prasad K, Rajyaguru MR, Reddy SKCR, Pandya JB, Tewari A. Integrated method for production of carrageenan and liquid fertilizer from fresh seaweeds; 2005. US Patent 6893479.
8. Zodape ST, Mukherjee S, Reddy MP, Chaudhary DR. Effect of *Kappaphycus* alvarezii (Doty) Doty ex silva extract on grain quality, yield and some yield components of wheat (*Triticum aestivum* L.). Int J Plant Prod. 2010;3(2):97–101.
9. Shah MT, Zodape ST, Chaudhary DR, Eswaran K, Chikara J. Seaweed sap as an alternative liquid fertilizer for yield and quality improvement of wheat. Journal of Plant Nutrition. 2013;36:192–200.
10. Ray K, Banerjee H, Bhattacharyya K, Dutta SK, Phonglosa A, Pari A, Sarkar S. Site-specific nutrient management for maize hybrids in an inceptisol of West Bengal, India. Experimental Agriculture. 2017;54 (4):874-887.
11. Devi M, Sharma U, Kumari G, Kumari Y. Effect of integrated nutrient management on soil physico-chemical properties and yield of Capsicum (*Capsicum annuum*). Int. J. Curr. Microbiol. 2018;7(5):363-372.
12. Prasad K, Das AK, Oza MD, Brahmbhatt H, Siddhanta AK, Meena R, Eswaran K, Rajyaguru MR, Ghosh, PK. Detection and quantification of some plant growth regulators in a seaweed-based foliar spray employing a mass spectrometric technique sans chromatographic separation. J Agric Food Chem. 2010;58:4594–4601.
DOI:10.1021/jf904500e
13. Layek J, Das A, Ramkrushna GI, Trivedi K, Yesuraj D, Chandramohan M, Kubavat D, Agarwal PK, Ghosh A. Seaweed sap: A sustainable way to improve productivity of maize in North-East India. Int J Environ Studies. 2015;75(2):305-315.
14. Hunt R. Plant growth analysis. Edward Arnold, London. 1978;37.
15. Donald CM. Competition among crop and pasture plants. Advances in Agronomy. 1963;15:91-118.
16. Parihar CM, Yadav MR, Jat SL, Singh AK, Kumar B, Pradhan S, Chakraborty D, Jat ML, Jat RK, Saharawat YS, Yadav OP. Long term effect of conservation agriculture in maize rotations on total organic carbon, physical and biological properties of a sandy loam soil in north-western Indo-Gangetic Plains. Soil Tillage Res. 2016;161:116-128.
17. IRRI. Statistical tool for agricultural research, Version 2.0.1. In: User's manual. Biometrics and Breeding Informatics, PBGB, Division. International Rice Research Institute, Los Bãnos, Philippines; 2014.
18. Vera J, Castro J, Contreras RA, González A, Moenne A. Oligo-carrageenans induce a long-term and broad-range protection against pathogens in tobacco plants (var. Xanthi). Physiol Mol Plant Pathol. 2012;79: 31–39.
19. Taylor IEP, Wilkinson AJ. The occurrence of gibberellins and gibberellins-like substances in algae. Phycologia. 1997;16: 37–42.

20. Sharma SHS, Lyons G, McRoberts C, McCall D, Carmichael E, Andrews F, McCormack R. Brown seaweed species from Strangford Lough: Compositional analyses of seaweed species and biostimulant formulations by rapid instrumental methods. J Appl Phycol. 2012;24:1141–1157.
21. Rathore SS, Chaudhary DR, Boricha GN, Ghosh A, Bhatt BP, Zodape ST, Patolia JS. Effect of seaweed extract on the growth, yield and nutrient uptake of soybean (*Glycine max*) under rainfed conditions. South African J Bot. 2009;75: 351–355.
22. Mondal D, Ghosh A, Prasad K, Bhatt N, Zodape ST, Chaudhary JP, Chaudhari J, Chatterjee PB, Seth A, Ghosh PK. Elimination of gibberellin from *Kappaphycus* alvarezii seaweed sap foliar spray enhances corn stover production without compromising the grain yield advantage. Plant Growth Regulation. 2014; 75(3):657-666.
23. Stirk WA, Tarkowská D, Turečová V, Strnad M, Van SJ. Abscisic acid, gibberellins and brassinosteroids in Kelpak, a commercial seaweed extract made from Ecklonia maxima. J Appl Phycol. 2013;26:561–567.
24. Wally OSD, Critchley AT, Hiltz D, Craigie JSH, Zaharia LI, Abrams SR, Prithiviraj B. Regulation of phytohormone biosynthesis and accumulation in adrydopsis following treatment with commercial extract from the marine macroalga ascophyllum nodosum. J Plant Growth Regul. 2013;32:324–339.
25. Pramanick B, Brahmachari K, Ghosh A, Zodape, ST. Foliar nutrient management through *Kappaphycus* and *Gracilaria* saps in rice-potato-greengram crop sequence. J Scientific and Industrial Res. 2014;73:613–617.
26. Mondal D, Ghosh A, Prasad K, Singh S, Bhatt N, Zodape ST, Chaudhary JP, Chaudhari J, Chatterjee PB, Seth A, Ghosh PK. Elimination of gibberellin from *Kappaphycus alvarezii* seaweed sap foliar spray enhances corn stover production without compromising the grain yield advantage. Plant Growth Regul. 2015;75: 657–666.
27. Guinn EJ, Pegram LM, Capp MW, Pollock MN, Record MT. Quantifying why urea is a protein denaturant, whereas glycine betaine is a protein stabilizer. PNAS. 2011; 108:16932–16937.
28. Ferreira MI, Lourens AF. The efficacy of liquid seaweed extract on the yield of canola plant. South African J Plant and Soil. 2002;19:159-161.
29. Arthur GD, Stirk WA, Van SJ. Effect of seaweed concentrates on the growth and yield of three varieties of Capsicum annum. South African J Bot. 2003;69:207-211.
30. Thirumaran G, Arumugam M, Arumugam R, Anatharaman P. Effect of seaweed liquid fertilizer on growth and pigment concentration of *Cyamopsis tetragonoloba* L. Taub. Am-Euras. J Agron. 2009;2:50–56.
31. Khan W, Rayirath UP, Subramanian S. Seaweed extracts as biostimulants of plant growth and development. J Plant Growth Regul. 2009;28:386–399.
32. Mondal D, Sharma M, Maiti P. Fuel intermediates, agricultural nutrients and pure water from *Kappaphycus alvarezii* seaweed. Royal Society of Chemistry Advances. 2013;3:17989–17997.
33. Pramanick B, Brahmachari K, Ghosh D, Bera PS. Influence of foliar application seaweed (*Kappaphycus* and *Gracilaria*) saps in rice (*Oryza sativa*)–potato (*Solanum tuberosum*)–black gram (*Vigna mungo*) sequence. Indian J Agron. 2018; 63(1):7-12

Peer-review history:
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