

Crop growth and productivity of rainy maize-garden pea cropping sequence as influenced by *Kappaphycus* and *Gracilaria* saps at alluvial soil of West Bengal, India

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 rely 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 *Gracilaria* seaweed sap (G-sap) (5.0 and 10%) and a control [Recommended dose (RD) of NPK only].

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, yield attributes and yield, which was closely followed G sap (10%). The same treatment came up with the greatest system productivity (11.10 t ha⁻¹).

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 *Kappaphycusalvarezii* 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, *Kappaphycusalvarezii* 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, P₂O₅ and K₂O 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 33.9°C (July 2016) and 11.9°C (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], *Gracilariasp* [G-sap] and GA₃ free *Kappaphycus* sap [K-GA₃ sap] (5% and 10%) and a control Recommended dose of fertilizer (RDF) i.e. 200: 60: 60 kg N, P₂O₅ and K₂O ha⁻¹, respectively [10] was given through urea (46% N), single super phosphate (16% P₂O₅), and muriate of potash (60% K₂O) 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, P₂O₅ and K₂O ha⁻¹, respectively [11] was given through urea (46% N), single super phosphate (16% P₂O₅), and muriate of potash (60% K₂O) as basal.

2.2 EXTRACTION OF SAP FROM SEAWEED

Kappaphycus sp. and *Gracilariasp*. were 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 *Gracilariasp*. 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 [3] and [7]. The obtained sap further diluted as per the treatment requirements. GA₃-free K-sap was prepared by methods as described by [12]. The composition of sap (Table 1) used for the present study was from the same lot as that previously described by [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:

$$\text{CGR} = \frac{W_2 - W_1}{t_2 - t_1} \text{ gm}^2 \text{ day}^{-1}$$

Where,

W₁ = Initial dry weight per unit area at t₁ time

W₂ = Final dry weight per unit area at t₂ 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 [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 [16].

$$\begin{aligned} & \text{Maize equivalent yield (t ha}^{-1}\text{)} \\ & = \frac{\text{Garden pea yield (t ha}^{-1}\text{)} \times \text{Market price of garden pea (US\$ t}^{-1}\text{)}}{\text{Minimum support price of maize (US\$ t}^{-1}\text{)}} \end{aligned}$$

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 GA₃ 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 GA₃ 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). [25] also observed a gradual increase in plant height; dry matter accumulation and LAI with increasing seaweed extract application.

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

$^2 \text{ day}^{-1}$ and $13.13 \text{ g m}^{-2} \text{ day}^{-1}$ respectively, while the lowest was found under control plot ($9.37 \text{ g m}^{-2} \text{ day}^{-1}$ and $10.63 \text{ g m}^{-2} \text{ day}^{-1}$ 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) ($5.65 \text{ g m}^{-2} \text{ day}^{-1}$) of garden pea was observed from the plots received K-sap 10 % with RD_{NPK} which was statistically at par ($5.49 \text{ g m}^{-2} \text{ day}^{-1}$) with the performance of GA_3 free K-sap at 10% concentration level along with RD_{NPK} . On the contrary, the least CGR ($3.80 \text{ g m}^{-2} \text{ day}^{-1}$) 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 ($6.97 \text{ g m}^{-2} \text{ day}^{-1}$) 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 [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} 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 RD_{NPK} . 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 RD_{NPK} , which was closely followed by supplementary spraying of G-sap at 10 % concentration with RD_{NPK} , 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 GA_3 free *Kappaphycus* and *Gracillaria* Sap 5% along with RD_{NPK} respectively (Fig.1). The same trend was reported previously by [33] where utmost concentration of *Kappaphycus* along with 75 % RD_{NPK} resulted highest system productivity ($30.25 \text{ t ha}^{-1} \text{ year}^{-1}$) 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 *Gracillaria* 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.

REFERENCES

1. FAO (Food and Agriculture Organization of the United Nation), 2016, Maize Production Statistic (Rome: FAO) Available online at:<http://faostat.fao.org>.
2. Indian Agriculture, 2016: Performance and Challenges, Report on State of Indian Agriculture 2015–16 (New Delhi, Government of India, Ministry of Agriculture and Cooperation).
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* *salvarezii*. J ApplPhycol. 2017;29(6):253–260.
4. Hong DD, Hien HM, Son PN. Seaweeds from Vietnam used for functional food, medicine and biofertilizer. J ApplPhycol. 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 AgrScand 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 *Kappaphycusalvarezii* (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 annum*). *Int.J.Curr.Microbiol.* 2018;7(5): 363-372.
12. Prasad K, Das AK, Oza MD, Brahmabhatt 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 2014. 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.
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 ApplPhycol*. 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 *Kappaphycusalvarezii* 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 ApplPhycol*. 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 *Gracilariasaps* 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, S.T.; Chaudhary, J.P.; Chaudhari, J.; Chatterjee, P.B.; Seth, A. and Ghosh, P.K. 2015. Elimination of gibberellin .,from *Kappaphycusalvarezii* seaweed sap foliar spray enhances corn stover production without compromising the grain yield advantage. *Plant Growth Regul* 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 *Cyamopsistetrogonolaba* 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 *Kappaphycusalvarezii* 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

Table 1: Composition of sea weed sap

Composition	Concentration	
	K Sap	G Sap
Indole acetic acid (mg/L)	23.36	8.67
<i>Gibberelin</i> 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)

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
<i>Kappaphycus</i> sap 5% + RDF	59.25	130.35	191.27	130.45	463.73	826.85
<i>Kappaphycus</i> sap 10 % + RDF	58.50	139.50	200.32	133.65	502.05	889.65
<i>Gracillaria</i> sap 5% + RDF	57.50	132.15	193.50	120.85	426.45	780.25
<i>Gracillaria</i> 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≤0.05)	3.26	5.04	7.90	10.31	36.18	59.45

RDF (Recommended dose of fertilizer): N: P₂O₅: K₂O = 200:60:60

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	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
<i>Kappaphycus</i> sap 5% + RDF	21.51	47.63	56.87	51.07	127.01	245.36
<i>Kappaphycus</i> sap 10 % + RDF	28.07	52.05	61.53	56.94	170.02	309.37
<i>Gracillaria</i> sap 5% + RDF	23.68	45.85	55.75	48.84	138.27	261.62
<i>Gracillaria</i> 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≤0.05)	1.68	3.32	3.79	4.42	16.36	21.05

RDF (Recommended dose of fertilizer): N: P₂O₅: K₂O = 20:60:40

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	60 DAS	90 DAS	30-60 DAS	60-90 DAS
<i>Kappaphycus</i> sap 5% + RDF	1.91	3.65	4.76	11.11	12.10
<i>Kappaphycus</i> sap 10 % + RDF	2.00	3.57	4.99	12.28	12.92
<i>Gracillaria</i> sap 5% + RDF	1.95	3.40	4.50	10.19	11.79
<i>Gracillaria</i> 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≤0.05)	0.15	0.31	0.47	0.69	0.88

RDF (Recommended dose of fertilizer): N: P₂O₅: K₂O = 200:60:60

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	40 DAS	60 DAS	20-40 DAS	40-60 DAS
<i>Kappaphycus</i> sap 5% + RDF	2.50	4.63	4.93	3.80	5.92
<i>Kappaphycus</i> sap 10 % + RDF	3.17	5.63	6.03	5.65	6.97
<i>Gracillaria</i> sap 5% + RDF	2.30	4.25	4.50	4.47	6.17
<i>Gracillaria</i> 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≤0.05)	0.32	0.68	0.91	0.24	0.44

RDF (Recommended dose of fertilizer): N: P₂O₅: K₂O = 20:60:40

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)	Kernels row ⁻¹	Grain weight cob ⁻¹ (g)	Test wt. (g)	Grain yield (t ha ⁻¹)	Stover yield (t ha ⁻¹)	Harvest Index (%)
<i>Kappaphycus</i> sap 5% + RDF	2.13	14.60	22.35	86.62	206.84	4.48	5.72	43.91
<i>Kappaphycus</i> sap 10 % + RDF	2.21	14.45	24.03	97.17	212.71	5.23	6.01	46.54
<i>Gracillaria</i> sap 5% + RDF	2.10	14.10	21.68	81.50	202.21	4.32	5.58	43.66
<i>Gracillaria</i> 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≤0.05)	0.09	0.51	1.73	9.50	NS	0.48	0.43	-

RDF (Recommended dose of fertilizer): N: P₂O₅: K₂O = 200:60:60

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 (%)
<i>Kappaphycus</i> sap 5% + RDF	4.63	3.85	4.30	43.32	6.79	2.98	69.53
<i>Kappaphycus</i> sap 10 % + RDF	5.17	3.97	4.79	44.48	7.83	3.20	70.97
<i>Gracillaria</i> sap 5% + RDF	4.19	3.68	4.45	43.63	6.65	3.13	68.00
<i>Gracillaria</i> 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≤0.05)	0.32	NS	0.21	NS	0.57	0.25	-

RDF (Recommended dose of fertilizer): N: P₂O₅: K₂O = 20:60:40

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	
<i>Kappaphycus</i> sap 5% + RDF	1195.0	2716.7	1521.7	2.27
<i>Kappaphycus</i> sap 10 % + RDF	1221.3	3147.3	1926.0	2.58
<i>Gracillaria</i> sap 5% + RDF	1195.0	2645.3	1450.3	2.21
<i>Gracillaria</i> 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)

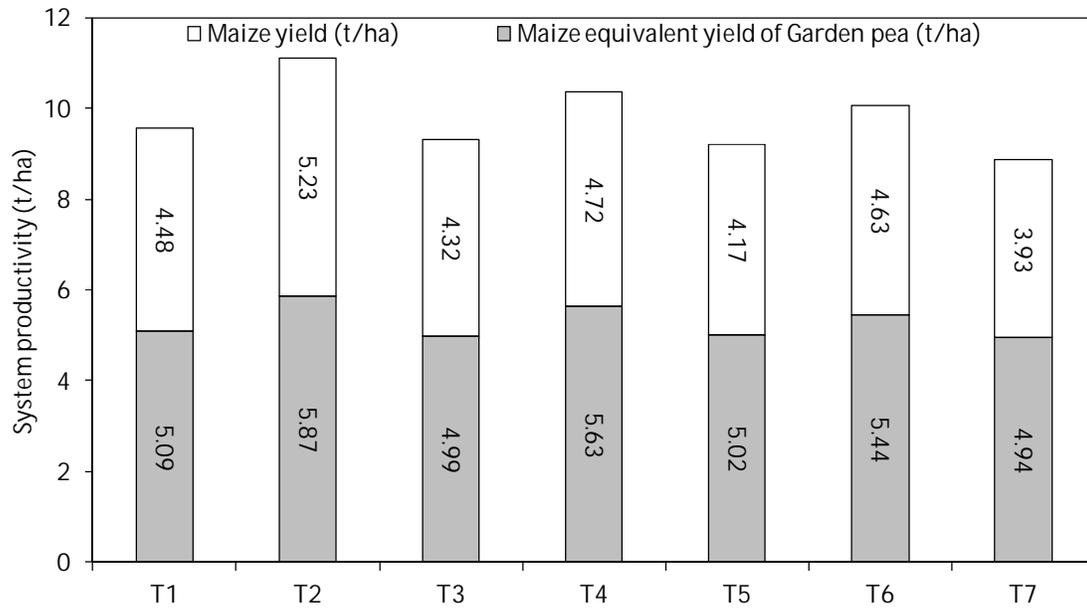


Figure 1: System productivity of the *winter* maize - garden pea sequence

UNDER PEER REVIEW