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RESEARCH COMMUNICATION

Efficacy of seaweed extract granules and liquid fertilizer on growth and yield of brinjal (*Solanum melongena* L.) during the *rabi* season

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Abstract

The extracts of seaweeds are used in granules and liquid forms for promoting growth of plants and yield of crops. These extracts act as bio stimulants as they contain cytokinins, auxins, gibberellins and macro- and micro-nutrients. To determine the effectiveness of seaweed extract granules enriched with growth substances and essential trace minerals, as well as seaweed liquid containing 15 % seaweed extract, 5 % stabilisers and 80 % fillers, a field experiment was carried out on a sandy loam soil during the *rabi* 2022-2023 season. The seaweed application either in granule or liquid form over and above the recommended level of fertilizer to brinjal crop has improved the growth, yield attributes and fruit yield, the increase in these parameters was noticed with enhancement of seaweed extract application in both forms. The percent increase in brinjal fruit yield with application of 100 % recommended dose of fertilizer (RDF) + seaweed extract granules @ 75 kg/ ha was 12 % (3.5 t/ha), 26 % (6.6 t/ha), 24 % (6.3 t/ha) and 135 % (18.6 t/ha) over 100 % RDF + seaweed extract granules @ 50 kg /ha, 100 % RDF + seaweed extract granules @ 25 kg/ha, 100 % RDF and control, respectively. The fruit yield recorded with 100 % RDF + seaweed liquid fertilizer 6 mL/l spraying done three times at maximum vegetative stage, flowering and fruiting was 20, 49 and 51 % over 100 % RDF + seaweed liquid fertilizer 4 mL /l, 100 % RDF + seaweed liquid fertilizer 2 mL/l and 100 % RDF, respectively.

Keywords: brinjal; brinjal fruit yield; seaweed extract granules; seaweed extract liquid

Introduction

In the context of vegetable production, research on eco-friendly nutrient sources like seaweed extracts contributes significantly to sustainable crop management and yield improvement, particularly in crops like brinjal (*Solanum melongena* L.). The seaweeds are being used for substitution of fertilizers. Seaweed extracts, available in both solid liquid forms, act as bio-stimulants due to the presence of plant hormones like cytokinins, auxins, gibberellins as well as macro- and micro-nutrients. Their application enhances nutrient uptake from soil (1-4). Various studies of seaweed extracts have shown beneficial effects on crop establishment, growth and yield of crops. These include improved crop yields and increased nutrients from soil and resistance to stress (5-10). Various combinations and types of seaweed formulations like liquid and granular are available in market. It has been reported that the algal manure found to improve the yield of cereals and pulses (11). The foliar spray of seaweed increases yield of cereals, vegetables, fruit plants and horticultural crops and it is recommended for use in increasing the yield of commercial crops (12, 13). Seaweed extracts are natural, non-toxic, biodegradable and safe for animals, humans and soil microbes (14, 15). Hence, seaweed extracts as fertilizer additives will be one of the solutions to mitigate environmental problems that arise due to use of fertilizers. Reports indicate that the application of seaweed extract to soil growing tomato improved plant growth and yield attributes, yield and quality (16). Further, application of seaweed extracts improved the growth and yield of brinjal (17). This study evaluates the effectiveness of two seaweed-based formulations on the growth and yield of brinjal. The first is a seaweed extract coated on bentonite granules (Amogh granules), enriched with growth factors and essential trace elements. The second is a liquid seaweed fertilizer (Amogh liquid) containing 15 % seaweed

extract, 5 % stabilizers and 80 % fillers.

Materials and Methods

A field experiment was conducted at the Post-graduate experimental farm, M.S. Swaminathan School of Agriculture, Centurion University of Technology and Management, Paralakhemundi, Gajapati district, Odisha which is located at Lat. 23°39' N, Long. 87°42' E and at an altitude of 182.9 m above mean sea level during *rabi* 2022 - 23 to evaluate the efficacy of seaweed extract granules (Amogh granules of Sahasra organic product) enriched with growth substances and essential trace minerals and are coated on carrier bentonite granules and seaweed liquid containing seaweed extract 15 %, stabilizers 5 % and fillers 80 % (Amogh liquid of Sahasra organic product) on growth and yield of brinjal crop. The soil of the experimental site was sandy clay loam with a pH of 6.6, organic carbon 0.5 %, 166 kg ha^{-1} available nitrogen, 12.2 kg ha^{-1} available phosphorus and 126.6 kg ha^{-1} available potassium. The experimental farm experiences a tropical environment, with 1150 mm of annual precipitation in 2022. The daily mean maximum and minimum temperatures recorded were 37.1 °C and 15 °C, respectively. The relative humidity ranged from 88 to 96.6 % in the morning and 45.9 to 87.4 % in the afternoon and sunshine hours ranged from 2.5 to 9 hr per day. Brinjal (*Solanum melongena* L.), Arka Neelanchal Kranthi was used for the field experiment. It is an early variety, suitable for *kharif* and *rabi* seasons. Fruits are round and green with light purple shade, weighing up to 190 - 200 g / fruit. It is moderately tolerant to *Phomopsis* blight and having yield potential of 34 t / ha. The treatment details of the experiment on granules of seaweed extract (Amogh granules) is as follows: Control (no fertilizer); 100 % Recommend Dose of Fertilizer (RDF); 100 % RDF + seaweed extract granules 25 kg/ha at planting-flowering-fruiting (corresponding to 0, 70 and 90 DAT); 100 % RDF + sea weed extract granules 50 kg/ha at planting-flowering-fruiting and 100 % RDF + sea weed extract granules 75 kg/ha at planting-flowering-fruiting (Table 1). The experiment on sea weed extract liquid (Amogh liquid) is as follows control (no fertilizer); 100 % RDF; 100 % RDF + sea weed extract liquid @ 2mL/L (at 45, 70 and 90 DAT); 100 % RDF + sea weed extract liquid @ 4mL/L (at 45, 70 and 90 DAT) and 100 % RDF + sea weed extract liquid @ 6mL/L (at 45, 70 and 90 DAT) (Table 2).

A well pulverized raised nursery bed was prepared thoroughly by mixing well rotten Fram Yard Manure (FYM). The seeds were treated with Bavistin @ 2 g/kg and then sowed in lines at a depth of 2 cm on Aug 10, 2022. Following sowing, seeds were coated with soil and FYM mixture. Light irrigation was given immediately after sowing. Eliminating weeds prevented crop-weed competition and resulted in healthy seedlings. Irrigation was given with the help of rose can when required. Spraying with chloropyriphos @ 1 mL/L of water or bavistin @ 2 g/L of water was also done to protect the seedling from pests and diseases. The field was prepared by criss-cross ploughing with cultivator and pulverized the soil with rotovator and then it was levelled with leveler. The field was made in to plots of 4 m X 5 m and each plot was properly bunded with channels for irrigation. The five treatments were imposed as per plan with four replications and tested in Randomized Block Design (RBD). The RDF @ 125:75:125 NPK kg ha^{-1} was applied to the crop. The entire dose of phosphorus and potassium fertilizer was applied at transplanting and N was applied in three splits each of 1/3rd dose at planting, flowering and fruiting stage. The seaweed extract granules were applied at vegetative state (45 days after transplanting (DAT), flowering stage (at 70 DAT) and maximum fruiting stage (at 90 DAT). The seaweed extract liquid was sprayed at vegetative stage (at 45 DAT), flowering stage (70 DAT) and maximum fruiting stage (90 DAT). Pre-emergence herbicide Pendimethalin @ 2mL per liter was applied at 3 days after planting and whenever needed, the manual weeding was done. The pests were controlled by Emamectin benzoate @ 0.5g/L, Spiromesifen @ 0.3mL/L and metalaxyl +

Table 1. Growth attributes of brinjal as influenced by seaweed extract granules during *rabi* 2022-23

Treatments	Plant height at 90 DAT (cm)	Number of branches per plant at 90 DAT	Days to 50 % flowering	Number of flowers per cluster	Fruit length (cm) Mean of 30 fruits	Fruit width (mm) Mean of 30 fruits
Control (No fertilizer)	46.8	4.1	74	1.2	5.7	43.6
100 % RDF	68.4	6.9	63	3.3	8.1	57.0
100 % RDF + sea weed extract granules *@ 25 kg/ha	64.6	7.0	59	3.5	8.6	58.2
100 % RDF + sea weed extract granules *@ 50 kg /ha (Basal-Flowering-Fruiting)	69.6	7.3	53	4.1	8.4	60.0
100 % RDF sea weed extract granules*@ 75 kg/ ha (Basal-Flowering-Fruiting)	70.5	8.4	48	5.1	8.9	62.7
S.Em. (±)	2.39	0.33	1.3	0.4	0.2	1.6
CD(0.05)	5.21	0.72	2.8	0.8	0.6	4.9
CV (%)	5.29	6.9	3.1	14.5	4.6	5.7

*Applied at basal, flowering and fruiting

Table 2. Growth attributes of brinjal as influenced by seaweed liquid during *rabi* 2022-23

Treatments	Plant height, cm at 90 DAT	Number of branches/plant at 90 DAT	Days to 50% flowering	Number of flowers per cluster	Fruit length (cm) Mean of 30 fruits	Fruit width (mm) Mean of 30 fruits
Control (No fertilizer)	39.8	4.1	73	1.8	5.4	43.4
100 % RDF	59.4	6.8	66	3.4	8.0	53.2
100 % RDF + sea weed liquid* @ 2mL/ L	69.6	7.4	57	4.1	8.6	60.3
100 % RDF + sea weed liquid* @ 4mL/ L	69.8	7.1	54	4.7	8.9	61.3
100 % RDF + sea weed liquid*@ 6mL/L	69.4	8.1	50	6.0	9.0	63.5
S.Em. ±	2.8	0.3	1.0	0.3	0.2	1.7
CD(0.05)	8.7	0.8	3.0	0.6	0.5	5.1
CV (%)	9.2	7.5	3.1	9.3	4.4	5.9

*Sprayed at maximum vegetative, flowering and fruiting stages

mancozeb@ 2g/L in rotation to get healthy and robust plants. Irrigation was given once in a week. Observations on plant height at different stages, number of branches/ plants, days to fifty percent flowering, number of flowers per cluster, fruit length and width, days to first fruit harvest, average fruit weight, fruit yield at each harvest was recorded. Harvesting was done when the fruits attained marketable size approximately at an interval of 7-10 days and the total yield of fruits was presented by summing the 10 harvests done from Dec 8, 2022 to March 3, 2023 and presented in tons per hectare. The data were subjected to statistical analysis. Wherever the treatment differences were significant, critical differences were worked out at 5 % probability level and the values were furnished. The treatment differences that were not significant at 5 % were denoted as "NS".

Results and Discussion

Levels of seaweed extract granules and liquid

The results with seaweed application either in granule or liquid form over and above the recommended level to brinjal crop have improved the growth (Table 1 & 2) and yield attributes and fruit yield (Table 3 & 4).

The brinjal fruit yield was significantly influenced due to different seaweed extract granules (Amogh granules) along with fertilizer (Table 3). Application of 100 % RDF has recorded significantly higher fruit yield over control and the fruit yield in this treatment was comparable with the fruit yield obtained with application of 100 % RDF + seaweed extract granules @ 25 kg /ha applied at planting-flowering-fruiting. The fruit yield in the latter treatment was significantly lower than that of 100 % RDF + seaweed extract granules @ 50 kg /ha applied at planting-flowering-fruiting. Significantly higher fruit yield was observed with 100 % RDF + seaweed extract granules @ 75 kg/ ha applied at planting-flowering-fruiting over all other treatments. The percent increase in fruit yield with application of 100 % RDF + seaweed extract granules @ 75 kg/ ha was 12 % (3.5 t/ha), 26 % (6.6 t/ha), 24 % (6.3 t/ha) and 135 % (18.6 t/ha) over 100 % RDF + seaweed extract granules @ 50 kg /ha, 100 % RDF + seaweed extract granules @ 25 kg/ha, 100 % RDF and control, respectively.

The brinjal fruit yield differed significantly due to seaweed liquid fertilizer application quantity (Table 4). There was significant increase in fruit yield with application of 100 % RDF over control (no fertilizer application). The increase in fruit yield at 100 % RDF was 88 % over control. The fruit yield recorded with 100 % RDF + seaweed liquid fertilizer 6 mL/l spraying done three times at maximum vegetative stage, flowering and fruiting recorded significantly higher fruit yield over all other treatments. The increase in fruit yield in this treatment was 20, 49 and 51 % over 100 % RDF + seaweed liquid fertilizer 4 mL/l (spraying done three times at maximum vegetative stage, flowering and fruiting), 100 % RDF + seaweed liquid fertilizer 2 mL/l and 100 % RDF, respectively. On the other hand, the fruit yield observed with 100 % RDF and 100 % RDF + seaweed liquid fertilizer 2 mL/l (spraying done three times at maximum vegetative stage, flowering and fruiting) was comparable each other and inferior to the fruit yield obtained with 100% RDF + seaweed liquid fertilizer 4 mL/l spraying done three times at maximum vegetative stage, flowering and fruiting.

The brinjal yield increased with of the application seaweed either in granule or liquid form, at doses of 25, 50 and 75 kg/ha for granules or 2 to 4 and 6 mL/l for foliar spray during the growth period compared to the recommended level of fertilizer (Table 2 & 4). Further, the yield improvement was higher with seaweed application in granular form than that applied as spray (Table 2 & 4). There was increase in yield in both the seaweed application (granular or liquid form) over recommended level of fertilizer application. This improvement is primarily attributed to enhanced growth parameters - plant height (cm), number of branches/plants, number of flowers per cluster (Table 1 & 3) and yield attributing characters - fruit length and width and average fruit weight and total number fruits per m^2(Table 2 & 4). These parameters showed a positive correlation with brinjal yield (Fig. 1) indicating that the improvement in yield attributes enhanced the

Table 3. Yield attributes and yield of brinjal as influenced by seaweed extract granules during *rabi* 2022-23

Treatments	Days to first fruit harvest	Average fruit weight of brinjal, (g) Mean of 30 fruits	Number of fruits per m^2	Fruit yield (t/ha)
Control (No fertilizer)	88	61.7	23.5	13.8
100 % RDF	77	80.0	31.2	26.1
100 % RDF + sea weed extract granules *@ 25 kg/ha	75	89.8	33.0	25.8
100 % RDF + sea weed extract granules *@ 50 kg /ha (Basal-Flowering-Fruiting)	72	106.5	33.6	28.9
100 % RDF sea weed extract granules*@ 75 kg/ ha (Basal-Flowering-Fruiting)	63	107.6	36.4	32.4
SEm. (±)	0.8	2.8	0.7	0.6
CD(0.05)	2.5	8.5	2.2	2.0
CV (%)	2.2	6.2	4.5	5.1

*Applied at basal, flowering and fruiting

Table 4. Yield attributes and yield of brinjal as influenced by seaweed liquid during *rabi* 2022-23

Treatments	Days to first fruit harvest	Average fruit weight, (g) Mean of 30 fruits	Number of fruits per m^2	Fruit yield (t/ha)
Control (No fertilizer)	88	57.3	16.9	8.5
100 % RDF	81	85.6	23.2	16.0
100 % RDF + sea weed liquid* @ 2ml/l	76	101.4	25.4	16.2
100 % RDF + sea weed liquid* @ 4ml/l	70	110.7	26.6	20.2
100 % RDF + sea weed liquid *@ 6ml/l	67	115.5	30.0	24.2
S.Em. ±	1.0	3.7	0.4	0.9
CD(0.05)	2.9	11.4	1.2	2.7
CV (%)	2.5	7.9	3.2	9.8

*Sprayed at maximum vegetative, flowering and Fruiting stages

yield. The improved yield at higher levels of seaweed application compared to the recommended level suggests the potential to further enhance yield through increased seaweed application.

It has been reported that the seaweed application improves the chlorophyll of leaves (18, 19) which helps in increased photosynthesis thereby the growth and yield of the crop. This was expressed in the treatments which received higher levels of seaweed extract (Table 1 & 3). These results collaborate with those that demonstrate that seaweed enhances growth and yield of crop (13, 10).

The increase in yield with application seaweed extract over and above the recommender fertilizer application might be due to improvement of soil physical, chemical and biological properties (9) which has helped in better growth in seaweed extract applied plots than that in recommended fertilizer applied plots (20). Further, the seaweed contains macro and micronutrients and phyto-hormones (21) which play positive role in physiological processes that result in higher plant and fruit growth and protein synthesis (21-23). The seaweed which was applied has given additional nutrients and bio-stimulants (biofertilizer) to increase plant growth and yield that resulted in proportional increase in yield with enhanced levels of seaweed application (24).

Correlation between growth, yield attributes and yield of brinjal

Correlation analysis revealed strong and significant relationships between brinjal yield and various growth and yield attributes due to application of seaweed extract in both granular and liquid forms.

In the case of seaweed granules, highly significant positive correlations were observed between fruit yield and plant height at 90 DAT (r = 0.97**), number of branches per plant at 90 DAT (r = 0.97**), number of flowers per cluster (r = 0.95*), fruit length (r = 0.97**), fruit width (r = 0.94*), average fruit weight (r = 0.93*) and number of fruits per m^2 (r = 0.99**). A strong and significant negative correlation was observed with days to 50 % flowering (r = -0.91*) and days to first fruit harvest (r = -0.96**), indicating that earlier flowering and fruiting were associated with higher yields under seaweed granule application.

Similarly, seaweed liquid fertilizer also exhibited significant correlations with most growth and yield traits. Positive correlations were recorded with number of branches per plant at 90 DAT (r = 0.92*), number of flowers per cluster (r = 0.99**), fruit length (r = 0.91*), fruit width (r = 0.93*), average fruit weight (r = 0.95*) and number of fruits per m^2 (r = 0.98**). Negative correlations with days to 50 % flowering (r = -0.94*) and days to first fruit harvest (r = -0.97**) were also significant, suggesting that seaweed application not only enhanced yield traits but also promoted early crop maturity. However, the correlation between plant height and yield under liquid seaweed application was not significant (NS). The visual representation in Fig. 1 further substantiates these findings, showing consistent trends of positive correlations between yield and major growth/yield parameters. Notably, seaweed granules exhibited slightly stronger correlations across most parameters compared to the liquid form.

Conclusion

The present study suggests that the currently recommended fertilizer dose may not be adequate for achieving optimal brinjal fruit yields. There is a need to apply growth promoters which can be made available through seaweed extracts either in granule or liquid form along with micro nutrients. From these results, it can be concluded that application of 100 % RDF (125:75:125 kg N, P_2O_5 and K_2O/ha, respectively) + seaweed extract granules @ 75 kg/ha applied in three splits at planting-flowering-fruiting gives higher brinjal fruit yield as compared to 100 % RDF. On the other hand, application of 125 kg N, 75 kg P_2O_5 and 125 kg K_2O ha^{-1} along with seaweed liquid fertilizer @ 6 mL/l three times spraying at 45, 70 and 90 days after transplanting (DAT) gives higher fruit yield of brinjal over recommended dose of fertilizer application of 125 kg N, 75 kg P_2O_5 and 125 kg K_2O ha^{-1}. However, detailed studies are need to be conducted by using seaweed extracts for

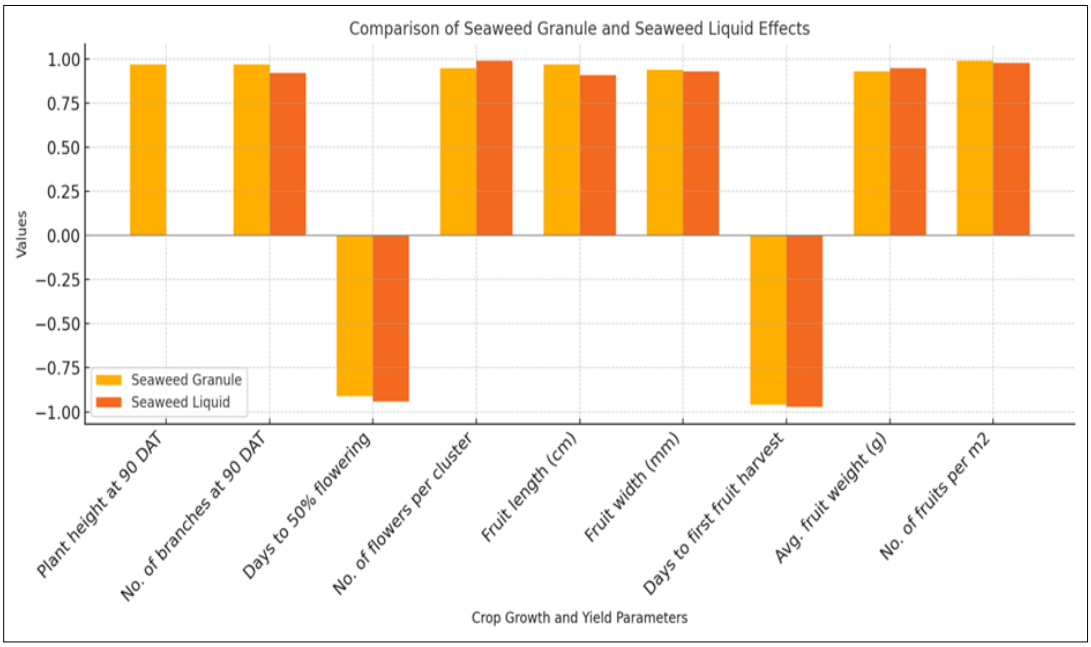

Fig. 1. Correlation between growth, yield attributes and yield of brinjal under granular and liquid seaweed applications during *rabi* 2022-23.

*Significant at 5 % and ** Significant at 1 %

enhancement of vegetable yield with environmental protection as these seaweed extracts are degradable easily.

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Authors' contributions

Conceptualization of the manuscript was given by NSR, MDR, ASS, TS and SM. Methodology was done by TS and SM. Validation was done by MDR, ASS, TS and SM. TS and SM did the analysis. Data curation by TS and SM. MDR, ASS, TS and NSR prepared the original draft paper. Writing- review and editing was carried out by NSR, MDR, ASS and TS. Supervised by NSR, MDR, ASS, TS and SM. All authors have read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The authors of this paper declare that they have no conflict of interest.

Ethical issues: None

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