Efficacy of seaweed extracts as biostimulant on growth and yield attributes of peanut *(Arachis hypogaea)*

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ABSTRACT

Background and Objective: Peanuts *(Arachis hypogaea)* are a leguminous crop with significant importance in enhancing human nutrition, making them a vital component of crop production. However, extractive farming practices such as intensive cultivation and imbalanced fertilization have been identified as contributing to yield reduction. Therefore, there is a growing interest in exploring natural products like seaweed extracts that promote growth and productivity and reduce the reliance on synthetic agricultural inputs. This study sought to evaluate the effects of various seaweed extracts on various agronomic parameters specific to peanut cultivation.

Methodology: The study employed a randomized complete block design (RCBD) with four replications and five treatment groups: T_1 - Negative control, T_2 - Positive control, T_3 - *Kappaphycus alverezii* (12.5 mL), T_4 - *Cottoni, Spinossum,* and *Sargasssum* (10 mL), and T_5 - Brown kelp mass (15 mL). Data collected from the study were analyzed and compared through LSD at $P<0.05$ using STAR software. Significant variations in growth and yield-related traits of peanuts among different treatments were assessed using analysis of variance (ANOVA).

Main Results: Superior plant height at 30 and 60 days after sowing was observed in positive control with values of 24.09 ± 3.64 and 52.77 ± 2.38 cm, respectively, compared to the other treatment ($P < 0.01$). Consequently, all seaweed extracts significantly influenced ($P < 0.05$) various peanut parameters, including the number of days to flowering, number of pods per plant, 100-seed weight, shelling percentage, pod yield, seed yield, and harvest index. Notably, the application of *Kappaphycus alverezii* significantly ($P < 0.001$) increased pod yield (2.42 ± 0.26 t/ha) and seed yield (1.71 ± 0.17 t/ha) compared to the other treatments.

Conclusions: Applying seaweed extracts, particularly *Kappaphycus alverezii,* significantly improved the growth and yield-related traits of peanuts. Therefore, utilizing natural extract derived from macroalgae can serve as an alternative to synthetic inputs to enhance crop productivity.

Keywords: Biostimulant, efficacy, *Kappaphycus alverezii*, peanut, seaweed extract

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INTRODUCTION

Peanut *(Arachis hypogaea)* is a legume that has been widely grown due to edible oil and its unique capability to enhance ecological services through biological fixation. However, peanuts are susceptible to fertilizer burn; thus, balanced fertilization is one of the most crucial crop management to elevate crop yield and quality. Legumes such as peanuts are profitable agronomic crops; however, they require large amounts of agrochemicals to increase and achieve potential yield, and due to this, many agroecological factors affect crop performance, such as salinity, high temperature, low fertile soil, pests, and diseases (Das *et al.*, 2023). It is worth mentioning that globally, around 52% of arable land is already degraded soil (Patel and Minocheherhomji, 2018), which affects the production system and leads to hunger and famine; thus, we expect that in the next two decades, there will be at least 12% yield penalty. On the other hand, since 2021, the cost of synthetic fertilizer has more than doubled, significantly stressing the farming community. Therefore, an alternative method of reducing the use of agrochemicals is the introduction of seaweed extracts as an eco-friendly approach to the production system (Di Filippo-Herrera *et al.*, 2019). Seaweed liquid fertilizer can stimulate crop growth while providing a range of high and medium micronutrients, including polysaccharides, amino acids, vitamins, and other active ingredients, while biostimulants are organic, natural compounds that provide crops with nutrients when combined with fertilizer, perhaps enhancing growth and output (Abbas *et al.,* 2020; Meng *et al*., 2022). Therefore, using seaweed as a biostimulant is an alternative and holistic approach to resolving agro-environmental crop production issues. Numerous studies have been conducted regarding the use of seaweed extract for crops; however, there is a lack of research on the use of seaweed on peanuts. Thus, the study aims to apply seaweed extracts to peanuts to determine their response.

MATERIALS AND METHODS

Experimental Site and Planting Material

The study was conducted at Castillo, Concepcion, Tarlac, Philippines, wherein the area has a type I climate with two seasons: the dry season (from November to April) and the wet season (throughout the rest of the year). The experimental area is identified as loam soil with a pH of 6.0. This study used peanut seed (Kalbo), a typical farmer's variety classified as a bunch type produce pod that yields about two tons/hectare, with two to three seeds of pods with a maturity period of 80–90 days from planting.

Experimental Design, Treatments, and Layout

The field experiment was laid out using a randomized complete block design (RCBD) consisting of five treatments and four replications. The experimental plot size was 4 m × 3 m, while the experiment consisted of five treatments. Plants without inoculants and no fertilizer applied were designated as negative control (T_1), while positive control (T_2), a plant applied with synthetic fertilizer with the recommended rate (67-30-30 of NPK). On the other hand, the remaining treatments were a group of extracts derived from different species of seaweed, namely, *Kappaphycus alverezii* (12.5 mL; T_3), *Cottoni, Spinossum*, and *Sargasssum* (10 mL; T_4), and brown kelp mass (15 mL; T_5).

Crop Management

An area of about 441 m^2 was prepared by plowing and harrowing twice using a tractor to incorporate weeds and pulverize the soil. Before planting, 40 g of inoculant (*Rhizobium*) was mixed in 2 kg of peanut seeds until the seeds were evenly coated with inoculant. This was followed by planting two peanut seeds per hill with a planting distance of 20 cm between plants and 50 cm between furrows. Watering was provided from the germination, flowering, and pegging until pod settings and watering were reduced during the maturity stage. Hilling up was 23 days after sowing or before the onset of flowering. Weeds were controlled manually using a hoe, while no insect pests or diseases were observed during the growing period. Harvesting was done 80 days after sowing when at least 80% of pods matured (R8) in every treatment or when the plant leaves turned green to yellow or brown. The crop was harvested manually, pulling the plants until the attached soil was removed.

Seaweed Extract Application

Foliar application of various seaweed extracts was applied in different stages of the plant.

The first application occurred during R1 (initial flowering) or 27 days after plant emergence and subsequent applications were made at R2 (beginning of the pegging) and R3 (pod development). Treatment applications for *Kappaphycus alverezii* (12.5 mL), *Cottoni, Spinossum*, and *Sargassum* (10 mL), and brown kelp mass (15 mL) were calibrated individually in every 16/liter of water and applied during the early morning. The elemental content (macro and micronutrients) of seaweed was also identified. *Kappaphycus alverezii* was found to have 0.02% of nitrogen (N), 0.03% of potassium (K), 120 ppm of calcium (Ca), and 5 ppm of magnesium (Mg). The *Cottoni, Spinossum*, and *Sargassum* contain 0.45% N, 0.25% P, 0.40% K, 0.70 ppm of Zn, and 1.60 ppm of B, while brown kelp mass contains 11% N, 3% P, 4% K, and 20 ppm of B.

Plant Height and Days to Flowering

The ten sample plants were randomly selected from each treatment and measured at 30 and 60 days after sowing for plant height (cm). In contrast, days to flower were recorded when at least 75% of sample plants could produce flowers in every treatment.

Yield Related Traits

Ten sample plants from each experimental unit were uprooted to measure yield-related traits such as pod number, shelling percentage (%), the weight of 100 seeds (g), pod yield (t/ha), seed yield (t/ha), and harvest index (HI; %). The values of these traits were counted and averaged for further analysis. The pod number was calculated by adding the number of pods in each sample plant and dividing by the 10 sample plants to attain the average. The weight of 100 seeds was gained from 100 seeds from sample plants. The pods were removed from the sample plants and weighed using an electrical weighing scale, and the conversion of pod yield into t/ha. The shelling percentage was based on the formula of Konlan *et al*. (2013); this was followed by the percent harvest index (HI), which was determined by dividing economic yield (seed yield) by the total biological yield (crop biomass). The seed yield was calculated and converted into t/ha after deshelling the pod and computed using the formula below.

$$\text{Shelling percentage} = \frac{\text{Weight of shelled seeds}}{\text{Total pod weight}} \times 100$$

$$\text{Harvest Index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

$$\text{Seed yield} = \frac{\text{Seed weight/plot (g)}}{1{,}000} \times \frac{100\ \text{m}^2}{\text{Sample plant area}}$$

Statistical Analysis

Statistical Tool for Agricultural Research (STAR) software was used to conduct an Analysis of Variance (ANOVA) on all the collected agronomic data. Least Significant Difference (LSD) was used to evaluate the significance of the interventions at a probability ($P < 0.05$).

RESULTS AND DISCUSSION

The study shows that regardless of the content of seaweed extracts, there was no significant difference in plant height ($P > 0.05$) at 30 and 60 days after sowing. In contrast, various treatments significantly influenced the days to flower ($P < 0.05$). Table 1 shows that the recommended rate of fertilizer or RRF (positive control) greatly dictates the plant height for 30 (24.09 ± 3.64 cm) and 60 (52.77 ± 2.38 cm) days after sowing. In contrast, the plants treated with seaweed extracts and those treated under negative control were statistically not significantly different. On the other hand, the number of days to flower in peanut was shortened by applying both *Kappaphycus alverezii* (23.50 ± 0.58 days) and *Cottoni, Spinossum,* and *Sargasssum* (23.75 ± 0.96 days), respectively. At the same time, plants treated with brown kelp mass (24.75 ± 0.50 days) showed a comparable result to *Kappaphycus alverezii* and *Cottoni, Spinossum, and Sargassum.* In comparison, treatment under positive (25.75 ± 0.96 days) and negative control (27.25 ± 0.96 days) delayed the number of days to flower in peanuts.

Dwivedi *et al.* (2014) revealed that a biostimulant from seaweed extract can induce early flowering in legumes such as black gram *(Phaseolus mungo* L.*)* while encouraging vegetative growth and improving both fruiting and seed yield. Turck *et al.* (2008) found that seaweed extract promotes the early production of flowers, indicating its potential to supplement the plant's leaf functions in producing the flowering hormone. Moreover, several findings show that applications of an extract derived from *Kappaphycus alverezii* or *Sargassum* can trigger floral initiation due to the existence of phytohormones like cytokinin as an integral component of seaweed extracts (Issa *et al.,* 2019). It was reported that the hormonal characteristics of seaweed, such as cytokinins, auxin, gibberellins, and salicylic acid, are almost similar to higher plants. Thus, it was suggested that they are involved in the growth and floral transition of plants, particularly the cytokinins (D'Aloia *et al.*, 2011; Stirk and Van Staden, 2014; Mohammed *et al.*, 2023).

Table 2 indicates that the pod numbers in peanuts substantially increased by applying different seaweed extracts compared to the positive and negative control. The number of pods increased by at least 76.33–78.52% (average of 9.25 pods) when plants were treated with various seaweed extracts compared to the control plants. Hence, it is noteworthy to mention that the increase in the number of pods produced might be due to the presence of cytokinin, commonly present in seaweed extract and which has the potential to enhance plant productivity in legumes through the number of pods produced (Zodape *et al*., 2010). Similar to the findings of Makawita *et al.* (2021), the application of extracts derived from seaweed can increase the pod number in mung beans, while Zewail (2014) and Ashour *et al.* (2021) reported that biostimulants such as seaweed can improve the number of pods in common bean and peanut respectively which result to a total increase in yield.

Furthermore, the foliar application significantly ($P < 0.05$) affected the 100-seed weight (Table 2). Plants sprayed under seaweed groups such as *Kappaphycus alverezii* and *Cottoni, Spinossum, Sargassum,* and brown kelp mass, produced the heaviest seeds with an average value of 44.55 ± 0.54, 45.12 ± 1.46, and 41.88 ± 1.38 g, respectively. While RRF (positive control) had an average value of 38.35 ± 0.93 g followed by negative control which had the lowest 100-seed weight of 34.48 ± 1.40 g. These findings show that yield attributes such as the number of pods per plant and 100-seed weight could be related to the beneficial effect of seaweed on improved growth and yield characteristics of peanuts. This merits effect on pulse crops such as peanuts was similar to reports of Seif *et al.* (2016) who found that foliar application of liquid extract from seaweed significantly upsurges the seed weight of *Glycine max* L. and *Phaseolus vulgaris.* Further, Khan *et al*. (2009) conveyed that utilizing biostimulants from seaweed extracts enhanced yield by 24% in beans.

Consequently, enhancement in agronomical characteristics due to the application of seaweed might help to advance root for nutrient acquisition (Hanafy Ahmed *et al.,* 2010), thereby increasing yield traits such as pod number and seed weight. Hence, seaweed extracts commonly contain an exogenous amount of plant growth regulators, such as gibberellin, auxin, and cytokinins, which stimulate plant development. Thirumaran *et al*. (2009) specified that crop improvement due to growth regulators such as gibberellin in seaweed could promote crop growth as a critical factor for both seed weight and size.

Table 1 Effect of various seaweed extracts on plant height at 30 and 60 days after sowing (DAS) and days to flower on peanuts

Treatments	Plant height (cm)		Days to flower
	30 DAS	60 DAS	
T_1- Negative control	20.80 ± 2.59[b]	46.75 ± 2.62[c]	27.25 ± 0.96[c]
T_2- Positive control	24.09 ± 3.64[a]	52.77 ± 2.38[a]	25.75 ± 0.96[b]
T_3- *Kappaphycus alverezii* (12.5 mL)	21.06 ± 3.33[b]	50.33 ± 2.63[b]	23.50 ± 0.58[a]
T_4- *Cottoni, Spinossum*, and *Sargasssum* (10 mL)	21.31 ± 1.80[b]	49.95 ± 2.07[b]	23.75 ± 0.96[a]
T_5- Brown kelp mass (15 mL)	20.85 ± 3.59[b]	49.88 ± 3.74[b]	24.75 ± 0.50[ab]
$LSD_{(0.05)}$	1.8141	1.6344	1.3780
P-value	0.0089	0.0010	0.0004

Note: Data are means ± standard deviation. Means within the same column with the same letter are not significantly different between treatments of each factor based on LSD at a 5% level of significance. Negative control = aqueous solution (water alone), positive control = a recommended rate of fertilizer (67-30-30 of NPK).

Table 2 The number of pods per plant and the weight of 100 seeds as influenced by different seaweed extracts as biostimulants

Treatments	Number of pods	Weight of 100 seeds (g)
T_1- Negative control	11.99 ± 0.51[c]	34.48 ± 1.40[d]
T_2- Positive control	15.51 ± 0.50[b]	38.35 ± 0.93[c]
T_3- *Kappaphycus alverezii* (12.5 mL)	21.19 ± 0.65[a]	44.55 ± 0.54[a]
T_4- *Cottoni, Spinossum*, and *Sargasssum* (10 mL)	21.40 ± 0.99[a]	45.12 ± 1.46[a]
T_5- Brown kelp mass (15 mL)	21.14 ± 0.96[a]	41.88 ± 1.38[b]
$LSD_{(0.05)}$	1.0755	1.0760
P-value	0.0010	0.0010

Note: Data are means ± standard deviation. Means within the same column with the same letter are not significantly different between treatments of each factor based on LSD at a 5% level of significance. Negative control = aqueous solution (water alone), positive control = a recommended rate of fertilizer (67-30-30 of NPK).

Agronomic yield traits of peanuts, such as shelling percentage, pod yield, seed yield, and harvest index, are shown in Table 3. Statistical analysis revealed that applying liquid extracts from seaweed enhanced agronomic parameters in peanuts regardless of the profile characteristics of macroalgae. The plant received a seaweed extract drastically improved shelling percentage significantly ($P < 0.05$) compared to control treatments. This is parallel to the findings of Raofa (2021), an increase in shelling percentage in soybean was predominantly due to seaweed extract, which led to increased overall yield, while Gatan and Gatan (2020) stated that utilization of carrageenan extract from *Kappaphycus alverezii*, remarkably increased the shelling percentage in *Vigna radiata* which directly boost crop yield.

Applying seaweed extracts in various treatments resulted in significant ($P < 0.05$)

differences in the computed pod yield of peanuts. Plants sprayed with seaweed extracts, specifically treatments T_3, T_4, and T_5, recorded the highest pod yields, with 2.42 ± 0.26, 2.38 ± 0.24, and 2.40 ± 0.18 t/ha, respectively. In contrast, the RRF (T_2) had the lowest pod yield of 1.72 ± 0.29 t/ha, followed by the negative control (T_1) with a yield of 1.50 ± 0.26 t/ha. Studies by El-Yazied *et al.* (2012) on snap beans and recent findings by Priyadarshini and Madhanakumari (2021) on bush beans have reported that using seaweed extract can increase pod yield. Mandaliya *et al*. (2022) also found that seaweed biostimulants gradually increase crop output in *Vigna unguiculata* (L.). Furthermore, using seaweed extract significantly improved peanut pod yields by up to 25% compared to other treatments, as Abad *et al.* (2018) reported.

Table 3 Agronomic yield traits of peanuts influenced by various seaweed extracts as biostimulants

Treatments	Shelling percentage (%)	Pod yield (t/ha)	Seed yield (t/ha)	Harvest index (%)
T_1- Negative control	61.23 ± 3.69[b]	1.50 ± 0.26[c]	0.91 ± 0.12[c]	55.63 ± 6.31[b]
T_2- Positive control	62.25 ± 3.97[b]	1.72 ± 0.29[b]	1.07 ± 0.15[b]	56.14 ± 6.69[b]
T_3- *Kappaphycus alverezii* (12.5 mL)	70.16 ± 1.38[a]	2.42 ± 0.26[a]	1.71 ± 0.17[a]	62.20 ± 8.72[a]
T_4- *Cottoni, Spinossum*, and *Sargasssum* (10 mL)	70.08 ± 2.26[a]	2.38 ± 0.24[a]	1.67 ± 0.20[a]	60.66 ± 7.32[a]
T_5- Brown kelp mass (15 mL)	68.83 ± 2.22[a]	2.40 ± 0.18[a]	1.65 ± 0.13[a]	60.59 ± 6.92[a]
$LSD_{(0.05)}$	2.7139	0.1764	0.1284	3.4705
P-value	0.0001	0.0001	0.0001	0.0040

Note: Data are means ± standard deviation. Means within the same column with the same letter are not significantly different between treatments of each factor based on LSD at a 5% level of significance. Negative control = aqueous solution (water alone), positive control = a recommended rate of fertilizer (67-30-30 of NPK).

Regarding seed yields, various seaweed extracts were found to enhance crop output. For instance, plants treated with *Kappaphycus alverezii* produced the maximum seed yield of 1.71 ± 0.17 t/ha. *Cottoni, Spinossum*, and *Sargassum* yielded 1.67 ± 0.20 t/ha, while Brown Kelp extracts produced a 1.65 ± 0.13 t/ha yield. The positive control yielded an average value of 1.07 ± 0.15 t/ha, while the negative control had the lowest seed yield at 0.91 ± 0.12 t/ha. Additionally, the HI in peanuts did not show significant differences among the seaweed extract groups, but it was enhanced compared to the positive and negative controls. Similar findings were reported by Dahmardeh *et al*. (2020) and Kurakula and Rai (2021), indicating that seaweed extract can significantly increase the harvest index in peanuts and chickpeas, likely due to the presence of substances that promote plant development.

The significant increase in yield attributes of peanut productivity may be attributed to the presence of essential nutrients, amino acids, and phytohormones in the seaweed extracts. These extracts stimulate hormone synthesis within the plant, thereby contributing to enhanced yield, as Kulkarni *et al.* (2019) suggested. This finding aligns with reports by Abad *et al*. (2018) and Khan *et al.* (2009) that seaweed biostimulants contain elements and phytohormones associated with increased legume seed yield. Furthermore, studies on soybean, chickpea, and green gram have demonstrated that seaweed extract can substantially increase crop yield, as Kurakula and Rai (2021) and Zodape *et al.* (2010) reported. Several studies have also highlighted the presence of exogenous phytohormones such as auxin and cytokinins in seaweed extract, which are known to provide benefits. Specifically, cytokinins in seaweed extract are associated with nutrient partitioning during the early stage of plant organs and with the distribution of photosynthates to developing pods during the reproductive phase, promoting pod development and superior yield characteristics, as stated by Kocira *et al.* (2019) and Kharbyngar and Shing (2019).

CONCLUSIONS

The study concluded that various seaweed extracts could be an alternative eco-friendly bio-based stimulant for peanut production. Compared to other treatments, superior plant height at 30 and 60 days after sowing was observed in positive control; consequently, the number of days to flower, number of pods, the weight of 100 seeds, pod yield, seed yield, and harvest index were significantly enhanced, through the application of seaweed extracts as compared to positive and negative control. Hence, the study would recommend the application of extract from seaweeds to stimulate plant growth and crop yield.

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