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*RESEARCH ARTICLE*

# SYNERGISTIC EFFECT OF TROPICAL SEAWEED BASED BIOSTIMULANT WITH HUMIC PRODUCTS ON GRAIN YIELD OF MAIZE (VAR. SYNGENTA NK-6240) FARMED UNDER SEMI-ARID REGION

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**ABSTRACT**

Synergism of seaweed extract with humic acid was evaluated by in-vitro bioassay where the root development of green gram seedling was assessed by Win Rhizo root analyser. At 100ppm treatment level concentrated seaweed extract and humic acid (1:1.6 ratio) increased the total root length by 1.82 times whereas it was only 0.77 times in concentrated seaweed extract alone with same dosage level as compared to nutrient control (LANS). A field experiment in semi-arid zone on maize crop was conducted during 2021, concentrated seaweed extract (CSW) standalone and in combination with humic acid at different ratio were applied through foliar on maize at its different growth stages. Plant treated with CSW and humic acid at 1:1.6 (i.e. 0.25% + 0.4%) produced 41.93% grain yield significant ($p$ = 0.001) increase (8570 kg/ha) followed by 37.50% by plant applied with CSW and humic acid at 1:0.8 (i.e. 0.25% + 0.20%) – 8302 kg/ha and pure seaweed extracts alone at same dosage level (0.25%) recorded 18.84% increase over control plants (6038 kg/ha). Higher stover biomass (9663 kg/ha – 32.18% increase) and improved vegetative growth of maize crop was also recorded in the present studies. Therefore, the results suggest seaweed extract may be used in conjunction with humic acid to increase the crop yield and stover of maize.

**Keywords**

Seaweed extract; Humic products; Synergism; Seedling Assay; Maize grain

## 1. INTRODUCTION

Maize is one of the three staple food crops being extensively cultivated and its production accounted 1.1 billion tonnes next to sugarcane production (1.9 billion tonnes) followed by rice and wheat crop with 0.8 billion tonnes production each, (FAO, 2021). India's average maize productivity (2.9 t/ha) is almost half the global average of 5.75 t /ha, (IIMR, 2019). Bio stimulants have been given much importance in sustainable agriculture and seaweed biostimulants, particularly, through foliar or soil application to crops are known to increase crop productivity and alleviate the abiotic stress (Kunicki et al., 2010; Norrie and Keathly, 2006; Trivedi et al., 2018). Biostimulants from seaweed *Kappaphycus alvarezii* has been extensively studied in India on wide range of agricultural and horticultural crops in different agro climatic conditions for its improved productivity (Pramanick et al., 2014; Mondal et al., 2015; Karthikeyan and Shanmugam, 2014; 2016).

*Ascophyllum nodosum* a cold-water brown seaweed is the most researched seaweed on agriculture and other brown seaweeds such as *Sargassum* spp*.* *Fucus* spp, *Laminaria* spp., and *Turbinaria* spp., *Sargassum crassifolium* on tomato, *Sargassum vulgare* on red radish crop are also used in agriculture (Ugarte et al., 2006; Hong et al., 2007; Somasundaram et al., 2014; Mahmoud et al., 2019). Use of pure red or brown seaweed extract in agriculture is the common practice, but a blend of red and brown seaweed extract at particular ratio proven to be excellent bio stimulant at low dosage level and it is being manufactured and marked by IFFCO and AquAgri Processing (P) Ltd.) under the brand name of "Sagarika". It was tested across the 16 different agroclimatic condition on a wide range of crops in rabi and kharif season in India and has proven to be an effective bio stimulant. Application of concentrated extracts of Sagarika on green gram crop had significantly increased the grain yield (Iswarya et al., 2019; Alagundagi, 2020). A group researcher reported that 25% fertilizer can be saved by application of Sagarika liquid at 0.25% through foliar spray and 25 kg/ha seaweed granule (Sagarika granule) by soil application on rice without compromising the yield and quality of rice obtained from paddy treated with 75% of recommended dose of fertilizers (RDF) (Banjare et al., 2022).

Recently Seaweed extracts, humic acid, fulvic acid and their derivatives have been classified as biostimulants under Schedule IV category (Organic Fertilizers) of Fertilizer Control Order, 1985 (The Gazette of India: Extraordinary, Part II- Sec 3(ii), 2017). Humic and Fulvic acid products have been in agricultural use for many years (Calvo et al., 2014) and their positive effect on seed germination to crop establishment and yield improvements were well documented in the literature. Visser had listed 33 studies on 30 agricultural crops and other plants that found to have positive effects by humic application on plant biomass, yield, and root growth (Visser, 1986). Some researchers reported that foliar application of humic product in the US Corn Belt had significantly increased the grain yield of maize (*Zea mays* L.) and soybean (*Glycine max* (L.) Merr.) in a cropping rotation sequence (Olk et al., 2013).

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Exogenous application of humic substances and random-effects meta-analysis showed shoot and root dry weights of different plant species increased by 22%. (Rose et al., 2014). The synergistic effect of seaweed extract and humic acid substance is substantiated by fewer scientific studies particularly with brown seaweed (Sandepogu et al., 2019). Humic acid and seaweed extracts treatments caused a significant increase in all vegetative growth and yield characteristics of potato (Sarhan, 2011). A group researcher observed a positive effect between growth and nutrient accumulation of bent grass treated with mixture of seaweed and humic acid (Zhang et al., 2003). The presence of cytokinin in seaweed and humic acid combination improved drought resistance in treated Bent grass crop (Zhang and Ervin, 2004). In the present investigation, synergistic effect of red and brown seaweed extract blend in conjunction with humic acids on green gram seedling root development, grain and stover yield of maize crop farmed in semi-arid zone was studied.

## 2. Materials and Methods

### 2.1 Concentrated seaweed extract

The concentrated extract (Sagarika liquid) used in the study was a mixture of red (*Gracilaria salicornia*) and brown algae (*Sargassum swartzii*) was collected from commercial production (Sagarika batch no: IFF 826 ), humic liquid composite used in the study comprises 75% potassium humate + 25% concentrated sea weed liquid, whereas as humic powder composite contains 92.5% potassium humate + 7.5% soluble sea weed powder and soluble sea weed extract powder (Sagar Amrit) was derived from rhodophytes (Table 1).

**Table 1:** Nutrient profile of concentrated seaweed extract and humic products and composites

| Physiochemical Parameters | Unit | Concentrated seaweed extract (CSE) | Soluble seaweed extract powder | Humic liquid composite | Humic powder composite |
|---|---|---|---|---|---|
| Moisture content | % | 70.45 ± 1.50 | 2.51 ± 0.12 | 91.82 ± 0.59 | 2.32 ± 0.20 |
| Total organic matter | % | 3.96 ± 0.47 | 25.28 ± 0.61 | 2.31 ± 0.04 | 42.43 ± 1.02 |
| pH (at 1% solution) | - | 7.53 ± 0.05 | 7.40 ± 0.05 | 8.38 ± 0.09 | 9.37 ± 0.10 |
| Total soluble solids | % | 29.55 ± 1.50 | 97.49 ± 0.12 | 8.18 ± 0.59 | 97.65 ± 0.17 |
| Total ash content | % | 25.59 ± 1.96 | 72.21 ± 0.62 | 5.87 ± 0.55 | 55.22 ± 1.13 |
| Specific gravity | gm $cc^{-1}$ | 1.16 ± 0.02 | - | 1.08 ± 0.02 | - |
| Bulk density | gm $cc^{-1}$ | - | 0.56 ± 0.02 | - | 0.90 ± 0.05 |
| Total nitrogen (N) | % | 0.19 ± 0.01 | 0.77 ± 0.03 | 0.11 ± 0.01 | 0.92 ± 0.01 |
| Total phosphorous ($P_2O_5$) | % | 0.15 ± 0.01 | 0.28 ± 0.01 | 0.12 ± 0.01 | 0.23 ± 0.02 |
| Total potassium ($K_2O$) | % | 8.62 ± 0.35 | 22.81 ± 0.48 | 0.86 ± 0.12 | 8.46 ± 0.24 |
| Calcium (Ca) | % | 0.24 ± 0.01 | 0.23 ± 0.02 | 0.18 ± 0.03 | 1.26 ± 0.04 |
| Magnesium (Mg) | % | 0.13 ± 0.00 | 0.24 ± 0.02 | 0.40 ± 0.02 | 0.31 ± 0.02 |
| Sulphur (S) | % | 1.41 ± 0.05 | 2.75 ± 0.07 | 0.35 ± 0.02 | 0.65 ± 0.05 |
| Iron (Fe) | % | 0.02 ± 0.00 | 0.02 ± 0.02 | 0.09 ± 0.00 | 0.02 ± 0.00 |
| Zinc (Zn) | mg $kg^{-1}$ | 5.34 ± 0.15 | 34.33 ± 2.08 | 0.04 ± 0.00 | 39.67 ± 1.53 |
| Copper | mg $kg^{-1}$ | 7.05 ± 0.20 | 20.67 ± 2.52 | 156 ± 2.52 | 33.33 ± 1.79 |
| Manganese (Mn) | mg $kg^{-1}$ | 37.33 ± 2.08 | 124.33 ± 3.51 | 0.1 ± 0.01 | 41.33 ± 2.02 |

### 2.2 Preliminary green gram seedling bio assay technique.

A preliminary in-vitro trial on green gram crop grown under plant growth chamber was conducted during post monsoon season (January, 2021) prior to maize field trial. The green gram seedling cut assay technique (Figure 1a) is a modified semi hydroponics method from is fed with Long Ashton Nutrient solution - LANS for fast evaluating bio-stimulatory action of concentrated seaweed liquid tested standalone or with humic liquid composite and humic powder composite (Wilson et al., 1994; Hewitt, 1952). The root morphology of transplanted plants grown from stem cuttings (Figure 1b) was measured after 7 days of transplantation using root imaging software (Win Rhizo Pro, Regent Instruments, Canada) and protocol was followed according to the method described by (Gopi Krishna & Shanmugam Munisamy, Personal communication, 2020). A completely randomized design (CRD) was chosen for the experiment with three replications and a concentration of 100 ppm per treatment is taken on total solid content basis excluding moisture content. The experiment consists of seven treatments viz., $T_1$- Concentrated seaweed liquid (CSW) - 100 ppm, $T_2$- Humic powder composite - 100 ppm, $T_3$-Humic liquid composite - 100 ppm, $T_4$- 100 ppm (1.0:0.8 Ratio of $T_1$:$T_2$), $T_5$- 100 ppm (1.0:1.6 Ratio of $T_1$:$T_3$), $T_6$- Soluble seaweed powder - 100 ppm and $T_7$ – Long Ashton Nutrient Solution (LANS). From the experiment, total root length (cm) and root volume ($cm^3$) was measured and results were statistically drawn.

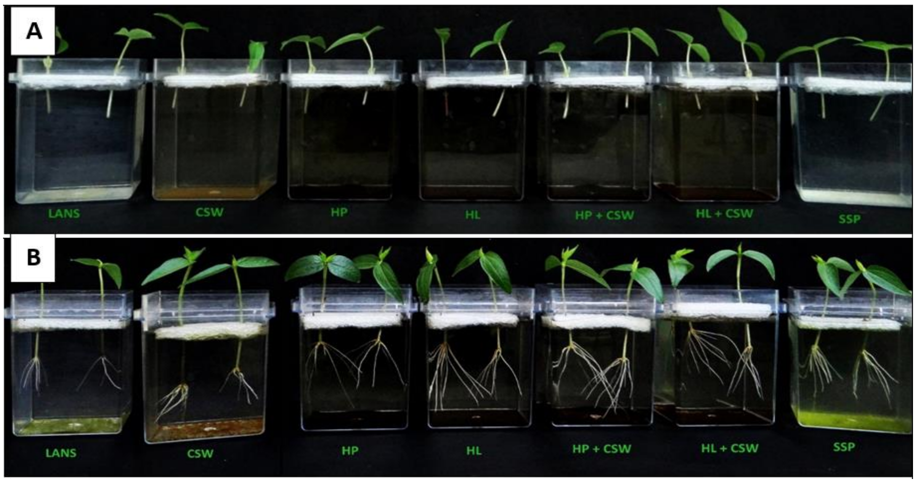


**Figure 1:** Synergistic effect of Concentrated seaweed extract in combination with humic acid on the root development of green gram (a)-root removed seedlings of green gram were transplanted to treament samples (100ppm), (b)-re-development root in the seedlings after 7 days

**Note:** LANS- Long Astron Nutrient Solution; CSW-Concentrated seaweed extract; HP-Humic powder composite; HL-Humic liquid composite; SSP-Soluble Seaweed Powder.

### 2.3 Designing of trial plot

The experiment was carried out in the Research & Development Experimental plots, AquAgri Processing Private Limited, Manamadurai, Sivagangai Dt., Tamil Nadu, India (9° 42′56″N; 78° 28′2″E). Maize crop (variety: Syngenta NK 6240) is grown during summer season (2021). A Randomized Complete Block Design (RCBD) was selected for the experiment consisting of seven treatments with three replications each viz; ($T_1$-Humic Powder Composite - 2 g per litre, $T_2$- Soluble seaweed powder - 2 g per litre, $T_3$- $T_6$ + Humic powder composite - 2 g per litre, $T_4$- $T_6$+ Humic liquid composite - 4 ml per litre, $T_5$- Humic liquid composite - 4 ml per litre, $T_6$- Concentrated seaweed liquid - 2.5 ml per litre and $T_7$ – Control (Water Spray). All the agronomic practices starting from seed sowing to harvest of maize crop were followed according to standard practice laid by Tamil Nadu Agricultural University Crop Production Guide, 2020 guide, where seeds were in sown in fine tilth flat beds (4.8 x 4.5 m = 21.6 m$^2$ per plot) maintaining a spacing of 60 x 25 cm between inter row and intra rows respectively, containing 144 plants per replication. The different treatments and its recommended dose are applied as foliar spray using 250 litres of water per hectare uniformly on 20 and 40 DAS (Days After Sowing).

### 2.4 Elemental Analysis

The physical parameters, total nitrogen and total phosphorus were determined by Fertilizer Control Order, 1985 procedure, where elemental analysis and its sample preparation is followed according to A.O.A.C (2016) method and quantified by Atomic Absorption Spectrophotometer (Agilent 240 AA).

### 2.5 Growth Characteristics

Five plants were ear marked randomly per replication and growth attributes such as plant height, Leaf length, leaf breadth& No of leaves were measured using 1metre stainless steel ruler on 40 and 60 days after sowing, respectively with 20 days interval from each foliar application. Leaf areas were computed using K factor of 0.75 a non-destructive leaf analysis by linear measurement technique (Musa et al., 2016). Subsequently, Leaf Area Index was computed by dividing leaf area by ground area occupied by the plant (Watson, 1947).

Leaf Area (cm$^2$) = Maximum leaf length x maximum leaf width x k (where k = 0.75 was the coefficient)

Leaf Area Index = Leaf area / Ground Area

### 2.6 Yield Attributes

After manual harvest of cobs, it was sundried for a week and were thrashed to remove grains and grain yield per hectare was calculated with parameters like shelling percentage (%), individual cob weight, grain rows per cob and 100 grain test weight of seeds were recorded.

### 2.7 Statistical Analysis

The root length, root volume, crop biometric data and yield data recorded were subjected to the statistical analysis of variance using One-way-ANOVA technique was performed using SPSS Version 22 and mean comparison between treatments were drawn using Duncan Multiple Range Test (DMRT) with 5 % error degrees of freedom and critical difference (LSD) was also given in tabulation for comparison.

## 3. Results and Discussion

### 3.1 Effect of concentrated seaweed liquid and humic acid composite on green gram root

From the laboratory experiment (Table 2), a higher root length of 38.79 cm was recorded with application of $T_5$ (Concentrated seaweed liquid + Humic liquid composite) and $T_4$ (Concentrated seaweed extract + Humic powder composite) – 38.79 cm which was significant ($p$ = 0.013 & 0.042) from the pure seaweed products viz., concentrated sea weed liquid (24.35 cm) and soluble sea weed powder 27.73 cm. There was no significant difference ($P > 0.05$) in performance among two different humic acid composites, where humic liquid composite ($T_3$) applied produced 30.13 cm root length and humic powder composite ($T_2$) - 26.66 cm root length was significant ($p < 0.05$) over Long Ashton Nutrient Solution (LANS) which produced the least root length (13.76 cm). The combined application of humic acid composites with concentrated seaweed liquid significantly ($p < 0.05$) increased root volume than its pure applied form of $T_3$ (concentrated seaweed liquid + humic powder composite) has produced higher root volume (0.12 cm$^3$) followed by $T_3$ (concentrated sea weed liquid + humic liquid composite) with 0.09 cm$^3$ which is at par to $T_1$ (concentrated sea weed liquid – 0.09 cm$^3$). Performance of all the products tested were significantly ($p < 0.05$) higher than control product LANS (0.03 cm$^3$).

**Table 2:** Effect of concentrated seaweed extract and humic acid composites on green gram root length and root volume

| Treatment details | Total root length (cm) | Root volume (cm$^3$) |
|---|---|---|
| $T_1$ – Concentrated seaweed extract (CSE) @ 100 mg L$^{-1}$ | 24.35 ± 0.64$^b$ | 0.09 ± 0.01$^{cd}$ |
| $T_2$ – Humic powder composite @100 mg L$^{-1}$ | 26.66 ± 1.33$^b$ | 0.08 ± 0.00$^c$ |
| $T_3$ – Humic liquid composite @ 100 mg L$^{-1}$ | 30.13 ± 3.39$^{bc}$ | 0.08 ± 0.00$^c$ |
| $T_4$ – $T_1$ @ 50 ppm + Humic powder composite @ 50 mg L$^{-1}$ | 36.58 ± 7.72$^{cd}$ | 0.12 ± 0.02$^e$ |
| $T_5$ – $T_1$ @ 50 ppm + Humic liquid composite @ 50 mg L$^{-1}$ | 38.79 ± 5.41$^d$ | 0.09 ± 0.01$^d$ |
| $T_6$ – Soluble seaweed extract powder @ 100mg l$^{-1}$ | 24.73 ± 4.93$^b$ | 0.06 ± 0.01$^b$ |
| $T_7$ - LANS Nutrient Solution | 13.76 ± 0.29$^a$ | 0.03 ± 0.00$^a$ |
| SEd | 3.48 | 0.01 |
| CD | 8.51 | 0.02 |

Mean values (±SEd) in a column with different letter(s) are significantly different according to Duncan's Multiple Range Test ($p < 0.05$).

### 3.2 Maize Plant Growth Attributes - Effect on Plant Height

The foliar spray of concentrated seaweed liquid + humic liquid composite significantly ($P < 0.05$) improved the plant height (147.2 cm) which is on par with concentrated seaweed liquid + humic powder composite (143.2 cm) and humic liquid composite (140.2 cm) over control (110.5 cm) in early stages of plant growth and distinct growth response (Table 3-4) to concentrated seaweed liquid + humic liquid or humic powder composite application [209.0 cm & 194.9 cm] over concentrated seaweed liquid (169.3 cm)) was seen after second foliar application which continued till harvest of crop.

**Table 3:** Effect of concentrated seaweed extract and humic acid composites on maize crop at knee high stage (40 DAS)

| Treatments details | Plant height (cm) | Leaf length (cm) | Leaf breadth (cm) | Number of leaves | LAI (leaf area index) |
|---|---|---|---|---|---|
| $T_1$- Humic powder composite @ 2 gm L$^{-1}$ | 131.17 ± 2.08$^{bc}$ | 72.88 ± 3.25$^{bc}$ | 7.97 ± 0.13$^{bc}$ | 13.13 ± 0.22$^b$ | 3.81 ± 0.25$^{bc}$ |
| $T_2$- Soluble seaweed powder @ 2 gm L$^{-1}$ | 129.22 ± 3.41$^b$ | 71.07 ± 4.5$^{bc}$ | 7.66 ± 0.2$^{bc}$ | 12.40 ± 0.12$^b$ | 3.38 ± 0.27$^b$ |
| $T_3$- $T_6$ + Humic powder composite @ 2gm L$^{-1}$ | 143.42 ± 17.33$^{bc}$ | 82.71 ± 9.35$^c$ | 8.34 ± 1.01$^c$ | 13.80 ± 1.65$^b$ | 4.82 ± 1.4$^{cd}$ |
| $T_4$- $T_6$+ Humic liquid composite @ 4 ml L$^{-1}$ | 147.20 ± 7.43$^c$ | 84.88 ± 4.67$^c$ | 8.54 ± 0.43$^c$ | 14.00 ± 0.72$^b$ | 5.07 ± 0.47$^d$ |
| $T_5$- Humic liquid composite @ 2 gm L$^{-1}$ | 140.20 ± 11.5$^{bc}$ | 78.26 ± 5.81$^{bc}$ | 8.28 ± 0.68$^{bc}$ | 13.40 ± 0.72$^b$ | 4.35 ± 0.6b$^c$ |
| $T_6$- Concentrated seaweed extract @ 2.5 ml L$^{-1}$ | 125.60 ± 1.81$^b$ | 68.56 ± 0.99$^b$ | 7.37 ± 0.11$^b$ | 12.80 ± 0.81$^b$ | 3.24 ± 0.28$^b$ |
| $T_7$ – Control (Water spray) | 110.53 ± 9.92$^a$ | 59.42 ± 4.62$^a$ | 6.14 ± 0.55$^a$ | 10.60 ± 0.30$^a$ | 1.94 ± 0.35$^a$ |
| SEd | 6.92 | 4.01 | 0.40 | 0.67 | 0.47 |
| CD (P = 0.05) | 12.19 | 7.06 | 0.71 | 1.17 | 0.84 |

Mean values (±SEd) in a column with different letter(s) are significantly different according to Duncan's Multiple Range Test (P<0.05)

**Table 4:** Effect of concentrated seaweed liquid and humic acid composites on maize crop at tasselling and silking stage (60 DAS)

| Treatments details | Plant Height (cm) | Leaf Length (cm) | Leaf Breadth (cm) | Number of Leaves | LAI (Leaf Area Index) |
|---|---|---|---|---|---|
| $T_1$- Humic powder composite @ 2gm $L^{-1}$ | 178.00 ± 6.14$^{b}$ | 80.50 ± 2.78$^{bc}$ | 8.28 ± 0.13$^{bc}$ | 14.60 ± 0.64$^{b}$ | 4.86 ± 0.24$^{bc}$ |
| $T_2$- Soluble seaweed powder @ 2gm $L^{-1}$ | 173.00 ± 6.52$^{b}$ | 76.30 ± 2.88$^{b}$ | 7.86 ± 0.21$^{b}$ | 14.00 ± 0.52$^{b}$ | 4.20 ± 0.32$^{b}$ |
| $T_3$- $T_6$ + Humic powder composite @ 2gm $L^{-1}$ | 194.99 ± 20.64$^{bc}$ | 88.38 ± 9.35$^{cd}$ | 8.68 ± 1.05$^{bc}$ | 15.20 ± 1.23$^{b}$ | 5.83 ± 1.08$^{cd}$ |
| $T_4$- $T_6$ + Humic liquid composite @ 4 ml $L^{-1}$ | 209.00 ± 24.14$^{c}$ | 93.08 ± 10.75$^{d}$ | 9.24 ± 0.47$^{c}$ | 15.80 ± 0.28$^{b}$ | 6.81 ± 1.03$^{d}$ |
| $T_5$- Humic liquid composite @ 2 gm $L^{-1}$ | 183.20 ± 13.50$^{b}$ | 84.80 ± 6.25$^{bcd}$ | 8.46 ± 0.69$^{bc}$ | 14.80 ± 0.44$^{b}$ | 5.29 ± 0.27$^{bc}$ |
| $T_6$- Concentrated seaweed extract @ 2.5 ml $L^{-1}$ | 169.30 ± 17.68$^{b}$ | 74.10 ± 7.74$^{b}$ | 7.76 ± 0.11$^{b}$ | 14.20 ± 1.88$^{b}$ | 4.10 ± 0.81$^{b}$ |
| $T_7$ - Control (Water spray) | 144.00 ± 3.94$^{a}$ | 63.20 ± 1.73$^{a}$ | 6.78 ± 0.61$^{a}$ | 11.80 ± 0.43$^{a}$ | 2.53 ± 0.25$^{a}$ |
| SEd | 10.91 | 4.89 | 0.42 | 0.79 | 0.51 |
| CD (P = 0.05) | 19.20 | 8.61 | 0.74 | 1.39 | 0.90 |

Mean values (±SEd) in a column with different letter(s) are significantly different according to Duncan's Multiple Range Test (P<0.05).

### 3.3 Effect on Leaf Length, Leaf Breadth and Number of leaves

From the Table (2-5), Concentrated seaweed liquid and its combination with humic product composites significantly ($p < 0.05$) improved leaf length, leaf breadth and number of leaves over control at all stages of plant growth over control of which ($T_4$) recorded a leaf length ranging from 84.8 cm to 97.7 cm vs 59.5 cm to 69.7 in control at 40 DAS and harvest stages. However, the combination is not significant ($P > 0.05$) from that of humic liquid composite (82.7 cm vs 90.7 cm) application alone. A profound effect was also seen in leaf breadth of maize crop with application of concentrated seaweed liquid + humic liquid composite ($T_4$) produced largest leaf at 20 DAS, 40 DAS & harvest stage (8.54 cm – 9.24 cm & 9.66 cm), which is significant ($p < 0.05$) over control (6.14 cm – 6.78 cm & 7.06 cm) and the concentrated seaweed liquid + humic powder composite (8.54 – 8.68 & 9.06 cm) combination results are in conjunction with concentrated seaweed liquid (7.37 cm – 7.76 cm & 8.13 cm) and soluble sea weed powder (7.66 cm – 7.86 cm & 8.15 cm ) application.

**Table 5:** Effect of concentrated seaweed extract and humic acid composites on maize crop at harvest stage

| Treatments details | Plant height (cm) | Leaf length (cm) | Leaf breadth (cm) | Number of leaves | LAI (Leaf Area Index) |
|---|---|---|---|---|---|
| $T_1$- Humic powder composite @ 2 gm $L^{-1}$ | 221.60 ± 3.18$^{c}$ | 84.84 ± 2.44$^{b}$ | 8.54 ± 0.57$^{bc}$ | 13.44 ± 1.49$^{bc}$ | 4.85 ± 0.33$^{bc}$ |
| $T_2$- Soluble seaweed powder @ 2 gm $L^{-1}$ | 216.50 ± 18.54$^{c}$ | 82.26 ± 6.15$^{b}$ | 8.15 ± 0.3$^{ab}$ | 13.13 ± 0.84bc | 4.40 ± 0.43$^{b}$ |
| $T_3$- $T_6$ + Humic powder composite @ 2 gm $L^{-1}$ | 244.60 ± 28b$^{c}$ | 90.58 ± 2.86$^{bc}$ | 9.06 ± 0.21$^{bc}$ | 14.40 ± 0.12$^{bc}$ | 5.91 ± 0.29$^{d}$ |
| $T_4$- $T_6$+ Humic liquid composite @ 4 mL $L^{-1}$ | 253.17 ± 14.61$^{c}$ | 97.68 ± 9.16$^{c}$ | 9.66 ± 1.25$^{bc}$ | 14.60 ± 0.2$^{c}$ | 6.86 ± 0.85$^{e}$ |
| $T_5$- Humic liquid composite @ 2 gm $L^{-1}$ | 223.70 ± 21.37$^{b}$ | 88.20 ± 9.14$^{bc}$ | 8.84 ± 0.22$^{bc}$ | 13.80 ± 1.28$^{bc}$ | 5.37 ± 0.66$^{cd}$ |
| $T_6$- Concentrated seaweed extract @ 2.5mL $L^{-1}$ | 214.90 ± 2.32$^{b}$ | 80.63 ± 7.05$^{b}$ | 8.13 ± 0.07$^{ab}$ | 12.80 ± 0.23$^{b}$ | 4.20 ± 0.46$^{b}$ |
| $T_7$ - Control (Water spray) | 185.70 ± 8.03$^{a}$ | 68.57 ± 5.19$^{a}$ | 7.06 ± 0.76$^{a}$ | 10.93 ± 1.25$^{a}$ | 2.64 ± 0.46$^{a}$ |
| SEd | 13.26 | 5.17 | 0.46 | 0.73 | 0.38 |
| CD (P = 0.05) | 23.36 | 9.10 | 0.89 | 1.28 | 0.68 |

Mean values (±SEd) in a column with different letter(s) are significantly different according to Duncan's Multiple Range Test (P<0.05).

The differential application of standalone concentrated seaweed liquid or its combination with humic liquid composite ($T_4$) or humic powder composite ($T_3$) had marginal influence on number of leaves produced over pure standalone alone sea weed liquid or seaweed powder formulations ($T_1$, $T_5$ & $T_6$) at vegetative stage of crop and profound effect of ($T_4$) was observed at harvesting stage produced more number of leaves (14.60) which was significant ($p = 0.001$) from control and $T_3$ (14.40) and standalone seaweed products $T_2$ (13.13) or $T_6$ (12.80) and all the treatments tested were found significant ($p < 0.05$) from control (10.93) at all stages of maize crop tested.

### 3.4 Effect on LAI (Leaf Area Index)

The combined application (Table 2-4) of concentrated seaweed liquid + humic liquid composite ($T_4$) and its positive effect on leaf length, leaf breadth and number of leaves resulted in more leaf area index at 40 DAS, 60 DAS and harvest stage (5.07 – 6.81 & 6.86) of maize crop which is significant ($p < 0.05$) over its control (1.94 – 2.53 & 2.64).

### 3.5 Effect on grain yield

From the table 6, it is seen that plant treated with concentrated seaweed liquid + humic liquid composite ($T_4$) yielded 41.93% (8570 kg $ha^{-1}$) more than control (6038 kg $ha^{-1}$) followed by concentrated seaweed liquid + humic powder composite ($T_3$), 37.50% (8302 kg $ha^{-1}$), humic liquid composite ($T_5$), 32.50 % (8000kg $ha^{-1}$) over control and also significantly ($p < 0.05$) higher over plants treated with humic powder composite (T1) (21.84%, 7357 kg $ha^{-1}$), soluble seaweed powder (T2) (21.84%, 7261 kg $ha^{-1}$) and concentrated seaweed liquid (T6) (18.84%, 7176 kg $ha^{-1}$).

### 3.6 Effect on grain rows, cob weight and stover yield

Table 6 results indicates that concentrated seaweed liquid + humic liquid composite ($T_4$) application recorded higher individual cob weight 150.4g increased by 39.13% which is significant ($p = 0.001$) over control (108.1g) and it was comparable with $T_3$- concentrated seaweed liquid + humic powder composite (145.8g). From the results, application of pure humic composite products such as $T_5$- humic liquid composite (141.8g), humic powder composite (131.5g) or pure seaweed products – concentrated seaweed liquid (127.7g) and soluble seaweed powder (129.8g) performance is significantly lower ($p > 0.05$) than their combined application with concentrated seaweed liquid. Similar results with foliar application on grain rows was recorded in $T_4$ (17.7 rows – 38% increase) and $T_3$ (16.3 rows) was significantly ($p < 0.05$) higher than control (12.8 rows). More dry matter accumulation (stover yield- 9662 kg $ha^{-1}$) is recorded in concentrated seaweed liquid + humic liquid composite ($T_4$) which is 32% higher compared to control (7309 kg $ha^{-1}$). No significant differences ($p > 0.05$) were recorded with application of seaweed products or its combination with humic composite products tested in combination or pure form on shelling percentage (%), test weight and harvest index over control plots.

**Table 6:** Effect of concentrated seaweed liquid and humic acid composites on maize grain yield and stover yield

| Treatments details | Plant height (cm) | Leaf length (cm) | Leaf breadth (cm) | Number of leaves | LAI (Leaf Area Index) |
|---|---|---|---|---|---|
| $T_1$- Humic powder composite @ 2 gm $L^{-1}$ | 221.60 ± 3.18$^{c}$ | 84.84 ± 2.44$^{b}$ | 8.54 ± 0.57$^{bc}$ | 13.44 ± 1.49$^{bc}$ | 4.85 ± 0.33$^{bc}$ |
| $T_2$- Soluble seaweed powder @ 2 gm $L^{-1}$ | 216.50 ± 18.54$^{c}$ | 82.26 ± 6.15$^{b}$ | 8.15 ± 0.3$^{ab}$ | 13.13 ± 0.84bc | 4.40 ± 0.43$^{b}$ |
| $T_3$- $T_6$ + Humic powder composite @ 2 gm $L^{-1}$ | 244.60 ± 28b$^{c}$ | 90.58 ± 2.86$^{bc}$ | 9.06 ± 0.21$^{bc}$ | 14.40 ± 0.12$^{bc}$ | 5.91 ± 0.29$^{d}$ |
| $T_4$- $T_6$+ Humic liquid composite @ 4 mL $L^{-1}$ | 253.17 ± 14.61$^{c}$ | 97.68 ± 9.16$^{c}$ | 9.66 ± 1.25$^{bc}$ | 14.60 ± 0.2$^{c}$ | 6.86 ± 0.85$^{e}$ |
| $T_5$- Humic liquid composite @ 2 gm $L^{-1}$ | 223.70 ± 21.37$^{b}$ | 88.20 ± 9.14$^{bc}$ | 8.84 ± 0.22$^{bc}$ | 13.80 ± 1.28$^{bc}$ | 5.37 ± 0.66$^{cd}$ |
| $T_6$- Concentrated seaweed extract @ 2.5mL $L^{-1}$ | 214.90 ± 2.32$^{b}$ | 80.63 ± 7.05$^{b}$ | 8.13 ± 0.07$^{ab}$ | 12.80 ± 0.23$^{b}$ | 4.20 ± 0.46$^{b}$ |
| $T_7$ - Control (Water spray) | 185.70 ± 8.03$^{a}$ | 68.57 ± 5.19$^{a}$ | 7.06 ± 0.76$^{a}$ | 10.93 ± 1.25$^{a}$ | 2.64 ± 0.46$^{a}$ |
| SEd | 13.26 | 5.17 | 0.46 | 0.73 | 0.38 |
| CD (P = 0.05) | 23.36 | 9.10 | 0.89 | 1.28 | 0.68 |

Mean values (±SEd) in a column with different letter(s) are significantly different according to Duncan's Multiple Range Test (P<0.05).

### 3.7 Effect on number of grains per cob, cob length and cob breadth

The maximum number of grains per cob (460) [Table 7] was recorded in concentrated seaweed liquid + humic liquid composite ($T_4$) was comparable with humic powder composite combination $T_3$ (449), $T_5$ (431) which is significantly ($p < 0.05$) higher than control (345). From the results higher cob length was observed with $T_4$ (19.82 cm) & $T_5$ (18.52 cm) application significant ($p < 0.05$) over control (14.62) and no significant differences ($p > 0.05$) on cob breadth were recorded with application of seaweed extract, humic acid products or their combinations.

**Table 7:** Effect of concentrated seaweed extract and humic acid composites on maize grain yield attributes

| Treatments details | 100 grain weight | No of grains per cob | Shelling percentage (%) | Cob length (cm) | Cob girth (cm) |
|---|---|---|---|---|---|
| $T_1$- Humic powder composite @ 2 gm $L^{-1}$ | 26.74 ± 0.70$^{a}$ | 413 ± 44$^{bcd}$ | 83.93 ± 1.01$^{a}$ | 17.4 ± 0.92$^{b}$ | 4.63 ± 0.14$^{bc}$ |
| $T_2$- Soluble seaweed extract powder @ 2 gm $L^{-1}$ | 26.55 ± 0.70$^{a}$ | 410 ± 18$^{bcd}$ | 83.97 ± 1.03$^{a}$ | 17.21 ± 1.84$^{b}$ | 4.43 ± 0.49$^{b}$ |
| $T_3$- $T_6$ + Humic powder composite @ 2 gm $L^{-1}$ | 27.67 ± 0.80$^{a}$ | 450 ± 19$^{cd}$ | 85.41 ± 0.65$^{a}$ | 18.52 ± 0.40$^{bc}$ | 4.79 ± 0.28$^{bc}$ |
| $T_4$- $T_6$+ Humic liquid composite @ 4 mL $L^{-1}$ | 27.98 ± 1.63$^{a}$ | 460 ± 26$^{d}$ | 85.44 ± 1.18$^{a}$ | 19.82 ± 0.19$^{c}$ | 5.12 ± 0.32$^{c}$ |
| $T_5$- Humic liquid composite @ 2 gm $L^{-1}$ | 27.8 ± 0.94$^{a}$ | 431 ± 24$^{bcd}$ | 84.56 ± 1.32$^{a}$ | 17.5 ± 1.65$^{b}$ | 4.68 ± 0.07$^{bc}$ |
| $T_6$- Concentrated seaweed extract @ 2.5 mL $L^{-1}$ | 26.42 ± 0.16$^{a}$ | 407 ± 23$^{bd}$ | 84.33 ± 0.69$^{a}$ | 16.8 ± 0.35$^{b}$ | 4.59 ± 0.39$^{bc}$ |
| $T_7$ - Control (Water spray) | 26.31 ± 1.22$^{a}$ | 345 ± 14$^{a}$ | 83.77 ± 0.8$^{a}$ | 14.62 ± 1.06$^{a}$ | 3.73 ± 0.12$^{a}$ |
| SEd | 0.73 | 20 | 0.8 | 0.96 | 0.24 |
| CD (P = 0.05) | NS | 36 | NS | 1.68 | 0.42 |

Mean values (±SEd) in a column with different letter(s) are significantly different according to Duncan's Multiple Range Test (P<0.05)

The preliminary experiment results indicated the synergistic effect of concentrated seaweed extract with humic acid composites ($T_4$ & $T_5$). It's application increased total root length by 50 & 59 % and increased root volume by 6.55 & 33 % respectively (Figure 2) on green gram tested by rooting assay. Biostimulants with mineral nutrients and several plant growth promoter hormones bundled in them can alter higher root to shoot ratio on crops being applied with them the increased root surface leads to better nutrient uptake, translocation and metabolic assimilation will increase crop yields and biomass potential (Zhang and Ervine, 2004). The auxin like compounds present help plant to promote root growth and more lateral development. A group researcher made similar results with hydroponically grown rocket plant treated with Actiwave, an extract of brown seaweed *Ascophyllum nodosum* (Vernieri et al., 2005). The seaweed extracts are known for its rich in natural source of potassium, sulphur, macro-secondary-trace nutrient elements, plant growth promoters, oxidative stress scavenging activity and osmo-protectants such as glycine betaine, proline or polyamines (Ali et al., 2021). The bio stimulatory effect of *Kappaphycus alvarezii* and *Sargassum* sp. Has been well documented. The humic acid and its derivatives and fulvic acid improve plant growth by their chelating properties, cation exchanging capacity, soil pH buffering activity, enhancing water holding capacity of soil, improving crop mineral nutrient uptake and alleviating abiotic stress (Ampong et al., 2022).

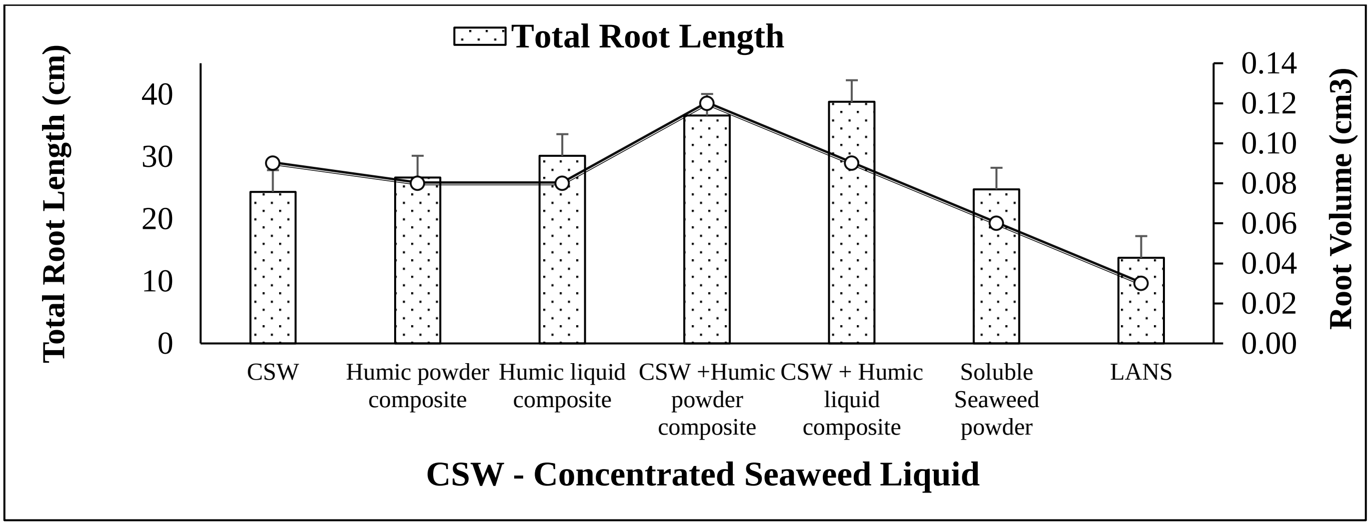


**Figure 2:** Effect of CSW and humic and composite on green gram root length and root volume

In the present investigation, from trial $T_4$ a blend of CSW and humic (1:1.6) performed well and increased the grain yield of maize by 41.93 %. Application of extract of *Ecklonia maxima*, *Sargassum* spp in combination with humic acid significantly promoted the growth and development of maize crop. (Matysiak et al., 2011). Kavipriya and Parusuraman had reported that application of 0.5% of extract from *Kappaphycus alvarezii* and 0.2% humic acid improved physiological and biochemical traits of tomato crop (Kavipriya and Parusuraman, 2018). A group researcher found foliar application of 10% *Kappaphycus* sap exogenous application at grain filling stage improved the drought tolerance, nutrient uptake and yield of maize crop (Trivedi et al., 2018). In the present study, CSW and humic combination ($T_4$) improved the grain yield, individual cob weight, grain rows, number of grains per cob and stover yield of maize crop (Figure 3).

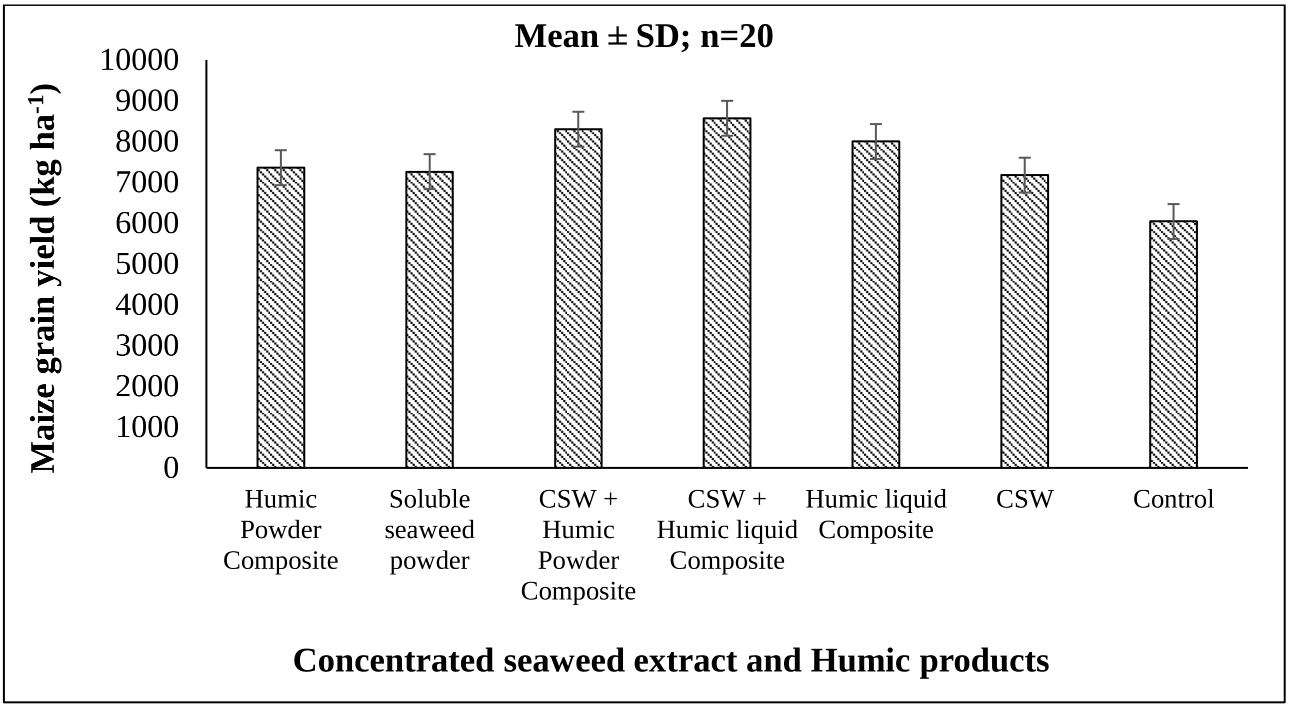


**Figure 3:** Yield of grain from maize treated with concentrated seaweed extract and humic acids in combination and standalone

In another study on potato crop foliar application of 0.033% Alga 600 (a combination of *Sargassum sp, Laminaria sp* & *Ascophyllum nodosum*), 0.25% sea force 2 with 0.3% humic acid improved the vegetative grow and potato yield by 44%. (Sarhan, 2011). Some researchers also made similar findings that foliar application of 0.15% Oligo-X (A mixture of *Ascophyllum nodosum*, *Laminaria* sp., *Sargassum* sp. & *Fucus* sp.) along with soil application of humic acid (400 mg $l^{-1}$) significantly improved growth, flowering and fruit yield and quality of strawberry plants grown in climate-controlled polyhouse (Alkharpotly et al., 2017).

The plant height, leaf length, leaf breath, leaf area and plant biomass (dry weight/kg/ha) was found significantly higher from plants treated with CSW and humic acid ($T_4$) which could be due better nutrient uptake, assimilation and delayed senescence coupled with efficient photosynthate process which improved crop growth. A group researchers also reported Ascophyllum meal and leonardite derived humic acid treated soil grown bent grass produced healthy shoots and has shown beneficial reduced fertilizer regimes with less fungicidal inputs (Zhang et al., 2003). Similar, findings were also reported on foliar application of 0.25% *Ascophyllum nodosum* extract combined with 0.2% humic acid improved fresh and dry biomass of lettuce and spinach crop (Sandepogu et al., 2019). The combined application of 0.3% humic acid product on red radish plants improved growth and yield over 0.3% seaweed extract application alone (Jitendra et al., 2022).

## 4. Conclusion

Bio stimulants has already opened up a new area of research for making contribution to sustainable agriculture with low inputs. Application of seaweed extract and humic acid in combination will further reduce input cost and dosage as well. Thus, from the present study, it can be concluded that application of seaweed extract in conjunction with humic acid had performed better than seaweed extract alone on maize crop. Since a synergistic effect has been observed between seaweed extract and humic acids, it can be applied together on maize for better yield and quality of grains.

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## Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request

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