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Effect of seaweed sap foliar application on growth and yield of maize (*Zea mays* L.) cultivars

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Abstract
A field experiment was conducted during *zaid* season of 2020 and 2021 at crop research farm in Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj on sandy loam soil to investigate the response of seaweed sap foliar application on maize cultivars under eastern UP condition. The experiment was laid out in Split Plot Design along with two factor *viz.*, four maize cultivar (VMH-27, VMH-53, VLMH-57 and VLQPMH-59) as main plot and two seaweed (*Kappaphycus sp. & Sargassum* sp.) sap at different concentration (5%, 7.5% & 10%) as sub-plot factor treatment along with one water spray and their combination of 28 treatments replicated thrice. Each main plot (4 plot) was divided into 7 subplots to allocate the different concentration of both sap, i.e. 5, 7.5, 10% and water spray along with recommended dose of nutrients. Pooled results indicated that foliar application of seaweed extracts at different concentrations (5.0, 7.5 and 15.0% V/V) significantly enhanced the growth and yield of maize cultivars. Cultivars V_3: VLMH-57 which produced maximum plant height (186.67 cm), number of leaves/plant (11.99) and grain yield (5868.17 kg/ha). While, foliar application of S_7: S-Seaweed sap 10% (*Sargassum* sp. sap) were produced highest plant height (181.62 cm), number of leaves/plant (12.00) and grain yield (5427.59 kg/ha).

Keywords: Cultivars, seaweed, maize, growth, yield

Introduction
Maize is one of the world major food crop, feeding the human since ages, it has higher value of food, use as a forage, feed for livestock, poultry and cheaper source of raw material for agro based industry. Maize is used for food and fodder, and it is also required by numerous industries. About 35% in food processing (corn flakes, popcorn, etc.) and other sectors (starch, dextrose, corn syrup, corn oil, etc.) in India. Because of its monoecious character, superior carbon dioxide assimilation capacity, wider flexibility, and high yielding potential, maize is known as the 'Queen of Cereals' (Begam *et al*., 2018) [5]. In 2025, the demand for food grains is expected to be over 300 metric tonnes. It is higher than the expected current production of 233.88 metric tonnes (Anonymous, 2020) [3]. Target food production must be grown at a pace of 4.48 metric tonnes in the first year in the coming years to actualize the future of food grains. Corn, because of its high productivity and adaptability, provides an ideal opportunity to promote contributing to the national food basket. India is fourth in terms of area and seventh in terms of production among maize-growing countries, accounting for roughly 4% of global maize area and 2% of total production. In India, the maize acreage increased to 9.2 million hectares in 2018-19. (Anonymous, 2020) [3]. In 1950-51, India produced 1.73 million metric tonnes of maize, which has climbed to 27.8 million metric tonnes in 2018-19, an almost 16-fold increase in production. It is estimated that maize demand will continue to increase because of its diversified uses and increasing population.

Main constraints to maize production include declining soil fertility, low yield potential of existing genotypes, limited and irregular access to improved seed and quality fertilisers, and the advent of new insect species. Thus, maize production could be improved by cultivating new high-yielding varieties using the best cultural methods and applying the required nutrients in the right amounts and at the right times (Ahmad, *et al*., 2018) [2], maize production can be maximized by cultivating hybrid, well developed new maize varieties with great potential help to increase production upto 30-40% (Adhikari, *et al*., 2021) [1]. In plant nutrition, natural manures, bioenhancers like seaweed extract, vermicompost etc. play vital role, as they act immediately for growing the crop yields both via way of means of acceleration of respiration technique with growing molecularly development and hormonal increase movement or via way of means of aggregate of these types of processes.

It substances macronutrients and micronutrients (Fe, S, Mo and Zn etc.) in to be had shape to the flora via organic manner and improves physical-chemical homes of soil in addition to stimulate of soil flora and fauna etc. Sea weeds (*Kppaphycus alvarezii* and *Sargassum wightii*) extricate has been found rich in dietary supplements which include plant improvement controllers as an example IAA, kinetin, zeatine, auxin, cytokinin and gibberellins (Layek *et al*., 2016) [11]. The compound auxin performs a position in physiological strategies in plants, which includes increase, cellular development and differentiation, and protein synthesis. Cytokinin performs a critical position in cell division which reasons a plant reaction with admire to plant increase, fruit formation and sprout germination (Fatriana *et al*., 2020) [8]. Sea weed sap is a much less steeply-priced wellspring of complement simply as herbal in nature on the way to address soil health and weather as well. Seaweed Liquid Fertilizer (SLF) is a mix of each plant increase regulators and natural nutrient enter is eco-friendly, selling sustainable productiveness and retaining soil health (Mohanty *et al*., 2013 and Shah, *et al*., 2013) [13, 17]. Therefore, in view of the above, the present investigation were undertaken with an aim to evaluate the effect of seaweed sap foliar application on growth and yield of Maize (*Zea mays* L.) cultivars to encourage sustainable development in maize production.

Material and Methods

The experiment was conducted during *Zaid* season of 2020 and 2021 at Crop Research Farm (CRF), Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj (25° 39'42''N and 81°67'56''E and 98m altitude) on sandy clay loam soil of Uttar Pradesh condition. Prayagraj features the typical version of a humid subtropical climate that is common to cities in north-central India. Prayagraj experiences three seasons: hot dry summer, cool dry winter and warm humid monsoon. The summer season lasts from April to June with the maximum temperatures ranging from 40 °C (104 °F) to 45 °C (113 °F). Monsoon begins in early July and lasts till September. The winter season lasts from December to February. The experimental soil initially before sowing crop was nearly neutral in soil reaction (pH – 7.28 and 7.15, low in organic carbon (0.37% and 0.29%) medium in available Nitrogen (226.49 and 210.66 kg/ha), medium in available Phosphorous (16.90 and 18.44 kg/ha) and low in available Potassium (192.20 and 196.39 kg/ha) during *zaid* seasons of 2020 and 2021. The experiment was laid out in split plot design with twenty eight treatments replicated thrice. The main plot comprised of 4 cultivars *i.e.* (a) VMH-27 (b) VMH-53 (c) VLMH-57 and (d) VLQPMH-59 and in subplot 3 concentrations (5%, 7.5% and 10%) of both Seaweed sap (*Kappaphycus sp. & Sargassum sp.*) foliar applications along with water spray. The amount of different fertilizers required to supply the needed quantities of nutrients were calculated on per plot basis as per recommended dose of fertilizer. The nitrogen, phosphorus and potash were applied through urea, single superphosphate and muriate of potash, respectively. Irrigation was based on the necessity and as per the time of sowing. The recommended cultural practices were under taken as per recommendation. Data on growth attributes *viz*., Plant height (cm), Number of leaves per plant, leaf-area index (LAI) was estimated with a standard process suggested by Sestak *et al*, (1971) [16], Leaf area duration (LAD) measures the ability to produce leaf area on unit land throughout its life and calculated as per the formula given by Powar *et al*., (1967) [14], however, Seed yield (kg/ha) and HI (%) data was recorded with standard process. All the data were subjected to analysis of variance (ANOVA) by using a split-plot design and main effects and interactions were tested for significance. Treatment means obtained by ANOVA were compared using critical difference (CD) at P=0.05 level of significance (Gomez and Gomez, 1984) [9].

Results and Discussion

Effect on growth attributes plant height (cm) and Number of leaves/plant (No.)

Data regarding the effect of maize cultivars and seaweed sap foliar spray on growth attributes, plant height and number of leaves/plant (60 and 80 DAS) are presented in Table 1. At 60 and 80 days after sowing (DAS), significantly higher plant height 169.57 cm and 186.67 cm were recorded with V_3: VLMH-57, at 80 DAS, cultivar V_1: VMH-27 was statistically at par with V_3: VLMH-57, lowest plant height was recorded with VMH-53 (V_2) at 60, 80 DAS. In respect of seaweed sap foliar spray, with increase in concentration of sap from 5 to 10 per cent, though S_7: S-Seaweed sap 10% were recorded maximum plant height 167.75 cm and 181.62 exhibited superiority than other concentration except foliar application of S_4: K-Seaweed sap 10% and S_6: S-Seaweed sap 7.5% was found statistically at par to foliar application of S_7: S-Seaweed sap 10%.

Number of leaves/plant was significantly influenced by cultivars during both the years of experimentation at 80 DAS but it was found non significant relation at 60 days after sowing. Number of leaves/plant was found significantly maximum (11.99) with V_3: VLMH-57 which statistically superior among all cultivars at 80 DAS. However, number of green leaves per plant was positively responded to the seaweed sap foliar spray (S) at 80 days after sowing, maximum number of leaves/plant (12.00) was recorded at 80 DAS with S-Seaweed sap 10% foliar spray (S_7) compared to others. Application of K-Seaweed sap 7.5% foliar spray (S_3), K-Seaweed sap 10% foliar spray (S_4) and S-Seaweed sap 7.5% foliar spray (S_6) was observed comparatively at par at 80 DAS with S-Seaweed sap 10% foliar spray (S_7). The least number of green leaves/plant (10.44) at 80 DAS was observed under water spray (S_1). This increasing effect might be due to the presence of macro and micro nutrients as well as growth promoting substances like auxin and cytokinin in seaweed liquid extract of *Sargassum sp*. Seaweed extracts along with major and minor nutrients contain amino acids, vitamins, cytokinins, auxin and abscisic acid like growth promoting substances and have been reported to stimulate the growth and yield of plants, develop tolerance to environmental stress (Zodape *et al.*, 2010) [21]. Similar results were also obtained by Pramanick *et al.* (2014) [15].

Table 1: Effect of cultivars and seaweed sap on growth parameter of maize (2 year pooled analysis)

Treatments	Plant height (cm)		Leaves/plant (No.)	
	60 DAS	80 DAS	60 DAS	80 DAS
Cultivars (V)				
V_1: VMH-27	152.97	172.31	10.26	11.39
V_2: VMH-53	146.92	164.62	9.83	11.08
V_3: VLMH-57	169.59	186.67	10.43	11.99
V_4: VLQPMH-59	155.28	165.09	10.04	10.89
F-test	S	S	NS	S
S.Em(±)	3.54	4.44	0.13	0.16
CD (P=0.05)	12.25	15.38	0.46	0.55
CV (%)	10.39	11.83	5.99	6.46
Seaweed sap foliar spray (S)				
S_1: Water Spray	135.32	154.15	9.72	10.44
S_2: K- Sea-weed sap 5%	153.88	170.77	10.28	11.13
S_3: K- Sea-weed sap 7.5%	158.93	173.47	10.25	11.48
S_4: K- Sea-weed sap 10%	164.29	179.76	10.36	11.80
S_5: S- Sea-weed sap 5%	152.57	169.86	9.98	10.94
S_6: S- Sea-weed sap 7.5%	160.56	175.56	10.03	11.57
S_7: S- Sea-weed sap 10%	167.75	181.62	10.38	12.00
F-test	S	S	NS	S
S.Em(±)	2.83	3.34	0.21	0.20
CD (P=0.05)	8.18	9.66	0.59	0.58
CV (%)	6.27	6.72	7.02	6.07
Cultivars x Seaweed sap (VxS)	NS	NS	NS	NS

Note: K- Seaweed sap: *Kappaphycus alvarezii* seaweed sap; S- Seaweed sap: *Sargasssum wightii* seaweed sap

Effect on leaf area index (LAI) and leaf area duration (LAD)

Summary of data on Leaf area index (LAI) and Leaf area duration (LAD) of maize as influenced by the improved maize cultivars and foliar application of seaweed sap have been presented in Table 2. Among the four improved cultivars, maximum leaf area index (5.33 and 5.36) and leaf area duration (70.77 and 106.92 days) were recorded significantly superior with cultivar V_3: VLMH-57 at 60 and 80 DAS among rest of the cultivars. In case of seaweed sap foliar application, significant effect of on leaf area index and leaf area duration was evaluated at 60 and 80 DAS. Maximum leaf area index (5.04 and 4.65) and leaf area duration (67.80 and 96.96 days) recorded with S_7: S-Seaweed sap 10% foliar spray which were statistically significant among all foliar application except foliar application of S_4: K-Seaweed sap 10% was found to be at par with higher one. The lowest leaf area duration was recorded with cultivar V_2: VMH-53. Seaweed sap improve plant growth as well as leaf area index (LAI), the promotive effects of seaweed application at three different steps *viz.*, vegetative, initiation of tassel and at maturity stage in the present investigation might be due to increased root proliferation and establishment, there by plants were able to mine more nutrients even from distant places and deeper soil horizons, in balanced proportion (Singh, *et al.*, 2016) [19]. LAD is a function of leaf area index which indicates persistence of photosynthetic activity in the plant (Aravinth *et al.*, 2011) [4]. Improved cultivars with better nutrient management resulted in development of required efficient photosynthetic system as reflected by higher LA and LAI and retention of it for longer period of time as evidenced by higher LAD. Sulochana *et al.* (2015) [20] also recorded similar results in maize crop.

Table 2: Effect of cultivars and seaweed sap on growth indices of maize (2 year pooled analysis)

Treatments	LAI		LAD (days)	
	60 DAS	80 DAS	60 DAS	80 DAS
Cultivars (V)				
V_1: VMH-27	4.40	3.58	57.52	79.80
V_2: VMH-53	3.68	2.91	51.50	65.94
V_3: VLMH-57	5.33	5.36	70.77	106.92
V_4: VLQPMH-59	4.81	4.98	62.13	97.96
F-test	S	S	S	S
S.Em(±)	0.04	0.06	0.36	0.82
CD (P=0.05)	0.14	0.19	1.25	2.83
CV (%)	4.17	6.03	2.73	4.28
Seaweed sap foliar spray (S)				
S_1: Water Spray	3.75	3.45	50.13	71.95
S_2: K- Sea-weed sap 5%	4.41	4.13	57.80	85.35
S_3: K- Sea-weed sap 7.5%	4.65	4.27	61.30	89.14
S_4: K- Sea-weed sap 10%	4.91	4.54	65.84	94.48
S_5: S- Sea-weed sap 5%	4.36	4.04	57.31	84.02
S_6: S- Sea-weed sap 7.5%	4.79	4.38	63.18	91.69
S_7: S- Sea-weed sap 10%	5.04	4.65	67.80	96.96

F-test	S	S	S	S
S.Em(±)	0.08	0.07	0.90	1.32
CD (P=0.05)	0.22	0.20	2.59	3.81
CV (%)	5.91	5.76	5.13	5.20
Cultivars x Seaweed sap (VxS)	NS	NS	NS	NS

Note: K- Seaweed sap: *Kappaphycus alvarezii* seaweed sap; S- Seaweed sap: *Sargasssum wightii* seaweed sap

Effect on Grain yield and Harvest Index

The effect of treatment variables on grain yield (t/ha) and harvest index (%) are furnished in Tables 3. The influence of treatments *viz*., cultivars (V), seaweed sap foliar spray (S) on maize grain yield indicated that it was highly influenced by both the treatments. Among the different cultivars, V_3: VLMH-57 maize cultivar resulted in achieving significantly superior maize grain yield i.e. 5.87 t/ha and also contributes significantly maximum harvest index (37.37%) among rest of the cultivars except cultivar V_1: VMH-27 was found statistically at par in case of harvest index (%). Growth and Yield attributing characters *viz.* higher plant height, number of cob, number of grains/cob, cob weight and seed index were the main characters which were responsible for higher grain yield of V_3: VLMH-57 maize cultivars. With respect to seaweed sap foliar application, it is quite clear from the data (Table 3) through foliar application of S-Seaweed sap 10% foliar spray (S_7) recorded significantly higher grain yield 5.43 t/ha, it was significantly differed from the other treatments except foliar application of K-Seaweed sap 10% foliar spray (S_4) and S-Seaweed sap 7.5% foliar spray (S_6) was noticed on par with maximum yield producing treatment S-Seaweed sap 10% foliar spray (S_7). The lowest grain yields were recorded due to foliar application of water spray (S_1) plant failure to contribute maximum growth and yield ultimately. Growth hormones like cytokinin and gibberellins have been detected in the extract of *Kappaphycus alvarezii* and *Sarggasum spp.* which might be responsible for beneficial effects in the present study (Devi and Mani, 2015) [7]. Besides presence of cytokinin and magnesium in the seaweed extract, which are chief constituents of chlorophyll biosynthesis might have played a vital role in enhancement of growth and physiology of crop (Singh *et al.*,2015) [18].

Table 3: Effect of cultivars and seaweed sap on yield of maize (2 year pooled analysis)

Treatments	Grain yield (kg/ha)	HI%
Cultivars (V)		
V_1: VMH-27	4957.05	36.32
V_2: VMH-53	4706.84	35.30
V_3: VLMH-57	5868.17	37.37
V_4: VLQPMH-59	4147.58	33.02
F-test	S	S
S.Em(±)	74.288	0.34
CD (P=0.05)	257.079	1.19
CV (%)	6.919	4.43
Seaweed sap foliar spray (S)		
S_1: Water Spray	4008.57	32.51
S_2: K- Sea-weed sap 5%	4783.67	35.43
S_3: K- Sea-weed sap 7.5%	4992.95	35.83
S_4: K- Sea-weed sap 10%	5232.31	36.35
S_5: S- Sea-weed sap 5%	4848.75	35.68
S_6: S- Sea-weed sap 7.5%	5145.53	36.07
S_7: S- Sea-weed sap 10%	5427.59	36.65
F-test	S	S
S.Em(±)	127.411	0.51
CD (P=0.05)	368.697	1.49
CV (%)	8.971	5.01
Cultivars x Seaweed sap (VxS)	NS	NS

Note: K- Seaweed sap: *Kappaphycus alvarezii* seaweed sap; S- Seaweed sap: *Sargasssum wightii* seaweed sap

Effect of cultivars and seaweed sap on correlation coefficient among growth and yield

Data related correlation among different variable are tabulated in Table 4. Result obtained on the correlation analysis between growth and yield characteristics of the 28 treatment combination (Main plot 4 x Sub plot 7 = 28) is as presented in Table 4. Plant height correlated positively and significantly with Plant height at 80 DAS (r = 0.932**), number of leaves/plant (r = 0.722**), LAI at 60 and 80 DAS (r = 0.897** and 0.773**), LAD at 60 and 80 DAS (r = 0.944** and 0.836**), grain yield (r = 0.817**) and harvest Index (HI%) (r = 0.692**). Rest of the variables also showed significantly correlated with each other except LAI and LAD at 80 DAS with harvest index (HI%) was non-significantly correlated with each other. The correlation tables showed that plant traits were interrelated between them, which showed that the traits of the plant complemented each other in achieving plant productivity with different role of each trait from the other (Jader, *et al.*, 2019) [10]**.** A similar result was also reported by Chen, *et al*., (2021) [6] and Maruti Sankar and Reddy (2005) [12].

Table 4: Correlation coefficient study among growth and yield variables

Variables		Plant height (60 DAS)	Plant height (80 DAS)	No. of leaves/plant (60 DAS)	No. of leaves/plant (80 DAS)	LAI (60 DAS)	LAI (80 DAS)	LAD (60 DAS)	LAD (80 DAS)	Grain yield (kg/ha)	HI (%)
Plant height (60 DAS)	R	1	0.932	0.722	0.848	0.897	0.773	0.944	0.836	0.817	0.692
	Sig		**	**	**	**	**	**	**	**	**
	p-value		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N		28	28	28	28	28	28	28	28	28
Plant height (80 DAS)	R		1	0.726	0.902	0.797	0.620	0.859	0.703	0.924	0.821
	Sig			**	**	**	**	**	**	**	**
	p-value			0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N			28	28	28	28	28	28	28	28
No. of leaves/plant (60 DAS)	R			1	0.698	0.691	0.533	0.700	0.607	0.643	0.607
	Sig				**	**	**	**	**	**	**
	p-value				0.000	0.000	0.003	0.000	0.001	0.000	0.001
	N				28	28	28	28	28	28	28
No. of leaves/plant (80 DAS)	R				1	0.680	0.483	0.752	0.572	0.891	0.837
	Sig					**	**	**	**	**	**
	p-value					0.000	0.009	0.000	0.001	0.000	0.000
	N					28	28	28	28	28	28
LAI (60 DAS)	R					1	0.938	0.982	0.978	0.615	0.431
	Sig						**	**	**	**	*
	p-value						0.000	0.000	0.000	0.000	0.022
	N						28	28	28	28	28
LAI (80 DAS)	R						1	0.905	0.990	0.414	0.183
	Sig							**	**	*	
	p-value							0.000	0.000	0.028	0.352
	N							28	28	28	28
LAD (60 DAS)	R							1	0.951	0.704	0.514
	Sig								**	**	**
	p-value								0.000	0.000	0.005
	N								28	28	28
LAD (80 DAS)	R								1	0.503	0.288
	Sig									**	
	p-value									0.006	0.137
	N									28	28
Grain yield (kg/ha)	R									1	0.943
	Sig										**
	p-value										0.000
	N										28
HI (%)	R										1
	Sig										
	p-value										
	N										
	** correlation is significant at the 0.01 level					* correlation is significant at the 0.05 level					

Conclusion

The present investigation confirmed that maize cultivars well performed and produced higher yield to the added seaweed sap concentration. Improved cultivars and seaweed foliar application results indicated that foliar application of seaweed extracts at different concentrations (5.0, 7.5 and 15.0% V/V) significantly enhanced the growth and yield of maize cultivars. Cultivars V_3: VLMH-57 which produced maximum plant height (186.67 cm), number of leaves/plant (11.99) and grain yield (5868.17 kg/ha). While, foliar application of S_7: S-Seaweed sap 10% (*Sargassum sp* sap) were produced highest plant height (181.62 cm), number of leaves/plant (12.00) and grain yield (5427.59 kg/ha). Correlation matrix among traits (growth and yield) showed significantly and positively associated with each other.

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