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Research Paper

Effect of seaweed sap on germination, growth and productivity of maize (*Zea mays*) in North Eastern Himalayas

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ABSTRACT

The productivity of maize (*Zea mays* L.) is very low (1.5 t/ha) in North Eastern Region (NER) of India compared to India's national average (2.5 t/ha). Farmers of the NER hardly use any chemical fertilizers and other synthetic agro-chemicals in crop production. Seaweed sap (contains macro and micro nutrients and plant growth hormones) could be a potential and cheap organic bio-stimulant to enhance the growth and productivity of maize. A 2-year study (2012–13) was conducted during the rainy (*kharif*) seasons at ICAR Research Complex for North Eastern Hill Region, Umiam, Meghalaya, to study the impact of foliar application of seaweed extracts from *Kappaphycu salvarezii* (Doty) doty ex. P.C. Silva and *Gracilaria edulis* (S.G. Gmelin) P.C. Silva on germination, physiological parameters and yield of maize. Treatments consisted of 2 types of sap K-sap from *Kappaphycus* and G-sap from *Gracilaria* with 2 concentrations (5 and 10%) and 3 spray schedule [at 25 days after sowing (DAS), 25 and 50 DAS and 25, 50 and 75 DAS]. Results revealed that soaking of maize seeds with low concentrations (5%) of K or G sap improved the germination and seedling vigour of maize. However, soaking of seeds in higher concentration (10 and 15% of K or G sap) decreased the germination and root length of maize. Three foliar spray (at 25, 50 and 75 DAS) of K or G sap @ 5 and 10% concentrations resulted in significantly higher plant height, dry-matter accumulation, chlorophyll content and lower leaf temperature as compared to the control (water spray). The yield attributes like length of cobs, grain rows/cob, grains/row and grain yield were significantly higher with foliar application of 10% G or K sap either 3 or 2 times. The net returns were increased significantly only up to 2 time applications of 10% G or K sap (at 25 and 50 DAS) by ₹4,746 and 3,305 over the control (water spray) respectively. Thus, 2 times spray of 10% G or K sap (at 25 and 50 DAS) is recommended to improve growth, yield and profitability of maize for NER of India.

Key words **:** Bio-stimulant, Chlorophyll index, Maize, Organic, Root length, Seaweed sap

Seaweeds form an integral part of marine coastal ecosystems. They include the macroscopic and multicellular marine algae which commonly inhabit the coastal regions of the world's oceans. Brown seaweeds are the second most abundant group, comprising about 2,000 species and they are the types most commonly used in agriculture (Blunden and Gordon, 1986). Apart from relieving the pressure on agricultural land, it is also noteworthy that the cultivation method neither requires any irrigation water nor any fertilizer. Seaweeds contain all the trace elements and plant growth hormones such as auxins, cytokinins and gibberellins that provide a major boost to crop yields by accelerating the plant's metabolic function. The Council of Scientific and Industrial Research (CSIR)-Central Salt and Marine Chemical Research Institute (CSMCRI), India, had introduced the commercially important seaweeds, *Kappaphycus alvarezii*) and *Gracilaria edulis* in India and developed a practical cultivation technology leading to large-scale farming of this seaweed in shallow coastal waters. While the extracts from *Kappaphycus alvarezii* (K sap) contain good amount of indole acetic acid (23.4 mg/L), gibberelin (27.8 mg/L) and kinetin + zeatin (31.9 mg/L), while the extracts from *Gracilaria edulis* (G sap) contain significant amount of phosphorous (278.5 mg/L), sodium (1952 mg/L), iron (12.7 mg/L) and manganese (32.9 mg/L) (Rathore *et al*., 2009; Benjama and Masniyom,

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2012; Pramanick *et al*., 2013). Significant enhancement in productivity owing to foliar application of seaweed sapin wheat (Shah *et al*., 2013), tomato (Demir *et al*., 2006), okra (Zodape *et al*., 2008) and blackgram (Murugalakshmikumari *et al*., 2002) have been reported.

Maize is the secondmost important food crops of North Eastern Region (NER) of India after rice, occupying an area of about 0.18 m ha with an average productivity of 1.5 t/ha, which is much below the national average (2.5 t/ha). Maize productivity in NER India is low due to inappropriate nutrient-management practices among many other reasons. One of the available strategies to improve the productivity is use of chemical fertilizer and pesticides. But the farmers of this region have apathy towards the use of chemical fertilizers and other agro-chemicals in crop production (Das *et al*., 2013). Organic manure application is also very less in maize due to poor availability, bulky nature, difficultiesin transportation and application preference towards high-value crops like vegetables. The region has great potential for the promotion of organic farming. Thus seaweed sap can become an alternative, as it is an organic product. Studies revealed that seaweed saps are successful in enhancing productivity of crops when applied along with chemical fertilizer or organic manure (Zodape, 2008). So far there is no report on seaweed sap application on maize for hill ecosystems of India. There is a need to standardize the concentration and number of foliar spray of seaweed saps on maize. Hence, present investigation was conducted to study the effect of foliar applications of Ksap and Gsapon growth, yield and quality of maize.

MATERIALS AND METHODS

The experiment was carried out during the rainy (*kharif*) seasons of 2012 and 2013 at the research farm (upland agronomy field, 25°302 N and 91°512 E) of the ICAR Research Complex for NEH Region, Umiam, Meghalaya. The long-term average rainfall of the site is about 2450 mm. Daily mean temperature during the monsoon season (June–October) ranges from 23 to 32°C. The year 2012 and 2013 received less amount of rainfall (2089.4.1 mm and 2021.8 mm respectively) than the long-term average annual rainfall (2,450 mm) of the site. The soil was sandy loam, acidic (*p*H 5.2) with low in available N (249.3 kg/ha) and phosphorus (9.9 kg P/ha) and medium in available potassium (251.8 kg/ha).

Before initiating field experiment, sea weeds saps (K sap from *Kappaphycus* and G sap from *Gracilaria*) were tested for their efficacy in improving germination percentage and seedling vigour of maize. Two sea weed saps (K sap and G sap) were tested in petridish experiment for their efficacy in improving germination percentage and seedling vigour of maize. Fifty maize seeds were soaked with concentration of 5, 10 and 15% of K sap and G sap, each for 24 h and thereafter, seeds were placed in various petri-dishes and watered with distilled water regularly. Water-soaked seeds were used as the control. Observations on germination, shoot length and root length were recorded. Seed vigour index-I was calculated based germination (%) and seedling length using the following formulae of Abdul-Baki and Anderson (1973).

Seed vigour index I = Germination % × seedling length (cm)

Treatments consisted of 2 types of seaweed sap (K sap and G sap), 2 concentrations (5 and 10%) and 3 spray schedules[at 25 days after sowing (DAS), 25 and 50 DAS and 25, 50 and 75 DAS] along with no sap (water spray) as the control. Thirteen treatment combinations wereT_1, no sap (water spray); T_2, 5% K sap at 25 DAS; T_3, 5% K sap at 25 and 50 DAS; T_4, 5% K sap at 25, 50 and 75 DAS; T_6, 10% K sap at 25 DAS; T_7, 10% K sap at 25 and 50 DAS; T_7, 10% K sap at 25, 50 and 75 DAS; T_8, 5% G sap at 25 DAS; T_9, 5% G sap at 25 and 50 DAS; T_{10}, 5% G sap at 25, 50 and 75 DAS; T_{11}, 10% G sap at 25 DAS; T_{12}, 10% G sap at 25 and 50 DAS and T_{13}, 10% G sap at 25, 50 and 75 DAS. Thirteen treatment combinations were tried in a randomized-block design, replicated thrice. The gross plot size was 5.0 m × 4.0 m. Recommended dose on nitrogen, phosphorous and potassium, i.e. 80, 60 and 40 kg N, P_2O_5 and K_2O kg/ha were supplied for maize in the form urea, single super phosphate and muriate of potash respectively.

Sowing of maize (cultivar 'DA 61' A, high-yielding variety, recommended for mid-altitudes, up to 950 m above sea level) was done with the onset of pre-monsoon rain (in the 1st week of May) after proper field preparation. Seeds were sown in narrow furrows at a spacing of 50cm × 25cm. Thinning of excess plants and gap filling was carried out 15 DAS to maintain optimum plant population. Maize was fertilized with 50% N and 100% of P and K (as per the treatments) basal at the time of sowing, while the remaining 50% of N was applied in 2 equal splits at 30 DAS and 60 DAS.

Matured cobs were harvested from net plot (4.0 m × 3.0 m) manually. The harvested produce was allowed to sun dry on the concrete floor for 5–7 days before threshing. The grain yield was adjustedat 14% moisture content. The growth (plant height, dry-matter production) of maize were recorded at 90 DAS and harvesting, while the physiological attributes like chlorophyll index and leaf temperaturewere recorded at 90 DAS. Chlorophyll readings (index) were recorded in fully-expanded leaf using SPAD meter (Konica Minolta, SPAD 502) at active growth stage. Leaf temperature was recorded in the same leaves by Infra-red thermometer(Fluke 59 Max). The yield parameters, i.e. cob length, grain rows/cob, and grains/ row, were measured at maturity from randomly selected 10 plants in each plot. The post-harvest data on grain yield and straw yield were recorded from the net plot area of 4.0 m × 3.0 m. The 1,000-grain weight of maize was also recorded for all the treatments by random sampling from the graincollected from net plot area.

All the costs involved in carrying out farm operations and inputs were worked out individually for each treatment and taken as cost of cultivation. The revenue generated from the crops by way of seeds and stovers was taken as gross return and the difference between gross return and cost of cultivation was taken as net returns. The ratio between gross return and cost of cultivation was computed as benefit: cost ratio.

The experimental data pertaining to each parameter were subjected to statistical analysis by using the technique of analysis of variance and their significance was tested by 'F' test (Gomez and Gomez, 1984). Standard error of means (SEm±) and critical difference (CD) at 5% probability (P=0.05) were worked out for each character studied to evaluate differences between treatment means.

RESULTS AND DISCUSSION

Germination and seedling vigour

The maize seeds soaked with lower concentrations (5%) of both the seaweed saps (K sap and G sap) showed the highest rate of germination, while the higher concentration (15%) of the extracts inhibited the germination (Table 1). Improvement in germination and seedling vigour owing to seed soaking in low concentrations of seaweed saps were also reported in *Cajanus cajan* (Mohan *et al*., 1994) and *Dolichos* (Anantharaj and Venkatesalu, 2002). Spraying of 5% K sap being at par with 5% G sap recorded significantly higher root length and seed vigour index-I of maize seedlings compared to 10 and 15% K and G sap and the control. The highest shoot length was recorded under 10% G sap; however, it was statistically at par with 5% G sap, 10% K sap and 5% K sap as compared to rest of the treatments. Both the root and shoot lengths were recorded to be lower with 15% concentration of K or G sap as compared to water soaking. Sivasankari *et al*. reported (2006) increase in root and shoot length of different crops owing to application of low concentration of seaweed sap in *Vigna sinensis*. The increase in germination and seedling vigour at low concentrations of K or G sap may be due to presence of auxin and Gibberellins, phenyl acetic acid and micronutrients in the sap (Sivasankari*et al*., 2006).

Growth and physiological attributes

The plant height of maize was significantly influenced by the different concentrations of 2 types of seaweed sap (K or G sap) at 90 DAS and at harvesting (Table 2). Three (at 25, 50 and 75 DAS) or 2 (at 25 and 50 DAS) application of 5% K or G sap also recorded taller maize plant in both 90 DAS at harvesting over the control (water spray). The highest plant height of maize was recorded with 10% G sap applied 3 times (at 25, 50 and 75 DAS) followed by 10% K sap applied threetimes, 10% G sap applied twice and 5% G sap applied thrice. However, these treatments at par with each other and recorded significantly higher plant height than control. This increase in plant height may be owing to higher nutrient availability with higher concentration of saps applied (Shah *et al*., 2013). Significantly higher dry-matter of maize at both 90 DAS was recorded with foliar spray 5 or 10% of K or G saps applied 2 or 3 times as compared to the single application and the control. At harvesting, significantly highest dry-matter was recorded with 10% G sap applied 3 times; however, it was at par with 2 time application of 10% G sap, 3 time application of 10% K sap and 3 time application of 5% G sap.The increase in dry matter may be due to the presence

Table 1. Effect of seaweed sap on germination and seedling vigour of 'DA 61 A' maize (pooled data of 2 years)

Treatment	Germination (%)	Root length (cm)	Shoot length (cm)	Seed vigour index I
Water soaking (0% sap)	83	9.9	6.1	821.7
5% K sap	94	11.7	7.4	1099.8
10% K sap	89	9.3	7.8	827.7
15% K sap	75	8.4	5.3	630.0
5% G sap	91	11.3	7.9	1028.3
10% G sap	85	9.7	8.1	824.5
15% G sap	73	7.9	5.9	576.7
SEm±	3.29	0.34	0.26	34.7
CD (P=0.05)	8.30	0.85	0.68	87.5

K sap, *Kappaphycus alvarezii* sap; *G sap, gracilariaedulis* sap of micronutrient (Sridhar and Rengasamy, 2011) and some growth-promoting substances (Blunden, 1991) in the seaweed extract leading to increased plant height, leaf area etc.

Foliar application of 10% G sap, 10% K sap, 5% G sap and 5% K sap twice or morerecorded significantly higher chlorophyll index in maize leaf at 90 DAS than 5% K sap applied once and the control. The highest chlorophyll index was recorded under 10% G sap applied 3 times, followed by 10% K sap applied 3 times, 10% G sap applied 2 times and 5% G sap applied 3 times. However, these treatments were statistically at par among them and significantly higher than the control. This increase in chlorophyll content in leaves can be attributed to reduction in chlorophyll degradation due to presence of betaines in the seaweed extract (Sivasankari *et al.,* 2006). Foliar application of 10% K or G sap sprayed 3 times also reduced the leaf temperature of maize at 90 DAS as compared to the control (no sap). This reduction in leaf temperature may be owing to efficient transpiration and subsequent cooling caused by application of seaweed saps.However, lower concentration of saps (5%) did not produce any significant effect of leaf temperature.

Yield attributes and yield

The yield attributes of maize like length of cob and number of rows/cob significantly increased by spraying with 3 or 2 application of 10% K or G sap and 3 times application of 5% K or G sapas compared to the control (water spray). However, the number of grains/row in maize cob increased significantly even under 5% K or G sap spayed twice compared to the control (Table 3). Improvement in yield attributes of maize could be attributed to the increase in movement of photosynthates from vegetative part to the developing grains (Nooden and Leopold, 1978).

Significantly highest grain yield of maize was recorded with 10% G sap applied 3 times (at 25, 50 and 75 DAS). However, it was at par with 10% K sap applied thrice, 10% G sap applied twice, 10% K sap applied twice, 5% G sap applied thrice, 10% G sap applied once and 5% K sap applied thrice. The remaining treatments were statistically at par with the control (water spray). Three times application (at 25, 50 and 75 DAS) of 10% G sap, 10% K sap and 2 times application (at 25 and 50 DAS) of 10% G and K sap sprays increased the maize yield by 19.5, 17.1, 16.1 and 13.4% respectively, over the control. The stover yield of maize was also significantly higher with foliar spray of 10% G or K sap applied 3 or 2 times and 5% K sap applied 3 times as compared to the control. Increase in yield attributes and yield owing to application of K sapand G sap extracts were also reported in soybean (Rathore *et al.,* 2009) and tomato (Zodape *et al.,* 2011). Presence of micro-elements (Featonby-Smith and van Staden, 1984) and plant growth regulators, especially cytokinins in *Kappaphycus* and *Gracilaria* extracts (Zhang and Ervin, 2008) could be the reason for this yield enhancement. The test weight of maize statistically did not vary with the treatments, as this characteris mainly governed by genetic factors.

Table 2. Growth and physiological attributes of maize as influenced by foliar application of seaweed saps (pooled data of 2 years)

Treatment	Plant height (cm) At harvest	Dry matter (g/plant) At 90 DAS	Dry matter (g/plant) At harvesting	Chlorophyll index at 90 DAS (SPAD reading)	Leaf temperature at 90 DAS (°C)
Control (water spray)	186.0	184.9	225.8	39.7	29.2
K sap 5% at 25 DAS	193.6	187.9	227.7	40.2	28.9
K sap 5% at 25 and 50 DAS	198.4	198.1	232.7	41.6	28.1
K sap 5% at 25, 50 and 75 DAS	200.8	202.4	237.9	42.3	28.0
K sap 10% at 25 DAS	195.3	192.3	231.6	41.3	28.9
K sap 10% at 25 and 50 DAS	200.4	203.2	240.5	42.1	28.0
K sap 10% at 25, 50 and 75 DAS	204.7	205.0	244.4	43.2	27.6
G sap 5% at 25 DAS	194.3	191.7	231.4	41.8	28.4
G sap 5% at 25 and 50 DAS	198.3	197.9	239.3	42.6	28.3
G sap 5% at 25, 50 and 75 DAS	201.6	199.0	242.7	42.7	28.1
G sap 10% at 25 DAS	196.0	193.1	235.1	41.8	28.8
G sap 10% at 25 and 50 DAS	202.1	208.4	245.1	42.8	28.5
G sap 10% at 25, 50 and 75 DAS	206.1	210.5	253.2	43.7	28.1
SEm±	3.2	4.3	3.7	0.5	0.3
CD (P=0.05)	9.4	12.5	10.7	1.3	0.9

K sap, *Kappaphycus alvarezii* sap; *G sap, gracilaria edulis* sap; DAS, days after sowing

Table. 3. Yield attributes, yield and economics of maize as influenced by foliar application of seaweed saps (two years pooled data)

Treatment	Cob length (cm)	Grain rows/cob	Grains/ row	Grain yield (t/ha)	Stover yield (t/ha)	1000 grain weight (g)	Cost of cultivation (10^3₹/ha)	Gross return (10^3₹/ha)	Net return (10^3₹/ha)	Benefit: cost ratio
Control (water spray)	15.5	11.9	26.1	4.10	10.02	257.3	30.6	53.7	23.2	0.76
K sap 5% at 25 DAS	15.7	12.3	26.8	4.18	10.31	259.8	31.8	54.8	23.0	0.72
K sap 5% at 25 and 50 DAS	16.3	12.8	29.8	4.28	10.37	262.5	33.0	56.1	23.1	0.70
K sap 5% at 25, 50 and 75 DAS	16.9	13.5	30.8	4.45	11.34	266.7	34.2	58.3	24.1	0.71
K sap 10% at 25 DAS	16.2	12.4	28.4	4.37	10.73	260.8	32.5	57.3	24.7	0.76
K sap 10% at 25 and 50 DAS	17.0	13.3	31.8	4.65	11.39	269.2	34.5	60.9	26.5	0.77
K sap 10% at 25, 50 and 75 DAS	17.6	13.9	31.6	4.78	11.40	276.7	36.4	62.6	26.2	0.72
G sap 5% at 25 DAS	16.1	12.2	27.4	4.11	10.58	260.0	31.8	53.8	22.1	0.70
G sap 5% at 25 and 50 DAS	16.7	13.0	29.1	4.29	10.40	275.8	33.0	56.2	23.2	0.71
G sap 5% at 25, 50 and 75 DAS	17.5	13.3	30.5	4.59	10.81	277.5	34.2	60.13	26.0	0.76
G sap 10% at 25 DAS	16.9	12.5	29.1	4.46	10.81	265.8	32.5	58.4	25.9	0.80
G sap 10% at 25 and 50 DAS	17.7	13.3	30.5	4.76	11.67	273.3	34.5	62.4	27.9	0.81
G sap 10% at 25, 50 and 75 DAS	18.0	13.6	30.5	4.90	11.56	281.7	36.4	64.2	27.8	0.76
SEm±	0.4	0.4	0.6	0.17	0.29	7.8	0.89	1.43	0.78	0.02
CD (P=0.05)	1.3	1.1	1.7	0.49	0.85	NS	2.57	4.13	2.25	0.06

K sap, *Kappaphycus alvarezii* sap; *G sap, gracilaria edulis* sap; DAS, days after sowing; B: C ratio, Benefit cost ratio

Economics

The cost of cultivation was the lowest with control and it increased with increase in seaweed sap concentrations and number of sprays (Table 3). The highest cost of cultivation was recorded with 3 time application of 10% K or G sap (25, 50 and 75 DAS). This is due to additionof cost of seaweed sap to the overall cost of cultivation. The highest gross returns and net returns were observed under 3 time application of 10% G sap (at 25, 50 and 75 DAS). However, it was being at par with three time spray of 10% K sap (25, 50 and 75 DAS) and two time spray of 10% G or K sap (25 and 50 DAS). This may be due to higher yield of maize observed under 3 time application of 10% G or K sap. However, the benefit: cost ratio was highest in 2 time application of 10% G sap (25 and 50 DAS) followed by single application of 10% G sap (at 25 DAS) to maize.

It is evident from the study that 2 time application of 10% from *Kapphaphycus alvarezii* (K sap) and *Gracilaria edulis* (G sap) at 25 and 50 DAS may be recommended to improve growth, yield and profitability of maize in north eastern region of India.

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