Madras Agric. J., 104 (4-6): 161-165, June 2017

Evaluating the Effect of Seaweed Formulations on the Quality and Yield of Sugarcane

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The effect of seaweed formulations on the growth and development, quality and yield response of sugarcane variety Co 86032 was evaluated by conducting field experiment. The results of the study indicated that the foliar application of seaweed formulations with different concentrations significantly improved the plant height, LAI, SPAD value and total dry matter production (TDMP), yield and yield components compared to control plants. Among the seaweed extract formulations tested, LBS 6 @ one ml/L recorded significantly higher plant growth parameters, yield attributes and cane yield (161 t. ha^{-1}) compared to other treatments studied. It was found that sugarcane cane yield was increased significantly by 22.2 % over control. This treatment also recorded higher economic returns (Rs. 2,38,300. ha^{-1}) and benefit cost ratio (2.08).

Key words: Seaweed biostimulant, Sugarcane, Yield, Quality, B:C ratio.

Seaweeds are the macroscopic marine algae found attached to the bottom in shallow coastal waters. Marine algae grow in the intertidal, shallow and deep sea areas up to the 180 meter depth and also in the solid substrates such as rocks, dead corals and pebbles. The seaweeds are totally different from higher plants as they neither have true leaves, stems and roots (Thirumaran *et al.,* 2009). In agriculture, seaweed has proved effective in enhancing yield, pest and frost resistance in vegetables, fruits, cereals, and pulses. Seaweed extracts had the beneficial effect on seed germination and plant growth (Bhosle *et al.,* 1975). Verklejj (1992) reported that content of seaweed helps to promote plant growth, increase cell elongation, nutritional value and also sugar content of the product and thus, result in high yield and early maturity. It stimulates cell division, activates metabolism of each cell, and increases crop physiological activity. It increases root growth and development, flowering, bloom set and fruiting. Sunarpi and Nirahman (2008) reported significant growth of bean plants, tomato plants and yield and quality of okra (Zodape *et al.,* 2008) due to spraying of seaweed extract.

Further, seaweed extracts have proven to accelerate the health and growth of plants. These extracts supply nitrogen, phosphorous, potash as well as trace minerals like Zn, Mn, Mg, Fe, etc (Crouch *et al.,* 1990). These trace elements present in seaweed extract are in naturally chelated form and are readily available to plants. It accelerates photosynthesis and further develops healthy foliage (Kavitha *et al.,* 2008). Its extract contains natural plant growth substances like auxins, gibberellins and cytokinins (Crouch and Van Staden, 1993) and have been reported to stimulate the growth and yield of plants (Rama Rao, 1992), increase nutrient uptake from soil (Turan and Kose, 2004) and enhance antioxidant properties (Verkleij, 1992). Liquid extracts obtained from seaweeds have recently gained importance as foliar sprays for many crops including various grasses, cereals, flowers and vegetable species. Foliar spraying of seaweed sap to crops, vegetables and trees increased growth, grain and yield of plants (Stirk and Van Staden, 1997). In sugarcane, the reduced productivity being observed in India could be addressed by application of biostimulant, which indirectly enhances the plant to assimilate more nutrients from the soil, which translates into increased yield. A significant influence of seaweed saps (crude farm of 5 % *Kappaphycus* and 7.5 % *Gracilaria* saps as sett treatment and 2 foliar spray at formative phase) on shoot population, LAI, TDMP, yield parameters and yield was recently reported in sugarcane (Vasantha *et al.,* 2014). In the present study, the main focus is to test the effect of purified Sea6 formulation in different concentrations on growth, yield and quality of sugarcane.

Material and Methods

A field experiment was conducted at Bannari Amman Sugar Factory, Sathiaymangalam during 2016-17 by ICAR-Sugarcane Breeding Institute, Coimbatore. The experiment was conducted in Randomized Block Design with three replications and nine treatments. The sugarcane variety Co 86032 was used for this study. The foliar spray of seaweed saps was effected thrice during formative phase (30, 60 and 90 DAP). The foliar application of liquid biostimulant (LBS) formulations namely, LBS 3 @ 5 ml/L (T_1), LBS 4 @ one ml/L (T_2), powder biostimulant (PBS) 1 @ 0.25 g/L (T_3), LBS 7 @ one ml/L (T_4), LBS 6 @ 0.5 ml/L (T_5), LBS 6 @ one ml/L (T_6), *Ascophyllum nodosum* (ASN) 1 @ one ml/L (T_7), LBS 7 @ 0.5

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ml/L (T_8) and T_9 as control (without foliar spray). The recommended dose of fertilizers and other packages of practices for sugarcane were imposed uniformly for all the treatments including control. The field observations of biometric, growth and yield parameters were taken at different stages of the crop and at harvest. Sugarcane juice quality for Brix and Pol percentage was analyzed as per the standard methods. The economics was worked out for treatment plots. The data on biometric, growth, yield and quality of sugarcane were statistically analyzed with methods given by Gomez and Gomez (1984). The physiochemical property of biostimulant product given by the firm is listed in Table 1.

Results and Discussion

Germination is a critical process in the life of sugarcane plant. Good germination provide the healthy and strong basis for a better crop yield.

Table 1. Specification for liquid biostimulant formulation

Specifications	
Solid, per cent by weight, minimum	20
Colour	Dark brown
Odour	Marine smell
Solubility (in water)	Soluble
Specific gravity	1.12-1.15
Total organic carbon (g/kg), minimum	2.6
Total potassium (K_2O), (g/kg), minimum	60
Total Sulfur (S), g/kg), minimum	0.75
Total Heavy metal content, (mg/kg)	
Arsenic (As)	2.00
Cadmium (Cd)	0.50
Chromium (Cr)	5.00
Mercury (Hg)	0.01
Nickel (Ni)	2.00
Lead (Pb)	0.50

Hence, the germination was recorded at 35 days after planting (DAP) in plant crop. Germination was uniform and it was 100 % in the entire experimental plot studied (Table 2).

Shoot population was recorded at 60, 90, 120 and 150 DAP and the population was found higher in all the treatment studied over the control (Table 2). In general, shoot population reached the maximum at 90 DAP (170.9 thousand ha^{-1}) and declined at 120 DAP (161.8 thousand ha^{-1}) and 150 DAP (135.8 thousand ha^{-1}) thereafter population was maintained till harvest. Except for 60 DAP, the treatment effect was found to be significant at 90, 120 and 150 DAP. At 60 DAP the seaweed formulation treatments did not influence the shoot population. However, at later stages, application of foliar spray of sea6 formulation particularly, LBS 6 @ one ml/L (T_6) recorded maximum shoot population of 168.9 and 141.7 thousand ha^{-1} at 120 and 150 DAP, respectively. The results were on par with LBS 3 @ 5 ml/L (T_1) and followed by LBS 7 @ one ml/L (T_4) at 150 DAP. The minimum shoot population of 155 and 129 thousand ha^{-1} was recorded in control at 120 and 150 DAP, respectively. Similar improvement in tiller production due to seaweed sap was reported in sugarcane at early growth phase (90 DAP) and the difference in tiller production was smoothened at later stages *i.e.* 150 DAP (Vasantha *et al.,* 2014). In the present study, the application of seaweed formulation up to 90 DAP perhaps effected in significant improvement in tiller production even at later stages of the crop, which helps to sustain the number of millable canes (NMC) (Table 2).

Crop growth parameters

Sugarcane, in general posses fairly high crop growth rate, compared to other cultivated crops. Crop growth and physiological parameters *viz.,* plant height, leaf area index (LAI), SPAD value and total dry matter production (TDMP) recorded at 120, 150 and 210 DAP shows that foliar application of seaweed formulations with different concentrations significantly improved plant growth compared to the control plants (Table 3). The higher plant height (149, 180.2 and 251.3 cm), LAI (3.84, 4.88 and 5.33) and SPAD value (40.9, 43.3 and 47.6) were recorded in

Table 2. Effect of seaweed biostimulant formulations on germination (%) and shoot population of sugarcane

Treatments	Germination (%)	Shoot population (000' ha^{-1}) / DAP				NMC (000' ha^{-1})
		60	90	120	150	
LBS 3 @ 5 ml/L	100	159.8	170.6	166.3	140.2	138.5
LBS 4 @ 1 ml/L	100	157.2	168.8	163.3	137.0	135.3
PBS 1 @ 0.25 g/L	100	154.0	169.2	156.8	134.9	131.2
LBS 7 @ 1 ml/L	100	161.3	177.2	165.4	139.9	135.2
LBS 6 @ 0.5 ml/L	100	156.2	171.7	163.3	133.3	132.6
LBS 6 @ 1 ml/L	100	163.3	179.4	168.9	141.7	140.0
ASN 1 @ 1 ml/L	100	158.2	173.9	158.3	133.5	130.8
LBS 7 @ 0.5 ml/L	100	154.6	167.2	158.6	132.3	131.6
Absolute control	100	161.3	160.9	155.0	129.0	125.4
Mean	100	158.4	170.9	161.8	135.8	133.3
SEd	-	4.5	5.0	4.6	4.0	5.4
CD (P=0.05)	-	NS	11.0	9.8	8.6	11.5

Note: Liquid biostimulant (LBS), Powder biostimulant (PBS), Ascophyllum nodosum (ASN) foliar application of seaweed extract LBS 6 @ one ml/L (T_6) at 120, 150 and 210 DAP, respectively. It was on par with LBS 7 @ one ml/l (T_4), LBS 3 @ 5 ml/L (T_1) followed by ASN 1 @ one ml/L (T_7) in all the stages studied. The significantly lower plant height (130.6, 147.5 and 201.5 cm), LAI (3.39, 3.41 and 3.69) and SPAD value (38.1, 40.5 and 43) were recorded in control at 120, 150 and 210 DAP, respectively. Similar improvement in plant height and SPAD value due to sea sap foliar application was reported in sugarcane (Vasantha *et al.,* 2014). However, they could not find any significant difference in LAI with sea sap treatments, but for higher tiller mortality.

Table 3. Effect of seaweed biostimulant formulations on growth parameters at different stages of sugarcane

Treatments	Plant height (cm) / DAP			Leaf area index (LAI) / DAP			SPAD value / DAP			Total dry matter production (TDMP) (t. ha^{-1}) / DAP		
	120	150	210	120	150	210	120	150	210	150	210	360
LBS 3 @ 5 ml/L	139.9	161.8	234.8	3.51	4.55	5.29	40.3	42.4	46.6	45.9	52.9	71.4
LBS 4 @ 1 ml/L	128.1	148.2	217.2	3.42	3.45	4.76	40.3	41.2	45.3	40.2	46.4	62.7
PBS 1 @ 0.25 g/L	133.4	160.0	227.3	3.46	3.99	4.18	39.5	42.0	45.8	42.3	47.6	64.2
LBS 7 @ 1 ml/L	140.1	164.8	236.2	3.57	4.56	5.25	40.5	43.5	47.4	43.1	51.1	68.9
LBS 6 @ 0.5 ml/L	132.2	158.0	218.8	3.40	4.22	4.66	39.4	41.9	45.6	42.6	49.1	66.3
LBS 6 @ 1 ml/L	149.0	180.2	251.3	3.84	4.88	5.33	40.9	43.3	47.6	59.4	66.7	86.7
ASN 1 @ 1 ml/L	140.1	161.5	230.0	3.46	3.42	3.78	39.6	42.1	45.4	40.4	46.6	62.9
LBS 7 @ 0.5 ml/L	136.2	156.2	224.5	3.51	4.52	4.94	39.8	41.3	46.4	37.6	43.4	58.5
Absolute control	130.6	147.5	201.5	3.39	3.41	3.69	38.1	40.5	43.0	31.5	36.4	50.2
Mean	137.2	159.8	226.9	3.51	4.11	4.65	39.8	42.0	45.9	42.6	48.9	65.8
SEd	4.6	5.4	7.8	0.11	0.14	0.15	1.2	1.3	1.4	2.2	2.5	3.2
CD (P=0.05)	9.7	11.6	16.6	0.24	0.30	0.33	2.5	2.7	2.9	4.7	5.2	6.8

Note: Liquid biostimulant (LBS), Powder biostimulant (PBS), *Ascophyllum nodosum* (ASN)

Application of LBS 6 @ one ml/L (T_6) showed maximum dry matter production of 59.4, 66.7 and 86.7 t. ha^{-1} at 150, 210 DAP and 360 DAP, compared to control 31.5, 36.4, 50.2 t. ha^{-1}, respectively. Next to LBS 6 @ one ml/l (T_6), the treatment LBS 3 @ 5 ml/L (T_1), LBS 7@ one ml/L (T_4) and ASN 1 @ one ml/L (T_7) recorded higher TDMP. The foliar application of seaweed formulation to improve the nutrient mobilization, increased leaf area, dry matter production, and crop growth rate has been reported by Vasantha *et al.* (2014) and Zodape *et al.* (2009) in sugarcane and wheat, respectively.

Table 4. Effect of seaweed biostimulant formulations on yield components and juice quality parameters of sugarcane

Treatments	Number of internodes	Cane length (cm)	Cane thickness (mm)	Single cane weight (kg)	Brix (%)	Sucrose (%)	Purity (%)	CCS
LBS 3 @ 5 ml/L	26.8	245.6	31.5	1.09	19.7	17.5	89.1	12.2
LBS 4 @ 1 ml/L	25.6	242.0	29.0	1.06	19.3	17.0	87.9	12.7
PBS 1 @ 0.25 g/L	24.6	232.5	28.3	1.07	19.4	17.5	89.8	12.2
LBS 7 @ 1 ml/L	26.2	247.0	31.4	1.12	20.0	17.6	88.2	12.2
LBS 6 @ 0.5 ml/L	24.7	233.5	30.4	1.10	19.7	17.5	88.1	12.4
LBS 6 @ 1 ml/L	27.7	261.5	32.2	1.23	21.0	18.9	89.6	13.0
ASN 1 @ 1 ml/L	25.7	242.6	29.5	1.04	20.1	18.0	89.6	12.9
LBS 7 @ 0.5 ml/L	25.8	244.2	29.3	1.15	20.7	18.3	88.4	12.6
Absolute control	23.6	222.8	28.7	1.03	20.5	17.8	87.0	12.2
Mean	25.6	241.3	30.0	1.10	20.0	17.8	88.5	12.4
SEd	0.8	7.9	0.9	0.04	0.8	0.7	3.3	0.5
CD (P=0.05)	1.8	16.8	1.9	0.08	NS	NS	NS	NS

Note: Liquid biostimulant (LBS), Powder biostimulant (PBS), Ascophyllum nodosum (ASN)

Yield and Yield attributes

Foliar application of Seaweed formulations with different concentrations significantly improved yield attributes compared to control plants (Table 4). The yield attributes *viz.,* the number of internodes (27.7), cane length (261.5 cm), cane thickness (32.2 mm) and single cane weight (1.23 kg) were increased significantly by 17.31, 17.36, 12.09 and 19.41 % over control with foliar application of seaweed extract LBS 6 @ one ml/L and it was followed by LBS 7 @ one ml/L (T_4), LBS 3 @ 5 ml/L (T_1) and ASN 1 @ one ml/L (T_7). Foliar spraying of seaweed extract significantly increased higher growth and yield attributes of wheat (Shah *et al.,* 2013) and sugarcane (Vasantha *et al.,* 2014). Similar by foliar application of seaweed sap as biostimulant has been reported to enhance yield and quality of tomato (Zodape *et al.,* 2011). Whereas, in paddy, it recorded 26 % higher grain yield as compared to control (Kavitha *et al.,* 2008).

The presence of plant growth regulators, trace elements, vitamins and micronutrients in seaweed extract enhanced the growth and yield contributing characters of number, weight, and length of the spike as well as grain weight (Ramya *et al.,* 2001). The significantly lower number of internodes (23.6), cane length (222.8 cm), cane thickness (28.7 mm) and single cane weight (1.03 kg) were recorded in control at harvest.

Table 5. Effect of seaweed biostimulant formulations on cane yield and economics of sugarcane

Treatments	Cane yield (t. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio
LBS 3 @ 5 ml/L	145.1	213815	413535	199720	1.83
LBS 4 @ 1 ml/L	139.8	206770	398430	191660	1.92
PBS 1 @ 0.25 g/L	138.8	205445	395580	190135	1.93
LBS 7 @ 1 ml/L	148.2	212230	422370	210140	1.90
LBS 6 @ 0.5 ml/L	142.1	207815	404985	197170	1.85
LBS 6 @ 1 ml/L	161.0	220550	458850	238300	2.08
ASN 1 @ 1 ml/L	135.7	204105	386745	182640	1.89
LBS 7 @ 0.5 ml/L	141.9	207685	404415	196730	1.95
Absolute control	131.7	200605	375345	174740	1.80
Mean	142.7	-	-	-	-
SEd	6.0	-	-	-	-
CD (P=0.05)	12.7	-	-	-	-

Note: Liquid biostimulant (LBS), Powder biostimulant (PBS), Ascophyllum nodosum (ASN)

The number of millable canes per ha increased due to seaweed extract foliar application (Table 2). The maximum millable canes (141 thousand ha^{-1}) was obtained with foliar application of seaweed extract LBS 6 @ one ml/L (T_6) and it showed 11.64 % over control. The above treatment was followed by foliar application of LBS3 @ 5 ml/L (T_1) and LBS 7 @ one ml/L (T_4). In contrast, application of seaweed sap does not show significant improvement in NMC in sugarcane (Vasantha *et al.,* 2014)

Cane yield of sugarcane was found to be significantly improved with the foliar application of seaweed formulations at different concentrations compared to control (Table 5). Among the treatments studied, foliar application of seaweed extract LBS 6 @ one ml/L (T_6) was observed to be significantly higher with respect to cane yield (161 t. ha^{-1}) with 22.2 % increase over control. It was followed by LBS 7 @ one ml/L (T_4), LBS 3 @ 5 ml/L (T_1) and ASN 1 @ one ml/L (T_7). Application of seaweed liquid fertilizer enhanced the water retention capacity of soil. The contents of seaweed help to promote plant growth, increase cell elongation, nutritional value and also sugar content of the product and thus result in high yield. This was due to the presence of readily available nutrients like nitrogen, phosphorous, potassium as well as trace minerals, which help in increasing the yield of rice as reported by Kavitha *et al.* (2008) and Patel *et al.* (2015).

Juice quality

The juice quality parameters with respect to Brix, sucrose, purity and CCS % presented in Table 4 indicated that the juice quality was not affected by foliar application of seaweed extract with different concentrations. Similar findings were also reported by Deshmukh and Phonde (2013).

Economics

The foliar application of seaweed extract formulation of LBS 6 @ one ml/L (T_6) recorded higher gross returns (Rs. 4,58,850. ha^{-1}), net returns (Rs. 2,38,300. ha^{-1}) and higher B:C ratio (2.08). This treatment recorded additional gross return (Rs. 83,505. ha^{-1}) and net returns (Rs. 63,560. ha^{-1}) compared to control (Table 5).

Conclusion

The seaweed extracts influence the biometric parameters and cane yield positively and significantly. Among the treatments, maximum improvement in cane yield was observed with LBS 6 @ one ml/L (T_6) at 22.2 % followed by LBS 7 @ one ml/L (T_4) at 12.5 %. The best treatment LBS 6 @ one ml/L (T_6) gave additional gross return of Rs. 83,505. ha^{-1} and net returns of Rs. 63,560. ha^{-1} compared to control. It is concluded that the foliar application of seaweed extract LBS 6 @ one ml/L (T_6) could increase cane yield with higher economic returns and benefit: cost ratio.

Acknowledgement

The financial support received from Sea6 Energy PVT Company, Bangalore is gratefully acknowledged. The authors are thankful to Bannari Amman Sugar Factory, Sathiaymangalum for providing field for conducting research and the Director, ICAR-Sugarcane Breeding Institute, Coimbatore for his encouragement and facilities.

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Received after revision : April 15, 2017; Accepted : May 31, 2017