J Appl Phycol
DOI 10.1007/s10811-017-1211-6

The effect of potassium-rich biostimulant from seaweed *Kappaphycus alvarezii* on yield and quality of cane and cane juice of sugarcane var. Co 86032 under plantation and ratoon crops

K. Karthikeyan[1] · M. Shanmugam[1]

Received: 2 August 2016 / Revised and accepted: 25 June 2017

Abstract A field experiment was conducted during 2011–2015 to study the effect of potassium-rich biostimulant manufactured from seaweed *Kappaphycus alvarezii* on growth, yield, and quality of sugarcane var. Co 86032 with plant and three consecutive ratoon crops. The concentrated biostimulant manufactured from *K. alvarezii* had 17.45% of solid content with majority potash (11.28%) and other macro-micro nutrients and plant growth substances. Sugarcane setts were treated with 0.3% of biostimulant and planted. During crop development, 1% of biostimulant was applied three times, i.e., first dose at the time of germination phase (30 days), second dose at tiller sprouting stage (75th day), and last dose was given at the stage of building of the sugar content (125 days) in both plantation and three consecutive ratoon crops. The higher cane yield obtained from treated plant over control was 24.90, 28.79, 20.47, and 26.16% more in plant crop, 1st, 2nd, and 3rd ratoon crops, respectively, with statistically significant values in commercial cane sugar yield, brix, purity, and polarity. The present research suggests that natural potash from seaweed can be applied on sugarcane to improve yield and quality of cane and cane juice.

Keywords Seaweeds · *Kappaphycus alvarezii* · Biostimulant · Natural potash · Sugarcane · Variety Co 86032

✉ M. Shanmugam
m.shanmugam@aquagri.in

[1] Research and Development Division, AquAgri Processing Private Limited, #B5, SIPCOT Industrial Complex, Manamadurai - 630 606. Sivaganga District, Tamil Nadu, India

Introduction

Sugarcane is one of the important commercial crops in India; it is the third largest crop, next to rice and wheat. Globally, about 70% of sugar is manufactured from sugarcane and 30% from sugar beet (Tamil Selvi 2012). The average yield of cane stalk per year is 60–70 t ha^{-1}. Sugarcane is not only a cash crop, but it is also used as livestock fodder (Perez 1997).

Globally, Brazil is the major sugar producer contributing 21.81% in 2014–2015, followed by India (14.68%), European Union (11.0%), and China (8.04%). In India, sugarcane is mainly cultivated in Uttar Pradesh (47.05%), Maharashtra (17.52%), Karnataka (7.76%), and Tamil Nadu (7.47%) and the highest sugarcane production is from Maharashtra (37.63%) followed by Uttar Pradesh (27.39%), Karnataka (13.53%), and Tamil Nadu (6.77%) (Commission for Agricultural Costs and Prices 2014). Production of sugarcane and sugar during 2013–2014 from 50.12 × 10^5 ha was about 359.33 and 25.05 Mt, respectively, and in 2014–2015 from same cultivation area it was 352.14 and 24.55 Mt. About 173.4 Mt was recorded as the production of sugar in total worldwide in the year 2015–2016 and it was 174.3 Mt in the year 2014 to 2015. In India, sugar production has increased 2.63% in last 10 years at CAGR. The country's sugar demand is around 25.6 Mt and is expected to grow at 3–4% per annum; by 2020, sugar demand is pegged at 30 Mt (AGRICOOP 2016).

In the nineteenth century, coastal people started using seaweed as fertilizer and gained the knowledge about the application of seaweeds on crops. Most use brown seaweeds such as *Ascophyllum nodosum*, *Laminaria* spp., *Turbinaria* spp., *Sargassum* spp., and *Fucus* spp. as biofertilizers in agriculture crops (Hong et al. 2007), but the red seaweed *Kappaphycus alvarezii* also has gained attention in this regard in recent years (Mondal et al. 2015; Karthikeyan and Shanmugam 2016).

Published online: 15 July 2017

Seaweeds are rich in macro- and micronutrients, amino acids, vitamins, and plant growth regulators (Stirk et al. 2004; Lötze and Hoffman 2016; Karthikeyan and Shanmugam 2016). Seaweeds have a high fiber content which acts as soil conditioner and in moisture retention. Verkleij (1992) reported that the application of seaweed liquid fertilizer enhanced the water retention capacity of soil. The content of seaweed helps to promote plant growth like increasing cell elongation, nutritional value, and increases the sugar content which result in high yield without compromising quality. Seaweed extracts stimulate cell division and improve the metabolic activity of each cell and physiological activity of the crops. It increases root growth and development, flowering, bloom, and fruiting. The application seaweed-based plant nutrients on agricultural crops has been reviewed by Khan et al. (2009), Craigie (2011), Tuhy et al. (2013), and Arioli et al. (2015). Biostimulant (sap) from *K. alvarezii* is reported to have potash, inorganic nutrients, and four plant growth substances, viz. indole acetic acid (IAA), gibberellic acid (GA3), kinetin, and zeatin (Prasad et al. 2010). Rathore et al. (2009) reported that virgin sap of *K. alvarezii* contained 1.97% potash together with other micronutrients. Mondal et al. (2015) claims that GA3 and IAA free biostimulant (K-Sap) from *K. alvarezii* applied on corn through foliar spray yielded high photosynthetic activity which translated into a 26% increase in corn stover yield compared to one treated with pristine sap. The function of potassium is in the synthesis of protein, starch formation, photosynthesis, regulating stomata opening and closure, and in addition to this it helps in the plant to absorb the nutrients and water more proficiently. The most important role of K is that to synthesis and translocation of sucrose and proteins from leaves to store tissues and promote the development of roots. If there is potash deficiency, sugars will remain in the leaves instead of being transported, stored, and harvested in the stalks (Filho 1985). Land preparation and initial seedlings costs contribute to about 50% of total production cost in the sugarcane crop, therefore minimizing these without compromising the yield and quality of cane would be great advantage to farmers. The present investigation attempts to study the impact of potash-rich concentrated sap from seaweed *K. alvarezii* on the growth, development, cane yield, and brix level of sugarcane variety Co 86032 on plantation and three consecutive ratoons.

Material and methods

Preparation of the field experiment The experiment was carried out at R&D plot of AquAgri Processing Private Limited in Manamadurai, Sivagangai Dt., Tamil Nadu, India (9° 42′56″N; 78° 28′2″E). Farmyard manure was applied at 12.5 t ha^{-1} basis and plowed the experimental site for three times and soil was broken into fine soil with a rotovator. The trial plot was prepared as recommended by Tamil Nadu Agriculture University, India, as follows. Irrigation and drainage channel of 40 cm depth and 30 cm width at intervals of 6 m was plotted across the field borders. Ridges and furrows were formed with a spacing of 80 cm between formed rows with a spade. The furrows were hand hoed and the soil allowed to weather for 5 days.

Selection and plantation of setts Healthy setts with minimum three eye buds and disease-free canes were selected for plantation. The seed was planted at a rate of 40,000 per hectare. The setts were treated with 0.3% biostimulant for 10 min and placed along the center of the furrows, accommodating 12 buds m^{-1}. Buds were kept in the lateral position and pressed gently beneath the soil in the furrow. Exposure of setts to sunlight was avoided. The gaps found were filled within 30 days after planting with sprouted setts. Flooding method of irrigation was done for every 7–8 days during winter season and in summer the irrigation interval was 4–5 days. Chemical fertilizers were applied to crops as per the recommendation of Tamil Nadu Agriculture University.

Production and analysis of biostimulant Fresh *K. alvarezii* was pulverized into slurry and the slurry was passed through a decanter to separate liquid and residue as per the method described by Eswaran et al. (2005). The liquid portion was then double filtered to get clear sap with total solid (TS) content of 3.0 to 3.5% which was then concentrated to about five times through triple effect evaporators to get concentrated sap with TS of 17.45% to obtain Aquasap-5X (Shanmugam et al., personal communication). (Aquasap-5X is the brand name of AquAgri Processing (P) Ltd. and herein after called "biostimulant"). Biostimulant used in the present investigation was collected from the stock of AquAgri Processing (P) Limited, Manamadurai, India (Batch no: 28042012-3). The pH of biostimulant was measured using pH meter. Elements were analyzed by flame photometer and atomic absorption spectroscopy (Association of Analytical community's 18th edition, 2005). PGRs such as auxin (Gordon and Paley 1957), cytokinin (Syono and Torrey 1975), and gibberellic acid (Holbrook et al. 1961) were estimated using colorimetric methods (Table 1).

Application of biostimulant The concentrated biostimulant was applied to sugarcane at 1% concentration three times through foliar application. First spray was given at the germination stage (30 days), second dose was applied at the time of tiller sprouting stage (75th day), and last application was given at the stage of building the sugar content (125 days). The application of biostimulant was similar for both plantation and the three consecutive ratoon crops.

Measurement of growth parameters Physical parameters such as cane height, stalk height, number of internodes, and

Table 1 Physicochemical properties and nutrients profile of concentrated biostimulant from seaweed *K. alvarezii*

Parameters	Results
Physical properties	
Organic matter (g 100 g^{-1})	5.08
Specific gravity (g cm^{-3})	1.05
Electrical conductivity (dS m^{-1})	59.1
pH (1% solution)	8.5
Moisture content (g 100 g^{-1})	82.55
Total ash (g 100 g^{-1})	12.37
Macro and micro nutrients	
Nitrogen (N) (g 100 g^{-1})	0.15
Phosphorous (P) (g 100 g^{-1})	0.02
Potash (K) (g 100 g^{-1})	11.28
Calcium (Ca) (g 100 g^{-1})	0.33
Magnesium (Mg) (g 100 g^{-1})	0.32
Sulfur (S) (g 100 g^{-1})	0.20
Boron (B) (mg kg^{-1})	7680
Chloride (Cl^{-}) (g 100 g^{-1})	4.27
Copper (Cu) (mg kg^{-1})	200.7
Iron (Fe) (g 100 g^{-1})	0.03
Manganese (Mn) (mg kg^{-1})	5.93
Zinc (Zn) (mg kg^{-1})	3.13
Sodium (Na) (g 100 g^{-1})	1.34
Cobalt (Co) (mg kg^{-1})	1.18
Silica (Si) (g 100 g^{-1})	0.88
Amino acid	
Alanine (g 100 g^{-1})	0.022
Arginine (g 100 g^{-1})	0.034
Aspartic acid (g 100 g^{-1})	0.115
Cystine (g 100 g^{-1})	0.019
Glycine (g 100 g^{-1})	0.028
Histidine (g 100 g^{-1})	0.04
Isoleucine (g 100 g^{-1})	0.12
Leucine (g 100 g^{-1})	0.12
Lysine (g 100 g^{-1})	0.08
Tryptophan (g 100 g^{-1})	0.023
Methionine (g 100 g^{-1})	0.070
Phenylalanine (g 100 g^{-1})	0.031
Proline (g 100 g^{-1})	0.010
Serine (g 100 g^{-1})	0.145
Threonine (g 100 g^{-1})	0.031
Tyrosine (g 100 g^{-1})	0.065
Valine (g 100 g^{-1})	0.035
Glutamic acid (g 100 g^{-1})	0.059
Vitamins	
Vitamin C (mg kg^{-1})	26.419
Vitamin D (IU 100 g^{-1})	0.081
Vitamin B_2 (mg kg^{-1})	0.006
Vitamin B_3 (mg kg^{-1})	0.004
Vitamin B_5 (mg kg^{-1})	0.026
Vitamin B_6 (mg kg^{-1})	0.034
Growth hormones	
Auxin (mg kg^{-1})	330
Cytokinin (mg kg^{-1})	180
Gibberellic acid (mg kg^{-1})	550

cane girth were measured during growing period and at the time of harvest plant, and three consecutive ratoon crops.

Analysis of quality parameters Brix was measured using hand refractometer (ATAGO Brix meter), polarity was determined using polarimeter (Halmarc digital polarimeter), and purity was determined from the harvest of crop of plantation and ratoon as well. Percentage of purity was estimated as below:

$$Purity\ Percentage = (Sucrose\%/Brix) \times 100$$

Sugar recovery (%) was calculated by the following formula:

$$Sugar\ Recovery\ (\%) = [S{-}0.4\ (B{-}\mathrm{S})] \times 0.73$$

Where, S = Sucrose % in juice; B = Corrected Brix (%).

The commercial cane sugar (CCS) was calculated as below:

$$\mathrm{CCS}\ \left(\mathrm{t\ ha^{-1}}\right) = \left[Yield\ \left(\mathrm{t\ ha^{-1}}\right) \times Sugar\ Recovery\ (\%)\right]/100$$

Analysis of the results Tukey's HSD test was applied for post hoc comparisons. Pearson correlation analysis was used to find out the significant increasing in cane yield, cane height, stalk height, number of internodes, cane girth, and cane weight and to analyze the quality parameters like brix, polarity, purity, CCS and sugar recovery. Regression analysis was used to understand the determining factor(s) on cane yield, growth, and quality parameters of sugarcane. All the statistical analyses were made using the SYSTAT version 7 (Systat 1997).

Results

Physicochemical properties of biostimulant

Physicochemical properties and nutrients content of biostimulant manufactured from *K. alvarezii* are given in Table 1. Total solid content of concentrated biostimulant was 17.45% with total organic matter of 5.08% and 12.37% ash content. The contents of primary nutrients were nitrogen (0.15%), phosphorous (0.02%), and potassium (11.28%). Secondary nutrient concentrations were calcium (0.33%), magnesium (0.32%), and sulfur (0.20%). The amino acids ranged between 0.019 and 0.12% and vitamins ranged from 0.006 to 26 ppm. The content of growth promoters like auxin, cytokinin, and gibberellic acid estimated in biostimulant were as follows: auxin (330 ppm), cytokinin (180 ppm), gibberellic acid (500 ppm).

Cane yield

Cane yield obtained from plantation crop and three consecutive ratoons of both control and treated is given in Table 3. The cane yield in control plants were 102.59, 88.74, 90.91, and

88.53 t ha^{-1} in plantation, ratoons 1, 2, and 3, respectively, and they were 128.14, 114.29, 109.52, and 111.69 t ha^{-1} in treated plants.

Growth parameters of cane

Cane and stalk height The millable cane height with leaves of control plants in plantation, ratoons 1, 2, and 3 were 378.20 ± 19.17, 357.80 ± 28.75, 372.80 ± 20.09, and 351.00 ± 21.92 cm, respectively, and they were 448.20 ± 35.90, 428.00 ± 29.13, 431.60 ± 30.33, and 408.40 ± 46.74 cm in treated plants. The millable cane stalk height of 236.6 cm was found in control plants, and in three ratoons it was 218.4, 222.2, and 215.4 cm, respectively, and in treated plants they were 296, 269.20, 279, and 271.40 cm, respectively.

Internodes Number of internodes in control plants of plantation crop ranged from 12 to 18 (avg. 15.8) and in treated plant it was 16 to 20 (avg. 18.6) with 17.7% higher over control plants. Average of 17.6 (15 to 21) of internodes was observed in control plants against 19.8 (avg.) with range of 18 to 22 in treated plants of first ratoon. The range observed was 15 to 22 (avg. 17.80) in control plants and 15 to 24 (avg. 20.2) in treated plants of 2nd ratoon plants and the number of internodes in 3rd ratoon of control plant was 15.2 (12 to 22) and 19.20 (14 to 24) in treated plants.

Cane girth and cane weight The average girth in control at plantation crop was 30 mm, and in ratoons 1, 2, and 3 it was 26.9, 26.0, and 29.9 mm, respectively, and it was found to be greater in the respective treated plants, i.e., 36.7 mm in plantation plants and 33.9, 31.1, and 34.3 mm in the three ratoons, respectively. The average cane weight in control and treated plantation crop was 1.34 and 1.74 kg, respectively. In the 1st ratoon, it was 1.48 kg (1.11 to 1.77 kg) in control and 1.81 kg (1.59 to 1.92 kg) in treated plants and a similar trend also was observed between control and treated plants of the 2nd and 3rd ratoon crop (Table 3).

Quality of cane juice

Brix content The average brix content (%) of cane juice of control plant was 18.96 ± 1.24, 15.53 ± 1.42, 17.89 ± 1.55, and 17.06 ± 1.90 in plantation and three ratoons, respectively, and 19.21 ± 1.30, 16.93 ± 1.08, 18.91 ± 1.28, and 18.26 ± 1.72 in the respective treated plants (Fig. 1).

Polarity and purity The polarity level in treated plants of plantation crop was 16.19 ± 1.56%, and in the three ratoons it was 14.68 ± 1.36, 16.05 ± 1.27, and 15.46 ± 1.41%, respectively, against the control plants 15.71 ± 1.34, 12.24 ± 1.54, 14.62 ± 1.63, and 14.95 ± 1.38. The purity level in control plants of plantation, 1st ratoon, 2nd ratoon, and 3rd ratoon was 82.86 ± 4.77, 78.82 ± 5.11, 81.72 ± 5.37, and 87.63 ± 6.24%, respectively, against 84.28 ± 4.95, 81.71 ± 4.66, 83.26 ± 5.19, and 89.16 ± 6.66% in treated plants.

Commercial cane sugar Commercial cane sugar (CCS) obtained in control plants of plantation was 10.52 ± 0.87% and in treated it was 10.94 ± 0.94%. In 1st ratoon, 7.97 ± 0.54 and 8.06 ± 0.55% were recorded in control and treated, respectively. In control and treated plants of 2nd ratoon, it was 9.72 ± 0.61 and 11.34 ± 0.60% and 10.30 ± 0.53 and 11.53 ± 0.60% in control and treated plants of 3rd ratoon plants.

Sugar recovery Sugar recovery of 10.93 ± 0.78% was obtained from treated plants of plantation crop, and for 1st, 2nd, and 3rd ratoons of treated crop, it was 8.79 ± 0.56, 10.88 ± 1.0, and 10.47 ± 0.98%, respectively. In control plants and the three ratoons, it was 10.51 ± 0.78, 7.97 ± 0.45, 9.71 ± 0.58, and 10.29 ± 0.96%, respectively (r = 0.926; p = 0.05).

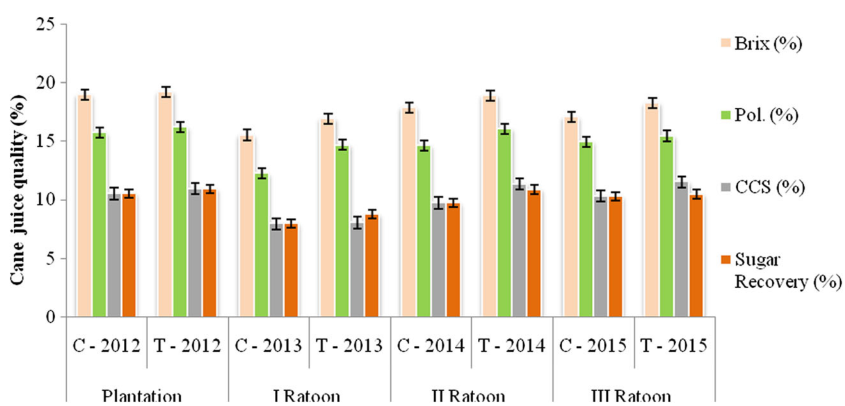

Fig. 1 Quality of cane juice obtained from cane treated with biostimulant along with control of plantation and ratoon crops. The *bars* show standard deviation and n = 5 cycle^{-1}

Discussion

Cane yield and growth parameters

The cane yield of control plants was 102.5 and 128.1 t ha^{-1} in the treated one plantation crop, i.e., 24.90% more yield in treated over control plants. The 1st ratoon crop was harvested in May 2013 and yield in control and treated crops were 88.74 and 114.29 t ha^{-1}, respectively, with 28.79% higher yield in treated crop. Similar results were obtained from 2nd and 3rd ratoons with yield improvement of 20.47 and 26.16%, respectively (r = 0.930; p = 0.05) (Table 2) and the average cane yield of this variety is 110 t ha^{-1}. A similar observation was made by Deshmukh and Phonde (2013) that sugar applied with seaweed at 1500 g ha^{-1} together with RDF at 45 and 120 days of planting yielded 89.23 t ha^{-1}.

Cane height is the main parameter of growth and yield. Although property of internodes (length, thickness, and shape) is one of the varietal characters, yet the rate of elongation and length of the internodes and the plant height provide information about the general condition of the crop (Hamid and Dagash 2014). In the present study, the average cane height of control plants was 378.2 cm, and in treated plants, it was 448.2 cm, therefore, a 18.51% higher yield was observed in plantation crop during 2011–2012 and similar observations were made in the three consecutive ratoon crops with significant correlation (r = 0.916; p = 0.05) (Table 3). Khalid et al. (2014) have reported that clone MS-99-HO-391 t exhibited the maximum plant height of 252.5 cm and minimum plant height of 171.5 cm in the cultivar Mardan-93, whereas Islam and Begum (2012) have reported a plant height of Isd 33, 38, and 31 varieties of sugarcane as 4.91, 4.75, and 4.14 m, respectively. Mondal et al. (2015) reported that corn treated with K-Sap, a biostimulant from *K. alvarezii*, resulted in increasing corn stover to 26%.

Stalk characteristics are one of the reflected mirrors to the expected yield. In all four crops, i.e., one plantation and three consecutive ratoons, control stalk heights were significantly positive correlated with treated plants (r = 0.976; p = 0.01). Islam and Begum (2012) reported the highest number of internodes in variety Isd 34 (31.8) and while the lowest number of internodes per stalk were in variety Isd 33 (25.1 m). The girth of control cane ranged from 26.0 to 30.0 mm and in treated it was 33.1 to 36.0 mm (r = 0.925; p = 0.05). In the literature, it is reported that an average girth of sugar cane variety Isd-32 was 2.78 cm and the lowest was in variety Isd, 1.46 cm (Islam and Begum 2012). The average cane weight per plant in control ranged from 1.34 to 1.48 kg and in treated it was 1.74 to 1.89 kg (r = 0.985; p = 0.01) (Table 3).

Table 2 Production (t ha^{-1}) and yield (%) of cane in plantation and ratoon crops treated and untreated with biostimulant of *K. alvarezii*

Date	Ratoon	Control (t ha^{-1})	Treated (t ha^{-1})	% of yield
05.04.2012	Plantation	102.59a	128.14a	24.90
13.05.2013	1st ratoon	88.74a	114.29b	28.79
15.04.2014	2nd ratoon	90.91a	109.52a	20.47
19.04.2015	3rd ratoon	88.53a	111.69b	26.16

Different letters indicate significant difference at the 0.05 level

Analysis of quality parameters

The brix content of juice from cane treated with biostimulant was significantly higher than one from control plants of both plantation and three consecutive ratoons tested (r = 0.978; p = 0.01) (Fig. 1). Brix is the only juice quality characteristic, in sugarcane generally it ranges from 10 to 20% of sucrose, 1 to 2% reducing sugar, 0.3 to 0.5% ash, and 0.5 to 1.0% nitrogen compounds (Oliveira and Horii 1998). Deshmukh and Phonde (2013) reported 21.94 to 22.91% of brix from cane applied with seaweed products through foliar and soil application as well. In sugarcane treated with sulfur at 27, 57, 86 and 117 kg ha^{-1}, brix values varied as 18.64% in control followed by 17.87, 17.28, 17.32, and 18.08% in treated plants, respectively (Hamid and Dagash 2014).

The polarity level in treated plants of plantation crop was 16.19%, and in treated three ratoons it was 14.68, 16.05, and 15.46%, respectively, against the control plants 15.71, 12.24, 14.62, and 14.95% (r = 0.901; p = 0.05) respectively. Islam et al. (2011) had recorded same range of polarity level in different sugarcane clone like clone I 149-00(13.4%), clone I 133-00 (13.2%), and clone I 80-00 (12.0%) under water-logging condition. Deshmukh and Phonde (2013) had observed polarity level of 23.80 to 24.61% in sugarcane treated with seaweed products. Highest purity was recorded in 3rd ratoon treated plant, i.e., 89.16%, and lowest was in 1st ratoon of control (78.82%) plants (r = 0.988; p = 0.01). Deshmukh and Phonde (2013) reported the purity level from 90.97 to 96.11% in some variety of sugarcane applied with seaweed products.

Commercial cane sugar (CCS%) in control plant in plantation and three consecutive ratoon crops were 10.52, 7.97, 9.72, and 10.30, respectively, and they were 10.94, 8.06, 11.34, and 11.53 in treated crops (r = 0.925; p = 0.05). The CCS of seaweed-treated sugarcane as reported by Deshmukh and Phonde (2013) was 15.58 to 17.22%.

Impact of potassium in sugarcane

To maximize the profit in the sugarcane industry, quality of sugarcane is one of the most essential characters. In the cell sap of sugarcane, potassium which is obtained as the potassium ion is the richest cation to accumulate in it. The main role of potassium in sugarcane is that it acts as an enzyme in the plant metabolism (Filho 1985). K is a highly transportable nutrient in the plant and symptoms of its deficiency are

Table 3 Growth parameters in sugarcane treated with biostimulant along with control of plantation and ratoon crops (standard deviation and *n* = 5 cycle)

Year	Plantation/ratoon	Application	Millable cane height with leaf (cm)	Stalk height (cm)	Internodes per cane (no.)	Cane girth (mm)	Cane weight (kg)
2012	Plantation	Control	378.20 ± 19.17a	236.60 ± 24.72a	15.80 ± 2.14a	30.00 ± 2.18a	1.34 ± 0.24a
		Treated	448.20 ± 35.90b	296.00 ± 12.89b	18.60 ± 1.49b	36.74 ± 3.89b	1.74 ± 0.48b
2013	1st ratoon	Control	357.80 ± 28.75a	218.40 ± 27.23a	17.60 ± 2.15a	26.90 ± 3.47a	1.48 ± 0.24a
		Treated	428.00 ± 29.13b	269.20 ± 29.63b	19.80 ± 1.47a	33.92 ± 2.75b	1.81 ± 0.12b
2014	2nd ratoon	Control	372.80 ± 20.09a	222.20 ± 17.29a	17.80 ± 2.32a	26.02 ± 3.72a	1.45 ± 0.27a
		Treated	431.60 ± 30.33b	279.00 ± 13.72b	20.20 ± 3.49a	31.12 ± 2.14b	1.79 ± 0.22a
2015	3rd ratoon	Control	351.00 ± 21.92a	215.40 ± 25.09a	15.20 ± 3.54a	29.90 ± 1.65a	1.36 ± 0.17a
		Treated	408.40 ± 46.74a	271.40 ± 28.10b	19.20 ± 3.19a	34.38 ± 3.35b	1.76 ± 0.13b

Different letters indicate significant difference at the 0.05 level

initially observed in the older leaves. The symptoms are that yellow-orange chlorosis observed in the leaf borders and the tips with numerous chlorotic spots that consequently combined into brownish chlorotic blotches found in the control plant (Fig. 2a) could be due to potash deficiency. Similarly, the mid rib with dark red color and, in older leaves, dead areas or dark red stripes between leaf veins and along leaf edges and tips particularly resistance to disease is reduced as a symptom of K deficiency. Sudama et al. (1998) showed in pot experiments that the application of K at time of planting under water stress conditions significantly improved stomata diffusive resistance, decreased rate of transpiration, and increased leaf water potential, cane length, sucrose content in juice, and cane yield. Verma et al. (1998) reported that potassium gave higher cane yield, but had no effect on sugar content. In contrast to the above result, Singh et al. (1999) found that potassium application had no significant effect on cane yield, but increased the content of commercial cane sugar. El-Geddawy et al. (2005) found that application of potassium in the form of K_2O favored cane growth and juice quality and our present investigation is in agreement with this observation.

Mondal et al. (2015) observed that function PGR free K-Sap (biostimulant) from *K. alvarezii*, on corn and stover yield, was similar to one with pristine sap. Therefore, yield and quality improvement in plant system could be due to potash which is more than 50% in the solid content of biostimulant and other micro-macro nutrients; however, this hypothesis needs to be validated.

Control of plant disease

Sugarcane is widely affected by biotic (Fig. 2b) and abiotic factors, of which the loss to fungal pathogens is critical (Fig. 2c). One of the most diseases that affected sugarcane is that of red rot caused by the fungus *Colletotrichum falcatum* which adversely affects and reduces cane yield by 29 and 31% loss in sugar recovery, sucrose content by 75 and 90% loss in juice yield (Hussnain and Afghan 2006). In India, it has been estimated that annual loss of revenues due to *C. falcatum*

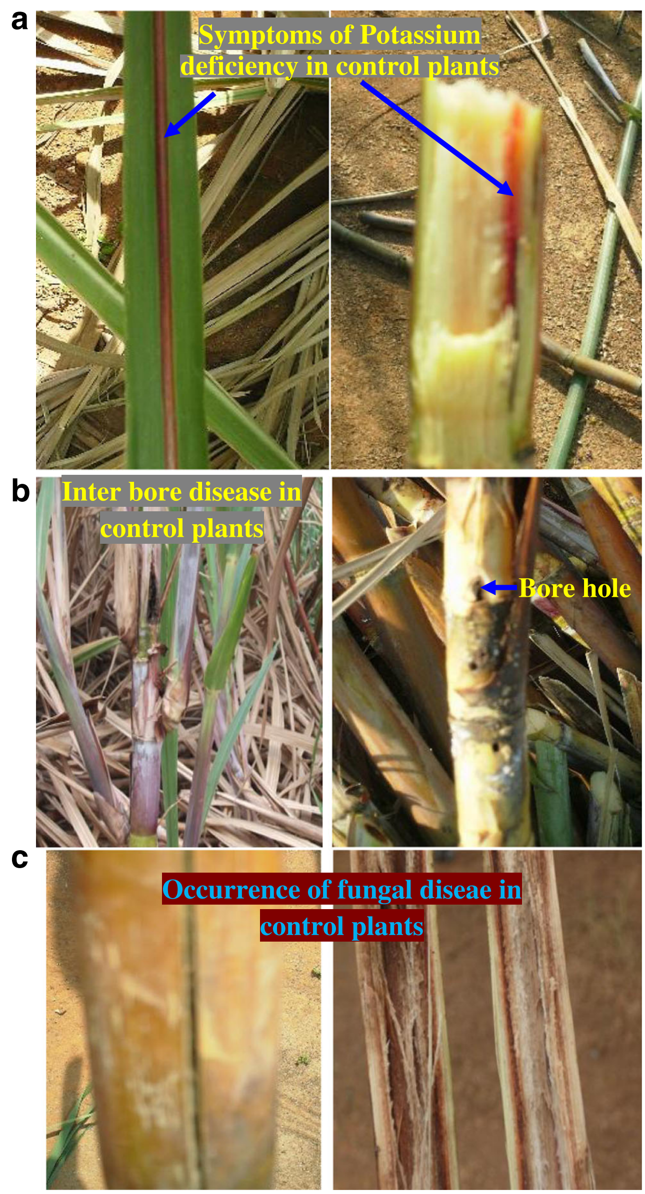

Fig. 2 **a** Occurrence of potassium deficiency symptoms in control plants. **b** Occurrence of internode bore disease in control plants. **c** Occurrence of cracking and fungal disease due to *Fusarium* wilt dot in control plants

infection was between 500 and 1000 million US$ (Viswanathan and Samiyappan 2002) and was responsible for the elimination of many sugarcane varieties (Siddique et al. 1983). Various chemical fungicides are commonly used for controlling this disease. Due to the eco-friendly role of seaweeds, in recent years, seaweeds are applied to control soil-borne plant diseases (Ambika and Sujatha 2015). Macroalgae are an attractive and natural source of bioactive molecules (Demirel et al. 2009). Natural products such as organic farming may have capability to control fungal diseases in sustainable agriculture. Bioactive substances derived from seaweeds have been used for several decades to improve plant growth and productivity (Rathore et al. 2009). Jayaraj et al. (2008) found that the application of seaweed extracts checked leaf blights caused by *Botrytis* and *Alternaria* as effectively as the fungicide chlorothalonil on carrot plants. Jayaraman et al. (2011) found that a commercial extract from *Ascophyllum nodosum* decreased fungal disease in cucumber and which showed better activities of various enzymes including peroxidase, 3-gulcanase chitinase, lipoxygenase, phenylalanine ammonialyase, B-1, and polyphenol oxidase. Brown seaweeds contain high amounts of flavonoid and phenolic compounds which could act as antifungal activity as reported by Cowan (1999).

The results obtained in this research suggest that sugarcane varieties of Co 86032 increase significantly the parameter assessed when 1% of biostimulant manufactured from seaweed *K. alvarezii* is applied. Cane yield increased 24.90, 28.79, 20.47, and 26.16% in plantation crop, 1st ratoon, 2nd ratoon, and 3rd ratoon, respectively, with statistically significant yield and quality of juice. It is well known that cane and sugar yield as well as sugar recovery are important elements for sugarcane growers and sugar factories. This research suggests that potassium-rich biostimulant from *K. alvarezii* increases significantly the cane yield, recovery, and quality of sugarcane juice variety Co 86032, in addition to controlling disease. Present findings encourage the application of such potassium-rich seaweed-based biostimulant in sugarcane cultivation for the benefit of both grower and processor of sugarcane.

Acknowledgements The authors are very grateful to Mr. Abhiram Seth, MD, and Mr. Arun Patnaik, CEO, and Mr. Tanmaye Seth of AquAgri Processing Private Limited for their valuable guidance and financial support to carry out the present research. Authors also express their sincere thanks to Sakthi Sugars, India, for assisting in carrying out the trials and analyzing the samples.

References

AGRICOOP (2016) Commodity profile for sugar—April 2016. Downloaded from http://agricoop.nic.in/Admin_Agricoop/Uploaded_File/SugarProfileApril%202016.pdf

Ambika S, Sujatha K (2015) Antifungal activity of aqueous and ethanol extracts of seaweeds against sugarcane red rot pathogen (*Colletotrichum falcatum*). Sci Res Essays 10:232–235

Arioli T, Mattner SW, Winberg PC (2015) Applications of seaweed extracts in Australian agriculture: past, present and future. J Appl Phycol 27:2007–2015

Commission for Agricultural Costs and Prices (2014). Report of price policy for sugar cane—2015-2016. Commission for Agriculture costs and price (2014) downloaded from http://cacp.dacnet.nic.in/

Cowan MM (1999) Plants products as antimicrobial agents. Clin Microbiol Rev 12:564–582

Craigie JS (2011) Seaweed extract stimuli in plant science and agriculture. J Appl Phycol 23:371–393

Demirel Z, Yilmaz KF, Karabay YU, Ozdemir G, Sukatar A (2009) Antimicrobial and antioxidant activity of brown algae from the Aegean Sea. J Serb Chem Soc 74:6119–6628

Deshmukh PS, Phonde DB (2013) Effect of seaweed extract on growth, yield and quality of sugarcane. Int J Agri Sci 9:750–753

El-Geddawy LH, Rady MS, Dawwam HA, Hendawy A, El-Ghait RAMA (2005) Response of some sugar cane varieties to nitrogen and potassium application. Egypt J Ag Res 83:693–707

Eswaran K, Ghosh PK, Siddhanta AK, Patolia JS, Periyasamy C, Mehta AS, Mody KH, Ramavat BK, Prasad K, Rajyaguru MR, Reddy SKCR, Pandya JBP, Tewari A (2005) Integrated method for production of carrageenan and liquid fertilizer from fresh seaweeds. US patent 6893479 B2

Filho JO (1985) Potassium nutrition of sugarcane. In: Munson RD (ed) Potassium in agriculture. Soil Science Society of America, Madison, pp 1045–1062

Gordon SA, Paley LG (1957) Observations on the quantitative determination of indole-acetic acid. Physiol Plantarum 10:39–47

Hamid AAM, Dagash YM (2014) Effect of sulfur on sugarcane yield and quality at the heavy clay soil "Vertisols" of Sudan. Univers J Appl Sci 2:68–71

Holbrook AA, Edge WJW, Bailey F (1961) Spectrophotometric method for determination of gibberellic acid in gibberellins. Adv Chem 28: 159–167

Hong DD, Hien HM, Son PN (2007) Seaweeds from Vietnam used for functional food, medicine and biofertilizer. J Appl Phycol 19:817–826

Hussnain Z, Afghan S (2006) Impact of major cane diseases on sugarcane yield and sugar recovery. Annual Report, Shakarganj Sugar Research Institute, Jhang. Pakistan

Islam MS, Begum MK (2012) Comparative studies of chlorophyll content, yield and juice quality of eight sugarcane varietés. J Agrofor Environ 6:121–124

Islam MS, Miah MAS, Begum MK, Alam MR, Arefin MS (2011) Biochemical studies of juice quality and yield performance of some promising sugarcane clones under water-logging stress condition. J Agrofor Environ 5:87–90

Jayaraj J, Wan A, Rahman M, Punja ZK (2008) Seaweed extract reduces foliar fungal diseases on carrot. Crop Protect 27:1360–1366

Jayaraman J, Norrie J, Punja ZK (2011) Commercial extract from the brown seaweed *Ascophyllum nodosum* reduces fungal diseases in green house cucumber. J Appl Phycol 23:353–336

Karthikeyan K, Shanmugam M (2016) Grain yield and functional properties of red gram applied with seaweed extract powder manufactured from *Kappaphycus alvarezii*. Int J Rec Adv Mul Dis Res 3:1353–1359

Khalid M, Rahman HU, Rabbani MA, Farhatullah KA (2014) Qualitative and quantitative assessment of newly selected sugarcane varieties. Sarhad J Agric 30:187–191

Khan W, Rajirath UP, Subramanian S, Jithesh MN, Rayorath P, Hodges DM, Critchley AT, Craigie JS, Norrie J, Prithiviraj B (2009) Seaweed extract as biostimulants of plant growth and development. J Plant Growth Regul 28:386–399

Lötze E, Hoffman EW (2016) Nutrient composition and content of various biological active compounds of three South African-based commercial seaweed biostimulants. J Appl Phycol 28:1379–1386

Mondal D, Gosh A, Prasad K, Singh S, Bhatt N, Zodape ST, Chaudhary JP, Chaudhari J, Chaterjee PB, Seth A, Gosh PK (2015) Elimination of gibberellins from *Kappaphycus alvarezii* seaweed sap foliar spray enhances corn stover production without compromising the grain yield advantage. Plant Growth Regul 75:657–666

Oliveira FRM, Horii J (1998) Cellular viability of *Saccharum cerevisiae* in mixed culture with *Lactobacillus fermentum*. Sci Agric 55:520–527

Perez R (1997). Feeding pigs in the tropics. Food and Agriculture Organization of the United Nations, Rome. http://www.fao.org/docrep/003/w3647e/w3647e00.htm

Prasad K, Dass AK, Oza MD, Brahmbhatt H, Siddhanta AK, Meena R, Eswaran K, Rajyaguru MR, Ghosh PK (2010) Detection and quantification of some plant growth regulators in a seaweed-based foliar spray employing a mass spectrometric technique sans chromatographic separation. J Agri Food Chem 58:4594–4601

Rathore SS, Chaudhary DR, Boricha GN, Ghosh A, Bhatt BP, Zodape ST, Patolia JS (2009) Effect of seaweed extract on the growth, yield and quality of soybeen (*Glycine max*) under in rain fed conditions. S Afr J Bot 75:351–355

Siddique MM, Khanzada MI, Maazulla K (1983) Incidence and effects of sugarcane red rot caused by *Colletotrichum falcatum* in northern Pakistan. J Agric Res 4:208–210

Singh KDN, Mishra GK, Ojha JB (1999) Effect of potassium on yield and quality of sugarcane in calciothents. Ind Sugar 49:499–507

Stirk WA, Arthur GD, Lourens AF, Novak O, Strnad M, Van Staden J (2004) Changes in cytokinin and auxin concentrations in seaweed concentrates when stored at an elevated temperature. J Appl Phycol 16:31–39

Sudama S, Tiwari TN, Srivastava RP, Singh GP, Singh S (1998) Effect of potassium on stomatal behavior, yield and juice quality of sugarcane under moisture stress conditions. Indian J Plant Physiol 3:303–305

Syono K, Torrey JG (1975) Identification of cytokinins in root nodules of the garden pea, *Pisum sativum*. Plant Physiol 57:602–606

Tamil Selvi D (2012) Sugarcane: Tamil Nadu leads the way towards higher yields. Facts for you. 26–28. www.efymag.com/admin/issuepdf/26-28_Sugarcane_June-12.pdf. Accessed Oct 2015

Tuhy K, Chowanska J, Chojnacka K (2013) Seaweed extracts as biostimulants of plant growth: review. Chem Aust 67:636–641

Verkleij FN (1992) Seaweed extracts in agriculture and horticulture: a review. Biol Agricult Horticult 8:309–324

Verma RDN, Singh SB, Vishvakarma ML, Tiwari TN (1998) Optimum and economic dose of nitrogen, phosphorus and potash for autumn planted soils sugarcane in Bhat soils of U.P. Indi Sugar 48:451–453

Viswanathan R, Samiyappan R (2002) Induced systemic resistance by fluorescent pseudomonads against red rot disease of sugarcane caused by *Colletotrichum falcatum*. Crop Protect 21:1–10