

Enhanced Yield and Quality in Some Banana Varieties Applied with Commercially Manufactured Biostimulant Aquasap from Sea Plant *Kappaphycus alvarezii*

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Abstract: A field study was conducted to investigate the effect of Aquasap, a commercially manufactured biostimulant from seaweed *Kappaphycus alvarezii* on some hills and foothills banana varieties namely Robusta (AAA), Njali poovan (AB), Red banana (AAA) and Nendran (AAB) by applying at 5% through foliar spray at the 3rd, 5th and 7th month of plantation. Both quantitative and quality data of fruits were analyzed along with vegetative growth of the plants. The seaweed biostimulant was found very effective on increasing the weight and nutritional contents of all four banana varieties tested. The highest yield was found in Robusta with 56.58% over control followed by Njali poovan, Red banana and Nendran with 19.08%, 39.35% and 11.46%, respectively. Yield of fruits per hectare of four varieties treated were 76.96, 19.23, 29.68 and 23.37 metric ton (mt), respectively. Fruits of treated plants also showed less moisture level as compared to control with 240.61%, 62.30%, 61.68% and 37.18% more carbohydrate, 283.71%, 94.07%, 62.87% and 38.93% higher proteins and 153.02%, 47.37%, 58.73% and 31.48% higher minerals respectively as compare to control plants. Therefore, the simple practice of application of eco-friendly seaweed based biostimulant would benefit small and marginal farmers of banana.

Key words: Seaweeds/sea plants, *Kappaphycus alvarezii*, Aquasap, biostimulant, banana yield, Red banana (AAA), Njali poovan (AB), Robusta (AAA), Nendran (AAB).

1. Introduction

Seaweeds are marine macro algae and are classified into three main groups, viz., 1. Chlorophyta (Green Algae), 2. Phaeophyta (Brown Algae) and 3. Rhodophyta (Red Algae) based on pigments present in them. For centuries, seaweeds have been used in agriculture to increase the yield and qualities by the agricultural areas which are close the coastal region. Today seaweed meals and soil amendment are available in ready-to-apply dry form for use in crop soils and home gardens. Nowadays, high quality

liquid and powder seaweed extract products are available in pure form or recipe with ingredients of traditional agri. inputs like fertilizers, pesticides etc. and non-traditional products like humates, fish extracts etc.. Of all the seaweeds and extract products currently on the market, *Ascophyllum nodosum*, a cold water brown alga, is the most used and researched seaweed species in agriculture [1]. Significant increase in crop yield due to foliar application of seaweed extracts has been reported by Zodape [2]. In this series, *Kappaphycus alvarezii*, a tropical water species of family solieriaceae is gaining momentum in recent years. A method for production of liquid fertilizer from fresh form of *K. alvarezii* has been

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patented [3]. *K. alvarezii* has been commercially cultivated in Indian waters for more than a decade as an alternative livelihood to fisher-folks [4].

AquAgri Processing (P) Ltd. has sourced and commercialized the technology for the production of liquid seaweed nutrient (Brand name: Aquasap) from Central Salt and Marine Chemicals Research Institute, one of the premier research institutes of India [3]. The efficacy trials conducted on wide range of crops in the field over 12 years clearly demonstrated enhanced crop yield ranging from 12% to 45% when the Aquasap at 5% was applied as foliar spray [3]. The Aquasap is rich in potash with other primary and secondary nutrients, additionally, it contains substantial amount of plant growth regulators such as auxin, cytokinin and gibberellins [5].

Considerable evidence has been accumulated in recent years to support the benefits associated with the use of seaweed extract in crop productions [6]. Application of *Ascophyllum nodosum* under field conditions, trials on tomato showed 8% yield increase and 30% weight gain was observed with pepper, bananas (2.5%), grapes (31%) and apples (7%) [1]. 2.5% of *K. alvarezii* extract on okra by foliar application increased 20.47% yield [7]. It has also been reported that higher dosage of seaweed extract retard the growth [8].

Bananas are cultivated in more than 120 countries and India is the largest producer with an annual production of 16.82 million metric ton (mt) from an area of 0.49 million hectares. In India, Tamil Nadu leads in total area and production with 2.52 million mt from 71,088 hectares. State of Indian Agriculture 2012-2013 reported that Tamil Nadu contributes 35% of total production of banana in India. Therefore, since then high yield, short term growth and disease resistant varieties by Agriculture Institutions in India have increased the volume of banana at harvest. The most important genomics groups of banana cultivated in India are Virupakashi (AAB), Robusta (AAA), Red banana (AAA), Poovan (Mysore AAB), Rasthali (Silk

AAB), Nendran (AAB), Monthan (ABB/AAB), Karpuravalli (ABB), Sakkai, Peyan and Matti (AA) [9-13].

Plant growth hormones found in seaweed extracts are mainly responsible for plant growth stimulation and increase the intensity of photosynthesis. Cytokinins protect plants from the consequences of temperature changes [14, 15], auxins show to promote root formation and inhibit its elongation and gibberellins are to initiate seed germination [16]. Seaweed extracts are also a rich source of macro and micronutrients which play many important roles in plant [17]. Seaweed extracts can act as plant biostimulants improving condition and vitality of plants due to the presence of many bioactive compounds important for higher plants [18] and can enhance nutrient uptake from soil [19]. There are many proved advantages of using seaweed extracts as biostimulants of plant growth [20]. They revealed beneficial effect on seed germination and root development [6, 21], and plant biostimulants are also able to improve crop yields [22]. Currently, seaweed extracts are the components of many commercial products like Nitrozime, Kelprosoil, etc., applied as plant growth stimulants [6, 21, 23].

The present study attempts to evaluate the biostimulant potential of commercially manufactured Aquasap from *K. alvarezii* on the yield and quality of fruits of some hills and foothills banana varieties grown under filed condition in Manamadurai, a semi-arid area of Tamil Nadu for the first time.

2. Materials and Methods

2.1 Preparation of Trial Plots

The trial was carried out at Research & Development plot of AquAgri Processing Private Limited, Manamadurai, Sivagangai DT., Tamil Nadu, India. Latitude is 9°42'56"N and longitude 78°28'2"E. A red soil area is used with average annual rain fall of 850 mm.

The trial plot was prepared as recommended by

Indian Horticulture Department. Plot size was 40 m × 2 m and distances between plots were 3.5 m. The number of total plants per plot was 36 and two plots were used for each variety. Flooding method of irrigation was done for every 7-8 d during winter season and in summer the irrigation interval was 4-5 d. Chemical fertilizers were applied to crops as per the recommendation of National Horticulture Board, India.

2.2 Selection of Banana Varieties for Trial

Four varieties of banana, i.e., Robusta, Njali poovan, Red banana and Nendran, which are generally cultivated in hill and foothills area of Tamil Nadu were selected for present study.

Suckers of Robusta (AAA), Njali poovan (AB) and Red banana (AAA) were sourced from Tamil Nadu Agriculture University, Coimbatore, and Nendran (AAB) was obtained from Banana Research Centre at Trichy (Tamil Nadu, India). The suckers free from disease and mechanical injuries were selected and weight of 500 g ± 50 g were selected for plantation.

Robusta (Syn. Bombay Green, Pedda Pacha Arati and Harichal Borjahaji) is semi-tall variety. The crop life cycle is 12 months and it is mostly cultivated in Theni District of Tamil Nadu and some parts of Karnataka, Andhra Pradesh and Maharashtra [24].

Basically, Njali poovan (Syn. Ney poovan, Elakki Bale, Ney Kadali, Hoobale, Vadakkan Kadali, Deva bale, Putta Sugantha and safed Velchi) is slender and medium tall plant and it is cultivated in Tamil Nadu, Kerala, Karnataka and Maharashtra. It is also cultivated as intercrop with coconut and areca nut. The stem is greenish yellow in color and petiole is pink to red in color. The crop life cycle is 12 months to 13 months [24].

Red banana (Syn. Lal Kela, Chenkadali, Chevvazhai, Yerra Arati, Anupam, Chandra bale, Kembale and Agniswar) is triploid AAA genomic characters of robust plant. Other banana varieties that are coming under AAA genomic characters are

Grandnaine, Green red, Dwarf Cavendish and Robusta. In Red banana, the pseudo stem, petiole, midrib and fruits are red in color. It is a very popular variety of banana cultivated in Tamil Nadu and Kerala and its crop life cycle is 16 months [9, 25].

Nendran (Syn. French Plantain, Rajeli and Bhorot.) is very tall variety and mainly cultivated in Kerala in India. The fruit of Nendran is generally used for making chips. Its bunch size is different with other banana varieties. Young leaves and pseudo stem are shaded with pink color [24].

2.3 Application of Aquasap

Commercially manufactured Aquasap (Batch No.: 09122011-3) was collected from stock of AquAgri Processing Private Limited and used for trial. 5% solution was prepared and applied as foliar application at the 3rd (juvenile phase), 5th (flowering and budding differentiation stage) and 7th month of plantation of all four varieties tested.

2.4 Collection of Data

Physical parameters like tree height and width, number of leaves, its length and breadth, bunch weight, number of hands, number of fruits, length, breadth and weight of hands and fruits weight, fruits and skin ratio were measured. Development of side suckers were not allowed in all cases of control and experimental plants till complete harvest. Chemical parameters like moisture, crude protein, crude fiber, crude fat, crude carbohydrate, ash content, macro and micro elements, and vitamins of fruits were analyzed.

Elements were analyzed by atomic absorption spectroscopy (Association of Analytical Communities 18th edition: 2005) and vitamins by titration method (AOAC 985.33). Crude protein, total carbohydrate, crude fiber contents of harvested banana fruits were determined by spectrophotometric methods using Chemito Spectra Scan UV-2600, double beam UV-visible spectrophotometer.

2.5 Statistical Analysis

Statistical analysis such as analysis of variance (ANNOVA, SYSTAT version 7), correlation and regression were applied to analysis the data.

3. Results

3.1 Yield and Quality of Fruits of Robusta (AAA)

The bunch weights of control plants ranged from 10.85 kg to 21.95 kg with average of 15.96 kg and in Aquasap treated plants, the average bunch weight was 24.99 kg with a range from 13.25 kg to 42.2 kg, therefore, 56.58% more yield over control with positive significant variation (F -ratio = 11.846; $P \leq 0.005$) was observed in treated plants (Table 1). Number of hands per bunch ranged from 7 to 9 (average 7.9) and 7 to 10 (average 8.7) in control and treated plant respectively with significant positive correlation with fruits weight ($r = 0.975$; $P = 0.05$), fruits skin weight ($r = 0.977$; $P = 0.05$), fruits

circumference ($r = 0.956$; $P = 0.05$) and significant negative correlated with fruits length ($r = -0.990$; $P = 0.01$). Average hands weight in control and treated plants were 1.36 kg (1.16 kg to 1.78 kg) and 2.07 kg (1.13 kg to 3.75 kg) respectively with positive correlation with fruits weight ($r = 0.982$; $P = 0.02$), tree height ($r = 0.959$; $P = 0.05$), tree width ($r = 0.978$; $P = 0.05$) and number of leaves ($r = 0.975$; $P = 0.05$) and significant negative correlated with leaf breadth ($r = -0.988$; $P = 0.02$). Weight of hand in treated was 52.62% more when compared to control with significant variation (F -ratio = 5.248; $P \leq 0.05$) (Table 1).

3.2 Nutritional Content of Fruits of Robusta

The color of the fruit was dark green to greenish yellow in both control and treated plants. Fruit sizes were generally in uniform in treated plants (Fig. 1). The number of fruits per bunch ranged from 90 to 145 (average 115.6) and 125 to 189 (average 139.96) in control and treated plants, respectively with significant

Table 1 Effect of Aquasap on fruits and vegetative growth of four varieties of bananas.

Variety name	Robusta		Njali poovan		Red banana		Nendran	
	Control	Aquasap applied	Control	Aquasap applied	Control	Aquasap applied	Control	Aquasap applied
Date of plantation	12.10.2012	12.10.2012	12.10.2012	12.10.2012	12.10.2012	12.10.2012	12.10.2012	12.10.2012
Date of harvest	08.07.2013	08.07.2013	17.09.2013	17.09.2013	26.10.2013	26.10.2013	18.07.2013	18.07.2013
Bunch weight (kg)	15.96 ± 3.19	24.99 ± 8.51	5.25 ± 1.06	6.26 ± 1.87	6.92 ± 1.91	9.64 ± 2.18	6.81 ± 1.41	7.59 ± 1.39
No. of hands per bunch	7.90 ± 0.83	8.70 ± 0.90	11.78 ± 1.13	11.89 ± 0.99	4.52 ± 0.65	4.87 ± 0.92	5.33 ± 0.47	5.67 ± 0.47
No. of fruits in bunch	115.60 ± 22.62	139.96 ± 8.39	176.50 ± 25.55	189.25 ± 23.10	50.43 ± 9.64	60.78 ± 13.16	58.50 ± 5.25	68.17 ± 5.52
Hands weight (kg)	1.36 ± 0.19	2.07 ± 0.81	0.37 ± 0.07	0.42 ± 0.11	1.19 ± 0.42	1.54 ± 0.45	0.73 ± 0.07	0.75 ± 0.07
Fruits weight (kg)	0.09 ± 0.02	0.18 ± 0.02	0.02 ± 0.01	0.03 ± 0.01	0.10 ± 0.03	0.12 ± 0.02	0.07 ± 0.01	0.08 ± 0.01
Fruits skin weight (g)	24.00 ± 0.05	37.70 ± 0.77	4.20 ± 0.04	5.80 ± 0.12	26.00 ± 0.69	23.00 ± 0.90	17.30 ± 0.15	18.00 ± 0.14
Fruits length (cm)	15.05 ± 1.66	15.30 ± 2.56	9.44 ± 0.73	10.26 ± 2.15	12.27 ± 1.49	11.76 ± 1.36	17.74 ± 2.01	20.19 ± 1.19
Fruit circumference (cm)	12.51 ± 0.82	12.87 ± 1.90	9.31 ± 0.71	9.33 ± 0.55	13.84 ± 1.68	13.59 ± 1.37	9.35 ± 0.67	10.13 ± 0.77
Tree height (m)	1.79 ± 0.28	1.79 ± 0.19	2.35 ± 0.24	2.59 ± 0.27	2.50 ± 0.38	2.54 ± 0.31	3.12 ± 0.12	3.16 ± 0.07
Tree girth (m)	0.57 ± 0.77	0.60 ± 0.06	0.61 ± 0.04	0.61 ± 0.04	0.71 ± 0.05	0.70 ± 0.09	0.60 ± 0.04	0.62 ± 0.05
No. of side suckers	8.23 ± 1.97	9.07 ± 2.34	12.90 ± 3.61	14.40 ± 2.73	8.50 ± 3.58	8.04 ± 3.30	6.66 ± 1.79	7.50 ± 1.70
No. of leaves	14.9 ± 2.02	16.30 ± 2.68	15.50 ± 1.91	16.00 ± 2.41	17.50 ± 1.75	18.50 ± 2.55	11.17 ± 1.77	12.33 ± 1.37
Leaves length (m)	1.78 ± 0.21	1.80 ± 0.17	2.09 ± 0.23	2.04 ± 0.25	2.32 ± 0.19	2.30 ± 0.25	2.21 ± 0.19	2.28 ± 0.14
Leaves breadth (m)	0.56 ± 0.01	0.62 ± 0.05	0.53 ± 0.05	0.53 ± 0.03	0.64 ± 0.04	0.65 ± 0.05	0.62 ± 0.06	0.57 ± 0.08
Central axis weight (kg)	1.70 ± 0.53	2.46 ± 0.83	1.14 ± 0.35	1.10 ± 0.29	1.02 ± 0.24	1.07 ± 0.35	0.60 ± 0.21	0.59 ± 0.16



Fig. 1 Fruits of control & Aquasap treated Robusta.

positive correlated with number of leaves ($r = 0.976$; $P = 0.05$) and leaf length ($r = 0.974$; $P = 0.05$) with 33.62% more yield in treated plants (Tables 1 and 2). The fruits' weight ranged from 0.079 kg to 0.112 kg (average 0.09 kg) and 0.113 kg to 0.246 kg (average 0.176 kg) in control and treated plants respectively with significant positive correlated with fruits skin weight ($r = 1.000$; $P = 0.001$) and significant negative correlated with fruits length ($r = -0.997$; $P = 0.01$), i.e., fruits weight increased to 112.56% as compared with control (Tables 1 and 2). In control, skin of fruit weight ranged from 0.024 kg to 0.038 kg (average 0.024 kg) and in treated plants it ranged from 0.027 kg

to 0.045 kg (average 0.038 kg) with significant negative correlation with fruits length ($r = -0.997$; $P = 0.01$). Fruits length ranged from 12.2 cm to 17.22 cm (average 15.05 cm) and 12.37 cm to 18.66 cm (average 15.3 cm) in control and treated plants respectively and with 1.66% increase in treated one (Table 1). Fruits circumference of control plants ranged from 11.38 cm to 13.71 cm (average 12.51 cm) and 10.33 cm to 16.26 cm (12.87 cm) in treated plants with significant positive correlation with tree height ($r = 0.995$; $P = 0.01$) and tree width ($r = 1.000$; $P = 0.001$) and significant negative correlated with leave breadth ($r = -0.999$; $P = 0.001$) and with 2.88% increase in treated one (Tables 1-3).

Moisture content in fruits of all four varieties in Robust, Red banana, Njali poovan and Nendran were less in treated than fruits of control plants and it was 74.84%, 77.2%, 67.7% and 72.8% in treated and 76.16%, 80.93%, 70.97% and 74.1% in control plants respectively. Though there was not much difference in fiber and fat content of fruits from treated and control but, protein (45.8%) and carbohydrate (29.56%) were found more in treated plants. Some elements like potassium

Table 2 Effect of Aquasap on nutritional factors of four varieties of bananas.

Variety	UOM	Robusta		Njali poovan		Red banana		Nendran	
		Control	Aquasap applied	Control	Aquasap applied	Control	Aquasap applied	Control	Aquasap applied
Moisture	g/100 g	80.93	77.20	70.97	67.70	76.16	74.84	74.10	72.80
Crude protein (NX6.25)	g/100 g	1.20	1.75	1.08	1.45	1.13	1.20	1.02	1.11
Crude fiber	g/100 g	0.43	0.42	0.39	0.36	0.49	0.51	0.42	0.41
Crude fats	g/100 g	0.14	0.31	0.40	0.11	0.14	0.15	0.56	0.44
Crude carbohydrate	g/100 g	15.32	19.85	26.00	29.18	19.70	20.75	22.32	23.93
Ash content	g/100 g	1.18	1.27	1.16	1.2	1.16	1.17	1.13	1.24
Potassium (K)	mg/100 g	339.89	322.89	334.19	341.91	325.18	336.72	318.21	328.43
Sodium (Na)	mg/100 g	54.12	50.62	59.12	58.69	40.15	46.33	41.23	42.18
Calcium (Ca)	mg/100 g	28.27	29.90	31.10	32.50	30.80	29.70	29.80	30.10
Iron (Fe)	mg/100 g	0.29	0.31	0.38	0.34	0.26	0.29	0.25	0.25
Phosphorus	mg/100 g	31.69	33.49	32.33	29.18	31.81	30.70	32.35	33.26
Vitamin C	µg/100 g	7.12	7.80	7.10	7.81	7.13	6.93	7.85	7.61
Cartotene (vitamin A)	IU/100 g	1.77	1.10	1.00	1.21	1.60	1.30	1.20	1.50
Thiamin	µg/100 g	4.23	1.82	1.90	4.17	2.13	2.45	1.40	1.60
Riboflavin	µg/100 g	2.31	3.93	4.10	2.40	2.71	2.46	2.70	2.86
Niacin	µg/100 g	5.76	2.95	2.80	5.61	3.10	3.50	4.63	4.72

(5.29%), calcium (5.77%), iron (6.89%) and phosphorus (5.68%) were also higher in fruits of treated plants. Vitamin riboflavin (70.12%) was found more in treated plant, however, there was not significant variation in the levels of other vitamins between control and treated plants (Table 2).

3.3 Height and Leaves of Robusta Trees

Apart from improvement in yield and quality of the fruits of treated plants, vegetative growth in terms of tree height and width, number of leaves, leaves length and breadth were also found 20% more as to compare with the control (Table 1).

Similar positive results were also observed in other banana varieties studied in the present investigation, viz., Njali poovan (AB), Red banana (AAA) and Nendran (AAB) as shown in Tables 1 and 2 with Analysis of Variance (ANOVA) interpretation of control and treated plants (Tables 4-6).

4. Discussion

4.1 Banana Yield and Vegetative Growth

4.1.1 Yield of Control Vs Aquasap Applied Banana

All four varieties of banana viz. Robusta (AAA), Njali poovan (AB), Red banana (AAA) and Nendran (AAB) studied had responded well to 5% Aquasap (Brand name of AquAgri for biostimulant from seaweed of *K. alvarezii*). The highest yield was found in Robusta with 56.58% over control followed by Njali poovan, Red banana and Nendran with 19.08%, 39.35% and 11.46%, respectively. Yield of fruits per hectare of four varieties treated were 76.96, 19.23, 29.68 and 23.37 t, respectively (Table 7).

It was also observed that emerging of first flower appeared in all treated plants 10-15 d earlier to control crop. The maximum value of 42.2 kg of bunch weight was observed in Aquasap treated Robusta. The hands weight increased to 67.81% in Robusta, 24.94%, 8.01% in Red banana and Njali poovan, respectively. The numbers of hands were 22.22%, 6.25% and

4.35% more in Red banana, Robusta and Njali poovan, respectively (Table 1). Similar observations had been made on *Abelmoschus esculentus* and 20.47% higher yield was obtained when treated with 2.5% extract of *K. alvarezii* [7].

Higher crop yields had been observed with brinjal (41.1%), wheat grain (42.8%), onion bulb (22.0%) and sesamum (34.15%) when they treated with extract of *K. alvarezii* [3]. The number of fruits is one of the important characters of the yield. In this study, number

Table 3 ANOVA interpretation of control and treated plants of Robusta.

	Parameters	F-ratio	P
1	Bunch weight	11.846	0.002
2	Hands per bunch	3.840	0.066
3	No. of fruits	4.463	0.056
4	Hands weight	5.248	0.038
5	Fruits weight	5.918	0.072
6	Fruits skin weight	5.948	0.071
7	Fruits length	0.049	0.828
8	Fruits circumference	0.211	0.653
9	Tree height	0.043	0.838
10	Tree girth	1.103	0.303
11	No. of side suckers	1.380	0.251
12	No. of leaves	1.561	0.228
13	Leaves length	0.033	0.859
14	Leaves breadth	1.655	0.219
15	Central branch weight	2.305	0.167

Table 4 ANOVA interpretation of control and treated plants of Njali poovan.

S.NO	Parameters	F-ratio	P
1	Bunch weight	1.952	0.179
2	Hands per bunch	0.043	0.837
3	No. of fruits	0.959	0.344
4	Hands weight	0.953	0.346
5	Fruits weight	6.730	0.032
6	Fruits skin weight	6.737	0.032
7	Fruits length	1.054	0.320
8	Fruits circumference	0.002	0.965
9	Tree height	3.791	0.066
10	Tree girth	0.011	0.916
11	No. of side suckers	0.986	0.334
12	No. of leaves	0.238	0.631
13	Leaves length	0.291	0.596
14	Leaves breadth	0.099	0.756
15	Central branch weight	0.071	0.793

Table 5 ANOVA interpretation of control and treated plants of Red banana.

S.NO	Parameter	F-ratio	P
1	Bunch weight	19.429	0.000
2	Hands per bunch	1.614	0.211
3	No. of fruits	8.851	0.005
4	Hands weight	10.705	0.002
5	Fruits weight	5.373	0.029
6	Fruits skin weight	0.584	0.452
7	Fruits length	1.249	0.271
8	Fruits circumference	0.239	0.628
9	Tree height	0.135	0.715
10	Tree girth	0.071	0.792
11	No. of side suckers	0.182	0.672
12	No. of leaves	2.190	0.146
13	Leaves length	0.032	0.858
14	Leaves breadth	0.356	0.554
15	Central branch weight	0.290	0.594

Table 6 ANOVA interpretation of control and treated plants of Nendran.

S.NO	Parameters	F-ratio	P
1	Bunch weight	0.776	0.399
2	Hands per bunch	1.250	0.290
3	No. of fruits	8.048	0.018
4	Hands weight	0.115	0.741
5	Fruits weight	2.846	0.123
6	Fruits skin weight	0.526	0.485
7	Fruits length	5.521	0.041
8	Fruits circumference	2.868	0.121
9	Tree height	0.327	0.580
10	Tree girth	0.536	0.481
11	No. of side suckers	0.566	0.469
12	No. of leaves	1.354	0.272
13	Leaves length	0.462	0.512
14	Leaves breadth	0.680	0.429
15	Central branch weight	0.005	0.945

Table 7 Per hectare yield of fruits and other nutritional contents of four varieties of banana studied.

Yield/ha	Robusta		Njali poovan		Red banana		Nendran	
	Control	Aquasap applied	Control	Aquasap applied	Control	Aquasap applied	Control	Aquasap applied
Total yield of fruits (t)	49.15	76.97	16.15	19.24	21.30	29.69	20.97	23.37
Carbohydrate (t)	4.91	16.72	3.25	5.27	2.90	4.70	2.86	3.92
Protein (kg)	384.40	1475.00	135.00	262.00	167.00	272.00	131.00	182.00
Minerals (kg)	0.15	0.37	0.06	0.08	0.06	0.10	0.05	0.07

of hands and hands weight increased by 10.13% and 52.62% respectively in treated Robusta. Zodape et al. [7, 26] have reported that number of fruits increased to 37.47% in *Abelmoschus esculentus* and 30.11% yield increase in green gram when they were treated with extract of *K. alvarezii* [7, 26], and similar observations were also observed with groundnut, paddy and chilly when they were applied with extract of *K. alvarezii* [27].

In this present investigation, number of finger per hands and their weight increased to 23.70% and 112.56% respectively with Robusta plants. The maximum finger length (13.81%) and circumference (8.36%) were observed with treated plants of Nendran. Zodape et al. [7] had also reported 31.77% increase in length and 18.24% diameter with lady's finger when it was with treated 5% extract of *K. alvarezii* [7].

4.1.2 Vegetative Growth of Control Vs Aquasap Applied Banana

In treated plants, the pseudo stem height increased to 10.45% with Njali poovan whereas Robusta showed 4.76% more girth as compared to control. Generally length and breadth of leaves were also higher in Aquasap treated plants (Table 1).

4.2 Quality of Fruits

4.2.1 Nutritional Contents

The higher nutrient value of crude protein (45.8%), crude carbohydrate (29.56%), calcium (5.77%), phosphorous (5.68%), vitamin C (9.55%) and riboflavin (70.13%) were observed in Aquasap treated Robusta plants. Crude fiber (4.08%), potassium (3.55%), iron (11.55%) and thiamine (15.02%) were observed in maximum level with treated Red banana. Fruits of treated Njali poovan and Robusta had also

10% higher vitamin C when compared to their control plants (Table 3). Interestingly, fruits of treated plants showed less moisture level as compared to control, with 240.61%, 62.30%, 61.68% and 37.18% more carbohydrate, 283.71%, 94.07%, 62.87% and 38.93% higher proteins and 153.02%, 47.37%, 58.73 and 31.48% higher minerals respectively as compare to control plants (Table 7) and this is in agreement with observation made by Pise and Sabale [28] who had reported higher content of carbohydrate, proteins, free amino acid, polyphenols and nitrogen in fenugreek treated with seaweed extracts. Zodape et al. [26] had also observed similar kind of result with green gram treated with extract of *K. alvarezii* [26] and higher yield and improved quality of fruits in *Zizyphus mauritiana* was found when treated with extract of *Sargassum wightii* [29].

4.2.2 Impact of Micronutrients

Micronutrients present in Aquasap [5] have improved the quality of fruits (Figs. 1-13) and deficiency of those in control plants caused some quality problems. Occurrences of fruits cracking were more in control plants (11.8%) than treated one (3.55%) which could again be due to deficiency of boron (Figs. 2 and 6). Boron deficiency in control plants of Robusta and Red banana deformed foliage (Figs. 4 and 12) [13]. Similarly, calcium deficiency in control plants of Njali poovan led to crinkled leaves (Fig. 7). Separation of pseudo stem in control plants of Nendran and Red banana was observed, which could be due to deficiency magnesium [13].



Fig. 2 Cracking in fruits of Robusta due to boron deficiency.



Fig. 3 Closer view of cracking in fruits of control plant of Robusta.



Fig. 4 Deformed foliage in control plant of Robusta due to boron deficiency.



Fig. 5 Fruits of control & Aquasap treated Njali poovan.

4.2.3 Impact of Potassium

K. alvarezii extract contains micro, macro nutrients and growth hormones [5, 26]. Aquasap, an extract of *K. alvarezii* is rich of potash (1.6%). The potash is involved in protein synthesis and play role for the opening and closing of stomata (Wikipedia). The potash also plays a role of enzyme activation, photosynthesis,



Fig. 6 Cracking in fruits of Njali poovan due to boron deficiency.



Fig. 10 Moderate potassium deficiency (necrosis starts at leaf margin of Nendran).



Fig. 7 Early foliar symptoms of calcium deficiency (crinkled leaves).



Fig. 11 Fruits of control & Aquasap treated Red banana.



Fig. 8 Fruits of control & Aquasap treated Nendran.



Fig. 12 Deformed foliage due to boron deficiency in Red banana.



Fig. 9 Separation of leaves from the pseudostem due to magnesium deficiency in Nendran.



Fig. 13 Separation of leaves from the pseudostem due to magnesium deficiency.

transport of sugar, water and nutrient transport and starch synthesis [30]. Ho et al. [31] had reported that during the fruiting phase potash concentration decreased in pseudo stem and most of the potash was accumulated in fruit stalk and inflorescence [31]. Potassium deficiency in control plant of nendran showed necrosis at leaf margin was observed in control plants when compared with treated plants (Fig. 10) [30].

Yield increase and quality improvement may be due to presence of plant growth regulators and other macro and micro nutrients present in the seaweed extract Aquasap and it could also played a role in absorbing other chemical inputs applied to the plant.

5. Conclusions and Recommendations

It can be concluded from present study that banana varieties of hills and foothills viz. Robusta (AAA), Njali poovan (AB), Red banana (AAA) and Nendran (AAB) had responded well to 5% Aquasap (Brand name of AquAgri for biostimulant of seaweed *K. alvarezii*) with average yield increase of 56.58%, 19.08%, 39.35% and 11.46% respectively and much improved fruits quality. Present findings encourage the application of such seaweed extract as biostimulant in agricultural sector. Therefore, this simple practice of application of eco-friendly seaweed plant nutrient to different range of banana would be benefit small and marginal farmers.

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