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Foliar application of seaweed sap as biostimulant for enhancement of yield and quality of tomato (*Lycopersicon esculentum* Mill.)

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Effect of *Kappaphycus alvarezii* sap (seaweed) on growth and yield of tomato was studied in field during *kharif* season of 2006-07. *K. alvarezii* sap, applied as a foliar spray (5.0%), increased yield of tomato fruit (60.89%) as compared to control plants sprayed with water, attributed to increase in number of fruits per plant and size of fruit. With application of sap, fruit quality and also macro (13.24-67.50%) and micro (23.84-42.61%) elements content increased over control. Nutrient uptake by fruit and shoot was improved with foliar application of *K. alvarezii* sap. Plants receiving foliar applications showed resistance to leaf curl, bacterial wilt and fruit borer.

Keywords: Foliar spray, *Kappaphycus alvarezii*, Tomato, Seaweed sap

Introduction:

Disadvantages of chemical fertilizers have led farmers turning towards organic fertilizers[1]. To meet increasing demand of organic fertilizer, among many viable options[2], one of such option is use of seaweed extracts (SEs) as fertilizer[3]. Use of seaweed formulations as biostimulants in crop is well established[4]. In agriculture and horticulture, application of SEs has proved beneficial for the growth and yield[5], deeper root development and better seed germination[6], delay of fruit senescence, and improved plant vigour and yield quality and quantity[7]. SEs are applied to crops as root dips, soil drenches or foliar sprays. SEs contain major and minor nutrients, amino acids, vitamins, and also cytokinins, auxins, and ABA like growth substances[8]. Positive responses observed in different crops with application of SE are attributed to the presence of cytokinin[9]. Significant increase in yield of different crops due to foliar application of SEs have been reported[10,11]. Seaweed fertilizer was found to be superior to chemical fertilizer because of high level of organic matter aids in retaining moisture and minerals in upper soil level available to roots[12].

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This study evaluates foliar application of *Kappaphycus alvarezii* sap in enhancing growth, yield, quality and nutrient uptake of tomato cv. Pusa Ruby in the field.

Experimental Section

Field experiment was carried out at Horticulture Farm (Vegetable Section), Rajasthan College of Agriculture, Udaipur (Rajasthan) during 2006-07 *kharif* season. Farm is situated at 24°312 North latitude and 73°422 East longitude at an elevation of 582.17 m above mean sea level. Soil [bulk density, 1.48 (Mg m^{-3}) and particle density 2.61(Mg m^{-3})] of experimental site was clay loam. Soil aqueous extract (1:2 w/v) had: pH, 8.0; and electrical conductivity, 0.94 dSm^{-1}. Soil contained: available nitrogen (N), 201.1; available phosphorus (P), 20.2; and available potassium (K), 282.9 kg ha^{-1}. Plot size (6 m x 0.90 m) had row to row distance at 45 cm and plant to plant at 30 cm. A farm yard manure (25 t ha^{-1}) and vermicompost (0.25 t ha^{-1}) was applied. A dose (60 kg ha^{-1}) of urea (N), single super phosphate (P_2O_5) and muriate of potash (K_2O) was applied. A spray of insecticides (1% monocrotophos) was given as a plant protection measure. Experiment laid out in a randomized block design with five replications and five treatments [0 (control, water spray), and 2.5, 5.0, 7.5, and 10.0% (v/v) of

Table 1—Effect of *K. alvarezii* sap on yield, yield attributing characters and quality of fruit

Treatment	Yield and yield attributing characters							Quality of fruit									
	Plant height cm	Root Length cm	Chlorophyll mg/100 g FW	No. of fruits /plant	Fruit yield t/ha	Polar diam. cm	Equatorial diam. cm	Ascorbic acid mg/100g	Acidity %	Total solid %	N %	P %	K %	Fe mg/kg	Cu mg/kg	Zn mg/kg	Mn mg/kg
Control	90.60	9.10	0.73	13.58	23.68	4.44	3.04	42.21	0.74	4.04	3.70	0.42	2.00	70.80	5.95	30.20	35.20
2.5%	104.00	11.40	0.85	18.54	31.35	5.08	3.30	44.89	0.81	4.70	3.80	0.49	2.80	76.00	6.80	32.80	39.70
5.0%	121.80	13.20	1.12	23.78	38.09	5.86	3.80	52.26	0.92	5.32	4.19	0.53	3.35	91.40	7.45	37.40	50.20
7.5%	109.00	10.80	0.96	21.72	35.12	5.29	3.54	48.24	0.87	5.00	4.17	0.53	3.25	85.40	7.37	37.00	48.70
10.0%	105.68	10.30	0.89	20.32	32.51	5.12	3.44	45.56	0.82	4.78	4.10	0.52	3.20	83.40	7.22	35.90	48.20
CD at 5%	10.23	1.35	0.03	2.16	4.68	0.61	0.31	2.88	0.05	0.54	0.11	0.02	0.12	4.54	0.29	2.04	2.53

K. alvarezii sap]. Sap derived from fresh *K. alvarezii*[13] and having chemical constituents[14] was used in this study with appropriate dilutions. For proper adherence, sap was mixed with surfactant. Two foliar applications of *K. alvarezii* sap were applied; first at 7 days before and second at 7 days after flowering.

Measurements and Observations

Five plants were tagged in each plot for recording observations. Plant height was recorded 90 days after transplantation (DAT) from ground level to extreme growing tip using meter scale. Number of fruits per plant was computed based on the average number of fruits harvested from five tagged plants. At the ripe stage of fruit bearing, three fruits per tagged plant (15 fruits per plot) were used to measure diameter of fruit using vernier caliper. Total fruit yield of various pickings were recorded as yield. Length of tap root was recorded on randomly selected two plants in each plot at 90 DAT. For this purpose, plants were uprooted along with a ball of earth without disturbing nearby plants, washed in running water and root length was recorded. Leaf curl and bacterial wilt among plant diseases and fruit borer among insect pests were observed and incidences were recorded at 90 DAT. Rating for leaf curl and bacterial wilt was considered as no infection (0% infestation), low (0-10%), medium (11-25%), high (26-50%), and more than 50% was considered very high[15]. Similarly, rating for fruit borer was considered as no infection (0% infestation), low (0-5%), medium (5-15%), high (15-25%), and more than 25% was considered very high[16].

Analytical Determinations

Total chlorophyll content in fresh leaves was estimated following reported method[17]. Ascorbic acid (vitamin C) was determined in well developed fruit at peak stage of growth following indophenols dye reduction method and acidity of fruit juice was estimated by titrating with standard alkali using phenolphthalein as an indicator[18]. Total solid of fruit was estimated in well developed fruits at peak stage of growth[19] and nitrogen was determined following reported method[20]. Phosphorus was determined by vanadomolybdate method while potassium by flame photometer[21] and minerals (Zn, Mn, Cu and Fe) by atomic absorption spectrophotometer[22]. Data were analyzed using analysis of variance (ANOVA) and differences were considered significant at 5% level of probability[23].

Results and Discussion

Plant Growth

Studies conducted with seaweed sprays under controlled experiments, resulted in increased leaf size in spinach and improved root growth in tomatoes[5]. Application of *K. alvarezii* sap (5.0%) has significantly increased height (34.44%) and root length (45.05%) over control plants (Table 1). Similar results have been reported in *Vigna sinensis* L[12]. and in tomato[24,25], might be due to macro and micro elements as well as growth promoting substances like cytokinin[26]. There was significant increase in chlorophyll content in leaves under different treatments and maximum (53.85% over control) was recorded under 5.0% sap. Present results confirmed previously reported[27] results that chlorophyll a and b content was enhanced in seedlings treated with Dravya (seaweed extract). Enhanced leaf chlorophyll concentration of plants treated with SE is reported[28] due to presence of betaines.

Yield and Yield Attributing Characters

Foliar application of *K. alvarezii* sap has resulted in increase in yield and yield contributing characters in almost all concentrations (optimum at 5.0%). Maximum increase in fruit yield (60.89%) over control in plants receiving

Table 2—Effect of *K. alvarezii* sap on uptake of nutrients

Treatment	N, kg/ha		P, kg/ha		K, kg/ha		Cu, g/ha		Fe, g/ha		Zn, g/ha		Mn, g/ha	
	Shoot	Fruit	Shoot	Fruit	Shoot	Fruit	Shoot	Fruit	Shoot	Fruit	Shoot	Fruit	Shoot	Fruit
Control	148.39	112.94	17.84	12.86	175.05	61.03	23.96	18.19	594.57	216.53	120.46	92.25	239.66	107.91
2.5%	199.26	167.27	24.91	21.60	242.12	127.83	26.64	29.99	855.81	334.35	171.46	144.54	306.13	174.91
5.0%	219.16	215.09	28.35	28.00	283.44	168.25	38.72	37.96	997.19	479.51	237.37	188.83	381.27	264.09
7.5%	215.16	208.64	27.96	26.52	292.55	159.21	37.56	36.94	1033.89	425.58	257.33	185.11	375.56	242.41
10.0%	202.14	193.85	25.56	24.22	280.32	153.28	35.60	34.45	969.86	387.52	253.52	172.53	354.10	223.90
CD at 5%	23.00	22.79	3.52	2.98	35.70	18.89	6.19	5.14	140.47	55.43	34.75	21.95	53.80	32.63

5.0% foliar application of sap (Table 1) was due to increase in size of fruits as measured by polar and equatorial diameter and increase in number of fruits per plant. Compared to control, number of fruits per plant has increased by 75.11% for the plants receiving 5.0% foliar application of *K. alvarezii* sap. Similar results in tomato with applications of seaweed extract are reported[29,30]. Increase in yield and yield attributes may be due to the presence of plant growth regulators (indole 3 acetic acid, gibberellins GA_3, kinetin and zeatin) present in *K. alvarezii* sap[31,13]. Combined treatment of dipping the seedlings in 0.4% Kelpak solution for 2 h prior to transplanting followed by three foliar applications of 0.4% Kelpak during the growth of plants significantly increased number and size of marketable fruit of *Capsicum annuum*[10]. Increased yield may be due to increased fruit set and latter fruit weight through better plant canopy establishment, better inception of light and through significant reduction in inter plant competition for solar energy and soil nutrients. This would increase efficiency of plant to do photosynthesis and translocation of assimilates to the points of fruit set[29].

Quality Improvement

Minerals as well as acidity, total solids and ascorbic acid in fruit improved over control (Table 1) in all concentrations of *K. alvarezii* sap (optimum at 5.0%). A foliar application of sap showed increase in ascorbic acid (23.81%), acidity (24.46%) and total solids (23.81%) over control plants. Similarly, macro [13.24% (N) - 67.50% (K)] and micro [23.84 (Zn) – 42.61 (Mn)] minerals also increased under influence of *K. alvarezii* sap. This is in accordance with earlier results reported[11]. Quality improvement in terms of vitamin C in *Trigonella foenum-graecum*[32] and N of beans[33] has been reported with the application of SE. This is the first report on yield increase and quality improvement in tomato due to foliar application of *K. alvarezii* sap. Beneficial effects observed in present study might be due to presence of microelements and plant growth regulators especially cytokinin present in sap. However, effect of increased yield may well be an expression of effects considered elsewhere (resistance to diseases, root development)[6].

Nutrient Uptake

Treatments had higher values over control for nutrient uptake by shoot and fruit while highest values were recorded for plants receiving 5.0% foliar application of *K. alvarezii* sap. Compared to control, uptake of N (47.69%), P (58.91%), and K (61.92%) in shoot has increased under influence of 5.0% of *K. alvarezii* sap (Table 2). Similarly, there was an increase in uptake of macro nutrient of fruit up to 5.0% and then it declined with increase in the concentration. Increase in uptake of micro nutrients in fruit and shoot was maximum at 5.0% except Fe and Zn in shoot. Though, increase in uptake of Fe and Zn in shoot is maximum at 7.5%, it is at par with 5.0%. Present results are in conformity with reported results[14] of nutrient uptake (N, P, K and S) with application of SE. Similar results have reported[34] for increased uptake of Ca, K and Mg in leaves of lettuce with application of seaweed concentrate (Kelpak). Turan & Kose[35] reported increase in uptake of Cu with application of SE, due to increasing membrane permeability of roots, leaves and stoma cells, and hormone-like activities of SE through their involvement in cell respiration, photosynthesis, and enzymatic reactions[5].

Disease and Insect Infestation

Application of *K. alvarezii* sap has reduced disease and infestation in treated plants as compared to control (Table 3). Leaf curl and fruit borer infestations were positively controlled up to 5.0% concentration of *K. alvarezii* sap, beyond which it had no beneficial effect . On the other hand, bacterial wilt infestation remained unaffected with sprays. Crouch & Van Staden[36] reported resistance to infection with *Meloidogyne incognita* in tomato with application of seaweed concentrate. Carrot

Table 3—Effect of *K. alvarezii* sap on disease and insect infestation

Treatment	Leaf curl	Bacterial wilt	Fruit borer
Control	Medium	Low	High
2.5%	Low	Low	Medium
5.0%	Low	Low	Low
7.5%	Low	Low	Low
10.0%	Low	Low	Low

plants sprayed with SW showed less disease due to *Alternaria* and *Botrytis* compared to SA and control. Molecular analysis of SE-treated plants showed accumulation of defense gene transcripts at higher levels, with enhanced defense enzyme activities and accumulation of phenolics and phytoalexins. Disease control observed in SE-treated plants could be attributed to elicitor activity of carbohydrate (oligosaccharides) fractions present in seaweed extract[37]. Active ingredients of Dravya promote growth and elicit a plant defense response in various crops. Present study also indicated that a possible mechanism of control of bacterial blight by Dravya is through induction of systemic resistance in host[27].

Conclusions

Foliar applications of *K. alvarezii* sap at 5.0% concentration increased yield of tomato fruit. Quality of fruit also improved along with improvement in nutrient uptake, proving potential use of seaweed sap as supplemental fertilizer.

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