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EFFECT OF FOLIAR APPLICATION OF HUMIC ACID AND SEAWEED EXTRACT IN STRAWBERRY (*Fragaria × ananassa* Duch.)

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ABSTRACT

The investigation was carried out to evaluate the effect of foliar application of humic acid (HA) and seaweed extract (SWE) on growth, yield and quality in two cultivars (Camarosa and Nabila) of strawberry. The HA and SWE were applied as foliar sprays individually (1.0 ml l^{-1} and 2.0 ml l^{-1}) as well as in combination to the strawberry plants starting from one month after planting of uniform runners upto 120 days after planting at 15 days interval. The plants which received foliar spraying of water were treated as control. There were total nine treatments, which were replicated thrice under factorial randomized block design. The results indicated that foliar spraying of 2.0 ml l^{-1} HA + 1.0 ml l^{-1} SWE significantly increased the plant spread, number of leaves, number of crowns, leaf area, length of petiole, number of flowers, number of fruits, fruit weight, length of fruits and fruit yield over control plants. However, fruits with significantly the highest total soluble solid, ascorbic acid, total sugar content were recorded with the foliar application of 2.0 ml l^{-1} HA + 2.0 ml l^{-1} SWE. This treatment also found to be the best for producing the lowest acidic fruits. Among the strawberry cultivars, the performance of Camarosa in respect of fruit yield and quality was better than Nabila.

Keywords: Humicacid, Sea weed extract, Foliar application, Strawberry

Introduction

Strawberry (*Fragaria × ananassa* Duch.) is a perennial, herbaceous plant belonging to the family Rosaceace. The fruits are very attractive, delicious and rich in antioxidants (Giampieri *et al.*, 2012). It also contains fair amount of Vitamin C, Ca, K and Fe. Strawberry can be consumed both as fresh as well as in the processed forms like jam, jellies etc. Apart from the edible quality, strawberry has been used to prepare various kind of cosmetic products (Gasparrini *et al.*, 2017). Strawberry provides a huge return in the shortest possible time (Saroj *et al.*, 2021). Analysing the potential health benefits and demand in domestic market, many progressive farmers have initiated strawberry cultivation across the country, mainly under open field conditions. However, lesser yield with inferior fruit quality is the common phenomena under such conditions. Hence, sustainable strategies are required to boost up the strawberry yield maintaining the optimum fruit quality for open field cultivation.

Foliar application of bio-stimulants like humic acid (HA) and seaweed extract (SWE) can be a step forward as a sustainable strategy to improve the yield without affecting fruit quality. HA represents the major pool of organic C on the soil surface. It originates from chemical and biological transformations of plants and animal matters through microbial actions. HA known to improve the plant growth by regulating the soil C and N cycling. It also take part in structural development of soil (Canellas *et al.*, 2015). On the other hand, SWE are derived from marine macroalgae and reported to have growth promoting effects and recover the plants suffering from abiotic stresses. SWE contains complex polysaccharide, fatty acids, phytohormones, vitamins and mineral like P, K, Ca, Mg, Cu, Fe, Mn, and Zn. (Hong *et al.*, 2007; Battacharyya *et al.*, 2015). Both HA and SWE have a positive impact on crop productivity as well as quality and widely used in horticulture particularly in fruit crops. These biostimulants are ideally suitable both soil and foliar application to the crop plants. Meagre studies on the separate use of HA and SWE as foliar application have been documented. However, the combined effects of both HA and SWE on strawberry has not been studied so far. Hence, the present investigation was undertaken to study the effects of HA ad SWE on growth, yield and quality parameters of two cultivars of strawberry.

Materials and Methods

The present investigation was carried out at Research Farm (26°31' N and 89°45' E), Regional Research Station (*Terai* Zone), Uttar BangaKrishiViswavidyalaya, Punidbari, India. The experimental site was sandy to sandy loam and neutral in reaction with pH 6.4. The available N, P and K of the field soil were 315.6, 61.7 and 230.50 kg ha^{-1}, respectively with 0.79 % organic C. The recommended dose of NPK fertilizer (120:80:150 kg NPK ha^{-1}) is partially supplemented with vermicompost prepared from the farm waste materials and analyzed for major nutrient content (N = 0.83 %, P = 0.54 % and K = 0.39 %) before field application. Vermicompost @ 8.0 t ha^{-1} along with the required quantity of chemical fertilizer 53.6 kg N, 36.8 kg P, 118.8 kg K (as Urea, SSP and MOP, respectively) to meet the above said fertilizer dose were applied in top 12-15 cm layer of soil in the experimental beds for strawberries. Seven days after fertilizer application and subsequent bed preparation, healthy, well developed, almost uniform, pest and disease-free runner plantlets of strawberry cv. Camarosaand Nabila were planted at first week of November at a spacing of 45 cm × 30 cm in the experimental beds (0.90 m × 1.8 m). Each bed was comprised of 12 plants and paddy straws were placed as bedding material 15 days after planting of runners. Foliar spraying of humic acid (HA) and seaweed extract (SWE) alone and with combinations was carried out at 30, 45, 60, 75, 90,105 and 120 days after planting at two concentrations (1.0 ml l^{-1} and 2.0 ml l^{-1}). Thus, the foliar treatments were T_1 = 1.0 ml l^{-1}HA, T_2 = 2.0 ml l^{-1} HA, T_3 = 1.0 ml l^{-1} SWE, T_4 = 2.0 ml l^{-1} SWE, T_5 = 1.0 ml l^{-1} HA + 1.0 ml l^{-1} SWE, T_6 = 1.0 ml l^{-1} HA + 2.0 ml l^{-1} SWE, T_7 = 2.0 ml l^{-1} HA + 1.0 ml l^{-1} SWE, T_8 = 2.0 ml l^{-1} HA + 2.0 ml l^{-1} SWE, The control plot (T_9) received foliar application of distilled water. The experiment was laid out in Factorial Randomized Block Design (FRBD) with nine treatments and replicated thrice. Five plants from the net plot area were selected randomly and tagged to record the plant growth and ancillary observations Ten berries from the harvested fruit lot of each treatment were randomly selected to record the observations on physico-chemical properties. The titratable acidity, sugar content and ascorbic acid of fruits were determined following the standard procedures (AOAC, 1980). The data were analyzed for the variance and least significant differences (LSD) were calculated to compare significant effects at $p \leq 0.05$ (Snedecor and Cochran, 1967).

Results and Discussion

Effect on plant growth and flowering characters

The plant growth and flowering parameters of strawberry were significantly influenced by the foliar application of humic acid and seaweed extract. The plant growth in terms of plant spread (28.85 cm) was recorded maximum in the plants which received foliar spraying of 2.0 ml l^{-1}HA + 1.0 ml l^{-1}SWE (Table 1). The same treatment was also found to be the best for producing longest petiole (9.52 cm), maximum number of leaves plant^{-1} (32.27) and crowns plant^{-1} (2.95). However, plants having maximum leaf lamina (118.63 cm^2) were found with the foliar application of 2.0 ml l^{-1}HA + 2.0 ml l^{-1}SWE. All the above parameters were recorded minimum in control plants which received only water as foliar treatment. Humic acid (HA) is known to enhance the nutrient uptake ability of plants by increasing the permeability of cell walls (Muftyand Taha, 2021). Additionally, SWE contains trace amount of auxin, cytokinin and gibberellins (Battacharyya *et al*., 2015) and some nutrients like Mg, B and S (Hong *et al*., 2007). Further, SWE is also reported to be helpful for uptake of micronutrients in the plant system through chelation (Hong *et al*., 2007). Thus, more uptake of essential elements following HA application coupled with presence of growth promoting susbtances in SWE might have resulted better growth performances in the strawberry plants which received foliar application of both HA and SWE. Improvement in plant growth parameters with the foliar application HA and SWE are also reported in canola (Sani, 2014) and strawberry (Al-Shatri *et al*., 2020), respectively. Foliar application of 2.0 ml l^{-1} HA + 2.0 ml l^{-1} SWE had also resulted maximum numbers of flowers plant^{-1} (38.17). Similar findings is also reported earlier in strawberries (Al-Shatri *et al*., 2020). The plant growth parameters like plant spread (26.05 cm), leaf area (112.63 cm^2), length of petiole (9.17 cm) and crowns plant^{-1} (2.56) were recorded maximum in Nabila. However, the plants with maximum number of leaves (25.19) was noted in Camarosa. Nearly 7.05 % more flowers had been produced in Camarosa than Nabila. The interaction effect of foliar applications and cultivars for all the studied growth and flowering parameters were found to be non-significant. The strawberry cultivars are reported to be genetically diverse in nature and thus exhibited differential growth and flowering responses following HA and SWE application (Sharma *et al*., 2021).

Table 1: Effect of foliar application of humic acid and seaweed extract on plant growth and flowering characters of strawberry

Foliar Treatments (T)	Plant spread (cm)	Leaves plant^{-1}	Crown plant^{-1}	Leaf area (cm^2)	Length of petiole (cm)	Flowers plant^{-1}
1.0 ml l^{-1} HA	23.65	26.52	2.38	106.83	8.40	31.50
2.0 ml l^{-1} HA	26.20	27.55	2.43	110.43	8.74	34.17
1.0 ml l^{-1} SWE	22.68	26.35	2.32	105.31	8.26	29.67
2.0 ml l^{-1} SWE	25.61	26.93	2.48	107.95	8.50	33.67
1.0 ml l^{-1} HA + 1.0 ml l^{-1} SWE	26.73	28.47	2.53	114.46	9.12	35.17
1.0 ml l^{-1}HA + 2.0 ml l^{-1}SWE	27.01	30.37	2.72	114.97	9.17	35.83
2.0 ml l^{-1}HA + 1.0 ml l^{-1}SWE	28.85	32.27	2.95	116.99	9.52	38.17
2.0 ml l^{-1}HA + 2.0 ml l^{-1}SWE	27.56	30.77	2.83	118.63	9.36	36.33
Control (Water spray)	22.29	26.25	2.23	103.73	8.17	29.50
$P \leq 0.05$	1.02	1.81	0.02	4.18	0.41	1.45
Variety (V)						
Camarosa	25.19	29.25	2.52	109.43	8.44	34.93
Nabila	26.05	27.52	2.56	112.63	9.17	32.63
$P \leq 0.05$	0.48	0.85	NS	1.97	0.19	0.68
T × V	NS	NS	NS	NS	NS	NS

Effect on yield and yield attributing characters of strawberry

The plants received foliar application of 2.0 ml l^{-1}HA + 1.0 ml l^{-1}SWE resulted the highest number of fruits (28.83) plant^{-1}(Table 2). The same set of plants also produced the fruits with highest length (37.81 cm)and weight (13.59 g). This treatment was also found to be the best for producing the highest fruit yield (393.53 g plant^{-1}, 115.83 q ha^{-1}). Almost 63.8 % increase in fruit yield of strawberry was recorded with foliar application of 2.0 ml l^{-1} HA + 1.0 ml l^{-1}SWE over control plants. The foliar application of HA and SWE failed to produce any significant effect on fruit setting of the plant. However, the highest fruit setting was noted on the plants which received foliar application of 2.0 ml l^{-1} HA + 1.0 ml l^{-1} SWE. Fruits are acting as a sink organs in plants. The size of fruits is dependent on the dry matter accumulation by sink that developed during the process of photosynthesis (Man *et al*., 2015). Foliar application of HA is reported to stimulate the process of photosynthetic pigment accumulation in the leaves and thus boosting the photosynthetic efficiency of plants (Neri *et al*., 2002). Enhanced net photosynthetic rate with the application of HA was described in tomato (Haghighi and Teixeira da Silva, 2013). Additionally, the SWE is also reported to have a positive effect on the photosynthetic efficiency of plants by increasing the surface area of leaves (Lola-Luz *et al*., 2013), leaf chlorophyll content (Blunden *et al*., 1997) and ultimately the net photosynthic rate of plants (Yao *et al*., 2020).Thus, plants received foliar application of 2.0 ml l^{-1} HA + 1.0 ml l^{-1} SWE might have synthesized more dry matter in the process of photosynthesis which sinked to developing fruits resulted better sized fruits and thereby increased the yield of strawberry. Increased yield of strawberry with the foliar application of HA (Neri *et al.* 2002) and SWE (El-Miniawy *et al*., 2014) were also reported earlier. The lowest number of fruits (total and marketable) plant^{-1} and yield were recorded in the control plants. Irrespective of foliar application, it had been observed that all yield attributing characters were found to be best in Camarosa than Nabila. The interaction effects of yield and yield attributing characters were non-significant. The differential yield responses of the said strawberry cultivars were also reported earlier (Gaikwad *et al*., 2018).

Table 2: Effect of foliar application of humic acid and seaweed extract on yield and yield attributing characters of strawberry

Foliar Treatments (T)	Fruits plant^{-1}	Fruit set (%)	Fruit weight (g)	Fruit length(cm)	Fruit yield	
					g plant^{-1}	q ha^{-1}
1.0 ml l^{-1} HA	23.50	74.66 (8.67)*	11.55	32.24	271.49	101.00
2.0 ml l^{-1} HA	25.50	74.60 (8.67)	12.01	33.02	306.81	106.12
1.0 ml l^{-1} SWE	22.00	74.38 (8.65)	11.49	31.83	252.94	99.19
2.0 ml l^{-1} SWE	25.17	74.84 (8.68)	11.86	32.62	298.38	103.44
1.0 ml l^{-1} HA + 1.0 ml l^{-1} SWE	26.33	74.87 (8.68)	12.31	33.97	324.68	107.05
1.0 ml l^{-1} HA + 2.0 ml l^{-1} SWE	26.83	74.86 (8.68)	12.77	35.70	343.33	109.91
2.0 ml l^{-1} HA + 1.0 ml l^{-1} SWE	28.83	75.59 (8.72)	13.59	37.81	393.59	115.83
2.0 ml l^{-1} HA + 2.0 ml l^{-1} SWE	27.33	75.29 (8.70)	12.91	36.12	354.33	113.02
Control (Water spray)	21.00	71.29 (8.47)	11.44	29.96	240.21	98.12
$P \leq 0.05$	0.90	NS	0.84	1.51	28.90	7.18
Variety (V)						
Camarosa	26.33	75.28 (8.71)	12.58	34.12	333.88	108.38
Nabila	24.00	74.03 (8.60)	11.84	33.26	285.18	103.55
$P \leq 0.05$	0.42	NS	0.40	0.71	13.62	3.38
T × V	NS	NS	NS	NS	NS	NS

* Figures in the parentheses indicated the arc sing transformed values

Effect on fruit quality of strawberry

The plants treated with 2.0 ml l^{-1}HA + 2.0 ml l^{-1}SE produced the fruits with highest TSS (10.03 °B) including highest total sugar content of 9.51% (reducing sugar 5.33% and non-reducing sugar 4.18%) (Table 3). However, the highest non-reducing sugar was obtained from the fruits where the plants were treated with 2.0 ml l^{-1}humic acid + 1.0 ml l^{-1} seaweed extract. Foliar applied of HA and SE might have involved in hydrolysis of starchy compounds which ultimately raised the TSS level. Similar findings is also reported earlier in cucumber (Shafeek *et al*., 2016) and strawberry (El-Miniawy *et al*., 2014). The higher enzymatic activity like α-amylase and in vertage with the application of NAA might be responsible for higher total sugar content and non-reducing sugar content of strawberry fruits. The same treatment found best as to obtain lowest acidic fruits (0.64%), which were nearly 14.67% less acidic than the fruits of control plants. Increased TSS can cause parallel decrease in acidity (El-Razek *et al*., 2012). Seaweed extract contains adequate level of potassium which helps in different enzyme activation and protein synthesis. On the other hand humic acid enhanced the permeability of bio membranes for electrolytes accounted for increased uptake of potassium and phosphorous (Rathod *et al*., 2022). Highest increase of 29.92% in the value of ascorbic acid content was found in the fruits from 2.0 ml l^{-1} humic acid + 2.0 ml l^{-1} seaweed extract treated plants. The improvement in the ascorbic acid content of strawberry fruits might be due to increase level of metabolites that stimulate the precursor of ascorbic acid biosynthesis in plants which received foliar application of both HA and SE. Increased level of ascorbic acid content with the foliar application of HA and SE is also reported earlier in strawberry (El-Miniawy *et al*., 2014; Rostami *et al*., 2022). All preferred fruit quality parameters i.e. highest TSS (9.29 °B), highest reducing (5.27 %) as well as non-reducing sugar (4.25 %,), lowest acidity (0.67 %) and highest ascorbic acid content (69.41 mg 100 g^{-1}) was found in Camarosa variety than Nabila. The interaction effects of foliar application and cultivars on quality parameters were found non-significant. The differential quality attributes among the cultivars might be due to existence of genotypic variation (Sharma *et al*., 2021).

Table 3: Effect of foliar application of humic acid and seaweed extract on fruit quality of strawberry

Foliar Treatments (T)	TSS (°Brix)	Ascorbic acid (mg 100 g^{-1})	Acidity (%)	Reducing sugar (%)	Non-reducing sugar (%)	Total sugar (%)
1.0 ml l^{-1} HA	8.69	64.28	0.71	4.97	4.10	9.06
2.0 ml l^{-1} HA	8.93	65.92	0.72	5.03	4.12	9.15
1.0 ml l^{-1} SWE	8.74	62.92	0.71	4.98	4.08	9.06
2.0 ml l^{-1} SWE	9.07	65.67	0.70	5.03	4.11	9.13
1.0 ml l^{-1} HA + 1.0 ml l^{-1} SWE	9.26	68.46	0.67	5.07	4.12	9.18
1.0 ml l^{-1} HA + 2.0 ml l^{-1} SWE	9.49	71.88	0.67	5.13	4.21	9.34
2.0 ml l^{-1} HA + 1.0 ml l^{-1} SWE	9.75	74.90	0.64	5.16	4.22	9.39
2.0 ml l^{-1} HA + 2.0 ml l^{-1} SWE	10.03	79.90	0.65	5.33	4.18	9.51
Control (Water spray)	8.44	61.50	0.75	4.51	3.95	8.46
$P \leq 0.05$	0.58	3.74	0.04	0.41	NS	0.47
Variety (V)						
Camarosa	9.29	69.41	0.67	5.27	4.25	9.52
Nabila	9.02	67.35	0.71	4.78	3.99	8.76
$P \leq 0.05$	NS	1.76	0.02	0.19	0.11	0.23
T × V	NS	NS	NS	NS	NS	NS

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