Response of Chitosan Salicylic Acid Nanoformulations on Growth, Yield and Quality Attributes of Strawberry cv. Winter Dawn

Abstract

A field experiment was conducted during 2022-23 at horticulture farm, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan, India. The experiment was laid out in a Randomized Block Design with three replications. In this experiment, data showed that growth, yield and quality attributes of strawberry were significantly enhanced by Chitosan salicylic acid nanofromulation(CS-SA NF)@ 800-1200 ppm as compare to salicylic acid(SA) @ 100-300 ppm, bulk chitosan (BCH)@ 100-1200 ppm. According to the data themaximum values of growth attributes *viz.* plant height (25.92 cm), number of branches (11.84) and yield attributes *viz.* number of fruits per plant (28.68), fruit weight (20.02 g), yield per plant (659.65 g),estimated yield per hectare (366.47 qt.) and quality attributes *viz.* TSS (7.54 ^{o}Brix), ascorbic acid (62.91 mg/100g) and total sugar (7.30 %) were found maximum in CS-SA NF 800 ppm.

Keywords: Chitosan, CS-SA NF, Salicylic acid, BCH, Strawberry.

Introduction

The cultivated strawberry (Fragaria X ananassa Duch.) belongs to the family Rosaceae with chromosome number, 2n = 56. It is one of the delicious and nutritious among soft fruits with 98 percentedible portion. Strawberry plants are stoloniferous herbs and spread via stolons or runners. Strawberry plant has a short thickened stem called "crown" and shallow root system. The leaves are trifoliate and arise from the crown. Fruit is a small berry developed from one ovule with multiple achenes called true fruit which is non-climacteric. Strawberry occupies a unique place among cultivated berry fruits, as its fruits are attractive, luscious, tasty nutritious with pleasant aroma and delicate flavor. Strawberry contains anticancer compound i.e., ellagic acid and vitamin-C (Wange and Kzlogoz, 1998). Strawberry can be grown under sub-tropical climate and even at high altitude of tropical climate. It can be grown wide range of soil from heavy clays to light sand and gravels. However, strawberry plant grows well in sandy loam soil with pH 5.5-6.5. Strawberry requires an optimum day temperature of 22^0C and night temperature of 7^0C to 13^0C for maximum growth and development. In India, it is grown commercially in the states of Maharashtra, Punjab, Haryana, Karnataka, Madhya Pradesh, Jammu & Kashmir, Himachal Pradesh and Uttarakhand (Thakur *et al*., 2017). In India strawberry is cultivated in 1000 hectare with a production of 8000 MT (Anonymous, 2020).Flower induction in strawberry is controlled primarily by the interaction of photoperiod temperature and genotype. An individual flower typically has 10 green sepals five white petals 20 to 30 stamens and 60 to 600 pistils. The greatest number of pistils occurs on the primary flower and decreases successively down the inflorescence. Each pistil contains a single ovary that develops into an achene (Darnell *et al*., 2010). The achenes (the true fruits of strawberry) together with receptacle form an aggregate fruit which is referred to as a berry (the eterio of achenes, which is an aggregate of achene fruitlets developed from a single flower) but it is not a true berry in the botanical sense (Hancock, 2000).

Chitosan, a biopolymer derived from biowaste of sea food industry and soluble in organic acids. It is considered environment-friendly for agricultural uses as it is easily degraded in the environment and nontoxic to humans. Chitosan and its derivatives have been reported to elicit natural defense responses in plants, and have been used as a natural compound to control pre- and post-harvest pathogenic diseases(Rahman *et al*., 2018). Salicylic acid (SA) or orthohydroxylbenzonic acid and related compounds belong to a diverse group of plant phenolics. SA is involved in the induction of plant defence mechanisms under different biotic and abiotic stresses. It has been reported that the exogenous application of SA increased the photosynthetic rate, exchange of gas, and accumulation of osmotic regulators (sugars, proline, and glycine betaine) and it enhanced the mineral and water relations of the plants, therefore leading to better plant growth (Aghaeifard*et al.*, 2016).

Materials and methods

Data for growth parameters *viz.* plant height (cm) and No. of branchesplant^{-1} were recorded by five randomly selected plants from each plot at 60 and 90 days after transplanting.Fruit weight (g), No. of fruits plant^{-1}, total yield plant^{-1} (g), estimated yield ha^{-1} (kg) were calculated by five randomly selected plants from each plot at harvest.The TSS of ripe fruit juice was determined with the help of a hand refractometer (0-32 ^{0}B) by putting a few drops of juice on the prism. The refractometer calibrated with distilled water before use.

Treatment	Plant height At 90 DAT (cm)	Number of branches at 90 DAT	Number of fruits per plant

The total soluble solid was expressed in ^{0}Brix. The percent total sugars present in strawberry fruits were determined by (Lane and Eynon method, 1965).

Result

The plant height was significantly increased by foliar spray of CS-SA NFs 800 ppm (25.92 cm at 90 DAT) followed by CS-SA NFs 1200 ppm (25.77 cm) and BCH 1200 ppm (25.73 cm) as compared to control (16.64 cm). The number of branches was also significantly increased by CS-SA NFs 800 ppm (11.84 at 90 DAT) followed by CS-SA NFs 1200 ppm (10.45 at 90 DAT) and BCH 1200 ppm (10.26 at 90 DAT) as compared to control (7.55 at 90 DAT) and other treatments (Table- 1).

Number of fruits per plant was significantly increased by foliar spray of CS-SA NFs 800 ppm and CS-SA NFs 1200 ppm (28.68 and 28.53 fruits respectively) as compared to control (18.17 fruits). Fruit weight was also maximum in foliar spray of CS-SA NFs 800 ppm (20.02 g) followed by CS-SA NFs 1200 ppm (17.88 g) as compared to control (14.84 g) and other treatments. Moreover, total yield per plant (659.65 g), estimated yield per hectare (366.47 qt.) were significantly higher in 800 ppm CS-SA NFs followed by 1200 ppm CS-SA NFs (595.21 gand 330.67 qt.) as compared to control (324.42 gand 180.23 qt.) (Table- 2).

Table- 1: Effect of chitosan-salicylic acid NFs on growth parameters of Strawberry cv. Winter Dawn.

Control (water)	16.64±0.35[f]	7.55±0.16[e]	18.17±0.32[d]
Salicylic acid (SA)			
SA (100 ppm)	19.29±0.01[e]	8.36±0.00[de]	19.02±0.01[d]
SA (200 ppm)	21.17±0.56[de]	8.75±0.23[d]	22.47±0.52[c]
SA (300 ppm)	[illegible]	[illegible]	[illegible]
Bulk chitosan			
BCH (100 ppm)	21.31±0.09[de]	8.94±0.03[d]	22.76±0.33[c]
BCH (400 ppm)	23.42±0.07[bcd]	9.04±0.02[cd]	22.81±0.17[c]
BCH (800 ppm)	23.86±0.72[abc]	10.35±0.17[b]	23.12±0.06b[c]
BCH (1200 ppm)	25.73±0.44[ab]	10.26±0.28[b]	23.56±0.15b[c]
CS-SA NFs			
CS-SA NF (100 ppm)	22.85±0.17[cd]	8.51±0.06[de]	23.12±0.06b[c]
CS-SA NF (400 ppm)	23.97±0.78[abc]	9.96±0.32[bc]	24.93±0.71[b]
CS-SA NF (800 ppm)	25.92±0.77[a]	11.84±0.27[a]	28.68±0.60[a]
CS-SA NF (1200 ppm)	25.77±0.60[ab]	10.45±0.24[b]	28.53±0.58[a]

Treatment	Fruit weight (g)	Yield per plant (g)	Estimated yield per ha (q.)
Control (water)	14.84±0.31[d]	324.42±11.49[e]	180.23±6.38[e]
Salicylic acid (SA)			
SA (100 ppm)	[illegible]	[illegible]	[illegible]
SA (200 ppm)	16.07±0.42[bcd]	429.02±19.40[d]	238.34±10.78[d]

The growth parameters were recorded at 90 days after transplanting (DAT). Each value is mean of triplicate and each replicate consisted of 5 plants. 1[st]foliar was done at 30 days and 2[nd]at 60 days after transplanting. Mean ± SE followed by same letter is not significantly different at p = 0.05 as determined by Tukey- Kramer HSD. BCH represents bulk chitosan dissolved in 0.5% acetic acid.

SA (300 ppm)	16.55±0.07^{bcd}	441.40±3.23^{d}	245.22±1.79^{d}
Bulk chitosan			
BCH (100 ppm)	16.33±0.65^{bcd}	440.04±15.61^{d}	244.47±8.67^{d}
BCH (400 ppm)	16.99±0.05^{bc}	456.17±3.46^{cd}	253.43±1.92^{cd}
BCH (800 ppm)	17.21±0.29^{bc}	467.21±5.61^{cd}	259.56±3.12^{cd}
BCH (1200 ppm)	17.32±0.47^{bc}	479.±14.37^{cd}	266.12±7.98^{cd}
CS-SA NFs			
CS-SA NF (100 ppm)	17.10±0.13^{bc}	464.69±1.76^{cd}	258.16±0.98^{cd}
CS-SA NF (400 ppm)	17.78±0.58^{bc}	519.02±29.14^{c}	288.34±16.19^{c}
CS-SA NF (800 ppm)	20.02±0.46^{a}	659.65±0.44^{a}	366.47±0.25^{a}
CS-SA NF (1200 ppm)	17.88±0.42^{a}	595.21±0.45^{b}	330.67±0.25^{b}

Table-2:Effect of chitosan-salicylic acid NFs on yield attributes of Strawberry cv. Winter Dawn.

The yield parameters were recorded at harvest. Each value is mean of triplicate and each replicate consisted of 5 plants. 1stfoliar was done at 30 days and 2ndat 60 days after transplanting. Mean ± SE followed by same letter is not significantly different at p = 0.05 as determined by Tukey- Kramer HSD. BCH represents bulk chitosan dissolved in 0.5% acetic acid.

The data regarding quality parameters revealed that maximum TSS was found in CS-SA NFs 800 ppm (7.54^{0}Brix) followed by CS-SA NFs 1200 ppm (7.43 ^{0}Brix) and BCH 1200 ppm (7.34^{0}Brix) as compared to control (5.22 ^{0}Brix) and rest of treatments. The data showed that ascorbic acid content in strawberry fruit significantly higher in CS-SA NFs 800 ppm (62.91 mg/100g) followed by CS-SA NFs 1200 ppm (60.75 mg/100g) and BCH 1200 ppm (60.26 mg/100g) as compared to control (54.17 mg/100g) and other treatments. The maximum total sugar content was also observed in CS-SA NFs 800 ppm (7.30 %) followed by CS-SA NFs 1200 ppm (7.07 %) as compared to BCH 1200 ppm (6.73 %) and lowest in control (4.67 %) (Table- 3).

Table-3:Effect of chitosan-salicylic acid NFs on quality attributes of Strawberry cv. Winter Dawn.

Treatment	TSS (°Brix)	Ascorbic acid (mg/100g)	Total sugar (%)
Control (water)	5.22±0.11^{g}	54.17±1.16	4.67±0.09^{g}
Salicylic acid (SA)			

SA (100 ppm)	6.16±0.00^{ef}	56.13±0.04	5.12±0.00^{fg}
SA (200 ppm)	6.23±0.16^{def}	57.06±1.52	5.26±0.14^{efg}
SA (300 ppm)	6.48±0.02^{def}	58.43±0.24	5.46±0.02^{def}
Bulk chitosan			
BCH (100 ppm)	6.23±0.02^{def}	57.27±0.24	4.66±0.02^{g}
BCH (400 ppm)	6.71±0.02^{cde}	59.58±0.18	6.27±0.02^{bc}
BCH (800 ppm)	6.87±0.11^{bcd}	59.62±1.02	6.38±0.10^{bc}
BCH (1200 ppm)	7.34±0.20^{abc}	60.26±1.66	6.73±0.18^{ab}
CS-SA NFs			
CS-SA NF (100 ppm)	5.97±0.04^{f}	56.44±0.42	5.85±0.04^{cde}
CS-SA NF (400 ppm)	6.44±0.20^{def}	56.09±1.83	6.01±0.19^{cd}
CS-SA NF (800 ppm)	7.54±0.17^{a}	62.91±1.45	7.30±0.16^{a}
CS-SA NF (1200 ppm)	7.43±0.17^{ab}	60.75±1.43	7.07±0.16^{a}

The quality parameters were recorded at harvesting. Each value is mean of triplicate and each replicate consisted of 5 samples. 1stfoliar was done at 30 days and 2ndat 60 days after transplanting. Mean ± SE followed by same letter is not significantly different at $p = 0.05$ as determined by Tukey- Kramer HSD. BCH represents bulk chitosan dissolved in 0.5% acetic acid.

Discussion

Plant height and number of branches were recorded after twice foliar spray (30 and 60 days after transplanting) of CS-SA NFs, SA, BCH and water (control). Overall, positive effect was observed specially in 800-1200 ppm concentrations of CS-SA NFs. On the basis of mean value CS-SA NFs was more effective growth promotor. Application of CS-SA NFs significantly increased plant height and number of branches as compared to control. Earlier this formulation was tested on wheat and maize (Kumaraswamy *et al*., 2019 and Kadam *et al*. 2021). In earlier study, salicylic acid-chitosan nanoparticles (SA-CS NFs) were developed where chitosan matrix slowly released the encapsulated SA for its sustained availability to growing plant. Slow release of SA comprehensively stimulated plant antioxidant strength, protected maize crop from disease and improved yield as compared with SA (Kumaraswamy *et al*., 2019).The bio-efficacy of the developed CS-SA NF was evaluated on yield attributes in strawberry. In agreement with earlier findings, foliar application of CS-SA NFs (800-1200 ppm) significantly increased photosynthesis and vegetative growth which ultimately led to higher production and productivity in terms of fruit weight, fruit length, fruit volume, fruit diameter, number of fruits per plant, total yield plant^{-1} and estimated yield ha^{-1}. Quality attributes *viz.* TSS, ascorbic acid, reducing sugar, total sugar,were significantly higher in foliar application of CS-SA NFs (800-1200 ppm). Previous studies confirms that a slow releasing SA from SA-CS NPs as compared with bulk SA considerably increases source-activity and sink- strength. Despite the prominent role of slow release of SA, intrinsic growth regulating activity of chitosan due to availability of nitrogen (N) from $-NH_2$ group of chitosan and phosphorus (P) from tri-sodium- polyphosphate may also contributes to plant growth, yield and ultimately the fruit quality.

Conclusion

Response of CS-SA NF in present study due to slow and sustained release of SA to maintained cellular redox, plant growth activity of chitosan and availability of N via $-NH_2$ group of chitosan. We concluded that developed CS-SA NF can be tested at farmers field and other fruits crops for its efficacy.

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