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Salinity, Supplementary Calcium and Potassium Effects on Fruit Yield and Quality of Strawberry (*Fragaria ananassa* Duch.)

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Abstract: Fruit set and quality in strawberry cv. Selva were influenced by salinity (NaCl) and supplementary calcium and potassium ($CaSO_4$, $CaCl_2$, K_2SO_4) treatments applied to the root medium of plants growing in soilless culture under heated greenhouse conditions. Yield components such as primary fruit weight and fresh fruit weight (at harvest time) and fruit number were higher in control and there was no significant differences between control and NaCl (35 mM)+$CaSO_4$(10 mM). Primary fruit weight and fresh fruit weight (at harvest time) were decreased by salinity, even by $CaSO_4$ or $CaCl_2$ or K_2SO_4. Total acidity was higher in NaCl+$CaCl_2$ (5 mM) treatment compared to others. Total soluble solid and vitamin C were higher in NaCl+$CaSO_4$ (10 mM) treatment compared to other treatments. TSS/TA ratio was higher in NaCl+K_2SO_4 (10 mM) treatment compared to others. Our results suggest that in saline conditions, $CaSO_4$ application cause increase in fruit yield and quality of strawberry.

Key words: Strawberry % salinity % fruit yield % fruit quality % calcium and potassium

INTRODUCTION

Depressive effect of salinity on growth can be a useful management tool to regulate crop productivity and fruit quality. It has long been recognized that vegetative and reproductive growth in strawberry are antagonistic [1]. A reduction in leaf growth at an appropriate stage in the plants development could have some beneficial effects on fruit yield. Increased salinity has some application in restricting vegetative growth in young reproductive tomato plants, particularly under low light to improve early fruit setting [2]. But saline treatment reduced tomato yields, mainly as a result of a small fruit size [2]. Because NaCl salinity impairs leaf metabolism in sensitive species, photosynthesis is reduced and carbohydrate production is limited. This should result in a lower strawberry fruit yield and quality loss [3]. Awang *et al*. [4] reported a reduction in fruit yield in strwaberry, but fruit quality was improved at moderate salinity stress, because the concentration on reducing sugar and acids increased on a fresh weight basis due to decreasing fruit water content. Moreover,it was shown that fruit fresh weight in strawberry was lowered at higher salinity levels, but fruit dry weight was less affected. This also indicated that fruit dry-matter concentration was promoted by salinity. Increasing the fruit dry-matter content may have some beneficial effects on fruit quality [4].This has been demonstrated for a number of horticultural crop species, e.g. tomato [5], cucumber [6] and sweet peppers [7]. In most cases the absolute content of sugars and acids per fruit was lower at higher salinity level. Production and accumulation of organic constituents in fruits involve enzyme systems that sensitive to changes in NaCl concentration in plant tissue [8, 9]. In addition to increasing fruit dry matter content and hence improvement of flavour, fruits grown at high salinity level appeared to be more attractive [10] and have greater resistance to damage [11]. Saline water has been used to improve fruit quality of tomatoes grown in nutrient film culture [12, 13] on sand culture [10] and under field conditions [14-16]. In a sand culture experiment [17], fruit osmotic potentials was significantly reduced by salinity and corresponded primarily to reductions in fruit water import rather than increases in solute accumulation. This concentration of fruit solutes resulted in considerable improvements in fruit quality characteristics of SSC and acidity. Total inorganic ion accumulation on a dry weight basis was increased by salinity. Increasing in the fruit cation: anion ratio resulted in significantly higher titrable acidity levels and organic acid accumulation under salinity throughout fruit development. Mitchel *et al*. [17] reported that salinity leads to an increase fruit inorganic

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ion import, particularly cation import that change in the cation: anion ratio stimulate organic acid production increases and lower pH of tomato fruits. Salinity increase was lead to increase the fruit dry-matter content and acid concentration on fresh weight of strawberry fruits [18]. In a sand culture experiment, salinity caused reduction in water-soluble dry matter [19]. Moreover in tomato Perez-Alfocea [20] reported that salinity reduced soluble dry-matter in fruit. Potassium (K^+) applying in saline solution restored water-soluble dry matter [21]. However, acidity in tomato is positively correlated with fruit k+content [22] which could be reduced by high salinity. Hayward and Long [23] showed that increasing amounts of Na salts to the basic nutrient solution progressively reduced the size and dry-weight of the fruits, however reducing sugars and organic acids continued to improve in tomato fruits. Adames [5] reported that the concentration of reducing sugar in the tomato fruit juices increased with salinity and was higher with NaCl salts that with major nutrients (NO_3^--N, K^+, Ca^{2+}). But, the total sugar content per fruit was depressed at high level of salinity (12 ms cm^{-1}). Also, titrable acidity of the fruit juices increased with the salinity and was higher where major nutrients were used. But, total acid content per fruit, was decreased at high level of salinity (12 ms cm^{-1}). However, addition of major nutrients caused increase in acidity relative to NaCl (specially k^+). But he demonstrated that the increase in the acidity of the fruit is due to salinity rather than to k+per se. Kaya *et al*. [19] showed that addition of increasing amounts of Na+salts to the basic nutrient solution progressively reduced average fruit weight, number of fruit per strawberry plants and water-soluble dry matter in 35mM NaCl treatment compared to control. However, supplementary calcium mitigated the effect of high salt and water-soluble dry matter with supplementary Ca^2+treatments restored to levels that not significantly different from the control values. Cheour *et al*. [24] showed that foliar application of $CaCl_2$ on strawberry plants increased the free-sugar contents but, titrable acidity decreased. Jose *et al*. [25] reported that $CaCl_2$ treatment caused the delay in the decrease in soluble solids, as has been found in tomatoes and apples [26].

The aim of this study was to investigate the effects of salinity, supplementary calcium and potassium on fruit yields and quality of strawberry plants.

MATERIALS AND METHODS

A pot-experiment was conducted with strawberry cultivar 'Selva' in hydroponic-culture in greenhouse. Cold stored bare-rooted of strawberry plants each with one well-developed crown of diameter 8-10 mm were planted in pots containing perlite. Air temperature ranged between 14-16°C (night) and 24-30°C (day). Plants were irrigated with a nutrient solution. Treatments were:
Nutrient solution (N) (CONTROL)

- N+NaCl SALT (35 mM)
- N+SALT+$CaCl_2$ (5 mM)
- N+SALT+$CaCl_2$ (10 mM)
- N+SALT+$CaSO_4$ (5 mM)
- N+SALT+$CaSO_4$ (10 mM)
- N+SALT+K_2SO_4 (5 mM)
- N+SALT+K_2SO_4 (10 mM)

The experiment was arranged in Completely Randomized Design (CRD) with 8 treatments and 9 replications. Means were compared using Duncan's multiple range tests at 5% level. (Insert Reference)

Three replications were used for fruit number and primary fruit weight and fruit yield at harvest time. Measurements were taken two times in the experimental periods.Total yield was assessed for 9 replications at the end of experiment. Three samples of fruit juices of each treatment were taken during experiment for quality assessment. Fruits were homogenized in a Waring blender and volumes of the juices were taken for determination of total soluble solids, titrable acidity and vitamin-C. Acidity was determined by titration of fruit juices with 0.1 N NaOH and was expressed as mg citric acid in 100 g^{-1} fruit fresh weight. Total soluble-solids were determined by refractometer. Results were expressed as % of soluble solids in fruit fresh weight. Vitamin-C was determined by titration of fruit juices with Indophenol Method (Insert Reference).

Results were expressed as mg ascorbic acid in 100 mg^{-1} fruit fresh weight.

RESULTS

The salinity treatments and supplementary Ca^{2+} and K+ altered the fruit yield and quality. Higher primary fruit weight was obtained (Table 1) in control at each of two times and lower weight was resulted from NaCl in stage one, in NaCl and N+SALT+$CaCl_2$ (10 mM) and N+SALT+K_2SO_4 (5 mM) treatments in stage two. Moreover, with altering the concentration of $CaCl_2$ (from 10 to 5 mM), $CaSO_4$ (from 5 to 10 mM) and K_2SO_4 (from 5 to 10 mM) primary fruit weight at two stages increased. Higher fruit fresh weight at harvest time Fig. 5

Fig. 1: $CaCl_2$ (5mM) [LEFT] and (10mM) [RIGHT]

Fig. 2: $CaSO_4$ (10mM) [LEFT] and (5mM) [RIGHT]

Fig. 3: NaCl (35mM) [LEFT] and $CaCl_2$ (10mM) [RIGHT]

Fig. 4: NaCl (35mM) [LEFT] and K_2SO_4 (5mM) [RIGHT]

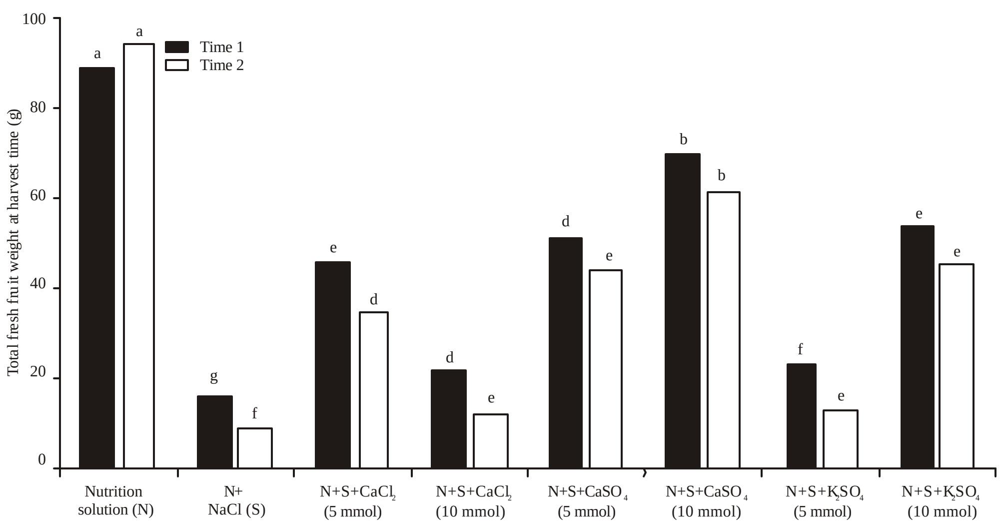

Fig. 5: Salinity, supplementary Ca^{2+} and K^+ effects on total fresh fruit weight (g) at harvest time

Table 1: Supplementary Ca^{2+} and K^+ effects on primary fruit weight, fruit set and total yield in strawberry under salinity

Treatment	Nutrient solution (N)	N+Salt NaCl (35 mM)	N+S+ $CaCl_2$ (5 mM)	N+S+ $CaCl_2$ (10 mM)	N+S+ $CaSO_4$ (5 mM)	N+S+ $CaSO_4$ (10 mM)	N+S+ K_2SO_4 (5 mM)	N+S+ K_2SO_4 (10 mM)
Primary fruit weight (g)								
Time 1	26.24a	9.29f	17.50d	11.81e	17.35d	21.31b	12.28e	18.79c
Time 2	26.21a	7.77e	14.72d	8.11e	16.34c	18.96b	7.68e	17.87b
Fruit number								
Time 1	5.33a	2.00d	3.66 c	2.33d	4.33bc	5.00ab	2.33d	4.33bc
Time 2	6.00a	1.33c	3.66 c	1.66c	4.33 b	5.33a	2.00c	4.00b
Total yield (g)								
	723.36a	220.98h	461.05e	280.27g	479.81d	683.07b	310.24f	497.66c

Table 2: Salinity, supplementary Ca^{2+} and K^+ effects on fruit quality

Treatment	Nutrient solution (N)	N+Salt NaCl (35 mM)	N+S+ $CaCl_2$ (5 mM)	N+S+ $CaCl_2$ (10 mM)	N+S+ $CaSO_4$ (5 mM)	N+S+ $CaSO_4$ (10 mM)	N+S+ K_2SO_4 (5 mM)	N+S+ K_2SO_4 (10 mM)
TA (g/100 g FW)	0.42c	0.41c	0.90a	0.68b	0.37c	0.44c	0.35c	0.30c
TSS (g/100 g FW)	7.77ab	7.83ab	6.87b	6.70b	7.90ab	8.97a	6.80b	7.60b
TSS/TA ratio	18.67b	19.35b	7.80c	10.01c	21.42ab	20.42ab	19.16b	25.64a
Vitamin C (g/100 g FW)	31.33d	45.33b	10.00f	26.67e	40.67c	56.00a	29.33de	26.00e

was obtained in control at two stages and lower weight was resulted from NaCl treatment at two stages of measurements. Moreover, by altering the concentration of $CaCl_2$ (from 10 to 5 mM), $CaSO_4$ (from 5 to 10 mM) and K_2SO_4 (from 5 to 10 mM) fresh weight at harvest time in two stages of measurements increased. Higher fruit number per plants Table 1 was resulted from control at two stages, but there were no significant differences between control and N+SALT+$CaSO_4$ (10 mM) at two stages. In addition, by altering the concentration of $CaCl_2$ (from 10 to 5 mM) Fig. 1, $CaSO_4$ (from 5 to 10 mM) Fig. 2 and K_2SO_4 (from 5 to 10 mM) fruit number at two stages increased. In this case, at each of two times, significant differences were not obtained between $CaCl_2$ (10 mM) and K_2SO_4 (5 mM) and NaCl treatments Fig. 3 and 4. At stage two, there were no significant differences were resulted between $CaCl_2$ (5 mM) and $CaSO_4$ (5 mM) and K_2SO_4 (10 mM). Higher total yield was resulted in control Table 1. By altering the concentration of $CaCl_2$ (from 10 to 5 mM), $CaSO_4$ (from 5 to 10 mM) and K_2SO_4 (from 5 to 10 mM) total yield increased. Total acidity Table 2 was higher in $CaCl_2$ treatments. Even between control and NaCl treatments, no significant differences were not resulted. However, with increasing the concentration of $CaCl_2$ (from 5 to 10 mM) total acidity decreased.Total soluble-solid content Table 2 was higher in $CaSO_4$ (10 mM) treatments. By increasing the concentration of $CaSO_4$ (from 5 to 10 mM), total soluble solids increased, however, there were no significant differences between $CaSO_4$ (5 mM) and $CaSO_4$ (10 mM) treatments. In the case of vitain-c Table 2, significant differences were resulted among treatments and higher vitamin-c was obtained from $CaSo_4$ (10 mM) treatment. There was no significant differences among K_2SO_4 (5, 10 mM) and $CaCl_2$ (10 mM) treatments and lower vitamin-c was found in $CaCl_2$ (5 mM) treatment. TSS/TA ratio Table 2 was higher with K_2SO_4 (10 mM) treatments. There were no significant differences in TSS of fruits under NaCl treatments with compared to control plants. The amount of vitamin-C significantly changed among different treatments and higher vitamin-C was obtained from $CaSO_4$ (10mM) Table 2. There were no significant differences among K_2SO_4 (5,10 mM) and $CaCl_2$ (10 mM) treatments and lower vitamin-C was found in $CaCl_2$ (5 mM) treatment. TSS/TA ratio Table 2 was higher in K_2SO_4 (10 mM) treatment.

DISCUSSION

Salinity in the nutrient solution and consequently in the root environment altered fruit yield and quality. Reduction in fruit yield by salinity was due to reduction of fruit number and fruit weight. However, fruit weight was more reduced than fruit number at two stages of measurements. These results are agreement with Mitchel *et al*. [17] findings in tomato and Yahya *et al*. [27] and Saied *et al*. [3] in strawberry. Supplementary Ca^{2+}improved fruit weight and number and $CaSO_4$ were the best source for calcium in this experiment. $CaCl_2$ in lower concentration was well, probably because Cl- concentration was low in N+SALT+$CaCl_2$ (5 mM) than N+SALT+$CaCl_2$ (10 mM). These results are agreement with Kaya *et al*. findings [21] on strawberry and Adams [28] in tomato. Supplementary K+has mitigated negative effects of NaCl treatment on strawberry [19]. Moreover, by increasing the concentration of K_2SO_4 (from 5 to 10 mM), fruit number and yield were increased. Probably, K_2SO_4 in higher concenteration is more efficient to reduce NaCl negative effects on strawberry. Increasing in sugar and acid contents due to salinity were also reported in other fruits including tomatoes [5, 10, 11, 29, 30], guava [31], sweet pepper [6] and cucumber [7]. The taste quality of strawberries depends mainly on the sugar content [32]. The higher fruit quality has the higher TSS/TA ratio. The average TSS/TA ratio recorded in this study were 25.64, 21.42, 20.42, 19.35, 19.16, 18.67, 10.01 and 7.8 for K_2SO_4 (10 mM), $CaSO_4$ (5 mM), $CaSO_4$ (10 mM), NaCl (35 mM), K_2SO_4 (5 mM), $CaCl_2$ (10 mM) and $CaCl_2$ (5 mM), respectively. Fruits with higher total soluble solids are generally preferred by consumers and this was confirmed in this study. The same trend was also reported for tomatoes [10, 11]. A lower net non-structural carbohydrate and acid accumulation in salinized plants could be due to several reasons. Strawberry plants grown at salinity have been shown to have a lower photosynthetic area [33] and could also have a lower rate of photosynthesis [8, 34]. Reduction in ion uptake, including K^+, has often been reported in salinized plants [35] and would have had some effect on the production of soluble-solids, acids and other organic compounds in fruits. The concentration of K+in the fruit has been shown to be positively correlated with fruit acidity [22] and have a clear relationship to carbohydrate metabolism [36]. Furthermore, a portion of the photosynthate produced by these plants would have been consumed for osmotic adjustment. An effective osmotic adjustment is known to occur in salinized strawberry [4]. All these factors could have contributed to lower production of dry matter [4]. In this experiment, in contrast with Adams *et al*. [22] results, lower and higher acidity were obtained by K_2SO_4 and $CaCl_2$ treatments, respectively and no clear effect of $CaCl_2$ was seen on the TA. Lower acidity by K_2SO_4 treatments, probably, resulted from competition between Na+and K+in nutrient solution and this concentration of K_2SO_4 was no efficient to mitigated the effects of NaCl salinity. Higher total soluble solids and vitamin-C were obtained from $CaSO_4$ (10 mM) treatment. Supplementary Ca mitigated the detrimental effect of high salt [19] for strawberry and [37] for cotton. Higher TSS and vitamin-C may explained by the effect of the Ca^{2+} on metabolism of soluble solids and organic acids [26, 38].

However, Robinson [39] reported that vitamin-C biosynthesis generally parallels with a high level of sugar contents. Reduction of fruit yield under saline conditions could be partially compensated for by superior quality fruits. Since, fruit yield is partially dependent on inflorescence number and fruit set; a smaller negative effect of salinity on fruit yield could be expected if salinity was introduced at a later stage of plant development. Managed salinity treatments could achieve a better quality fruits with small adverse effect on yield.

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