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EFFECT OF FOLIAR SPRAY WITH SOME SAFETY MATERIALS ON THE PRODUCTIVITY AND STORABILITY OF STRAWBERRY FRUITS UNDER SANDY SOIL CONDITIONS

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ABSTRACT

This experiment was carried out during the two successive winter seasons of 2014/2015 and 2015/2016 at the Experimental farm of El-Kassasein, Hort. Res. Station, Ismailia Governorate, Egypt, to investigate the effect of foliar spray with chitosan (Cs), calcium chloride ($CaCl_2$) and potassium silicate (K_2SiO_3) , beside of the control treatment (foliar spray with tap water) on growth, yield and storability of strawberry cv. Festival grown in sandy soil under drip irrigation system. The obtained results showed that, sprayed strawberry plants with Cs+ K_2SiO_3 significantly increased shoot dry weight , early yield / plant and total yield, as well as TSS and vitamin C in fruits at harvested time in both growing seasons.

Under the storage conditions, the lowest total weight loss and decay percentages and highest values of TSS in fruits were noticed when the plants were treated with Cs+$CaCl_2$. While the fruit firmness had the highest values when the plants sprayed with $CaCl_2$+ K_2SiO_3 treatment in both growing seasons. On the other hand, the maximum values of vitamin C in fruits were recorded as a result of the plants sprayed with the treatment of Cs+ K_2SiO_3.

***Conclusively,** it could be concluded that the treatment of Cs + K_2SiO_3 in most cases , being the most effective treatment for obtained highest values of shoot dry weight, early yield, total yield, TSS, firmness, vitamin C, as well as , for obtained lowest values in weight loss and decay percentages of strawberry fruits during storage periods.*

Key words: Strawberry, chitosan, calcium chloride and potassium silicate, foliar spray, yield, yield quality & storability.

INTRODUCTION

Strawberry (*Fragaria x ananassa* Duch.) is a small fruit crop with great nutritional and medicinal values (Maas *et al*., 1991) and is one of the most popular fruits in the worldwide. In the last two decades, strawberry has become one of the very important horticultural vegetable crop for local fresh consumption, food processing and export, in Egypt. Strawberries are unique with highly desirable taste, flavor, and excellent dietary sources of ascorbic acid, potassium, fibers and simple sugar sources of energy (Perez *et al*., 1997). Crop yield and early harvests are of the most important target for growers, and fruit quality is a considerable important to the consumers.

Chitosan is a natural, low toxic and inexpensive compound that is biodegradable and environmentally friendly with various applications in agriculture. Structurally, chitosan is a straight-chain co-polymer composed of D-glucosamine and N-acetyl D-glucosamine, being obtained by the partial deacetylation of chitin. It is the most abundant basic biopolymer and its structurally similar to cellulose, which is composed of only one monomer of glucose (De Alvarenga, 2011). Chitosan is derived from chitin, a polysaccharide found in the exoskeleton of shellfish, such as shrimp, lobster, and/ or crabs and cell walls of fungi (Wojdyla, 2001). Recently, chitosan has been reported to act as a plant growth regulator and considered to elicit the induction of plant defense mechanisms in many plants (Ben-Shalom *et al*., 2003; and Photchanachai *et al*., 2006). Moreover, chitosan has been shown to stimulate plant growth (Mondal *et al*., 2012); to posses antioxidants activity (Xie *et al*., 2001and Chen *et al*., 2009), act as antitransparent compound that has proved to be effective in many crops (Khan *et al*., 2002 on rice and Karimi *et al*., 2012 on castor bean) and to improve storability of post harvest fruits and vegetables (El-Ghaouth *et al*., 1991). Spraying strawberry plants with chitosan as growth stimulator, positively affected plant length, number of leaves/plant, leaf area, both of plant fresh and dry weight , fruit weight, early and total yields/plant compared to the control treatment (Abdel-Mawgoud *et al.*,2010, Shafshak *et al.*, 2011 and El-Miniawy *et al.*, 2013)

Calcium is an important nutrient that plays a key role in the structure of cell walls and cell membranes, fruit growth, and development, as well as general fruit quality (Kadir, 2004). Spraying tomato plants with $CaCl_2$ resulted in a significant increases in plant height, fruits weight per plant, and fruit firmness compared to control (Rab and Haq , 2012). Also, spraying with $CaCl_2$ increased the strawberry yield and TSS , TA (total acidity) and vitamin C in fruits compared to control (Kazemi, 2013)

Potassium silicate is a source of highly soluble silicon; it is used in agricultural production system primarily as a silicon fertilizer (Abou-Baker *et al.*, 2011). Foliar spray with potassium silicate increased plant growth, chlorophyll content, N,P and K contents in leaves and yield and its components of strawberry (Wand and Galletta 1998), Kamal, (2013) on sweet pepper and Salim *et al.*, 2014 on potato).

Therefore, the aim of the present study is to investigate the effects of chitosan, calcium chloride and potassium silicate on growth, fruit yield ,yield quality and storability of strawberry grown under sandy soil conditions with using drip irrigation system.

MATERIALS AND METHODS

This experiment was carried out during two successive winter seasons of 2014/2015 and 2015/2016 at the Experimental Farm of El-Kassasein, Hort. Res. Station, Ismailia Governorate, Egypt., to study the effect of foliar spray with chitosan, calcium chloride and potassium silicate individually or combinations on growth, yield, yield quality and storability of strawberry under sandy soil conditions. The soil was sandy in texture which had 0.07 and 0.08 % organic matter, 8.01 and 7.88 pH, 1 and 1.14 mmhos/cm EC, 4.74 and 4.92 ppm available N, 3.53 and 3.49 ppm available P and 9.53 and 9.58 ppm available K, respectively.

The experiment included eight treatments, which were i.e., 1-control (foliar spray with tap water),2- Chitosan 1.5% (Cs), 3- calcium chloride, 2% (CaCl), 4- Potassium silicate, 5ml/l (K_2SiO_3), 5- $CaCl_2$ + K_2SiO_3, 6- CS + K_2SiO_3, 7- Cs +$CaCl_2$ and 8- Cs + $CaCl_2$+ K_2SiO_3. These treatments were arranged in a randomized complete block design (RCBD) with three replicates.

The experimental unit area was 12.6 m^2. It contains three dripper lines, 6 m length and 70 cm distance between the two drippers lines. The distance between each two transplants in the dripper line was 25cm. One line (4.2 m^2) was used to measure the morphological and physiological traits and the other two lines (8.4m^2) were used for yield and quality determinations. In addition, one row was left between each two experimental units as a guard area to avoid the overlapping foliar sprayed.

Frigo transplants of strawberry (Festival cultivar) were transplanted on 22th and 24th September during the 1st and 2nd seasons, respectively

Chitosan powder (poly – (1,4-B-D-glycopyranosamine); 2-Amino-2-deoxy- (1->4)- B-D-glucopyranan) was prepared by dissolving 1.5% chitosan in 0. 5 % acetic acid solution and manufactured by Chengdu Newsun Biochemistry Co., Ltd, China.

Potassium silicate contains of 10 % K_2O and 25 % Si. Foliar application treatments were sprayed four times at 75, 90 , 105 and 120 days after transplanting. Untreated plants were left as a control treatment and sprayed with tap water.

The agricultural practices concerning cultivation, irrigation, fertilization and insect and disease control were conducted according to the recommendation of the Ministry of Agriculture for strawberry commercial production.

Data recorded:

A random sample of five plants from each plot was taken after 120 days from transplanting in the two growing seasons for measuring the vegetative growth , i.e., plant height/cm , number of leaves/plant, and shoot dry weight/plant (g) was measured using dried fresh shoot / plant at 70 ^{o}C till constant weight.

Yield and its components

The early yield was determined as weights of all harvested fruits from each plot during February and March months, and then early yield per fadden was calculated. Total yield was recorded from each plot all over the harvested season up to the mid of May , then total yield per fadden (ton) was calculated.

Fruit quality :

They were measured after six weeks from the first harvest as follows: Total soluble solids contents (TSS) as brix^{o}: Samples of ten ripe fruits were chosen randomly from each experimental plot at full ripe stage to measure the percentage of total soluble solids content using the hand refractometer. Total titratable acidity (TA %), Samples of 100g fruits from each experimental plot at full ripe stage were randomly chosen to determine the total titratable acidity of juice by titration with 0.1 NaOH soluation, using phenol phthalein indicator, according to the method described in A.O.A.C. (1990). Ascorbic acid content, it was determined in mg/100g fresh weight using 2, 6 Di chloro phenol Indophenol for titration as the method mentioned in A.O.A.C. (1990).

Firmness was determined by using a Chattilon pressure meter equipped with a plunger (N,4, USA) a needle 3mm diameter.

Storability

About 500g of strawberries fruits of each experimental plot of uniform size and colour were freshly harvested, washed thoroughly to remove any extraneous material, surface-dried using blotting paper, divided into three lots , (5, 10, and 15 days) and were stored at zero C^{o} ± 1 C^{o} and 90 -95 % relative humidity, when cold storage period to determine the following data.

Weight loss (%):

Weight loss percentage was measured after 5, 10 and 15 days. The weight measured (Digital Electrical Balance) at zero days was taken as reference weight and calculated by using the following equation;

$$\text{Weight loss(\%)} = \frac{\text{Initial weight - Weight of fruits at different sampling dates}}{\text{Initial weight of fruits}} \times 100$$

Fruits of each treatment were weighed at 5 days by intervals, then weight loss percentage was calculated.

Fruit decay:

Two phome plats from each experimental plot were used to determine the fruit decay. Percentage of fruit decay was calculated according to the following equation;

$$\text{Fruit decay \%} = \frac{\text{Initial fruit – Fruit decay during storage}}{\text{Initial fruit}} \text{ X } 100$$

Different quality parameters, *i.e.* total soluble solids, firmness , vitamin C and acidity were determined following the same methods as previously mentioned in fruit quality after 5, 10 and 15 days from storage

Statistical analysis:

Recorded data were subjected to the statistical analysis of variance according to Snedecor and Cochran (1980), and means separation between treatments were done according to least significant difference (LSD) at 5 % level.

RESULTS AND DISCUSSION

Plant growth

Results in Table 1 show that, vegetative growth of significance parameters of strawberry plant, *i.e.* plant height and number of leaves/plant were significantly improved in response to foliar application of chitosan at 1.5 (CS) % , calcium chloride 2% ($CaCl_2$) and potassium silicate at 5ml/l (*K_2SiO_3*) individually or in combination comparing to the control treatment in both growing seasons. Plants sprayed with $CaCl_2$+ K_2SiO_3 recorded the tallest plants (17.66 and 18.00 cm in the 1st and 2nd seasons, respectively) with no significant differences with Cs + $CaCl_2$+ K_2SiO_3 in both seasons. Number of leaves/ plant was the highest with plants which sprayed with Cs+ $CaCl_2$ (17.66 and 18.00 leaf/ plant) in the 1st and 2nd seasons, respectively without no significant differences between combined with Cs+ K_2SiO_3 or Cs+$CaCl_2$+ K_2SiO_3 in both seasons . On the other hand, the

lowest values of plant height and number of leaves were obtained by the treatment of control in both growing seasons (11.66 and 10.00 cm) and (12.16 and 12.66 leaf / plant), respectively.

Regarding shoot dry weight, such data in Table 1 reveal that, foliar spraying with different treatments had a significant improved dry shoot weight / plant of strawberry than unsprayed plants in both seasons under sandy soil condition. Cs + K_2SiO_3 treatment had a significantly increased in shoot dry weight as compared to the other treatments in both seasons. The relative increase in shoot dry weight/ plant due to sprayed plants with Cs+ K_2SiO_3 were about 83.23 and 82.96 %, followed by Cs+ $CaCl_2$ + K_2SiO_3 treatment 77.83 and 75.71 % in both seasons, respectively than control treatment.

The stimulating effect of chitosan on plant growth may be attributed to an increase in the availability and uptake of water and essential nutrients through adjusting cell osmotic pressure and reducing the accumulation of harmful free radicals by increasing the antioxidants and enzyme activities (Guan *et al*. 2009). As well as Calcium carbide stimulates root growth and early onset the flowering in agronomic and vegetable crops (Yaseen *et al*. 2006)

These results are in harmony with those reported by Bittelli *et al.* (2001) on pepper , Abdel-Mawgoud *et al.*,(2010), Shafshak *et al.*, (2011) and El-Miniawy *et al.*,(2013) on strawberry regarding chitosan effect, and El-Mansi *et al*. (2005) on tomato respecting calcium effect, and Wand and Galletta (1998) on strawberry, Aranda *et al*. (2006) on tomato and Abou-Baker *et al.* (2011) on bean with regard to the effect of potassium silicate .

Yield and its components:

Early and total yield per plant and per faddan were significantly affected with Cs, $CaCl_2$, K_2SiO_3 singly, double or in combination as compared to the control treatment in both seasons (Table 2). Sprayed plants with Cs+ K_2SiO_3 , being the most effective on early yield/ plant 85.63 and 102.58g/ plant and total yield 4.795 and 5.744 ton/fad. in both seasons, respectively without any significant differences with the treatment of Cs + $CaCl_2$ + K_2SiO_3 in both seasons. Moreover, the highest yield/ plant and total yield/ fad. were obtained as a result of Cs + K_2SiO_3 317.49 and 374.12 g/ plant and 17.779 and 20.950 ton/fed. in both seasons, respectively.

The relative increases in total yield/fed., due to sprayed plants with Cs + K_2SiO_3 were about 52.541 and 48.34 % , followed by the combined effect with Cs + $CaCl_2$ + K_2SiO_3 recorded values about 38.51 and 38.53 % in the 1^{st} and 2^{nd} seasons, respectively.

The increase in strawberry yield due to chitosan application may be due to its effects in stimulating physiological processes, improving

vegetative growth, followed by the active translocation of photoassimilates from source to sink tissues (Farouk and Ramadan , 2012).

The beneficial effect of calcium in increasing fruit set might be due to the higher availability of photosynthesis and these chemicals are also associated with hormone metabolism which promotes synthesis of auxin, essential for fruit set and growth (Kazemi, 2014)

These results are in accordance with those obtained by Mondal *et al.* (2012) on okra , Shehata *et al*. (2012) on cucumber and El-Miniawy *et al.*, 2013) on strawberry as regard to the effect of chitosan and Rab and Haq , (2012) and Kazemi, (2014) on strawberry regarding calcium effect. Wand and Galletta (1998) on strawberries, Kamal (2013) on sweet pepper and Salim *et al.* (2014) on potato as for potassium silicate effect.

Fruit quality:

Data in (Table 3) show that treating strawberry plants with Cs, $CaCl_2$, K_2SiO_3, singly, double or in combination had a significantly affected TSS, total acidity, vitamin C and firmness in fruits as compared to the control treatment in both seasons .

Sprayed strawberry plants with Cs + $CaCl_2$ had a significant effect on TSS with the highest values 10.16 and 10.0 in the 1^{st} and 2^{nd} seasons, respectively without any significant differences by the treatment of Cs+ K_2SiO_3 in both seasons.

Regarding the total acidity content in fruits, the same data in the same table showed that , the lowest values of fruit total acidity was obtained by $CaCl_2$ or Cs + K_2SiO_3.

The highest values of Vitamin C was recorded by sprayed plants with Cs + K_2SiO_3 43.3 and 43.7(mg/ml juice) without significant differences with Cs+$CaCl_2$ in both seasons. Fruit firmness was recorded with the combination of $CaCl_2$ + K_2SiO_3 486.6 and 516.6 (g/cm^2) in both seasons , respectively.

Calcium is an important nutrient that plays a key role in the structure of cell walls, cell membranes, fruit growth, and development, as well as general fruit quality (Kadir, 2004). Moreover, Potassium silicate is consider as a significant supplement of K, since potassium plays an important role in water status of plant, promoting the translocation of newly synthesized photosynthetics and mobilization of metabolites, as well as promoting the translocation synthesis of sugars and polysaccharides (Mengel and Kirkby, 1982). These results are in harmony with those reported by Abdel-Mawgoud *et al*. (2010) on strawberry and Ghoname *et al.* (2010) on sweet pepper regarding chitosan effect. Kadir (2004) on apple, Rab and Haq (2012) on

tomato and Kazemi, (2013) on strawberry concerning calcium effect. Abou El-Khair and Mohsen (2016) on Jerusalem artichoke regarding potassium silicate.

Fruits storability

Weight loss and decay percentages

The total weight loss (Table 4 and Figure1) and decay percentages of fruits (Table 5) were significantly affected throughout the cold storage period (5, 10 and 15 days from storage) by different treatments, in both seasons, except after 5 days regarding weight loss % in both seasons. Fruit weight loss and decay percentages were increased by the period up to 15 days. However, the increment in fruit weight loss and decay with increasing storage, consequently in turn might increased weight loss through evaporation and dry matter loss through respiration of fruits. The lowest total weight loss and decay percentages were obtained by sprayed strawberry plants with Cs+$CaCl_2$, treatment followed by Cs+$CaCl_2$+ K_2SiO_3 or Cs + K_2O_3Si . This treatment has reduced the percentage of weight loss by 56.18 % and 72.12% and decay by 53.84% and 47.08 % with Cs +$CaCl_2$ treatment the end of storage period (15 days in both seasons, respectively) as comparing to the control treatment. These results may be due to the increasing in TSS and fruit firmness (Table 3).

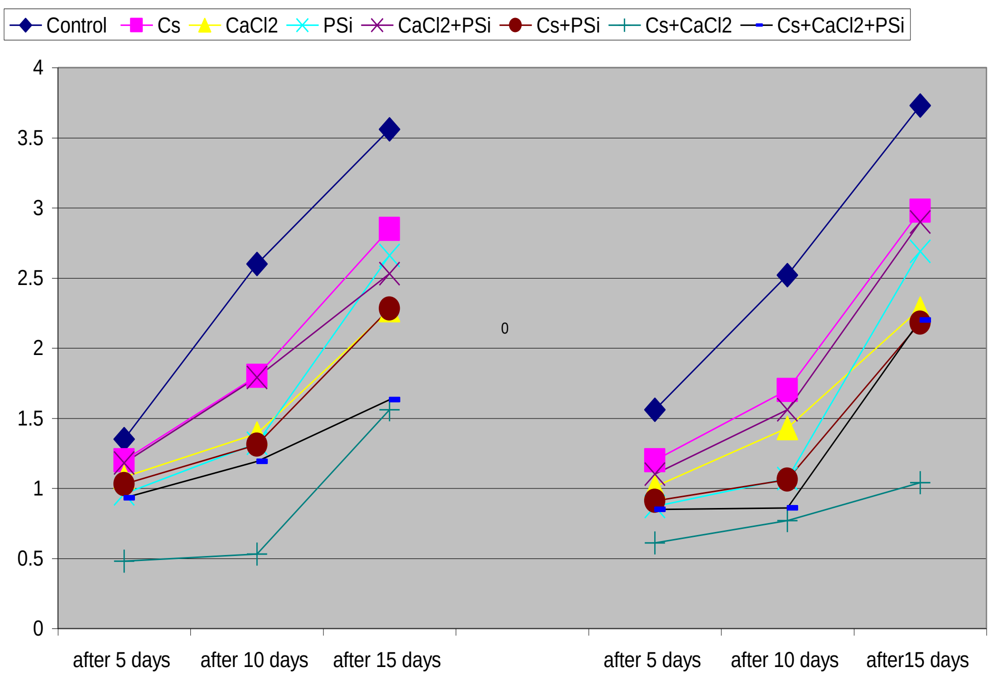

Figure1. Weight loss

As regards to chitosan , it has been shown that chitosan seemed to have anti-fungal activity against a wide range of fungi (El-Ghaouth *et al*., 1991) and induced the expression of a variety of genes involved in plant defense responses (Loschke *et al*. , 1983; Walker-Simmons *et al*., 1983). Moreover, chitosan can reduce pathogenesis infection through direct toxicity or chelation of nutrients and minerals from pathogens and also from physical barriers around the penetration sites of pathogens , preventing them from spreading to healthy tissues (El-Hadrami *et al*., 2010).

In addition, chitosan have shown a great potential as natural biodegradable substances which have anti-microbial activities and could effectively inhibit postharvest diseases of fruits by direct inhibition on spore germination, germ tube elongation and mycelia growth of phytopathogens and indirect inducement of defenses related enzyme such as phenylalanine ammonialyase (Zhang *et al.*, 2011).These reasons may be in turn plants have a highest growth characters (Table 1) and highest fruit yield (Table 2).

Foliar applications of calcium chloride have been reported to delay ripening and retard fungal growth on strawberries (Wojcik and Lewandowski, 2003).

These results are in agreement with those obtained by Abou El-Khair (2015) on sweet potato. They found that dipping the base of the stem cutting in 0.075 % chitosan solution before planting + spraying plants with 0.075 % chitosan solution gave the best treatment for increasing storability of sweet potato plants.

Fruit quality under the storage conditions:

TSS as brix^o in fruits were gradually decreased with increasing the storage period up to 15 days in both seasons (Table 6). The singly or in combination of Cs, K_2SiO_3 and $CaCl_2$ were better in TSS content of fruit than that of the control plants during and end of cold storage period (15 days). Moreover, sprayed plants with Cs + K_2SiO_3 was more beneficial than other treatments or control treatment, and recorded TSS values of about 25.54 and 29.85 % than control treatment in both seasons, respectively, after 15 days of storage.

As for total acidity, concentration of acidity in strawberry fruits were significantly decreased by foliar application of plant with different treatments than control treatment (Table 7). Total acidity in fruits were gradually increased by increasing cold storage period up to 15 days from storage. The lowest values of total acidity in fruits were obtained from chitosan treatment and recorded the percentage about 53.34 and 54.55 % less than control treatment in the 1st and 2nd seasons, respectively.

Regarding Vitamin C contents in fruit, data in (Table 8)indicated that, Vitamin C in fruits was gradually decreased by increasing the cold storage period up to 15 days from storage . Foliar spray with Cs, K_2SiO_3 and $CaCl_2$ singly, double or triple had a significant effect on Vitamin C contents in fruits at different storage periods than control. Moreover, the highest contents of vitamin C in fruits were recorded as a result of sprayed plants with the combination of Cs and K_2SiO_3 in both seasons . The increases in vitamin C due to the sprayed plants with this treatment were about 96.38 and 84.44 % than control treatment in both growing seasons, respectively.

Concerning the fruit firmness, it is clear from data in (Table 9) that the positive effect regarding different tested treatments of fruit firmness of strawberry during the storage period 5 ,10 and 15 days from storage. Fruit firmness were gradually decreased with the increasing of storage period up to 15 days from storage. The highest fruit firmness during and till the end of the storage period (15 days) was obtained from sprayed plants with $CaCl_2$+ K_2SiO_3 and recorded values were about 69.53 and 83.30 % over control treatment in the 1^{st} and 2^{nd} seasons, respectively.

Pre and postharvest treatments with calcium salts have been effective in control of several physiological disorders, reducing the incidence of fungal pathogens and maintaining fruit firmness (Bakshi *et al.* 2005). Also, calcium may be more critical for the TSS contents of strawberry fruit. These results could be ascribed to increasing the soluble matter in the juice by the penetrated calcium chlorides. Also, Ca pre-harvest treatment, fruits of 'Pajaro' strawberry have higher TSS and ascorbic acid content, lower acidity than control.(Kazemi, 2014).

Conclusively, it could be concluded that the treatment of Cs + K_2SiO_3 in most cases , being the most effective treatment for obtained highest values of shoot dry weight, early yield, total yield, TSS, firmness, vitamin C, as well as , for obtained lowest values in weight loss and decay percentages of strawberry fruits during storage periods.

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تأثير الرش الورقى ببعض المواد الآمنة على الانتاجية والقدرة التخزينية لثمار الفراولة تحت ظروف الارض الرملية

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أجريت هذه التجربة خلال موسمى 2015/2014 ، 2016/2015 بمزرعة محطة بحوث البساتين بالقصاصين ، محافظة الاسماعلية – مصر لدراسة تأثير الرش الورقى بالشيتوسان وكلوريد الكالسيوم وسليكات البوتاسيوم بجانب معاملة المقارنة (الرش بماء الصنبور) على النمو ، المحصول والقدرة التخزينية للفراولة للصنف فيستيفال النامى فى الأرض الرملية باستخدام الرى بالتنقيط.

توضح النتائج أنه رش نباتات الفراولة بالشيتوسان+ سليكات البوتاسيوم أدى إلى زيادة معنوية فى الوزن الجاف للبنات ، المحصول المبكر والكلى للنبات وكذلك المواد الصلبة الذائبة وفيتامين ج فى الثمار عند الحصاد فى كلا الموسمين.

أما تحت ظروف التخزين ، لوحظ أقل القيم للفقد الكلى فى الوزن ونسبة التلف فى الثمار واعلى القيم للمواد الصلبة الذائبة فى الثمار عندما عوملت النباتات بالشيتوسان + كلوريد الكالسيوم . بينما كانت أعلى القيم لصلابة الثمرة مع النباتات التى عوملت بكلوريد الكالسيوم + سليكات البوتاسيوم فى كلا الموسمين. ومن ناحية أخرى كانت أعلى القيم لمحتوى الثمرة من حمض الاسكوربيك (فيتامين ج) قد لوحظت في الثمار المعامله بالشيتوسان + سليكات البوتاسيوم .

التوصية: فى معظم الحالات يمكن ان نوصى باستخدام معاملة الشيتوسان + سليكات البوتاسيوم حيث كانت هذه المعاملة هى الاكثر فاعلية للحصول على أعلى القيم للوزن الجاف للعرش ، المحصول المبكر والمحصول الكلى ، المواد الصلبه الذائبة الكليه للثمار ، صلابة الثمرة ، محتوى الثمرة من فيتامين ج وكذلك الحصول على أقل النسب للفقد فى الوزن والتلف فى ثمار الفراوله أثناء مدة التخزين