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USING ANTIOXIDANTS AND SOME ORGANIC NUTRIENTS TO IMPROVE FRUIT PRODUCTIVITY OF SWEET PEPPER UNDER HIGH TEMPERATURE STRESS CONDITION
I. YIELD AND ITS COMPONENTS AND FRUIT QUALITY CHARACTERS

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ABSTRACT

Two field experiments were conducted at El-Baramoon experimental farm of Horticultural Research Institute, Mansoura Governorate during 2006 and 2007 late summer seasons, on sweet pepper plants cv. California Wonder. The study aimed to investigate the effect of some antioxidants and nutrients in organic form to alleviate the adverse effects of high temperature stress and its related oxidative one; vitamin E-selenium (150 ppm vitamin E) – vitamin C (150 ppm) – zinc citrate (100 ppm Zn) – calcium citrate (2000 ppm Ca) were sprayed singly or in combinations. The obtained results showed that, all applied treatments ameliorated stress effects and significantly improved fruit yield (No. of fruits / plant, fruit average weight, fruit yield / plant and total fruit yield / fed.) and its physical (fruit length, fruit diameter and flesh thickness) and chemical quality(TSS %, vitamin C, total acidity % and dry matter %). The combination of zinc citrate + calcium citrate (100 ppm Zn + 2000 ppm Ca) or vitamin E-selenium + zinc citrate (150 ppm vitamin E + 100 ppm Zn) gave the highest significant results in both seasons, respectively.

INTRODUCTION

Sweet pepper (*Capsicum annuum*, L) is known as a favorite and widespread vegetable crop over the world, its fruit rich in antioxidants, vitamins and minerals for human diet and healthy (Mateos *et al*., 2003; Marin *et al*., 2004 and Charanjit *et al*., 2007).

Its vitamin C, carotenoids and crypto xanthin rich fresh fruits have an important health advantages. Epidemiological data have indicated possible roles of those natural antioxidants in preventation of numerous chronic diseases including cancer, cardio vascular disorders, stroke, athero sclerosis and cataracts (Blok and Langseth, 1994; Steinmetz and Potter, 1996 and Van-Poppel and Van Den Berg, 1997).

On the other hand, it was known that sweet pepper plants are sensitive to high temperature and adversely affected, when day and night temperature exceeded 25 / 20 °C, especially during flowering and fruit setting peaks (Wien *et al*., 1993 and Wien, 1997). Under Egyptian conditions, sweet pepper is frequently subjected to severe high temperature extremes (heat stress) that prevailing during its long summer growing season.

Such environmental stressful condition known to induce serious internal physiological oxidative stress, enhancing the production of reactive oxygen species (ROS) in elevated toxic and destructive levels (Diknson *et al*., 1991; Bowler *et al*., 1992 and Dat *et al*., 2000).

Over accumulation of ROS during heat and / or other abiotic stresses can result in cell membrane damage, lipid peroxidation, protein oxidation and denaturation, enzymes inactivation and inhibition, DNA and RNA damage, destruction of cell active metabolic sites, leakage of cell solutes and impairment of the whole metabolic machinery (Stroev, 1989; Richter and Schweizer, 1997; Dat *et al*., 2000; Kovtun *et al*., 2000 and Mittler, 2002).

Also, shortage of bio-assimilates, mineral nutrients and hormones, thereby lacking of their supply into reproductive sinks of high and argent demand. In this connection, the elemental status of sweet pepper plant especially of calcium and zinc is known to be tightly associated and participated in such stress physiological events. These elements are frequently occurred in deficient levels, as their availability and mobility are adversely affected by soil and air environment (El-Fouly and Abdalla, 1996; Balakrishnan, 1999; Bar-Tal *et al*., 1999 and Karni *et al*., 2000). This case consequents by serious agronomical problems of poor fruit setting, progressive abscission of flowers and small fruits and at least low fruit productivity (Wien and Zhang, 1991; Wien *et al*., 1993; Moon *et al*., 1995; Huberman *et al*., 1997; Schroeder *et al*., 2001 and Fathy and Khedr, 2005a).

Recently, many workers illustrated that suppression the extreme enhanced production of ROS during such stressful conditions is to great extent protect and ameliorate the above mentioned injurious and destructive effects (Dat *et al*., 2000). This will be established by using antioxidants (ROS-scavengers), i.e.; vitamin C, vitamin E and selenium those which activate group of enzymes (antioxidant enzymes), i.e.; peroxidases, catalases and dismutases to allow detoxification of the excess ROS, protect the plants against heat / oxidative stress effects (Bowler *et al*., 1992; Willekens *et al*., 1997; Kovtun *et al*., 2000 and Mittler, 2002).

In addition, improving Ca and Zn status of high temperature affected plants known to be of great benefit under the same conditions. Since it was well known that Ca (Robson, 1993) and Zn (Hu and Sparks, 1990) are in similarly enhance cell division and differentiation, viability and retentability of reproductive organs. Also Ca (Hepler and Wayne, 1985 and Schroeder *et al*., 2001) and Zn (Suge *et al*., 1986 and Domingo *et al*., 1990) induce an active and balanced hormonal status of IAA and GA's vs. ABA and ethylene within reproductive and other organs. They (Ca and Zn) play a defensive protective role against the adverse effects of high temperature via their antioxidant and gene regulatory functions (Cakmak and Marschner 1988 b & c, Chesters, 1992, Clayton *et al*., 1999 and Sanders *et al*., 2002). It was also reported that Ca (Ferguson and Drobak, 1988) and Zn (Cakmak and Marschner, 1988 a) enhance translocation of bio-assimilates and nutrients within plant tissues as they activate membrane transporter enzymes.

Meanwhile, it was reported that foliar application of Ca (Santos *et al*., 1990; Moon *et al*., 1995; Marcelis and Ho, 1999; Lin *et al*., 2000 and Pereira and Mello, 2002) and Zn (Balakrishnan, 1999 and Dongre *et al*., 2000) greatly improved growth and productivity of sweet pepper crop under different conditions.

Besides, Fathy *et al*. (2003) illustrated that foliar application of vitamin E-selenium and vitamin C considerably improved growth, mineral composition, chlorophyll, antioxidants content, fruit yield and quality of eggplant, protected it against heat stress injurious effects. Also, Khedr *et al*. (2004) demonstrated that foliar feeding with Ca and Zn highly ameliorated high temperature adverse effects on the same crop and improved its growth, minerals content, bio-constituents and productivity. Similar effects of Ca and Zn on heat stressed sweet pepper and cowpea were reported (Fathy and Khedr, 2005a and Fathy and El-Hamady, 2007), respectively.

The present work aimed to study the effect of foliar Ca, Zn (citrate form), vitamin E-selenium and vitamin C applied individually or in pair combinations on late summer / heat stressed sweet pepper plant towards alleviation of the severity of the prevailing abiotic thermal stress and its inducible destructive oxidative stress on different agronomical performances of such important vegetable crop.

MATERIALS AND METHODS

The present investigation was carried out during the two successive seasons of 2006 and 2007 at El-Baramoon farm of Mansoura Horticultural Research Station. The objective of this work is to study the effect of calcium and zinc in organic form, some antioxidants (oxygen free radicals scavengers), i.e. ascorbic acid (vitamin C) and α-tocopherol (vitamin E) + selenium and their combinations on the morphological and metabolical performance of sweet pepper (*Capsicum annuum,* L.) cv. California Wonder towards alleviation the adverse effects of high temperature stress and its corresponding oxidative one, improving its fruit yield and quality during late summer season.

In 15 March during the two seasons, Seeds were sown in foam trays filled with peat and vermiculite (1:1), enriched with different nutrients. After 45 days (beginning of May in the two seasons), sweet pepper transplants were transplanted into one side ridges of 5m long, 0.65m width and 0.35m apart and the plot area was $9.75m^2$. During the growing seasons, all agricultural practices were performed according to Ministry of Agriculture and Land Reclamation recommendations.

Experimental design:

Randomized complete block design with three replications was adopted, each replication contained 12 treatments, all applied as foliar sprays.

Experimental treatments:

Treatments were as follows:-

1- Vitamin E-selenium (150 ppm vitamin E) from commercial veterinary formulation contains (20 % vitamin E).
2- 2- Vitamin C (150 ppm) from commercial veterinary formulation contains (20 % ascorbic acid).
3- Zn citrate (100 ppm Zn) from zinc citrate (12 % Zn) formulation of Horticulture Research Institute.
4- Ca citrate (2000 ppm Ca) from calcium-citrate (25 % Ca) formulation of Horticulture Research Institute.
5- Vitamin E-selenium + vitamin C.
6- Vitamin E-selenium + Zn citrate.
7- Vitamin E-selenium + Ca citrate.

8- Vitamin C + Zn citrate.
9- Vitamin C + Ca citrate.
10- Zn citrate + Ca citrate.
11- Mix* (vitamin E-selenium + vitamin C + zinc citrate + calcium citrate).
12- Control, its plants sprayed only with tap water.

The plants were sprayed 4 times, the first one applied 30 day after transplanting and repeated every 15 day.

Experimental parameters:

The following measurements and determinations were recorded in both seasons:

1- Fruit yield and its components:

From the cumulative fruit harvestings of each plot, the following parameters were calculated:

1.1- Number of fruits per plant: calculated according to total No. of fruits of each plot divided on No. of plants per plot.

1.2- Fruit yield per plant (gm): calculated according to total fruit yield of each plot divided on No. of plants per plot.

1.3- Fruit average weight (gm): calculated according to the following equation:

$$\text{Fruit average weight} = \frac{\text{Yield of fruits/plant}}{\text{No. of fruits/plant}}$$

1.4- Total fruit yield per feddan (ton): calculated according to the following equation:

Total fruit yield/fed. = fruit yield/plant × No. of plants/fed. (17500 plant).

1.5- Relative yield percentage: calculated according to the following equation:

$$\text{Relative yield \%} = \frac{\text{Yield of each treatment}}{\text{Yield of control}} \times 100$$

2- Fruit quality characteristics:

Representative samples of green mature fruits (20 fruits) were taken from each plot at the middle of harvesting season for determining the following physical and chemical quality characters:

2.1-Fruit physical characteristics:

2.1.1- Fruit length (L) cm: measured by Vernier caliper from top to bottom of the fruit that under fruit stalk.

2.1.2- Fruit diameter (D) cm: measured by Vernier caliper under fruit stalk where the top, middle and bottom of the fruit then the average was taken.

2.1.3- Fruit shape index (L/D): calculated according to fruit length divided on fruit diameter.

2.1.4- Flesh thickness (cm): a lengthwise slice was made in each fruit and the flesh thickness was measured by Vernier caliper from top, middle and bottom then the average was taken.

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* **All agents of the applied pairs had the same concentration as they individually applied.**

2.2- Fruit chemical characteristics:

2.2.1- Total soluble solids percentage (TSS %): Determined by a hand refractometer.

2.2.2- Vitamin C and acidity: Determined by titration against 2, 4, 6-dichlorophenol indophenol and phenolphytheline, respectively, according to methods of A.O.A.C. (1970).

2.2.3- Fruit dry matter percentage: Fresh samples of fruits (100 gm) were allowed to dry in oven at 70°C till reaching constant weight, and percent of dry matter was calculated for each treatment.

Statistical analysis:

All data were statistically analyzed based on ANOVA and Duncan's Multiple Range Test of means by using Costat statistical software (V. 6.311 CoHort Software).

In addition, data of day and night air temperature through out the experiment period (two seasons) was obtained from Department of Agricultural Extension, Directorate of Agriculture, Mansoura, Dakahlia Governorate, was presented in Table (1).

Table (1): Monthly means of day and night temperatures during 2006 and 2007 summer seasons at El-Mansoura, Dakahlia Governorate, Egypt.

Month	2006		2007	
	Day	Night	Day	Night
May	30.5	16.1	32.5	18.2
June	33.9	20.8	34.8	21.9
July	33.7	22.6	35.4	24.5
August	35.5	23.5	35.2	24.4
September	34.7	20.3	33.5	21.3
October	30.6	18.2	31.2	19.6

RESULTS AND DISCUSSION

Fruit yield and its components:

Data presented in Table (2) showing the effect of vitamin E-selenium, vitamin C, calcium citrate, zinc citrate and their combinations on fruit yield and its components (No. of fruits / plant, fruit average weight, fruit yield / plant, total fruit yield / feddan and relative yield %) of sweet pepper plants, during 2006 and 2007 late summer seasons.

The same data revealed that all applied treatments significantly increased fruit yield and its components per plant, compared with control plants. Also they were differed considerably, in most cases, in the two seasons. Moreover, it was obvious that the pair combinations showed higher improvements than individual ones in most studied parameters.

It was also clear from the presented data that the treatment of zinc citrate + calcium citrate gave significantly the highest values for number of fruits / plant, fruit yield / plant and total fruit yield/feddan, followed by vitamin E-selenium + zinc citrate, in the two seasons, then vitamin C + calcium citrate in fruit yield / plant and total yield/feddan and calcium citrate in number of fruits / plant of both seasons. Concerning fruit average weight parameter, it was distinct that vitamin C treatment showed significantly the highest value, in the two seasons, followed by vitamin E-selenium, then vitamin E-selenium + vitamin C, with no significance differences between the least one and vitamin E-selenium treatment, in the second season.

Table (2): Effect of vitamins (E-selenium & C), organic nutrients (Calcium citrate & Zinc citrate) and their combinations on fruit yield and its components of sweet pepper cv. California Wonder, during 2006 and 2007 seasons.

Characters	No. of fruits/plant		Fruit average weight (gm)		Fruit yield / plant (gm)		Total fruit yield / fed. (ton)		Relative yield %	
Seasons / Treatments	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**
Vitamin E-sel.	18.93 i	19.67 i	49.33 b	48.00 b	934.0 j	943.7 i	16.345 j	16.514 i	175.35	175.38
Vitamin C	19.40 i	20.23 i	51.70 a	49.77 a	1002.7 h	1007.3 g	17.547 h	17.628 g	188.24	187.22
Zn citrate	23.63 ef	24.10 f	42.70 ef	42.33 ef	1009.3 g	1020.3 f	17.663 g	17.856 f	189.49	189.64
Ca citrate	26.03 c	25.97 c	39.80 g	40.30 g	1035.3 f	1046.0 e	18.118 f	18.307 e	194.37	194.44
Vit. E-sel. + vit. C	22.73 g	23.10 g	47.87 c	47.57 b	1088.0 d	1098.7 c	19.040 d	19.224 c	204.26	204.17
Vit. E-sel. + Zn cit.	26.87 b	27.23 b	41.90 f	41.70 f	1126.3 b	1134.0 b	19.711 b	19.845 b	211.45	210.77
Vit. E-sel. + Ca cit.	24.00 e	24.50 e	43.33 e	42.83 e	1039.7 f	1048.3 e	18.194 f	18.344 e	195.18	194.81
Vit. C + Zn cit.	23.10 fg	23.40 g	46.40 d	46.00 c	1072.0 e	1078.3 d	18.760 e	18.871 d	201.26	200.42
Vit. C + Ca cit.	25.07 d	25.60 d	43.77 e	43.10 de	1096.3 c	1103.3 c	19.186 c	19.308 c	205.82	205.07
Zn cit + Ca cit.	28.27 a	28.57 a	43.97 e	43.73 d	1243.0 a	1249.3 a	21.753 a	21.863 a	233.36	232.20
Mix	22.00 h	22.50 h	43.57 e	42.87 e	958.7 i	964.3 h	16.777 i	16.876 h	179.98	179.23
Control	14.63 j	15.03 k	36.43 h	35.83 h	532.7 k	538.0 j	9.322 k	9.416 j	100	100

Means followed by the same letter(s) within each column do not significantly differ using Duncan's Multiple Range Test at significance level of 5%.

In contrary, the control plants showed significantly the lowest values for all the studied traits, this is, to far extent, proved that these plants were greatly affected in severe and harmful way during their reproductive stage by the prevailing temperature extremes (Table 1) and its probable inducible oxidative stress. Temperature extremes known to impacts directly on fruit productivity, causing aggressive abortion in flowers and buds as well as impair pollen viability and germination, which in turn cause poor fruit setting (Han-xiao Bing *et al*., 1996; Aloni *et al*., 2001 and Erickson and Markhart, 2002).

In addition, flooding internal plant tissues with toxic free radicals that forming in large quantities under intensive high temperatures attacking cell solutes and membranes, leading to protein denaturation, destruction of enzymes, damage of nucleic acids, degradation of chlorophyll and suppression of all metabolic activities (Kovtun *et al*., 2000). Moreover, it is well known that heat stress adversely affects the relationship between source and sink by inhibition the formation and translocation of photo-assimilates, thereby suppression of fruit loading and bulking (Marcelis *et al*., 2004).

Herein, it was markedly observed from the same data that these yield increments, as affected by the applied treatments, were greatly associated with their similar enhancable effect on number of fruits, fruit average weight and / or both of them.

This internal physiological disturbances and events and the accompanied agronomical depression of high temperature affected control plants were greatly ceased by all the applied antioxidant treatments, which succeed in alleviating the deleterious effects of high temperature stress, due to their antioxidant roles in quench formed reactive oxygen radicals or activating enzymes related with scavenging and removing the toxic and degradable ROS away from the center of the active metabolic machinery of plant tissues i.e. peroxidase, superoxide dismutase and catalase (Noctor and Foyer, 1998; Clayton *et al*., 1999 and Schneider, 2005).

Once again, from the same data, relative yield % remarkably exhibit total yield increments of all treatments over that of the control one. These increments in descending order for the treatments of Zn cit. + Ca cit., vitamin E-sel. + Zn cit, vitamin C + Ca cit., vitamin E-sel. + vitamin C, vitamin C + Zn cit., vitamin E-sel., + Ca cit., Ca cit., Zn cit., vitamin C, mix and vitamin E-sel. were 132.78, 111.11, 105.44, 104.21, 100.84, 94.99, 94.40, 89.57, 87.73, 79.60 and 75.36 %, respectively (means of the two seasons).

This obviously indicates that minerals Ca and Zn in citrate form over yielded the vitamins C and E-sel. Also Ca cit. superiored Zn cit. and vitamin C superiored vitamin E-sel., and all mostly behave in similar fashion when they applied in pair combinations, react synergistically and gave considerable enhancable additive effects.

The results of fruit yield and its components were in harmony with those obtained by Moon *et al*., 1995; Paraikovic *et al*., 2004; Fathy, 2005; Fathy and Khedr, 2005a; El-Tohamy *et al*., 2006 and Moftah and Al-Redhaiman, 2006 all using calcium on pepper. With respect of zinc application similar results were observed by Dongre *et al*., 2000; Hatwar *et al*., 2003; Fathy and Khedr, 2005a and Kappel *et al*., 2006 all on pepper. Regarding vitamin treatments, the results were coincided with those of Fathy *et al*., 2003 using vitamin C or vitamin E-selenium on eggplant; Fathy and Khedr, 2005b using vitamin E-selenium on tomato and Hala *et al*., 2005 using vitamin E or vitamin C on Vicia faba plants.

Nevertheless, the beneficial effects of the applied treatments (vitamin E-selenium, vitamin C, zinc citrate and calcium citrate) individually or paired may be also explained due to their functional roles since calcium is tightly related with membrane stability and integrity, structure of cell walls, signal transduction system, cell division and formation, involved in nitrogen metabolism and aids translocation of photo-assimilates from leaves to fruiting organs (Ferguson and Drobak, 1988 and Marschner, 1995).

Also, zinc is associated with carbohydrate metabolism enzymes, enhance translocation of bio-assimilates and nutrients within plant tissues, essential for activating the membrane transporter enzymes, enhance cell division and differentiation, important for viability and retentability of reproductive organs and essential for activating and balancing hormonal status within plant organs (Kitagishi and Obata, 1986; Cakmak and Marschner, 1988a & b; Domingo *et al*., 1990 and Hu and Sparks, 1990). As for vitamin E, it is involved in protection of pigments and proteins of the photosynthetic apparatus and of thylakoid lipids against oxidative degradation (Fryer, 1992 and Kanwischer *et al*., 2005). Concerning the importance of vitamin C, it is involved in metabolism and photosynthesis, acts as a co-factor for many enzymes, plays a role in cell division and elongation, in addition to its defensive role against ROS toxic radicals (Smirnoff, 1996; Noctor and Foyer, 1998 and Lee and Kader, 2000).

Fruit physical characters:

The presented data in Table (3) illustrate physical quality characters of sweet pepper fruits expressed as fruit length and diameter, fruit shape index and flesh thickness as affected by foliar application of vitamin E-selenium, vitamin C, zinc citrate, calcium citrate and their pairs and mix of all combinations, during the two successive late summer seasons of 2006 and 2007.

In this regard, the ideal fruit quality parameters of sweet pepper cv. California Wonder are mainly characterized as blocky form (nearly equal length and diameter) and flesh thickened fruits. So, it is acceptable and highly required to attempt increasing fruit and yield mass in parallel with maintaining the known ideal physical quality characters of this cultivar.

Once again it was distinct from Table (3) that either the applied individual antioxidant vitamins and nutrients or their combinations all were exhibited considerable higher values and beneficial effect on length, diameter and flesh thickness of their fruits than the control, in the two seasons.

With regard to fruit shape index, it was clear from the data (Table 3) that significantly the highest values were of mix treatment (combination of all agents), followed by vitamin E-selenium + calcium citrate, vitamin E-selenium and control, in the two seasons, as well as zinc citrate in the second season only, with less or no considerable differences among them in most cases. The rest of treatments relatively show low values for fruit shape index. Even though, these results reflect no considerable changes in the fruit shape. To far extent, all treatments maintained the ideal blocky form of their fruits without any fruit malformation.

Similar results were obtained by Moon *et al*., 1995; El-Tohamy *et al*., 2004; Fathy, 2005 and Fathy and Khedr, 2005a, using calcium foliar application on pepper, and those of Iyengar and Raja, 1988; Husain *et al*., 1989; Dongre *et al*., 2000; Hatwar *et al*., 2003 and Fathy and Khedr, 2005a, using zinc on pepper. Regarding application of vitamins, similar results were reported by Carvajal *et al*., 1997 using vitamin C on pepper; Fathy and Khedr, 2005b using vitamin E-selenium on tomato and Fathy *et al*., 2003 using vitamin C or vitamin E-selenium on eggplant.

Table (3): Effect of vitamins (E-selenium & C), organic nutrients (Calcium citrate & Zinc citrate) and their combinations on physical quality characters of sweet pepper fruits cv. California Wonder, during 2006 and 2007 seasons.

Characters	Fruit length (cm)		Fruit diameter (cm)		Fruit shape index (L/D)		Flesh thickness (cm)	
Seasons	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**
Treatments								
Vitamin E-sel.	9.67 bc	9.93 ab	9.03 bc	9.20 c	1.073 abc	1.083 b	0.453 a	0.457 ab
Vitamin C	9.87 ab	10.07 a	9.43 a	9.33 ab	1.043 cde	1.080 de	0.463 a	0.467 a
Zn citrate	8.90 fg	9.67 cd	8.87 cde	8.97 d	1.003 f	1.080 bc	0.393 c	0.387 f
Ca citrate	8.70 g	8.90 e	8.47 f	8.77 e	1.023 de	1.060 d	0.404 bc	0.413 d
Vit. E-sel. + vit. C	9.97 a	10.10 a	9.47 a	9.43 a	1.050 bcde	1.067 cd	0.453 a	0.460 ab
Vit. E-sel. + Zn cit.	9.50 cd	9.53 d	9.03 bc	9.27 bc	1.050 bcde	1.028 e	0.424 b	0.433 c
Vit. E-sel. + Ca cit.	9.43 cd	9.60 d	8.73 de	8.77 e	1.080 ab	1.093 b	0.403 bc	0.403 de
Vit. C + Zn cit.	9.23 de	9.53 d	8.93 cd	9.17 c	1.030 de	1.037 e	0.457 a	0.453 b
Vit. C + Ca cit.	9.13 ef	9.80 bc	8.97 c	9.27 bc	1.018 e	1.057 d	0.423 b	0.410 de
Zn cit + Ca cit.	9.53 c	9.57 d	9.20 b	9.27 bc	1.033 de	1.030 e	0.417 b	0.437 c
Mix	9.63 bc	9.67 cd	8.70 e	8.63 f	1.107 a	1.120 a	0.403 bc	0.400 e
Control	7.37 h	7.56 f	6.87 g	6.98 g	1.073 abc	1.083 b	0.300 d	0.310 g

Means followed by the same letter(s) within each column do not significantly differ using Duncan's Multiple Range Test at significance level of 5%.

These results may be explained by the essential role of calcium in maintaining cell walls and membranes, transducting signals that related with environmental responses and metabolic events as well as its involvements in cell division and translocation of photosynthetic assimilates from leaves to fruiting organs (Ferguson and Drobak, 1988 and Marschner, 1995). Also, the functional role of zinc in enzymes that associated with carbohydrate metabolism and its role in bio-synthesis of auxins, protein metabolism, gene expression, structural and functional integrity of bio-assimilates and photosynthetic carbon metabolism (Kitagishi and Obata, 1986; Domingo *et al*., 1992 and Marschner, 1995). In addition to the role of vitamin E in protecting proteins and membranes against oxidative degradation (Fryer, 1992 and Kanwischer *et al*., 2005). Moreover, the fundamental role of vitamin C in regulation of cell division and elongation, protection against oxidative stress, act as a co-factor for many enzymes and play a role in signal transduction system, thereby regulation of growth and defense responses (Smirnoff, 1996; Lee and Kader, 2000 and Pignocchi and Foyer, 2003).

These physiological and metabolical roles of Ca citrate, Zn citrate, vitamin C and vitamin E-selenium became more obvious and effective, leading in most cases to more fruit quality improvement when they applied in pair combinations, as they may behave and impact in synergistic and complementary way. Also from these cited roles, it could be suggested that the superior effects of the mentioned pair combinations on fruit quality may be mainly concentrated on their effects on activation of cell division and enlargement, activation of bio-metabolites and mineral transporter enzymes, thereby increasing size, mass and flesh thickness of fruits, as well as the general antioxidant protective effects against the adverse effects and attributes of high temperature stress.

Fruit chemical characters:

Data presented in Table (4) show the effect of vitamin E-selenium, vitamin C, calcium citrate, zinc citrate and their different combinations on fruit chemical characters (total soluble solids, vitamin C, total acidity and dry matter %) of sweet pepper plants, during 2006 and 2007 late summer seasons.

It was evident from such data that all applied treatments significantly increased all determined characters over the control one and differed among them in most cases. Also, it was clear that paired treatments were generally more effective than single ones, in the two seasons.

The same data reveled that the absolutely most effective treatment in improving fruit TSS, total acidity % and dry matter % was of zinc citrate + calcium citrate which gave the highest significant values, in both seasons then vitamin E-selenium + zinc citrate followed by vitamin C + calcium citrate.

Regarding the fruit content of vitamin C, significantly the highest value, in the two seasons, obtained by vitamin C treatment followed by zinc citrate + calcium citrate, then

The low values of control treatment reflects the condition of its plants which subjected to intense heat stress (Table 1) and probably its accompanied destructive oxidative one (Bowler *et al*., 1992). These conditions may be severely suppressed the availability of bio-assimilates needed for fruit development as well as reducing sugars intake and utilization by reproductive organs and fruits (Wien *et al*., 1989 and Aloni *et al*., 1991). Also, it has been reported that heat / oxidative stress leading to shortage in distribution of photo-assimilates from source to reproductive sinks and reduces enzymatic functions that tightly associated with all metabolical events (Wien *et al*., 1993; Buchner *et al*., 1998; Kovtun *et al*., 2000 and Marcelis *et al*., 2004).

Table (4): Effect of vitamins (E-selenium & C), organic nutrients (Calcium citrate & Zinc citrate) and their combinations on chemical characters of sweet pepper fruits cv. California Wonder, during 2006 and 2007 seasons.

Characters	TSS %		Vitamin C (mg/100g F. wt.)		Total acidity %		Dry matter %	
Seasons / Treatments	2006	2007	2006	2007	2006	2007	2006	2007
Vitamin E-sel.	4.70 d	4.73 ef	56.40 i	57.73 fg	0.534 i	0.550 j	6.22 k	6.21 k
Vitamin C	4.53 e	4.57 g	73.30 a	74.77 a	0.503 j	0.526 k	6.40 i	6.42 i
Zn citrate	4.77 bcd	4.83 cd	56.27 i	57.23 g	0.544 h	0.563 i	6.51 h	6.53 h
Ca citrate	4.73 cd	4.80 de	58.87 h	59.40 ef	0.654 e	0.661 f	6.61 g	6.65 g
Vit. E-sel. + vit. C	4.83 bc	4.99 bc	61.53 f	62.90 d	0.603 f	0.614 g	7.24 d	7.21 d
Vit. E-sel. + Zn cit.	4.87 b	4.93 b	67.50 c	68.63 c	0.715 b	0.726 b	7.49 b	7.52 b
Vit. E-sel. + Ca cit.	4.70 d	4.70 f	60.33 g	60.77 e	0.651 e	0.669 e	7.15 e	7.11 e
Vit. C + Zn cit.	4.73 cd	4.83 cd	62.77 e	63.63 d	0.685 d	0.682 d	6.71 f	6.73 f
Vit. C + Ca cit.	4.83 bc	4.93 b	66.33 d	67.00 c	0.695 c	0.704 c	7.33 c	7.35 c
Zn cit. + Ca cit.	5.03 a	5.23 a	70.90 b	72.43 b	0.735 a	0.749 a	7.79 a	7.84 a
Mix	4.77 bcd	4.83 cd	58.47 h	59.17 ef	0.555 g	0.572 h	6.35 j	6.33 j
Control	3.77 f	3.83 h	48.67 j	49.30 h	0.453 k	0.463 l	5.82 l	5.86 l

Means followed by the same letter(s) within each column do not significantly differ using Duncan's Multiple Range Test at significance level of 5%.

vitamin E-selenium + zinc citrate. The rest of treatments gave a beneficial effect on all studied characters in both seasons.

The ameliorative effects of the applied treatments (vitamin E-selenium, vitamin C, zinc citrate, calcium citrate and their combinations) could be explained by their antioxidant functions against the reactive oxygen species that forms in corresponding with exposing to heat stress (Fryer, 1992; Vallee and Falchuk, 1993 and Noctor and Foyer, 1998). Also the enhancement effect of these treatments may be due to their essential roles in signal transduction system, membrane stability and functions, activating transporter enzymes, metabolism and translocation of carbohydrates (Ferguson and Drobak, 1988; Marschner, 1995 and Kitagishi and Obata, 1986).

These results and interpretations were in harmony with those obtained by Lin *et al*., 2000; Park *et al*., 2001 and Flores *et al*., 2004 using calcium on pepper; Siviero *et al*., 1996; Lin *et al*., 2000 and Dong *et al*., 2004 on tomato.

Regarding zinc application, similar results were obtained by Zhamsran and Amgalan, 1973 on potatoes; Kiryukhin and Bezzubtseva, 1980 and Ravichandran *et al*., 1995 on eggplant; Lalit and Srivastava, 2005 on tomato and Kappel *et al*., 2006 on pepper. With respect of vitamins treatments, the results were in conformity with those of Carvajal *et al*., 1997 using vitamin C on pepper; Fathy and Khedr, 2005b using vitamin E-selenium on tomato.

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استخدام مضادات الاكسده وبعض المغذيات العضوية لتحسين إنتاجية الفلفل الحلو تحت ظروف إجهاد الحرارة المرتفعة

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نفذت تجربتان حقليتان فى المزرعة البحثية بالبرامون التابعة لمحطة بحوث البساتين بالمنصورة، محافظة الدقهلية خلال موسمى الزراعة ٢٠٠٦ و ٢٠٠٧ فى العروة الصيفية المتأخرة على نبات الفلفل الحلو صنف كاليفورنيا وندر. لدراسة استخدام مضادات الأكسدة (فيتامين هـ-سيلينيوم ١٥٠جزء فى المليون ، فيتامين ج ١٥٠ جزء فى المليون) وبعض المغذيات فى صورة عضوية (سترات الزك ١٠٠ جزء فى المليون زنك ، وسترات الكالسيوم ٢٠٠٠ جزء فى المليون كالسيوم) رشاً لتخفيف الأثر السلبى للحرارة المرتفعة وما يرافقه من اجهاد تأكسدى على النباتات بهدف تحسين مكونات المحصول وصفات الجودة للثمار تحت هذه الظروف.

تم تصميم التجربة بنظام القطاعات كاملة العشوائية فى ثلاث مكررات حيث احتوت على ١٢ معاملة بواقع ٤ معاملات فردية (فيتامين هـ-سيلينيوم ، فيتامين ج ، سترات الزنك ، سترات الكالسيوم) و٦ معاملات زوجية (فيتامين هـ-سيلينيوم + فيتامين ج ، فيتامين هـ-سيلينيوم + سترات الزنك ، فيتامين هسيلينيوم + سترات الكالسيوم ، فيتامين ج + سترات الزنك ، فيتامين ج + سترات الكالسيوم) ومعاملة تضم خليط من كل المواد الفردية وكانت التركيزات المستخدمة فى المعاملات الزوجية والخليط هى نفس التركيزات المستخدمة فى المعاملات الفردية وأخيراً معاملة المقارنة، وقد تم رش النباتات ٤ مرات أولها بعد ٣٠ يوم من الشتل ثم كل ١٥ يوم.

وكانت أهم النتائج التى أمكن الحصول عليها مايلى:

١- زاد المحصول وكذلك صفات الجودة الطبيعية والكيميائية للثمار بصورة معنوية نتيجة لاستخدام المعاملات.

٢- كانت أعلى النتائج المتحصل عليها المعاملة بسترات الزنك + سترات الكالسيوم (١٠٠ جزء فى المليون زنك + ٢٠٠٠ جزء فى المليون كالسيوم ، المعاملة بفيتامين هـ-سيلينيوم + سترات الزنك (١٥٠ جزء فى المليون فيتامين هـ + ١٠٠ جزء فى المليون زنك) حيث أعطت هاتين المعاملتين أعلى نتائج معنوية فى كلا الموسمين على التوالى.