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Studying the Effects of Foliar Spraying of Seaweed Extract as a Bio-Stimulant on the Increase on the Yield and Quality of Tomato (*Lycopersicon Esculentum L.*)

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ABSTRACT

This study aimed to investigate the effect of foliar spraying of seaweed extract as a bio-stimulant throughput on some quantitative and qualitative properties of tomato. The experiment was carried out in factorial form within the format of complete randomized block design with four replications during 2014 in a mechanized greenhouse belonging to Gol Azin Maghsoud Company in Tus Industrial Estate in Mashhad. The study treatments were as follows: seaweed extract in four (distilled water) levels of 1, 2, and 3 ml per 1000L (of seaweed extract under the trademark of Stimplex) and verities in three levels of Hungarian Mobil, Dutch Mobil, and Super Queen. The results indicated that the concentration "2 ml per 1000 L" had a significant effect on the performance, antioxidant percentage, acidity, and vitamin C content of tomatoes. No significant difference was evidenced in terms of the other studied traits but the differences were considerably significant between the varieties.

Keywords: *Tomato, Foliar Spray, Biostimulant Throughput, Variety.*

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1. INTRODUCTION

Tomato is a perennial plant, belonging to the Solanaceae family, and an important source of antioxidant compounds, lycopene, and polyphenols (Crouch and Van Staden, 1992). This plant is enumerated among the important fruit vegetables per capita consumption is increasing in Iran due to its high levels of vitamins A and C and various nutrients (Booth, 1965). During the recent decades, the use of chemical throughputs in the agricultural lands has led to bioenvironmental problems, including pollution of water resources, reduction in the quality of the agricultural products, and decrease in the soil's fertility (Crouch, Beckett and Van Staden, 1990). Therefore, future agricultural systems emphasis on the reduction of using energy and throughputs; appropriate management of water, soil, and biological resources; and environment conservation to attain optimal and sustainable performance (Jameson, 1993). The immethodical use of the fertilizers and chemicals by the farmers in the production process, especially for the greenhouse cropping is the issue that is currently considered as Iran's agricultural problem (Zodape et al., 2011). However, efforts have been recently made for familiarizing the agricultural society with the production of organic and/or healthy products and use of permitted inputs in cropping. One of the permitted throughputs in organic cropping is the use of seaweed extract that can be properly substituted for chemical fertilizers. Although seaweed has been used as a food source by the Japanese since 700BC, it was applied as an agricultural input in the 12th century by English farmers. Its use was gradually forgotten until the 1950s and 1960s with the production of chemical fertilizers, during which the interest in the production of healthy and organic products drew everyone's attention to this valuable substance. Nowadays, seaweed is used in large amounts in such countries as Romania, England, France, Japan, and China for producing agricultural and horticultural products (Calam, 2002). Seaweed was being used for centuries as a fertilizer in the coastal regions (Javanmardi and Azadi, 2012). The researches have shown that seaweed contains plant hormones including auxin, cytokine, and abscisic acid (Crouch and Van Staden, 1992). It has been demonstrated that it boosts plant growth (ash tree), increases chlorophyll content (Golchin and Aflaki, 2004), and strengthens flowering and performance (Blunden, Jenkins and Liu, 1996). The research conducted on the application of the seaweed extract to the plants suggests that the use of seaweed extract is effective in protecting the seeds against the germs, improving the plant growth, increasing the performance, and heightening the plant resistance to the biotic and abiotic stresses (Sharma and Sharma, 2002). It has been reported that these kinds of effects are due to the existence of materials increasing the cell metabolism such as the plant growth regulators including auxin, gibberellin, and cytokines (Berlyn and Russo, 1990) as well as due to such organic osmolytes as betaine, amino acids, mineral elements, and vitamins (Lai et al., 2007). Considering the outcomes of the immethodical use of fertilizers and chemicals during the agricultural cropping process, the present study was carried out to determine the optimum level of seaweed extract used as a nutrient organic material as well as a biostimulant for increasing the quality and quantity of tomatoes.

2. MATERIALS AND METHODS:

In this experiment, the seaweed extract of Ascophyllum Nodosum (brown) under the trademark Stimplex was used. Seaweed extract is produced and supplied to the markets under different names by various companies. It is commonly offered under such trademarks as Stimplex, Phylgreen Vega, Marmarine, Daljin, and AlgAran Stimplex is produced by a Canadian company. In botanical terms, Ascophyllum Nodosum is a large brown algae representing the only species in fucaceae family and growing in the shallow water and swamp and mostly rocky regions of Atlantic Ocean in Canada as well as in the northwestern coasts of Europe. As for the formulation and apparent shape, it is a brown liquid that can be mixed with surfactants (muyanes or moisturizers). It contains growth stimulants, macro- and micro-organic food elements, vitamins, antioxidants, organic NPK acids plus amine acids with seaweed origins in addition to the phytohormones derived from Ascophyllum algae. Stimplex has been tested on 80 products in 70 countries worldwide and it is also currently being widely applied. This input is completely natural and organic with no adverse effects on the environment and it has been registered by the American Agency of Environment Conservation.. This experiment was undertaken in the factorial form within the format of complete randomized block design in 3×4 arrangements with two factors. The first factor (the primary factor) was the variety in three levels (Hungarian Mobil, Dutch Mobil, and Super Queen) and the second factor (ancillary factor) was the concentration in four levels (0 ml, 1 ml, 2 ml, and 3 ml per a thousand liters). The experiment was conducted in Gol Azin Maghsoud Company, a subsidiary of Chini-e-Maghsoud Company, situated in the 1st phase of Tus Industrial Estate in Mashhad. Geographically, the greenhouse has been built north-southward in longitude 59.37º and latitude 36.19º and it is 10.65m above sea level. The work method was in a form that the seeds were seminally planted in a Styrofoam cultivation tray containing a mixture of cocopeat and perlite with a ratio of 60:40. Two weeks after sprouting,the plantlets were provided with nutrients in the irrigation water at the recommended concentrations (Zodape et al., 2011). It is worth mentioning that the plantlet trays were kept in the greenhouse untill transplantation to the main plots and six weeks after sowing the seeds, they were transferred into the plastic pots, 40×50 in dimensions, on 05/11/2015. At the time of the plantlets' transplantation, the trays were firstly watered and the transplantation was carried out during early morning so that withering could be reduced and the error percentage could be minimized. The greenhouse's average temperature was 24 to 28 °C during the day and 18 to 22 °C at night; the relative humidity was kept between 50% and 60% on average during the growth period by using fogger, fan, and pad systems.

Work Method in Greenhouse:

The treatments were implemented in the form of the foliar spray (nourishment) with 0 ml, 1 ml, 2 ml, and 3 ml per 1000L of distilled water in five stages using a manual sprayer. Due to the fact that the surface tension of Stimplex is very high, use was made of surfactant (moisturizer) with a concentration of 1 ml per a thousand liters. The use of surfactant causes an increase in the surface tension of the solution hence the entire plant organs are completely wetted and the solution can be absorbed better. Moreover, in order to prevent the solution's evaporation from the surfaces of the plant organs as well as to protect the plants against leaf scorch, foliar spraying was conducted during the early morning. Foliar sprays were conducted in five stages, once every ten days as explained below:

1) The first foliar spray was done in the 20-cm stage of growth (when the plantlets had reached a height of 20 cm).
2) The next stages of foliar spray were carried out once every ten days.

In this experiment, the following traits were investigated and measured.

Performance: The fruits were harvested in a completely ripen stage and each plant was separately weighed and the total performance was calculated at the end of the period.

Length and diameter of the fruit: During every harvest, five fruits were randomly selected from every plant and their lengths and widths were measured using a caliper.

Fruit shape: During every harvest, five fruits were randomly selected and the shapes were recorded based on the fruits' lengths and widths.

Acidity: the extracts' acidity rates were measured using a digital pH-meter.

Vitamin C content: To measure vitamin C content of the fruits (in milligram ascorbic acid per every 100g of the wet sample), 2, the 6-dichloroindophenol method was employed (Hosseini, 2003).

Antioxidant percentage: DPPH method was applied for measuring the antioxidant capacity of the fruit extracts and evaluation of the neutralization activity of the free radicals. In this method, 0.1ml of the extract of each plant sample was added to 1ml DPPH (500 micromoles in methanol); then, the resulting mixture was shaken intensively and the absorption rate was read after 30 minutes in 517nm.

Number of Locules (chambers): During every harvest from every plant, five fruits were randomly selected and cut and the number of chambers was counted.

Tissue Firmness: During every harvest, five fruits were randomly selected from every plant and a manual penetrometer with a piston diameter of 0.8cm was used to measure the tissue firmness in kilogram per square meter.

The Percentage of the Total Suspended Solids (TSS): One droplet of the fruit juice was placed on the glass part of a manual refractometer, model ATC-1E, UK, to measure the total suspended solids.

Blossom End Rot: all of the fruits that had been afflicted with blossom end rot were counted and written down for each plant.

In the end, the results obtained for all of the traits were statistically analyzed in JMP8 Software and diagrams were drawn in Excel Software and the mean values of the traits were measured based on LSD test at a 5% level.

Table 1: mean squares of the measured traits

Total Suspended Solids (TSS) (%)	Number of locules (cells)	Antioxidant (%)	Vitamin C (mg/g)	Yield per plant (kg)	Degree of Freedom (DF)	Source of variation
0.08ns	0.02ns	0.92ns	1.05ns	0.005ns	3	Replication
0.25ns	0.13ns	41.51**	15.61**	0.01**	3	Fertilizer
6.77**	15.25**	1.53ns	0.08ns	0.0002**	2	Variety
0.1ns	0.05ns	6.53ns	0.44ns	0.001ns	6	Fertilizer × variety
0.26	0.11	2.77	0.54	0.004	33	Error
*, **, and ns significant difference over control at P< 0.01 and P< 0.05 and not significant, respectively.						

Table 2: mean squares of the measured traits

PH Acidity	Diameter of fruit	Length of fruit	Tissue firmness (kg/m²)	Blossom end rot	Degree of freedom	Source of variation
0.0002ns	0.01ns	0.005ns	0.01ns	1.55ns	3	Replication
0.03**	0.01ns	0.11ns	0.02ns	0.55ns	3	Fertilizer
0.0002ns	0.005ns	0.21ns	2.47**	11.39**	2	Variety
0.0002ns	0.005ns	0.03ns	0.01ns	0.28ns	6	Fertilizer × variety
0.0002	0.006	0.06	0/01	0.60	33	Error
*, ** and ns significant difference over control at P< 0.01 and P< 0.05 and not significant, respectively.						

Table 3: mean comparison of the measured traits

Antioxidant (%)	Vitamin C (mg/100g)	PH acidity	Yield per plant	Seaweed extract
74.01b	30.41b	4.5b	2.45b	Control
75.10b	30.91b	4.49b	2.46ab	1 ml/l
78.35a	33a	4.6a	2.52a	2 ml/l
75.34b	31b	4.5b	2.46ab	3 ml/l
Numbers followed by the same letter are not significantly different (P<0.05)				

3. RESULTS AND DISCUSSION:

The results of the data variance analysis (tables 1 & 2) indicated that, among the investigated traits, the effect of seaweed extract foliar spray has not been statistically significant on the fruits' length and diameter, tissue firmness, number of cells, blossom end rot, total suspended solids (TSS), and fruit shape but a very significant difference was evidenced between the varieties except for the fruit length, width and shape. In regard to the other evaluated traits like performance, antioxidant percentage, vitamin C content, and acidity, the effect of seaweed extract was found highly statistically significant. Amon the concentrations of the seaweed extract (0 ml, 1 ml, 2 ml, and 3 ml per 1000 L), the best result was found for the concentration 2 ml per 1000 L and the lowest value was for the control treatment. The results obtained herein are consistent with what has been found in the prior research indicating the positive effect of seaweed extract foliar spray on the performance increase, vitamin C content increase, and antioxidant percentage and acidity (Zodape et al., 2011).

Blossom End Rot:

The Super Queen variety was found with the largest number of fruits with blossom end rot and the Dutch Mobil variety was found with the lowest number of blossom end rot and this reflects the idea that Super Queen variety is more sensitive to blossom end rot in contrast to Dutch Mobil and Hungarian Mobil.

Number of Locules (cells):

As it is observed in Table (4), Super Queen variety had a larger number of locules in comparison to Dutch Mobil and Hungarian Mobil varieties. Thus, this variety seems to be more appropriate than the other two for processing industries (producing and conserving tomato paste). Multi-locular fruits are more increasingly delicious and resistant to impact than bi-locular fruits (attachment, 2011).

Tissue Firmness:

The mean comparison tables indicate that Super Queen variety features more solidarity as compared to the other two varieties due to its containing a larger number of locules hence it is more suitable for delivery to more distant spots and export. Multi-locular fruits are more increasingly tastier and more resistant in contrast to the bi-locular fruits (attachment, 2008).

Percentage of Total Suspended Solids (TSS):

In this experiment, the highest percentage of the total suspended solids in tomato extract belonged to the Super Queen and the lowest percentage of it was scored for Dutch and Hungarian Mobil varieties and no significant difference was observed between Hungarian Mobil and Dutch Mobil varieties. It seems that there is a positive relationship between tissue firmness, number of locules, and percentage of total suspended solids (TSS).

Ascorbic Acid (Vitamin C):

The mean comparisons indicated that the use of 2 ml seaweed extract per 1000 L caused an increase in the vitamin C content of tomato paste (table 3). Before now, an increase of 23% in vitamin C content of tomatoes following the seaweed extract foliar spray using had been reported in comparison to the control treatment (Van Staden, Upfold and Drewes, 1994).

Acidity (pH):

Mean comparisons indicated that the highest rate of pH pertains to 2 ml per 1000 L of seaweed extract treatment and the lowest rate of pH belongs to control treatment and the concentration of 3 ml per 1000 L of seaweed extract and this finding is consistent with the results found in the prior research (Van Staden, Upfold and Drewes, 1994).

Performance:

According to Table (3), the mean comparisons indicated that the use of a concentration of 2 ml per 1000 L of seaweed extract has the highest effect on the performance elevation and the lowest performance rate was documented for the control treatment. It was also found out that there is no significant difference between 1ml and 3ml per 1000 L treatments. It seems that the increase in the performance shows itself in the form of the percentage of fruit formation on every branch and acceleration of flowering onset and this finding is consistent with the results obtained in the prior research (Verkleij, 1992; Craigie, 2011).

Antioxidant Percentage:

The mean comparisons indicated that the highest antioxidant percentage belongs to the concentration of 2 ml per 1000 L of seaweed extract and the lowest antioxidant percentage was found for the control treatment. The increase might have been due to the elevation of the fruits' vitamin C contents (Eris, Sivritepe and Sivritepe, 1995).

Furthermore, the positive relationship between the amount of vitamin C and antioxidant activity has been proved for oranges; it has been figured out that vitamin C accounts for about 87% of the antioxidant activity (Hajilo et al., 2010).

It was observed based on the measurements of the fruits' length and width that there is no significant relationship between the varieties and use of seaweed extract (mutual effect of fertilizer and variety); in terms of the apparent shape, all of the treatments were found producing round fruits.

4. CONCLUSION:

It can be concluded by the precise investigation of the results that the performance, vitamin C, antioxidant percentage, and acidity increase by 2 ml per 1000 L of seaweed extract and also the extract is non-effective on the fruit's length and diameter, number of fruit's locules, blossom end rot, fruit shape, and TSS in the aforesaid concentration. These findings are inconsistent with the results found by the other researchers might have been due to the botanical origin of the algae, place, time, and even the concentration differences in the use of seaweed. Thus, according to the results obtained in the present study, farmers can be advised to use organic fertilizers, including the seaweed extract for preventing the environmental destruction, reducing the costs of purchasing chemical fertilizers and, finally, boosting the plants' performance. In addition, considering that super queen variety was found more sensitive than Hungarian Mobil and Dutch Mobil varieties to blossom end rot, it is suggested that other varieties can be utilized instead of Super Queen when the conditions are favorable for the infliction with this side effect (water stress) so that this physiological disease can be avoided. Moreover, according to the fact that the flesh percentage is higher in Super Queen variety in comparison to the other two varieties (Dutch Mobil and Hungarian Mobil), it can be used for industrial usages and producing tomato paste; it has also been found more persistent in comparison to the other two varieties and this variety can be used in cases that a higher persistence rate is intended.

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