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Improving the Establishment, Growth and Yield of Tomato Seedlings Transplanted during Summer Season by Using Natural Plant Growth Bio-stimulants

E.H. Abd El-Samad[1], A.A. Glala[2], A. Abd El Baset[3] and Nadia M. Omar[1]

[1]*Vegetable Research Dept., Agricultural & Biological Research Division, National Research Centre (NRC), 33 El-Buhouth St., 12622 Dokki, Giza, Egypt.*
[2]*Horticultural Crops Technology Dept., Agricultural & Biological Research Division, National Research Centre (NRC), 33 El-Buhouth St., 12622 Dokki, Giza, Egypt.*
[3]*Plant Production Dept., Ecology and Dry Land Agriculture Division, Desert Research Center (DRC), El-Matareya, Cairo, Egypt.*

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ABSTRACT

In organic and sustainable agriculture, nature plant growth bio-stimulants are commonly used as a good agricultural practice. Therefore, two field experiments were conducted at The Experimental and Production Station of the National Research Centre, El-Noubaria region, Beheira Governorate, Egypt. With a view to investigate the effect of using natural bio-stimulants, seaweed extract "Kelpak", *Bacillus subtilis "*Companion 2-3-2", Kelpak plus Companion 2-3-2 and control treatments were studied on vegetative growth characters, plant survival %, early and total fruit yields, and leaf mineral contents of five tomato hybrids (Alisa, GS-12, GS-556, Super Jackal and VT-737) transplanted during the summer seasons of 2015 and 2016. The experiments were laid in a split plot design with 4 replicates. Results showed that highly significant differences were realized among tomato hybrids in relation to all measured parameters. The highest values of plant length, stem diameter, plant survival%, fresh and dry weights of shoot and N, P, Ca, Mg and Fe contents were recorded by GS-12 tomato hybrid. On the other hand, GS-556 tomato hybrid gave the highest values of number of leaves/plant, plant root length and fresh and dry weights of root as well as root/shoot ratio. Furthermore, VT-737 hybrid showed the highest early fruit yield, leaf SPAD readings and K content. However total fruit yield was obtained by Super Jackal hybrid. Application of natural plant growth bio-stimulants caused a significant enhancement over the control treatment in all studied parameters. Application of Kelpak at 10 ml/l combined with Companion 2-3-2 at 1.25 ml/l recorded the superiority to the rest of treatments, where, it gave the highest values of all studied parameters followed by the treatment of Companion 2-3-2 at 1.25 ml/l. However, the lowest values were obtained by the control treatment. The interaction had significant differences on all studied characters in both growing seasons. It is evident from the obtained results that the highest values of all measured parameters were obtained by the treatment of Kelpak at 10 ml/l plus Companion 2-3-2 at 1.25 ml/l but the tomato hybrid was fluctuated among different hybrids according to the determined parameter. Generally, the results suggested that the best values for all parameters, except for early and total fruit yields, SPAD readings and K content were achieved when plants of GS-12 or GS-556 hybrids treated with Kelpak at 10 ml/l plus Companion 2-3-2 at 1.25 ml/l.

***Keywords*:** *Solanum lycopersicum*, *Bacillus subtilis*, Seaweed extract, Seedlings growth, Plant survival%, Early and total fruit yield, Leaf mineral contents.

Introduction

Tomato (*Solanum lycopersicum* L.) is an economically important vegetable crop grown in Egypt under different environmental conditions. It has become an important commercial crop so far as the cultivation area, production and industrial values. The tomato cultivation area occupied 490 thousands feddan with a total production of 8.3 million tons a year (FAOSTAT, 2017).

Plant bio-stimulant is any substance or micro-organism applied to plants aiming to stimulate plant growth, enhance nutrient contents and stress tolerance, as well as influence several plants metabolic processes (du Jardin, 2015). Plant bio-stimulants may be of natural origin i.e. seaweed extracts, amino acids, yeast, plant growth-promoting rhizobacteria, effective micro-organisms, humic

Corresponding Author: E.H. Abd El-Samad, Vegetable Research Dept., Agricultural & Biological Research Division, National Research Centre (NRC), 33 El-Buhouth St., 12622 Dokki, Giza, Egypt. E-mail: emadhassanein@hotmail.com

and fulvic substances and chitosan (Calvo *et al.,* 2014), or synthetic origin include plant growth regulators, inorganic salts, essential elements, antioxidant and phenolic compounds and other substances (Przybysz *et al.,* 2014).

Marine macroalgae broadly classified into three main categories, brown (*Phaeophyta*), red (*Rhodophyta*) and green (*Chlorophyta*) based on their pigmentation (Khan *et al.,* 2009). Seaweed extracts have gained a great interest in organic and sustainable agriculture, and commonly used as plant bio-stimulants (Ugarte *et al.,* 2006; Craigie, 2011), owing to their biological origin, natural material and eco-friendly (Matysiak and Kaczmarek, 2008; Khan *et al.,* 2009).

Seaweed extracts contain various biologically active compounds such as polysaccharides, amino acids, polyphenols, vitamins, micro and macro-nutrients (Duarte *et al.,* 2001; Lane *et al.,* 2006), natural phytohormones, cytokinins (Stirk *et al.,* 2003), auxins and auxin-like compounds (Crouch and Van Staden, 1992), gibberellins (Stirk *et al.,* 2014) and polyamines (Papenfus *et al.,* 2012), such compounds leading to stimulate plant growth and crop yield (Crouch and Van Staden, 1993; Durand *et al.,* 2003; Ördög *et al.,* 2004).

The seaweed extract Kelpak® is a commercially available plant growth bio-stimulator derived from the brown marine alga *Ecklonia maxima*. It contains natural auxins and auxin-like compounds (11 mg/l), as well as cytokinins and cytokinin-like compounds (0.031 mg/l) as reported by Robertson-Andersson *et al.* (2006). It is widely used as a plant growth bio-stimulator in horticultural crops production (Battacharyya *et al.,* 2015).

Seaweed extracts have the ability to stimulate seedlings root and shoot growth and root:shoot ratio (Crouch *et al.,* 1992; Durand *et al.,* 2003; Stirk *et al.,* 2004; Craigie, 2011), enhance seedling vigour in a wide variety of plants and improve seedling establishment (Crouch and Van Staden, 1992; Papenfus *et al.,* 2013). The improvement of plant root growth was found to be more pronounced when seaweed extract applied at the early stage of growth (Matysiak *et al.,* 2011), enhance leaf chlorophyll content which positively reflected on the photosynthetic efficiency (Blunden *et al.,* 1997; Jannin *et al.,* 2013; Kulkarni *et al.,* 2019), increase growth and yield as well as improve quality of various crops (Arthur *et al.,* 2003; Zodape *et al.,* 2011; Papenfus *et al.,* 2013; Kocira *et al.,* 2018), and improve nutrient uptake by plant root (Crouch et al., 1990; Dobromilska *et al.,* 2008). Furthermore, they ameliorate plant tolerance to biotic (Dixon and Walsh, 2004; Sultana *et al.,* 2005; Craigie, 2011), due to accumulation of phenolics and phytoalexins (Jayaraj *et al.,* 2008), and abiotic (Zhang and Ervin, 2008; Sharma *et al.,* 2014) stressful conditions by increasing the antioxidant defense system (Zhang and Schmidt, 2000).

Crouch and Van Staden (1992) reported that application of seaweed extract reduced transplanting shock in tomato seedlings through increasing root growth, root-to-shoot ratio and fresh and dry root and shoot biomass. Also, early and total fruit yield were increased. In another study, Kumari *et al.* (2011) concluded that seaweed extract caused an increase in root and shoot lengths, and fresh weight of tomato. Furthermore, mineral nutrient contents in tomato leaf were also increased by application of seaweed extract (Dobromilska *et al.,* 2008).

Plant growth-promoting rhizobacteria (PGPR) is a root-colonizing, non-pathogenic, free-living and beneficial bacterium in the rhizosphere. These rhizobacteria can synthesize useful bioactive substances i.e. antimicrobial, amino acids, vitamins, sugars, enzymes and phytohormones. Such substances had an effective role in stimulating root and plant growth as well as yield, increasing nutrient mobilization, availability and absorption (Vessey, 2003; Adesemoye *et al.,* 2008; Dursun *et al.,* 2010; Glala *et al.,* 2010; Ibiene *et al.,* 2012; Ruzzi and Aroca, 2015), mineralization of organic phosphate and solubilization of inorganic phosphate (Khan and Khan, 2001), enhancing the beneficial microflora in the rhizosphere and suppressing soil borne pathogens (Zehnder *et al.,* 2001; Kloepper *et al.,* 2004). Shanmugam and Kanoujia (2011) revealed that disease suppression may be achieved directly, through synthesis of antimicrobial substances and/or indirectly, through induction of systemic resistance (ISR). In addition, these rhizobacteria alleviate the negative impact of environmental stresses (Mayak *et al.,* 2004; Yildirim *et al.,* 2006; Fu *et al.,* 2010). Using PGPR for sustainable and organic agriculture has been greatly increased due to its eco-friendly, cost effective and maintaining soil fertility and sustainability. Also using PGPR as bio-fertilizers and/or bio-control agents became commonly used as good agricultural practices.

Significant increases in tomato and pepper seedling growth, root length, stem diameter, transplant survival and yield with application of PGPR (Kokalis-Burelle *et al.,* 2002). Application of

Bacillus subtilis increased transplants shoot fresh and dry weights, root diameter, root length, root fresh and dry weights, stem diameter, leaf area and leaf chlorophyll contents as well as leaf nutrient contents compared to the control treatment in tomato (Glala *et al.,* 2010; Walia *et al.,* 2014) and in cauliflower (Ekinci *et al.,* 2014).

Inoculation of tomato plant with *Bacillus subtilis* led to significant increases in root dry weight, root length and fruit yield compared to the control treatment (Mena-Violante and Olalde-Portugal, 2007). Also increased tomato plant yield and reduced rhizospheric population of wilt fungus (Khan and Khan, 2001). In this regards, Shanmugam and Kanoujia (2011) and Loganathan *et al.* (2014) reported that *Bacillus subtilis* treatment could be effectively used to enhance tomato plant growth and yield besides suppression of tomato wilt disease caused by *Fusarium*. The application of *Basillus subtilis* may be a promising practice for biological control of tomato wilt (Mohammed *et al.,* 2019).

The current study was undertaken to improve seedling establishment, vegetative growth, early and total tomato fruit yields and leaf mineral contents of five tomato hybrids transplanted during the summer season under newly reclaimed sandy soil conditions by application of natural plant growth bio-stimulants.

Materials and Methods

The experimental site

Two field experiments were conducted under newly reclaimed sandy soil conditions at The Experimental and Production Station of the National Research Centre, El-Noubaria region, Beheira Governorate, Egypt (latitude 30° 72' 66" N, longitude 30° 20' 18" E and altitude of 27 m above sea level), during the two consecutive growing summer seasons of 2015 and 2016. The current study was performed to investigate the effect of using natural bio-stimulants (Kelpak, seaweed liquid extract, Companion 2-3-2, natural biological liquid of *Bacillus subtilis* and Kelpak plus Companion 2-3-2) on seedling establishment, vegetative growth, early and total fruit yields and leaf mineral contents of five tomato hybrids (Alisa, GS-12, GS-556, Super Jackal and VT-737) transplanted during the summer season. The physical properties and chemical analysis of the experimental soil are presented in Table 1. Also, the metrological data for the experimental site throughout the entire experiment were obtained from the Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center (http://www.clac.edu.eg), including maximum and minimum of air temperature and relative humidity (RH) as well as average day length. Values were expressed as weekly interval means during the two summer growing seasons as shown in Table 2.

Experimental design

The experiment comprised of twenty treatments and was set in a split plot design with 4 replicates. The five tomato hybrids (Alisa, GS-12, GS-556, Super Jackal and VT-737) were randomly distributed within the main plots, whereas the four nature bio-stimulants treatments (Kelpak, Companion 2-3-2, Kelpak plus Companion 2-3-2 and control) were randomly arranged within the sub-plots. Each experimental sub-plot consisted of 5 drip irrigated ridges with 4.5 m in length and 0.8 m width with a net area of 18 m^2.

Table 1: Physical properties and chemical analysis of the experimental soil.

Physical properties											
Sand (%)			**Silt (%)**			**Clay (%)**			**Soil texture**		
90.05			6.49			3.46			Sandy		
Chemical analysis											
EC	**pH**	**OM**	**$CaCO_3$**	**Cations** (meq/l)					**Anions** (meq/l)		
(dS/m)		**(%)**	**(%)**	**Ca^{++}**	**Mg^{++}**	**Na^{+}**	**K^{+}**	**$CO_3^{=}$**	**HCO_3^{-}**	**Cl^{-}**	**$SO_4^{=}$**
1.12	8.17	0.54	10.5	1.1	0.23	0.81	0.41	Nil	1.05	1.1	0.4

Table 2: Metrological data for the experimental site expressed as weekly means for maximum and minimum air temperatures and relative humidity as well as average day length during both growing summer seasons of 2015 and 2016.

Weeks	Temperature (°C)		Relative humidity (RH %)		Average day length (h:min/day)
	Max.	Min.	Max.	Min.	
First season of 2015					
1st week of July	30.6	23.0	86.7	52.7	14:04
2nd week of July	30.0	22.3	90.4	54.3	14:00
3rd week of July	32.7	22.2	90.1	44.6	13:52
4th week of July	32.8	22.6	92.1	46.0	13:43
1st week of Aug.	34.2	23.9	93.1	47.1	13:32
2nd week of Aug.	34.1	24.6	91.1	43.1	13:21
3rd week of Aug.	33.8	24.8	86.7	45.0	13:12
4th week of Aug.	32.6	24.2	90.0	50.4	12:58
1st week of Sept.	31.3	22.9	90.1	46.4	12:43
2nd week of Sept.	32.4	23.3	91.7	51.0	12.31
3rd week of Sept.	31.9	22.3	89.4	41.7	12:19
4th week of Sept.	33.0	22.0	82.7	39.4	12:04
Second season of 2016					
1st week of July	31.4	23.9	90.1	52.3	14:04
2nd week of July	31.0	22.8	93.4	51.9	14:00
3rd week of July	32.7	23.7	86.3	48.7	13:52
4th week of July	31.8	22.9	89.6	50.1	13:43
1st week of Aug.	32.4	23.0	90.3	50.3	13:32
2nd week of Aug.	31.1	23.9	88.7	52.4	13:21
3rd week of Aug.	30.9	22.6	90.7	49.3	13:12
4th week of Aug.	31.0	22.6	92.0	49.9	12:58
1st week of Sept.	29.9	21.8	85.9	50.0	12:43
2nd week of Sept.	32.3	23.4	87.6	60.9	12.31
3rd week of Sept.	30.6	22.4	82.9	49.6	12:19
4th week of Sept.	30.7	20.9	75.5	51.5	12:04

Experimental treatments

Imported seeds of the five tomato hybrids obtained from local seed agencies were sown in 209 cell Styrofoam seedling trays filled with a mixture of peat moss and vermiculite (1:1 v/v) media with a capacity of one seed per cell, 30 days before transplanting date, on 10th June in both growing summer seasons of 2015 and 2016. Then the Styrofoam seedling trays were kept in a greenhouse covered by black shading nets with 63% shading at the above mentioned station and cared by regular practices for seedlings production under greenhouse conditions. Seedling foam trays for each tomato hybrid were divided into four groups for nature bio-stimulants treatments. The first group was treated with Kelpak® seaweed liquid extract of brown marine alga *Ecklonia maxima* [Kelp Products (Pty) Ltd., Simon's Town, South Africa, https://www.kelpak.com] at a rate of 10 ml/l, while the second group was treated with Companion 2-3-2 natural biological liquid of *Bacillus subtilis* strain GB-03 (Growth Products, Ltd., New York, USA, https://www.growthproducts.com), at a rate of 1.25 ml/l with a bacterial cell concentration of $1.5X10^7$ CFU/ml. Kelpak at 10 ml/l plus Companion 2-3-2 at 1.25 ml/l were also used for treatment of the third group of seedlings trays, while the fourth group was treated with tap water and served as a control. Naturally bio-stimulants treatments were carried out for 3 times, starting at the seedling first true leaf stage at the greenhouse as soil drenched of seedlings trays and then the trays were dipped into the treatment solution for 1 hour prior to transplanting directly. Whereas, the third one was took place in the field, 5 days after transplanting date as soil

drenched by plant side dressing with 300 ml of treatment solution per plant. The treatment solution of natural bio-stimulants was freshly prepared in each time of application with the same concentration.

Experimental site preparation and cultivation

Experimental soil was prepared by land plough and ridges construction then divided into the four experimental replicates. All experimental sub-plots were received the organic manure as compost at a rate of 4 tons/feddan and poultry manure at a rate of 4 m^3/feddan. Also, the plots received the recommended doses of inorganic fertilizers; phosphorus at 70 kg P_2O_5/feddan as calcium super-phosphate (15.5% P_2O_5). The full doses of compost, poultry manure and phosphorus were applied during the final preparation of experimental soil and thoroughly mixed and incorporated into the soil. Nitrogen fertilizer was used at 150 kg N/feddan in the form of ammonium sulphate (20.6% N). The full dose of nitrogen fertilizer was divided into six equal portions added through drip irrigation system 10, 15, 25, 35, 50 and 60 days after transplanting date. Also, potassium fertilizer was added at a rate of 120 kg K_2O/feddan in the form of soluble potassium sulphate (50% K_2O). The whole amount of potassium was divided into four equal portions and added through drip irrigation system 30, 45, 60 and 70 days from transplanting date.

Uniform thirty-day-old- tomato seedlings with 3 true leaves, treated at seedling first true leaf stage (trays soil drenching) and in the same day of transplanting (trays dipping) with natural bio-stimulants as described above, were transplanted into the field on one side of drip irrigated ridge and 50 cm apart on 10th July in both growing summer seasons of 2015 and 2016. Five days later, tomato plants in the field were received the third natural bio-stimulants treatments as soil drenched. The standard agricultural practices for tomato production under drip irrigation conditions in El-Noubaria region of regular irrigation, fertilization, controlling of pest, disease and weed as well as other management practices were performed throughout the entire experiment according to the recommendations of the Egyptian Ministry of Agriculture.

Data recorded

Plant vegetative growth characters

After three weeks from transplanting date, a random sample of 10 tomato plants per each experimental sub-plot was taken. The plants were carefully shoveled out of the soil, to prevent damage to the root system, and then the excess soil around the roots was carefully removed. After that the roots were washed using a plenty of tap water to remove the rest of adhered soil. Then harvested plants were transferred to the laboratory for measurements of some plant vegetative growth characters i.e. plant length, stem diameter, number of leaves/plant, root length, fresh and dry weights of shoot (leaves + stem) and root as well as root/shoot ratio.

Plant survival percentage

Survival percentage of tomato plants was calculated by counting the total number of tomato plants per each hybrid in each experimental sub-plot after transplanting (T_1). Afterwards, the total number of tomato plants per each hybrid in each experimental sub-plot was recounted after three weeks from transplanting date (T_2). Subsequently, the tomato plant survival percentage was calculated using the following formula:

$$\textbf{Survival percentage} = T_2 / T_1 \text{ X } 100$$

Early and total tomato fruit yields

All red ripe tomato fruits were harvested twice a week along the harvesting season. In each harvest, fruits weight per each sub-plot were recorded. The total fruit yield was calculated by the sum of fruit weights of all harvests. Also, early fruit yield was calculated as the sum of fruit weights of the first four harvests. Then the early and total fruit yields per feddan were estimated.

Leaf SPAD readings

After three weeks from transplanting date, the average of tomato leaf greenness of the second fully expanded leaves from the top of randomly selected 10 tomato plants per experimental sub-plot

was determined using a portable chlorophyll meter (SPAD-502 Plus, Konica Minolta Sensing, Inc., Osaka, Japan).

Leaf mineral contents

Tomato plant samples were randomly taken from each experimental sub-plot three weeks after transplanting date to determine leaf mineral contents. Leaf samples were oven dried at 70ºC until constant weight, and then the dried leaf samples were ground in a stainless-steel grinder to a fine powder to pass a 2 mm sieve size. Afterward a weight of 200 mg of dried leaf samples was wet digested by using a mixture of sulphuric acid (H_2SO_4 98%) and hydrogen peroxide (H_2O_2 30%). In acid digested solution the contents of N, P, K, Ca, Mg and Fe were measured on a dry weight basis. Total nitrogen was determined using Kjeldahl method (UDK 139 Semi-Automatic Kjeldahl Distillation Unit, VELP Scientific, Inc., New York, USA). Phosphorus was assayed according to the modified colorimetric (molybdenum blue) method using spectrophotometer (SPECTRONIC 20D, Milton Roy Co. Ltd., New York, USA) according to the procedures described by Cottenie *et al.* (1982). In addition, potassium and calcium were measured using flame photometer method (JENWAY, PFP-7, ELE Instrument Co. Ltd., Staffordshire, UK) as described by Chapman and Pratt (1982). While, Mg and Fe were determined using Atomic Absorption Spectrometer (AAnalyst-200, Perkin Elmer, Inc., MA, USA), as described by Chapman and Pratt (1982).

Statistical analysis

All data sets were subjected to the statistical analysis of variance procedure using Two-way-ANOVA of the Statistical Package for the Social Sciences software (SPSS 2008 release 17.0 for Windows, SPSS Inc., Chicago, IL, USA). Duncan multiple range test was employed to compare the significant differences among treatment means at 5% level of probability according to the procedures reported by Gomez and Gomez (1984).

Results

Plant length, stem diameter and number of leaves/plant

Data presented in Table 3 showed that plants of GS-12 tomato hybrid recorded the highest significant values of plant length in both seasons. Also, Alisa and GS-12 hybrids gave the highest values of stem diameter without significant differences between them. On the other hand, GS-556 gave the highest significant values of number of leaves/plant, where VT-737 tomato hybrid recorded significantly the lowest values of these parameters in both gowning summer seasons.

Application of natural plant growth bio-stimulants treatments illustrated a significant enhancement over the control treatment in the three studied parameters of tomato plants in both experimental seasons. Data presented in Table 3 clearly revealed that application of Kelpak at 10 ml/l plus Companion 2-3-2 at 1.25 ml/l gave significantly ($p \leq 0.05$) the highest values of these characters in both seasons. On the contrary, the lowest values were obtained by the control treatment.

Concerning the interaction between tomato hybrids and different natural plant growth bio-stimulants treatments significant differences were detected on the three studied parameters. Data in Table 3 revealed that treated tomato plants of GS-12 hybrid with Kelpak at 10 ml/l plus Companion 2-3-2 at 1.25 ml/l gave the highest values of plant length and stem diameter in both seasons. On the other hand, Alisa and GS-12 plants treated Kelpak at 10 ml/l plus Companion 2-3-2 at 1.25 ml/l along with GS-556 hybrid treated with Kelpak or Companion 2-3-2 separately or in combination gave the highest significant values of number of leaves per plant in both experimental seasons.

Root length, plant survival percentage and SPAD readings

Data shown in Table 4 clearly indicated that tomato plants of GS-556 and VT-737 hybrids gave significantly ($p \leq 0.05$) the highest values of plant root length in both seasons. GS-12 hybrid exhibited significantly the highest plant survival percentage, while VT-737 hybrid significantly gave the highest leaf SPAD readings in both seasons of 2015 and 2016.

Concerning the application of natural plant growth bio-stimulants treatments, it was obvious that application of Kelpak at 10 ml/l plus Companion 2-3-2 at 1.25 ml/l gave significantly ($p \leq 0.05$) the highest values of these characters in both seasons. On the contrary, the lowest values were obtained by the control treatment.

Table 3: Effect of natural bio-stimulants treatments on plant length, stem diameter and number of leaves/plant of five tomato hybrids after three weeks from transplanting date in the summer seasons of 2015 and 2016.

Tomato Hybrids	Natural bio-stimulants	Plant length (cm)		Stem diameter (mm)		Number of leaves/ plant	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Alisa	Control	14.30 de	14.27 i	2.97 ef	3.08 h	4.73 hij	6.21 g
	Kelpak[a]	15.03 cd	15.71 g	3.20 cde	3.53 de	5.40 cdef	6.78 bcdef
	Companion[b]	15.33 bc	16.91 de	3.50 a	3.69 bc	6.00 a	6.91 bcde
	Kelp. + Comp.	15.67 bd	17.34 bcd	3.40 bcd	3.77 b	5.67 abcd	7.21 ab
	Mean	**15.08 B**	**16.06 C**	**3.27 A**	**3.52 A**	**5.45 B**	**6.78 B**
GS-12	Control	15.10 cd	15.35 g	2.60 gh	3.15 gh	4.90 ghi	6.19 g
	Kelpak	15.47 bc	16.72 ef	3.07 ef	3.33 f	5.10 efghi	6.40 fg
	Companion	16.17 ab	17.42 bc	3.50 b	3.60 cd	5.50 bcde	6.84 bcdef
	Kelp. + Comp.	16.87 a	18.15 a	4.00 a	4.15 a	5.73 abc	7.09 abc
	Mean	**15.90 A**	**16.91 A**	**3.29 A**	**3.56 A**	**5.31 B**	**6.63 B**
GS-556	Control	14.20 e	14.75 h	2.80 fg	3.19 gh	5.20 efg	6.50 efg
	Kelpak	15.63 bc	16.29 f	3.03 ef	3.25 fg	5.73 abc	7.00 abcd
	Companion	15.63 bc	17.10 cde	3.17 cde	3.39 ef	5.90 ab	7.17 ab
	Kelp. + Comp.	16.20 ab	17.64 b	3.43 bc	3.58 cd	6.00 a	7.40 a
	Mean	**15.42 B**	**16.44 B**	**3.11 B**	**3.34 B**	**5.71 A**	**7.02 A**
Super Jackal	Control	11.83 f	12.55 jk	2.50 h	1.99 ij	5.27 defg	6.68 cdef
	Kelpak	11.67 f	12.25 kl	2.13 i	2.32 kl	5.13 efgh	6.60 defg
	Companion	12.33 f	12.92 j	2.20 i	2.27 l	5.00 fghi	4.16 g
	Kelp. + Comp.	12.20 f	12.57 jk	2.57 h	1.94 jk	5.67 abcd	6.95 cd
	Mean	**12.01 C**	**12.49 D**	**2.35 D**	**2.38 C**	**5.28 B**	**6.60 B**
VT-737	Control	11.63 f	12.68 jk	2.60 gh	3.05 h	4.43 j	5.55 h
	Kelpak	11.90 f	11.39 l	2.57 gh	2.60 i	4.70 ij	6.19 g
	Companion	11.97 f	12.46 jk	2.93 ef	3.02 h	5.07 efghi	6.23 g
	Kelp. + Comp.	12.30 f	12.88 j	3.13 de	3.35 f	5.40 cdef	6.98 abcd
	Mean	**11.95 C**	**12.57 D**	**2.81 C**	**3.00 C**	**4.90 C**	**6.24 C**
Mean	Control	**13.41 D′**	**13.92 D′**	**2.69 C′**	**2.98 C′**	**4.91 D′**	**6.22 C′**
	Kelpak	**13.94 C′**	**14.58 C′**	**2.80 C′**	**3.01 C′**	**5.21 C′**	**6.60 B′**
	Companion	**14.29 B′**	**15.36 B′**	**3.06 B′**	**3.19 B′**	**5.49 B′**	**6.66 B′**
	Kelp. + Comp.	**14.65 A′**	**15.72 A′**	**3.31 A′**	**3.46 A′**	**5.69 A′**	**7.13 A′**

Kelpak[a] = seaweed liquid extract of brown marine alga *Ecklonia maxima*.
Companion[b] = natural biological liquid of *Bacillus subtilis* strain GB-03.
Capital letters, capital letters with apostrophe and small letters for the significant difference ($p \leq 0.05$) according to Duncan's multiple range test for hybrids, natural bio-stimulants and their interaction, respectively.

Table 4: Effect of natural bio-stimulants treatments on root length, plant survival percentage and SPAD readings of five tomato hybrids after three weeks from transplanting date in the summer seasons of 2015 and 2016.

Tomato Hybrids	Natural bio-stimulants	Root length (cm)		Plant survival (%)		SPAD readings	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Alisa	Control	9.43 h	9.12 h	75.23 j	80.57 f	37.78 g	39.13 i
	Kelpak[a]	9.83 fgh	10.13 fg	88.23 cde	93.28 ab	37.89 g	40.59 hi
	Companion[b]	10.93 abc	11.65 abcd	93.23 a	94.07 a	41.13 feg	45.76 fg
	Kelp. + Comp.	11.23 ab	12.25 a	90.90 abc	93.16 ab	40.33 efg	46.89 ef
	Mean	**10.36 A**	**10.79 B**	**86.90 AB**	**90.27 B**	**39.28 C**	**43.09 C**
GS-12	Control	8.31 i	9.44 gh	84.73 fg	90.83 bc	37.78 g	40.13 hi
	Kelpak	9.33 h	10.22 efg	86.07 ef	92.27 ab	43.22 cde	45.68 fg
	Companion	9.93 efgh	10.79 def	88.07 cde	93.87 a	45.18 bc	47.46 def
	Kelp. + Comp.	10.60 abcde	11.47 abcd	90.40 abc	94.00 a	46.01 bc	48.36 cdef
	Mean	**9.54 B**	**10.48 BC**	**87.32 A**	**92.74 A**	**43.05 B**	**45.41 B**
GS-556	Control	10.20 defg	11.00 def	81.67 h	87.52 d	41.89 def	42.57 hg
	Kelpak	10.47cd ef	11.07 cde	81.77 h	87.63 d	43.22 cde	45.35 fg
	Companion	10.77 abcd	11.93 abc	88.90 bcd	93.33 ab	44.90 bcd	47.83 cdef
	Kelp. + Comp.	11.27 a	12.12 ab	90.90 abc	94.30 a	45.53 bc	50.51 bcd
	Mean	**10.68 A**	**11.53 A**	**85.81 BC**	**90.69 B**	**43.89 B**	**46.56 B**
Super Jackal	Control	9.30 h	10.31 ef	77.10 ij	82.59 ef	38.67 fg	41.76 hi
	Kelpak	8.17 i	9.12 h	81.70 h	87.56 d	39.89 efg	43.08 hg
	Companion	9.40 h	10.32 ef	89.40 bcd	94.21 a	41.23 efg	45.87 fg
	Kelp. + Comp.	9.60 gh	11.01 def	91.73 ab	94.02 a	41.73 def	49.40 bcd
	Mean	**9.13 C**	**10.19 C**	**84.98 C**	**89.59 B**	**40.38 C**	**45.03 B**
VT-737	Control	10.53 bcdef	11.08 cde	87.03 i	83.60 e	51.04 a	43.13 hg
	Kelpak	10.47 cdef	11.00 def	82.47 gh	88.38 cd	47.37 b	51.16 bc
	Companion	10.47 cdef	11.28 bcd	87.10 def	93.39 ab	47.40 b	52.52 b
	Kelp. + Comp.	10.93 abc	11.98 abc	91.70 ab	93.76 a	47.17 b	56.94 a
	Mean	**10.60 A**	**11.34 A**	**84.83 C**	**89.78 B**	**48.24 A**	**50.94 A**
Mean	Control	**9.57 C′**	**10.19 C′**	**79.35 D′**	**85.02 C′**	**41.43 B′**	**41.34 D′**
	Kelpak	**9.65 C′**	**10.31 C′**	**84.05 C′**	**89.82 B′**	**42.32 B′**	**45.17 C′**
	Companion	**10.30 B′**	**11.20 B′**	**89.34 B′**	**93.82 A′**	**43.97 A′**	**47.89 B′**
	Kelp. + Comp.	**10.73 A′**	**11.77 A′**	**91.13 A′**	**93.85 A′**	**44.16 A′**	**50.42 A′**

Kelpak[a] = seaweed liquid extract of brown marine alga *Ecklonia maxima*.
Companion[b] = natural biological liquid of *Bacillus subtilis* strain GB-03.
Capital letters, capital letters with apostrophe and small letters for the significant difference ($p \leq 0.05$) according to Duncan's multiple range test for hybrids, natural bio-stimulants and their interaction, respectively.

As for the interaction treatments, Alisa, GS-12, GS-556 and VT-737 hybrids treated with Kelpak at 10 ml/l plus Companion 2-3-2 at 1.25 ml/l gave the highest and significant values of root length and plant survival percentage in both growing summer seasons, moreover, no significant differences were noticed between them and Alisa plants treated with Companion for both characters. Regarding, leaf SPAD readings, it is of interest to clarify that tomato plants of VT-737 showed the highest values when treated with control and Kelpak at 10 ml/l plus Companion 2-3-2 at 1.25 ml/l in the first season and second seasons, respectively. On the contrary, the lowest values were obtained when control treatment applied on tomato plants of Alisa hybrid in both seasons.

Fresh and dry weights of shoot and root, and root/shoot ratio

Data shown in Tables 5 and 6 demonstrated that significant differences were noticed among tomato hybrids on fresh and dry weights of shoot (leaves + stem), root and root/shoot ratio in both seasons. The highest significant values of fresh and dry weights of tomato shoot were obtained by tomato plants of Alisa, GS-12 and GS-556 hybrids without significant differences among them in both seasons. On the other hand, GS-556 hybrid recorded the highest and significant values of fresh and dry weights of root in both growing seasons and root/shoot ratio in the first season only, whereas in the second season the highest and significant value was recorded by Super Jackal and VT-737 without a significant difference between them.

As for the application of natural plant growth bio-stimulants treatments, Kelpak at 10 ml/l plus Companion 2-3-2 at 1.25 ml/l treatment illustrated a significant enhancement of fresh and dry weights of shoot, root and root/shoot ratios in both seasons. Moreover, there were no significant differences between Kelpak plus Companion and Companion treatments on fresh root/shoot ratio in both growing seasons. On contrast, the lowest values were obtained by the control treatment in both seasons.

Concerning the interaction treatments, data in Tables 5 and 6 revealed that GS-556 hybrid treated with Kelpak at 10 ml/l plus Companion 2-3-2 at 1.25 ml/l exhibited the highest and significant values of fresh and dry weights of shoot and root in both seasons and root/shoot ratio in the first season only. While, plants of Super Jackal hybrid with the same treatment gave the highest value of root/shoot ratio in the second season. On the other hand, the lowest values of fresh and dry weights of shoot and root were obtained when plants of Super Jackal hybrid received Kelpak at 10 ml/l in both seasons. However, the lowest values of fresh and dry weights of root/shoot ratio were attained by those plants of Super Jackal hybrid with control treatment in both seasons.

Early and total fruit yields

Significant differences were noticed among tomato plants of different hybrids on early and total fruit yields during seasons of 2015 and 2016 (Table 7). Tomato plants of VT-737 gave significantly ($p \leq 0.05$) the highest values of early fruit yield followed insignificantly by Super Jackal hybrid compared to the rest of tomato hybrids in both seasons. Furthermore, the highest values of total fruit yield were recorded by those plants of Super Jackal, followed by plants of VT-737 hybrid, but insignificantly in the first season and significantly in the second season. In the same regards, tomato plants of Alisa hybrid recoded significantly the lowest values of early and total fruit yields during both experimental seasons.

Natural plant growth bio-stimulants treatments led to a gradual significant increment of tomato plants early and total fruit yields in both seasons of the study. Treatment of Kelpak at 10 ml/l plus Companion 2-3-2 at 1.25 ml/l gave significantly ($p \leq 0.05$) the highest values of early and total fruit yields of tomato plants, followed by treatments of Companion 2-3-2 at 1.25 ml/l, then by Kelpak at 10 ml/l and lastly by control treatment. Application of Kelpak at 10 ml/l plus Companion 2-3-2 at 1.25 ml/l caused an increment over the control treatment by about 51.94, 12.76% and 54.52, 14.87% for early and total fruit yields in the first and second seasons, respectively.

The interaction between five tomato hybrids and natural plant growth bio-stimulants treatments had significant differences effects on early and total tomato fruit yields in both experimental seasons. It is evident from the obtained results that the highest values of early and total fruit yields were achieved when plants of both tomato hybrids VT-737 and Super Jackal received Kelpak at 10 ml/l plus Companion 2-3-2 at 1.25 ml/l. On the other hand, plants of Alisa hybrid with control treatment gave the lowest values. Similar trends were obtained in both seasons.

Table 5. Effect of natural bio-stimulants treatments on tomato plant fresh weight of shoot and root as well as the ratio of root-to-shoot of five tomato hybrids after three weeks from transplanting date in the summer seasons of 2015 and 2016.

Tomato Hybrids	Natural bio-stimulants	Fresh weight				Root/Shoot ratio	
		Shoot (g)		Root (g)			
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Alisa	Control	8.73 d	9.78 e	1.84 gh	2.91 g	0.211 g	0.298 fg
	Kelpak[a]	8.87 cd	10.13 de	1.85 gh	2.92 g	0.209 g	0.288 g
	Companion[b]	9.28 bc	10.73 bc	2.07 ef	3.13 f	0.223 def	0.292 fg
	Kelp. + Comp.	9.10 bcd	10.91 ab	2.00 f	3.28 bcd	0.219 efg	0.301 cdef
Mean		**8.99 A**	**10.58 A**	**1.94 C**	**3.06 C**	**0.216 D**	**0.289 C**
GS-12	Control	8.87 cd	8.88 fg	2.09 ef	2.79 h	0.236 cd	0.314 defg
	Kelpak	8.73 d	10.33 cd	2.14 de	3.16 ef	0.245 bc	0.306 cdefg
	Companion	9.08 bcd	10.69 bc	2.22 cd	3.22 de	0.244 bc	0.301 cdefg
	Kelp. + Comp.	9.37 b	11.41 a	2.28 c	3.35 ab	0.243 bc	0.294 defg
Mean		**9.01 A**	**10.33 A**	**2.19 B**	**3.13 B**	**0.243 B**	**0.303 B**
GS-556	Control	7.53 e	10.04 de	1.73 i	3.08 f	0.230 cde	0.307 cde
	Kelpak	8.93 bcd	10.35 cd	2.07 ef	3.23 cde	0.232 cde	0.312 bcd
	Companion	9.27 bcd	10.82 bc	2.77 b	3.32 abc	0.299 a	0.307 cde
	Kelp. + Comp.	9.93 a	11.13 ab	3.01 a	3.38 a	0.303 a	0.304 cde
Mean		**8.92 A**	**10.59 A**	**2.39 A**	**3.25 A**	**0.268 A**	**0.307 B**
Super Jackal	Control	7.13 ef	8.45 g	1.61 j	2.41 k	0.226 efg	0.285 h
	Kelpak	6.01 g	7.05 j	1.45 l	2.47 jk	0.241 cd	0.350 a
	Companion	6.05 g	7.33 i	1.44 l	2.54 j	0.238 de	0.347 ab
	Kelp. + Comp.	6.35 g	7.54 hi	1.50 kl	2.67 i	0.236 de	0.354 a
Mean		**6.38 C**	**7.54 C**	**1.51 E**	**2.52 E**	**0.237 C**	**0.334 A**
VT-737	Control	7.17 ef	7.86 h	1.59 jk	2.63 i	0.222 fg	0.335 bc
	Kelpak	7.00 f	8.54 fg	1.76 hi	2.82 h	0.251 b	0.330 bcd
	Companion	7.38 ef	8.71 fg	1.88 g	2.95 g	0.255 b	0.339 ab
	Kelp. + Comp.	7.51 e	9.04 f	1.89 g	2.99 g	0.252 b	0.331 bcd
Mean		**7.27 B**	**8.54 B**	**1.78 D**	**2.85 D**	**0.245 B**	**0.334 A**
Mean	Control	**7.89 C′**	**9.00 D′**	**1.77 D′**	**2.76 D′**	**0.224 C′**	**0.307 B′**
	Kelpak	**7.91 C′**	**9.28 C′**	**1.85 C′**	**2.42 C′**	**0.234 B′**	**0.261 C′**
	Companion	**8.21 B′**	**9.66 B′**	**2.08 B′**	**3.03 B′**	**0.253 A′**	**0.314 A′**
	Kelp. + Comp.	**8.45 A′**	**10.01 A′**	**2.14 A′**	**3.14 A′**	**0.253 A′**	**0.314 A′**

Kelpak[a] = seaweed liquid extracts of brown marine alga *Ecklonia maxima*.
Companion[b] = natural biological liquid of *Bacillus subtilis* strain GB-03.
Capital letters, capital letters with apostrophe and small letters for the significant difference ($p \leq 0.05$) according to Duncan's multiple range test for hybrids, natural bio-stimulants and their interaction, respectively.

Table 6. Effect of natural bio-stimulants treatments on tomato plant dry weight of shoot and root as well as the ratio of root-to-shoot of five tomato hybrids after three weeks from transplanting date in the summer seasons of 2015 and 2016.

Tomato Hybrids	Natural bio-stimulants	Dry weight				Root/Shoot ratio	
		Shoot (g)		Root (g)			
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Alisa	Control	0.88 de	0.94 g	0.19 hij	0.30 ij	0.216 i	0.319 de
	Kelpak[a]	0.87 de	1.03 cdef	0.19 hij	0.33 fg	0.218 i	0.320 de
	Companion[b]	0.95 b	1.08 bc	0.26 c	0.34 f	0.274 ef	0.315 de
	Kelp. + Comp.	0.93 bc	1.07 bc	0.26 c	0.38 cd	0.280 def	0.355 b
	Mean	**0.91 A**	**1.03 A**	**0.23 B**	**0.34 C**	**0.253 D**	**0.330 D**
GS-12	Control	0.86 e	0.89 gh	0.21 gh	0.29 j	0.244 h	0.326 d
	Kelpak	0.87 de	1.02 def	0.22 fg	0.36 e	0.253 h	0.353 b
	Companion	0.90 cd	1.04 cde	0.23 f	0.37 d	0.256 gh	0.356 b
	Kelp. + Comp.	0.94 bc	1.13 a	0.23 ef	0.40 ab	0.245 h	0.354 b
	Mean	**0.89 AB**	**1.02 A**	**0.22 B**	**0.35 B**	**0.247 D**	**0.343 C**
GS-556	Control	0.76 f	0.99 f	0.18 ij	0.31 hi	0.237 h	0.313 de
	Kelpak	0.87 de	1.01 ef	0.25 d	0.39 bc	0.287 cd	0.386 a
	Companion	0.89 de	1.06 bcd	0.36 b	0.38 cd	0.405 a	0.358 b
	Kelp. + Comp.	0.99 a	1.09 ab	0.40 a	0.41 a	0.404 a	0.376 a
	Mean	**0.88 B**	**1.04 A**	**0.30 A**	**0.37 A**	**0.341 A**	**0.356 A**
Super Jackal	Control	0.74 f	0.88 h	0.18 ij	0.25 m	0.243 h	0.284 f
	Kelpak	0.61 h	0.71 j	0.15 l	0.26 l	0.246 gh	0.366 bc
	Companion	0.61 h	0.75 j	0.16 kl	0.27 k	0.262 fg	0.360 b
	Kelp. + Comp.	0.64 h	0.76 j	0.19 hij	0.29 j	0.297 c	0.382 a
	Mean	**0.65 D**	**0.77 C**	**0.17 D**	**0.27 E**	**0.262 C**	**0.351 B**
VT-737	Control	0.69 g	0.83 i	0.17 k	0.26 kl	0.246 gh	0.313 e
	Kelpak	0.69 g	0.86 hf	0.19 hij	0.29 j	0.275 de	0.337 cd
	Companion	0.73 f	0.87 hi	0.20 hi	0.34 f	0.274 def	0.391 a
	Kelp. + Comp.	0.75 f	0.89 h	0.25 de	0.32 gh	0.333 b	0.360 b
	Mean	**0.72 C**	**0.86 B**	**0.20 C**	**0.30 D**	**0.278 B**	**0.349 B**
Mean	Control	**0.79 C′**	**0.91 D′**	**0.19 D′**	**0.28 D′**	**0.241 D′**	**0.308 C′**
	Kelpak	**0.78 C′**	**0.93 C′**	**0.20 C′**	**0.33 C′**	**0.256 C′**	**0.355 B′**
	Companion	**0.82 B′**	**0.96 B′**	**0.24 B′**	**0.34 B′**	**0.293 B′**	**0.354 B′**
	Kelp. + Comp.	**0.85 A′**	**0.99 A′**	**0.27 A′**	**0.36 A′**	**0.318 A′**	**0.364 A′**

Kelpak[a] = seaweed liquid extracts of brown marine alga *Ecklonia maxima*.
Companion[b] = natural biological liquid of *Bacillus subtilis* strain GB-03.
Capital letters, capital letters with apostrophe and small letters for the significant difference ($p \leq 0.05$) according to Duncan's multiple range test for hybrids, natural bio-stimulants and their interaction, respectively.

Table 7. Effect of natural bio-stimulants treatments on tomato plant early and total fruit yields of five tomato hybrids transplanted in the summer seasons of 2015 and 2016.

Tomato Hybrids	Natural bio-stimulants	Early yield (ton/fed.)		Total yield (ton/fed.)	
		1st season	2nd season	1st season	2nd season
Alisa	Control	1.673 j	1.790 l	17.281 k	17.394 n
	Kelpak[a]	2.305 ghi	2.858 ij	18.496 ijk	19.263 l
	Companion[b]	2.858 efg	3.591 g	19.274 ij	20.725 j
	Kelp. + Comp.	3.472 bcd	4.171 cde	20.657 gh	22.131 i
Mean		**2.577 C**	**3.102 D**	**18.927 D**	**19.878 D**
GS-12	Control	1.577 j	1.772 l	18.077 jk	18.674 m
	Kelpak	2.819 efg	3.142 hi	19.454 hi	19.777 k
	Companion	3.387 cde	3.939 def	19.745 hi	20.374 j
	Kelp. + Comp.	3.705 bc	4.293 c	21.304 fg	22.862 h
Mean		**2.872 B**	**3.286 C**	**19.645 C**	**20.422 C**
GS-556	Control	1.733 ij	2.036 l	20.751 gh	22.262 i
	Kelpak	2.659 fg	3.093 hi	21.797 efg	24.050 fg
	Companion	3.058 def	3.878 efg	22.752 cde	24.631 de
	Kelp. + Comp.	3.757 bc	4.705 b	23.725 abc	26.186 b
Mean		**2.802 B**	**3.428 B**	**22.256 B**	**24.282 B**
Super Jackal	Control	1.877 hij	2.404 k	22.014 defg	24.184 efg
	Kelpak	2.333 gh	2.765 j	23.358 bcd	24.989 d
	Companion	3.325 cde	3.802 fg	24.483 ab	25.576 c
	Kelp. + Comp.	4.022 ab	4.768 ab	25.000 a	26.958 a
Mean		**2.889 B**	**3.435 B**	**23.714 A**	**25.427 A**
VT-737	Control	2.432 gh	2.435 k	22.236 def	23.038 h
	Kelpak	2.855 efg	3.174 h	23.238 bcd	23.844 g
	Companion	3.562 bcd	4.223 cd	23.986 abc	24.507 def
	Kelp. + Comp.	4.385 a	5.013 a	24.353 ab	25.848 bc
Mean		**3.309 A**	**3.711 A**	**23.453 A**	**24.309 B**
Mean	Control	**1.859 D′**	**2.087 D′**	**20.072 D′**	**21.112 D′**
	Kelpak	**2.594 C′**	**3.006 C′**	**21.268 C′**	**22.385 C′**
	Companion	**3.238 B′**	**3.886 B′**	**22.048 B′**	**23.163 B′**
	Kelp. + Comp.	**3.868 A′**	**4.589 A′**	**23.008 A′**	**24.799 A′**

Kelpak[a] = seaweed liquid extracts of brown marine alga *Ecklonia maxima*.
Companion[b] = natural biological liquid of *Bacillus subtilis* strain GB-03.
Capital letters, capital letters with apostrophe and small letters for the significant difference ($p \leq 0.05$) according to Duncan's multiple range test for hybrids, natural bio-stimulants and their interaction, respectively.

Leaf mineral contents

Data shown in Tables 8 and 9 declared that Alisa and GS-12 hybrids gave the highest content of tomato leaf N, while Alisa, GS-12 and VT-737 hybrids the highest ones for leaf content of P in both seasons. On the other hand, VT-737 plants recorded the highest significant values of K, while GS-12 and GS-556 hybrids exhibited the highest significant values of Ca in both growing seasons. On the contrary, no significant differences were detected among the different tomato hybrids concerning Mg and Fe contents especially in the first seasons. It is of interest to note that tomato plants of GS-12 hybrid recorded the highest values of tomato leaf mineral contents of N, P, Ca, Mg and Fe in both growing seasons.

Table 8. Effect of natural bio-stimulants treatments on tomato leaf mineral contents of N, P and K of five tomato hybrids after three weeks from transplanting date in the summer seasons of 2015 and 2016.

Tomato Hybrids	Natural bio-stimulants	N		P		K	
		%					
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Alisa	Control	2.88 hij	2.70 j	0.31 ghi	0.28 jk	1.57 j	1.58 k
	Kelpak[a]	3.63 def	3.45 f	0.39 bcdef	0.38 defg	2.76 h	2.67 i
	Companion[b]	3.81 de	4.75 e	0.43 bc	0.41 cde	2.97 g	2.92 fg
	Kelp. + Comp.	4.54 b	4.27 c	0.59 a	0.56 a	3.15 ef	3.16 de
	Mean	**3.73 A**	**3.54 AB**	**0.43 A**	**0.41 A**	**2.61 D**	**2.58 D**
GS-12	Control	2.90 ghij	2.62 j	0.31 fghi	0.29 ijk	2.57 j	1.60 k
	Kelpak	3.40 efg	3.32 fg	0.35 defghi	0.33 ghi	2.73 h	2.66 i
	Companion	4.00 cd	3.78 e	0.45 b	0.43 c	2.85 gh	2.77 hi
	Kelp. + Comp.	4.66 b	4.84 b	0.60 a	0.56 a	2.95 g	3.04 ef
	Mean	**3.74 A**	**3.64 A**	**0.43 A**	**0.41 A**	**2.53 E**	**2.52 E**
GS-556	Control	2.67 ij	2.49 j	0.28 hi	0.26 k	1.83 i	1.90 j
	Kelpak	2.93 ghij	2.97 hi	0.36 defgh	0.35 fgh	2.87 gh	2.86 gh
	Companion	3.25 fgh	3.85 de	0.41 bcde	0.39 cdef	3.01ig	2.93 fg
	Kelp. + Comp.	4.41 bc	4.05 cd	0.56 a	0.51 b	3.17 def	3.19 d
	Mean	**3.48 B**	**3.34 C**	**0.403 A**	**0.38 B**	**2.73 C**	**2.72 C**
Super Jackal	Control	2.44 j	2.56 j	0.27 i	0.26 k	1.67 ij	1.67 k
	Kelpak	2.88 hig	2.73 ij	0.31 fghi	0.29 jk	3.27 de	3.20 d
	Companion	3.92 d	3.13 gh	0.35 defghi	0.35 fgh	3.35 cd	3.29 cd
	Kelp. + Comp.	5.55 a	5.53 a	0.45 b	0.43 cd	3.54 b	3.43 b
	Mean	**3.53 AB**	**3.49 B**	**0.35 B**	**0.33 C**	**2.96 B**	**2.90 B**
VT-737	Control	2.68 ij	2.47 j	0.34 efghi	0.31 hij	1.73 ij	1.59 k
	Kelpak	3.15 fghi	3.03 h	o.37 cdefg	0.36 efgh	3.34 cd	3.28 cd
	Companion	3.56 def	3.46 f	0.42 bcd	0.41 cde	3.51 bc	3.38 bc
	Kelp. + Comp.	4.84 b	4.87 b	0.56 a	0.52 ab	3.72 a	3.62 a
	Mean	**3.56 AB**	**3.46 BC**	**0.42 A**	**0.40 A**	**3.08 A**	**2.97 A**
Mean	Control	**2.71 D′**	**2.57 D′**	**0.30 D′**	**0.28 D′**	**1.67 D′**	**1.67 D′**
	Kelpak	**3.20 C′**	**3.60 C′**	**0.36 C′**	**0.34 C′**	**3.00 C′**	**2.97 C′**
	Companion	**3.72 B′**	**3.59 B′**	**0.41 B′**	**0.40 B′**	**3.11 B′**	**3.06 B′**
	Kelp. + Comp.	**4.80 A′**	**4.71 A′**	**0.55 A′**	**0.52 A′**	**3.31 A′**	**3.29 A′**

Kelpak[a] = seaweed liquid extracts of brown marine alga *Ecklonia maxima*.
Companion[b] = natural biological liquid of *Bacillus subtilis* strain GB-03.
Capital letters, capital letters with apostrophe and small letters for the significant difference ($p \leq 0.05$) according to Duncan's multiple range test for hybrids, natural bio-stimulants and their interaction, respectively.

Table 9: Effect of natural bio-stimulants treatments on tomato leaf mineral contents of Ca, Mg and Fe of five tomato hybrids after three weeks from transplanting date in the summer seasons of 2015 and 2016.

Tomato Hybrids	Natural bio-stimulants	Ca		Mg		Fe	
		%				ppm	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Alisa	Control	1.26 g	1.27 i	0.66 hi	0.63 f	294.17 g	288.60 k
	Kelpak[a]	1.93 de	1.89 ef	o.74 fgh	0.69 h	335.03 f	325.65 ij
	Companion[b]	1.94 de	1.91 e	0.82 cdef	0.77 ef	367.63 e	359.01 ef
	Kelp. + Comp.	2.15 cd	2.16 d	0.90 abc	0.84 bcd	393.00 bcd	382.00 bcd
	Mean	**1.82 B**	**1.81 BC**	**0.78 A**	**0.73 A**	**347.46 A**	**338.81 C**
GS-12	Control	1.42 g	1.45 h	0.60 ij	0.54 j	296.20 g	291.24 k
	Kelpak	1.79 ef	1.84 ef	0.79 efg	0.76 fg	337.33 f	353.22 fgh
	Companion	2.27 c	2.14 d	0.81 defg	0.80 def	373.63 de	366.50 def
	Kelp. + Comp.	2.90 a	2.70 b	0.91 ab	0.86 bc	402.10 ab	394.17 ab
	Mean	**2.11 A**	**2.03 A**	**0.78 A**	**0.74 A**	**352.32 A**	**351.22 A**
GS-556	Control	1.39 g	1.37 hi	0.58 ij	0.52 j	272.80 h	265.17 m
	Kelpak	1.81 ef	1.75 f	0.73 fgh	0.70 h	346.80 f	337.09 hij
	Companion	2.13 cd	2.16 d	0.88 abcd	0.82 cde	379.40 cde	368.78 cd
	Kelp. + Comp.	3.00 a	3.00 a	0.95 a	0.89 ab	402.13 ab	390.88 b
	Mean	**2.08 A**	**2.07 A**	**0.79 A**	**0.73 A**	**350.28 A**	**340.40 BC**
Super Jackal	Control	1.29 g	1.24 i	0.57 j	0.52 j	277.70 gh	273.55 l
	Kelpak	1.82 ef	1.74 f	0.72 gh	0.63 hi	346.03 f	343.01 ghi
	Companion	1.97 de	1.87 ef	0.76 efg	0.71 gh	384.73 bcde	377.29 bcd
	Kelp. + Comp.	2.60 b	2.63 b	0.93 a	0.87 bc	414.40 a	406.13 a
	Mean	**1.29 B**	**1.87 B**	**0.75 A**	**0.69 B**	**355.72 A**	**350.61 AB**
VT-737	Control	1.32 g	1.30 i	0.55 j	0.50 j	289.23 gh	277.80 kl
	Kelpak	1.63 f	1.59 g	0.74 fgh	0.69 h	330.07 f	320.83 j
	Companion	1.85 ef	1.79 ef	0.83 bcde	0.78 ef	376.20 de	362.33 def
	Kelp. + Comp.	2.50 b	2.49 c	0.96 a	0.93 a	398.80 abc	390.93 b
	Mean	**1.82 B**	**1.79 C**	**0.77A**	**0.72 A**	**348.58 A**	**337.98 C**
Mean	Control	**1.34 D′**	**1.33 D′**	**0.59 D′**	**0.54 D′**	**286.02 D′**	**279.28 D′**
	Kelpak	**1.80 C′**	**1.76 C′**	**0.74 C′**	**0.70 C′**	**339.05 C′**	**335.96 C′**
	Companion	**2.03 B′**	**1.98 B′**	**0.82 B′**	**0.76 B′**	**376.32 B′**	**366.78 B′**
	Kelp. + Comp.	**2.63 A′**	**2.61 A′**	**0.93 A′**	**0.88 A′**	**402.09 A′**	**392.83 A′**

Kelpak[a] = seaweed liquid extracts of brown marine alga *Ecklonia maxima*.
Companion[b] = natural biological liquid of *Bacillus subtilis* strain GB-03.
Capital letters, capital letters with apostrophe and small letters for the significant difference ($p \leq 0.05$) according to Duncan's multiple range test for hybrids, natural bio-stimulants and their interaction, respectively.

Application of natural plant growth bio-stimulants, Kelpak, Companion 2-3-2, Kelpak plus Companion 2-3-2 and control treatments gained a significant effect on tomato leaf mineral contents as shown in Tables 8 and 9. Natural plant growth bio-stimulants treatments could by arranged in descending order according to significance differences as follow Kelpak plus Companion 2-3-2, Companion 2-3-2, Kelpak and control treatments. The highest significant values of leaf mineral contents of N, P, K, Ca, Mg and Fe were reached by Kelpak plus Companion 2-3-2 treatment. On the contrary, the lowest significant values were attained by control treatment in both seasons.

The interaction between tomato hybrids and natural plant growth bio-stimulants treatments recorded significant differences on tomato leaf mineral contents in both seasons. It is evident that tomato plants of Super Jackal treated with Kelpak plus Companion 2-3-2 displayed the highest significant values of N in both seasons. Alisa, GS-12 and VT-737 hybrids which received Kelpak plus Companion 2-3-2 treatment recorded the highest significant value of leaf P content, while only VT-737 hybrid showed significant content of leaf K in both seasons. On the other hand, application of Kelpak plus Companion 2-3-2 on GS-556 singly and along with VT-737 recorded significant highest values of Ca and Mg, respectively. Furthermore, GS-12 and Super Jackal hybrids showed significant highest value of Fe when the plants treated with Kelpak plus Companion. On contrast, the lowest values of all measured leaf minerals were obtained when control treatment was applied on Super Jackal plants in the first season and Super Jackal and VT-737 in the second season.

Discussion

The obtained results clearly indicated that significant differences were realized among different tomato hybrids on all vegetative growth measured parameters in both growing seasons. Tomato hybrids of GS-12 and GS-556 gave the vigorous plant vegetative growth characters (Tables 3 and 4) and the heaviest fresh and dry weights of shoot and root as well as root/shoot ratio compared with the rest of the hybrids in both seasons (Tables 5 and 6). The obtained results may be attributed to genetic diversity as well as to different genetic background of the studied tomato hybrids.

The obtained results are in a good agreement with the results obtained by Crouch and Van Staden (1992); Arthur *et al.* (2003); Dursun *et al.* (2010); Glala *et al.* (2010); Ekinci *et al.* (2014). They demonstrated that the differences observed in vegetative growth characters among various crops cultivars might be explained due to genetic variation, genetic background and/or favorable influence of environmental conditions. Moreover, plant vegetative growth was significantly influenced by the sown cultivar as reported by Koudela and Petříková (2008).

Tomato plants of VT-737 hybrid gave the highest leaf SPAD readings. In contrast, Alisa hybrid recorded the lowest values in both experimental seasons (Table 4). The obtained results are in good accordance with those of Blunden *et al.* (1997); Kulkarni *et al.* (2019). They reported that the differences observed in leaf chlorophyll content among cultivars might be explained due to different genetic background. Also they added that leaf chlorophyll content positively improved the photosynthetic efficiency, thereby causing an improvement of plant growth.

In the same respect, tomato plants of different hybrids showed significant differences among them on early and total fruit yields during seasons of 2015 and 2016. Tomato hybrids of VT-737 and Super Jackal recorded the heaviest early and total fruit yield, respectively. The lightest early and total fruit yields were obtained by Alisa hybrid in both seasons (Table 7). The obtained results are in line with findings of Crouch and Van Staden (1992); Arthur *et al.* (2003); Dobromilska *et al.* (2008); Dursun *et al.* (2010); Glala *et al.* (2010); Kumari *et al.* (2011); Zodape *et al.* (2011); Kocira *et al.* (2018).

The analysis of leaf mineral contents of different tomato hybrids showed that plants of GS-12 hybrid recorded the best values of leaf mineral contents of N, P, Ca, Mg and Fe, while, the best values of K were attained by VT-737 hybrid in both growing summer seasons (Tables 8 and 9). The obtained results may be attributed to the vigorous plant root system (root length and fresh and dry weights of root as well as root/shoot ratio) of GS-12 hybrid in relative to the rest of hybrids, which undoubtedly positively reflected on water and nutrients absorption from the soil by plant roots.

A varietal difference concerning leaf mineral contents has been reported by Dobromilska *et al.* (2008); Papenfus *et al.* (2013); Kocira *et al.* (2018). In addition, Masny *et al.* (2004) concluded that individual cultivars from the same species may be differently responded.

Natural plant growth bio-stimulants treatment of Kelpak plus Companion 2-3-2 was superior to the rest of the treatments, where it recorded the highest values of all studied parameters. However, control treatment gained the lowest values in both growing seasons. The most positive impact of Kelpak combined with Companion 2-3-2 more than using each of them singly could be explained due to the effect of these natural plant growth bio-stimulants, which contained or synthesized various biologically active compounds principally phytohormones i.e. auxins, cytokinins and polyamines. In the same regards, the effect of Companion 2-3-2 treatment was more pronounced than Kelpak treatment, this may be due to bio-enriched of the rhizosphere with *Bacillus subtilis* which led to increase the synthesize of biologically active compounds around the plant root. These biologically active compounds led to stimulate plant root and seedling establishment (Crouch and Van Staden, 1992; Papenfus *et al.,* 2013; Walia *et al.,* 2014), enhance seedling, plant growth and crop yield (Crouch and Van Staden, 1992; Arthur *et al.,* 2003; Masny *et al.,* 2004; Dursun *et al.,* 2010; Glala *et al.,* 2010; Zodape *et al.,* 2011; Ekinci *et al.,* 2014; Kocira *et al.,* 2018) and improve uptake capacity of water and nutrients from the soil by plant roots (Dobromilska *et al.,* 2008; Glala *et al.,* 2010; Ekinci *et al.,* 2014; Kocira *et al.,* 2018).

In addition several PGPR i.e. *Bacillus subtilis* produced volatile organic compounds (VOCs) that may be played a significant role in promoting plant growth and inducing systemic resistance (ISR) against plant pathogens (Ryu *et al.,* 2004; Bhattacharyya *et al.,* 2015). Moreover, natural plant growth bio-stimulants promoted the performance of seedlings under extreme temperatures and induced abiotic stress tolerance, such tolerance might be ascribed to phytohormone cytokinin activity (Zhang and Ervin 2008). Also, natural plant growth bio-stimulants enhanced leaf chlorophyll content which positively reflected on the photosynthetic efficiency and capacity thereby resulted in enhanced plant growth (Blunden *et al.,* 1997; Jannin *et al.,* 2013). The increment of leaf chlorophyll content may be a result of reduction in chlorophyll degradation, increasing of chlorophyll biosynthesis and delaying of leaf senescence (Blunden *et al.,* 1997; Kulkarni *et al.,* 2019). In this concern, cytokinins are responsible for increasing leaf chlorophyll content and inhibiting senescence of the plant tissues (Stirk *et al.,* 2003; Robertson-Andersson *et al.,* 2006).

The obtained results are in coincidence with Crouch and Van Staden (1992); Mena-Violante and Olalde-Portugal (2007). They reported that application of natural plant growth bio-stimulants reduced seedlings transplanting shock through increasing root growth, root-to-shoot ratio and fresh and dry root and shoot biomass and increased early and total tomato fruit yields compared to control treatment. Further, increased root and shoot length and fresh weight (Kumari *et al.,* 2011) and increased tomato leaf nutrient contents (Dobromilska *et al.,* 2008) as well as increased uptake of K, Ca and Mg in leaves of lettuce (Crouch *et al.,* 1990). Also, application of natural plant growth bio-stimulants increased seedling growth, root length, stem diameter, transplant survival and yield in tomato and pepper (Kokalis-Burelle *et al.,* 2002) and shoot and root weights, shoot length and stem diameter in muskmelon and watermelon (Kokalis-Burelle *et al.,* 2003). Moreover, inoculation of seedlings with *Bacillus subtilis* increased shoot and root fresh and dry weights, shoot and root lengths and diameters, leaf area, leaf chlorophyll contents and nutrient contents compared to the control treatment in tomato (Walia *et al.,* 2014) and in cauliflower (Ekinci *et al.,* 2014).

Conclusion

In conclusion, it could be concluded that the treatment of Kelpak at 10 ml/l plus Companion 2-3-2 at 1.25 ml/l gave the best values of vegetative growth, plant survival percentage, early and total fruit yields as well as leaf mineral contents of five tomato hybrids transplanted during the summer season. Application of seaweed extract (Kelpak) combined with PGPR (Companion 2-3-2) may be used as a promising agricultural practice in organic and sustainable agriculture owing to its natural, eco-friendly, cost effective and maintaining soil fertility and sustainability.

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