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Application of biostimulants promotes growth and productivity of heat-stressed tomato (*Solanum lycoperosicum*) plants.

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ABSTRACT:

Plant biostimulants are natural substances commonly used in recent decades in the agricultural practices primarily for plant defense and to enhance plant growth, yield and quality of tomato plant. This study was conducted to investigate the effect of biostimulants foliar application on growth, productivity, and fruit quality of tomato plants during the summer season of 2020 and 2021. Tomato plants were sprayed twice (at 15 days interval) with biostimulants i.e., date palm pollen grains extract, bee pollen grains extract, chito boom (5% chitosan, 9% B, 1.15% amino acids and 0.05% Mo), algeno plus (50% Potassium alginate, 0.92% Mg, 1.75% S, 0.52 % Fe, 0.25% Mn, 0.15 % Zn, 0.25% B, 0.004 % Mo and 0.73% cytokines), fast tunic (2.5% NAA and 0.6% sodium nitrophenolate), and water as control. The results indicated that date palm pollen and bee pollen extracts significantly increased plant height when compared to control. Bee pollen and algeno plus significantly increased number of branches. These treatments in addition to chito bom, increased leaf area and leaf perimeter. All biostimulants significantly decreased Malondialdehyde (MDA), while they exhibited a significant increase for peroxides, proline and total phenols, total fruit yield, fruit weight per plant and fruit number per plant. Bee pollen and chito bom improved fruit contents of total sugar, beta-carotene, lycopene and these treatments in addition to date palm pollen increased vitamin C and acidity. Bee pollen grains, and date palm pollen grains extracts, chitosan could be recommended to alleviate high temperature stress on tomato plants.

KEY WORDS: *Solanum lycoperosicum*, bee pollen grains, date palm pollen grains, chitosan, algae, heat stress.

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1. INTRODUCTION:

Climate change is the shift in the average of different climatic characteristics over a longer time period and a wider geographic area. The changes in climate may include the extreme high and low temperature, increase in soil salinity, waterlogging, high atmospheric CO_2 concentration and UV radiation. The increase in greenhouse gases like CO_2 and CH_4 in the atmosphere, often known as global warming or the greenhouse effect, is what causes the high temperatures **(Kumari et al., 2018)**. The average world temperature has risen by 0.740 °C during last 100 years and by the year 2100 best estimates predict between 1.80 °C and 40 °C rise in average global temperature, although could possibly be as high as 6.40 °C (**El-Sharkawy, 2014)**. By the end of the current century, the Intergovernmental Panel on Climate Change (IPCC) projects that average temperatures will have risen by 2.0 to 4.5 °C. (**Wahba, et al., 2019**). Global warming is predicted to worsen Egypt's drinking water shortage, put more strain on the country's land resources, and increase the frequency of sand and dust storms. Also, the predicted local land subsidence combined with the global sea level rise will result in the loss of numerous low-lying coastal areas and the entry of salt water into a number of coastal wells, which will destroy the agricultural productivity of low-lying areas **(Wahba, et al., 2019)**.

Crop production around the world is seriously threatened by global warming (**Kaushal et al., 2016**). The serious effects of high temperature in plants are decreased plant growth, inappropriate development, decreased produce quality, altered photosynthesis, phenology, and dry matter production, water loss, oxidative stress, and eventually decreased yield (**Vijayakumar and Beena, 2020**).

Tomato (*Solanum lycoperosicum* L.) belongs to the family of solanaceae, and it is a widely cultivated crop. Mexico, Brazil, Spain, and Italy are the major tomato producing countries. Belgium and Netherlands are leaders in the yield per hectare (**Tubiello et al., 2013**). In Egypt, it is one of the most significant commercial crops in terms of production, industrial value, and contribution to human nutrition. The total cultivated area of tomato is 380.011 thousand feddan, which produced about 6493724 tons in the year of 2019/2020 (FAOSTAT, 2021). Despite its ability to grow in a wide range of climates, tomato fruit production is affected by the stress of the high temperature. The increase in day/night temperatures above 29/19 °C, respectively, adversely reduce, fruit yield, due to reducing fruit setting, fruit quality (high fruit cracking, sunscald, blossom end rot and low lycopene content **(Pramanik, et al., 2021)**. Heat stress (temperatures above 30 °C) decreases the number of pollen grains developed and released in the anther, pollen viability, and germination in tomato and thus lead to low fruit setting and low yield; this phenomenon also affected the lycopene content, causing high evaporation and low fruit quality (**Alsamir et al., 2021**).

Using products with a wide range of ecologically friendly is one of the new methods in the agriculture sector. Nowadays several safety preparations, namely biostimulants, are available for agricultural production that used not only as fertilizer and plants stimulator, but also as a minimizer for the problems related to climate changes **(Byan, 2020 b)**. Plant biostimulants include natural substances, other than fertilizers and pesticides, able to promote plant growth, increase yield and improve quality. The plant biostimulants showed their efficiency when applied to the crop in low quantities **(Colla and Rouphael, 2015; Du Jardin, 2015)**.

Algae are a polyphyletic group of organisms that live in variable environment **(Hernández et al., 2017)**. Seaweed extracts play multiple roles as biostimulants through the regulation and modification of the primary and secondary metabolism in plants that leads to enhancement of productivity and reduce the adverse effect of abiotic stress on crops **(Rouphael et al., 2017)**. Recent study proved that seaweed extract improved growth and increased productivity of tomato plants under salinity stress **(Hernández-Herrera et al., 2022)**.

Foliar application of bee pollen grains extract showed a significant a bio-stimulation effect on the growth, yield and bulb quality of onion plants (*Allium cepa* L.) under sandy soil conditions **(Shafeek et al., 2015)** and elevating drought stress in *Ocimum basilicum* **(Taha et al., 2020)**. The bio-stimulation effect of bee pollens is related to their enriched contents of phytohormones, proteins, polysaccharides, polyphenols, minerals, vitamins, amino acids, fatty acids, enzymes and antioxidants (**Taha et al., 2020; Algethami, et al., 2022)**

The extract of date palm (*Phoenix dactylifera* L) pollen grains was also used as a biostimulant for pomegranate seedlings, as it improved vegetative qualities of vegetative growth (plant height, leaf area, number of leaves) and root growth, as well as the percentage of NPK in shoots **(Abdulkadhim and Sabaa, 2019; Abo AL-Mikh, 2019)**. Moreover, spray plants of eggplant during late hot summer **(Byan, 2020 a)** and common bean plants under deficit water **(Byan, 2020b)** with palm pollen grains extract increased all tested eggplant parameters (growth, yield and chemical composition of fruits) and increased common beans yield at 75% water deficiency as compared with the yield at 100% water level without treating with palm pollen grains, respectively.

Chitosan is a natural biopolymer derived from chitin, a polysaccharide found in exoskeleton of shellfish such as shrimp, lobster or crabs and cell wall of fungi, is known to have biological activity **(Gornik et al. 2008)**. Chitosan has been considered as a biostimulant, because it has shown to promote nutrition, growth and yield of crops. it acts as a growth regulator, speed up seed germination of seed, plant vigor and crop performance **(Reyes-Pérez et al., 2020)**.

Some researchers reported that chitosan exerts a stimulating effect on growth and quality of tomato under the conditions of open field **(Islam et al., 2016; Sultana et al., 2017)** plastic tunnel condition (Hussain et al., 2019), greenhouse (Reyes-Pérez et al., 2020) and water stress **(Hassnain et al., 2020)**.

Due to the harmful effect of global warming on the different vegetable crops, this forced us, to evaluate the influence of foliar application of some natural biostimulants materials as alternatives to the synthetic stimulants, on morpho-physiological parameters, yield and fruit quality of tomato plants under heat stress conditions.

2. MATERIALS AND METHODS:

2.1. Location, treatments, and experimental layout

Experiments were conducted at a private farm, at Bernnasht, Al Ayat (29°41´N; 31° 12´E) and Giza, Egypt in two successive summer seasons of 2020 and 2021. Agroclimatology data (Average of maximum temperature, minimum temperature, average temperature, and relative humidity) at both seasons (2020 and 2021) is illustrated at Fig.1. The tomato hybrid, namely

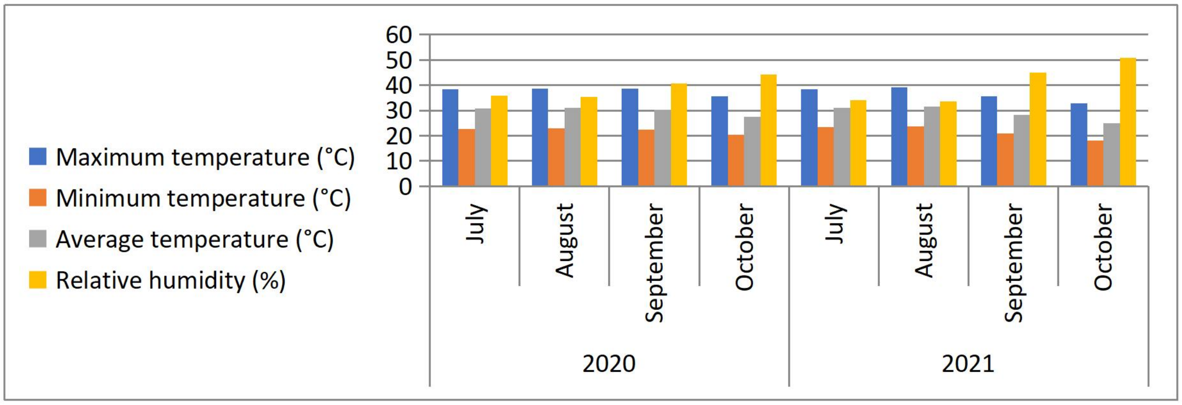

Fig. 1. Agroclimatology data (Average of maximum temperature, minimum temperature, average temperature, and relative humidity) at both seasons (2020 and 2021) during the growing period (from July to October) in experimental site (Brenshet, Al Ayat, Giza, Egypt (29°41´N; 31° 12´E)

023, Sakata Seed Com, Japan, was used. The transplanting dates were on 5 and 10 July, in the first and second season, respectively. The experiment included six treatments, that was laid out in a Randomized Complete Blocks Design (RCBD) in three replicates in each season. The length of the plot was 20 m and 1.5 m width with an area 30 m^2. The seedlings were transplanted on the middle of ridges at 0.5 m between the plants. The soil of experimental site was sandy soil. Five biostimulants foliar application (i.e., date palm pollen grains (PPG) extract, bee pollen grains (BPG) extract, chito boom (5% chitosan, 9% B, 1.15% amino acids and 0.05% Mo), algeno plus (50 % potassium alginate, 0.92% Mg, 1.75% S, 0.52 % Fe, 0.25% Mn, 0.15 % Zn, 0.25% B, 0.004 % Mo and 0.73% cytokines), fast tunic (2.5% NAA and 0.6% sodium nitrophenolate) (Chemical control)) and water (control) were investigated. Foliar application were applied twice (40 and 55 days after transplanting). Two drops of Tween 20 were added to the all-sprayed treatments as a surfactant. The extractions of 'PPG' and 'BPG' were prepared by graining 5 g of each of them and adding 10 cm of 100% ethanol. Finally, each mixture was dissolved in 10 Litre of distilled water on magnetic stirrer. PPG and BPG were exogenously applied as a foliar spray at a rate of 0.5 g/l. Fast tunic, chito boom and algeno plus were applied as a foliar spray at a rate of 0.4 cm/l, 2cm/l and 1.25 cm/l, respectively.

2.2. Measurements

Growth characterstics were recorded at 70 days after transplanting on randomly five plants per plot. Plant height, number of branches, leaf perimeter and leaf area of the 5th leaf from meristem tip). Leaf perimeter and leaf area were recorded by portable leaf meter (Biovis Leaf Av., Expert Vision Labs Pvt. Ltd., India). Harvesting was started from 30 th of September up to 15 October in both seasons, i.e, 2020 and 2021 for 5 pickings . Early yield (tons/fed) is the weight of all harvested fruits of the first picking from all plants was recorded. Total yield (tons/fed) is the weight of fruits all over the harvest period (5 pickings) from all plants in the plot. Marketable yield (tons/fed) is uniformity fruits in size, color and being free from any visual defects, physiological disorders, and insect or pathogeneses infestation were separated and weight.

Average fruit fresh weight was recorded at the second picking on 10 fruits randomly chosen from each plot.

The amount of chlorophyll of the 5th leaf from meristem tip was recorded 70 days after transplanting for five random plants per plot. Using Minolta chlorophyll SPAD -501 which SPAD unit = 10 mg /100 g fresh weight of leaves **(Netto, 2005)**.

Free proline was quantified according to **Claussen (2005)**. Approx. 0.5 g of the fifth fresh leaf was ground in 5 ml of 3% (w/v) sulfosalicylic acid solution. The homogenate was filtered and mixed with 2% (v/v) ninhydrin reagent. Pure proline was used as standard and the concentration of proline in the samples was estimated based on the absorbance at 546 nm.

The activity of peroxidase (POD) was determined using the method described by **Aebi 1984**. the peroxidase enzyme was isolated by freezing (0.5 g of leaves sample) in liquid nitrogen. The samples were crushed and centrifuged at 3930 rpm for 20 min with 10 mL of extraction buffer (50 mM phosphate buffer, pH 7, including 0.5 mM EDTA and 2 percent PVPP (w/v)). The peroxidase action was defined using a spectrophotometric method based on the structure of guaiacol in a l mL effect mixture (450 l 25 mM guaiacol, 450 l 225 mM H_2O_2) and 100 l of crude enzymes. A technique for examining the amount of MDA in plant leaves was used as illustrated by **Heath and Packer (1968)**. In 5 ml of 1% trichloroacetic acid (TCA), 0.2 g of plant leaves were crushed. The liquid was centrifuged at 10,000g for 5 minutes. The supernatant was added with 4 ml of 20% TCA, which included thiobarbituric acid. Next, the liquid was put in a water bath at 95 °C for 30 minutes before being directly cooled on ice. Then, the mixture was centrifuged for 10 minutes at 10,000 g. A spectrophotometer (Varian Cary 50 UV-Vis, Germany) was used to estimate MDA in the mixture at the wavelength of 532 nm. MDA content was expressed as nanomoles/g fresh weight.

Ten tomato fruits were used to extract juice by mixing it in the blinder. Total soluble solid of the extracted tomato juice was determined using a digital refractometer (model PR101, Co. Ltd., Japan). Ten grams of fruits were homogenized and made up to 100 ml with distilled water. Then 10 ml of the aliquot was taken and titrated with 0.1 N NaOH in present of phenolphthalein as an indicator in triplicates, from the titter, the titrable acidity % was calculated as the percentage of citric acid in the juice**.** The pH of extracted tomato juice is determined using the digital pH meter (Hanna Instruments, HI 9219). Ascorbic acid content was determined using titrimeteric method of 2, 6-dichlorophenol indophenols as mentioned in AOAC 2000. Ascorbic acid content was presented as mg/100 g of fruit (FW). Lycopene and β-carotene were determined according to **Nagata and Yamashita (1992)**. One gram of tomato samples was homogenized with the extraction solution (acetone–hexane, 4:6). The extraction was centrifuged (Centurion Scientific, model 42802, TA-3A, Chichester, UK) for 20 min at 4930.38 g. The optical densities of the supernatant were measured at 663, 645, 505 and 453 nm using a spectrophotometer. Total sugars were estimated according to the method described by **Ludwig and Rochester (1956)**. Total phenolic compounds were evaluated by Folin-Ciocalteu method **(Aryal et al*.,* 2019)**.

2.3. Statistical analysis

Regular analysis of variance of Randomized Complete Block Design (RCBD) with 3 replicates was performed for the obtained data of each season, the analysis of each season and differences between means were compared to the estimated value of L.S.D at 5% level of probability **(Snedecor and Cochran, 1982).**

3. RESULTS AND DISCUSSION:

3.1. Growth characteristics

Data in Table 1. reveal that the extractions of date palm pollen and bee pollen grains significantly increased plant height as compared with the control treatment. The number of branches was significantly increased by spraying with all biostimulants in the first season and with bee pollen grains and algeno plus in the second season as compared to the control.

The obtained results agreed with those of previous studied which indicated that spraying plants of eggplant during late hot summer **(Byan, 2020a)** and common bean plants under deficit water **(Byan, 2020 b)** with palm pollen grains extract increased all tested eggplant

Table 1. Effect of some bio-stimulants on plant height and number of branches/plant of tomato, 70 days after transplanting during summer season of 2020 and 2021

	Plant height (cm)		Number of branches/plant	
Treatment	**2020**	**2021**	**2020**	**2021**
Palm pollen	90.67 B	97 AB	7.33 AB	7.33 AB
Bee pollen	113.7 A	110 A	7.67 A	7.67 A
Fast tunic	80.33 BC	82.33 BC	7.33 AB	7.33 AB
Chito Bom	78.33 BC	79.33BC	7.00B	7.33 AB
Algeno plus	81.33 BC	83.67 BC	7.67 A	7.67 A
Control	70.33 C	69.67 C	6.33 C	6.67 B

. The bio-stimulation effect of bee pollens on tomato growth is related to their enriched contents of phytohormones, proteins, polysaccharides, polyphenols, minerals, vitamins, amino acids, fatty acids, enzymes and antioxidants **(Algethami, et al., 2022)**. According to **Komosinska-Vassev et al. (2015)**, the air-dried bee pollen (at the temperature 40° C) contains 32,8%, proteins, including 11,5%, essential amino acids, and 40,7%, reducing sugars, including 3,7%, sucrose, 12,8%, lipids, 0,19% vitamin C, 0,07%, β-caroteneand, 4,0% bioelements. This increment in the vegetative growth of tomato plants is similar to that found by **Abo AL-Mikh (2017) and Abdulkadhim (2019)** who found that the spray of date palm pollen grain extracts improved vegetative qualities of plant height, leaf area, number of leaves and dry weight of vegetative for pomegranate seedlings. The stimulative effect of date palm pollen grains because the fact that it contains phytohormones, enzymes, phenols, proteins, vitamins (A, C and E), minerals (such as B, Zn, Se, Fe, Mo, Cu, Mn), Carbohydrates, glycosides and amino acids **(Hassan, 2011; Basuny et al., 2013; Farouk et al., 2015; Taha et al., 2020)**

Table 2. Effect of some biostimulants on total chlorophyll (SPAD), area and perimeter of leaves of tomato, 70 days after transplanting during summer season of 2020 and 2021

Treatment	Total Chlorophyll (SPAD)		Leaf area (cm^2)		Leaf perimeter (cm)	
	2020	**2021**	**2020**	**2021**	**2020**	**2021**
Palm pollen	56.23 A	55.85 A	76.24 C	76.16 AB	108.4 AB	101.0 BC
Bee pollen	51.74 AB	51.35 AB	87.93 B	84.87 A	113 A	109.2 AB
Fast tunic	54.05 AB	54.37 AB	78.5 C	73.45 AB	108.5 AB	101.4 BC
Chito Boom	53.11 AB	53.27 AB	97.7 A	91.21 A	115.2A	120.5 A
Algeno plus	52.56 AB	53.95 AB	95.01 A	91.63 A	110.5 A	105.3 BC
Control	49.9 B	49.29 B	70.16 D	62.97 B	101.2 B	94.71 C

which may play an important role in improving growth characters. The use of palm pollen extract significantly increased the chlorophyll readings in leaves in both seasons (table 2). At the same time, leaf area was significantly increased using all biostimulatory treatments in the first season and using bee pollen, Chito Bom and Algeno plus in the second season (table 2). On the other hand, leaf perimeter was significantly increased by spraying with bee pollen and Chito Bom in both seasons as well as by spraying with Algeno plus in the first season (table 2).Reports have shown that the application of chitosan improved morphological characteristics in common beans (Zayed et a., 2017) and tomato grown under salinity stress **(Attia et al., 2021).** The role of chitosan in alleviating the harmful effect of water stress on yield may be due to an increase in stomatal conductance and net photosynthetic CO_2-fixation activity under water stress **(Khan et al., 2002)**

3.2. Malondialdehyde, Peroxides, proline and total phenolic compounds :

All biostimulant treatments and fast tunic caused a significant decrease in MDA in both seasons, while exhibited a significant increase in POD and proline in both seasons as compared with control treatment (Table 3). On the other hand, total phenolic compounds significantly increased, when plants spraying with palm pollen, bee pollen and Fast tunic in both seasons as well as spraying with chito bom in the first season as compared with control treatment (Table 3).

Table 3. Effect of some biostimulants on Malondialdehyde (MDA), peroxidase, (POD), total phenolic compounds and proline of tomato during summer season of 2020 and 2021.

Treatment	MDA (mg^{-1} protein)		POD (mg^{-1} protein)		Total phenolic compounds mg/100g F.W		Proline ug\g	
	2020	2021	2020	2021	2020	2021	2020	2021
Palm pollen	23.01C	25.98C	14.9A	15.8A	2.50AB	2.48ABC	19.88A	19.33AB
Bee pollen	21.15C	22.21CD	12.15BC	14.08B	2.56A	2.53AB	19.86A	18.30B
Fast tunic	21.04C	20.11D	10.87CD	9.95C	2.53AB	2.59A	14.88B	14.59C
Chito bom	23.17C	27.11C	13.88AB	15.82A	2.52AB	2.32BCD	19.55A	20.06A
Algeno plus	41.82B	44.9B	9.37D	10.02C	2.24BC	2.25CD	12.77C	12.52D
Control	61.62A	55.41A	5.8E	5.8D	2.12C	2.11D	7.90D	7.11E

All abiotic stresses, including high temperature elicit formation of reactive oxygen species (ROS) in plant cells **(Bhandari et al., 2017 and Szymańska et al., 2017)**. Excessive production of ROS damages cellular biomembranes that causes the accumulation of MDA **(Bhandari et al., 2017 and Fahad et al., 2017)**. MDA concentration increased after heat stress treatment **(Todorova et al., 2016 and Sergiev et al., 2018)** , by reducing the irrigation water levels **(Shehata et al., 2022)**. On the contrary, total peroxidases (POD) activity increased about 170% after 48 h of treatment with chitosan in hairy root of *Armoracia lapathifolia* **(Flocco and Giulietti, 2003)**. Total phenols, osmolytes (soluble sugars, soluble proteins, and proline) and Isozymes, such as superoxide dismutase (SOD), catalase (CAT), polyphenol oxidase (PPO) and peroxidase (POD) isozymes activities were greater in the plants grown under NaCl stress and treated with chitosan solutions against salinity-stressed tomato plants **(Attia et al., 2021)**. The osmolytes (soluble sugars, soluble proteins, and proline) play an important role in osmoregulation and ROS scavenging, while the non-enzymatically compounds (include phenolic compounds and ascorbic acid) prevent plant cells from oxidative damage **(Attia et al., 2021)**. On the other hand, enzymes act as initial steps in increasing plant resistance to various stresses as well as the formation of phenolic compounds **(Rios-Gonzalez et al., 2002)**

The role of Alga (in Algeno plus) in reducing effect of high temperature may be attributed to their role in producing enzymes. In this regard, **Hernández et al. (2017)** reported that algae could produce seven enzymatic, namely, carbonic anhydrase, hydrogenase, lipoxygenase, nitrilase, nitrogenase, phosphatase, and thiolase, **Al-Hussieny et al. (2019)** added that green Algae produced protease, -1 -1 amylase, and betaalactase.

Pollen grains extract (PGE) foliar spray caused significant increases in the activities of antioxidant enzymes, in basil plants, especially under deficit irrigation stress. This may be attributed to crucial roles of amino acids and phytohormones found in PGE, maintaining higher antioxidant defense system activities to cope with the deleterious effects of deficit irrigation (DI). Therefore, phytohormones and antioxidants are mechanisms by which PGE application enabled basil plants to mitigate the dangerous effects of DI stress **(Taha et al., 2020)**.

Similarly, the synthetic Fast tunic raised proline, total phenolic compounds, POD. MDA (Table 3). Phytohormones are mechanisms that mitigate the dangerous effects of stress **(Taha et al., 2020)**. Also **Sergiev et al (2018)**, found that proline increased, while MDA decreased in peas sprayed with auxin under heat stress condition.

Table 4. Effect of some biostimulants on early, total and marketable yield of tomato during summer season of 2020 and 2021.

Treatment	Early yield (ton/feddan)		Total yield (ton/feddan)		marketable yield (ton/feddan)	
	2020	2021	2020	2021	2020	2021
Palm pollen	7.1 AB	6.90 B	41.54 AB	42.99A	27.32 A	22.19 C
Bee pollen	7.8 AB	7.40 AB	50.02 A	50.62A	26.07 A	25.35 ABC
Fast tunic	10.1 A	9.20 A	46.81 A	46.35A	27.82 A	30.12 A
Chito bom	7.2 AB	7.60 AB	46.99 A	47.24A	27.18 A	28.79 AB
Algeno plus	6.6 B	7.68 AB	47.67 A	45.65A	24.64 A	28.74 AB
Control	6.1 B	6.50 B	32.99 B	30.63B	23.95 A	24.42 BC

3.3. Yield and its components:

It is obvious that all biostimulant treatments significantly increased total fruit yield, fruit weight per plant and fruit number per plant as compared with the water spray control treatment in both growing seasons. On the other hand, only the synthetic stimulant, fast tunic, led to a significant increase in early yield in both seasons and in marketable yield in the second season (Table, 4 and 5). Moreover, the foliar spraying with bee pollen grains extract exhibited the highest total fruits yield achieving 52.67% and 44.35 % increase in total over the control in the first and second season, respectively (Table, 4). The superiority pollen grains extract may be attributed to the superiority of plant branches and plant height in the plants treated with pollen grains extract. The increase in plant height and number of branches per plant may lead to producing more leaves per plants which could induce more photosynthetic rates. It was also clear that chito bom significantly increased total yield as compared with control, achieving 42.43 and 54.22% increase over the control. On the other hand, foliar spray with fast tunic (chemical control) increased number and weight of fruits per plant, as well as early, marketable and total yield as compared with water spray control, but with no significant differences with

Table 5. Effect of some biostimulants on fruits number/plant and fruits weight /plant and average fruit weight of tomato during summer season of 2020 and 2021.

Treatment	Fruits number/plant		Fruit weight/plant (Kg)		Average Fruit weight (g)	
	2020	2021	2020	2021	2020	2021
Palm pollen	81.0 BC	86.3 C	7.01 B	7.46 A	85.88A	86.49AB
Bee pollen	96.7 AB	93.7 BC	7.93 AB	7.92 A	86.18A	89.69A
Fast tunic	105.3A	96.0 B	8.29 A	7.85 A	81.41A	79.21BC
Chito boom	92.7ABC	94.7 BC	7.82 AB	7.44 A	80.45A	84.4AB
Algeno plus	114.7A	107.7 A	7.75 AB	7.74 A	73.98B	73.86 C
Control	74.3C	71.7 D	4.94 C	4.61 B	72.76B	73.02 C

bee pollen grains in both growing seasons. The superiority in number of fruits per plant, which led to significant increase in the total yield that obtained from spraying tomato plants with bee pollen grains extract, fast tunic and alga extract may be attributed to increasing fruit set. These three compounds contain, either synthetic auxin, as in the case of fast tunic, or natural auxins, or auxins, cytokinins and gibberellins, as bee pollen grains extract **(Mahfouz and Aib (2017)** and Algae extract **(Tarakhovskaya et al., 2007)**. Auxins play important roles in a number of plant activities, including fruit set and development **(Pramanik and Mohapatra, 2017)**. Foliar applications of synthetic auxins such as naphthaleneacetic acid have shown to stimulate parthenocarpic fruit set and to increase tomato fruit yield **(De Jong et al., 2009)**. The stimulative effect of chito bom on tomato yield may be attributed to that the application of chitosan induced the synthesis of plant hormones such as gibberellins. Furthermore, it enhanced growth by some signaling pathways related to auxin biosynthesis via a tryptophan independent pathway **(Uthairatanakij et al., 2007)**. Another possible mechanism involved in the significant biostimulant effect of Algeno plus and date palm pollen grains because the fact that they contain microelements minerals (such as B, Zn, Se, Fe, Mo, Cu, Mn). Micronutrients are required in minute amounts by plants but inexorably play an eminent role in plant metabolism, nutrient regulation, reproductive growth, chlorophyll synthesis, production of carbohydrates, fruit and seed development, etc **(Rahman et al., 2020)**. Also, pollen grains of bee and date palm and Chito Boom contain amino acids, that play a positive role in enhancing the plant yield and quality when they are sprayed at different growth stages especially the critical ones such as the tillering and flowering stages or under stress conditions (such as drought, high temperature, frost, salinity, or pathogens). Thus they contribute to reducing the stress effect of drought and salinity through the different physiological activities by changing the osmotic potential of plant tissue as well as greatly reducing harmful effects caused by bio stresses **(Baqir et al., 2019)**.

Many workers recorded significant increase in the fruit yield due to using alga extract on tomato **(Oancea et al., 2013; de Paula et al., 2022)**. Moreover, **Hernández-Herrera et al. (2022)** proved that seaweed extract improved growth and productivity of tomato plants under salinity stress

Plants treated with foliar Bee Pollen extract significantly improved yield of Calendula officinalis **(Mahfouz and Aib, 2017)**, onion **(Shafeek, et al,, 2015)**.

The previous studies registered that chitosan caused an increase in tomato yield under the conditions of open field **(Islam et al., 2016; Sultana et al., 2017)**,plastic tunnel condition **(Hussain et al., 2019)**, greenhouse **(Reyes-Pérez et al., 2020),** water stress **(Hassnain et al., 2020)** and Salinity Stress **(Attia et al., 2021)**. It was also determined that foliar applications of amino acids and micronutrients solution (Fe 2%, Zn 2%, Mn 2%, Cu 1% and B 0.5%) showed positive effect on yield, fruit number which significantly resulted in an increase in marketable yield in **Tomato (Salim et al., 2021)**.

Table 6. Effect of some biostimulants on TSS, pH and acidity of tomato fruits during summer season of 2020 and 2021.

	TSS (%)		pH		Acidity (%)	
Treatment	**2020**	**2021**	**2020**	**2021**	**2020**	**2021**
Palm pollen	4.33A	4.17A	4.24 B	4.25B	0.72AB	0.69 BC
Bee pollen	4.30A	4.23A	4.24 B	4.22B	0.78A	0.81B
Fast tunic	4.30A	3.97A	4.43 AB	4.29B	0.82A	0.94 A
Chito boom	4.17A	4.00A	4.25 B	4.26B	0.76A	0.77 BC
Algeno plus	4.43A	4.17A	4.42 AB	4.40AB	0.67AB	0.68 C
Control	4.00A	3.83A	4.55A	4.53A	0.54B	0.53 D

Fruit chemical quality

Spraying tomato plants with the biostimulants bee pollen and chito bom were similar to the synthetic auxin fast tunic where they caused significant improvement in tomato all fruit qualities (Vitamin C, total sugar, B carotene, lycopene and acidity) as compared with the control. Also, date palm pollen significantly increased fruit contents of itamin C, lycopene and acidity). On the other hand, no treatment had effect on TSS in tomato fruits, while pH decreased significantly, when tomato were plants sprayed with palm pollen, bee pollen, fast tunic and chito boom. (Table 6 and 7). Because the main components of bee pollen, palm pollen and Fast tunic is either natural phytohormones, as in the case of bee pollen and palm pollen, or synthetic auxin, as in Fast tunic, then auxin and the other phytohormones play the major role in fruit quality. Similar results were noticed by **Pramanik et al. (2018)**, who reported that auxin and gibberellin have greater role in influencing the quality parameters in fruits like sugar content, acidity, sugar acid ratio, dry matter content etc**. Saha (2009)** observed significant response of NAA (25 ppm) with respect to total soluble solid (TSS) and vitamin C was obtained over the control. Similarly, maximum vitamin C was obtained with the application of 40 ppm GA3. In the same line, **Islam et al. (2020)** found that treating tomato plants with foliar application of indol butyric a cid (IBA) + gibberellic acid (GA_3) + zinc (Zn) increased vitamin C content and TSS (%) as compared to control. Recently, **Ali et al. (2022)** revealed that GA_3 and 4-CPA postively affected TSS and ß-carotene content of tomato fruit. It was found that chitosan increased fruit contents of vitamin C **(Abd El-Gawad and Bondok , 2015; Reyes-Pérez et al., 2020)**, but decreased in total soluble solids and acidity, but it had no effect onpH **(Reyes-Pérez et al. (2020)**. The pronounced promotional effect of chitosan on polyphenolic substances and vitamin C content compared with control could be due to the enhanceable nature of chitosan on photosynthesis process that strongly correlated with the synthesis of sugars, polysaccharides and vitamins **(Khan et al. 2002)**. On the other hand, **El-Tantawy, 2009** reported that spraying tomato plants with chitosan did not reflect any significant effect on TSS of tomato fruits compared to control. The effect of chito bom and extraction on pollen grain on fruit quality may also attributed to their contents of amino acids that it was previous proved that they significantly improved lycopene and ascorbic acid concentrations in tomato fruits at harvest compared to control plants **(Salim et al., 2021)**.

Table 7.Effect of some biostimulants on lycopene, Beta carotene, total sugar and vitamin C of tomato fruits during summer season of 2020 and 2021

Treatment	Lycopene (mg/100 g F.W)		Beta Carotene ug\100g F.W		Total sugar mg/100g F.W		Vitamin C (mg/100 g)	
	2020	**2021**	**2020**	**2021**	**2020**	**2021**	**2020**	**2021**
Palm pollen	12.91 A	11.32 B	440.3 ABC	437.5 AB	13.9 ABC	11.9 BC	12.61 A	11.82 A
Bee pollen	13.13 A	12.84 A	445.2 A	444.7 AB	15.0 A	14.3 AB	13.01 A	12.11 A
Fast tunic	12.84 A	13.15 A	442.6 AB	446.5 A	14.3 AB	15.7 A	12.5 A	13.1 A
Chito bom	13.11 A	12.79 A	443.4 AB	439.6 AB	14.5 AB	13.0 BC	12.96 A	11.71 AB
Algeno plus	10.84 B	10.91 B	438.6 BC	437.8 AB	11.8 BC	10.6 C	9.33 B	9.89 BC
Control	10.69 B	11.41 B	435.2 C	432.7 B	11.3 C	11.5 C	9.41 B	9.38 C

Conclusion:

It can be concluded from the present study that adverse effects of high temperature and relative humidity on flowering and fruit setting can be reduced, and tomato yield can be increased through the foliar application of some biostimulants, such as the extractions of Palm Pollen, Bee Pollen and seaweed (Algeno Plus) and chitosan (chito bom) in the summer under Egyptian conditions.

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الملخص العربي

استخدام المحفزات الحيوية لتحسين نمو وإنتاجية نباتات الطماطم المجهدة بالحرارة (Solanum lycoperosicu

المحفزات الحيوية ل لنبات هي مواد طبيعية ، استخدمت في العقد الأخير في الممارسات الزراعية في المقام الأول للدفاع عن النبات وتعزيز نمو النبات والمحصول والجودة. أجريت هذه الدراسة لمعرفة مدى استجابة التطبيق الورقي لبعض المحفزات الحيوية النباتية على النمو الخضري والمحصول وخصائص الجودة للطماطم خلال فصلي الصيف لعامي 2020 و 2021. تم رش نباتات الطماطم مرتين (وذلك بفاصل زمني 15 يومًا) بمستخلص حبوب لقاح النخيل ، مستخلص حبوب لقاح النحل ، شيتوبورم (5% شيتوزان ، 9 % بورون ،1.15 % احماض امنية ، 0.05 موليبدنم) ، الجينو بلس (50 % ألجينات بوتاسيوم ، 0.92 ماغنسيوم ، 1.75 % كبريت ، 0.52 حديد ، 0.25 منجنيز ، 0.15 زنك، 0.25 بورون ، 0.004 موليبدنم ، 0.73 سيتوكينين) ، فاست تونيك ((2.5٪ NAA و 0.6٪ نيتروفينولات الصوديوم) ، المعاملة الكنترول الغير معاملة ، وذلك بفاصل زمني 15 يومًا. أشارت النتائج إلى أن مستخلص حبوب لقاح النخيل وحبوب لقاح النحل أدى إلى زيادة معنوية في طول النبات مقارنة بمعاملة الكنترول. أدى حبوب لقاح النحل والجينوبلس إلى زيادة معنوية في عدد الفروع ، كذلك أدى استعمالهم بالأضافة إلى شيتوبورم إلى زيادة مساحة الأوراق ومحيط الورقة مقارنةً بمعاملة الكنترول. أدت جميع المحفزات الحيوية إلى انخفاض معنوي في مالونداليهيد

(MDA) ، بينما أظهرت زيادة معنوية في البيروكسيدات (POD) والبرولين والمركبات الفينولية الكلية (TPC) وإجمالي محصول الثمار الكلى ، متوسط ووزن الثمار لكل نبات وعدد الثمار لكل نبات مقارنة مع معاملة الكنترول في كلا موسمي النمو. أدى رش نباتات الطماطم بحبوب لقاح النحل و شيتوبورم إلى تحسين محتوى الثمار من فيتامين C والسكريات الكلية والبيتاكاروتين والليكوبين والحموضة مقارنةً بالمعاملة الكنترول. كما أدت حبوب لقاح النخيل إلى زيادة معنوية في محتوى الثمار من فيتامين C والحموضة. ، و لذلك نوصى باستخدام مستخلص حبوب لقاح النحل أو مستخلص حبوب لقاح النخيل أو الشيتوزان لتخفيف الأجهاد الناتج من الحرارة العالية على نباتات الطماطم.

الكلمات المفتاحية: *Solanum lycoperosicum* ، حبوب لقاح النحل ، حبوب لقاح النخيل ، الشيتوزان ، الطحالب ، الإجهاد الحراري.