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EFFECT OF HUMIC ACID ON GROWTH AND PRODUCTIVITY OF TOMATO PLANTS UNDER HEAT STRESS

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ABSTRACT

The purpose of this study was to evaluate the effect of humic acid (HA) applied at 4.8, 9.6 and 14.4 $kg \cdot ha^{-1}$ on the growth and productivity of two tomato hybrids Nema 1400 and Platinium 5043 under hot continental climate. HA was applied twice to soil: the first one – three weeks from transplanting and the second one, after one week from the first application, in both seasons. Application of HA during the summer season targeted a great results on tomato plant growth and productivity. HA at 14.4 $kg \cdot ha^{-1}$ increased the vegetative growth of tomatoes (plant height and fresh weight) and flowering parameters (number of flower clusters and flowers per plant) as well as yield characters (fruit number per plant and fruit weight, which resulted in higher early and total yield) in both seasons. HA application had the least impact on fruit number per plant, and on vitamin C and total soluble solids (TSS) concentration as compared with control.

Key words: tomato, humic acid, heat stress, abiotic stress

INTRODUCTION

Today, the world faces dangerous problems which affected on human life headed by agriculture and food security. One of these problems is environmental changes and abiotic stresses that affects plant growth, development, and productivity.

Tomato (*Solanum lycopersicum* L.) is one of the major crops grown all over the world. According to FAO (2016), tomato occupies the first rank among the cultivated area of all vegetable crops in Egypt.

The major challenge in tomato cultivation is heat stress responses (Abdul-Baki 1991). The optimum temperature for tomato growing ranges from 21 to 24 ºC, and temperature above 24 ºC will gradually decrease the productivity with the death level at 35 ºC. According to Srinivasa Rao et al. (2016), high temperature is an important factor for growing tomato because of its effects on all stages of tomato plant from vegetative to reproductive phases.

Humic acid (HA) is a heterogeneous mixture of many compounds, a mixture of weak aliphatic and aromatic organic acids, which are not soluble in water under acid conditions but are soluble in water under alkaline conditions (Cacco & Dell'Agnolla 1984; Pettit 2004) that influences variously plant growth and soil traits (Tan 2003). HA is produced commercially and intended for organic fertilization. Its components improve soil fertility and increase nutrients availability, enhance plant growth, yield, and decrease the harmful effect of stresses through various mechanisms inside plants and soil (Rajaei 2010; Unlu et al. 2011; Moraditochaee 2012). In this study, we evaluated the effect of HA on solving tomato challenges to high temperature during summer season.

MATERIALS AND METHODS

This investigation was carried out during the two successive summer seasons of 2014 and 2015

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at the Farm of Minia University, under hot continental climate (Table 1). Two tomato hybrids Nema 1400 and Platinium 5043 were selected for this study and grown in a clay loam soil. CANADA HUMEX, commercial product containing 68% HA, 15% fulvic acids, 10% potassium, 5% nitrogen, 1% iron, 0.5% manganese, and 0.5% zinc was used at four concentrations (0, 4.8, 9.6 and 14.4 kg·ha^{-1}). It was melted in water and added to soil by pouring the solution immediately after irrigation. The treatment was repeated twice, the first one – after three weeks from transplanting and the second one, after one week from the first application, in both seasons. In addition, a typical fertilization contained 60 m^3·ha^{-1} organic fertilizer and 960 kg·ha^{-1} super phosphate calcium, 240 kg·ha^{-1} potassium sulfate, 480 kg·ha^{-1} ammonium sulfate, 240 kg·ha^{-1} sulfur, 60 kg·ha^{-1} iron sulfate, 60 kg·ha^{-1} magnesium sulfate, 60 kg·ha^{-1} zinc sulfate, and 60 kg·ha^{-1} manganese sulfate was applied.

Records for medium temperature and relative humidity percentage obtained from Malawy Meteorological Station, about 52 km away from the experiment location, are presented in Table 1. Data obtained as daily records and summarized as average of 15-day intervals.

Complete Randomized Blocks design in a split-plot arrangement with three replicates was used in each season. Main plots were assigned to genotypes, while the subplots were allocated to the HA levels. Each plot area was 14.40 m^2 with three rows; each one was 4-m long and 120 cm in width. Transplanting was done on one side of each strip with 40-cm intra-rows spacing between two hillocks with one plant/hillock.

Studied characteristics

Plant height (cm), fresh weight of plant without roots and fruits (g), and number of flower clusters and flowers per plant were recorded at the full blooming stage (after 55 days from transplanting) by randomly taking three plants from each treatment, while, early and total yield per hectare (ton) as well as average number of fruits per plant were determined during the harvest periods. Fruits were picked six times, the first three were considered as an early yield. On the third picking, 10 ripe fruits were randomly taken from each plot to record the average fruit weight (g) as well as vitamin C concentration (mg·100 g^{-1}), which was determined by using 2,4-dichlorophenol-indophenol dye according to A.O.A.C. (2000), and total soluble solids (TSS) percentage in the juice of fruits which was determined by using hand refractometer on the juice of ten ripe fruits after blending for 1–2 minutes.

Data were statistically analyzed with the help of MSTAT-C program to find out the statistical significance of the experimental results separately for each year of the experiment. The mean values of all parameters were separated by Duncan's multiple range test at 5% probability.

Table 1. Records for medium temperature and relative humidity percentage obtained from Malawy Meteorological Station, far about 52 Km from the experiment location. Data obtained as daily records and summarized as average of 15 day intervals

Months	Days	Seasons			
		2014		2015	
		medium temp. (°C)	humidity (%)	medium temp. (°C)	humidity (%)
April	1-15	24.56	53.20	21.69	61.93
	16-30	24.88	46.80	23.23	55.60
May	1-15	27.02	43.93	26.70	55.87
	16-30	27.30	43.0	30.63	46.93
June	1-15	29.17	45.73	30.61	75.33
	16-30	29.42	53.93	31.19	46.20
July	1-15	28.87	57.07	31.71	57.20
	16-30	29.06	59.67	32.96	53.93

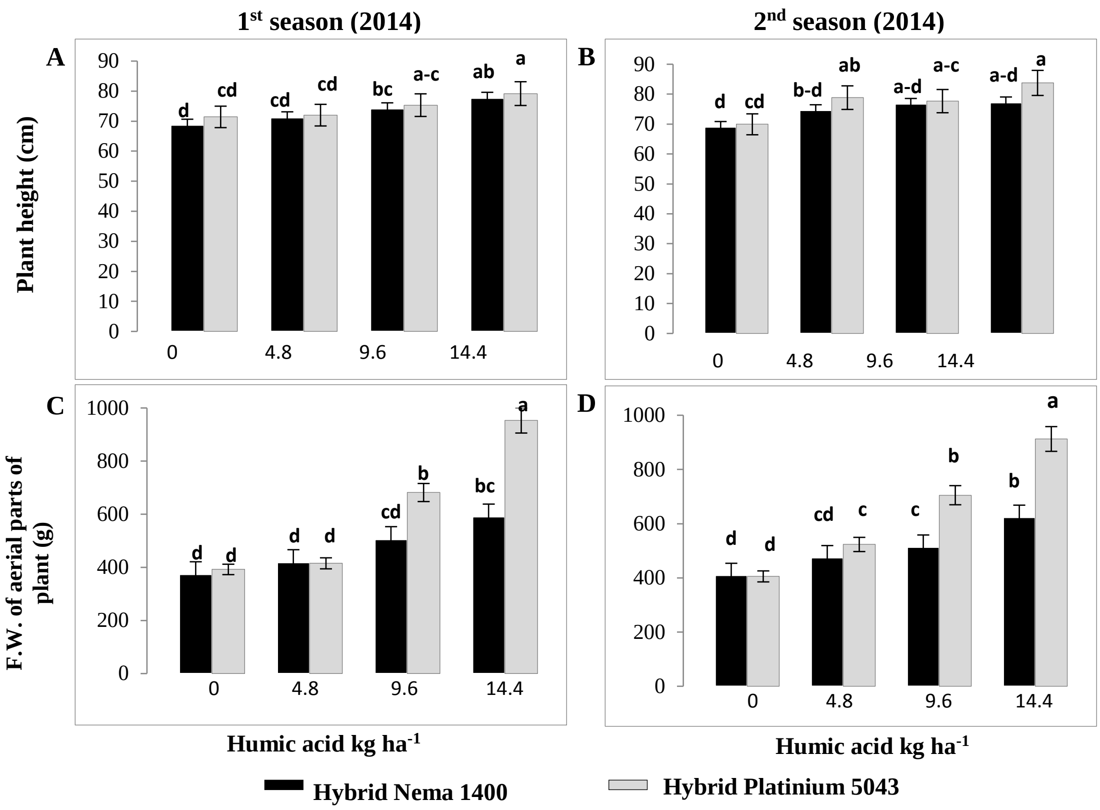

Fig. 1. The effect of humic acid (zero, 4.8, 9.6 and 14.4 kg ha^{-1}) on plant height (cm) and fresh weight of aerial plant parts (g) of two tomato hybrids Nema 1400 and Platinium 5043 during the summer seasons of 2014 and 2015

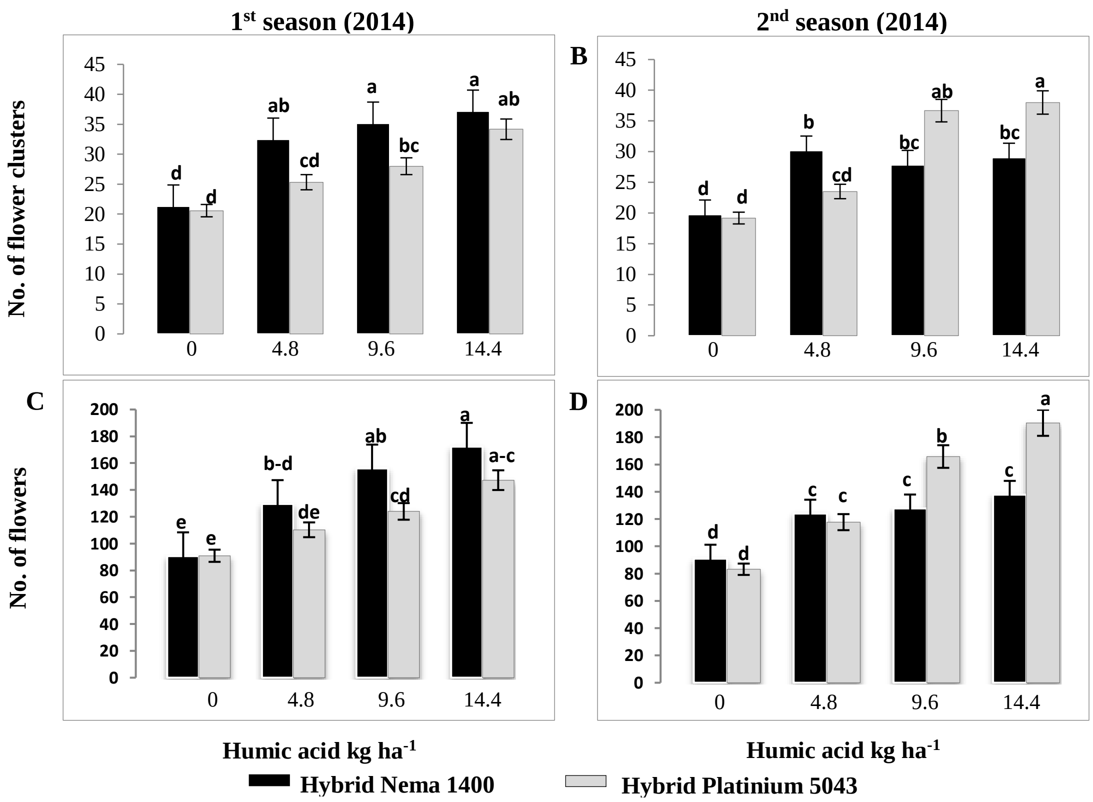

Fig. 2. The effect of four levels of humic acid preparation (control, 4.8, 9.6, and 14.4 kg·ha^{-1}) on number of flower clusters and flowers/plant of two tomato hybrids (Nema 1400 and Platinium 5043) during the summer seasons of 2014 and 2015

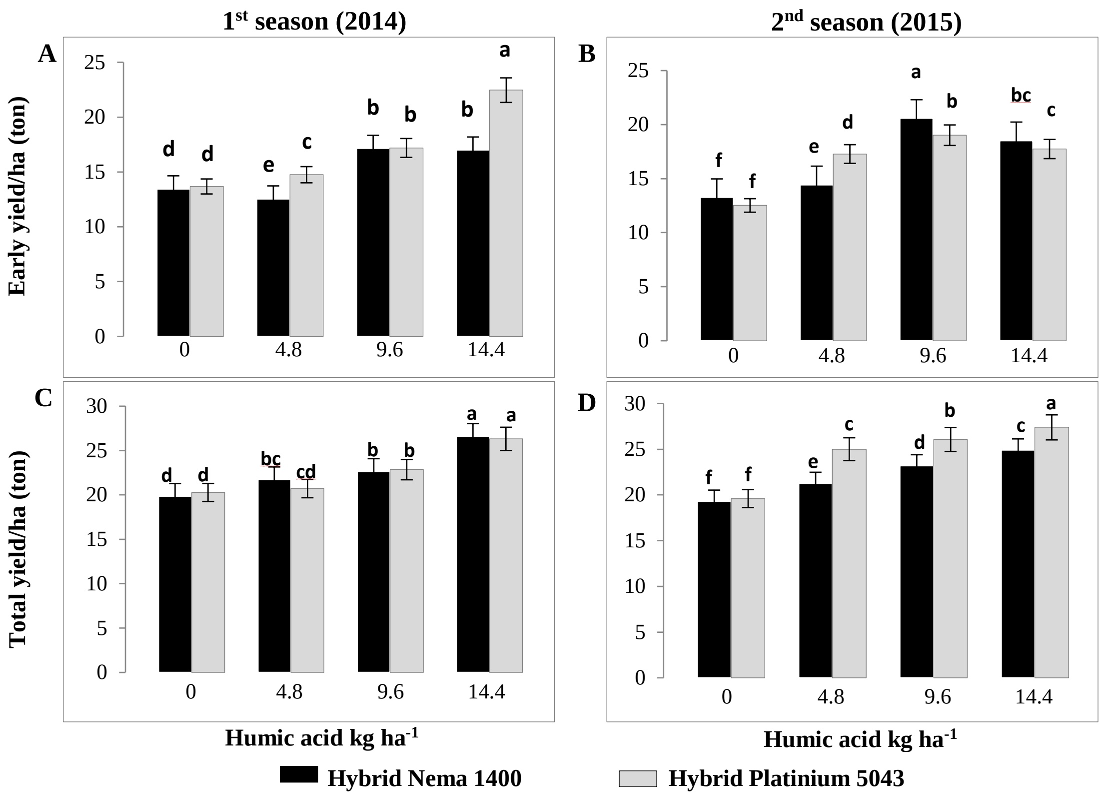

Fig. 3. The effect of four levels of humic acid preparation (control, 4.8, 9.6, and 14.4 kg·ha^{-1}) on early and total yield·ha^{-1} (ton) of two tomato hybrids (Nema 1400 and Platinium 5043) during the summer seasons of 2014 and 2015

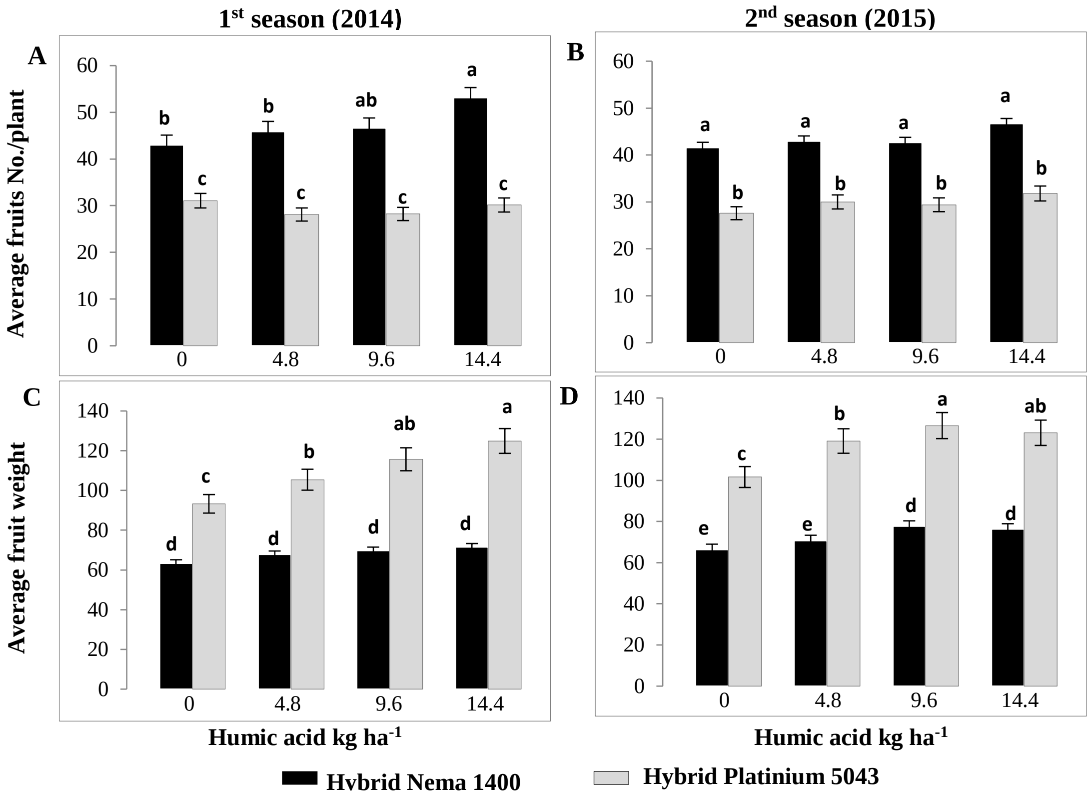

Fig. 4. The effect of four levels of humic acid preparation (control, 4.8, 9.6, and 14.4 kg·ha^{-1}) on average fruits number/plant and average fruit weight (g) of two tomato hybrids (Nema 1400 and Platinium 5043) during the summer seasons of 2014 and 2015

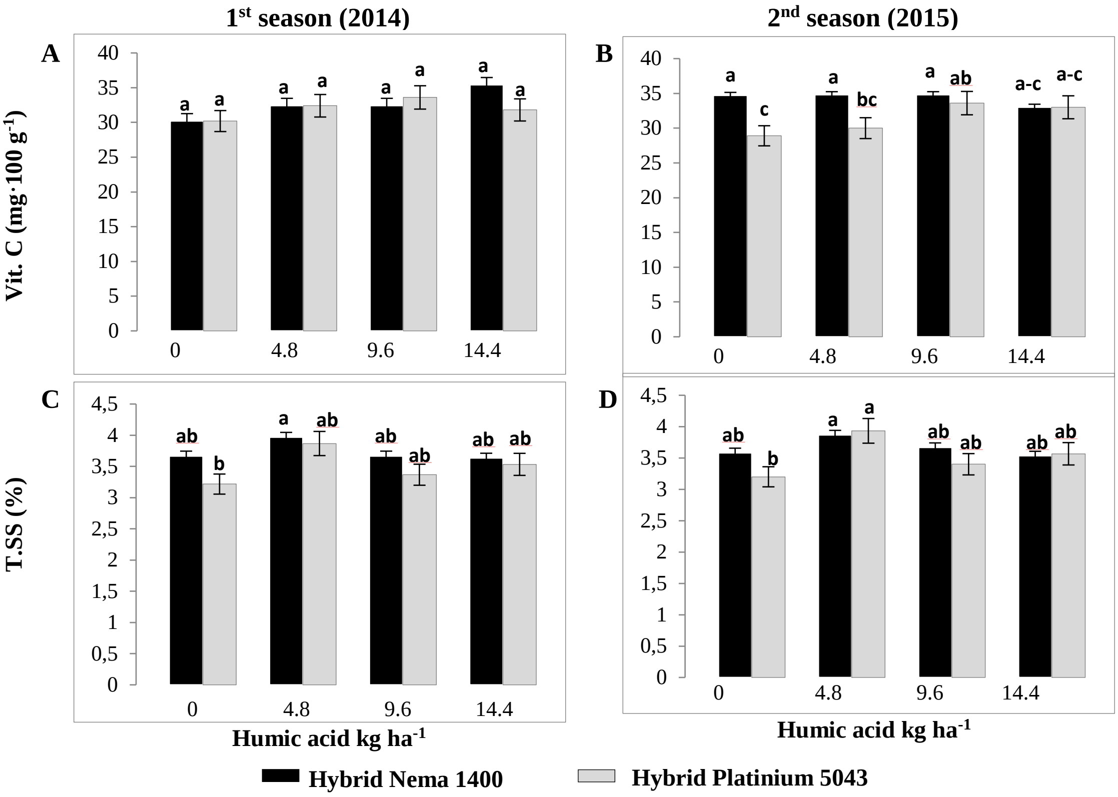

Fig. 5. The effect of four levels of humic acid preparation (control, 4.8, 9.6, and 14.4 kg·ha^{-1}) on vitamin C (mg·100 g^{-1}) and TSS (%) of two tomato hybrids (Nema 1400 and Platinium 5043) during the summer seasons of 2014 and 2015

RESULTS

Plant height (cm) and fresh weight of plants (g)
In the both hybrids, the highest plants were obtained when HA was applied at 14.4 kg·ha^{-1} and they significantly differed from control in both seasons (Fig. 1A, B).

The application of HA at 9.6 and 14.4 kg·ha^{-1} significantly increased the fresh weight of plants as compared with control in both seasons. The highest fresh weight was recorded when 14.4 kg·ha^{-1} of HA was applied in both hybrids and seasons (Fig. 1C, D).

Number of flower clusters and flowers per plant
Both tomato hybrids reacted for all levels of HA with increasing number of flowers per cluster and general number of flowers per plant as compared with control in both the seasons (Fig. 2A, B, C, D), with the highest values for levels 9.6 and 14.4 kg·ha^{-1}.

Early and total yield per hectare (ton)
Early yield in hybrid Nemo 1400, higher in comparison with control, was obtained with HA at 9.6 and 14.4 kg·ha^{-1}, respectively, in the first year and at the three levels in the second year of experiment (Fig. 3A, B), whereas in hybrid Platinium 5043, all levels of HA increased early yield. Also total yield of fruits was significantly higher after applying HA and increased with the increase in HA level (Fig. 3C, D).

Number of fruits per plant and fruit weight (g)
The average number of fruits in hybrid Nema 1400 was higher only with HA at 14.4 kg·ha^{-1} in the first season, whereas in the second season and in hybrid Platinium 5043, this trait was not affected by HA (Fig. 4A, B). The average fruit weight of hybrid Nema 1400 was not affected with HA application in the first year, but in the second year, it was increased at 9.6 and 14.4 kg·ha^{-1} HA. The hybrid Platinium 5043 increased fruit weight at each level of HA in the both years (Fig. 4C, D).

Vitamin C and TSS
HA application did not affect the mean vitamin C concentration in both hybrids as compared with control in both seasons except for 9.6 kg·ha^{-1} in hybrid Platinium 5043 in the second year (Fig. 5A, B). Also the TSS concentration did not change in the

first year, and in the second year, it increased in hybrid Platinium 5043 when 4.8 kg·ha^{-1} of HA was applied (Fig. 5C, D).

DISCUSSION

According to several reports, HA significantly increased the plant height of tomato (Kazemi 2013, 2014; Farnia & Moradi 2015), fresh weight of tomato (Abdel-Monaim et al. 2012), and number of flowers of tomato (Kazemi 2014), as well as early fruit yield of tomato (Yildirim 2007) and pepper plants (Karakurt et al. 2009) and total yield of tomato (Abdel-Monaim et al. 2012; Aman & Rab 2013; Kazemi 2013, 2014; Asri et al. 2015; Farnia & Moradi 2015). The reasons behind this increment are connected with each other. Also, several studies have shown that HA has the ability to decrease the harmful effect of stressors on plants (Ozkutlu et al. 2006; Rajaei 2010; Unlu et al. 2011; Moraditochaee 2012) and in soils (Baldotto et al. 2010). In our experiments, HA similarly positively influenced the growth and yield parameters of two tomato hybrid cultivars.

HA plays important roles on plants through stimulation of root growth and increase of water and nutrient uptake by vegetable crops (Cimrin & Yilmaz 2005). It can also influence the cell division (Chen et al. 2004) and enhance protein synthesis (El-Ghamry et al. 2009; Patil 2010), which result in enhancing total protein content in plants (Nardi et al. 2002). HA also provides growth regulators to regulate and control hormone levels in plants (Nardi et al. 2002) and stimulates production of plant enzymes and hormones (Sarir et al. 2005; Mart 2007). It also increases enzyme catalysis and enhances respiration and photosynthesis processes (Nardi et al. 2002; Nardi et al. 2002). These mechanisms refer to the direct influence of HA on plants and its influence on soil fertility is also very important (Nardi et al. 2002; Fahramand et al. 2014). It happens through the improvement of soil physical (Varanini & Pinton 1995; Nardi et al. 2002), chemical, and biological properties (Keeling et al. 2003; Mikkelsen 2005) that increase water holding capacity (McDonnell et al. 2001). Furthermore, it is a good source of energy for beneficial soil organisms (Chen et al. 2004; Pettit 2004; Zimmer 2004) by stimulating the enzyme activities (Burkowska & Donderski 2007). HA is used for soil reclamation purposes (Baldotto et al. 2010; Mauromicale et al. 2011; Khaled & Fawy 2011; Ameri & Tehranifar 2012).

I it can be concluded that HA added to the soil for growing tomatoes under hot continental climate in the amount of 9.6 and 14.4 kg·ha^{-1} can increase the yield, both early and total.

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