J. Plant Production, Mansoura Univ., Vol. 3 (7): 2123 - 2138, 2012

SALICYLIC ACID POSITIVELY AFFECTED PLANT GROWTH, PHOTOSYNTHETIC LEAF PIGMENTS AND FRUIT YIELD OF SUMMER SQUASH (*Cucurbita pepo* L.) GROWN UNDER DIFFERENT N-LEVELS

Elwan, M. W. M.* and R. S. A. El-Shatoury
Suez canal Univ., Fac. Agric., Dept. of Horticulture, Ismailia, Egypt
*** Corresponding author.**
E-mail addresses: Elwan_wasfy@yahoo.com (M.W.M. Elwan),
Tel/Fax numbers: 002-064-3201793

ABSTRACT

Nitrogen (N) fertilization plays a central role for improving yield in different vegetable crops and high N assimilation is desired to produce higher fruit yield. Several studies showed that salicylic acid (SA) application increases plant growth and productivity, but no attempts have been made to investigate the interaction effects of SA and N-nutrition. The aim of this study was to analyze the effects of different N-rates and SA concentrations, and their interaction on plant growth, photosynthetic pigments and fruit yield. Field experiments were carried out during two consecutive growing seasons under Egyptian conditions using different combinations of N and SA rates. Plant biomass and fruit yield were increased linearly in response to N addition from 0.0 to 90 kg/fed. in both years, however, this effect was true for photosynthetic pigments, especially chlorophyll a, b and total chlorophyll, in the second year of cultivation. Salicylic acid application showed mostly a significant increase in the previous traits under all N-rates. Carotenoids content in leaves was not affected significantly by N and SA in the first sampling date, however, in the second date it affected negatively by N fertilizer. The above mentioned results revealed a synergism between N fertilizer and SA application. This study showed that SA addition increased plant growth and yield mainly by increasing the N recovery from the soil.

Keywords: Squash, nitrogen, salicylic acid, plant biomass, chlorophyll and fruit production.

INTRODUCTION

N nutrition plays a significant role in both crop yield and quality (Sisson *et al*., 1991; Gastal and Lemaire, 2002; Wang *et al*., 2002; Stagnari *et al*., 2007; Petropoulos *et al*., 2008; Cabello *et al*., 2009; Zotarelli *et al*., 2009a; Konstantopoulou *et al*., 2010; He-xi *et al*., 2011). Since, N is required for the synthesis of nucleic acids and proteins, phospholipids and many secondary metabolites (Amtmann and Armengaud, 2009). Nitrate uptake and accumulation in plants primarily relates to the amount (Chen *et al*., 2004; Mantovani *et al*., 2005). However, a limited research effort has been carried to examine the effects of rates of the applied nitrogen on the yield of summer squash (Chance *et al*., 1999; Mohammad, 2004; El-Shatoury, 2005; Zotarelli *et al*., 2009b) which showed a significant effect. Farmers have increased application of N fertilizers to their land year by year (Wang *et al*., 2000), without considering the response of different species to N rate and forms.

Adequate supply of N can promote plant growth and increase crop production (Collins and McCoy, 1997), but excessive and inappropriate use of chemical N fertilizers causes accumulation of compounds in the edible products. Such compounds may be harmful to humans and also cause environmental pollution and economical losses.

It is well documented that phenolic compounds exert their influence on physiological and biochemical processes including, photosynthesis, ion uptake, membrane permeability, enzyme activities, flowering, growth and development of plants and has diverse effects on tolerance to biotic and abiotic stress (Hayat *et al*., 2007&2010; Arfan *et al*., 2007; Syeed *et al*., 2010; Wang *et al*., 2010&2011; Nazar *et al*., 2011). One, such a natural compound is salicylic acid that may function as plant growth regulator (Arberg, 1981). It has been identified as an important signaling element involved in establishing the local and systemic disease resistance response of plants after pathogen attack (Alvarez, 2000). After a pathogen attack, SA levels often increases and induced the expression of pathogenesis-related proteins and initiates the development of systemic acquired resistance and hypersensitive response (Grüner *et al*., 2003; Kachroo *et al*., 2005; Radwan *et al*., 2006; Radhakrishnan and Balasubramanian, 2009).

The metabolic aspects of plants, supplied with SA or its derivatives, shifted to a varied degree, depending on the plant type and the mode of application of SA. Out of the various concentrations of SA used, Fariduddin *et al*. (2003) observed maximum increase in dry matter accumulation, chlorophyll and activity of nitrate reductase (NR) at a concentration of 10^{-5} M, supplemented to the leaves of the standing plants of *Brassica juncea* but the concentrations, above that proved inhibitory. Moreover, wheat seedlings, raised from the grains soaked in 10^{-5} M of SA possessed more number of leaves, higher pigments content, higher fresh and dry mass and higher activity of NR, compared with water soaked, control (Hayat *et al*., 2005). Recently, Nazar *et al*. (2011) reported highest chlorophyll content in mungbean plants supplied with 0.5 mM SA. In the former study, SA application at low concentration (10^{-6} M) positively increased the foliage fresh and dry weight, fruit number, average fruit weight, fruit yield, vitamin C, carotenoids content, cuticle thickness of fruit pericarip and translocation of sugars from leaves to fruits. It was found that SA treatment (10^{-6} M) caused a reduction in peroxidase and increasing of invertase activities of pepper leaves and fruits (Elwan and El-Hamahmy, 2009).

Nonetheless, soaking the seeds of *Vigna mungo* in SA solutions (10-150 µm) decreased the contents of chlorophyll and carotenoid (Anandhi and Ramanujam, 1997). Also, the results of Wang *et al*. (2011) indicated that treated *Vallisneria natans* (Lour.) Hara plants with SA at 10 and 100 µM decreased total chlorophyll and carotenoids content.

Summer squash is one of the most popular and widely used vegetable crops in the world. Approximately 1.7 Million ha are planted yearly with squash, pumpkin and gourd all over the world and yielding 22.14 Million tons with an average of 13.3 tons/ha. Egypt produced 700 thousand tons from around 40 thousand ha from squash, pumpkin and gourd with an average of 17.5 tons/ha (FAOSTAT, 2009).

Phenolic acids based regulation of nitrogen metabolism due to environmental constraints require more study to understand their effects on growth and yield production. It is clear that SA plays a positive role in biotic and a biotic stress; however, little information has been reported about the role of SA in N-nutrition. Therefore, effects of exogenous SA on morphological and photosynthetic traits of summer squash cv. Eskandrani is determined to understand physiological responses to N-nutrition. The objectives of this study were to investigate role of SA in regulation of plant growth, leaf pigments and fruit yield of summer squash (*Cucurbita pepo* L. cv. Eskandrani) plants under different N-rates.

MATERIALS AND METHODS

Plant material and growth conditions

Two field experiments were conducted in consecutive fall growing season of 2011 and 2012 at the Experimental Research Farm, Faculty of Agriculture, Suez Canal University, Ismailia, Egypt to investigate the effect of nitrogen levels and Salicylic acid application and their interaction on plant growth, leaf pigments and fruit yield of summer squash cv. Eskandarani.

Randomized soil samples were collected at 0.0–50.0 cm depth, before each plantation and homogenized together to determine the physicochemical characteristics of air-dried, crushed and sieved (<2mm) soil in accordance to the methods of Gee and Bauder (1986) and Sparks *et al*. (1996). Soluble cations Na^+, K^+, Ca^{2+} and Mg^{2+} and anions HCO_3^- and Cl^- were determined in the soil solution (Richards, 1954). Sulfate (SO_4^{2-}) was precipitated by barium chloride as barium sulfate and gravimetrically determined (Jackson, 1967). Electrical conductivity of the saturated soil paste extract expressed asdSm−1 was measured using a conductivity meter model Jenway 3310 (Jenway Ltd., Essex, Cambridge, UK) according to Richards (1954). Soil pH was determined by bench type Beckman glass electrode pH meter, in 1: 2.5 soil–water suspensions according to Page *et al*. (1982). The soil of the experimental site was sandy soil (85.21% sand, 11.5% silt and 3.29% clay) with pH 8.27, electrical conductivity (EC) 0.47 dSm^{-1}, calcium (Ca) 0.4 mM, magnesium (Mg) 0.3 mM, potassium (K) 0.3 mM, Na 3.0 mM, bicarbonate (HCO_3) 1.6 mM, chloride (Cl) 3.0 mM, and sulfate (SO_4) 0.05 mM. Before each planting, the experimental location was prepared. During preparation, a rate of 20 m^3 of cattle manure plus 350 kg calcium super phosphate (15.5% P_2O_5) per Fadden were supplemented, then the soil of the site was cleared, ploughed, harrowed and divided into plots.

The experiments were laid-out in a split plot in randomized complete block design with three replicates. Experiment was subjected to combinations of three nitrogen levels and three salicylic acid concentrations. Nitrogen was supplied as ammonium nitrate at rate of 0.0, 45 and 90 kg N/fed. Salicylic acid supplied at rate of 0.0, 10^{-6} and 10^{-3} M as foliar spray. SA was initially dissolved in a few drops of dimethyl sulfoxide and the final volume was reached using distilled water, pH was adjusted with KOH (1.0 N) to a value of 7.0. The solutions of SA with a surfactant triton 0.1% were sprayed four times with 2 weeks intervals on the whole foliage in the morning (8–9 a.m.). The volume of sprayed solution ranged from 30 ml to 50 ml per plant each time, depending on plant development stage. The same amount of dionized water plus triton 0.1% was sprayed to the control plants. The sprays in all cases were carried out with a manual pump.

Main plots (0.0, 45 and 90 kg N/fed) were 27 rows 0.5 m apart, each row 25 m in length and 1.0 m in width containing fifty plants at a spacing of 0.5 m within the row. Sup-plots (0.0, 10^{-6} and 10^{-3} M SA) were nine rows with three replicates. Each two adjacent experiment units (sub plots) were separated, on each side, by 1m to protect against border effects. The environmental conditions were as follows: a 14 h photoperiod, temperature fluctuated between 35-40/23-26 °C day/night and a relative humidity ranged from 50% to 55%.

Seeds of summer squash cv. Eskandrani were direct seeded by hand at a soil depth of 0.015 m on the third top of slope ridges, from the first of April to the mid of June 2011 and 2012. Nitrogen fertilizer levels were added at four equal doses 2, 4, 6 and 8 weeks after sowing, also, salicylic acid applied foliarly four times during growing seasons, added in the same time of nitrogen fertilizer addition. The soil moisture content was kept at an appropriate field capacity for sandy soil (50–75%) as described by Klocke and Fischbach (1984) and Miles and Broner (1998). Recommended practices for disease and insect control were followed.

Data collection and analysis

Plant biomass

Foliage fresh and dry weights of 10 plants for each replicate were determined using gravimetric method. Dry weight was determined after fixing plant material at 90 °C and drying at 70 °C up to constant weight.

Leaf pigments

Chlorophyll a, b and carotenoid content of leaves were determined after 4 and 8 weeks from planting using a Spectro 22 spectrophotometer (Labomed Inco, USA, according to Lichenthaler and Wellburn (1983), and then calculated as mg/ g fresh weight.

Fruit yield

Fresh weights of fruits at commercial fresh market maturity were recorded four times per week on all plants in the experimental unit starting after 4 weeks from sowing. Fruits were harvested when they reached marketable size (over 12 cm).

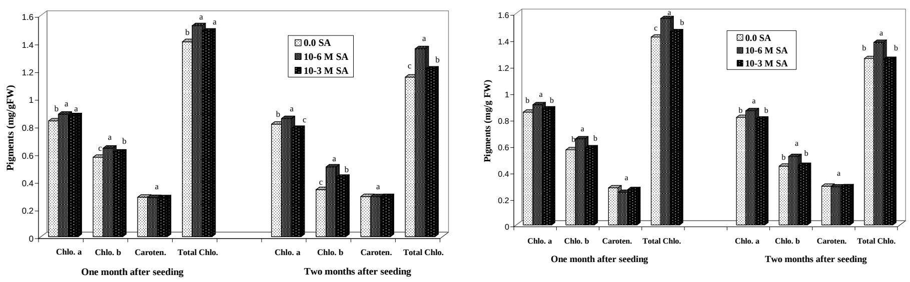
Statistical analysis

The results were evaluated using descriptive statistics and analysis of variance (ANOVA). Using two-way ANOVA, the effect of nitrogen levels and salicylic acid application as well as their interaction were evaluated by Fisher's F-test, followed by Duncan's multiple range test for comparing the nine N x SA combinations. All tests were performed at a significance level α of 0.05. Calculations were carried out using the software package Statistica™ for Windows version6.1 (Statsoft Inc., 2001, Tulsa, Oklahoma, USA).

RESULTS

Nitrogen, SA and their interaction strongly affect the leaf chlorophyll a,b and total chlorophyll content in both sampling dates and years have been observed, however leaf cartenoids content was affected only by N-fertilization (Table 1). The results (Table 1) indicated that N-fertilized summer squash plants had the significant highest chlorophyll a, b and total chlorophyll, however, non-fertilized plants with nitrogen had the highest leaf carotenoids content than fertilized plants, especially in the second sampling date (8 weeks). Data also (Table 1), proved that no significant differences were found between plants received 45 kg/ha and 90 kg/fed for chlorophyll a,b and total measured in the first sampling date (4 weeks) of both years. Nonetheless, in the second sampling date (8 weeks), chlorophyll a,b and total in the second year as well as chlorophyll a in the first year were significantly higher in plants fertilized with higher nitrogen level (90 kg/fed) comparing with medium nitrogen level (45 kg/fed).

High values of chlorophyll a, b and total appeared in foliar sprayed plants with SA at low (10^{-6} M) concentration than those treated with high SA (10^{-3} M) concentration or control treatments in both years and sampling dates, however, carotenoids content did not affected by SA application (Figure 1).



a b

Figure 1: Effect of SA concentrations on leaf pigments of summer squash, (a) season of 2011 and (b) season of 2011.

In the first sampling date, higher chlorophyll a and total chlorophyll in both cultivation years were found in plants sprayed with low SA concentration and fertilized with nitrogen at medium and high levels (45 and 90 kg/fed), however, the highest chlorophyll b was observed in plants received nitrogen at medium level (45 kg/fed) and sprayed with SA at 10^{-6} M (Table 1). While, in the second sampling date, higher chlorophyll a,b and total chlorophyll were associated with plants received high nitrogen level and low SA concentration (Table 1).

Nitrogen fertilizer, salicylic acid and their interaction significantly affected the marketable yield of squash in both seasons in addition to plant fresh weight in the first season, however, plant fresh and dry weights in the second season as well as dry weight% in both seasons affected significantly by only nitrogen fertilizer, while plant dry weight in the first season affected by nitrogen fertilizer and salicylic acid (Table 2). The results indicated that the significant highest plant fresh and dry weights and fruit yield were attributed with the 90 kg N/fed and 10^{-6} M SA (Table 2 & Figure 2), however, plant dry weight percentage was decreased with increasing nitrogen level (Table 2).

a b

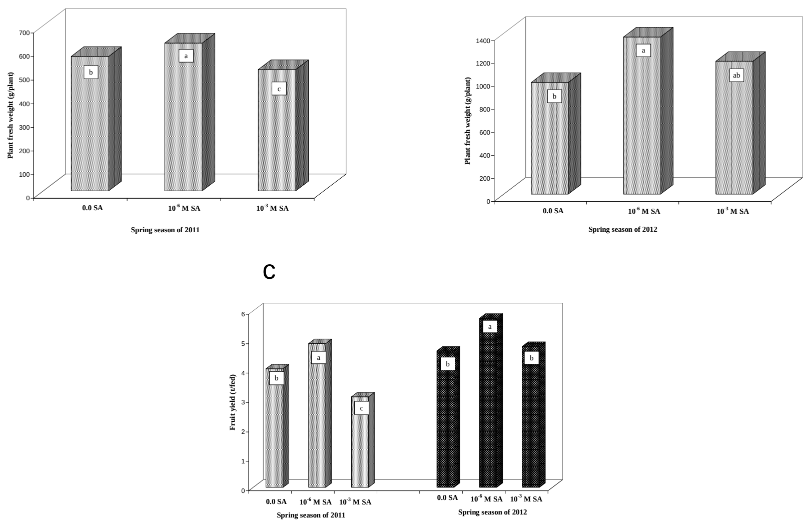


Figure 2: Effect of SA concentrations on plant fresh weight (a &b) and fruit yield (c) of summer squash during summer seasons of 2011 and 2012.

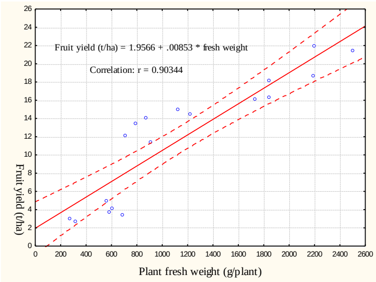
Regarding the interaction between nitrogen levels and SA concentrations, the data (Table 2) revealed that the significant highest plant fresh and dry weight in addition to fruit yield were attributed with plants received high nitrogen level and low SA (Table 2), however, plant dry weight percentage was significantly higher in plants without nitrogen fertilizer and SA application (Table 2). In this respect, the yield was significantly increased in sprayed plants with low SA by 15.3%, 31.9% and 15.37% in the first season and by 49.49%, 6.3% and 34.45% in the second season, in plants received nitrogen fertilizer at 0.0, 107.5 and 215 kg/ha, respectively. The increasing in plant fresh and dry weights by application of low SA concentration under nitrogen levels followed the same way as fruit yield.

Regarding correlations between measured parameters, the results in Table (3) revealed that the morphological parameters such as plant fresh and dry weights and fruit yield positively correlated at significant level with chlorophyll a, b and total chlorophyll, however, plant dry weight percentage negatively correlated at significant level with chlorophyll a, b and total chlorophyll.

1

2

Also, the results in Figure (3) revealed a significant positive correlation between total yield of summer squash and plant dry weight (*r* = 0.81746***). On the contrary, a highly significant negative correlation has been found between plant dry weight percentage and total yield of summer squash (*r* = -0.6515***).



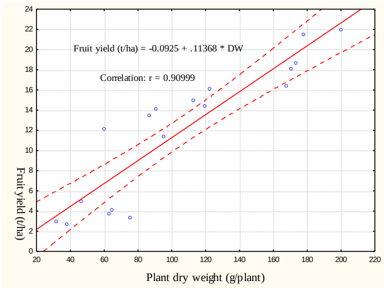


Figure (3): Regression of fruit yield on plant dry weight and plant dry weight percentage of summer squash plants grown for two summer seasons. The dashed lines represent the 95% confidence interval on the whole regression line.

Table (3): Correlation coefficient among chlorophyll pigments and morphological parameters

	Plant fresh weight	Plant dry weight	Plant dry weight%	Fruit yield
	Summer season of 2010			
Chlorophyll a	0.77***	0.81***	-0.66**	0.76***
Chlorophyll b	0.83***	0.88***	-0.60**	0.82***
Carotenoids	-0.42 ns	-0.41 ns	0.49*	-0.40 ns
Total chlorophyll	0.83***	0.87***	-0.63**	0.81***
	Summer season of 2011			
Chlorophyll a	0.71**	0.73**	-0.61**	0.88***
Chlorophyll b	0.2**	0.76***	-0.54*	0.91***
Carotenoids	0.21 ns	0.19 ns	-0.15 ns	0.39 ns
Total chlorophyll	0.73**	0.77***	-0.57*	0.92***

DISCUSSION

The reported research was undertaken to improve our understanding of physiological processes determining the effect of SA for improving the nitrogen assimilation. N-rate, salicylic acid and their interaction significantly influenced summer squash fruit yield and leaf photosynthetic pigments (chlorophyll a&b and total chlorophyll) (Table 1&2). Mostly, the highest leaf photosynthetic pigments were obtained when summer squash plants fertilized with high N-rate and sprayed with low SA concentration (10^{-6} M). This effect was more pronounced in the second sampling date (after 8 weeks from seeding), this finding may be due to that summer squash plants at the second sampling date received all spraying doses of SA.

It is well known that the nitrogen influences the structure and composition of photosynthetic apparatus. In crops, ribulose 1,5, bisphosphate carboxylase (rubisco) content increases linearly with leaf N accumulation (Kumar *et al*., 2002). Also, it is a well-established fact that salicylic acid potentially generates a wide array of metabolic responses in plants and also affects the photosynthetic parameters such as chlorophyll a and b and plant water relations. SA might be involved in mobilization of internal tissue nitrate and chlorophyll biosynthesis to increase the functional state of the photosynthetic machinery in plants (Shi *et al*. 2006), as indicated in our results by increasing it plant fresh and dry weight of summer squash (Table 2). Exogenous application of SA was found to enhance the net photosynthetic rate, internal CO_2 concentration, water use efficiency, stomatal conductance and transpiration rate in *B. juncea* (Fariduddin *et al*., 2003). The positive results regarding to increasing plant growth and fruit yield by SA could be due to the role of SA in inducing plant defense mechanisms against zucchini yellow mosaic virus infection by inhibition or activation of some antioxidant enzymes, reduction of lipid peroxidation or induction of H_2O_2 accumulation in summer squash (Radwan *et al*., 2006). Also, Radhakrishnan and Balasubramanian (2009) reported that pretreatment of *Curcuma longa* plants with SA suppressed the pathogen-induced oxidative damage of soilborne Oomycete, *Pythium aphanidermatum* through higher accumulation of peroxidases and induced defense through the activities of protease inhibitors and strengthened the tolerance of turmeric rhizomes towards pathogen infection.

In the present study, as expected, a greater plant biomass was observed when N fertilizer rate increased. However, the results showed an evident N x S synergism since the addition of SA boosted plant biomass as N fertilizer rates increased (Table 2 and Figure 2), also, the photosynthetic pigments in this study increased significantly when summer squash plants sprayed with low SA at high N-rate (Table 1). Reported results regarding to SA application were in accordance with the results of Nazar *et al*. (2011) who found that treated mungbean plants with 0.5 mM SA improved significantly leaf chlorophyll content. However, our results were in contradiction with the previous reports on Vigna *mungo* by Anandhi and Ramanujam, (1997) and Wang *et al*. (2011) on *Vallisneria natans* (Lour.) Hara, who found that treated seeds and plants, respectively, with SA affected negatively the chlorophyll when SA ranged between 10-100 µM. The decrease of total chlorophyll content was also detected in barley, radish and other plants exposed to SA (Canakci and Munzuroglu, 2009; Hayat *et al*., 2010).

The results of this experiment clearly showed a greater water uptake when N- rate was increased from 0.0 to 215 kg/ha, whereas the plant dry weight percentage was decreased with N fertilization increase and this effect did not affected by SA application (Table 2). It is clear, under N-deficiency the plants do not need to absorb more water, however, with increasing N-rate the demand for water increased to create more plant growth and higher fruit yield. With regard to the effect SA on water uptake (plant dry weight percentage), the effects was not clear may be due to SA enhance stomatal conductance and transpiration rate as reported before in *B. juncea* by Fariduddin *et al*. (2003).

Nitrogen assimilation increased when SA was added at low concentration, where the indicated results showed that plant fresh and dry weights of summer squash improved by application of SA (Table 2 and Figure 2). High doses of SA were required to observe inhibitory action on plant growth of summer squash plants. The explanation for that thanks to higher levels of SA may inhibit nitrate uptake system and cause retardation in growth and development. Previous results reported by Wang and Li (2003) showed that the exogenous application of 50 μM SA was beneficial for growth and development in comparison to high doses (500 μM) of SA. Our results regarding to low SA concentration may be explained by the fact of SA influence transport of substances in plants (Krasavina, 2007). Also, previous studies reported that the nitrogen metabolism is an important aspect and exogenous application of SA was found to affect the activities of the enzymes of nitrate/nitrogen metabolism as well. Such a lower concentration of SA when sprayed enhanced NR activity when sprayed on the foliage of *Brassica juncea* plants (Fariduddin *et al*., 2003) and mungbean (Nazar *et al*., 2011). However, at higher concentrations, SA proved to be inhibitory. The treatment of maize plants with lower concentrations of SA also enhanced the uptake of nitrogen and activity of enzyme NR, whereas, higher concentrations were proved to be inhibitory (Jain and Srivastava, 1981).

Bio-productivity of plants has been one of the main topics of agricultural sciences and different experts (geneticists, plant breeders, biotechnologists, plant nutritionists, plant physiologists, etc) have been trying to describe it (Larque-Saavedra and Martin-Mex, 2007). The presented data proved that the yield of summer squash linearly increased by increasing N-rate and this effect was efficiently at significant level when plants sprayed with SA at low concentration (Table 2). Also, significant positive correlations of plant fresh and dry weights and fruit yield with leaf photosynthetic pigments and a negative correlation of dry weight percentage with leaf photosynthetic pigments were detected in this study. In addition fruit yield correlated positively with plant fresh weight and negatively with percentage of plant dry weight. These data suggested that SA could play important role in the bio-productivity of plants and that could be linked to the observed effect of promoting the plant growth and fruit yield as mentioned earlier by Elwan and El-Hamahmy (2009) who found that low concentration of SA improved fruit yield by increasing invertase activity and translocation of sugar from leaves to fruits in pepper plants. The results of this study supported the hypothesis that SA favored growth and development by increasing nitrogen assimilation in summer squash plants. Here, according to our knowledge this is the first time that increasing N assimilation by application of SA, however, there are other reports examined the increasing N use efficiency by application of sulfur in chinese spring onion (Liu *et al*., 2009), wheat (Salvagiotti *et al*., 2009) and broccoli (Elwan and Abd El-Hamed, 2011), which all of them found that sulfur application improved N assimilation.

Under N-deficient (0.0 N-rates), the fruit yield slightly increased in plants treated with low SA (Table 2), this result supported the hypothesis that

SA in summer squash play protective role for nutritional disorder. Previous research indicated that limited nitrogen availability reduces the growth and plant productivity and induces secondary metabolism (Lattenzio *et al*. 2009; Chisaki and Horiguchi 1997).

In summary, the increase in fruit yield in response to low SA(10^{-6} M) concentration and high N-rate (90 kg/fed) was associated with a higher plant growth as a good indicator for more nutrient uptake by summer squash plant roots, in addition to increasing leaf photosynthetic pigments and water use efficiency. Therefore, this study shows that the concurrent management of N and SA is important for N recovery from the soil and sustaining high nitrogen assimilation for higher fruit production.

REFERENCES

Alverez, A.L., 2000. Salicylic acid in machinery of hypersensitive cell death and disease resistance. Plant Mol. Biol. 44, 429–442.

Amtmann, A., Armengaud, P., 2009. Effects of N, P, K and S on metabolism: new knowledge gained from multi-level analysis. Current Opinion in Plant Biology 12, 275–283.

Anandhi, S., Ramanujam, M.P., 1997. Effect of salicylic acid on black gram (*Vigna mungo*) cultivars. Ind. J. Plant Physiol. 2, 138–141.

Arberg, B., 1981. Plant growth regulators. Monosubstituted benzoic acid. Swed. Agric. Res., 11: 93-105.

Arfan, M., Arthar, R., Ashraf, M., 2007. Does exogenous application of salicylic acid through the rooting media modulate growth and photosynthetic capacity two differently adopted durum wheat cultivars under salt stress? J. Plant Physiol.164, 685–694.

Cabello, M.J., Castellanos, M.T., Romojaro, F., Martínez-Madrid, C., Ribas, F., 2009. Yield and quality of melon grown under different irrigation and nitrogen rates. Agricultural Water Management 9 6, 8 66 – 8 74.

Canakci, S., Munzuroglu, O., 2009. Effects of salicylic acid on growth and chlorophyll destruction of some plant tissues. World J. Agric. Sci. 5, 577–581.

Chance, W.O., Somda, Z.C., Mills , H.A., 1999. Effect of nitrogen form during the flowering period on zucchini squash growth and nutrient element uptake. Journal of Plant Nutrition 22(3), 597-607.

Chen, B.M., Wang, Z.W., Li, S.X., Wang, G.X., Song, H.X., Wang, X.N., 2004. Effect of nitrate supply on plant growth, nitrate accumulation, metabolic nitrate concentration and nitrate reductase activity in three leafy vegetables. Plant Sci. 167 (3), 635–643.

Chisaki, N., Horiguchi, T., 1997. Responses 273 of secondary metabolism in plants to nutrient deficiency. In Plant nutrition for sustainable food production and environment. Ando T, Fujita K, Mae T, Matsumoto H, Mori S, Sekija J (Eds.) Kluwer academic publishers, pp. 341-345.

Collins, M., McCoy, J.E., 1997. Chicory production, forage quality, and response to nitrogen fertilization. Agron. J. 89, 232–238.

El-Shatoury, R.S.A. 2005. Effects of plant density and nitrogenous fertilizer on growth characters of summer squash. M.Sc. Thesis, Department of Horticulture, Faculty of Agriculture, Suez Canal University, Ismailia, Egypt.

Elwan, M.W.M., AbdEl-Hamed, K.E., 2011. Influence of nitrogen form, growing season and sulfur fertilization on yield and the content of nitrate and vitamin C of broccoli. Scientia Horticulturae 127, 181–187.

Elwan, M.W.M., El-Hamahmy, M.A.M., 2009. Improved productivity and quality associated with salicylic acid application in greenhouse pepper. Scientia Horticulturae 122, 521–526.

FAOSTAT, 2009. http://faostat.fao.org/site/567/default.aspx#ancor.

Fariduddin, Q., Hayat, S., Ahmad, A., 2003. Salicylic acid influences net photosynthetic rate, carboxylation efficiency, nitrate reductase activity and seed yield in Brassica juncea. Photosynthetica 41, 281–284.

Gastal, F., Lemaire, G., 2002. N uptake and distribution in crops: an agronomical and ecophysiological perspective. J. Exp. Bot. 53, 789–799.

Gee, G. W., and J. W. Bauder. 1986. Particle-size analysis. In *Methods of soil analysis*, ed. A. Klute, 383–409. Madison, Wisc.: ASA and SSSA.

Grüner, R., Strompen, G., Pfitzner, A.J.P., Pfitzner, U.M., 2003. Salicylic acid and the hypersensitive response initiate distinct signal transduction pathways in tobacco that converge on the *as-1*-like element of the *PR-1a* promoter. European J. Biochem., 270: 4876.

Hayat, Q., Hayat, S., Irfan, M., Ahmad, A., 2010. Effect of exogenous salicylic acid under changing environment: A review. Environmental and Experimental Botany 68, 14–25

Hayat, S., Ali, B., Ahmad, A., 2007. Salicylic acid: biosynthesis, metabolism and physiological role in plants. In: S. Hayat and A. Ahmad (eds.), Salicylic Acid – A Plant Hormone, 1–14.

Hayat, S., Fariduddin, Q., Ali, B., and Ahmad, A.,2005. Effect of salicylic acid on growth and enzyme activities of wheat seedlings. Acta Agron. Hung., 53: 433-437.

He-xi, Z., Dao-cai, C., Qun, W., Jun, F., Xiao-yu, F., 2011. Yield and quality response of cucumber to irrigation and nitrogen fertilization under subsurface drip irrigation in solar greenhouse. Agricultural Sciences in China 10(6), 921-930.

Jackson, M.L., 1967. Soil Chemical Analysis. Prentice Hall Inc., Englewood Cliffs, N.J., Library of Congress, USA.

Jain, A., and Srivastava, H. S., 1981. Effect of salicylic acid on nitrate reductase activity in maize seedlings. Physiol. Plant., 51: 339-342.

Kachroo, P., Venugopal, S.C., Nvarre, D.A., Lapchyk, L., Kachroo, A., 2005. Role of salicylic acid and fatty acid desaturation pathways in *ssi2*-mediated signaling. Pant. Physiol., 139: 1717–35.

Klocke, N.L., Fischbach, P.E., 1984. Estimating Soil Moisture by Appearance and Feel. University of Nebraska-Lincoln Extension. G84-690.

Konstantopoulou, E., Kapotis, G., Salachas, G., Petropoulos, S.A., Karapanos, I.C., Passam, H.C., 2010. Nutritional quality of greenhouse lettuce at harvest and after storage in relation to N application and cultivation season. Scientia Horticulturae 125, 93.e1–93.e5.

Krasavina, M.S., 2007. Effect of salicylic acid on solute transport in plants. In: S. Hayat and A. Ahmad (eds.), Salicylic Acid – A Plant Hormone, 25-68.

Kumar, P.A., M.A.J. Parry, R.A.C. Mitchell, A. Ahmad, Y.P. Abrol, 2002. Photosynthesis and nitrogen use efficiency. In: Foyer CH, Noctor G, editors. Photosynthetic nitrogen assimilation and associated carbon and respiratory metabolism: advances in photosynthesis and respiration. Dordrecht: Springer, p. 23–34.

Larque-Saavedra, A., Martin-Mex, R., 2007. Effects of salicylic acid on the bioproductivity of plants. In: S. Hayat and A. Ahmad (eds.), Salicylic Acid – A Plant Hormone, 15-23.

Lattanzio, V.; Cardinali, A.; Ruta, C.; Fortunato, I.M.; Lattanzio, V.M.T.; Linsalata, V.; Cicco, N., 2009. Relationship of secondary metabolism to growth in oregano (*Origanum vulgare* L.) shoot cultures under nutritional stress. Environmental and Experimental Botany 65, 54-62.

Lichtenthaler, H.K., Wellburn, W.R., 1983. Determination of total carotenoids and chlorophylls a and b of leaf extracts in different solvents. Biochem. Soc. Trans. 11, 591–592.

Liu, S., He, H., Feng, G., Chen, Q., 2009. Effect of nitrogen and sulfur interaction on growth and pungency of different pseudostem types of Chinese spring onion (*Allium fistulosum* L.). Scientia Horticulturae 121, 12–18.

Mantovani, J.R., Ferreira, M.E., Da Cruz, M.C.P., 2005. Lettuce growth and nitrate accumulation in relation to nitrogen fertilization. Hortic. Brasileira 23 (3), 758–762.

Miles, D.L., Broner, I., 1998. IRRIGATION, Estimating Soil Moisture. Colorado State University Extension Crop Series. No. 4.700.

Mohammad, M.J., 2004. Squash yield, nutrient content and soil fertility parameters in response to methods of fertilizer application and rates of nitrogen fertigation. Nutrient Cycling in Agroecosystems 68, 99–108.

Nazar, R., Iqbal, N., Syeed, S., Khan, N.A., 2011. Salicylic acid alleviates decreases in photosynthesis under salt stress by enhancing nitrogen and sulfur assimilation and antioxidant metabolism differentially in two mungbean cultivars. Journal of Plant Physiology 168, 807–815.

Page, A.L., Miller, R.H., Keeney, D.R., 1982. Methods of Soil Analysis. Part 2: Chemical and Microbiological Properties. ASA, Madison, WI.

Petropoulos, S.A., Olympios, C.M., Passam, H.C., 2008. The effect of nitrogen fertilization on plant growth and the nitrate content of leaves and roots of parsley in the Mediterranean region. Scientia Horticulturae 118, 255–259.

Radhakrishnan, N., Balasubramanian, R., 2009. Salicylic acid induced defense responses in *Curcuma longa* (L.) against *Pythium aphanidermatum* infection. Crop Protection 28, 974–979.

Radwan, D.M., Fayez, K.A., Mahmoud, S.Y., Hamad, A., Lu, G., 2006. Salicylic acid alleviates growth inhibition and oxidative stress caused by zucchini yellow mosaic virus infection in *Cucurbita pepo* leaves. Physiological and Molecular Plant Pathology 69, 172–181

Richards, L.A. (Ed.), 1954. Diagnosis and improvement of saline and alkali soils. US Salinity Lab., US Department of Agriculture Handbook 60. California, USA.

Salvagiotti, F., Castellar, J.M., Miralles, D.J., Pedrol, H.M., 2009. Sulfur fertilization improves nitrogen use efficiency in wheat by increasing nitrogen uptake. Field Crops Research 113, 170–177.

Shi, Q., Bao, Z., Zhu, Z., Ying, Q., Qian, Q., 2006. Effects of 321 different treatments of salicylic acid on heat tolerance, chlorophyll fluorescence and antioxidant enzyme activity in seedlings of *Cucumis sativa* L. Plant Growth Reg. 48(2), 127-135.

Sisson, V.A., Rufty, T.W., Williamson, R.E., 1991. Nitrogen-use efficiency among flue-cured tobacco genotypes. Crop Sci. 31, 1615–1620.

Sparks, D. L., A. L. Page, P. A. Helmke, R. H. Loeppert, P. N Soltanpour, M. A. Tabatabai, C.T. Johnston, and M. E. Sumner. 1996. *Methods of soil analysis*. Madison, Wisc.: ASA and SSSA.

Stagnari, F., Di Bitetto, V., Pisante, M., 2007. Effects of N fertilizers and rates on yield, safety and nutrients in processing spinach genotypes. Scientia Horticulturae 114, 225–233.

Statsoft, Inc. 2001. STATISTICA fuer Windous [Software-system fuer Datenanalyse] Version 6. www.Statsoft.com.

Syeed, S., N.A., Anjum, R. Nazar, N. Iqbal, A. Masood, N.A. Khan, 2010. Salicylic acid-mediated changes in photosynthesis, nutrients content and antioxidant metabolism in two mustard (*Brassica juncea* L.) cultivars differing in salt tolerance. Acta Physiol Plant., doi:10.1007/s11738-010-12614-7.

Wang, A.M., Zhang, F.K., Huang, L.F., Yin, X.P., Li, H.F., Wang, Q.Y., 2010. New progress in biocatalysis and biotransformation of flavonoids. J. Med. Plants Res. 4,847–56.

Wang, M., Li, Z., 2003. Nonideal gas flow and heat transfer in micro- and nanochannels using the direct simulation Monte Carlo method. Phys. Rev. E 68(4), 046704 - 046710.

Wang, Y., Dai, C.C., Zhao, Y. W., Peng, Y., 2011. Fungal endophyte-induced volatile oil accumulation in Atractylodes lancea plantlets is mediated by nitric oxide, salicylic acid and hydrogen peroxide. Process Biochemistry 46, 730–735.

Wang, Z.-H., Wang, L., He, C.Y., Wang, H., Kui, X.L., Jiang, Z.X., 2000. Studies on effect of over N fertilization on nitrate accumulation in different vegetables and its regulation. Agro-environ. Protect. 19 (1), 46–49.

Wang, Z.-H., Zong, Z.-Q., Li, S.-X., Chen, B.-M., 2002. Nitrate accumulation in vegetables and its residual in vegetable fields. Environ. Sci. 23, 79–83.

Zotarelli, L., Dukes, M.D., Scholberg, G.M.S., Muñoz-Carpena, R., Icerman, J., 2009 a. Tomato nitrogen accumulation and fertilizer use efficiency on a sandy soil, as affected by nitrogen rate and irrigation scheduling. Agricultural Water Management 96, 1247–1258.

Zotarelli, L., Dukes, M.D., Scholberg, G.M.S., Hanselman, T., Femminella, L., Muñoz-Carpena, R., 2009 b. Nitrogen and water use efficiency of zucchini squash for a plastic mulch bed system on a sandy soil. Scientia Horticulturae 116, 8–16.

النمو الخضرى وصبغات التمثيل الضوئى والمحصول تأثرت إيجابيا بالرش بحامض السلسيلك لنباتات الكوسة النامية تحت مستويات مختلفة من التسميد النيتروجينى

محمد وصفى محمد علوان و رواء صلاح أحمد الشطورى
جامعة قناة السويس- كلية الزراعة – قسم البساتين – الأسماعيلية – مصر

يلعب السماد النيتروجينى دورا مركزيا لتحسين المحصول فى مختلف محاصيل الخضر و التمثيل العالى للنيتروجين مطلوب لإنتاج محصول ثمرى عالى. هناك عديد من الدراسات أكدت على دور الرش بحامض السلسيلك فى زيادة النمو النباتى والإنتاجية ولكن ليست هناك محاولات بحثية لدراسة تأثيرات تفاعل الرش بحامض السلسيلك و التغذية بإستخدام النيتروجين. ولذلك فإن هدف هذة الدراسة كان تحليل تأثيرات معدلات مختلفة من التسميد النيتروجينى و تركيزات الرش بحامض السلسيلك والتفاعل بينهما على النمو النباتى و صبغات التمثيل الضوئى والمحصول. تجارب حقلية أجريت خلال موسمين نمو متعاقبين تحت ظروف محافظة الأسماعيلية بإستخدام معدلات مختلفة من السماد النيتروجينى وحامض السلسيلك. أظهرت النتائج أن النمو النباتى والمحصول الثمرى زادوا زيادة معنوية أستجابة لزيادة مستوى السماد النيتروجينى من صفر حتى 90 كجم لكل فدان خلال موسمى النمو فى حين أن هذا التأثير كان صحيحا فيما يتعلق بصبغات التمثيل الضوئى خاصا كلوروفيل أ و ب والكلى فى موسم النمو الثانى. أوضحت النتائج أن الرش بحامض السلسيلك فى غالبية الأحيان أزادت معنويا النمو النباتى والمحصول الثمرى وصبغات التمثيل الضوئى تحت كل مستويات التسميد النيتروجينى تحت الدراسة. أظهرت النتائج أن محتوى الأوراق من الكاروتين لم يتأثر معنويا بإضافة النيتروجين أو حامض السلسيلك فى عينات الأوراق المأخوذة بعد شهر من الزراعة فى حين أنها تأثرت سلبيا فى النباتات المسمدة بالنيتروجين وذلك فى عينات الأوراق المأخوذة بعد شهرين من الزراعة. أوضحت النتائج المتحصل عليها أن هناك تعاون بين التسميد النيتروجينى والرش بحامض السلسيلك. هذة الدراسة أوضحت أن الرش بحامض السلسيلك أزاد النمو النباتى والمحصول الثمرى عموما بزيادة تمثيل النيتروجين داخل النباتات.

قام بتحكيم البحث

أ.د / سمير طه محمود العفيفي	**كلية الزراعة – جامعة المنصورة**
أ.د / سمير كامل الصيفي	**كلية الزراعة- جامعة قناة السويس**

Table 1: Effect of nitrogen levels and salicylic acid concentrations on the leaf pigments (mg/g FW) of summer squash.

N levels (Kg/fed.)	SA concentrations (M)	4 weeks from seeding				8 weeks from seeding			
		Chlo.a	Chlo.b	Total Chlo.	Caroten.	Chlo.a	Chlo.b	Caroten.	Total Chlo.
		Summer season of 2011							
0.0	**0.0**	0.6756 c	0.2639 f	0.9395 e	0.2892 a	0.7037 d	0.2630 e	0.2915 a	0.9667 f
	10^{-6}	0.8104 b	0.3792 e	1.1896 d	0.2832 ab	0.7894 c	0.3184 d	0.2898 ab	1.1078 d
	10^{-3}	0.7938 b	0.3826 e	1.1763 d	0.2821 ab	0.6223 e	0.4146 c	0.2908 a	1.0369 e
Mean		**0.7599 b**	**0.3419 b**	**1.102 b**	**0.2848 a**	**0.7051 c**	**0.332 c**	**0.2907 a**	**1.0370 b**
107.5	**0.0**	0.9163 a	0.7508 b	1.6670 ab	0.2821 ab	0.8266 c	0.5081 b	0.2882 ab	1.3348 c
	10^{-6}	0.9239 a	0.7944 a	1.7182 a	0.2799 b	0.8457 bc	0.5760 a	0.2876 ab	1.4217 b
	10^{-3}	0.9059 a	0.6574 d	1.5633 c	0.2818 ab	0.8298 c	0.4465 c	0.2883 ab	1.2762 c
Mean		**0.9154 a**	**0.7342 a**	**1.6500 a**	**0.2813 a**	**0.8340 b**	**0.5102 a**	**0.2880 b**	**1.3440 a**
215	**0.0**	0.9169 a	0.7036 c	1.6205 bc	0.2810 b	0.9089 a	0.2474 e	0.2889 ab	1.1563 d
	10^{-6}	0.9224 a	0.7451 b	1.6674 ab	0.2821 ab	0.9260 a	0.6169 a	0.2859 b	1.5430 a
	10^{-3}	0.9219 a	0.7937 a	1.7155 a	0.2795 b	0.8952 ab	0.4262 c	0.2891 ab	1.3214 c
Mean		**0.9204 a**	**0.7474 a**	**1.6680 a**	**0.2809 a**	**0.9100 a**	**0.4302 b**	**0.2880 b**	**1.3400 a**
		P value							
Nitrogen (N)		0.0000***	0.0000***	0.0000***	0.1233 ns	0.0000***	0.0000***	0.0326*	0.0000***
Salicylic acid (SA)		0.0026**	0.0004***	0.0004***	0.2993 ns	0.0017**	0.0000***	0.1792 ns	0.0000***
N*SA		0.0017**	0.0000***	0.0002***	0.4747 ns	0.0102*	0.0000***	0.7941 ns	0.0002***
		Summer season of 2012							
0.0	**0.0**	0.7256 d	0.2739 g	0.9995 g	0.2842 a	0.6937 f	0.2630 f	0.2965 a	0.9567 g
	10^{-6}	0.8604 b	0.3892 e	1.2496 e	0.2632 ab	0.7994 e	0.3380 e	0.2948 a	1.1378 e
	10^{-3}	0.7888 c	0.3526 f	1.1423 f	0.2396 b	0.6923 f	0.3446 e	0.2958 a	1.0369 f
Mean		**0.7916 b**	**0.3386 b**	**1.1301 b**	**0.2623 a**	**0.7285 c**	**0.3153 c**	**0.2957 a**	**1.0438 c**
107.5	**0.0**	0.9063 ab	0.7358 b	1.6420 bc	0.2821 a	0.8366 d	0.5231 c	0.2882 abc	1.3598 c
	10^{-6}	0.9339 a	0.8044 a	1.7382 a	0.2799 a	0.8657 c	0.5860 b	0.2876 abc	1.4517 b
	10^{-3}	0.9109 a	0.644 d	1.5583 d	0.2818 a	0.8148 de	0.4565 d	0.2883 abc	1.2712 d
Mean		**0.9170 a**	**0.7292 a**	**1.6462 a**	**0.2813 a**	**0.8390 b**	**0.52185 b**	**0.2880 b**	**1.3609 b**
215	**0.0**	0.9270 a	0.6936 c	1.6205 c	0.2760 a	0.9089 ab	0.5474 c	0.2939 ab	1.4563 b
	10^{-6}	0.9324 a	0.7601 b	1.6924 ab	0.2806 a	0.9260 a	0.6269 a	0.2809 bc	1.5530 a
	10^{-3}	0.9319 a	0.7487 b	1.6805 ab	0.2800 a	0.8952 b	0.5512 c	0.2806 c	1.4464 b
Mean		**0.9304 a**	**0.7341 a**	**1.6645 a**	**0.2789 a**	**0.9100 a**	**0.5752 a**	**0.2852 b**	**1.4852 a**
		P value							
Nitrogen (N)		0.0000***	0.0000***	0.0000***	0.1448 ns	0.0000***	0.0000***	0.02005*	0.0000***
Salicylic acid (SA)		0.0046**	0.0000***	0.0000***	0.3877 ns	0.0000***	0.0001***	0.2399 ns	0.0000***
N*SA		0.0177*	0.0001***	0.0004***	0.3158 ns	0.0041**	0.0002***	0.3707 ns	0.0001***

Values are the means of at least 3 samples per replicate. Values followed by the same letter within a column are not significantly different at the 0.05% level of probability according to Duncan's multiple range test. *,** and * significant at 0.1%, 1% and 5%; NS: not significant.**

Table 2: Effect of nitrogen levels and salicylic acid concentrations on the plant fresh and dry weights, plant dry weight percentage and cumulative fruit yield per fed of summer squash.

N levels (Kg/fed.)	SA concentrations (M)	Summer season of 2011				Summer season of 2012			
		Plant FW (g)	Plant DW (g)	Plant DW%	Fruit yield (t/fed)	Plant FW (g)	Plant DW (g)	Plant DW%	Fruit yield (t/fed)
0.0	0.0	216.00 f	24.84 e	11.50 a	1.44 e	297.50 e	35.00 f	11.75 a	1.24 h
	10^{-6}	208.00 f	19.88 e	9.60 abc	1.66 e	583.00 de	55.75 ef	9.52 abc	1.86 g
	10^{-3}	202.50 f	21.56 e	10.65 a	1.37 e	637.00 d	69.40 ef	10.89 ab	1.55 gh
Mean		**208.83 c**	**22.09 c**	**10.58 a**	**1.49 c**	**505.83 c**	**53.39 c**	**10.72 a**	**1.55 c**
45	0.0	575.00 de	58.91 cd	10.25 ab	4.23 d	835.00 d	88.82 de	10.65 abc	5.86 e
	10^{-6}	620.00 d	61.39 cd	9.90 abc	5.58 c	1173.50 c	116.38 cd	9.92 abc	6.23 d
	10^{-3}	530.00 e	51.70 d	9.75 abc	3.83 e	813.50 d	78.00 de	9.47 abc	5.04 f
Mean		**575.00 b**	**57.33 b**	**9.97a**	**4.55 b**	**940.67 b**	**94.40 b**	**10.01 a**	**5.71 b**
90	0.0	918.00 b	75.68 b	8.25 c	6.44 b	1787.00 b	145.24 bc	8.10 c	6.82 c
	10^{-6}	1050.00 a	86.25 a	8.25 c	7.43 a	2350.50 a	189.17 a	8.11 c	9.17 a
	10^{-3}	810.00 c	68.90 bc	8.50 bc	4.05 de	2021.00 b	172.00 ab	8.57 bc	7.79 b
Mean		**926.00 a**	**76.94 a**	**8.33 b**	**5.97 a**	**2052.8 a**	**168.80 a**	**8.26 b**	**7.93 a**
		P value							
Nitrogen (N)		0.0000***	0.0000***	0.00205**	0.0000***	0.0000***	0.0000***	0.0085**	0.0000***
Salicylic acid (SA)		0.0001***	0.0247*	0.29902 ns	0.0000***	0.00156**	0.0227*	0.3249 ns	0.0000***
N*SA		0.0019**	0.1009 ns	0.48529 ns	0.0000***	0.14552 ns	0.18392 ns	0.5244 ns	0.0000***

Values are the means of all plants for fruit yield and at least 3 plants per replicate for fresh and dry weights. Values followed by the same letter within a column are not significantly different at the 0.05% level of probability according to Duncan's multiple range test. *,** and * significant at 0.1%, 1% and 5%; NS: not significant.**