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

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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 pericarp 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 μ M) 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 μ M 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 as dSm^{-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 deionized 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. Sub-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 version 6.1 (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 carotenoids 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).

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/ha and 10^{-6} M SA (Table 2 & Figure 2), however, plant dry weight percentage was decreased with increasing nitrogen level (Table 2).

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.

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 CO₂ 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 H₂O₂ 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 spiralis* (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 μ M SA was beneficial for growth and development in comparison to high doses (500 μ M) 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.

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النمو الخضري وصبغات التمثيل الضوئي والمحصول تأثرت إيجابيا بالرش بحامض السلسليك لنباتات الكوسة النامية تحت مستويات مختلفة من التسميد النيتروجيني

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يلعب السماد النيتروجيني دورا مركزيا لتحسين المحصول في مختلف محاصيل الخضر و التمثيل العالي للنيتروجين مطلوب لإنتاج محصول ثمرى عالى. هناك عديد من الدراسات أكدت على دور الرش بحامض السلسليك في زيادة النمو النباتي والإنتاجية ولكن ليست هناك محاولات بحثية لدراسة تأثيرات تفاعل الرش بحامض السلسليك و التغذية باستخدام النيتروجين. ولذلك فإن هدف هذه الدراسة كان تحليل تأثيرات معدلات مختلفة من التسميد النيتروجيني و تركيزات الرش بحامض السلسليك والتفاعل بينهما على النمو النباتي و صبغات التمثيل الضوئي والمحصول. تجارب حقلية أجريت خلال موسمين نمو متعاقبين تحت ظروف محافظة الأسماعيلية باستخدام معدلات مختلفة من السماد النيتروجيني وحامض السلسليك. أظهرت النتائج أن النمو النباتي والمحصول الثمرى زادوا زيادة معنوية استجابة لزيادة مستوى السماد النيتروجيني من صفر حتى ٩٠ كجم لكل فدان خلال موسمى النمو فى حين أن هذا التأثير كان صحيحا فيما يتعلق بصبغات التمثيل الضوئي خاصة كلوروفيل أ و ب والكلى فى موسم النمو الثانى. أوضحت النتائج أن الرش بحامض السلسليك فى غالبية الأحيان أزادت معنويا النمو النباتي والمحصول الثمرى وصبغات التمثيل الضوئي تحت كل مستويات التسميد النيتروجيني تحت الدراسة. أظهرت النتائج أن محتوى الأوراق من الكاروتين لم يتأثر معنويا بإضافة النيتروجين أو حامض السلسليك 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 النيتروجيني والرش بحامض السلسليك. هذه الدراسة أوضحت أن الرش بحامض السلسليك أزداد النمو النباتي والمحصول الثمرى عموما بزيادة تمثيل النيتروجين داخل النباتات.

قام بتحكيم البحث

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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.