Scientific J. Flowers & Ornamental Plants
www.ssfop.com/journal
ISSN: 2356-7864
doi: 10.21608/sjfop.2022.234594

THE ROLE OF SALICYLIC ACID IN REDUCING WATER REQUIREMENTS FOR *HIBISCUS ROSA-SINENSIS* L. PLANT

Magda A. Ahmed and S.M. Shahin
Botanical *Gardens* Res. Dept., Hort. Res. Inst., Agricultural Research Center, Giza, Egypt

ABSTRACT: This investigation was conducted under full sun conditions at the nursery of Hort. Res. Inst., A.R.C., Giza, Egypt during 2020 and 2021 seasons to examine the effect of salicylic acid (SA) as a foliar spray at concentrations of 0, 50, 75 and 100 ppm on growth, flowering and chemical composition of *Hibiscus rosa-sinensis* L. transplants grown in 16-cm-diameter plastic pots filled with about 1.6 kg of clay and subjected to four water treatments: 100% field capacity (F.C.) as control, 75, 50 and 25% of F.C. as water stress treatments. The effect of interactions between SA and water treatments was also studied. The results indicated that mean values of various vegetative and root growth parameters were progressively increased with increasing either water amount or SA concentration compared to the means of low levels of both, with few exceptions. Thus, the highest means of the different growth traits were attained by the highest levels of both water treatments (75 and 100% of F.C.) and SA ones (75 and 100 ppm) as well as their interactions, with the superiority of a combination between 75% of F.C. water treatment and SA spray at 75 ppm, giving almost the highest records. A similar trend was also obtained regarding flowering parameters and chemical composition of the leaves with the exception of chlorophyll a concentration that was slightly affected by the different treatments used in this study, and the percentages of P and K which were fluctuated, as well as proline concentration that was descendingly decreased with increasing either SA concentration or water quantity and their interactions. Thus, it can be recommended to spray *Hibiscus rosa-sinensis* L. plants with salicylic acid at 75 ppm, 3 times at 3-weeks intervals and irrigate them with only 75% of F.C. to save as much water as 25% of F.C. with keeping growth, flowering and quality of the plants.

Scientific J. Flowers & Ornamental Plants, 9(1):13-25 (2022).

Received:
24/1/2022
Accepted:
20/2/2022

Corresponding author:
Magda A. Ahmed
magabhameed@gmail.com

Key words: *Hibiscus rosa-sinensis* L., Rose of china, salicylic acid, water requirements, water stress, growth, flowering, chemical composition.

INTRODUCTION

Rose of China or Chinese hibiscus (*Hibiscus rosa-sinensis* L.) is a large beautiful evergreen, nearly glabrous shrub to 5-7 m height, belongs to Fam. Malvaceae. Leaves are usually simple, ovate, toothed, or nearly entire; grown mostly in subtropical and tropical regions for their profuse large, very showy flowers which are born solitary on the leaf axils, and also in glasshouses for the summer bloom (Bailey, 1976). *H. rosa-sinensis* is the most significant and appealing species in the genus *Hibiscus* that is widely grown across the globe (Khan *et al*., 2014). It is a potential source of many bioactive natural products, which are used in folk medicinal system, especially for curing liver disorders and hypertension (Yasmin, 2010). Moreover, Jadhav *et al*. (2009) stated that more than 100 million women worldwide are using *H. rosa-sinensis* with contraception's to suppress fertility with almost 100% confidence and complete return to fertility at will. It is also used for regulation of the menstrual cycle, diuretic, antitussive, dysentery, amenorrhea and abortion. Bhaduri and Fulekar (2015) reported that hibiscus species are effective for metal uptake and can be fitted in long-term phytoremediation programs for removal of toxicants.

Water deficit is still a great threat to sustainable agriculture because it usually reduces plant growth, dry biomass, relative water content (RWC), pigment content, net photosynthetic rate (Pn), transpiration rate (Tr), stomatal conductance (Gs), water use efficiency (WUE), but significantly increases proline level, malondialdehyde (MDA), hydrogen peroxide (H_2O_2) and electrolyte leakage, whereas antioxidative activity, including superoxidase (SOX), peroxidase (POD) and catalase (CAT) activities, declines (XiaMei *et al*., 2016). However, several reports affirmed that the application of salicylic acid (SA) may be an effective and cheap method for alleviating the different drought hazardous effects on various plant species. In this regard, Barth *et al*. (2006) mentioned that SA promotes flowering, retards senescence and serves as a co-factor for many enzymes. On gladiolus, Kumar *et al*. (2006) reported that SA at 100 ppm reduced No. days to flowering, decreased the respiration rate and increased flowering %, spike length, No. florets/spike, floret size and No. cormels/plot. Abdel-Fattah and Shahin (2007) found that spraying the foliage of *Scindapsus aureus* with SA at 200 ppm significantly increased plant length, stem diameter, No. branches and leaves/plant, leaf area, aerial parts and roots fresh and dry weights, as well as pigments, N, P and K contents in the leaves. In order to reduce the deleterious effects of water deficit on *Gardenia jasminoides* seedlings subjected to drought stress for 14 days, XiaMei *et al*. (2016) found that application of SA at 0.5-1.0 mMol significantly ameliorated seedlings growth and considerably improved pigments content, photosynthetic process, RWC, antioxidative activity and proline accumulation. On the contrary, MDA and H_2O_2 contents and electrolyte leakage were greatly decreased. Hence, spraying SA at a proper concentration could enhance the drought tolerance of *G. jasminoides*.

Similar observations were also obtained by Hussain *et al*. (2008) on sunflower, Abdel-Fatth *et al*. (2009) on *Schefflera actinophylla*, Alvarez *et al*. (2009) on carnation, Sanchez-Blanco *et al*. (2009) on geranium, Saadwy *et al*. (2019) on *Taxodium disticum*, Abbaszadeh *et al*. (2020) on rosemary, Mohammadi *et al*. (2017) on *Aloysia citrodora* (a medicinal plant) and Abbaspour *et al*. (2017) on grapes.

This study, however aims to reveal the role of salicylic acid in reducing water amount needed for best growth, flowering and quality of rose of China plant.

MATERIALS AND METHODS

A pot experiment was consummated under the full sun condition at the nursery of Hort. Res. Ins., ARC, Giza, Egypt throughout 2020 and 2021 successive seasons to evaluate the alleviative role of salicylic acid on rose of China plant in reducing water supply from full field capacity up to 25% only.

Therefore, 3-months-old homogenous transplants of *Hibiscus rosa-sinensis* L. (about 18-20 cm in length with 8-10 leaves) were individually planted on April, 15th for each season in 16-cm-diameter plastic pots, filled with about 1.6 kg of clay. The physical and chemical properties of the clay used in the two seasons were determined and illustrated in Table (a).

Immediately after planting, plants were irrigated with 250 ml of fresh water/pot, once every 3 days till May, 1st, as they received the following treatments:

1. Irrigation treatments: irrigation water was applied at four levels of field capacity (F.C.), i.e. 100% of F.C. (as control) and reduced to 75, 50 and 25% of F.C. (as

Table a. The physical and chemical properties of the clay used in 2020 and 2021 seasons.

Seasons	Particle size distribution (%):				S.P.	E.C. (dS/m)	pH	Cations (meq/l)				Anions (meq/l)		
	Coarse sand	Fine sand	Silt	Clay				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^-	Cl^-	SO_4^{--}
2020	8.33	15.88	32.13	43.66	42.36	2.37	8.15	15.78	10.48	20.41	0.79	5.76	6.89	34.81
2021	8.53	16.61	33.15	41.71	50.78	2.30	7.98	13.50	5.43	17.50	0.71	6.33	8.33	22.48

water stress treatments), once every two days till the end of the experiment (on October 15th). The F.C. of the used clay (1.6 kg) was determined and was equal to 300 ml/pot, so the quantity of water required for irrigation of each pot to attain 100, 75, 50 and 25% of F.C. treatments were: 300, 225, 150 and 75 ml/pot, respectively.

2. Salicylic acid (SA) treatments: SA was applied as a foliar spray till the run-off point at 0, 50, 75 and 100 ppm concentrations, 3 times with 3-week intervals.

3. Interaction treatments: as the treatments of both irrigation (4) and SA (4) were combined factorially to form 16 interaction treatments.

The layout of the experiment in the two seasons was factorial in a complete randomized design, with 3 replicates, as each replicate contained 3 pots (plants) (Mead *et al*., 1993). All plants under the different treatments received the usual agricultural practices whenever required. At the end of each season, the following data were recorded: plant height (cm), stem diameter (cm), number of branches/plant, number of leaves/plant, leaf area (cm^2), root length (cm), as well as stem, leaves, and roots fresh and dry weights (g), flower diameter (cm), petiole length (cm) and flower fresh and dry weights (g). In fresh leaf samples taken from the middle part of the plants, photosynthetic pigments (chlorophyll a, b, carotenoids, as mg/g f.w.) and total carbohydrates (%) were determined according to the methods of Sumanta *et al*. (2014) and Herbert *et al*. (1971), respectively, while in dry ones the percentages of nitrogen, phosphorus and potassium were measured using the methods described by Chapman and Pratt (1975). Besides, proline concentration as mg/100 g f.w. was colorimetrically evaluated in fresh leaf samples by the method of Batels *et al*. (1973).

Data were then tabulated and subjected to analysis of variance using the assistant software program explained by Silva and Azevedo (2016), followed by Duncan`s New Multiple Range t-Test (Steel and Torrie, 1980) for comparison between means.

RESULTS AND DISCUSSION

Vegetative and root growth parameters:

It is obvious from data averaged in Tables (1, 2, 3, 4, 5 and 6) that the mean values of plant height (cm), stem diameter (cm), No. branches and leaves/plant, leaf area (cm^2), root length (cm), as well as stem, leaves and roots fresh and dry weights (g) were progressively increased with increasing either water amount or SA concentration compared to the means of low levels of both, with few exceptions in the two seasons. So, the highest mean values of the different growth traits mentioned above were recorded with the highest levels of both water treatment (75 and 100% of F.C.) and SA ones (75 and 100 ppm), with the superiority of 75 % of F.C. water treatment and 75 ppm SA one, as these two treatments gave the highest records in most cases of the two seasons. This may be due to the role of SA as a growth regulator of phenolic nature in the regulation of physiological processes in plants and in mitigating abiotic stresses (Mohammadi *et al*., 2017). Furthermore, XiaMei *et al*. (2016) reported that SA application greatly reduced injuries of water deficit via improving pigments formation, consequently, photosynthesis process,

Table 1. Effect of water treatments, salicylic concentrations and their interactions on height and stem diameter of *Hibiscus rosa-sinensis* L. plant during 2020 and 2021 seasons.

Salicylic acid concentrations	Water treatments (% F.C.)									
	25%	50%	75%	100%	Mean	25%	50%	75%	100%	Mean
	Plant height (cm)					Stem diameter (cm)				
	First season: 2020									
0.00 ppm	34.1g	36.33g	40.00fg	52.50cd	40.75c	0.73c	0.77c	1.13ab	1.20ab	0.96b
50 ppm	38.20g	43.00e-g	53.50cd	64.50ab	49.80b	0.73c	0.77c	1.23ab	1.30a	1.01ab
75 ppm	40.33e-g	48.67d-f	58.50bc	64.83ab	53.08a	0.93bc	0.93bc	1.27a	1.37a	1.13a
100 ppm	35.00g	49.00de	54.00cd	71.83a	52.46a	0.77c	0.75c	1.40a	1.43a	1.09a
Mean	36.93d	44.26c	51.50b	63.42a		0.79b	0.80b	1.26a	1.33 a	
	Second season: 2021									
0.00 ppm	35.50h	38.67gh	43.00gh	56.67cd	43.71c	0.90e	0.88e	1.32a-d	1.32a-d	1.11b
50 ppm	37.33gh	46.33e-g	58.00cd	65.67bc	51.83b	0.92de	0.90e	1.33a-c	1.50ab	1.16b
75 ppm	42.00gh	53.83de	63.00bc	76.67a	58.88a	1.20b-e	1.15b-e	1.52ab	1.53ab	1.35a
100 ppm	43.33f-h	52.83d-f	63.67bc	70.83ab	57.67a	0.95c-e	0.93c-e	1.70a	1.63a	1.31a
Mean	39.79d	47.92c	56.92b	67.46a		1.00b	0.97b	1.47a	1.50a	

Means followed by the same latter in a column or row are not significantly different according to Duncan's New Multiple Range t-Test at 5 % level.

Table 2. Effect of water treatments, salicylic concentrations and their interactions on No. branches and leaves of *Hibiscus rosa-sinensis* L. plant during 2020 and 2021 seasons.

Salicylic acid concentrations	Water treatments (% F.C.)									
	25%	50%	75%	100%	Mean	25%	50%	75%	100%	Mean
	No. branches/plant					No. leaves/plant				
	First season: 2020									
0.00 ppm	2.67d	3.00d	4.00cd	3.67cd	3.34c	19.33k	36.67g-i	43.17e-h	46.33d-g	36.38c
50 ppm	4.00cd	4.00cd	5.00a-c	4.67bc	4.42b	25.00jk	37.67f-i	57.00a-c	47.50c-f	41.79b
75 ppm	5.33a-c	6.00ab	6.67a	5.00a-c	5.75a	27.33i-k	46.00e-g	62.00ab	56.67a-d	48.00a
100 ppm	5.33a-c	6.00ab	6.33ab	5.00a-c	5.67a	34.00h-j	41.67f-h	65.33a	53.00b-e	48.50a
Mean	4.33c	4.75b	5.50a	4.58b		26.42d	40.50c	56.87a	50.87b	
	Second season: 2021									
0.00 ppm	3.00e	3.85d	5.00cd	5.00cd	4.21c	21.33k	39.67g-i	46.67e-h	50.00d-g	39.42c
50 ppm	3.76d	5.33cd	6.00bc	6.33a-c	5.36b	27.17jk	41.33f-h	61.00a-d	51.67c-f	45.29b
75 ppm	5.00cd	6.00bc	7.33ab	8.00a	6.58a	33.50ij	49.67e-g	67.50ab	62.33a-c	53.25a
100 ppm	4.50d	5.33cd	7.50ab	8.00a	6.33a	36.83h-j	45.00f-h	70.00a	57.83b-e	52.42a
Mean	4.07c	5.13b	6.46a	6.83a		29.71d	43.92c	61.29a	55.46b	

Means followed by the same latter in a column or row are not significantly different according to Duncan's New Multiple Range t-Test at 5 % level.

Table 3. Effect of water treatments, salicylic concentrations and their interactions on leaf area and root length of *Hibiscus rosa-sinensis* L. plant during 2020 and 2021 seasons.

Salicylic acid concentrations	Water treatments (% F.C.)									
	25%	50%	75%	100%	Mean	25%	50%	75%	100%	Mean
	Leaf area (cm^2)					Root length (cm)				
					First season: 2020					
0.00 ppm	9.91gh	11.89fg	11.88fg	21.70b-d	13.85c	44.00e-g	39.00fg	46.00e-g	42.33fg	42.83d
50 ppm	10.51gh	13.35fg	13.20fg	24.69b	15.44b	50.50c-g	61.00a-d	49.00d-g	52.33c-g	53.21c
75 ppm	13.78fg	14.33ef	14.93ef	30.71a	18.44a	55.00b-f	65.50a-c	70.76a	69.33a	65.15a
100 ppm	11.73fg	13.50fg	18.36de	26.78ab	17.59a	59.00a-e	67.00ab	62.33a-c	48.33d-g	59.17b
Mean	11.48c	13.27b	14.60b	25.97a		52.12b	58.13a	57.02a	53.08b	
					Second season: 2021					
0.00 ppm	11.41gh	13.22fg	13.05fg	24.08bc	15.44b	38.85i	42.33hi	48.00f-i	45.00g-i	43.55d
50 ppm	11.51gh	14.51fg	14.51fg	24.78bc	16.33b	48.33f-i	65.83a-e	53.17e-g	53.00e-g	55.08c
75 ppm	13.16fg	20.93cd	16.09ef	33.38a	20.89a	59.50c-g	70.67a-c	76.50a	73.80ab	71.12a
100 ppm	14.95fg	18.22e	19.36de	26.86b	19.85a	54.33d-i	70.33a-c	66.33a-d	65.00a-d	64.00b
Mean	12.74c	16.72b	15.75b	27.27a		50.25b	62.29a	61.00a	59.20a	

Means followed by the same latter in a column or row are not significantly different according to Duncan's New Multiple Range t-Test at 5 % level.

Table 4. Effect of water treatments, salicylic concentrations and their interactions on stem fresh and dry weights of *Hibiscus rosa-sinensis* L. plant during 2020 and 2021 seasons.

Salicylic acid concentrations	Water treatments (% F.C.)									
	25%	50%	75%	100%	Mean	25%	50%	75%	100%	Mean
	Stem fresh weight (g)					Stem dry weight (g)				
					First season: 2020					
0.00 ppm	9.86g	13.65d-g	12.60e-g	15.80b-f	12.98c	2.89g	3.99e-g	3.91e-g	4.45d-f	3.81c
50 ppm	12.02fg	15.37b-f	13.69d-g	20.29ab	15.34b	3.45fg	4.77c-e	3.96e-g	5.50a-d	4.42b
75 ppm	14.74c-g	18.37a-d	17.60a-e	21.18a	17.97a	4.38d-f	5.57a-d	5.69a-c	6.55a	5.55a
100 ppm	16.44a-e	14.83c-g	17.16a-e	20.67a	17.28a	5.23b-d	4.85c-e	4.91c-e	6.19ab	5.30a
Mean	13.27c	15.56b	15.26b	19.49a		3.99c	4.79b	4.62b	5.67a	
					Second season: 2021					
0.00 ppm	11.03f	14.82d-f	13.77ef	21.30a-d	15.23c	3.75gh	4.45e-g	3.78gh	4.80d-g	4.20c
50 ppm	13.19ef	16.17c-f	15.20d-f	21.96ab	16.63b	3.98f-h	5.16c-f	4.17f-h	6.03a-d	4.84b
75 ppm	16.07c-f	20.04a-d	19.45a-d	22.51a	19.52a	4.85c-g	6.11a-c	6.20a-c	7.30a	6.12a
100 ppm	17.77a-e	16.54b-e	18.30a-e	22.55a	18.79a	5.86b-d	4.95c-g	5.50c-e	6.79ab	5.78a
Mean	14.52c	16.89b	16.69b	22.08a		4.61c	5.17b	4.91b	6.23a	

Means followed by the same latter in a column or row are not significantly different according to Duncan's New Multiple Range t-Test at 5 % level.

Table 5. Effect of water treatments, salicylic concentrations and their interactions on leaves fresh and dry weights of *Hibiscus rosa-sinensis* L. plant during 2020 and 2021 seasons.

Salicylic acid concentrations	Water treatments (% F.C.)									
	25%	50%	75%	100%	Mean	25%	50%	75%	100%	Mean
	Leaves fresh weight (g)					Leaves dry weight (g)				
					First season: 2020					
0.00 ppm	5.94g	7.58fg	10.42d-f	11.65b-f	8.90c	1.23e	1.70c-e	1.85c-e	2.38a-c	1.79b
50 ppm	7.61fg	9.38d-g	11.60b-f	12.30a-e	10.22b	1.33de	1.75c-e	2.10b-d	2.51a-c	1.92b
75 ppm	8.62e-g	10.12d-g	15.76ab	16.21a	12.68a	1.67c-e	1.95b-e	2.49a-c	3.16a	2.32a
100 ppm	10.75c-f	9.69d-g	13.20a-d	15.03a-c	12.17a	1.93b-e	1.78c-e	2.30a-c	2.79ab	2.20a
Mean	8.23b	9.19b	12.74a	13.80a		1.54c	1.80bc	2.18b	2.71a	
					Second season: 2021					
0.00 ppm	7.10g	8.58fg	11.75d-f	12.82b-f	10.06c	1.65d	2.08b-d	2.34b-d	2.66b-d	2.19b
50 ppm	8.61fg	10.70d-g	13.10a-f	13.65a-e	11.52b	1.91cd	2.24b-d	2.68a-d	3.18ab	2.50a
75 ppm	9.91e-g	11.50d-g	17.26ab	16.33a-c	13.75a	2.20b-d	2.60b-d	3.01a-c	3.91a	2.93a
100 ppm	11.91c-f	10.53d-g	14.54a-d	17.55a	13.63a	2.50b-d	2.33b-d	2.79a-d	3.27ab	2.72a
Mean	9.39b	10.33b	14.16a	15.07a		2.06c	2.31bc	2.71ab	3.25a	

Means followed by the same latter in a column or row are not significantly different according to Duncan's New Multiple Range t-Test at 5 % level.

Table 6. Effect of water treatments, salicylic concentrations and their interactions on roots fresh and dry weights of *Hibiscus rosa-sinensis* L. plant during 2020 and 2021 seasons.

Salicylic acid concentrations	Water treatments (% F.C.)									
	25%	50%	75%	100%	Mean	25%	50%	75%	100%	Mean
	Roots fresh weight (g)					Roots dry weight (g)				
					First season: 2020					
0.00 ppm	7.12h	12.10d-g	8.71f-h	8.90f-h	9.21c	3.30d-f	5.28c-e	3.75d-f	4.36c-e	4.17c
50 ppm	9.27e-h	16.39a-c	8.76f-h	8.99f-h	10.85bc	3.35d-f	8.40ab	4.33c-e	4.65c-e	5.18b
75 ppm	15.11b-d	19.94a	12.65c-f	13.20c-e	15.23a	7.61bc	9.97ab	5.86b-d	5.20b-e	7.16a
100 ppm	15.96a-d	18.34ab	9.10e-h	13.10c-e	14.13ab	8.25ab	10.12a	5.31b-e	4.93c-e	7.15a
Mean	11.86b	16.69a	9.81c	11.05b		5.63b	8.44a	4.81b	4.79b	
					Second season: 2021					
0.00 ppm	8.28g	9.40fg	13.60c-f	14.36cd	11.41c	3.75d-f	4.05d-f	5.63de	4.50d-f	4.48b
50 ppm	10.60d-g	10.15d-g	15.73cd	15.10cd	12.90bc	3.98d-f	4.36d-f	8.67ab	4.72d-f	5.43b
75 ppm	16.28bc	14.15c-e	19.50ab	19.86ab	17.45a	4.84d-f	5.79de	10.69a	8.96ab	7.57a
100 ppm	17.29bc	13.76c-f	21.60a	18.11b	17.69a	5.87de	5.68de	10.30a	7.99bc	7.46a
Mean	13.11b	11.87c	17.61a	16.86a		4.61c	4.97c	8.82a	6.54b	

Means followed by the same latter in a column or row are not significantly different according to Duncan's New Multiple Range t-Test at 5 % level.

relative water content (RWC), proline accumulation and antioxidative activity, which were accompanied with reducing malondialdehyde (MDA) content, $O_2^{.-}$, H_2O_2 and electrolyte leakage.

Luxurious water also improved RWC, minerals uptake and metabolism, whereas water stress usually reduces growth and dry biomass production. So, plant cells protect themselves naturally from such stress by accumulating a variety of small organic metabolites which are referred to as compatible solutes (Ashraf and Follad, 2007). Compatible solutes are small molecules very soluble in water, thus allowing the maintenance of turgor pressure during water stress (Hussain *et al*., 2008). In this regard, Alvarez *et al*. (2009) found that potted carnation plants subjected to moderate deficit water for 15 weeks showed a slight reduction in total dry weight, plant height and leaf area, while those submitted to severe deficit water had a clear reduction in all growth parameters. Stressed plants restored their natural growth by SA application (100 ppm), which prevented turgor loss during drought stress. A similar trend was also gained by Sanchez-Blanco *et al*. (2009) on potted geranium.

The interaction treatments exerted also marked effects on various growth traits mentioned before, where applying SA significantly improved overall plant growth under the different water treatments, especially when applied at 75 and 100 ppm concentrations and the water supply was increased up to either 75 or 100% of F.C. Therefore, combining between spraying with either 75 or 100 ppm SA and irrigating with either at 75 or 100% of F.C. gave, in general, the highest records over all the other combinations in the two seasons. However, these two combinations were statistically at par with each other for most of the studied parameters, with few exceptions in both seasons. This may be attributed to lumping between benefits of the suitable water amount and the proper SA concentration, which created ideal circumstances for good and healthy growth of plants.

In this concern, Mohammadi *et al*. (2017) suggested that the exogenous application of SA at 0.5 and 1.0 mM to drought-stressed *Aloysia citrodora* plants reduced MDA and H_2O_2 content and increased SOD and POX activities leading to minimize the negative effects of drought on bio-chemical and physiological parameters. Likewise, Saadawy *et al*. (2019) recommended to treat *Taxodium distichum* seedlings with SA at 0.5 g/l and irrigating with 75% of F.C. to achieve the highest means of plant height, No. branches, shoot dry weight and root fresh and dry weights. On *Rosemarinus officinalis*, Abbaszadeh *et al*. (2020) declared that combining between 60 % of F.C. water treatment and foliar spraying with either 1 or 2 mM SA was the best for better growth and higher production of essential oil. Besides, Abbaspour *et al*., (2017) showed that plant height, stem diameter and leaf area of “Rasheh” and “Bidanesefid” grape cvs. were noticeably decreased by raising water deficit, but were increased by 2 mM SA rather than the 0 and 1 mM rates.

Flowering parameters:

It can be seen from data listed in Tables (7 and 8) that means of flower diameter (cm), petiole length (cm) and flower fresh and dry weights (g) exhibited a progressive increment as the level of either water quantity or SA concentration was increased to reach maximum by both the greatest volume of water (100% of F.C.) and the highest concentrations of SA (75 and 100 ppm), with the dominance of 75 ppm concentration that gave higher records, to some extent than 100 ppm one with non-significant differences among themselves in both seasons.

Accordingly, the interaction between irrigating at 100% F.C. and SA application at 75 ppm scored the widest flower diameter, longest petiole and heaviest fresh and dry weights of flower indicating the prevalence

Table 7. Effect of water treatments, salicylic concentrations and their interactions on flower diameter and petiole length of *Hibiscus rosa-sinensis* L. plant during 2020 and 2021 seasons.

Salicylic acid concentrations	Water treatments (% F.C.)									
	25%	50%	75%	100%	Mean	25%	50%	75%	100%	Mean
	Flower diameter (cm)					Petiole length (cm)				
					First season: 2020					
0.00 ppm	7.37e	9.30b-d	9.50b-d	10.10ab	9.07b	2.33h	2.37h	2.43h	3.27e-g	2.60c
50 ppm	8.37de	9.50b-d	9.60b-d	10.73ab	9.55a	2.43h	3.07f-h	3.27e-g	4.30a-d	3.27b
75 ppm	8.43c-e	9.80b-d	10.00a-c	11.47a	9.93a	2.87gh	3.97b-e	3.75d-f	4.75a	3.84a
100 ppm	8.40de	9.70b-d	9.73b-d	10.78ab	9.65a	3.00f-h	3.25e-g	3.90c-e	4.65ab	3.70a
Mean	8.14c	9.58b	9.71b	10.77a		2.66c	3.17b	3.34b	4.24a	
					Second season: 2021					
0.00 ppm	7.55e	9.47b-d	9.65b-d	10.00b-d	9.17b	2.67hi	2.70hi	2.78g-i	3.48d-g	2.91c
50 ppm	8.45de	9.68b-d	9.90b-d	10.33ab	9.59a	2.70hi	3.23e-i	3.55d-f	4.50a-c	3.50b
75 ppm	8.57c-e	10.00b-d	10.13a-c	11.65a	10.09a	3.17f-i	4.22b-d	3.98c-e	5.00a	4.09a
100 ppm	8.65c-e	9.85b-d	10.00b-d	11.03ab	9.88a	4.33b-d	3.50e-h	3.97c-e	4.85ab	4.16a
Mean	8.30c	9.75b	9.92b	10.75a		3.22b	3.41b	3.57b	4.46a	

Means followed by the same latter in a column or row are not significantly different according to Duncan's New Multiple Range t-Test at 5 % level.

Table 8. Effect of water treatments, salicylic concentrations and their interactions on flower fresh and dry weights of *Hibiscus rosa-sinensis* L. plant during 2020 and 2021 seasons.

Salicylic acid concentrations	Water treatments (% F.C.)									
	25%	50%	75%	100%	Mean	25%	50%	75%	100%	Mean
	Flower fresh weight (g)					Flower dry weight (g)				
					First season: 2020					
0.00 ppm	1.33f	1.43ef	1.49ef	2.04b-d	1.57b	0.13g	0.16fg	0.18e-g	0.21c-f	0.17b
50 ppm	1.30f	1.43ef	1.75de	2.19a-c	1.67b	0.15fg	0.17e-g	0.21c-f	0.25a-c	0.20b
75 ppm	1.49ef	1.57ef	1.98cd	2.44a	1.87a	0.19d-f	0.25a-c	0.28a	0.28a	0.25a
100 ppm	1.40f	1.54ef	2.10a-c	2.34ab	1.85a	0.20c-e	0.18e-g	0.25a-c	0.27ab	0.23ab
Mean	1.38c	1.49c	1.83b	2.25a		0.17b	0.19b	0.23a	0.25a	
					Second season: 2021					
0.00 ppm	1.44h	1.53gh	1.94d-g	2.19b-e	1.78b	0.22e	0.28c-e	0.33c-e	0.40a-d	0.31b
50 ppm	1.48h	1.65gh	1.91d-g	2.41a-c	1.86b	0.26de	0.35b-e	0.35b-e	0.45a-c	0.35b
75 ppm	1.75f-h	1.82e-h	2.10c-f	2.55ab	2.06a	0.40a-d	0.50ab	0.46a-c	0.49ab	0.46a
100 ppm	1.51gh	1.69f-h	2.30a-d	2.66a	2.04a	0.41a-d	0.42a-d	0.38a-e	0.55a	0.44a
Mean	1.55c	1.67c	2.06b	2.45a		0.32b	0.39b	0.38b	0.47a	

Means followed by the same latter in a column or row are not significantly different according to Duncan's New Multiple Range t-Test at 5 % level.

of such interaction over all the others in the two seasons. This may indicate the importance of applying the suitable concentration of SA at the proper time to the drought-stressed plants. In this respect, XiaMei *et al*. (2016) noticed that application of SA, especially at concentrations of 0.5 and 1.0 mmol/l considerably enhanced the drought tolerance of stressed seedlings of *Gardenia jasminoids*. Moreover, Hussain *et al*. (2008) revealed that foliar spraying with SA at 0.724 mM was more effective on improving head diameter, No. achenes and 1000-achenes weight in water-stressed *Helianthus annuus* plants when applied at the flowering stage than at the vegetative one. In addition, Alvarez *et al*. (2009) pointed out that moderate deficit water (70% of the control) did not affect No. flowers of carnation, while severe one (35% of the control) produced lower No. flowers and flower dry weight. Likewise, a reduction in No. flowers per geranium plant was observed by Sanchez-Blanco *et al*. (2009) when it was supplied with water 40% of the control.

Chemical composition of the leaves:

Data presented in Table (9) cleared that chlorophyll a concentration (mg/g f.w.) was slightly affected by either water levels or SA treatments and their interactions giving mean values closely near together without a constant trend. However, concentrations of chlorophyll b and carotenoids (mg/g f.w.) were linearly increased as a result of increasing either water supply or SA concentration to be the highest at 75 and 100 ppm SA treatments and at 75 and 100% of F.C. water ones. Thus, the combined treatments between these two concentrations of SA (75 and 100 ppm) and water levels (75 and 100% of F.C.) attained mostly the highest concentrations of those two constituents.

The percent of nitrogen was found to progressively increase with raising either SA concentration or water volume (Table, 10). So, the highest N concentrations were acquired at the highest concentrations of SA (75 and 100 ppm) and the highest levels of water volume (75 and 100 of F.C.), as well as their interactions. On the other hand, the percentages of P and K were fluctuated as affected by either water treatments or interaction ones, but were gradually increased with the increasing of SA concentrations, where 75 and 100 ppm concentrations recorded the utmost high means, which were very close together with non-significant differences in between (Table, 10).

As for total carbohydrates %, data presented in Table (11) show that its values were consequently raised as the concentration of SA was elevated to reach the maximum with 75 and 100 ppm concentrations, with the excellence of 75 ppm concentration. A similar trend was also occurred regarding the effect of water treatments, as the progressive increment of water amount was accompanied by gradual increases in the percent of such constituent up to only 75% of F.C., but raising water supply afterward to 100% of F.C. decreased the percent of this component to the minimum (20.849% against 23.315% achieved at 25% water treatment).

The opposite was the correct concerning proline concentration (mg/100 g f.w.), as the mean values of this amino acid were descendingly decreased with increasing either SA concentration or water amount. Thus, the highest concentrations of proline were obtained at zero and 50 ppm SA, 25% of F.C. water treatment and their interactions, whereas the least concentrations were attained at 75 and 100 ppm SA, 100% of F.C. water treatment and their interactions, (Table, 11).

The previous gains may be reasonable because water shortage (drought) usually declines relative water content (RWC) in plants, photosynthetic pigments, net photosynthetic rate and transpiration rate, while it increases the levels of proline, malondialdehyde (MDA), hydrogen peroxide (H_2O_2), $O_2^{\cdot-}$ and electrolyte leakage. On the contrary, applying SA and increasing water

Table 9. Effect of water treatments, salicylic concentrations and their interactions on pigments concentration in the leaves of *Hibiscus rosa-sinensis* L. plant during 2021 season.

Salicylic acid concentrations	Water treatments (% F.C.)														
	25%	50%	75%	100%	Mean	25%	50%	75%	100%	Mean	25%	50%	75%	100%	Mean
	Chlorophyll a (mg/g f.w.)					Chlorophyll b (mg/g f.w.)					Carotenoids (mg/g f.w.)				
0.00 ppm	1.641	1.593	1.579	1.606	1.605	0.439	0.460	0.655	0.649	0.551	0.139	0.129	0.23	0.196	0.174
50 ppm	1.568	1.605	1.593	1.61	1.594	0.447	0.476	0.715	0.71	0.587	0.142	0.178	0.241	0.261	0.206
75 ppm	1.631	1.669	1.63	1.638	1.642	0.463	0.59	0.797	0.811	0.665	0.157	0.246	0.255	0.273	0.233
100 ppm	1.633	1.631	1.644	1.637	1.636	0.496	0.569	0.756	0.88	0.675	0.168	0.26	0.238	0.251	0.229
Mean	1.618	1.625	1.612	1.623		0.461	0.524	0.731	0.763		0.152	0.203	0.241	0.245	

Table 10. Effect of water treatments, salicylic concentrations and their interactions on nitrogen, phosphorus and potassium concentrations of *Hibiscus rosa-sinensis* L. plant during 2021 season.

Salicylic acid concentrations	Water treatments (% F.C.)														
	25%	50%	75%	100%	Mean	25%	50%	75%	100%	Mean	25%	50%	75%	100%	Mean
	N (%)					P (%)					K (%)				
0.00 ppm	1.106	1.550	1.658	1.306	1.405	0.345	0.440	0.398	0.539	0.431	1.236	1.243	1.242	1.243	1.241
50 ppm	1.548	1.660	1.990	1.931	1.782	0.585	0.490	0.533	0.591	0.55	1.247	1.265	1.268	1.261	1.260
75 ppm	2.212	1.771	2.123	2.432	2.135	0.610	0.583	0.617	0.600	0.603	1.293	1.271	1.276	1.276	1.279
100 ppm	1.699	1.990	2.133	2.213	2.009	0.714	0.51	0.543	0.617	0.596	1.259	1.282	1.270	1.255	1.267
Mean	1.641	1.743	1.976	1.971		0.564	0.506	0.523	0.587		1.259	1.265	1.264	1.259	

Table 11. Effect of water treatments, salicylic concentrations and their interactions on total carbohydrates and proline of *Hibiscus rosa-sinensis* L. plant during 2021 season.

Salicylic acid concentrations	Water treatments (% F.C.)									
	25%	50%	75%	100%	Mean	25%	50%	75%	100%	Mean
	Total carbohydrates (%)					Proline (mg/100 g f.w.)				
0.00 ppm	18.170	24.056	25.546	18.762	21.634	61.878	49.237	43.500	39.718	48.583
50 ppm	22.932	24.078	26.907	19.033	23.238	61.771	42.556	38.055	33.510	43.973
75 ppm	26.618	26.820	28.587	23.330	26.339	43.707	35.707	35.117	23.248	34.445
100 ppm	25.541	28.634	27.005	22.271	25.863	50.358	40.690	33.306	23.330	36.921
Mean	23.315	25.897	27.011	20.849		54.429	42.048	37.495	29.952	

supply improved photosynthetic pigments, photosynthesis and RWC, but decreased proline and MDA accumulation, H_2O_2 content and electrolyte leakage (XiaMei *et al*., 2016). Besides, these findings could be supported by those postulated by Abdel-Fattah and Shahin (2007) on *Scindapsus aureus*, Hussain *et al*. (2008) on *Helianthus annuns*, Abdel-Fattah *et al*. (2009) on *Schefflera actinophylla.* Sanchez-Blanco *et al*. (2009) clarified that exposure of geranium plants to water deficit led to a leaf water potential of -0.8 MPa, which caused a great reduction in stomatal conductance, chlorophyll content and photosynthetic rate.

In this connection, Saadawy *et al*. (2019) advised to treat *Taxodium distichum* seedlings with 1 g/l SA + 100% of F.C. to obtain the highest concentrations of total chlorophyll and total carbohydrates. Moreover, Mohammadi *et al*. (2017) indicated that water deficit stress significantly increased protein and proline contents and oxidative enzymes activity in *Aloysia citrodora* plants, whilst application of SA at 1.0 mM level reduced them. Hence, they suggested that SA minimizes the harmful effect of drought and could be used for amelioration of its stress on *A. citrodora*. On Rasheh and Bidanesefid grape cultivars, Abbaspour *et al*. (2017) noticed that leaf total soluble sugars and chlorophyll index were increased at 2 mM SA treatment compared to 0 and 1 mM rates.

According to the aforementioned results, it is preferable to spray the foliage of *Hibiscus rosa-sinensis* L. plants with salicylic acid at a rate of 75 ppm and irrigate them at only 75% of field capacity to get the best growth and flowering, and saving as much water as 25% of soil F.C

REFERENCES

Abbaspour, N.; Babaei, L. and Farrokhzad, A.R. (2017). The effect of salicylic acid application on some morphological and physiological characteristics of grape cultivars (*Vitis vinifera* L.) under drought stress conditions. J. Hort., Sci., 31(2):269-280.

Abbaszadeh, B.; Layeghhaghighi, M.; Azimi, R. and Hadi, N. (2020). Improving water use efficiency through drought stress and using salicylic acid for proper production of *Rosemarinus officinalis* L. Industrial Crops and Products, 144:111-118.

Abdel-Fatth, Gehan, H. and Shahin, S.M. (2007). Effect of foliar spray with vitamin C and salicylic acid on growth and chemical constituents of *Scindapsus aureus* Bunt. Fayoum J. Agric. Res. & Dev., 21(2):121-132.

Abdel-Fatth, Gehan, H.; Abdel-Moniem, Azza, M. and El-Shamy, M.A.I. (2009). Response of Australian umbrella tree transplants to some fertilization, salicylic acid and dry yeast treatments. Annals of Agric. Sci., Moshtohor, 47(2):275-283.

Alvarez, S.; Navarro, A.; Banon, S. and Sanchez-Blanco, M.J. (2009). Regulated deficit in potted *Dianthus* plants: Effects of severe and moderate water stress on growth and physiological responses. Scientia Hort., 122(4):579-585.

Ashraf, M. and Follad, M.R. (2007). Role of glycinebetaine and proline in improving plant abiotic stress resistance. Environ. & Experi. Botany, 59:206-216.

Bailey, L.H. (1976). Hortus Third. Macmillan Publishing Co., Inc., 866 Third Avenue, New York, N.Y. 10022. Collier Macmillan Canada Inc., USA, 1290 p.

Barth, C.; De Tullio, M. and Conklin, Patricia, L. (2006). The role of chemicals in the control of flowering time and the onset of senescence. J. Experim. Botany, 57(8):1657-1665.

Batels, L.S.; Waldern, R.P. and Tear, I.D. (1973). Rapid determination of free proline under water stress studies. Plant and Soil, 39:205-207.

Bhaduri, A.M. and Fulekar, M.H. (2015). Bio-chemical and RAPD analysis of *Hibiscus rosa-sinensis* induced by heavy metals. Soil Sediment. Contam., 24:411-422.

Chapman, H.D. and Pratt, R.E. (1975). Methods of Analysis for Soil, Plant and Water. California Univ., Division of Agric. Sci., pp. 172-173.

Herbert, D.; Phipps, P.J. and Strange, R.E. (1971). Chemical analysis of microbial cells. In: Norris, J.R. and Ribbons, D.W.

(eds.), Methods in Microbiology, Academic Press, USA, 5:209-344.

Hussain, M.; Malik, M.A.; Farooq, M.; Ashraf, M.Y. and Cheema, M.A. (2008). Improving drought tolerance by exogenous application of glycinebetaine and salicylic acid in sunflower. J. Agronomy & Crop Science, 194:193-199.

Jadhav, V.M.; Thorat, R.M.; Kadam, V.J. and Sathe, N.S. (2009). Traditional medicinal uses of *Hibiscus rosa-sinensis*. J. Pharmacy Res., 2(8):1220-1222.

Khan, Z.A.; Naqvi, S.A.; Mukhtar, A.; Hussain, Z.; Anjum, S.; Mansha, A.; Ahmad, M.; Zahoor, A.F.; Bukhari, I.H.; Janjua, S.A.; Mahmood, N. and Yar, M. (2014). Antioxidants and antibacterial activities of *Hibiscus rosa-sinensis* flower extracts. Pakistan J. Pharm. Sci., 27:469-474.

Kumar, P.N.; Reddy, Y.N. and Chandrashekar, R. (2006). Flower induction in gladiolus cormels by application of chemicals. J. Ornam. Hort., 9(3):174-178.

Mead, R.; Curnow, R.N. and Harted, A.M. (1993). Statistical Methods in Agriculture and Experimental Biology. 2nd Ed., Chapman & Hall Ltd., London, UK, 335 p.

Mohammadi, B.; Rezayian, M.; Ebrahimzadeh, H.; Hadian, J. and Mirmasoumi, M. (2017). Positive effects of salicylic acid on some biochemical and physiological parameters of *Aloysia citrodora* under drought stress. Progress in Biol. Sci., 7(2):147-157.

Saadawy, F.M.; Bahnasy, M.I. and El-Feky, H.M. (2019). Improving tolerability of *Taxodium distichum* seedlings to water salinity and irrigation water deficiency: 1. Effect of salicylic acid on water stress. Scientific J. Flowers & Ornam. Plants, 6(1):57-68.

Sanchez-Blanco, M.J.; Alvarez, Sara; Navarro, A. and Banon, S. (2009). Changes in leaf water relations, gas exchange, growth and flowering quality in potted geranium plants irrigated with different water regimes. J. Plant Physiol., 166(5):467-476.

Silva, F.A.S. and Azevedo, C.A.V. (2016). The assistant software, ver.7.7 and its use in the analysis of experimental data. Afr. J. Agric. Res., 11(39):3733-3740.

Steel, R.G.D. and Torrie, J.H. (1980). Principles and Procedures of Statistics. McGrow Hill Book Co., Inc., New York, USA, 633 p.

Sumanta, N.; Haque, C.I.; Nishika, J. and Suprakash, R. (2014). Spectrophotometric analysis of chlorophyllous and carotenoids from commonly grown fern species by using various extracting solvents. Res. J. Chem. Sci., 4(9):63-69.

XiaMei, Y.; Jing, M.; Jing, J.; Chun, O. and WenQiang, G. (2016). Effect of exogenous application of salicylic acid on the drought stress responses of *Gardenia jasminoides*. Sciences in Cold and Arid Regions, 8(1):54-64.

Yasmin, S. (2010). Studies on bioactive natural products of selected species of family Malvaceae. Ph.D. Thesis, Government College Univ., Lahore, Pakistan, 220 p.

دور حمض السالسيليك في خفض الاحتياجات المائية لنبات الورد الصيني *Hibiscus rosa-sinensis* L.

ماجدة عبد الحميد أحمد وسيد محمد شاهين
قسم بحوث الحدائق النباتية، معهد بحوث البساتين، مركز البحوث الزراعية، الجيزة، مصر

أجري هذا البحث تحت الشمس الساطعة بمشتل معهد بحوث البساتين، مركز البحوث الزراعية، الجيزة، مصر خلال موسمي ٢٠٢٠ و ٢٠٢١ لدراسة تأثير الرش الورقي بحمض السالسيليك بتركيزات: صفر، ٥٠، ٧٥، ١٠٠ جزء في

المليون على النمو، الإزهار والتركيب الكيماوي لشتلات الورد الصيني (*Hibiscus rosa-sinensis* L.) النامية في أصص بلاستيك قطرها ١٦ سم ومملوءه بحوالي ١,٦ كجم طين، تعرضت لأربع معاملات من مقننات مائية هي: ١٠٠٪ (كمقارنة)، ٧٥ ،٥٠، ٢٥٪ من السعة الحقلية (كمعاملات إجهاد مائي). وأيضاً تم دراسة تأثير التفاعلات المشتركة بين معاملات حمض السالسيليك ومعاملات المقننات المائيه. أوضحت النتائج المتحصل عليها أن متوسطات جميع قياسات النمو الخضري والجذري قد زادت تدريجيا بزيادة كل من كمية المياه المستخدمة في الري وتركيز حمض السالسيليك مقارنة بمتوسطات المستويات المنخفضة لهذه المعاملات، مع بعض الاستثناءات البسيطة بكلا الموسمين. لذلك، فإن أعلى متوسطات لقياسات النمو المختلفة تم الحصول عليها مع المستويات الأعلى لكل من معاملات الري (٧٥، ١٠٠٪ من السعة الحقلية) وحمض السالسيليك (٧٥، ١٠٠ جزء في المليون) والتفاعلات بينهما، مع تفوق المعاملة المشتركة بين الري بـ ٧٥٪ من السعة الحقلية والرش بحمض السالسيليك بتركيز ٧٥ جزء في المليون، حيث أعطت هذه التوليفة تقريباً أعلى القيم في كلا موسمي الدراسة. أيضاً، تم الحصول على إتجاه مشابه فيما يتعلق بصفات الإزهار والتركيب الكيماوي للأوراق، باستثناء تركيز كلوروفيل (أ) والذي تأثير قليلاً بالمعاملات المختلفة التي استخدمت بهذه الدراسة، والنسب المئوية لعنصري الفوسفور والبوتاسيوم والتي كانت بدون اتجاه واضح، وكذلك تركيزات البرولين والتي انخفضت بشكل تنازلي مع زيادة تركيزات حمض السالسيليك، كمية مياه الري والتفاعلات المشتركة بينهما. وعليه، يمكن التوصية برش أوراق نبات الورد الصيني (*Hibiscus rosa-sinensis* L.) بحمض السالسيليك بتركيز ٧٥ جزء في المليون، ثلاث مرات وبفاصل ثلاثة أسابيع بين كل رشتين مع ريها فقط بـ ٧٥٪ من السعة الحقلية للتربة المنزرع بها لتوفير نسبة من المياه المستخدمة في الري بما يعادل ٢٥٪ من السعة الحقلية مع الحفاظ على النمو، والإزهار والجودة للنباتات الناتجة.

.