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Improving *Begonia semperflorens* Quality By Foliar Application with Silicon Nanoparticles and Brassinolide

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ABSTRACT

Since silicon nanoparticles have distinctive physiological properties, they can enter plants and influence their metabolic processes. Brassinolide, a novel, eco-friendly plant growth regulator, works by controlling, altering, or enhancement plant growth processes, such as improving leaves and flowers, the elongation of stems, the evolution and maturity of fruit, etc. In order to learn more about the effects of foliar spraying *Begonia semperflorens* plants with brassinolide and SiNPs at rate of 0, 5, 10, and 15 mg $L^{-1}$and 0, 1, 3, and 5 mg L^{-1}, respectively, on vegetative and flowering measurements furthermore their chemical composition. The experiments were conducted at the Kafr El-Sheikh University Faculty of Agriculture's research farm in two consecutive years (2019–2020 and 2020–2021). Plant height and its diameter, branches number , both the fresh and dry weights of vegetative parts, and both the fresh and dry weights of roots were the parameters for vegetative growth. and flowering measurements (the weight of the flowers, both fresh and dry, and the number of flowers per plant) as well as chlorophyll (SPAD) and chemical compositions of leaves (N, P, K%)[. The obtained results indicated that, there were significantly increment for all traits by using both of Brassinolide and SiNPs compared with control in the both seasons. It was noticed that applying SiNPs at 15 mg L^{-1} and brassinolide at 3 mg L^{-1} led to the best values for all traits under study.

Keywords: Quality, Brassinolide, SiNPs, Vegetative growth, Chlorophyll, Flowering.

INTRODUCTION

The most widely grown begonia species is *Begonia semperflorens*. It is greatly used in the horticulture industry due to its various advantages, having a 30 cm maximum midget plant height, great branching features, and high disease resistance. As mentioned by Dewitte *et al.* (2009); Horn (2004) and Tebbitt (2005) despite a long breeding history, *B. semperflorens* still lacks yellow and orange flower colors. Instead, it contains red, white, and pink blooms. It has been suggested that *B. semperflorens* originated as a hybrid between *B. cucullata* Willd. and *B. schmidtiana* Regel in the same section of the Begonia genus.

Silicon plays an important role in plants by reducing several kinds of stress in plants, owing to its aggregation in various plant organs and its metabolic regulation according to Rajput *et al.* (2021). Moreover, silicon has been effective in improving the antioxidant enzymes of plants under stress conditions as reported by Verma *et al.* (2020).

Silicon is more functional at motivating responses in plants at the nanoparticles because of the material's properties at this scale. Silicon nanoparticles have useful effects on the growth, physiology, and protection of plants because they can enhance the processes of water intake and nutrient uptake; improve the photosynthetic and metabolism , thereby promote the activity of antioxidation as mentioned by Hatami *et al.* (2021) and Mukarram *et al.* (2021). Another advantage of using SiO2 NPs is that it eliminates the negative effects of Ultraviolet radiation, metal toxicity, high salinity stress, and biotic stress Rajput *et al.* (2021). SiO2 nanoparticles can be used in controlling pests, weeds, and as a nanofertilizers Xia *et al.* (2021). Si or SiNPs can be applied to leaves or roots using either approach, however according to Artyszak (2018) foliar applications are more practical and affordable than root applications. Additionally, it has been reported that silicon application via leaves is more efficient than applying silicon via the soil due to silicon's strong sorption to soil organics and minerals and its relatively low level of soil solubility Syu *et al.* (2016).

BRs are among the groups of growth regulators that were added to the five groups, where the sixth group of plant hormones were counted for the substantial evidence in their physiological effects on plants and in the majority of cases they demonstrated a similar impact to the effect of auxins, gibberellins and cytokinins Davies (2010). Brassinolide was extracted for the first time from the pollen of the plant *Brassica nopus*, and they have been identified as plant hormones produced in various parts of the plant and have demonstrated to have a significant impact on the growth of plant and evolution through their effects and contribution to the regulation of a number of aspects of growth and development in the plant, including both division and extension Cellularity, the vital structure of the cell wall's constituent parts, growth of branches, formation of adventitious roots, flowering, increase in production or yield Zhou *et al.* (2013); AL-Khafaji (2014); Chen and Fang (2015) and Fan (2016). BRs regulate a variety of vital processes in plants as cell expansion, stem cell protection, vascular expansion, cell protraction , and flowering bud development wang *et al.* (2020).

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Therefore, the purpose of the research was to investigate the impact of foliar spraying Begonia semperflorens with SiNPs and brassinolide at various concentrations on vegetative growth, flowering, and chemical composition.

MATERIALS AND METHODS

Plant material and growing conditions:

The research was achieved at Kafr El-Sheikh University Faculty of Agriculture's research farm, Egypt, (Latitude:31° 6.3792` N, Longitude: 30° 56.5184` E), during two seasons (2019–2020 and 2020–2021) in green house conditions. On early October uniform young transplants two months old with (8-10 cm) height of *Begonia semperflorens* Link & Otto collected from commercial nursery and were transplanted into 20 cm pots full with a blend of peat moss and perlite (2:1 v/v). Plants have been fertilized monthly till early March with 1 g/plant Kristalon (19N:19P:19K) (Asefbv, Netherlands). The plants were placed in a greenhouse with a 22.5 °C and 300 mmol/ m^2s^1 of light intensity. They were watered manually every week using equal water amount for irrigation each pot.

SiNPs and brassinolide treatments and experimental design:

The plants were sprayed three times (on both sides of the leaves) with solutions containing either SiNPs at concentrations of 1, 3, and 5 mg L−1 or brassinolide at concentrations of 1, 3, and 5 mg L−1 at intervals of two weeks, whereas control plants sprayed with distilled water. SiNPs with the purity of 99%, particle size of 20–35 nm and were obtained from Nanotechnology Laboratory, Faculty of Science, Kafr Elsheikh University, Kafr El-Sheikh, Egypt. Brassinolide solutions was obtained (Titan Biotech Ltd. Corporation, New Delhi, India). In addition, distilled water was applied to the leaves of untreated plants at the same time that SiNPs and brassinolide were delivered.. The experiment was coordinated in a randomized complete block design (RCBD) and included seven treatments with three replicates for each treatment.

Plant measurements and minerals estimation:

Vegetative growth:

Vegetative growth of plants included plant diameter, height of plant, number of branches, both fresh and dry weight of vegetative parts and roots, and chlorophyll was assessed on leaves using the SPAD-501Yadava (1986).

Flowering:

Flowering measurements were the number of flowers per plant and both fresh and dry weight per plant.

Minerals estimation:

For the purpose of determining the amount of minerals in the leaves, the leaves were collected from both seasons, sampled, and washed many times with tap water and distilled water before being oven dried at 70°C to a constant weight. The dried material was then crushed and digested with sulfuric acid and hydrogen peroxide in accordance with Evenhuis and Dewaard (1980). Calorimetric analysis was used to determine nitrogen according to Evenhuis (1976). Spectrophotometer was used to measure phosphorus according to Murphy and Riely (1962), while a flame photometer was used to determine potassium Jackson (1967).

Statistical analysis:

During the two experimental seasons, Duncan's New Multiple Range Test Steel and Torrie (1990) was utilised to compare the means of the treatment.

RESULTS AND DISCUSSION

Vegetative growth:

Tables 1 show that using SiNPs and brassinolide with different concentrations by foliar application gave significant increments in the most traits of *Begonia semperflorens* compared with the control. In first season the best plant height and diameter, the number of branches, the fresh and dry weight of vegetative parts, and the fresh and dry weight of roots were obtained by using the highest rate of 15 mg L−1 SiNPs and 3 mg L−1 brassinolide compared with control and the other treatment which were 25.6cm, 17.3cm, 9.8 branch, 74.9g, 4.7g, 7.5g and 2.9g, respectively for 15 mg L−1 of SiNPs and 23.6cm, 16.5cm, 8.5 branch, 71.2g, 4.6g, 6.1g and 2.6g, respectively for 3 mg L−1 of brassinolide. Also, in the second season the best values of same traits were obtained from the same concentrations of the two materials as were 26.5 cm. 16.5 cm, 10.0 branches, 70.1, 4.2, 7.9 and 2.9 gm, respectively for 15 mg L−1 and 25.3cm, 17.2 cm, 9.1 branch, 73.6, 4.1, 6.9 and 2.7 gm, respectively for 3 mg L−1 brassinolide. Brassinollide primarily serves to increase plant growth, particularly cell elongation and division, as well as promote other physiological processes Mayumi and Shibaoka (1995) and Prusakova *et al.* (1999).

Table 1. The impact of spraying silica nanoparticles and brassinolide on vegetative growth of *Begonia semperflorens* during both seasons:

Treatments	Concentrations mg L^{-1}	Plant height (cm)	Plant diameter (cm)	No. of branches/ plant	F.W. of vegetative parts (g)	D.W. of vegetative parts (g)	F.W. of roots (g)	D.W. of roots (g)
First season								
Control	0	18.39 d	11.14 d	6.00 d	40.00 d	2.46 c	4.12 d	1.48 bc
	5	22.49 bc	15.28 b	8.50 ab	54.76 c	2.95 b	4.85 c	1.60 b
SiNPs	10	23.55 b	16.16 ab	8.10 b	60.66 b	3.06 b	4.96 c	1.71 b
	15	25.66 a	17.34 a	9.80 a	74.98 a	4.77 a	7.58 a	2.90 a
	1	20.95 c	13.62 c	7.90 b	51.36 c	3.06 b	5.23 c	4.10 bc
Brassinolide	2	23.63 a	16.50 a	8.50 ab	71.22 a	4.69 a	6.16 b	2.63 a
	3	21.66 c	14.28 bc	6.30 bc	58.63 b	3.66 b	4.33 cd	1.53 b
Mean		22.30	14.90	68.10	58.80	3.52	2.53	1.89
Second season								
Control	0	17.12 d	12.85 c	7.66 c	41.87 d	2.47 c	4.09 d	1.24 d
	5	20.53 c	14.82 b	8.75 b	49.95 c	2.81 b	4.78 c	1.61 c
SiNPs	10	22.64 b	15.73 b	8.76 b	62.61 b	2.95 b	5.55 bc	2.06 b
	15	26.58 a	16.95 a	10.03 a	70.15 a	4.26 a	7.96 a	2.93 a
	1	21.71 b	14.63 b	8.08 bc	50.36 c	3.66 b	5.86 b	1.52 c
Brassinolide	2	25.36 a	17.27 a	9.18 ab	73.65 a	4.14 a	6.94 a	2.70 ab
	3	20.79 c	14.89 b	7.27 bc	60.54 b	3.27 b	5.05 c	2.06 b
Mean		22.10	15.31	8.53	58.45	3.37	5.75	2.02

The Duncan's multiple range test revealed that means in a column that are followed by the same letter are not significantly different at the 5% level (DMRT)

Brassinollide seems to produce protraction by affecting wall extensibility and boosting wall relaxation characteristics, according to Wang *et al.* (1993). Recent researches have shown that Si-NPs may interact directly with plants and have a variety of effects on their morphological and physiological processes as well as pigments content in the plants and the promotion of plant outgrowth and productivity Bao-shan *et al*. (2004); Strout *et al*. (2013) and Suriyaprabha *et al.* (2014). According to Yassen *et al.* (2017), the nano-Si spray increased the yield parameters and growth parameters compared to untreated plants. Also, Liang *et al.* (2007) and Vasanthi *et al. (*2014) cleared that silicon promotes K absorption while slowing Na absorption and increasing vegetative growth.

Flowering measurements:

SiNPs and brassinolide foliar spray had visibly and significant affects on the studied flowering growth characteristic during two seasons as shown in Fig. 1. The increase in no. of flowers, fresh and dry weight of flowers (g) was observed with an increase in different concentrations of 5, 10, and 15 mg L^{-1} for SiNPs and 1, 3, and 5 mg L^{-1} for Brassinolide in comparison with the control. The highest flower numbers were 69.23 and 72.6 flowers/ plant at 15 mg/L for SiNPs and 55.65 and 66.32 flowers/plant at 3 mg L^{-1} for brassinolide in the first and second seasons, respectively. However the heaviest f.w. of flowers were 16.7 and 17.43 g at 15 mg L^{-1} for SiNPs and 14.8 and 15.64 g at 3 mg L^{-1} for brassinolide in the first and second seasons, respectively. furthermore, the heaviest d.w. of flowers were 1.39 and 1.89 g at 15 mg L^{-1} for SiNPs and 1.23 and 1.75 g at 3 mg L^{-1} for brassinolide in first and second seasons, respectively. The lowest number recorded at low concentrations for SiNPs and brassinolide in two seasons.

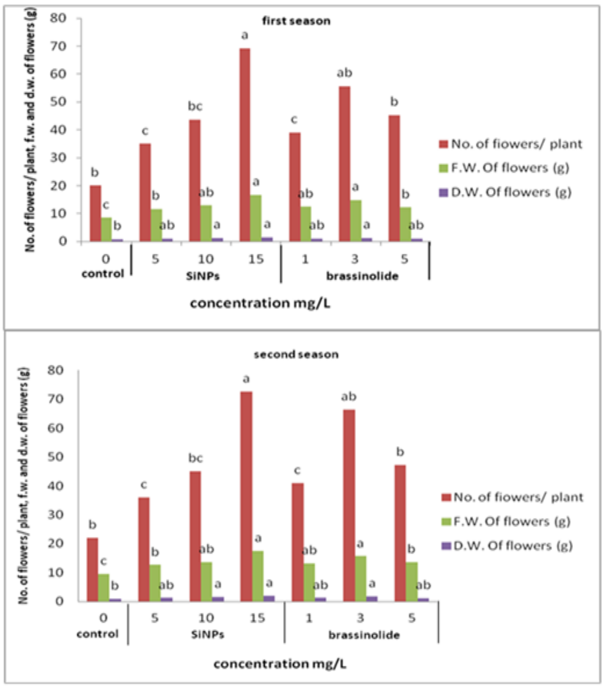

Fig. 1. The impact of spraying SiNPs and brassinolide on the flowering of *Begonia semperflorens* during two seasons.

This is in line with Debicz and Wróblewska (2011), who noticed an increment in average flower diameter and number of flowers at the highest silicon concentration for *Salvia farinacea*. Also, Debicz *et al*. (2016) reported that using a silicon increment the number of flowers on Gazania plants , *Salvia farinacea* and *Verbena hybrid* and it also increased the average flowers diameter of *verbena hybrida* and *Gazania rigens*. According to Magouz (2017), *Catharanthus roseus*, L. flowers number was considerably increased by silicon. Brassinolide foliar spraying improved plant growth and quality by increasing fruit and seed yields, promoting active constituents in the fruit pulp, and enhancing mineral content, oil production, and linoleic acid percentage regard to Atteya *et al.* (2022)..

Total chlorophyll:

Fig. 2 show that increasing SiNP and brassinolide concentrations foliar application increased leaf chlorophyll content with significant differences. The highest chlorophyll contents were 37.42 and 38.22 SPAD unit for SiNPs and 36.66 and 37.64 SPAD unit for brassinolide in both first and second seasons, respectively. The least values of chlorophyll were recorded at control and lower concentrations of SiNPs and BL. The increase in chlorophyll content caused by the use of silicon may be attributable to enhance photosynthetic rate and photochemical efficiency brought about by Si application, as well as to an increase in the number of grana and the enlargement of chloroplasts in leaves, or to the precipitation of si in the cell wall, which provides impedance and hardness, as mentioned by Epstein (1999). According to Abu Zaid (2000) who reported that the BL treatment increases the total chlorophyll percentage in addition to working to gather nutrients from the leaves and then increase the composition of the chlorophyll molecule. This may be because this regulator prevents the breakdown of this pigment by halting or decreasing the activity of the chlorophyll enzyme. Additionally, BL increased the amount of chlorophyll and leaf area in plants, as mentined by Iwahari *et al*. (1990).

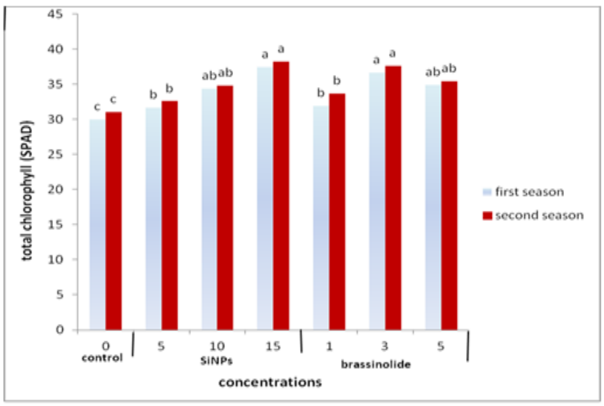

Fig. 2. The impact of spraying SiNPs and brassinolide on total chlorophyll of *Begonia semperflorens* during two seasons.

Leaf chemical compositions (N, P, K%):

Increasing concentrations of SiNPs and brassinolide foliar application for *Begonia semperflorens* increased leaf chemical compositions during two seasons as illustrated in Fig. 3. The increase in leaf chemical compositions may be related to the beneficial effects of foliar spraying brassinolide and SiO2 nanoparticles, which increase nutrient uptake while reducing the detrimental effects of salinity stress. The highest number of N, P, K % were recorded at higher concentrations of SiNPs and brassinolide, as they were 2.8, 0.44, and 3.28 % at 15 mg L^{-1} for SiNPs and 2.11, 0.42, and 3.49% for brassinolide in the first season, and 2.83, 0.48, and 3.49 % at 15 mg L^{-1} for SiNPs and 2.87, 0.46, and 3.39 % for brassinolide in the second season. In line with our findings, an increase in the amount of N in gerbera (Gerbera jamesonii) was reported by Savvas *et al*. (2007) and in rice by Neeru *et al*. (2016); Siddiqui and Al-Whaibi (2014); Gui *et al.* (2015) and Lui *et al.* (2015). spraying SiO2 nanoparticles reduced nitrogen release and increment N accumulation in the leaves. Si is also known to preserve a balance between macronutrients (N, P) and micronutrients like zinc and manganese, furthermore to increase the soil's availability of nutrients to plants, notably P. White *et al.* (2017).This could be due to brassinolides' role in increasing root length, size, and diameter as this makes it easier for the plant to absorb nutrients like nitrogen Bera *et al*. (2008). The fact that brassinolide promotes the uptake and utilization of soil nutrients for plant growth accounts for its advantageous effects. Due to the high uptake of soil minerals like nitrate and representation, it also enhances the nitrogen content of the leaves of the treated plants El-Khallal *et al*. (2009). It is positively reflected in Brassinolide's work to increment the potassium content in the plant Bera *et al*. (2008). Also, findings demonstrated brassinolide contribution to increase in nutrients and hormone content in the leaves was a result of its involvement in boosting most of the analysed features and having a favourable impact on soil nutrient absorption Ross and Quittenden (2016). Kuno (1987) discovered increased phosphorus translocation but decreased calcium content in mulberry leaves after BR treatment. Prior studies Pirogovskya *et al*. (1996); Ronch *et al*. (1993) made the case that brassinolides were used to help plants effectively absorb nutrients from the soil. Karlidag *et al.* (2009) mentioned that external addition of another plant growth regulator, salicylic acid, led to increment mineral content in the strawberry roots, including potassium, calcium, iron.

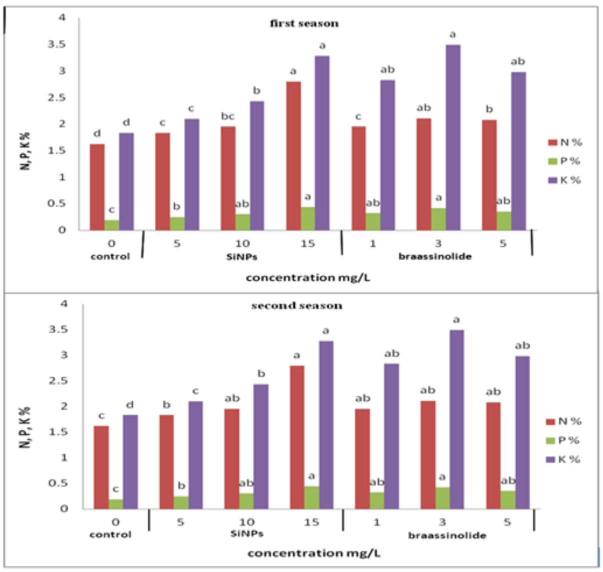

Fig. 3. The impact of spraying SiNPs and brassinolide on leaf chemical compositions of *Begonia semperflorens* during both seasons.

CONCLUSION

Applying SiNPs and brassinolide at different concentrations by foliar application significantly increased all growth traits of *Begonia semperflorens* compared to untreated plants. From the research results, conducted in two consecutive seasons under the same conditions, it can be recommended to spray *Begonia semperflorens* with SiNPs at 15 mg L^{-1} and Brassinolide at 3 mg L^{-1} to improve vegetative growth, flowering measurements, total chlorophyll (SPAD) and leaf chemical compositions (N, P, K%).

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تحسين جودة البيجونيا سمبرفلورنس بالرش الورقي بجزيئات النانو سيليكون والبراسينوليد

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الملخص

تتمتع جزيئات النانو سيلكون بخصائص فسيولوجية مميزة تسمح لها بدخول النباتات والتأثير على أنشطة التمثيل الغذائي للنبات .بينما يعتبر البراسينوليد منظمًا جديدًا لنمو النبات صديقًا للبيئة يعمل من خلال التحكم في عمليات نمو النبات و تنظيمها ، مثل تكوين الأوراق والازهار واستطالة السيقان وتطور الثمار ونضجها. أجريت هذه التجربة في المزرعة التجريبية لكلية الزراعة جامعة كفر الشيخ في موسمين متتالين 2020/2019 – 2021/2020 لدراسة تأثير الرش الورقي بجزيئات النانو سيلكون والبراسينوليد على نبات البيجونيا سمبرفلورنس. وقد تم استخدام تركيزات مختلفة من المادتين تحت الدراسة حيث كانت (0 ، 5 ، 10 ، 15) ملجم / لتر لمادة النانو سيلكون و (0 ، 1 ، 3 ، 5) ملجم / لتر لمادة البراسينوليد. وتم دراسة الصفات التالية: النمو الخضري (طول النبات ، قطر النبات ، عدد الأفرع ، الوزن الطازج و الجاف للأجزاء الخضرية ، الوزن الطازج و الجاف للجذور) وقياسات الإزهار (عدد الأزهار لكل نبات ، الوزن الطازج و الجاف للأزهار (جم) بالإضافة إلى المحتوى الكلى للكلوروفيل و محتوى الاوراق من النيتروجين و الفسفور و البوتاسيوم . أشارت النتائج المتحصل عليها إلى زيادة معنوية لجميع المعاملات بزيادة التركيز من 0 ل 15 ماجم/ لتر لمادة النانو سيليكون ومن 0 الى 3 ملجم/لتر لمادة البراسينوليد فى الموسمين. لقد لوحظ ان رش اوراق نبات البيجونيا بجزيئات النانو سيلكون بتركيز 15 ملجم/لتر ومادة البراسينوليد بتركيز 3 ملجم/لتر سجلت أعلى قيم للقياسات تحت الدراسة.