Scientific J. Flowers & Ornamental Plants
www.ssfop.com/journal
ISSN: 2356-7864 **doi: 10.21608/sjfop.2022.248726**

GROWTH CONTROL OF HIBISCUS POT PLANTS BY FOLIAR SPRAYING WITH PACLOBUTRAZOL AND TWO SOURCES OF POTASSIUM

T.M. Noor El-Deen* and Hanan M. Abou El-Ghit**
* Ornamental Plants and Landscape Gardening Res. Dept., Horticultural Res. Inst., Agricultural Res. Center, Giza, Egypt
** Botany and Microbiology Dept., Fac. of Science, Helwan Univ., Egypt

Scientific J. Flowers & Ornamental Plants, 9(1):69-86 (2022).

Received:
24/1/2022
Accepted:
13/2/2022

Corresponding author:
T.M. Noor El-Deen
tarek.noor@arc.sci.eg

ABSTRACT: In a trial to get an ideal growth of *Hibiscus rosa-sinensis* cv. Cooperi, a factorial pot experiment was carried out at the Botanical Garden of the National Gene Bank, Agricultural Research Center, Giza, Egypt during 2020 and 2021 seasons. Foliar spraying with both paclobutrazol (PBZ) at different levels (0, 50, 100 and 150 ppm) and two sources of potassium (K-sulfate at 1.5 and 3.0 g/l and K-humate at 2.0 and 4.0 g/l) and their interactions were applied. Vegetative growth, flowering parameters and some chemical constituents were evaluated. The results indicated that increasing PBZ level resulted in the lowest values for most studied parameters except PBZ at 100 ppm as recorded the highest values of number of leaves, branches and flowers/plant, vegetative growth fresh and dry weights, chlorophylls (a and b), carotenoids and indoles. Foliar spraying with two potassium sources was superior to control (without potassium foliar spraying) as recorded higher values. Integration of potassium foliar spraying reversed the undesirable effects of spraying with PBZ alone in particular at the high levels. The mastery was to PBZ at 100 ppm + K-humate at 2.0 g/l as recorded the highest values in most cases i.e. number of leaves, branches and flowers/plant, vegetative growth fresh and dry weights, chlorophylls (a and b), carotenoids and indoles. To produce high-quality *Hibiscus rosa-sinensis* cv. Cooperi pots, it is advised to treat the plants with PBZ at 100 ppm + K-humate at 2.0 g/l for 6 times at 2-week intervals.

Key words: *Hibiscus rosa-sinensis* cv. Cooperi, paclobutrazol, potassium sulfate, humate, growth, flowering, chemical constituents.

INTRODUCTION

Hibiscus is a genus of more than 200 species of deciduous and evergreen shrubs, trees, annuals, and herbaceous perennials, widely distributed in warm-temperate subtropical and tropical regions. *Hibiscus rosa-sinensis* shrubs are exotic and make great container plants on patios and decks (Nau, 2011). *H. rosa-sinensis* (rose of China) is a rounded, bushy, evergreen, large shrub or small tree with hairless or slightly hairy shoots and ovate to broadly lance-shaped, glossy, dark green leave (15 cm long), with toothed margins. Solitary, 5-petaled, bright crimson flowers, 10 cm across, with yellow anthered red stamens, are produced from the leaf axils from the summer to autumn. Flower colors range from crimson to orange, yellow, or white. Cooperi cultivar of *H. rosa-sinensis* is a compact (1-2 m), with lance-shaped leaves marbled olive green and white, sometimes tinted pink and bearing red flowers (Brickell, 1997).

To regulate the growth of ornamental plants throughout the production program, a lot of scenarios are adopted. Applying chemical retardants is one of these scenarios. Paclobutrazol (PBZ) as a chemical retardant is widely used to control the growth of plants. Bailey (1998) reported that many floriculture crops had been foliar sprayed with PBZ at different concentrations to control their height e.g. freesia (100 to 300 ppm), azalea and caladium (100 to 200 ppm), potted chrysanthemum (50 to 200 ppm), bedding plants (6 to 66 ppm), dianthus (5 to 60 ppm), celosia (4 to 50 ppm), ageratum, coleus and dahlia (5 to 45 ppm) and poinsettia (10 to 30 ppm). Bañón *et al.* (2009) cleared that paclobutrazol is used on ornamental crops with the aim to reduce the plant's height and to improve compactness and the other functional aspects. Positive effects of PBZ were reported on a lot of ornamental plants e.g. *Hibiscus rosa-sinensis* (Maus, 1987 and El-Sadek, 2016), poinsettia (Villegas and Lozoya, 1992), *Rhododendron obtusum* (Wilfret and Barrett, 1995), *Fuchsia magellanica* cv. Beacon (Gad *et al.*, 1997), potted poinsettia (El-Sallami, 2001), *Hibiscus coccineus*, *H. radiatus* and *H. trionum* (Warner and Erwin, 2003), *Lantana camara* (Matsoukis *et al.*, 2004), *Azalea japonica* (Meijón *et al.*, 2009), gaillardia (Saiyad *et al.*, 2010 and Vasoya *et al.*, 2015), snapdragon (Shanan and Soliman, 2011), *Tagetes erecta* L. (Rathore and Mishra, 2014), *Chrysanthemum carinatum* (Shahin *et al.*, 2014), ornamental pepper (Mutlu and Agan, 2015), *Lagerstroemia indica* (Mohamed, 2016) and *Ruellia simplex* (Noor El-Deen, 2020).

Potassium (K) is essential for many physiological reactions within the cell: osmosis control, drought, disease and frost resistance. It influences the uptake of other nutrients, e.g. Mg (Brown, 2002), it is the second most abundant mineral nutrient in plants after nitrogen and is involved in more than 60 enzymes, in photosynthesis and the movement of its products to storage organs, water economy. Also, it plays a role in regulating the stomatal opening and internal water relations of plants. K deficient plants may lose control over the rate of transpiration and suffer from internal drought (Simson, and Straus, 2010). There are a lot of available sources to supply plants with potassium e.g. potassium sulfate and potassium humate.

Potassium sulfate (K_2SO_4), also called sulphate of potash contains 48 to 54% potassium (as K_2O) and supplies 17 to 20% of sulphate (Gowariker *et al*., 2009). A positive role of potassium sulfate was observed on some ornamental plants by many authors e.g. Waly *et al.* (2001) and Abdullatif and Hamad (2019) on gladiolus and Abd El-Gayed and Knany (2020) on *Antirrhinum majus.*

Potassium humate is the potassium salt of humic acid, it is water-soluble and dark-colored (Kadam *et al*., 2011). To extract humic acid from leonardite, potassium hydroxide is used as a typical alkali, cause the remaining liquid solution is very alkaline, the product of adding acid to an alkaline solution, is a salt, therefore the word "humate" may be more appropriate (Kumar *et al*., 2013). Humic substances are used in agriculture as a fertilizer additive to increase the use efficiency of fertilizers, especially nitrogen and phosphorus, so they can regulate plant growth and provide potassium for plant growth (Pradip *et al*., 2016). Many authors proved the positive effects of potassium humate e.g. Heikal (2017) on *Salvia farinacea*, Shyala *et al.* (2019) on *Tagetes erecta*, Noor El-Deen and El-Ashwah (2019) on *Asparagus densiflorus* 'Meyerii', Badran *et al.* (2019) on *Calendula officinalis* and Mohamed and Ghatas (2021) on *Achillea millefolium*.

The present study was conducted to investigate the effect of foliar spraying with paclobutrazol (PBZ) and two sources of potassium (sulfate and humate) on hibiscus (*Hibiscus rosa-sinensis* cv. Cooperi) produced as pot plants.

MATERIALS AND METHODS

To investigate the effect of foliar spraying with paclobutrazol (PBZ) and two sources of potassium (K-sulfate and K-humate) on hibiscus (*Hibiscus rosa-sinensis* cv. Cooperi) plants, a pot experiment was carried out at the Botanical Garden of the National Gene Bank, Agricultural Research Center, Giza, Egypt during 2020 and 2021 seasons, to produce high-quality hibiscus pot plants.

Plant material:

In the first week of July each season, *Hibiscus rosa-sinensis* cv. Cooperi transplants (about 25-cm-height with three branches) were obtained from a local nursery in Al-Qanatir Al-Khayryah, Qalyubia Governorate, Egypt. They were then transplanted into 16-cm-plastic pots filled with about 225 g of peat moss + perlite (1:1, by volume). After two weeks (mid-July each season), all plants were pinched at 23 cm height. Meteorological parameters at Giza Governorate during the 2020 and 2021 seasons were collected from NASA Power Data Access Viewer Program (https://power.larc.nasa.gov) then edited and shown in Table (1). At the beginning of August each season, the treatments were started.

Experimental layout:

This experiment was laid out as a factorial experiment in a randomized complete block design (RCBD) (Gomez and Gomez, 1984) with two factors; foliar spraying with 4 concentrations of paclobutrazol (0, 50, 100, and 150 ppm) represented factor (A). While, foliar spraying with 5 concentrations of different potassium sources (without spraying, potassium sulfate at 1.5 and 3.0 g/l, potassium humate at 2.0 and 4.0 g/l) represented factor (B). So, this experiment contained 20 treatments, each treatment was replicated three times, and each replicate contained 5 pots.

Foliar spraying with paclobutrazol (PBZ):

To obtain the required concentrations employed in this study i.e. 50, 100 and 150 ppm, paclobutrazol was dissolved in distilled water to prepare solutions with desired concentrations. In this regard, PBZ at 0.0 ppm refers to the plants sprayed with distilled water only. Plants were foliar sprayed for 6 applications till runoff. The first one was done on August, 16^{th} and 17^{th} (for the first and second seasons, respectively) and then at 2-week intervals. Paclobutrazol ($C_{15}H_{20}ClN_3O$, MW: 293.80) manufactured in the USA was obtained from a local company in Egypt.

Foliar spraying with potassium sources:

Two sources of potassium were employed in this study. Commercial potassium sulfate fertilizer (K_2SO_4) containing 48% K_2O and 18% sulphur was used as a first source of potassium at 1.5 and 3.0 g/l. The commercial product Hummer (containing 85% humic acid and 10% K_2O) was used as a source of potassium humate at

Table 1. Some meteorological parameters at Giza Governorate, Egypt during 2020 and 2021 seasons.

Months	Temp. °C		Temp. max °C		Temp. min °C		R.H. (%)		Precip. (mm/day)		W.S. (m/s)	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
July	30.05	30.79	38.81	39.27	21.58	22.48	42.90	41.15	0.00	0.00	3.11	2.98
August	30.17	31.08	38.89	39.73	22.00	22.90	45.33	42.80	0.00	0.00	2.81	2.84
September	29.46	28.00	38.19	36.04	21.85	20.90	50.43	50.72	0.00	0.00	3.19	3.20
October	25.44	23.92	33.30	31.52	19.13	17.72	57.28	55.18	0.02	0.05	2.98	2.98
November	18.90	20.78	24.92	27.90	13.84	15.37	63.18	61.13	0.35	0.25	2.41	2.41
December	15.64	13.68	22.57	19.73	10.47	9.02	60.63	65.54	0.02	0.19	2.27	2.65

Temp. °C: temperature at 2 meters, Temp. max °C: maximum temperature at 2 meters, Temp. min °C: minimum temperature at 2 meters, R.H. (%): relative humidity at 2 meters, Precip. (mm/day): precipitation, W.S. (m/s): wind speed at 2 meters.

2.0 and 4.0 g/l. In this regard, spraying with distilled water only refers to control. Both potassium sulfate and humate were dissolved in distilled water to prepare the required concentrations. The plants were foliar sprayed 6 times at 2-week intervals, the first one was done after one week of spraying with paclobutrazol (on August, 23rd and 24th for the first and second seasons, respectively).

Data recorded:

At the beginning of December (1st and 2nd December for the first and second seasons respectively), the following data were recorded:

1. Vegetative growth and root parameters:

Plant height (cm), number of branches/plant, number of leaves/plant, leaf area (cm^2) and vegetative growth fresh and dry weights (g). To measure leaf area the method described by Ferreira and Rasband (2012) was adopted, by scanning fresh leaf samples with a digital scanner at a resolution of 300 dpi then ImageJ software was used to calculate the leaf area. In addition, root length for the longest root (cm), and roots' fresh and dry weights (g) were measured.

2. Flowering parameters:

Number of flowers/plant was counted at the full opening stage for each treatment from the beginning of bloom till the experiment was terminated. Flower diameter (width; mm). Flowers' fresh and dry weights (g) were also recorded.

3. Chemical constituents:

At the beginning of December 2021, the chemical analysis was performed as follows: in fresh leaf samples, chlorophylls (a and b) and carotenoids pigments (mg/g f.w.) were determined (Wellburn and Lichtenthaler, 1984). In dry leaf samples, the percentage of potassium (Jackson, 1973), percentage of total carbohydrates (Herbert *et al.*, 1971), total indoles (mg/100 g d.w.) contents (Larsen *et al.*, 1962), and percentage of total phenols (A.O.A.C., 1980) were determined.

Statistical analysis:

MSTAT Computer Program (MSTAT Development Team, 1989) was used to statistically analyze the obtained data. The means of various treatments were compared using Duncan's Multiple Range Test according to Duncan (1955).

RESULTS

Vegetative growth characteristics:

Paclobutrazol concentrations (PBZ) greatly influenced all studied vegetative growth traits (Tables, 2 and 3). In this regard, both plant height and leaf area were significantly reduced to the lowest values as the PBZ concentration was increased up to 150 ppm (27.85 and 29.47 cm for plant height and 11.94 and 13.94 cm^2 for average leaf area in the first and second seasons, respectively). Control plants (without the treatment of PBZ) gave the highest values in this concern (64.51 and 61.05 cm for plant height and 19.12 and 20.85 cm^2 for leaf area in the first and second seasons, respectively). On the other hand, PBZ at 100 ppm resulted in the highest values in both seasons in terms of number of branches (11.04 and 12.28), number of leaves (95.28 and 100.50), vegetative growth fresh (48.68 and 49.93 g), and dry weights (15.83 and 16.97 g/plant).

Spraying with different potassium sources showed significant influences on vegetative growth traits. The highest values were recorded by spraying with K-humate at 2.0 g/l as recorded 48.82 and 48.02 for plant height, 18.01 and 19.76 cm^2 for average leaf area, 102.20 and 106.80 for number of leaves, 51.56 and 52.97 g for vegetative growth fresh weight, and 15.81 and 17.00 g for vegetative growth dry weight in the first and second seasons, respectively. The only exception was for number of branches/plant which recorded the highest values by spraying with K-sulfate at 3.0 g/l (11.62 and 12.70, in both seasons, respectively). Control plants recorded the lowest values for all vegetative growth traits.

Table 2. Effect of foliar spraying with paclobutrazol (PBZ), two sources of potassium and their interaction on plant height (cm), number of branches and leaves/plant of *Hibiscus rosa-sinensis* cv. Cooperi during 2020 and 2021 seasons.

Potassium sources (B)	PBZ concentrations (ppm) (A)									
	0.0	50	100	150	Mean (B)	0.0	50	100	150	Mean (B)
	2020					2021				
	Plant height (cm)									
Cont.	60.17 b	51.33 de	46.67 fg	25.67 j	45.96 c	58.33 cd	44.50 f	37.00 h	27.33 j	41.79 b
K-sulfate 1.5 g/l	72.27 a	53.00 c-e	39.33 h	29.27 ij	48.47 ab	63.80 b	53.00 e	41.67 fg	31.27 i	47.43 a
K-sulfate 3.0 g/l	56.47 bc	43.67 gh	33.00 i	26.67 j	39.95 d	55.60 de	44.33 f	39.33 gh	28.00 ij	41.82 b
K-humate 2.0 g/l	73.07 a	50.00 ef	42.87 gh	29.33 ij	48.82 a	67.73 a	52.00 e	41.00 fg	31.33 i	48.02 a
K-humate 4.0 g/l	60.60 b	55.67 cd	41.00 h	28.33 j	46.40 bc	59.80 c	56.93 cd	39.07 gh	29.40 ij	46.30 a
Mean (A)	64.51 a	50.73 b	40.57 c	27.85 d		61.05 a	50.15 b	39.61 c	29.47 d	
	Number of branches/plant									
Cont.	6.47 ij	7.20 hi	7.00 h-j	5.67 j	6.58 c	7.47 ij	8.20 i	8.13 i	6.33 j	7.53 c
K-sulfate 1.5 g/l	8.27 gh	8.73 fg	12.00 bc	11.33 b-d	10.08 b	8.07 i	9.53 h	13.13 bc	12.47 cd	10.80 b
K-sulfate 3.0 g/l	10.40 de	9.73 ef	12.67 ab	13.67 a	11.62 a	11.20 d-g	11.07 e-g	13.87 ab	14.67 a	12.70 a
K-humate 2.0 g/l	8.73 fg	10.40 de	14.07 a	10.67 c-e	10.97 a	10.00 gh	11.33 d-f	14.93 a	12.13 c-e	12.10 a
K-humate 4.0 g/l	10.27 de	9.47 e-g	9.47 e-g	10.00 d-f	9.80 b	11.13 e-g	10.13 f-h	11.33 d-f	10.67 f-h	10.82 b
Mean (A)	8.83 c	9.11 c	11.04 a	10.27 b		9.57 c	10.05 c	12.28 a	11.25 b	
	Number of leaves/plant									
Cont.	75.67 g	68.00 h	65.67 h	62.33 h	67.92 d	79.67 k	77.33 k	67.93 l	64.67 l	72.40 c
K-sulfate 1.5 g/l	79.67 fg	99.33 c	101.70 bc	89.00 de	92.42 c	87.33 h-j	105.30 de	106.70 c-e	92.67 gh	98.00 b
K-sulfate 3.0 g/l	97.67 c	89.67 d	97.67 c	100.70 bc	96.42 b	102.70 de	91.33 g-i	101.00 ef	107.30 b-d	100.60 b
K-humate 2.0 g/l	83.67 ef	108.30 a	110.30 a	106.30 ab	102.20 a	85.67 ij	113.00 ab	115.30 a	113.30 a	106.80 a
K-humate 4.0 g/l	88.00 de	96.67 c	101.10 bc	78.00 fg	90.93 c	95.67 fg	101.70 de	111.70 a-c	82.67 jk	97.92 b
Mean (A)	84.93 c	92.40 b	95.28 a	87.27 c		90.20 c	97.73 b	100.50 a	92.13 c	

Means having the same letter are not significantly differed at 0.05 level of probability.

Combined treatments between different PBZ concentrations and the two potassium sources showed significant effects on vegetative growth traits. PBZ at 0.0 ppm + K-humate at 2.0 g/l resulted in the highest values in case of plant height (73.07 and 67.73 cm) and leaf area (22.29 and 23.95 cm^2) in both seasons, respectively. On the other hand, PBZ at 100 ppm + K-humate at 2 g/l recorded the highest values on the rest of the other vegetative growth traits, it gave 14.07 and 14.93 for number of branches/plant, 110.30 and 115.30 for number of leaves/plant, 54.32 and 57.38 g for vegetative growth fresh weight and 18.29 and 19.32 g for vegetative growth dry weight in both seasons, respectively. Such increases were significant in most cases. Also, the results regarding combined treatments showed that the highest concentration of PBZ (150 ppm) resulted in the lowest values for all studied vegetative growth traits without potassium application.

Table 3. Effect of foliar spraying with paclobutrazol (PBZ), two sources of potassium and their interaction on leaf area (cm^2), vegetative growth fresh and dry weights (g) of *Hibiscus rosa-sinensis* cv. Cooperi during 2020 and 2021 seasons.

Potassium sources (B)	PBZ concentrations (ppm) (A)									
	0.0	50	100	150	Mean (B)	0.0	50	100	150	Mean (B)
	2020					2021				
	Leaf area (cm^2)									
Cont.	14.73 d-h	12.23 f-h	11.73 gh	11.11 h	12.45 d	16.73 d-g	13.90 g	13.73 g	13.44 g	14.45 c
K-sulfate 1.5 g/l	16.49 b-e	14.81 d-h	14.16 d-h	11.67 gh	14.28 cd	18.49 c-f	17.14 d-g	15.16 e-g	13.67 g	16.12 bc
K-sulfate 3.0 g/l	20.17 ab	15.21 c-g	14.55 d-h	11.82 gh	15.44 bc	21.83 a-c	16.88 d-g	15.55 e-g	13.82 g	17.02 b
K-humate 2.0 g/l	22.29 a	18.77 a-c	17.68 b-d	13.31 e-h	18.01 a	23.95 a	20.77 a-d	19.35 b-e	14.97 fg	19.76 a
K-humate 4.0 g/l	21.92 a	16.03 c-e	15.66 c-f	11.82 gh	16.36 ab	23.26 ab	18.69 c-f	17.00 d-g	13.82 g	18.19 ab
Mean (A)	19.12 a	15.41 b	14.76 b	11.94 c		20.85 a	17.48 b	16.16 b	13.94 c	
	Vegetative growth fresh weight (g)									
Cont.	40.90 i	35.05 j	33.31 j	30.15 k	34.85 d	41.98 g	35.28 h	32.88 i	30.93 i	35.27 c
K-sulfate 1.5 g/l	48.49 e-g	51.07 cd	53.65 ab	41.46 i	48.67 b	48.54 ef	53.24 b	54.19 b	42.51 g	49.62 b
K-sulfate 3.0 g/l	49.10 d-g	47.61 gh	50.20 c-e	51.76 bc	49.67 b	49.70 de	46.42 f	50.79 cd	52.27 bc	49.80 b
K-humate 2.0 g/l	47.90 f-h	50.66 c-e	54.32 a	53.37 ab	51.56 a	47.08 f	53.46 b	57.38 a	53.96 b	52.97 a
K-humate 4.0 g/l	46.00 h	50.10 c-f	51.93 bc	40.48 i	47.13 c	48.34 ef	52.40 bc	54.42 b	41.32 g	49.12 b
Mean (A)	46.48 b	46.90 b	48.68 a	43.44 c		47.13 c	48.16 b	49.93 a	44.20 d	
	Vegetative growth dry weight (g)									
Cont.	12.06 g	11.84 g	10.90 g	8.75 h	10.89 c	12.72 f	12.17 fg	11.92 fg	10.42 g	11.81 b
K-sulfate 1.5 g/l	14.51 d-f	16.63 bc	17.01 ab	14.71 d-f	15.71 ab	15.50 de	17.96 ab	18.00 ab	15.04 e	16.63 a
K-sulfate 3.0 g/l	15.33 c-e	14.83 d-f	15.85 b-d	16.71 bc	15.68 ab	15.58 de	15.16 e	17.52 bc	17.74 ab	16.50 a
K-humate 2.0 g/l	14.14 ef	15.68 b-d	18.29 a	15.13 d-f	15.81 a	15.48 de	16.75 b-e	19.32 a	16.47 b-e	17.00 a
K-humate 4.0 g/l	13.81 f	15.15 d-f	17.08 ab	14.21 ef	15.06 b	15.77 c-e	17.12 b-d	18.11 ab	15.16 e	16.54 a
Mean (A)	13.97 c	14.82 b	15.83 a	13.90 c		15.01 c	15.83 b	16.97 a	14.96 c	

Means having the same letter are not significantly differed at 0.05 level of probability.

Root characteristics:

According to data recorded in Table (4), increasing PBZ concentrations led to a reduction in all studied root traits. Thus, the significant highest values were recorded in control plants (spraying with distilled water only) as recorded 44.93 and 47.26 cm for root length, 36.97 and 41.31 g for roots fresh weight, and 11.29 and 13.49 g for roots dry weight for the first and second seasons, respectively. The significant lowest values were recorded by applying PBZ at 150 ppm as recorded 29.52 and 31.65 cm for root length, 25.69 and 29.89 g for roots fresh weight, and 7.69 and 9.42 g for roots dry weight for the first and second seasons, respectively.

Application of the two potassium sources enhanced root characteristics when compared to control (untreated) plants. The most obvious treatment was k-humate at 2 g/l as recorded 40.78 and 42.87 for root

Table 4. Effect of foliar spraying with paclobutrazol (PBZ), two sources of potassium and their interaction on root characteristics of *Hibiscus rosa-sinensis* cv. Cooperi during 2020 and 2021 seasons.

Potassium sources (B)	PBZ concentrations (ppm) (A)									
	0.0	50	100	150	Mean (B)	0.0	50	100	150	Mean (B)
	2020					2021				
	Root length (cm)									
Cont.	39.97 ef	38.43 fg	34.93 g-i	23.30 j	34.16 c	42.63 cd	40.43 de	37.27 ef	25.97 g	36.58 c
K-sulfate 1.5 g/l	44.68 bc	45.80 b	36.17 gh	32.33 i	39.74 a	47.01 b	47.80 b	37.50 ef	34.00 f	41.58 a
K-sulfate 3.0 g/l	44.03 bc	43.53 b-e	40.33 d-f	34.80 hi	40.67 a	46.03 bc	45.20 bc	43.00 cd	36.80 ef	42.76 a
K-humate 2.0 g/l	43.90 b-d	45.37 b	41.37 c-f	32.50 i	40.78 a	45.90 bc	47.03 b	44.04 b-d	34.50 f	42.87 a
K-humate 4.0 g/l	52.07 a	44.43 bc	25.37 j	24.67 j	36.63 b	54.73 a	45.43 bc	27.03 g	26.99 g	38.55 b
Mean (A)	44.93 a	43.51 a	35.63 b	29.52 c		47.26 a	45.18 b	37.77 c	31.65 d	
	Roots fresh weight (g)									
Cont.	34.68 c	27.48 e	26.08 ef	21.70 h	27.48 c	36.68 cd	31.14 f	30.41 f	24.70 g	30.73 d
K-sulfate 1.5 g/l	36.01 bc	33.94 cd	28.13 e	27.08 ef	31.29 b	41.35 ab	38.94 b-d	31.79 ef	31.08 f	35.79 bc
K-sulfate 3.0 g/l	37.65 b	33.96 cd	26.22 ef	23.25 gh	30.27 b	43.32 a	38.96 b-d	28.22 fg	27.91 fg	34.60 c
K-humate 2.0 g/l	35.27 bc	36.20 bc	33.81 cd	31.84 d	34.28 a	40.60 a-c	38.20 b-d	38.81 b-d	35.84 de	38.36 a
K-humate 4.0 g/l	41.26 a	37.96 b	28.56 e	24.57 fg	33.08 a	44.59 a	40.62 a-c	31.89 ef	29.90 f	36.75 ab
Mean (A)	36.97 a	33.90 b	28.56 c	25.69 d		41.31 a	37.57 b	32.23 c	29.89 d	
	Roots dry weight (g)									
Cont.	10.51 c-e	9.19 fg	9.14 f-h	7.06 k	8.97 c	13.17 a-c	11.53 c-e	11.14 ef	8.72 h	11.14 b
K-sulfate 1.5 g/l	10.95 b-d	9.84 e-g	9.41 fg	7.90 i-k	9.53 b	13.29 ab	11.74 b-e	11.18 ef	9.57 f-h	11.44 ab
K-sulfate 3.0 g/l	11.57 ab	9.97 d-f	8.16 h-j	7.21 jk	9.23 bc	13.91 a	11.63 b-e	10.16 e-h	9.21 gh	11.23 b
K-humate 2.0 g/l	11.34 a-c	12.03 a	9.39 fg	8.87 g-i	10.41 a	13.00 a-d	13.70 a	11.39 de	10.87 e-g	12.24 a
K-humate 4.0 g/l	12.10 a	11.51 a-c	7.34 jk	7.41 jk	9.59 b	14.10 a	13.51 a	9.34 gh	8.74 h	11.42 ab
Mean (A)	11.29 a	10.51 b	8.69 c	7.69 d		13.49 a	12.42 b	10.64 c	9.42 d	

Means having the same letter are not significantly differed at 0.05 level of probability.

length, 34.28 and 38.36 g for roots fresh weight and 10.41 and 12.24 for roots dry weight. The lowest values were recorded by untreated plants (34.16 and 36.58 for root length, 27.48 and 30.73 g for roots fresh weight and 8.97 and 11.14 for roots dry weight).

The combined treatments between PBZ concentrations and potassium sources showed significant effects on root traits. PBZ at 0.0 ppm + K-humate at 4.0 g/l resulted in the highest values (52.07 and 54.73 cm for root length, 41.26 and 44.59 g for root fresh weight and 21.10 and 14.10 for root dry weight in both seasons, respectively). In this regard, the lowest values were recorded in plants sprayed with PBZ at 150 ppm without K fertilization (23.30 and 25.97 cm for root length, 21.70 and 24.70 g for roots fresh weight and 7.06 and 8.72 for roots dry weight in both seasons, respectively.

Flower characteristics:

Data presented in Table (5) showed that flower diameter and its fresh and dry weights were significantly reduced by increasing PBZ concentration. Spraying with PBZ at 150 ppm resulted in the lowest values (66.07

Table 5. Effect of foliar spraying with paclobutrazol (PBZ), two sources of potassium and their interaction on some flowering parameters of *Hibiscus rosa-sinensis* cv. Cooperi during 2020 and 2021 seasons.

Potassium sources (B)	PBZ concentrations (ppm) (A)									
	0.0	50	100	150	Mean (B)	0.0	50	100	150	Mean (B)
			2020					2021		
	Flower diameter (mm)									
Cont.	107.50 c	79.95 g	69.35 i	61.95 l	79.69 d	105.60 b	84.99 d	72.36 ef	63.31 g	81.57 c
K-sulfate 1.5 g/l	108.70 ab	95.30 e	71.80 h	68.45 ij	86.05 ab	107.40 ab	96.09 c	74.74 ef	70.61 fg	87.20 ab
K-sulfate 3.0 g/l	109.10 ab	96.65 d	72.45 h	68.00 j	86.54 a	113.50 a	97.21 c	73.80 ef	72.52 ef	89.26 a
K-humate 2.0 g/l	109.20 a	80.95 g	83.95 f	68.70 ij	85.69 b	113.60 a	84.73 d	86.60 d	69.85 fg	88.70 ab
K-humate 4.0 g/l	108.00 bc	80.85 g	82.90 f	63.25 k	83.75 c	110.20 ab	79.45 de	83.23 d	67.46 fg	85.08 bc
Mean (A)	108.50 a	86.74 b	76.09 c	66.07 d		110.10 a	88.49 b	78.15 c	68.75 d	
	Flower fresh weight (g)									
Cont.	1.81 c	1.26 gh	1.12 j	0.95 k	1.28 c	2.01 a	1.42 c-f	1.30 g	1.15 h	1.47 c
K-sulfate 1.5 g/l	1.88 ab	1.34 de	1.22 hi	1.17 i	1.40 b	2.06 a	1.53 bc	1.42 d-f	1.37 fg	1.59 ab
K-sulfate 3.0 g/l	1.93 a	1.39 d	1.28 fg	1.19 i	1.45 a	2.08 a	1.59 b	1.49 b-d	1.39 e-g	1.64 a
K-humate 2.0 g/l	1.85 bc	1.33 ef	1.25 gh	1.17 ij	1.40 b	2.03 a	1.48 c-e	1.40 d-g	1.33 fg	1.56 b
K-humate 4.0 g/l	1.82 c	1.37 de	1.28 fg	1.18 i	1.41 b	1.99 a	1.58 b	1.42 d-f	1.37 fg	1.59 ab
Mean (A)	1.86 a	1.34 b	1.23 c	1.13 d		2.04 a	1.52 b	1.41 c	1.32 d	
	Flower dry weight (g)									
Cont.	0.19 a-c	0.13 de	0.11 de	0.09 e	0.13 b	0.22 ab	0.15 d-f	0.13 h-j	0.11 k	0.15 b
K-sulfate 1.5 g/l	0.21 a	0.15 b-d	0.12 de	0.11 de	0.15 ab	0.21 b	0.16 d	0.14 e-h	0.11 jk	0.16 ab
K-sulfate 3.0 g/l	0.22 a	0.15 b-d	0.14 c-e	0.14 c-e	0.16 a	0.23 a	0.16 d	0.14 d-g	0.12 i-k	0.16 a
K-humate 2.0 g/l	0.18 a-c	0.14 b-d	0.14 c-e	0.11 de	0.14 ab	0.18 c	0.15 de	0.15 de	0.13 f-i	0.15 b
K-humate 4.0 g/l	0.19 ab	0.14 c-e	0.13 de	0.12 de	0.15 ab	0.17 c	0.15 de	0.14 d-g	0.13 g-i	0.15 b
Mean (A)	0.20 a	0.14 b	0.13 bc	0.12 c		0.20 a	0.15 b	0.14 c	0.12 d	

Means having the same letter are not significantly differed at 0.05 level of probability.

and 68.75 mm for flower diameter, 1.13 and 1.32 g for flower fresh weight and 0.12 and 0.12 g for flower dry weight in both seasons respectively). However, plants without PBZ treatments resulted in the highest values, the corresponding values were 108.50 and 110.10 mm, 1.86 and 2.04 g and 0.20 and 0.20 g in both seasons, respectively). The only exception in this regard was for number of flowers/plant (Fig., 1) which was increased to the highest number of flowers/plant with increasing PBZ up to 100 ppm as recorded 1.52 and 2.00 in the first and second seasons, respectively, then it has been reduced.

It is also clear that K-sulfate at 3.0 g/l resulted in the maximum number of flowers/plant (1.20 and 1.60), flower diameter (86.54 and 89.26 mm), flower fresh weight (1.45 and 1.64 g) and flower dry weight (0.16 and 0.16 g) in both seasons, respectively. However, untreated plants recorded the lowest values giving 79.69 and 81.57 mm for flower diameter, 1.28 and 1.47 for flower fresh weight and 0.13 and 0.15 for flower dry weight in both seasons, respectively.

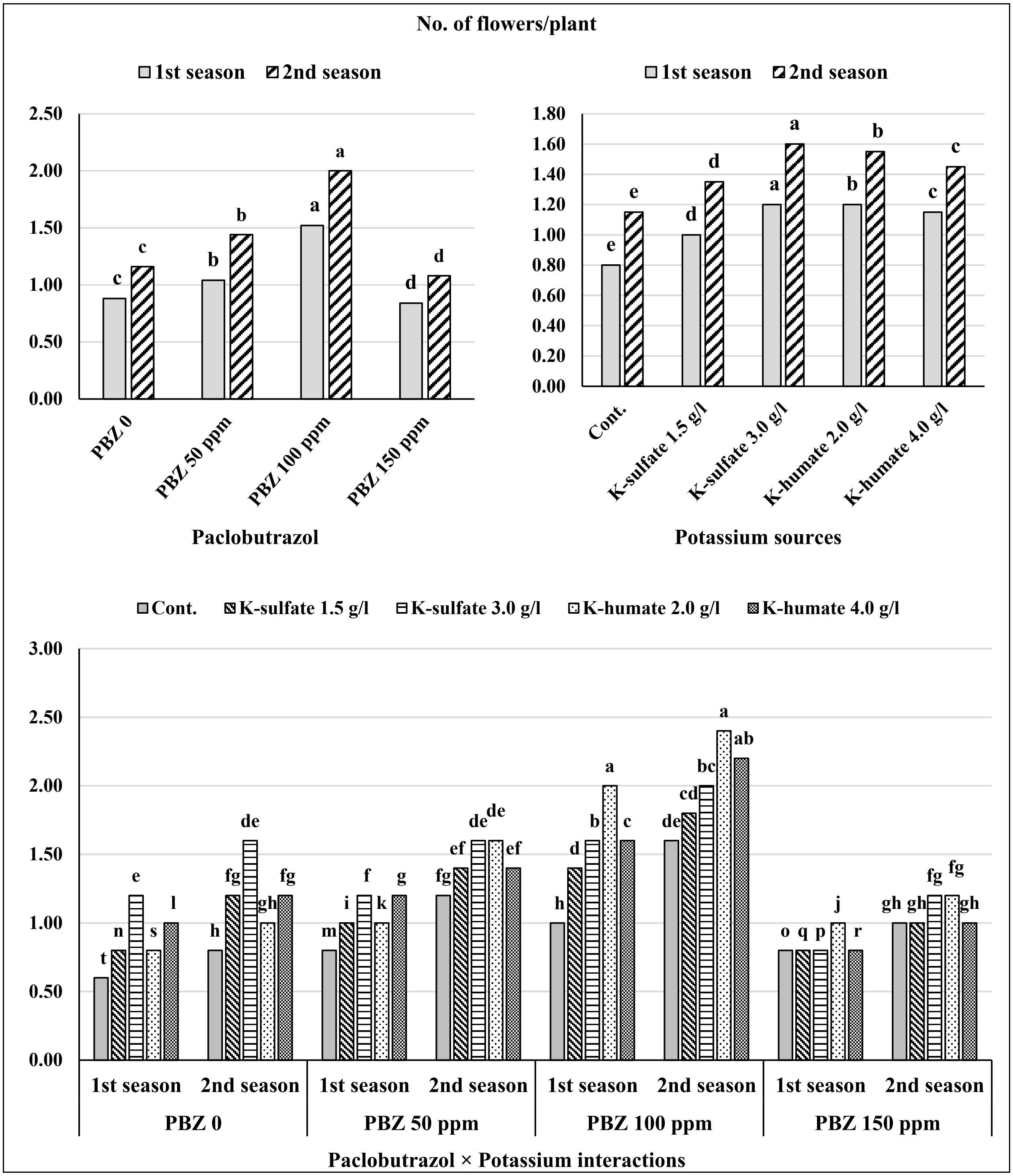

Fig. 1. Effect of foliar spraying with paclobutrazol (PBZ), two sources of potassium and their interaction on number of flowers/plant of *Hibiscus rosa-sinensis* cv. Cooperi during 2020 and 2021 seasons.

In most cases, PBZ at 150 ppm without adding any potassium source significantly resulted in the lowest values for flower diameter (61.95 and 63.31 mm), flower fresh weight (0.95 and 1.15 g) and flower dry weight (0.09 and 0.11 g). The highest values regarding flower diameter were obtained by spraying the plants with K-humate at 2.0 g/l without PBZ as recorded 109.20 and 113.60 mm in both seasons, respectively. In the same context, K-sulfate at 3.0 g/l without PBZ resulted in the heaviest weight of fresh flowers (1.93 and 2.08 g for the first and second seasons, respectively) and flowers dry weight (0.22 and 0.23 g for the first and second seasons, respectively). Regarding number of flowers/plant, the highest values were recorded by PBZ at100 ppm + K-humate at 2.0 g/l (2.00 and 2.40, for the first and second seasons, respectively).

Chemical constituents:

1. Pigments content:

Both chlorophylls a, b and carotenoids contents of *H. rosa-sinensis* leaves were significantly influenced by applying the different concentrations of paclobutrazol (Table, 6).

The mastery of the different treatments in this regard was to PBZ at 100 ppm as it

Table 6. Effect of foliar spraying with paclobutrazol (PBZ), two sources of potassium and their interaction on pigments content (mg/g f.w.) in fresh leaves of c *Hibiscus rosa-sinensis* cv. Cooperi during 2021 season.

Potassium sources (B)	PBZ concentrations (ppm) (A)				
	0.0	50	100	150	Mean (B)
			Chlorophyll a (mg/g f.w.)		
Cont.	0.172 k	0.174 jk	0.185 j	0.167 k	0.175 e
K-sulfate 1.5 g/l	0.250 gh	0.267 e	0.317 c	0.250 gh	0.271 c
K-sulfate 3.0 g/l	0.251 f-h	0.303 d	0.360 b	0.260 e-g	0.294 b
K-humate 2.0 g/l	0.295 d	0.320 c	0.389 a	0.323 c	0.332 a
K-humate 4.0 g/l	0.243 h	0.261 ef	0.327 c	0.207 i	0.259 d
Mean (A)	0.242 c	0.265 b	0.316 a	0.242 c	
			Chlorophyll b (mg/g f.w.)		
Cont.	0.102 ef	0.103 d-f	0.106 d-f	0.101 f	0.103 c
K-sulfate 1.5 g/l	0.110 c-f	0.113 c-f	0.115 c-f	0.113 c-f	0.113 b
K-sulfate 3.0 g/l	0.116 c-f	0.119 cd	0.123 bc	0.118 c-e	0.119 b
K-humate 2.0 g/l	0.118 c-e	0.139 ab	0.143 a	0.116 c-f	0.129 a
K-humate 4.0 g/l	0.113 c-f	0.117 c-f	0.140 a	0.109 c-f	0.120 b
Mean (A)	0.112 c	0.118 b	0.125 a	0.111 d	
			Carotenoids (mg/g f.w.)		
Cont.	0.125 l	0.129 l	0.146 k	0.108 m	0.127 e
K-sulfate 1.5 g/l	0.156 i-k	0.183 ef	0.191 de	0.159 h-j	0.172 b
K-sulfate 3.0 g/l	0.165 g-i	0.166 g-i	0.173 fg	0.160 h-j	0.166 c
K-humate 2.0 g/l	0.199 cd	0.210 b	0.224 a	0.204 bc	0.209 a
K-humate 4.0 g/l	0.153 jk	0.154 jk	0.167 gh	0.156 i-k	0.158 d
Mean (A)	0.160 c	0.169 b	0.180 a	0.158 c	

Means having the same letter are not significantly differed at 0.05 level of probability.

recorded the highest significant values (0.316, 0.125 and 0.180 mg/g f.w. for chlorophyll a, b and carotenoids, respectively). On the other hand, the plants that have been treated with PBZ at the highest level (150 ppm) shared the ones that have not been treated (PBZ at 0.0 ppm) and produced the lowest pigments content.

Regarding the effect of different potassium sources, K-humate proved its ability to enhance pigments content. Spraying the plants with K-humate at 2.0 g/l produced the highest contents (0.332, 0.129 and 0.209 mg/g f.w., for chlorophyll a, b and carotenoids, respectively). While the lowest ones were obtained in the control plants.

Regarding the combined treatments between paclobutrazol concentrations and potassium sources, it is clear that the foliar spraying with PBZ at 100 ppm + K-humate at 2.0 g/l resulted in the highest significant values in the case of pigments content as recorded 0.389, 0.143 and 0.224 mg/g f.w., for chlorophyll a, b and carotenoids, respectively. The recorded data showed also that plants that have been deprived of spraying with different potassium sources (control plants), resulted in the lowest values when combined with either PBZ at 0.0 ppm or at 150 ppm.

2. Potassium (%):

The effect of spraying with different paclobutrazol concentrations on potassium (%) of *H. rosa-sinensis* was significant (Table, 7). In this concern, increasing paclobutrazol concentration led to a significant reduction in potassium (%). So, PBZ at 0.0 ppm recorded the highest K value (1.50%) and on the contrary, PBZ at the highest level (150 ppm) recorded the lowest K one (1.29%).

It is also clear that foliar spraying with different potassium sources increased K %. Spraying with K-sulfate at 3.0 g/l significantly resulted in the highest K % (1.57%), this was significantly followed by spraying with K-humate at 2.0 g/l (1.50%). While plants that have been deprived of foliar spraying with potassium resulted in the lowest one (1.22%).

Combined treatments between PBZ concentrations and potassium sources significantly affected K %. Adding K-sulfate at 3.0 g/l alone showed a pronounced effect as recorded the highest value (1.71%). The lowest K % was recorded by control treatment (without potassium foliar spraying) + PBZ at 150 ppm which resulted in 1.07% only.

3. Total carbohydrates (%):

Total carbohydrates were significantly reduced by increasing PBZ concentrations. Spraying *H. rosa-sinensis* with PBZ at 0.0 ppm resulted in the highest values (19.28%). While plants sprayed with PBZ at 150 ppm resulted in the lowest values in this regard as recorded 13.25% (Table, 7).

Regarding the effect of spraying with potassium sources, it is clear that K-humate at 2.0 g/l resulted in the highest significant total carbohydrate percentage as recorded 19.07% against 15.03% resulted from spraying with distilled water (control). On the other hand, K-humate at 4.0 g/l resulted in the lowest value (14.15%).

As for the effect of combined treatment between spraying with paclobutrazol and potassium, the highest total carbohydrates percentage was recorded by PBZ at 0.0 ppm + K-humate at 2.0 g/l (21.69%), PBZ at 0.0 ppm + K-sulfate at 3.0 g/l (20.51%), PBZ at 50 ppm + K-humate at 2.0 g/l (20.31%) and PBZ at 100 ppm + K-humate at 2.0 g/l (19.71%) without significant differences between them. On the other hand, the lowest values (12.44 and 12.79%) were recorded by PBZ at 150 + K-humate at 4.0 g/l then PBZ at 150 ppm + control plants (sprayed with distilled water only), respectively without significant differences between them.

4. Total indoles (mg/100 g d.w.) and phenols (%):

Spraying with PBZ at 100 ppm significantly resulted in the highest indoles contents (3.83 mg/100 g d.w.), while

Table 7. Effect of foliar spraying with paclobutrazol (PBZ), two sources of potassium and their interaction on some chemical constituents in dry leaves of *Hibiscus rosa-sinensis* cv. Cooperi during 2021 season.

Potassium sources (B)	PBZ concentrations (ppm) (A)									
	0.0	50	100	150	Mean (B)	0.0	50	100	150	Mean (B)
	K (%)					Total carbohydrates (%)				
Cont.	1.29 k	1.22 l	1.31 j	1.07 m	1.22 e	18.74 bc	15.14 d-f	13.45 ef	12.79 f	15.03 cd
K-sulfate 1.5 g/l	1.40 h	1.39 h	1.35 i	1.32 j	1.37 d	19.01 a-c	16.46 cd	14.14 d-f	13.05 f	15.66 bc
K-sulfate 3.0 g/l	1.71 a	1.58 b	1.56 c	1.42 g	1.57 a	20.51 ab	16.72 cd	15.77 de	13.39 ef	16.60 b
K-humate 2.0 g/l	1.56 c	1.55 d	1.53 e	1.35 i	1.50 b	21.69 a	20.31 ab	19.71 ab	14.57 d-f	19.07 a
K-humate 4.0 g/l	1.54 de	1.46 f	1.40 h	1.28 k	1.42 c	16.46 cd	14.32 d-f	13.40 ef	12.44 f	14.15 d
Mean (A)	1.50 a	1.44 b	1.43 c	1.29 d		19.28 a	16.59 b	15.29 c	13.25 d	
	Total indoles (mg/100 g d.w.)					Total phenols (%)				
Cont.	1.73 l	1.89 kl	2.77 f	2.70 fg	2.27 e	0.409 k	0.451 jk	0.595 de	0.612 c-e	0.517 c
K-sulfate 1.5 g/l	1.97 k	1.91 kl	3.39 d	2.83 ef	2.53 d	0.465 ij	0.535 fg	0.584 ef	0.618 b-e	0.550 b
K-sulfate 3.0 g/l	2.22 j	2.30 ij	3.46 d	2.56 gh	2.64 c	0.467 h-j	0.533 fg	0.536 fg	0.669 b	0.551 b
K-humate 2.0 g/l	2.25 j	2.84 ef	5.04 a	2.47 hi	3.15 b	0.500 g-j	0.640 b-d	0.661 bc	0.832 a	0.658 a
K-humate 4.0 g/l	3.01 e	4.13 c	4.50 b	2.78 f	3.61 a	0.485 g-j	0.515 g-i	0.519 gh	0.657 bc	0.544 b
Mean (A)	2.24 c	2.61 b	3.83 a	2.67 b		0.465 d	0.535 c	0.579 b	0.678 a	

Means having the same letter are not significantly differed at 0.05 level of probability.

spraying with PBZ at 150 ppm resulted in the highest phenols percentage (0.678%) as registered in Table (7). On the other hand, control plants recorded the lowest values (2.24 mg/100 g d.w. for indoles and 0.465% for phenols).

K-humate at 4.0 g/l was more effective than other treatments in increasing the indole content to the highest value (3.61 mg/100 g d.w.). In this regard, the highest phenols percentage (0.658%) was recorded in plants treated with K-humate at 2.0 g/l. The lowest values concerning total indoles (2.27 mg/100 g d.w.) and phenols (0.517%) were recorded in control plants (deprived of potassium).

Both PBZ at 100 and 150 ppm in addition to spraying with K-humate at 2.0 g/l resulted in the highest significant values of total indoles (5.04 mg/100 g d.w.) and phenols (0.832%), respectively. In this concern, control plants recorded the lowest values for indoles (1.73 mg/100 g d.w.) and phenols (0.409%).

DISCUSSION

The present study revealed that the highest PBZ level (150 ppm) resulted in a great reduction in most studied characters except for number of branches and leaves, indoles and phenols contents. Previous studies emphasized these findings e.g. Maus (1987) on *Hibiscus rosa-sinensis* found that plant height was reduced due to using PBZ at different concentrations, but this was accompanied with an increase in the number of either branches or flowers. In this regard, Villegas and Lozoya (1992) reported that a single paclobutrazol spray at 120 mg/l reduced plant height of poinsettia plants. Gad *et al.* (1997) also reported that paclobutrazol decreased internodal length compared to control when applied as a foliar spray on *Fuchsia magellanica* cv. Beacon. On the other hand, Matsoukis *et al.* (2004) showed that the leaf area of *Lantana camara* greatly decreased as the concentrations of paclobutrazol increased (from 0 to 500 ppm).

El-Bably (2008) revealed that high concentrations of PBZ reduced plant height, fresh and dry weights of vegetative parts and roots, root length, total carbohydrates, but increased phenol and indole contents of *Anisacanthus wrightii*. Abd El-Aal and Mohamed (2017) reported that foliar spraying with PBZ caused a decrement in plant height and leaf area of *Pelargonium zonale* plants, this was accompanied with an increase in the number of branches/plant.

Although PBZ at the medium level (100 ppm) caused a plant length reduction as reported by the present study this level resulted in the highest values regarding the number of leaves, branches and flowers/plant, vegetative parts fresh and dry weights, and the contents of chlorophylls (a and b), carotenoids and indoles. This was in line with those obtained by El-Sallami (2001) who revealed that although paclobutrazol at 1000 ppm resulted in the greatest reduction in potted poinsettia plant height and leaf area, but the number of lateral branches and leaves were increased; Nazarudin (2012) found that paclobutrazol significantly reduced the plant height and leaf area of *Hibiscus rosa-sinensis* but increased the chlorophyll content and number of flower buds; Noor El-Deen *et al.* (2014) reported that PBZ foliar spraying at 50 or 100 ppm reduced plant height, roots fresh and dry weights and increased both chlorophyll a, b, carotenoids, total indoles and phenols of *Gaillardia pulchella*; Rathore and Mishra (2014) reported that paclobutrazol at 100 ppm significantly increased the number of flower/plant of *Tagetes erecta* L. cv. Pusa Basanti Gainda; Shahin *et al.* (2014) revealed that foliar spraying of *Chrysanthemum carinatum* with PBZ at 50 or 100 ppm reduced plant height but increased the contents of chlorophyll a, b, carotenoids, total indoles, and phenols; Vasoya *et al.* (2015) found that plant height was reduced while number of branches was increased by foliar spraying with PBZ on gaillardia; Abou-Dahab *et al.* (2015) demonstrated that although PBZ reduced plant height and root length, it was accompanied with an increment in the number of shoots and flowers/plant, chlorophyll a, b, carotenoids and total phenols of *Russelia equisetiformis*; Mutlu and Agan (2015) emphasized that paclobutrazol increased chlorophyll contents of ornamental pepper; Mohamed (2016) on *Lagerstroemia indica* found that the rate of photosynthesis was reduced as the concentration of foliar spraying with PBZ increased, this also led to a reduction in plant height and an increment in the number of flowers, and the contents of chlorophyll a and total chlorophyll compared to the non-treated plants. Recently, Noor El-Deen (2020) on *Ruellia simplex* reported that the reduction of plant height and leaf area as a result to spraying with paclobutrazol at 50 or 100 ppm was accompanied with an increment in the number of branches/plant, as well as flowers, chlorophylls a, b, carotenoids and total indoles contents.

Reducing the plant height of *H. rosa-sinensis* as a result of spraying with paclobutrazol may be attributed to the reduction in stem elongation. Paclobutrazol is considered a gibberellins inhibitor by inhibiting the kaurene oxidation sequence involved in the gibberellin biosynthesis (Warner and Erwin, 2003). Chaney (2005) declared that paclobutrazol blocks three steps in the terpenoid pathway for the production of the gibberellin by binding with and inhibiting the enzymes that catalyze the metabolic reactions. Paclobutrazol binds iron atoms in the enzymes required for the gibberellins production also has the capacity to bind to enzymes necessary for the production of steroids in fungi as well as those that promote the destruction of abscisic acid. He added that cell division still occurs, but the new cells do not elongate when gibberellin production is inhibited. PBZ-induced physiological responses may be also associated with increased cytokinin synthesis or prevention of its degradation (Desta and Amare, 2021). Increasing or preventing cytokinins degradation by paclobutrazol interprets the positive role of spraying with paclobutrazol in increasing both the number of branches and leaves. Not only vegetative growth influenced by paclobutrazol but also flowering. As reported in the present study medium concentration of paclobutrazol increased the number of flowers/plant. To interpreted these results, Meijón *et al.* (2011) showed that gibberellins inhibitors changed the levels of polyamines, gibberellin and cytokinins and in global DNA methylation levels during the floral transition; also, these changes in plant growth regulators and DNA methylation were correlated with flower development. Soumya *et al.* (2017) revealed that PBZ at appropriate concentration maintains relative water content, membrane stability index, photosynthetic activity, photosynthetic pigments and protects the photosynthetic machinery by enhancing the level of osmolytes, antioxidant activities and level of endogenous hormones and thereby enhancing optimum growth. Increasing some chemical constituents as a result of spraying with paclobutrazol may be due to blocking a portion of the so-called "terpenoid pathway" causing shunting of the accumulated intermediary compounds above the blockage. The consequence is increased production of the hormone abscisic acid and the chlorophyll component phytol (Chaney, 2005). Fletcher *et al.* (2000) also proposed that triazoles of paclobutrazol stimulate cytokinin synthesis, that enhance chloroplast differentiation, chlorophyll biosynthesis, and prevent chlorophyll degradation.

Regarding the effect of the different potassium sources and levels, the data cleared that both K-sulfate and K-humate increased all studied traits over control (treated with distilled water only). Although K-sulfate resulted in the highest values in terms of flower parameters (number/plant, diameter, fresh and dry weights) and K % and the mastery for the remaining traits was to K-humate. These results regarding the effect of potassium sulfate were in harmony with the results obtained by Waly *et al.* (2001) and Abdullatif and Hamad (2019) on gladiolus plants. Also, Abd El-Gayed and Knany (2020) on *Antirrhinum majus* reported that K-sulfate at 3.0 g/l resulted in the highest values of plant height, number of shoots/plant, total chlorophyll, fresh and dry weights of vegetative growth, roots and flowers, number of flowers and K %.

The positive role of potassium (K^+) on plant growth may be attributed (according to Marschner, 2012) to that (1) K^+ completely stimulates a large number of enzymes, (2) K^+ activates membrane-bound proton-pumping ATPases, (3) K^+ is required for protein synthesis in higher concentrations than for enzyme activation, (4) K^+ plays an important role in CO_2 fixation and stomatal regulation so it affects photosynthesis in higher plants, (5) K^+ enhances cell extension and osmoregulation. Simson and Straus (2010) added that K^+ is involved in the working of more than 60 enzymes, in photosynthesis and the movement of its products to storage organs.

On the other hand, the positive effect of potassium humate application was reported by Heikal (2017) on *Salvia farinacea*, Shyala *et al.* (2019) on *Tagetes erecta*, Noor El-Deen and El-Ashwah (2019) on *Asparagus densiflorus* 'Meyerii', Badran *et al.* (2019) (H007) on *Calendula officinalis* and Mohamed and Ghatas (2021) (H005) on *Achillea millefolium* plants.

Humic fertilizers contain a series of essential elements in the form of humates extracted from coal mass in complex NPK-type matrices which, after their incorporation in the soil, ensure the assimilation of the nutrient ions contained and intensify the nutrition process (Parvan *et al.*, 2013). Abd-El-Hady *et al.* (2019) emphasized that application of humic substances principally associated to the enhancement of nutrients absorption. It enhances protein synthesis, improves photosynthesis products and macro-elements such as K^+, NH_4^+, or Ca_2^+, and forms aqueous complexes with micronutrients.

Regarding the interaction treatments, the addition of potassium to *Hibiscus rosa-sinensis* cv. Cooperi sprayed with paclobutrazol emphasized its beneficial role to enhance physiological performance, this was in harmony with the findings reported by Nazarudin and Tsan (2016) on *Xanthostemon chrysanthus*. This effective role may be attributed to one or more of the points discussed above regarding potassium and humic substances.

CONCLUSION

Integration potassium foliar spraying reversed the undesirable effects of spraying with PBZ alone in particular at its high levels. The combined treatment of PBZ at 100 ppm + K-humate at 2.0 g/l was the optimum as recorded the highest values of number of leaves, branches and flowers/plant, vegetative growth fresh and dry weights, chlorophylls (a and b), carotenoids and indoles. In this context and to produce high-quality *Hibiscus rosa-sinensis* cv. Cooperi pots, it is advised to treat the plants with PBZ at 100 ppm + K-humate at 2.0 g/l for 6 times at 2-week intervals.

REFERENCES

Abd El-Gayed, M.E. and Knany, R.E. (2020). Effect of foliar application of different potassium forms on the growth and flowering of snapdragon (*Antirrhinum majus* L.) plants. Journal of Plant Production, 11(11):1035-1040.

Abd El-Aal, M.A. and Mohamed, Y.F.Y. (2017). Effect of pinching and paclobutrazol on growth, flowering, anatomy and chemical compositions of potted geranium (*Pelargonium zonale* L.) plant. International Journal of Plant & Soil Science, 17(6):1-22.

Abd-El-Hady, W.M.; Selim, E.M.M. and El-Sayed, N.I. (2019). Influence of humic and ascorbic acids on growth parameters and anthocyanin content of *Acalypha wilkesiana* irrigated with seawater. Plant Archives, 19(1):652-664.

Abdullatif, T.A.K. and Hamad, R.M. (2019). Effect of *Azospirillum brasilense*, water type and potassium in the growth and flowering of the gladiolus plant. Plant Archives, 19(2):2637-2649.

Abou-Dahab, M.A., Khella, E.A. and Emam, K.A. (2015). Effect of pinching and paclobutrazol (PBZ) on vegetative growth of *Russelia equisetiformis* for using as a pot plant. Egyptian Journal of Horticulture, 42(2):913-930.

A.O.A.C. (1980). Official Methods of Analysis of the Association of Official Agricultural Chemists. 15th Ed. Association of Official Agricultural Chemists, Arlington, Virginia, 22201: 877-878.

Badran, Wesam A.; Selim, S.M.; Abdella, Ebtsam M. and Matter, F.M.A (2019). The influence of ammonium nitrate and potassium humate on chemical composition of *Calendula officinalis*, L. plant under two types of soil conditions. Fayoum Journal of Agricultural Research and Development, 33(2):130-147.

Bailey, D. (1998). Height Control of Commercial Greenhouse Flowers. North Carolina State University College of Agriculture & Life Sciences, USA, 17 p.

Bañón, S.; Miralles, J.; Navarro, A. and Sánchez-Blanco, M.J. (2009). Influence of paclobutrazol and substrate on daily evapotranspiration of potted geranium. Scientia Horticulturae, 122(4):572-578.

Brickell, C. (1997). The American Horticultural Society A-Z Encyclopedia of Garden Plants. DK Publishing, Inc., New York, USA, 1092 p.

Brown, L.V. (2002). Applied Principles of Horticultural Science, 2nd Edition. Butterworth-Heinemann, UK, 322 p.

Chaney, W.R. (2005). Growth Retardants: A Promising Tool for Managing Urban Trees. Purdue Univ. Extension, USA., 6 p.

Desta, B. and Amare, G. (2021). Paclobutrazol as a plant growth regulator. Chemical and Biological Technologies in Agriculture, 8(1):1-15.

Duncan, D.B. (1955). Multiple range and multiple F test. Journal of Biometrics, 11:1-42.

El-Bably, S.Z. (2008). Growth and flowering of *Anisacanthus wrightii* plant as affected by cycocel and paclobutrazol application. Alexandria Journal of Agricultural Research, 53(1):73-80.

El-Sadek, Z.H. (2016). Effect of pinching and paclobutrazol on *Hibiscus rosa-sinensis*, L. cv. Yellow plant. Scientific Journal of Flowers and Ornamental Plants, 3(4):233-244.

El-Sallami, I.H. (2001). Controlling growth habit of potted poinsettia under two light intensity conditions. Assiut Journal of Agricultural Sciences, 32(4):109-139.

Ferreira, T. and Rasband, W.S. (2012). ImageJ User Guide-IJ-1.46. http://imagej.nih.gov/ij/docs/guide.

Fletcher, R.; Gilley, A.; Sankhla, N. and Davis, T. (2000). Triazoles as plant growth regulators and stress protectants. Hort. Rev., 24:55-137.

Gad, M.; Schmidit; G. and Gerzson, I. (1997). Comparison of application methods of growth retardants on the growth and flowering of *Fuchsia magellanica* Lam. Horticultural Science, 29(1-2):70-77.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research. John Wiley and Sons, New York, USA, 680 p.

Gowariker, V.; Krishnamurthy, V.N.; Gowariker, S.; Dhanorkar, M. and Paranjape, K. (2009). The Fertilizer Encyclopedia. John Wiley & Sons, Inc., Publication, USA, 861 p.

Heikal, A. (2017). The influence of foliar application of biostimulant atonik and different sources of potassium on full sun and partial shade *Salvia farinacea* plants. Egyptian Journal of Horticulture, 44(1):105-117.

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, 5B:209-344.

Jackson, M.L. (1973). Soil Chemical Analysis. Prentice-Hall of India Private Ltd. M-97, New Delhi, India, 498 p.

Kadam, A.S.; Wadje, S.S. and Patil, R. (2011). Role of potassium humate on growth and yield of soybean and black gram. International J. Pharama. Biol. Sci., 1:243-246.

Kumar, D.; Singh, A.P.; Raha, P.; Rakshit, A.; Singh, C.M. and Kishor, P. (2013). Potassium humate: A potential soil conditioner and plant growth promoter. International Journal of Agriculture, Environment and Biotechnology, 6(3):441-446.

Larsen, P.; Harbo, A.; Klungsour, S. and Asheim, T. (1962). On the biogenesis of some indole compounds in *Acetobacter xylinum*. Physiologia Plantarum, 15(3):552-565.

Marschner, H. (1995). Mineral Nutrition of Higher Plants, 3rd Ed. Academic Press., New York, USA., 651 p.

Matsoukis, A.S.; Tsiros, I. and Kamoutsis, A. (2004). Leaf area response of *Lantana camara* L. subsp. *camara* to plant growth regulators under different photosynthetic flux conditions. HortScience, 39(5):1042-1044.

Maus, W.L. (1987). Effect of paclobutrazol and uniconizole-p on *Hibiscus rosa-sinensis*. Proc. Fla. State Hort. Soc., 100: 373-375.

Meijón, M.; Jesús, C.M.; Valledor, L.; Rodríguez, R. and Feito, I. (2011). Epigenetic and physiological effects of gibberellin inhibitors and chemical pruners on the floral transition of azalea. Physiologia Plantarum, 141(3): 276-288.

Mohamed, N.T. (2016). Effect of Paclobutrazol Concentration, Application

Techniques and Frequency on Growth and Flowering of *Lagerstroemia indica*. M.Sc. Thesis, Fac. Agric., Putra Univ., Malaysia, 65 p.

Mohamed, Y. and Ghatas, Y. (2021). Effectiveness of various potassium sources on vegetative growth, flowering, essential oil productivity and some chemical constituents of yarrow (*Achillea millefolium* L.) plant. Scientific Journal of Flowers and Ornamental Plants, 8(1):101-121.

MSTAT Development Team (1989). MSTAT User's Guide: A Microcomputer Program for the Design Management and Analysis of Agronomic Research Experiments. Michigan State University, East Lansing, USA, 496 p.

Mutlu, S.S. and Agan, E. (2015). Effects of paclobutrazol and pinching on ornamental pepper. HortTechnology, 25(5): 657-664.

Nau, J., (2011). Ball Redbook, Volume 2: Crop Production, 18th Ed. Ball Publishing, West Chicago, Illinois, USA, 785 p.

Nazarudin, A.M.R. and Tsan, F.Y. (2016). Effects of drenched-applied paclobutrazol and potassium nitrate on the leaf area and physiological response of *Xanthostemon chrysanthus* (f. Muell.) Benth. International Journal of Agriculture, Forestry and Plantation, 4:56-92.

Nazarudin, A.M.R. (2012). Plant growth retardants effect on growth and flowering of potted *Hibiscus rosa-sinensis* L. J. Trop. Plant Physiol., 4:29-40.

Noor El-Deen, T.M. (2020). Production of stunted pot plants from *Ruellia simplex*. Middle East J. of Agric. Res., 9(2):308-320.

Noor El-Deen, T.M. and EL-Ashwah, M.A. (2019). Effect of fertilization with humic Acid and ammonium sulfate on the quality of *Asparagus densiflorus* 'Meyerii' plants. Journal of Horticultural Science and Ornamental Plants, 11(3):289-298.

Noor El-Deen, T.M.; El-Sayed, Boshra A. and Shahin, S. (2014). Chrysanthemum and gaillardia as stunted winter annuals, II. Blanket flower (*Gaillardia pulchella* Foug.). Scientific Journal of Flowers and Ornamental Plants, 1(2):155-162.

Pârvan, L.; Dumitru, M.; Sîrbu, C. and Cioroianu, T. (2013). Fertilizer with humic substances. Romanian Agricultural Research, 30:205-212.

Pradip, T.; Rajhans, V. and Sunil, K. (2016). Effect of potassium humate and bio-inoculants on cowpea (*Vigna unguiculata* L. Walp), influence of soil fertility, enzymatic activity and microbial population in soil. International Journal of Agriculture Sciences, 8(53):2638-2641.

Rathore, I. and Mishra, A. (2014). Effect of pinching and plant bioregulators on flowering, yield and root characteristics of marigold (*Tagetes erecta* L.) cv. Pusa Basanti Gainda under sub-humid region of Rajasthan. International Journal of Basic and Applied Agricultural Research, 12(3):369-373.

Saiyad, M.Y.; Jadav, R.G.; Parmar, A.B.; and Chauhan, K.M. (2010). Effect of plant growth retardants and pinching on growth, flowering and yield of gaillardia (*Gaillardia pulchella* Foug.) cv. Lorenziana. The Asian Journal of Horticulture, 5(1):121-122.

Shahin, S.; Noor El-Deen, T.M. and El-Sayed, Boshra A. (2014). Chrysanthemum and Gaillardia as stunted winter annuals I. Tricolor chrysanthemum (*Chrysanthemum carinatum* Schousb.). Scientific Journal of Flowers and Ornamental Plants, 1(2):145-154.

Shanan, N.T. and Soliman, A.S. (2011). Response of snapdragon plants to pinching and growth retardants treatments. American-Eurasian Journal of Sustainable Agriculture, 5(2):150-158.

Shyala, M.R.; Dhanasekaran, D. and Rameshkumar, S. (2019). Effect of foliar application of micronutrients and potassium humate on growth and flower yield of African marigold (*Tagetes erecta* L.). Annals of Plant and Soil Research, 21(2):101-107.

Simson, S.P. and Straus, M.C. (2010). Basics of Horticulture. Oxford Book Company, Jaipur, India, 312 p.

Soumya, P.R.; Kumar, P. and Pal, M. (2017). Paclobutrazol: a novel plant growth regulator and multi-stress ameliorant. Indian Journal of Plant Physiology, 22(3):267-278.

Vasoya, N.; Ramesh, V.; Nitesh, P. and Dilip, K. (2015). Response of gaillardia to plant growth regulators and pinching. Trends in Biosci., 8(16):4090-4095.

Villegas, T.O. and Lozoya, S.H. (1992). Effect of paclobutrazol (PBZ) on poinsettia (*Euphorbia pulcherrima* W.) cultivar Gutbier V-10 under greenhouse conditions in Chapingo, Mex. Revista Chapingo, 15(73-74):77-80.

Waly, A.A.; Ali, M.A.M.; Hassan, M.A. and Sadek, F.O. (2001). Effect of potassium foliar spray on growth, flowering and chemical constituents of gladiolus plants under North Sinai conditions. Annals of Agricultural Science, Moshtohor, 39(3):1681-1692.

Warner, R.M. and Erwin, J.E. (2003). Effect of plant growth retardants on stem elongation of *Hibiscus* species. HortTechnology, 13(2):293-296.

Wellburn, A.R. and Lichtenthaler, H. (1984). Formulae and program to determine total carotenoids and chlorophylls-a and b of leaf extracts in different solvents. Adv. Agric. Biotech., 2(1):9-12.

Wilfret, G.J. and Barrett, J.E. (1995). Effect of growth regulators on growth and flower development of potted azaleas. Proceedings of the Florida State Horticultural Society, 107:175-177.

التحكم في نمو نباتات الهيبسكس المزروعة في أصص عن طريق الرش الورقي بالباكلوبترازول ومصدرين من عنصر البوتاسيوم

طارق محمد نور الدين أحمد*، حنان محمد أبو الغيط**

* قسم بحوث الزينة وتنسيق الحدائق، معهد بحوث البساتين، مركز البحوث الزراعية، الجيزة، مصر

** قسم النبات والميكروبيولجي، كلية العلوم، جامعة حلوان، مصر

في محاولة للحصول على نمو مثالي لنباتات الهيبسكس صنف Cooperi، تم إجراء تجربة أصص عاملية وذلك بالحديقة النباتية بالبنك القومي للجينات، مركز البحوث الزراعية، الجيزة، مصر خلال موسمي ٢٠٢٠ و ٢٠٢١. تم تطبيق الرش الورقي لكل من الباكلوبترازول بمستويات مختلفة (صفر، ٥٠، ١٠٠ و ١٥٠ جزء في المليون) وبمصدرين من مصادر البوتاسيوم (سلفات البوتاسيوم بتركيزي ١,٥ و ٣,٠ جم/لتر وكذلك هيومات البوتاسيوم بتركيزي ٢,٠ و ٤,٠ جم/لتر) وكذا التفاعل فيما بينهما. تم تقييم النمو الخضري والتزهير وبعض المكونات الكيميائية. أظهرت النتائج أنه بزيادة تركز الباكلوبترازول تم الحصول على أقل القيم لمعظم الصفات التي تم قياسها باستثناء تركيز ١٠٠ جزء في المليون الذي أعطى أعلى القيم فيما يتعلق بعدد الأوراق والأفرع والأزهار، الوزن الطازج والجاف للمجموع الخضري، الكلوروفيل أ ، ب ، الكاروتينويدات وكذلك محتوى الإندولات الكلية. الرش الورقي بمصدري البوتاسيوم كان متفوق على نباتات المقارنة الغير معاملة بأي منهما حيث أدت إلى الحصول على أعلى القيم. دمج معاملات الرش الورقي بالبوتاسيوم أدى إلى التغلب على التأثيرات الغير مرغوبة للرش الورقي بالباكلوبترازول بمفرده خاصة التركيزات العالية منه. كانت أحسن النتائج في هذا الصدد للمعاملة بالباكلوبترازول بتركيز ١٠٠ جزء في المليون + هيومات البوتاسيوم بتركيز ٢,٠ جم/لتر حيث أدت إلى الحصول على أعلى القيم فيما يتعلق بعدد الأوراق والأفرع والأزهار، الوزن الطازج والجاف للمجموع الخضري، الكلوروفيل أ ، ب ، الكاروتينويدات وكذلك محتوى الإندولات الكلية. لإنتاج نباتات أصص ذات قيمة عالية من نباتات الهيبسكس صنف Cooperi فإنه ينصح بالرش الورقي بالباكلوبترازول بتركيز ١٠٠ جزء في المليون + هيومات البوتاسيوم بتركيز ٢,٠ جم/لتر على مدى ٦ مرات بفاصل زمني كل أسبوعين بين الرشات.