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RESPONSE OF FOUR ORIENTAL LILIUM CULTIVARS TO POTASSIUM SOURCES ACCOMPANIED BY INTEGRAL FERTILIZER APPLICATION

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ABSTRACT: Improving the quality of oriental Lilium is a big demand from farmers and florists in Egypt using proper fertilization. In this research, we studied different responses of four cultivars of oriental Lilium, ‘Bacardi®’, ‘Zambesi®’, ‘Adelante®’, and ‘Vonq®’, to six treatments of two potassium sources, potassium silicate (PS), and potassium gel (PG) with or without foliar application of Nofaterin® (Nofat.) as a source of the integral fertilizer. The results showed that the treatment PS + Nofat. produced the highest values for vegetative, flowering, and bulb growth parameters, and chemical composition like mineral contents, chlorophyll, and carbohydrate compared to the other treatments. This treatment increased leaf fresh weight, leaf dry weight, stem fresh weight, and stem dry weight at the rate of 56.92, 57.72, 61.96, 71.73%, respectively. For flowering growth, flower diameter (cm), flower fresh weight (g), and flower dry weight (g) recorded 22.95, 23.11, respectively. Nitrogen, phosphorus and potassium contents also increased as a result of PS + Nofat. treatment which recorded 4.01, 0.67, and 3.11 g/100 g D. wt, respectively. Worthy to note that potassium gel treatments did not show a notable increase in growth parameter and chemical composition. The comparison among all studied cultivars showed that *Lilium* cvs. Adelante and Vonq gave the best results for all growth parameters and chemical composition whereas *Lilium* cvs. Zambesi and Bacardi showed the lowest values. We concluded that potassium fertilization using potassium silicate with Nofaterin foliar application is recommended for oriental Lilium cultivars, but more investigations should be performed to improve Lilium cvs. Bacardi and Zambesi, as the response to our treatments indicated that it depends on the cultivars and genotypes. Our findings present successful response to potassium fertilizer in Lilium grown in Egypt opening a gate to increase commercial cut flowers by fertilizer application.

Keywords: Oriental Lilium, potassium sources, cut flower, nofaterin, integral fertilizer

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INTRODUCTION

Lilium is a perennial bulbaceous plant belonging to the family Liliaceae and consists of more than 80 species which are native to the Northern Hemisphere. Oriental *Lilium* hybrids are widely used as important economic cut flowers “Worldwide”. In Egypt, oriental Lilium cultivars are required in the floristic market due to their ornamental values and beautiful fragrant smell (El Sawy *et al.*, 2021). Also, Lilium oil, which are extracted from the flowers, has a significant importance for lily perfume fabrication. Moreover, *Lilium* oil has medicinal values, which is used for cardiovascular disease, detoxification, brain disfunction, fever reduction, and wound treatments (Zaccai *et al.*, 2020).

Cut flowers fertilizing is of special interest in Egypt due to the importance of the mineral content of these plants, which play an important role in vase life (Chang *et al.*, 2010). Like any cut flower, this species of plant needs a balanced nutrient application to improve the productivity and quality of the produced cut flowers. Fertilizing oriental Lilium plants is essential to ensure the required conserved nutrients for proper growth and flowering. For example, nitrogen has an essential role in plant mass production since it is the source of proteins and has important role in increasing the chlorophyll content (Anas *et al.*, 2020). Phosphorus plays an important role in flower quality in ornamental plants (Khan *et al.*, 2023) whereas potassium improves the roots and stem growth as well as flower production because of its role in respiration processes (Sardans and Peñuelas, 2021). Previously, it has been reported that NPK-fertilization is needed in lower quantities during early stage of growth compared to the late stage in *Lilium* 'Enhancement' (Van der Boon and Niers, 1986). Also, Niedziela *et al.* (2008) suggested that applying NPK-fertilizer is needed for suitable sized bulb production in *Lilium longiflorum*. Recently, more investigations for improving Lilium production using integral fertilization have been performed. In this respect, it has been indicated that NPA-fertilization increased the *Lilium* hybrid mass production and chemical composition (Alvarado-Camarillo *et al.*, 2023). Although, a few reports studying the production of Lilium in Egypt. In this respect, El-Shanhorey and Soffar (2013) studied the effects of slow-release fertilizers on Lilium production and they found that high levels of these fertilizers improve the flower yield, and chemical composition such as the contents of chlorophyll, carbohydrate, and NPK. Moreover, it has been indicated the importance of biofertilizers on bulb rot disease and flower productivity (Mohamed, 2021; Sewedan and Youssef, 2023), whereas Youssef *et al.* (2019) produced Lilium bulb by *in vitro* propagation using different concentrations of plant growth regulators. Since then, reports studied the improvement of Lilium quality production grown under the Egyptian conditions are very scarce

It is well known that ornamental flowering plants demand high quantity of potassium since they have a direct relation with the flower production and development (Jin *et al.*, 2023). So, lower amounts of nitrogen and phosphorus fertilizers are required for Lilium plant growth compared to amount of potassium application (Wang *et al.*, 2023). In previous studies, it has been reported that potassium fertilization increased vegetative and flower growth parameters due to plant cell increment leading to increase in mineral contents (Barrera-Aguilar *et al.*, 2013). Further, it has been suggested that potassium fertilizer has a positive effect of carbohydrate, and mineral contents in Lilium bulbs (Wang *et al.*, 2023).

By following previous researches mentioned above on the use of potassium sources in Lilium plants, we found that more investigations are needed. In this work, we studied the effects of two important potassium sources like organic potassium gel, potassium silicate in four cultivars of Lilium Oriental plants. Moreover, we used foliar application of integral fertilizer using a commercial product namely Nofaterin® along with the potassium source treatments.

MATERIALS AND METHODS

Study location and plant materials:

The present study was carried out during two successive seasons of 2021/2022 and 2022/2023 at The Nursery of Ornamental Horticulture Department, Faculty of Agriculture, Cairo University, Egypt (30°01'42.6"N, 31°12'28.4"E.). During the season of this experiment, the monthly temperature was the highest in June which (27 °C), whereas the monthly minimum temperature was in January (15 °C).

The plant materials were uniform bulbs of the studied Lilium cultivars, with an average diameter of 4.5 cm to 50 g fresh weight, and were planted on October 15, 2022 and 2023 for the first and second seasons. The planting is performed directly on the ground containing clay and sand at a ratio of 1:3, inside a shade cloth greenhouse. The used soil was analyzed at Soil and Water Research Institute, in Agricultural Research Center, Giza, Egypt and the results are summarized in Table (1).

The used Lilium cultivars:

The oriental *Lilium* cultivars used in this work are 'Bacardi®', 'Zambesi®', 'Adelante®', and 'Vonq®' which have red, white, pink, and yellow colors, respectively. The bulbs of 'Bacardi®', and 'Zambesi®' were imported from VWS Export,- Import of Flower bulbs B.V., The Netherlands whereas 'Zambesi®' and 'Vonq®' bulbs were imported from VAN DEN BOS Flower bulbs B.V., The Netherlands.

The used fertilizers for experimental treatments:

Two products were used as potassium sources, the first one is potassium silicate (PS) which was obtained from Abo-Ghaneima Group Company, Cairo, Egypt as a product called El-Ghanem® (Table, 2). The second potassium source is potassium gel (PG) (Table, 2) which is provided by the Central Laboratory for Organic Agriculture, in Agricultural Research Center, Giza, Egypt. Both fertilizers were applied with the irrigation water at the rate of 4 liter/acre. Nofaterin® product was used as a source of macro- and micro- nutrient sources (Table, 3) as a foliar application at the concentration of 3 ml/1 liter water (v/v) according to the Egyptian Ministry of Agriculture recommendations.

Experiment layout:

The experimental design was organized as a randomized complete block design. Three replicates were used for each treatment, each replicate contains three plants, and the main plots represented the oriental Lilium cultivars whereas the subplots represented the fertilization treatments of potassium silicate (PS) and potassium gel (PG) at the rate of 3 g/liter of water, and 40 g/liter of water with or without Nofaterin® foliar application at concentration of 3 ml/liter of water.

Harvesting and growth parameters:

The plants were harvested at the end of the flowering period (during May until June) (Fig., 1), therefore, the following data parameters on the Lilium cultivars were recorded for nine randomly selected plants with three replicates: Plant height (cm), stem diameter (mm), stem fresh weight (g), and stem dry weight (g). In addition, all leaves in each plant were sampled to measure the leaf area (cm^2), leaf number (n), leaf fresh weight (g), leaf dry weight (g). Also, flowering growth parameters were recorded as the flowering time (days), and vase life (days) were calculated while flower diameter (cm), flower fresh weight (g), and flower dry weight (g) were measured. Meanwhile, bulb growth parameters: Bulb diameter (cm), bulb fresh weight (g), bulb dry weight (g). For measuring dry weight, samples were oven-dried at 80 °C for 72 h, and then dry weight data were measured.

Minerals content determination:

Digestion of 0.5 g of dried leaf samples at 70 °C was performed using the H_2SO_4 and H_2O_2 as described by Cottenie *et al.* (1982). The digested solution of samples was used to determine the following minerals:

1. Nitrogen content (g/100 g D. wt) was determined in the digested solution by the modified Micro-Kjeldahl method as described by Plummer (1987).
2. Phosphorus content (g/100 g D. wt) was measured colorimetrically according to the method of Jackson (1958).
3. Potassium content (g/100 g D. wt) was determined against a standard using flame-photometer (Piper, 1950).

Table 1. Physical and chemical analysis of the used soil for planting Lilium bulbs.

No.	Method	Elements	Symbol (unit)	Result	Low	Medium	High	Very high
1	Soluble	Total salts	E.C. (mmhos/cm)	1.7	0.3-0.7	0.8-1.2	1.3-3	>3
			E.C. (ppm)	1182	192-448	512-768	832-1920	>1920
2	Water 1:2.5	pH	pH	7.9	5.5-6.6	6.5-7.5	7.5-8.2	>8.3
3	Walkley	Organic Mater	O.M. (%)	4.3	0.1-0.8	0.9-1.5	1.6-5	>5
4	Olsen	Phosphorus (available)	P (meq/liter)	21.1	10-22	23-30	31-36	>36
5	Soluble	Calcium	Ca (meq/liter)	8.2	50-100	101-250	250-450	>450
6	Soluble	Magnesium	Mg (meq/liter)	4.3	0-50	–	51-100	>100
7	Soluble	Potassium	K (meq/liter)	0.7	41-80	81-120	121-160	>160
8	Soluble	Sodium	Na (meq/liter)	5.2	41-80	81-120	121-160	>160
9	Soluble	Carbonate	CO_3 (meq/liter)	0	0	0	0	0
10	Soluble	Bicarbonate	HCO_3 (meq/liter)	5.3	50-75	76-100	101-250	>250
11	Soluble	Chloride	Cl (meq/liter)	12	30	45	60	>60
12	Soluble	Sulfur	SO_4 (meq/liter)	0.9	4-7	7-11	11-15	>15
13	Calculation	Sodium adsorption ratio	SAR	1.21	0-5	1-10	10-15	>15
14	Soluble	Density	Density (g/cm^3)	1.08	–	–	–	–
15	Soluble	Nitrogen	N (%)	0.18	0	0	0	0
16	Calculation	Saturation present	Sp (%)	24.6	10-15	16-20	21-28	>28

Table 2. The ingredients of potassium sources used for fertilization of Lilium cultivars.

Potassium sources	The ingredients	Percentage (%)
Potassium silicate	K_2O	10
	SiO_2	25
Potassium gel	K_2O	59
	MgO	2
	Fe EDTA-chelated	0.09
	Mn EDTA-chelated	0.045
	Mo	0.004
	Zn EDTA-chelated	0.018

Table 3. The ingredients of Nofaterin® used as an integral fertilization for the studied Lilium cultivars.

No.	The ingredients	Percentage (%)
1	N	5
2	P_2O_4	5
3	K_2O	5
4	Zn	0.4
5	Fe	0.4
6	B	0.5
7	Mo	0.02

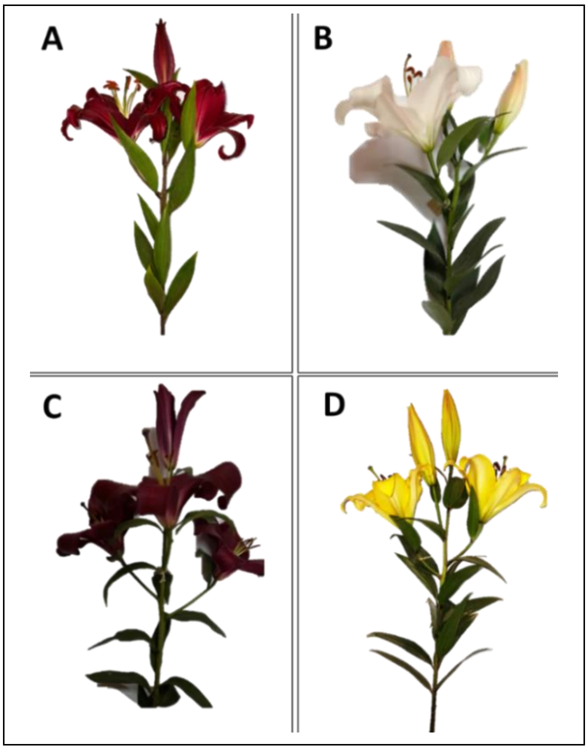

Fig. 1. The oriental *Lilium* cultivars used in this study after harvesting. A: *Lilium* cv. Bacardi. B: *Lilium* cv. Zambesi. B: *Lilium* cv. Adelante. C: *Lilium* cv. Vonq.

Protein estimation:

Crud protein content was calculated by multiplying total nitrogen by 6.25 as described by A.O.A.C. (1990).

Leaf total chlorophyll:

The leaves were harvested just before the end of the flowering period (during April). Total leaf chlorophyll was measured using SPAD meter as the measurements were done for upper, middle, and lower leaves for each plant.

Leaf total carbohydrate:

Three replicates of 0.1 g of dried leaf sample were kept in test tubes, then, 1 N HCl acid (10 ml) was added followed by sealing the tube and placed for 6 hours in an oven at 100 °C. After that, filtration of the produced solution was performed, and the filtrate was clarified by leading and deleading method using lead acetate solution (137 g/l). The excess lead salt was precipitated using N3 potassium oxalate solution. Afterwards, the extract was measured using a measuring flask (50 ml) and the combined filtrate was completed to the mark with distilled water. Total carbohydrate was determined according to the method of Dubois *et al.* (1956). The data was expressed as 100 g D.wt.

Statistical analyses:

The collected data for both seasons was recorded, and the obtained results were analyzed using MSTATC software. The experiment design was conducted as randomized complete block design for ANOVA two factors analysis, factor A (*Lilium* cultivars), with factor B (fertilization treatments) a split plot on A. Means were compared using L.S.D. test at 0.05 level according to Snedecor and Cochran (1989). Also, Duncan's multiple range test was performed for analyzing the interactions between the cultivars (Factor A) and treatments (Factor B) at $P \leq 0.05$.

RESULTS

Effects of fertilization with potassium sources with or without Nofaterin foliar application on vegetative, flowering, and bulb growth parameters:

In this research, two potassium source treatments with or without integral fertilizer foliar application using Nofaterin® (Nofat.) in four commercial oriental *Lilium* cultivars were implemented as well as the untreated plants (control). Our results revealed that the cultivars treated with PS + Nofat. had the highest record regarding the vegetative growth parameters, whereas the lowest parameters were recorded with the control treatment (Figs., 2 and 3). Other than the control, it is worth noting that PG treatment recorded the lowest vegetative growth parameters (Figs., 2, and 3). The values of plant height, leaf area, stem diameter, and leaf number were significantly increased with the treatment of PS + Nofat. compared to those with the other treatments (Fig., 2). Compared to the control, the treatment of PS + Nofat. resulted in a 70.55, 71.36, 66.12, 73.54% increase in plant height, leaf area, stem diameter, and leaf number, respectively (Fig., 2).

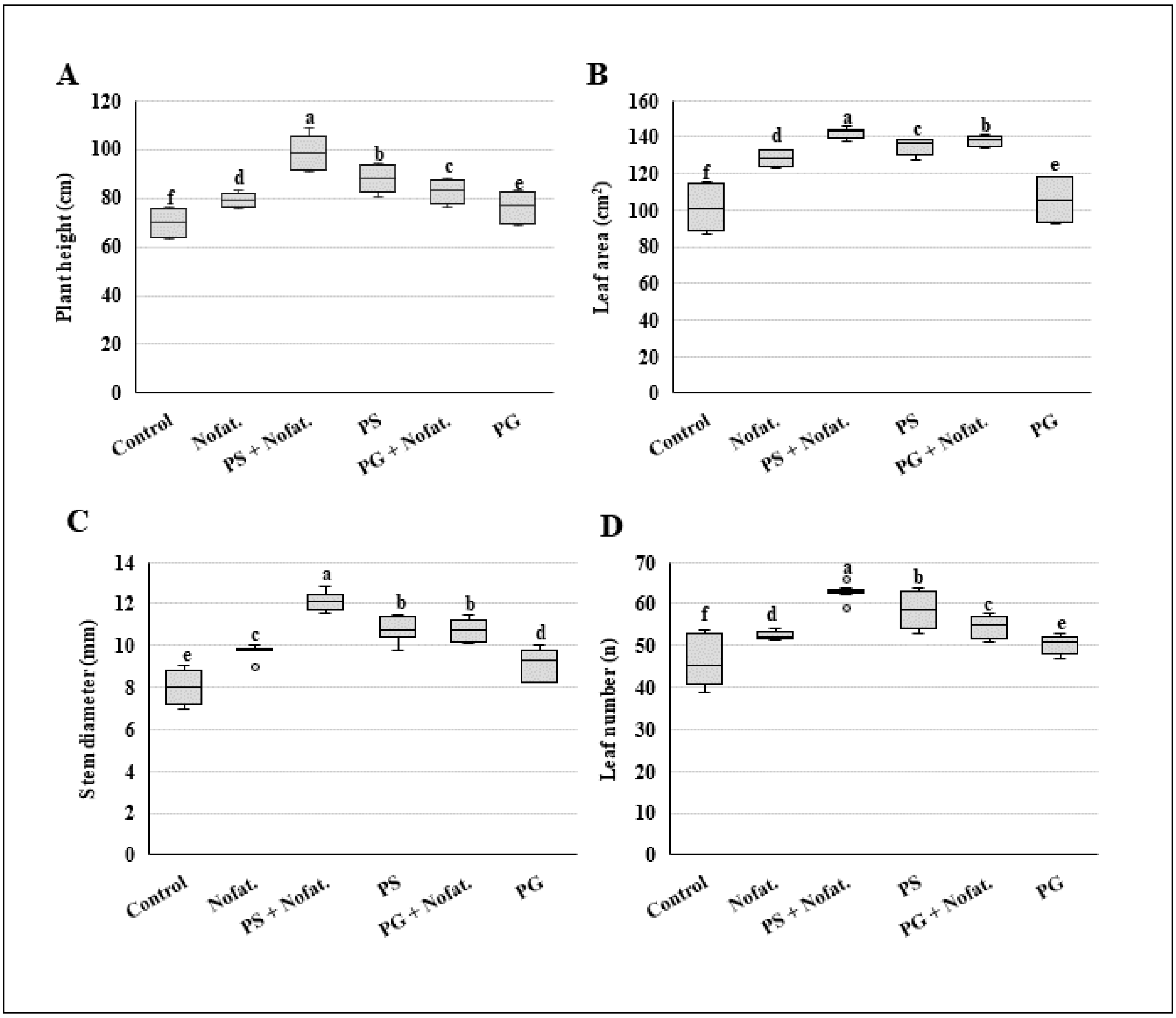

Fig. 2. Box plot of growth parameters of plant height, leaf area, stem diameter, and leaf number in oriental Lilium cultivars treated with potassium sources with or without Nofaterin foliar application. The plot illustrates the mean and median of these growth parameters representing four cultivars grown under treatments of control, Nofaterin (Nof.), potassium silicate and Nofaterin (PS + Nof.), potassium silicate (PS), potassium gel and Nofaterin (PG + Nof.), and potassium gel (PG). Analysis of ranking results was performed with point values of mean and median or uncertainty range with box. Data show mean ± standard deviation of 3 replicates. Small letters indicate statistically significant differences at LSD test (P ≤ 0.05).

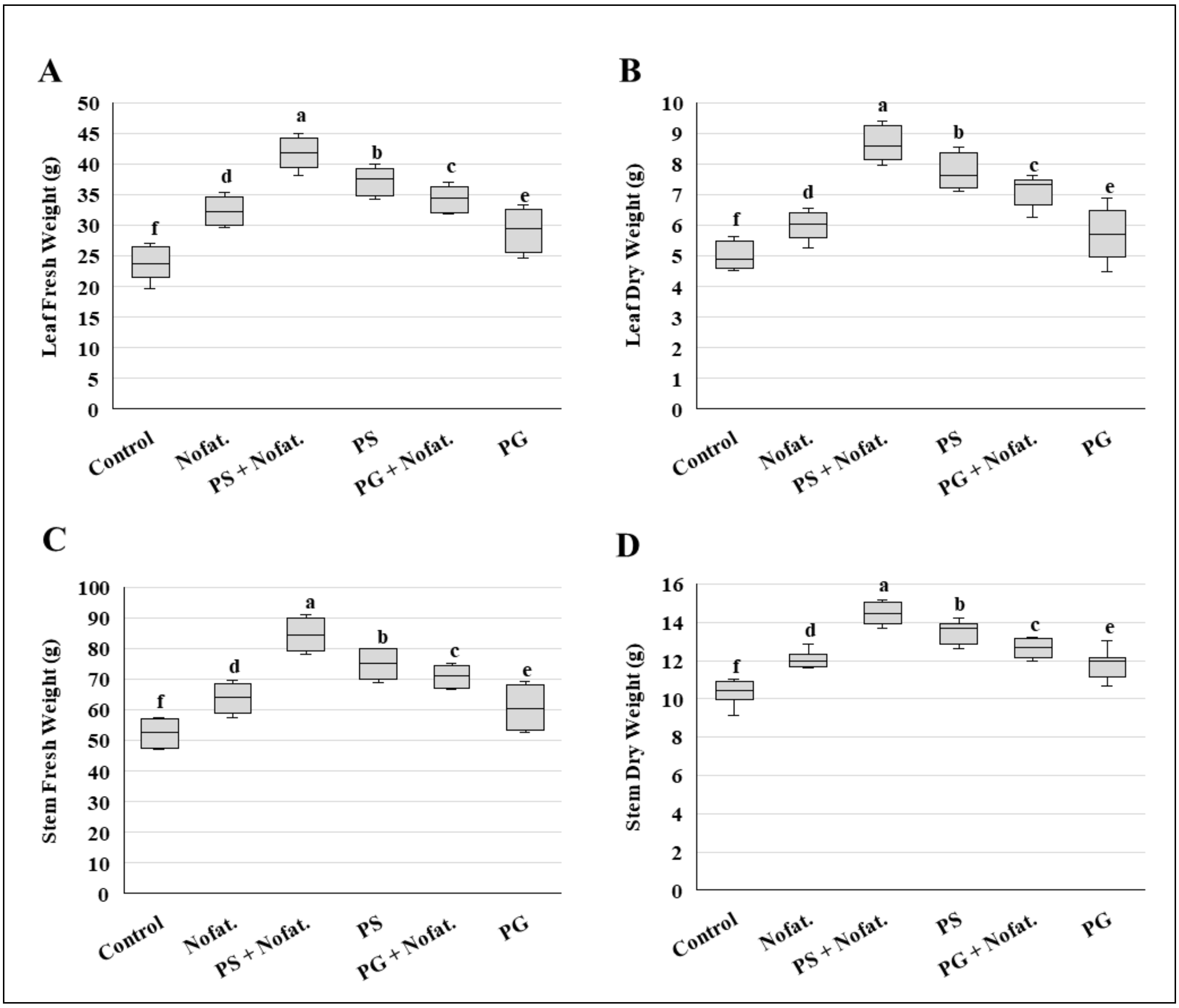

Fig. 3. Box plot of growth parameters of leaf fresh weight, leaf dry weight, stem fresh weight, and stem dry weight in oriental Lilium cultivars treated with potassium sources with or without Nofaterin foliar application. The plot illustrates the mean and median of these growth parameters representing four cultivars grown under treatments of control, Nofaterin (Nof.), potassium silicate and Nofaterin (PS + Nof.), potassium silicate (PS), potassium gel and Nofaterin (PG + Nof.), and potassium gel (PG). Analysis of ranking results was performed with point values of mean and median or uncertainty range with box. Data show mean ± standard deviation of 3 replicates. Small letters indicate statistically significant differences at LSD test ($P \leq 0.05$).

Also, the same treatment increased leaf fresh weight, leaf dry weight, stem fresh weight, and stem dry weight at the rate of 56.92, 57.72, 61.96, 71.73%, respectively (Fig., 3) indicating that the PS + Nofat. treatment induces and increases the vegetative growth parameters compared to the other fertilization treatments used in this study.

Regarding flowering growth parameters, we observed significant differences in flowering time which *Lilium* cvs. Adelante and Zambesi flowered on average 116 and 118 days, respectively from bulb planting day which were earlier than *Lilium* cvs. Vonq and Bacardi (Fig., 4).

Also, the fertilization treatments recorded significantly affected flowering time, as treating plants with PS + Nofat. treatment induced earlier flowering (125.14 days) than the other treatments whereas, the control represented the latest flowering time (Fig., 5; A). For vase life test, the treatment of PS + Nofat. recorded as the highest level while the PS and PG + Nofat. treatments were placed as the second and third levels, respectively followed by significant decreases in the rest of treatments (Fig., 5; B). Fig. (6) showed that flower growth parameters recorded the highest values for PS + Nofat. treatment while the control recorded the lowest value. For flower diameter, we observed that PS and PG + Nofat. treatments recorded 21.12, and 20.99 cm, respectively locating as the second and third places after PS + Nofat. treatment which recorded 22.95 cm while the control represented the lowest level which recorded 15.09 cm (Fig., 6; A). Regarding flower fresh and dry weight, we noticed that PS + Nofat. treatments represented the highest values which increased by 68.45, and 58.92 %, respectively over the control treatment (Fig., 6; B and C), whereas the second level was observed in PS treatment compared to the other treatments which no significant differences were observed (Fig., 6; B and C).

For bulb growth parameters, we observed that PS +Nofat. treatment showed the highest value recording 8.44 cm for bulb diameter, 57.61 g for bulb fresh weight, and 11.79 g for bulb dry weight while the control treatment recorded the lowest values for bulb diameter (4.84 cm), bulb fresh weight (37.99 g), and bulb dry weight (7.90 g) (Fig., 7).

The impact of potassium sources with or without Nofaterin foliar application on the endogenous chemical contents:

As PS + Nofat. treatment impacted growth parameters in *Lilium* cultivars, its influence on the chemical composition was investigated. In this respect, we observed that nitrogen, phosphorus and potassium contents dramatically increased as a result of PS + Nofat. treatment which recorded 4.01, 0.67, and 3.11 g/100 g D. wt, respectively compared to the other treatments (Fig., 8). Whereas the lowest levels of those mineral contents were obtained in the *Lilium* cultivars grown under control treatments which recorded 0.09 g/100 g D. wt for nitrogen content, 0.30 g/100 g D. wt for phosphorus content, and 2.64 g/100 g D. wt for potassium content (Fig., 8). Considering the effects of potassium sources with or without Nofaterin foliar application on the chemical contents, we analyzed the most important endogenous molecules distributed in the leaves like total protein, total chlorophyll, and total carbohydrate. We found that the content of total protein, total chlorophyll, and total carbohydrate of four commercial cultivars of *Lilium* treated with PS + Nofat. were significantly increased compared to the other treatments (Fig., 9).

Detecting the optimum potassium source treatments interacted with *Lilium* cultivars:

1. Growth parameters:

According to our previous data, the potassium sources accompanied by Nofaterin foliar application have an impact on all growth parameters and chemical composition in the studied *Lilium* cultivars. In this respect, we conducted an interaction effect of our treatments on growth parameters and chemical composition to detect the best treatment and to compare the studied cultivars

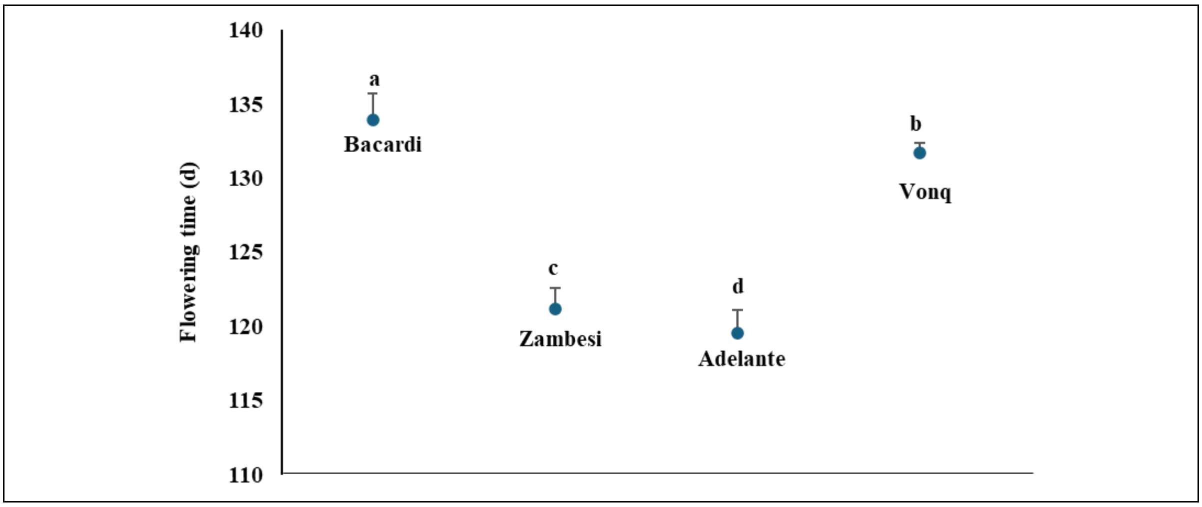

Fig. 4. Flowering time in four oriental Lilium cultivars. Data show mean ± standard deviation of 3 replicates. Small letters indicate statistically significant differences at LSD test (P ≤ 0.05).

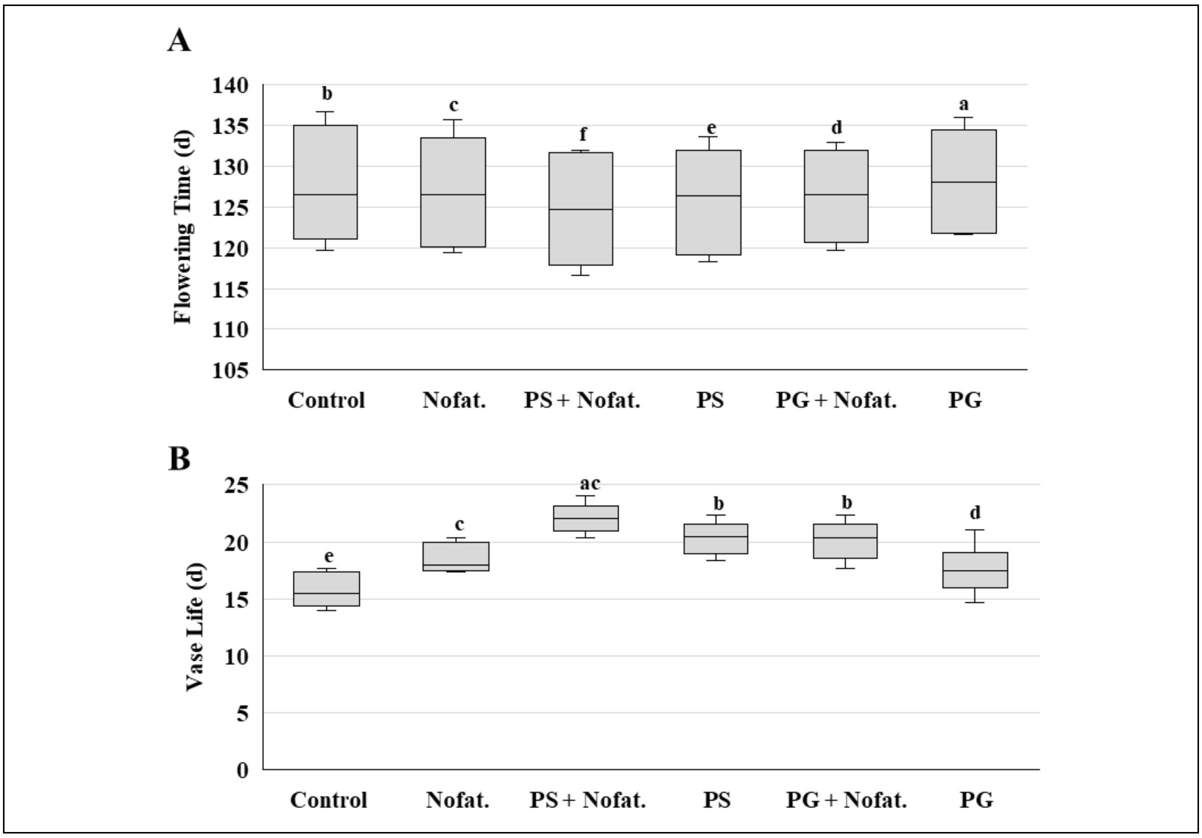

Fig. 5. Box plot of growth parameters of flowering time and vase life in oriental Lilium cultivars treated with potassium sources with or without Nofaterin foliar application. The plot illustrates the mean and median of these measurements representing four cultivars grown under treatments of control, Nofaterin (Nof.), potassium silicate and Nofaterin (PS + Nof.), potassium silicate (PS), potassium gel and Nofaterin (PG + Nof.), and potassium gel (PG). Analysis of ranking results was performed with point values of mean and median or uncertainty range with box. Data show mean ± standard deviation of 3 replicates. Small letters indicate statistically significant differences at LSD test (P ≤ 0.05).

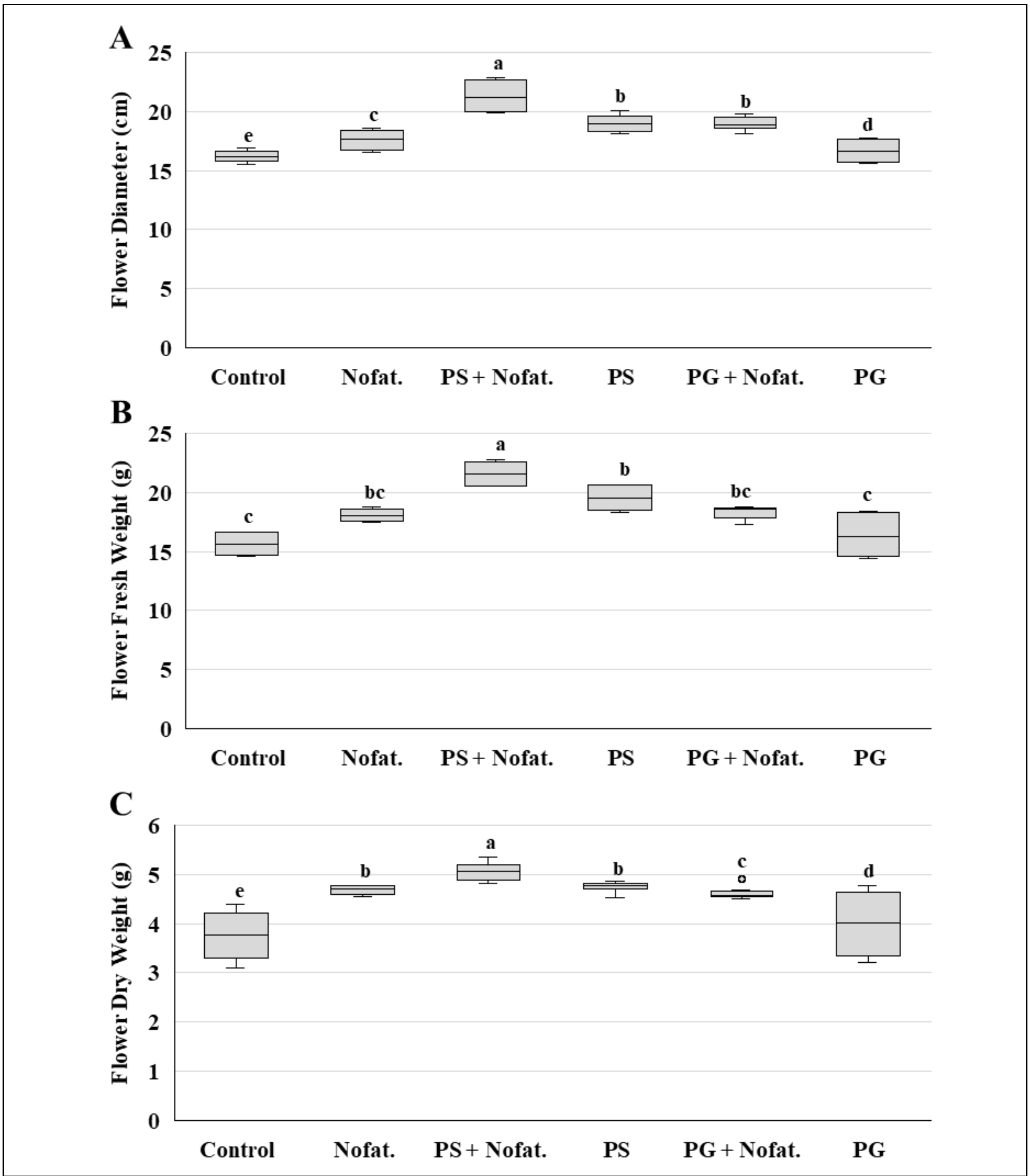

Fig. 6. Box plot of growth parameters of flower diameter, flower fresh weight, and flower dry weight in oriental Lilium cultivars treated with potassium sources with or without Nofaterin foliar application. The plot illustrates the mean and median of these growth parameters representing four cultivars grown under treatments of control, Nofaterin (Nof.), potassium silicate and Nofaterin (PS + Nof.), potassium silicate (PS), potassium gel and Nofaterin (PG + Nof.), and potassium gel (PG). Analysis of ranking results was performed with point values of mean and median or uncertainty range with box. Data show mean ± standard deviation of 3 replicates. Small letters indicate statistically significant differences at LSD test ($P \leq 0.05$).

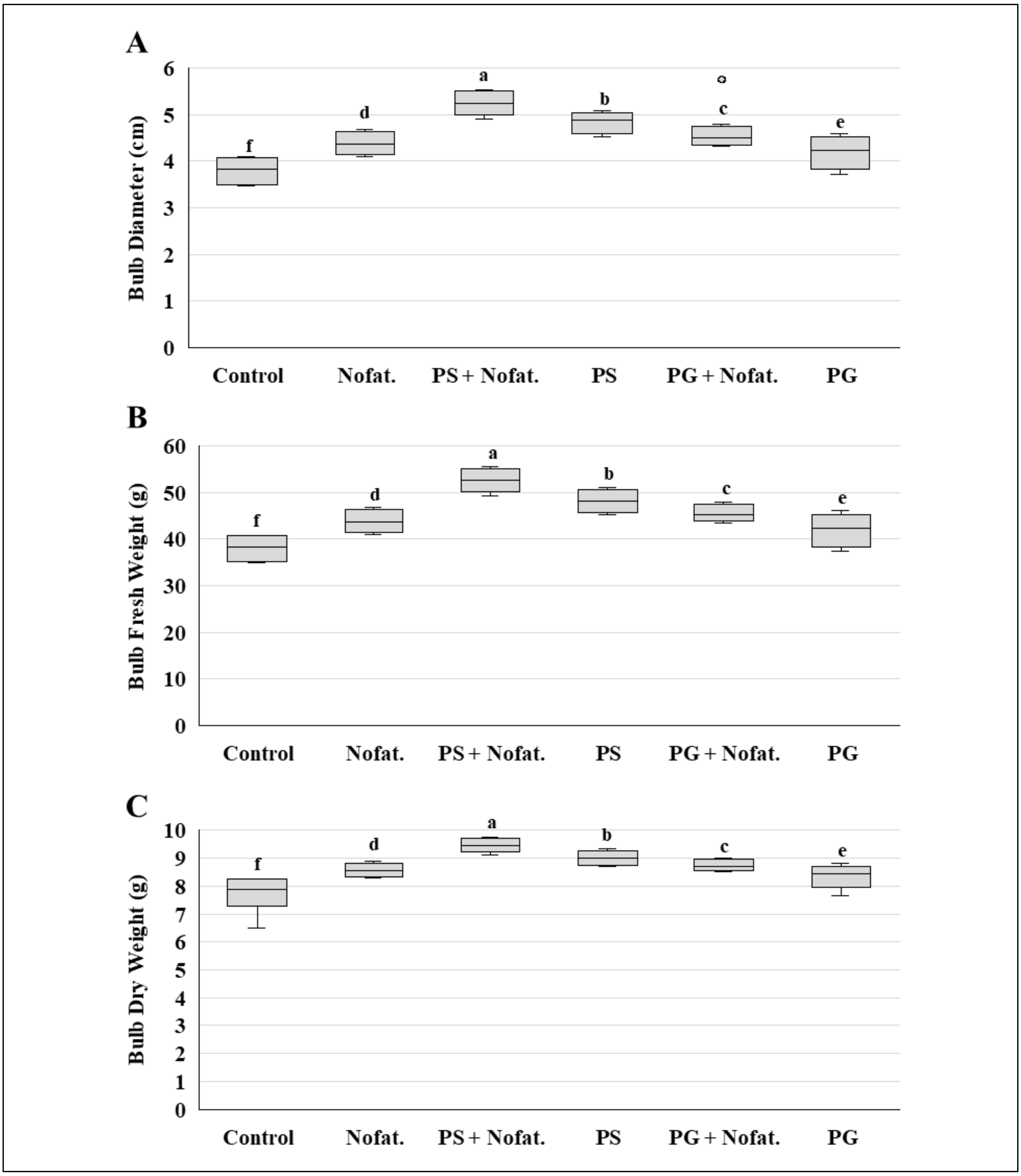

Fig. 7. Box plot of growth parameters of bulb diameter, bulb fresh weight, and bulb dry weight in oriental Lilium cultivars treated with potassium sources with or without Nofaterin foliar application. The plot illustrates the mean and median of these growth parameters representing four cultivars grown under treatments of control, Nofaterin (Nof.), potassium silicate and Nofaterin (PS + Nof.), potassium silicate (PS), potassium gel and Nofaterin (PG + Nof.), and potassium gel (PG). Analysis of ranking results was performed with point values of mean and median or uncertainty range with box. Data show mean ± standard deviation of 3 replicates. Small letters indicate statistically significant differences at LSD test (P ≤ 0.05).

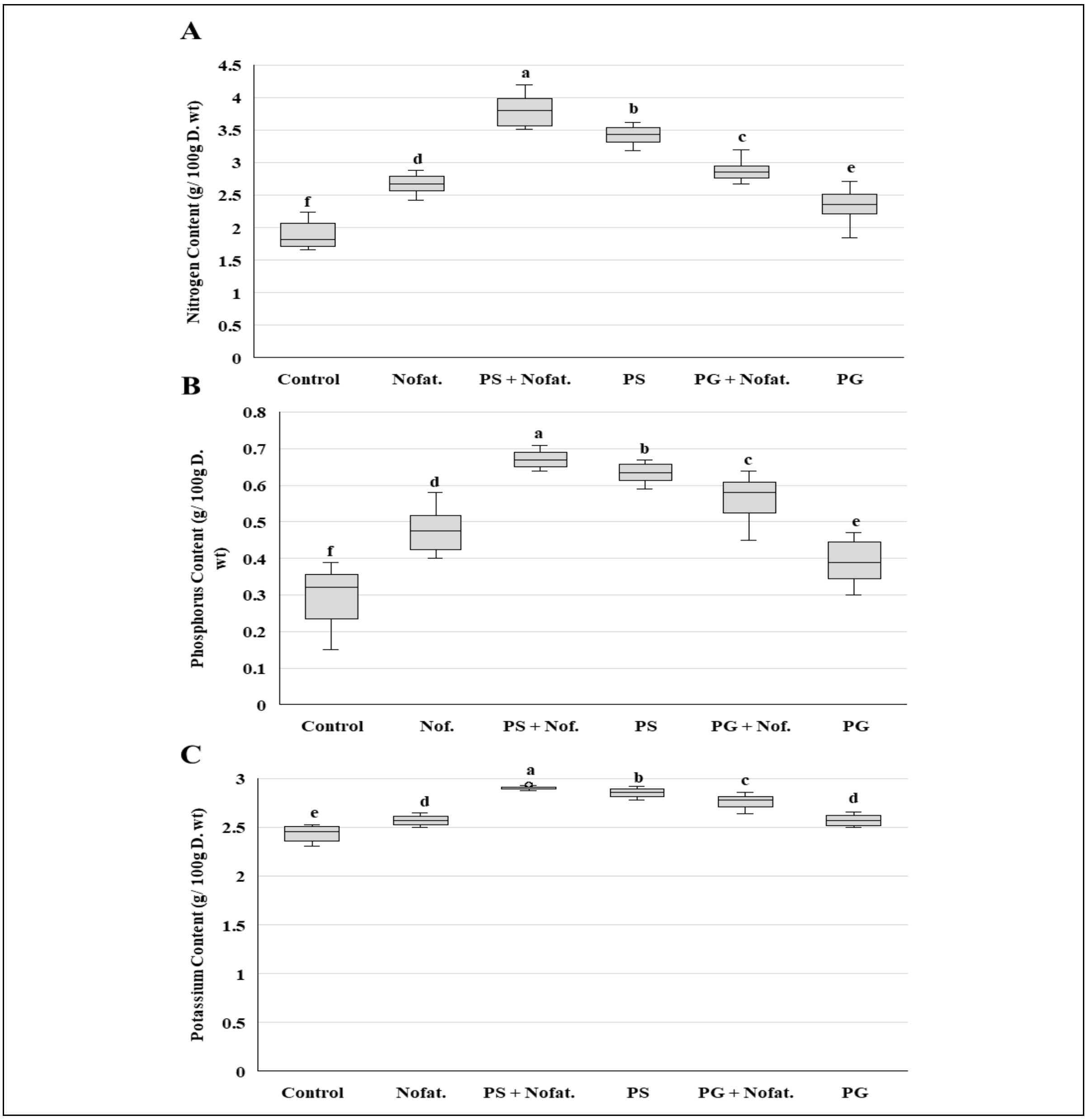

Fig. 8. Box plot of mineral composition of nitrogen, phosphorus, and potassium contents in oriental Lilium cultivars treated with potassium sources with or without Nofaterin foliar application. The plot illustrates the mean and median of these compositions representing four cultivars grown under treatments of control, Nofaterin (Nof.), potassium silicate and Nofaterin (PS + Nof.), potassium silicate (PS), potassium gel and Nofaterin (PG + Nof.), and potassium gel (PG). Analysis of ranking results was performed with point values of mean and median or uncertainty range with box. Data show mean ± standard deviation of 3 replicates. Small letters indicate statistically significant differences at LSD test ($P \leq 0.05$).

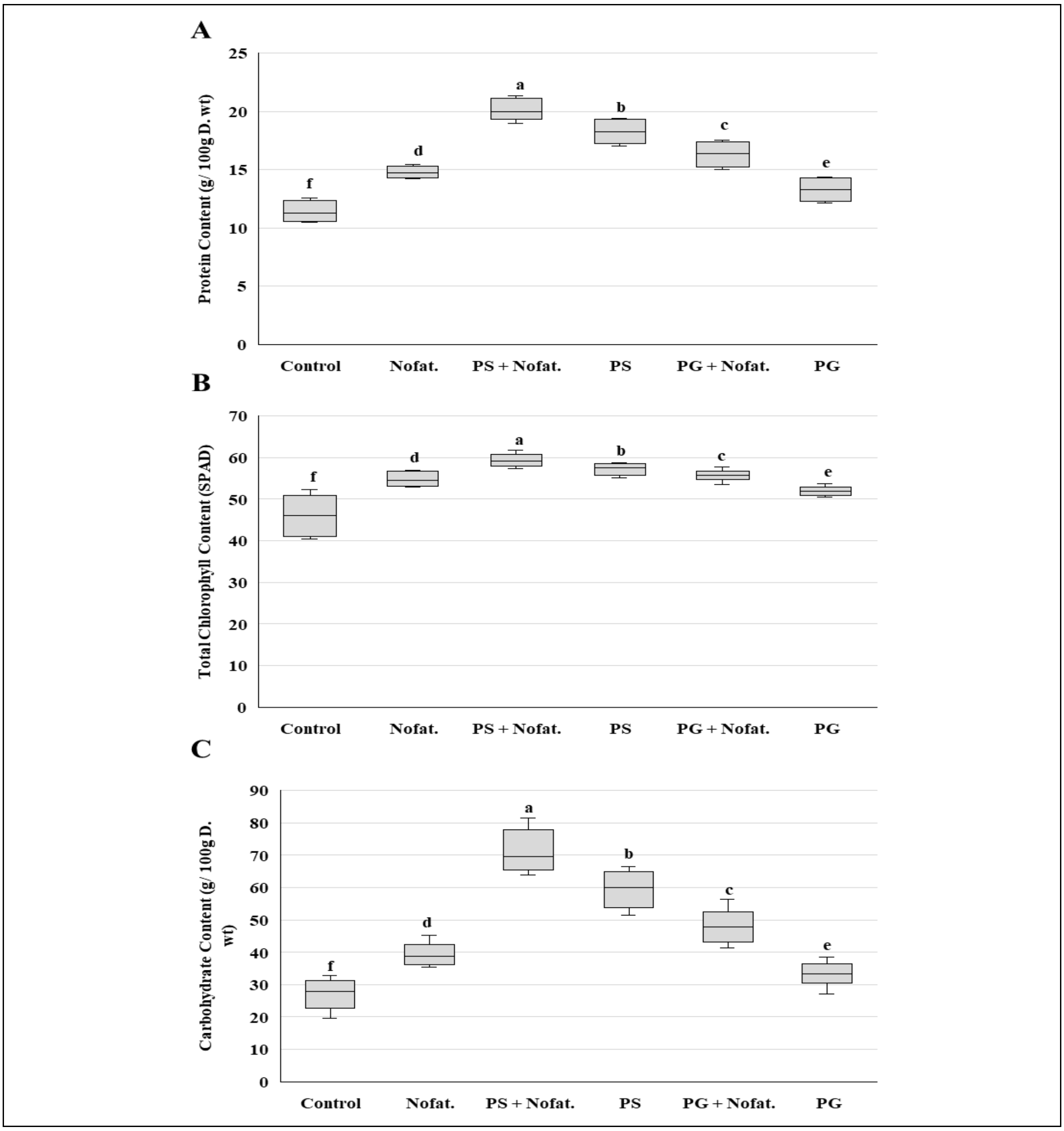

Fig. 9. Box plot of concentration of protein, total chlorophyll, and total carbohydrate in oriental Lilium cultivars treated with potassium sources with or without Nofaterin foliar application. The plot illustrates the mean and median of these concentrations representing four cultivars grown under treatments of control, Nofaterin (Nof.), potassium silicate and Nofaterin (PS + Nof.), potassium silicate (PS), potassium gel and Nofaterin (PG + Nof.), and potassium gel (PG). Analysis of ranking results was performed with point values of mean and median or uncertainty range with box. Data show mean ± standard deviation of 3 replicates. Small letters indicate statistically significant differences at LSD test ($P \leq 0.05$).

during two successive seasons followed by performing statistical analyses using ANOVA two factor.

In general, we noticed that the treatment of PS + Nofat. in *lilium* cv. Vonq recorded the best results for plant height, leaf area, and stem diameter while PS + Nofat. in *Lilium* cv. Adelante was placed as a second level (Fig., 10; A, B and C). On the contrary, *Lilium* cv. Adelante recorded the highest values, and no significant decrease was observed in *Lilium* cv. Vonq for leaf number (Fig., 10; D). Meanwhile, the control in *Lilium* cv. Bacardi recorded the lowest values for plant height, leaf area, stem diameter, and leaf number (Fig., 10). In detail, it can be noticed a significant increase in plant height for the treatment of PS + Nofat. in *Lilium* cvs. Vonq and Adelante compared to the rest of the *Lilium* cultivars which represented significant differences which *Lilium* cv. Bacardi represented the lowest value (Fig., 10; A). Whereas for leaf area parameter, no significant differences were observed for all studied cultivars regarding the PS + Nofat. treatment during the first season, but significant decreases were observed for *Lilium* cv. Zambesi and cv. Bacardi compared to *Lilium* cvs. Vonq and Adelante which recorded the highest values during the second season (Fig., 10; B). Regarding stem diameter, treatment of PS + Nofat. in *Lilium* cvs. Vonq and Adelante represented the best results compared to the other cultivars in which a significant decrease in *Lilium* cvs. Bacardi and Zambesi were observed for both seasons (Fig., 10; C). Regarding the leaf number, treatment of PS + Nofat. in *Lilium* cv. Adelante represented the highest level compared to the other cultivars which recorded a non-significant decrease during the first season and significant decrease in *Lilium* cv. Zambesi during the second season (Fig., 10; D). Regarding the fresh and dry weights of leaves and stems, we found that the treatment with PS + Nofat. in *Lilium* cvs. Vonq and Adelante represented the highest levels recorded with almost similar values, while the control in *Lilium* cv. Bacardi recorded the lowest values with a significant decrease (Fig., 11).

Regarding the treatment of PS + Nofat. which showed the best results for the vegetative growth parameters, we noticed that this treatment recorded the shortest flowering period for all *Lilium* cultivars (Fig., 12; A). In this respect, worthy to note that the control in *Lilium* cv. Bacardi recorded the longest flowering period showing the latest time of flowering (Fig., 12; A). For vase life, the treatment of PS + Nofat. in *Lilium* cv. Vonq showed the best results whereas the treatment of PS + Nofat. in *Lilium* cvs. Zambesi, and Adelante were placed as the second and third level, respectively (Fig., 12; B). Similar to the previous parameters, the treatment of control in *Lilium* cv. Bacardi recorded the shortest vase life as shown in Fig. (12; B).

For flower diameter, it was observed that the treatment of PS +Nofat. in *Lilium* cv. Adelante represented the highest record followed by the treatment of PS +Nofat. in *Lilium* cv. Vonq showing significant decrease during the first season and non-significant one during the second season, while the control in *Lilium* cv. Bacardi showed the lowest record with the observation that no significant differences were found with the PG in *Lilium* cv. Bacardi, and the control and PG treatment in *Lilium* cv. Zambesi (Fig., 13; A). On the other hand, it was observed that flower fresh and dry weights were significantly increased with the treatment of PS + Nofat. in *Lilium* cvs. Adelante and Vonq whereas the control in *Lilium* cv. Bacardi showed the lowest record as shown in Fig. (13; B). For the bulb diameter, we observed that the treatment of PS + Nofat. in *Lilium* cv. Adelante recorded the highest value followed by a non-significant decrease for the treatment of PS + Nofat. in *Lilium* cv. Vonq, whereas the control in *Lilium* cvs. Bacardi and Zambesi recorded the lowest values (Fig., 14; A). Similarly, the treatment of PS + Nofat. in *Lilium* cvs. Adelante and Vonq showed the best results for fresh and dry weights of bulbs whereas the control in *Lilium* cv. Bacardi resulted the lowest record (Fig., 14; B).

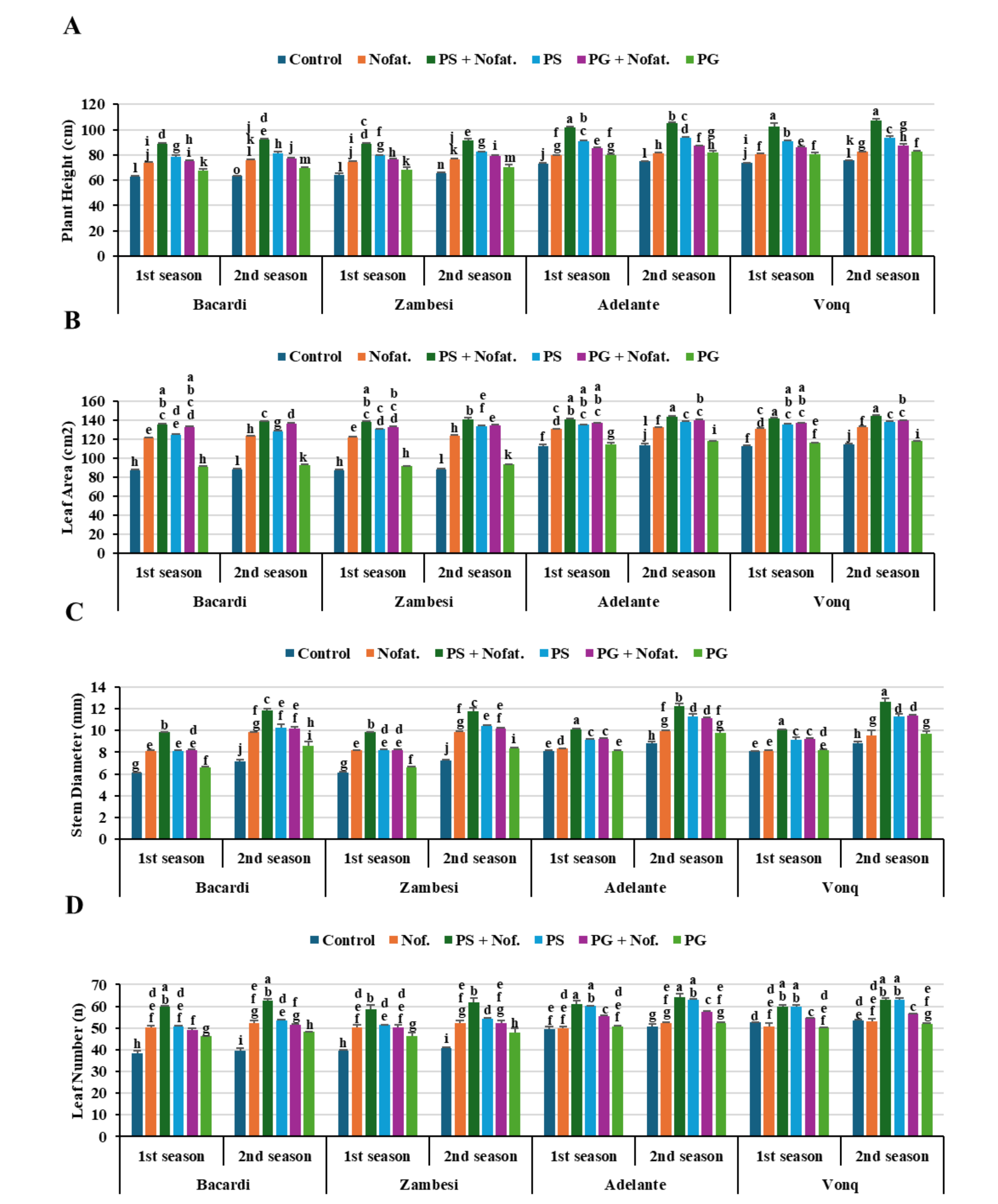

Fig. 10. Effect of potassium sources with or without Nofaterin foliar application on growth parameters of plant height, leaf area, stem diameter, and leaf number in four oriental Lilium cultivars. Data show mean ± standard deviation of 3 replicates. Small letters indicate statistically significant differences at Duncan's multiple range test ($P \leq 0.05$).

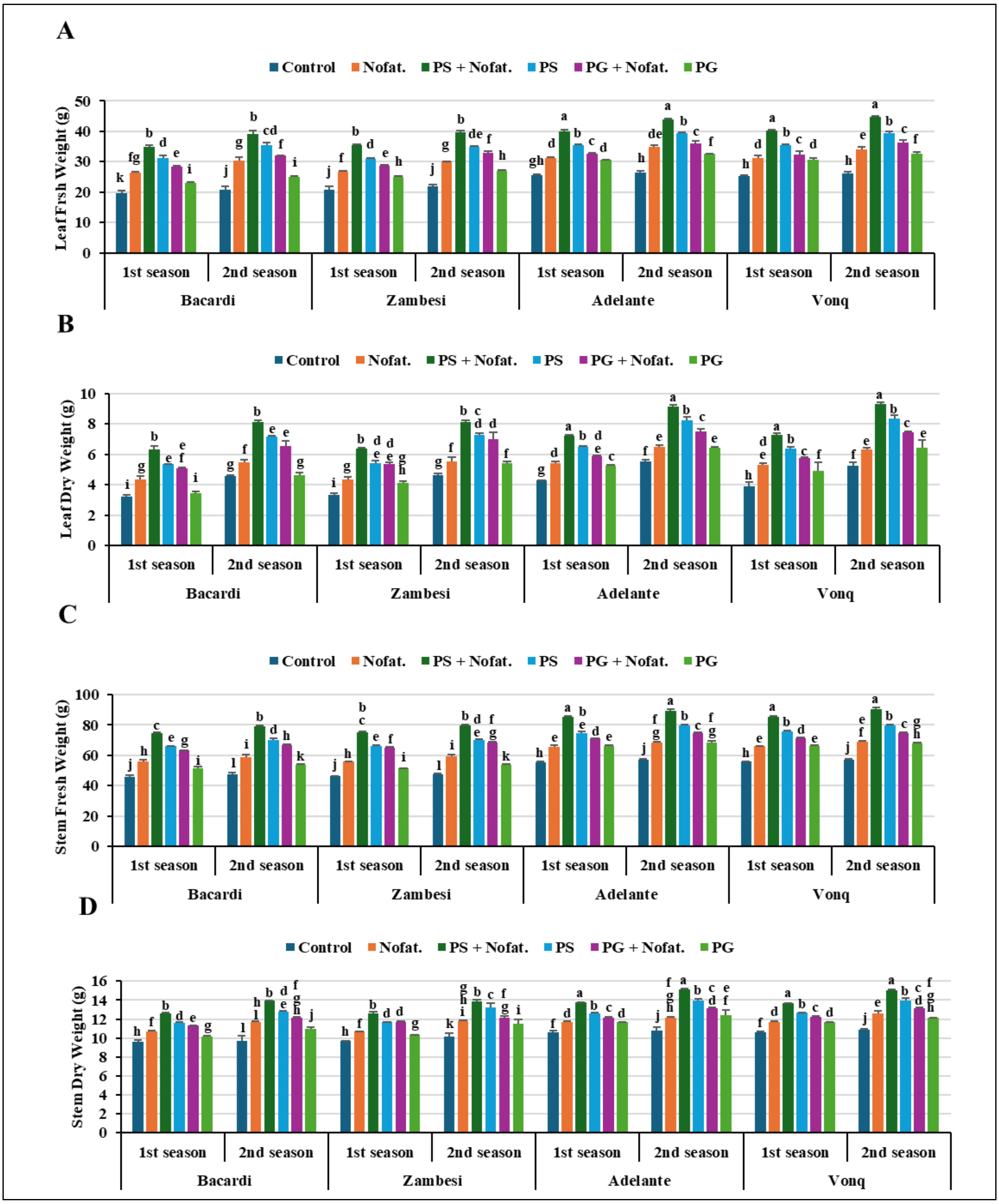

Fig. 11. Effect of potassium sources with or without Nofaterin foliar application on growth parameters of leaf fresh weight, leaf dry weight, stem fresh weight, and stem dry weight in four oriental Lilium cultivars. Data show mean ± standard deviation of 3 replicates. Small letters indicate statistically significant differences at Duncan's multiple range test (P ≤ 0.05).

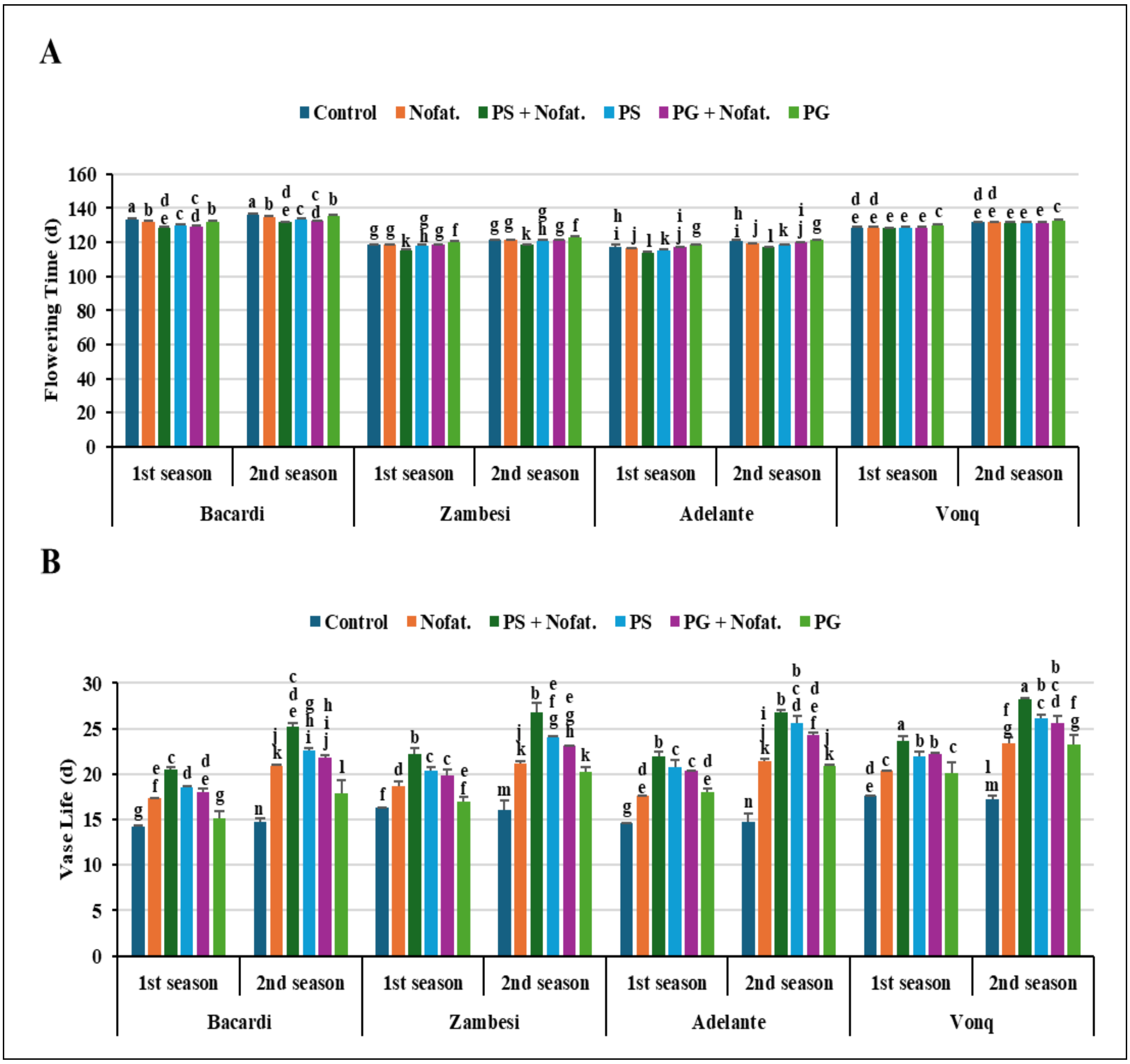

Fig. 12. Effect of potassium sources with or without Nofaterin foliar application on flowering time and vase life in four oriental Lilium cultivars. Data show mean ± standard deviation of 3 replicates. Small letters indicate statistically significant differences at Duncan's multiple range test ($P \leq 0.05$).

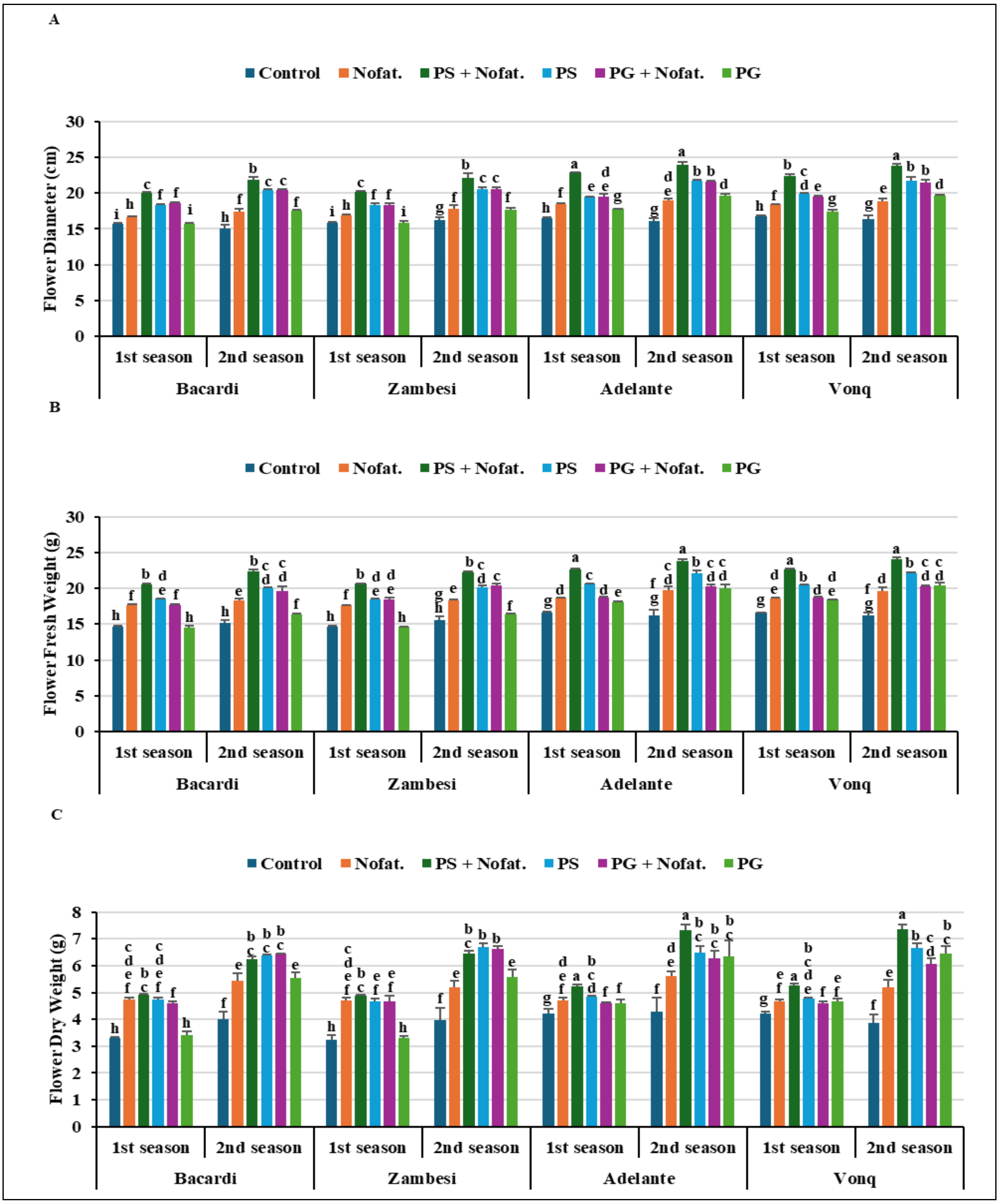

Fig. 13. Effect of potassium sources with or without Nofaterin foliar application on growth parameters of flower diameter, flower fresh weight, flower dry weight in four oriental Lilium cultivars. Data show mean ± standard deviation of 3 replicates. Small letters indicate statistically significant differences at Duncan's multiple range test ($P \leq 0.05$).

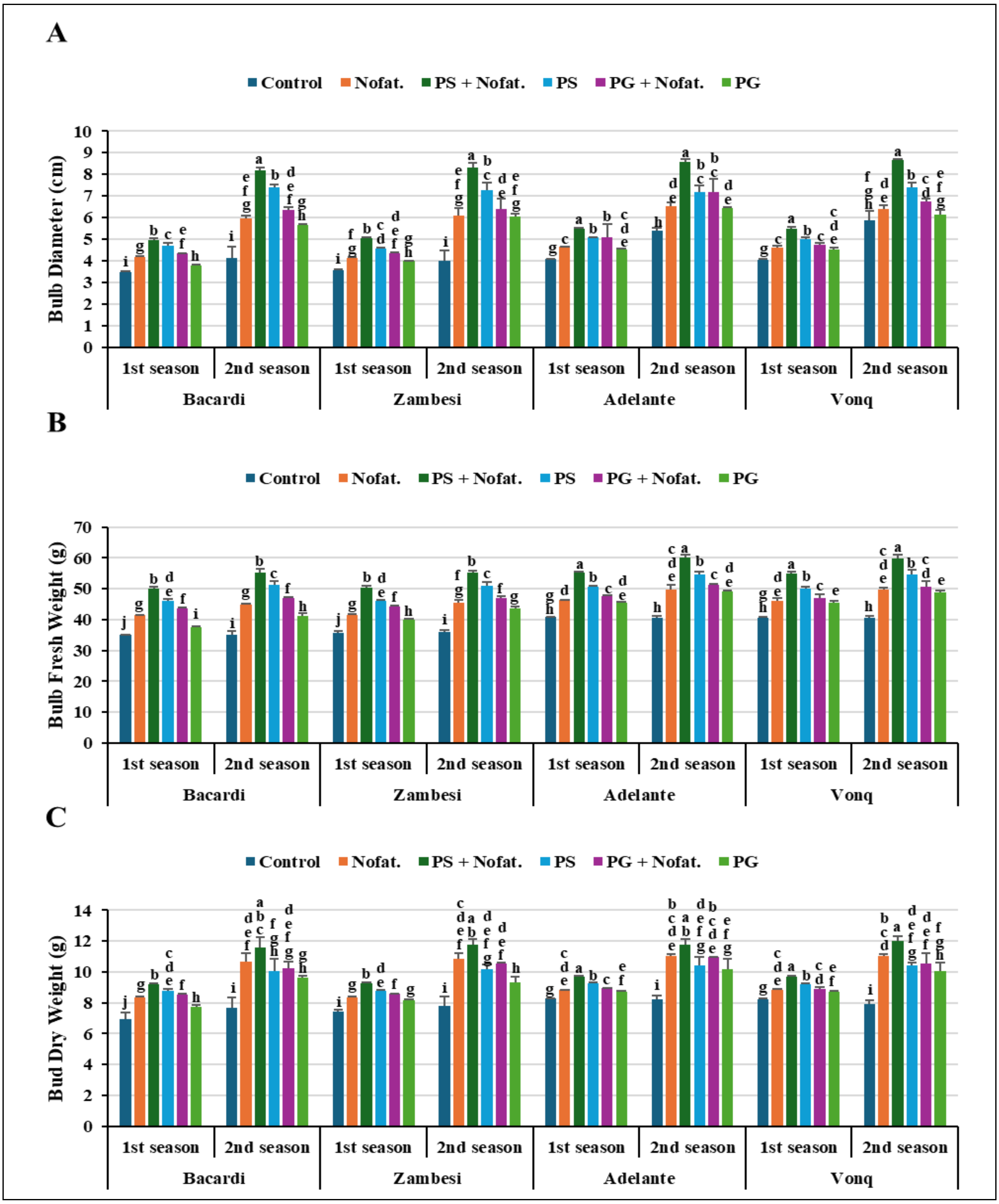

Fig. 14. Effect of potassium sources with or without Nofaterin foliar application on growth parameters of bulb diameter, bulb fresh weight, and bulb dry weight in four oriental Lilium cultivars. Data show mean ± standard deviation of 3 replicates. Small letters indicate statistically significant differences at Duncan's multiple range test (P ≤ 0.05).

2. Chemical composition

We estimated the most important chemical contents in the yielded dry weight were content of nitrogen, phosphorus, potassium, protein, and carbohydrate whereas the yielded fresh weight of leaves used for measuring chlorophyll concentration to detect the best potassium sources with or without Nofaterin® (Nofat.) in *Lilium* cultivars. Fig. (15; A) showed that the treatment of PS + Nofat. in *Lilium* cvs. Adelante and Vonq represented the highest records for nitrogen content whereas the control in *Lilium* cv. Bacardi recorded as the lowest value. Similarly, the treatment of PS + Nofat. in *Lilium* cvs. Adelante and Vonq showed the highest record while the control in *Lilium* cv. Bacardi represented the lowest record for phosphorus contents (Fig., 15; B). For potassium content, we found similar results of nitrogen and phosphorus contents, but no significant differences were found among the treatment of PS + Nofat. in all *Lilium* cultivars (Fig., 15; C). For total protein content, the treatment of PS + Nofat. in *Lilium* cvs. Adelante and Vonq recorded the highest values followed by significant decreasing in the rest of treatments and cultivars (Fig., 16A). The control in *Lilium* cv. Bacardi showed the lowest record with observation that no significant differences with the control in *Lilium* cv. Zambesi (Fig., 16; A). Similar results were found for total chlorophyll and carbohydrate contents (Fig., 16; B and C) but a notable peak was found with the treatment of PS + Nofat. in *Lilium* cv. Adelante compared to all treatments in *Lilium* cultivars for carbohydrate content (Fig., 16; C).

DISCUSSION

Because of the importance of potassium fertilizer for vegetative and flowering growth as well as the chemical composition in *Lilium*, we investigated the impact of two important potassium source treatments in four commercial cultivars of oriental *Lilium*. Besides enzyme activation and photosynthesis, the main role of potassium is the regulation of continuous osmotic balance in plant cell along with sucrose resulting strong drain water in the flowers (Gülser and Çiğ, 2021). The impact of fertilization by different potassium sources on flowering ornamental plants has been investigated in several reports. It has been demonstrated that potassium sources have positive effects on the vegetative growth and flower quality in *Zinnea elegans* (Hend, 2002), *Tagetes erecta* (Pal and Ghosh, 2010), and *Helichrysum bracteatum* (Badawy *et al.*, 2015). In this context, different potassium sources have been used for ornamental plants even in mineral or organic substances. For example, Matlabi *et al.* (2002) treated carnation plants with KCl and K_2SO_4 which increased significantly the flower yield at 1% level, whereas Khan *et al.* (2012) applied potassium sulphate to test its impact on the flower yield of tuberose plants at the rate of 88.1%. Also, it has been demonstrated that using grained organo-mineral glauconite as a potassium source increased the flower growth in ornamental sunflower which the flower stalk height, diameter flower stalks recorded 46.8 cm, and 9.24 mm, respectively (Torqueti *et al.*, 2016). Furthermore, using nano and humate potassium enhanced the vegetative, flowering and bulb yield in *Narcissus tazetta* (El-Attar *et al.*, 2022).

In our present study, we demonstrated that potassium silicate is the best potassium source for vegetative, flowering, and bulb growth as well as the most important chemical contents. Potassium silicate (K_2SiO_3) contains silicon which has a major role in biotic and abiotic stresses tolerance enhancing vegetative and flowering growth, and chemical composition (Hajipour *et al.*, 2019). Previously, it has been concluded that potassium silicate enhances the plant growth and chemical contents in *Dendanthema grandiflorum* (Abdelsadek *et al.*, 2021). Moreover, Camata *et al.* (2021) demonstrated that using potassium silicate at the concentration of 900 ppm increased leaf growth and flower longevity of chrysanthemum plants which leaf number and flowering time recorded 26.90, and 120.33 days, respectively. In *Lilium*, no report of potassium silicate fertilizer has been found

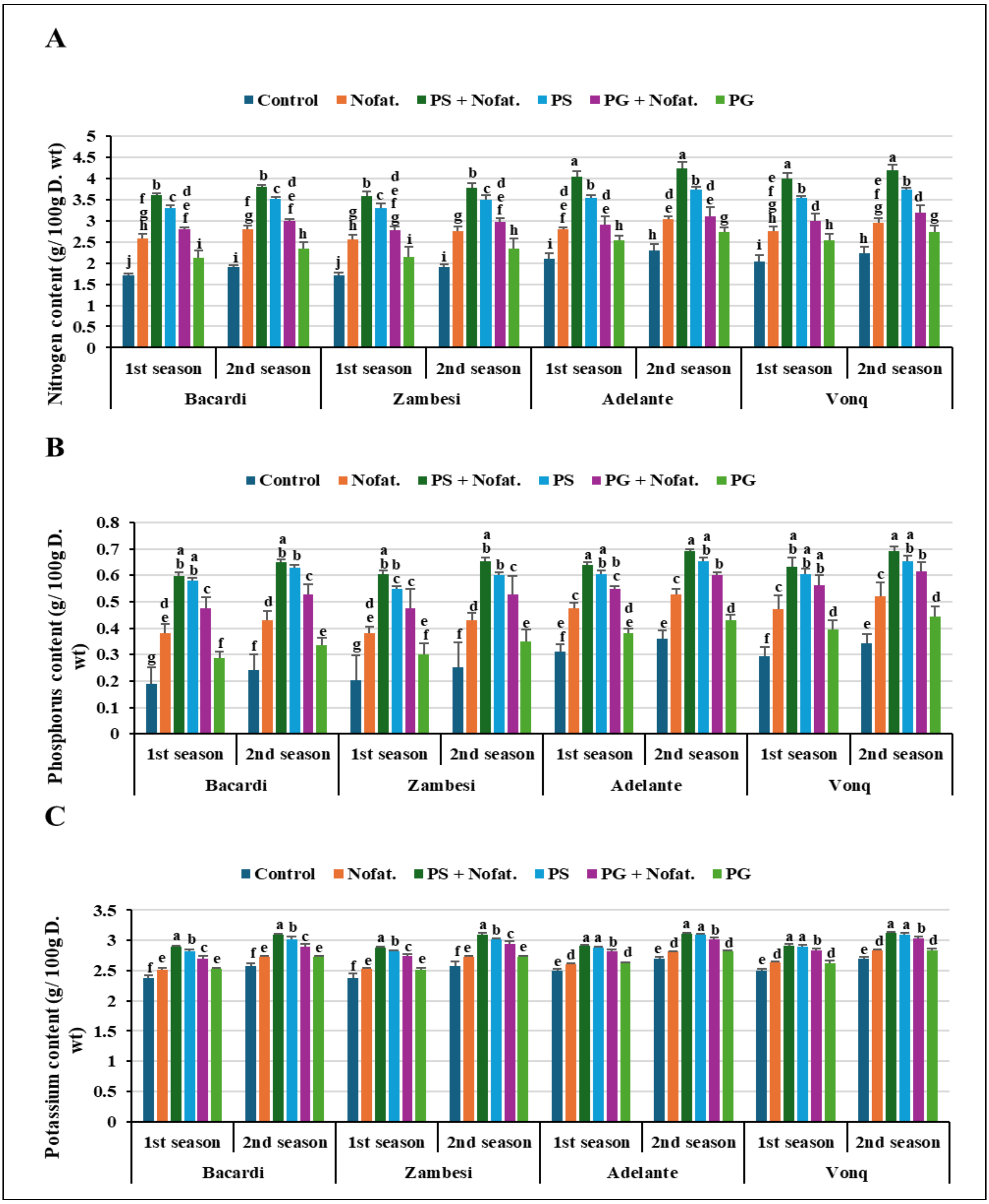

Fig. 15. Effect of potassium sources with or without Nofaterin foliar application on mineral composition of nitrogen, phosphorus, and potassium contents in four oriental Lilium cultivars. Data show mean ± standard deviation of 3 replicates. Small letters indicate statistically significant differences at Duncan's multiple range test ($P \leq 0.05$).

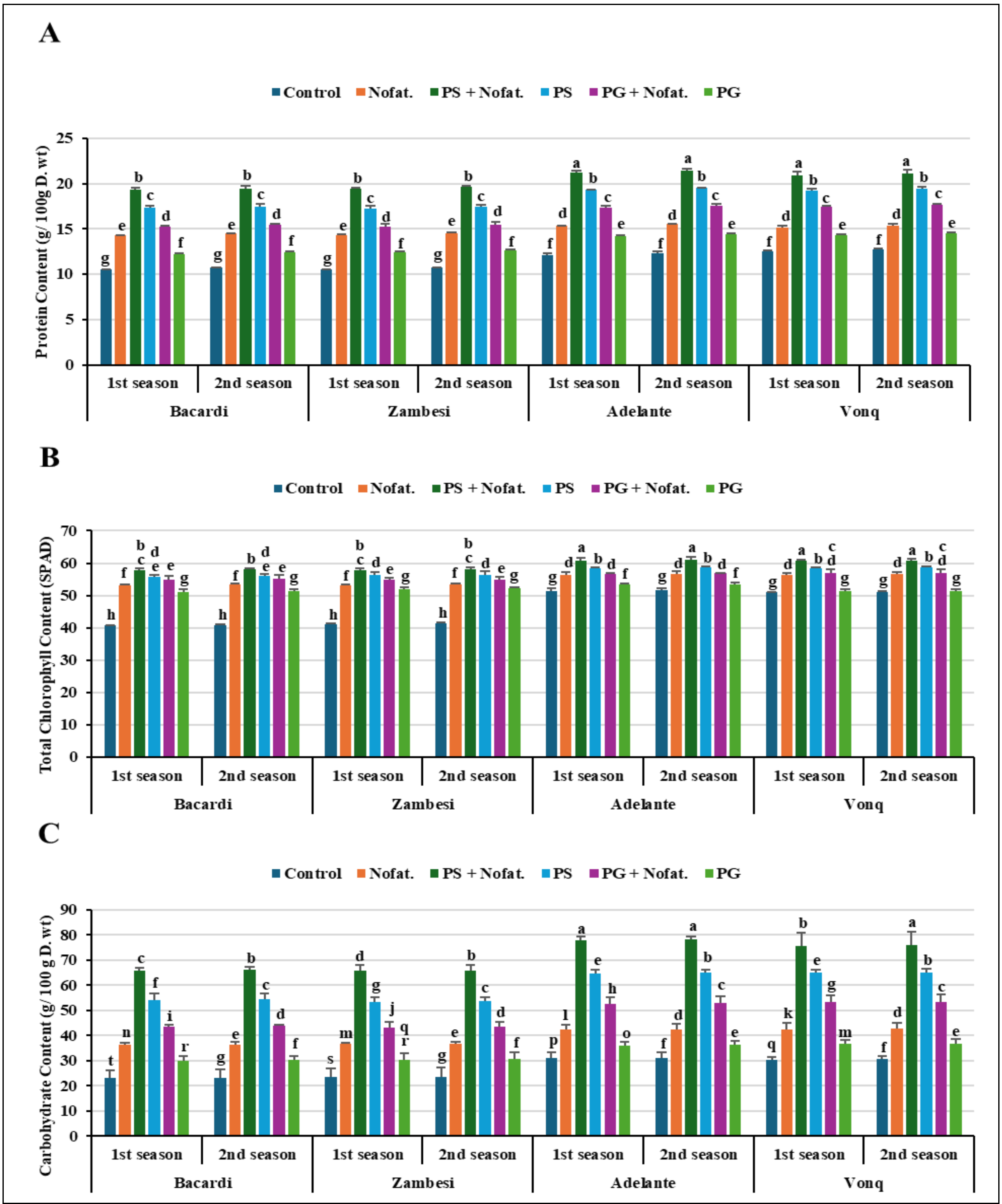

Fig. 16. Effect of potassium sources with or without Nofaterin foliar application on concentration of protein, total chlorophyll, and total carbohydrate in four oriental Lilium cultivars. Data show mean ± standard deviation of 3 replicates. Small letters indicate statistically significant differences at Duncan's multiple range test ($P \leq 0.05$).

except only one studied different concentration of potassium silicate to evaluate the flower production process (Mirabbasi *et al.,* 2013).

Compared to potassium silicate treatment results, potassium gel gave the lowest levels of vegetative and flowering growth parameters as well as chemical composition in our studied *Lilium* cultivars. Although potassium gel has more concentration of potassium as mentioned in Table (1), maybe our negative reveal is due to the monovalent ions as a result of hydrogel (Costa *et al.,* 2022). Also, the gel fertilizer has a slow-release capacity which may not recommended for herbaceous plants except in the case of cultivation under water deficit due to its ability to retain water (Lu *et al.,* 2023). On the other hand, degradation of gel fertilizer in the soil is difficult and it has toxicity for the soil microorganisms (Song *et al.,* 2020). In this respect, it has been demonstrated that gel fertilizer decreased the flower diameter in *Gazania rigens* and flower production in *Pelargonium peltatum* (Rydlová and Püschel, 2019).

Recently, it has been reported that balance between potassium fertilizer and the other nutrients is needed for high yield of different ornamental plants (Gülser and Çiğ, 2021). It has been found that potassium is needed in higher amount than nitrogen and phosphorus during late stages of development in *Lilium* (Niedziela *et al.*, 2008). Furthermore, Wang *et al.* (2023) reported that the combined application of nitrogen and potassium is essential for bulbs of *Lilium lancifolium*. In the present study, we performed NPK-fertilizer foliar application using the commercial fertilizer, Nofaterin accompanied by potassium sources, and we found that treatment of any potassium source with Nofaterin foliar application gave better results. On the other hand, Nofaterin foliar application without fertilizing by potassium source gave lower results compared to this application accompanied by potassium source indicating that higher amount of potassium is needed when we use integral fertilization to produce high quality for *Lilium* crops.

In comparison among all studied oriental *Lilium* cultivars, we found that *Lilium* cv. Adelante flowered earlier compared to the other cultivars; around two days later, *Lilium* cv. Zambesi started to flower. Notably, *Lilium* cvs. Vonq and Bacardi started to flower very late compared to the other two cultivars. On the other hand, worthy to note that *Lilium* cvs. Vonq and Adelante gave the highest values for mass production like vegetative, flowering, and bulb growth parameters as well as chemical composition indicating that response of *Lilium* plants to our performed treatments is depending on the genotypes and cultivars. Previous studies proved that there is wide variation among *Lilium* cultivars grown under controlled or field conditions (Sharma *et al.,* 2018). In addition, differences have been found in chlorophyll content for two *Lilium* cultivars which *Lilium* cv. Bernini gave higher concentration than in *Lilium* cv. Cebdazzle (Nikrazm et al 2011). Our results showed that fertilizing plants with potassium silicate in *Lilium* cvs. Vonq and Adelante gave the best results for plant growth and chemical composition in comparison with *Lilium* cvs. Zambesi and Bacardi which gave significant decrease opening more discussions to understand how to improve their response to potassium source fertilization.

CONCLUSION

In conclusion, the assessment of growth parameters and chemical composition of four oriental *Lilium* cultivars treated with two potassium sources accompanied by foliar application of Nofaterin as a source of integral fertilization provided a satisfying result. Treatment of potassium silicate with Nofaterin foliar application showed a positive impact on all the tested features in this research in *Lilium* cultivars. Interestingly, *Lilium* cvs. Adelante and Vonq are presented as the best cultivars to respond to our study assessment. In general, our findings show successful response to potassium fertilizer in *Lilium* grown in Egypt opening big hope to perform more investigation for commercial production. It is recommended to perform genetic and proteomic evaluation for *Lilium* cvs. Bacardi and Zambesi, since the response to our treatments indicated that is depending on the cultivars and genotypes. Further work on *Lilium* oil and flower pigments as a result of potassium source treatments under abiotic stresses in Egypt is needed to be performed, along with gene expression analysis of the fragrant enzymes.

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استجابة أربعة أصناف من الزنبق الشرقي لمصادر البوتاسيوم المصحوبة بالتسميد المتكامل

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إن تحسين جودة الزنبق الشرقي مطلب كبير من المزارعين وبائعي الزهور في مصر باستخدام التسميد المناسب. في هذا البحث، قمنا بدراسة استجابات مختلفة لأربعة أصناف من الزنبق الشرقي، ®Bacardi، ®Zambesi، ®Adelante، ®Vonq، لستة معاملات من مصدرين للبوتاسيوم، سيليكات البوتاسيوم، وهلام البوتاسيوم مع أو بدون تطبيق ورقي من النوفاتيرين كمصدر للسماد المتكامل. أظهرت النتائج أن المعاملة بسيليكات البتواسيوم مع النوفاتيرين أنتجت أعلى القيم لمعايير النمو الخضري والإزهار والبصل، والتركيب الكيميائي مثل محتوى المعادن والكلوروفيل والكربوهيدرات مقارنة بالمعاملات الأخرى. أدت هذه المعاملة إلى زيادة الوزن الطازج للأوراق، والوزن الجاف للأوراق، والوزن الطازج للساق، والوزن الجاف للساق بمعدل ٥٦,٩٢، ٥٧,٧٢، ٦١,٩٦، ٧١,٧٣٪، على التوالي. بالنسبة لنمو الإزهار، سجل قطر الزهرة (سم)، ووزن الزهرة الطازج (جم)، ووزن الزهرة الجاف (جم) ٢٢,٩٥، ٢٣,١١، على التوالي. كما زادت محتويات النيتروجين والفوسفور والبوتاسيوم نتيجة لمعاملة النباتات بسيليكات البوتاسيوم مع النوفاترين والتي سجلت ٤,٠١، ٠,٦٧، و ٣,١١ جم / ١٠٠ جم وزن جاف على التوالي. تجدر الإشارة إلى أن معالجات هلام البوتاسيوم لم تظهر زيادة ملحوظة في معامل النمو والتركيب الكيميائي. أظهرت المقارنة بين جميع الأصناف المدروسة أن صنف Adelante و Vonq أعطيا أفضل النتائج لجميع قياسات النمو والتركيب الكيميائي بينما أظهر صنفا Zambesi و Bacardi أدنى القيم. ونستنتج إلى أن التسميد بالبوتاسيوم باستخدام سيليكات البوتاسيوم مع الرش الورقى للنوفاتيرين موصى به لأصناف الزنبق الشرقى، ولكن يجب إجراء المزيد من الأبحاث لتحسين صنفى Bacardi و Zambesi، حيث أشارت الاستجابة للمعاملات إلى أنها تعتمد على الأصناف والأنماط الجينية. تُظهر نتائجنا استجابة ناجحة لسماد البوتاسيوم في الزنبق المزروع في مصر مما يفتح الباب لزيادة أزهار القطف تجاريًا عن طريق استخدام التسميد.