

Selection of appropriate pollination states using phenological and morphological characteristics in five varieties of *Phalaenopsis* orchid

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Abstract

Five varieties of *Phalaenopsis* (Nottingham, Dubrovnik, Andorra, Memphis, Bucharest) were self-pollinated and crossed with each other either as the male or the female parents. The five self-pollination and 20 cross-pollination states were evaluated for six phenological and morphological characteristics. Pollination was performed using an orchid pollination syringe in a greenhouse with a temperature of 20-27 °C, the humidity of 80% and light of 2500 lx during the 2018-2019 growing season. Nottingham under self-pollination conditions was better than other varieties and was superior to all crosses for all traits under investigation. The differences among males, females and their crosses were significant for all traits, except the time to the first pollination signs in which the effect of the female factor was not significant. In general, Nottingham was the superior variety in almost all traits and Dubrovnik was the worst variety in most traits either as male or female parents. Cross-pollination also had different outcomes in different traits. For example, for the time until swelling of the capsule, crosses Memphis × Nottingham and Nottingham × Memphis caused the capsule to fill later than the Nottingham parent. The cross Dubrovnik × Nottingham caused the capsule to fill earlier than the Dubrovnik parent. In the Dubrovnik × Nottingham cross, the weight of seeds per capsule, as an important trait, was higher than the Dubrovnik parent under self-fertilization conditions. Also, the cross-pollination was not suitable for increasing the weight of seeds per capsule in the Nottingham × Andorra cross. As an example for the capsule length, the Nottingham × Bucharest cross had smaller capsules than the self-pollination conditions of Nottingham and Bucharest. Therefore, depending on the importance of the traits under consideration in commercial production, cross-pollination can be used as a method, in addition to producing flowers with colors and shapes different from the parents, for improving the desired traits relative to one parent or both parents in self-pollination conditions.

Keywords: Capsule length; Capsule weight *Phalaenopsis*; Seed formation; Seed weight.

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Introduction

The Orchidaceae is one of the largest families of flowering plants with about 28,000 species classified into around 763 genera (Christenhusz and Byng 2016). The *Phalaenopsis* is a monopodial orchid in the Orchidaceae family. The genus *Phalaenopsis* comprising over 60 species belongs to the tribe Vandaeae under subfamily Vandoideae, which contains five subgenera, viz. subgenus *Proboscidioides*, subgenus *Aphyllae*,

subgenus *Parishianae*, subgenus *Polychilos*, and subgenus *Phalaenopsis* (Christenson 2001).

Darwin (1862) was the first scientist that studied the pollination of orchids and showed that orchids are propagated by insects. Other researchers pointed out the pollination orchid by bees, flies, beetles and birds (Liu *et al.* 2010). Lack of nutrients in the nectar of orchid flowers is one of the problems of natural pollination by

pollinators, but variation in color and scent of flowers that attracts insects compensates this problem in the food-deceptive orchids (Li *et al.* 2012).

Breeding new varieties of *Phalaenopsis* is time-consuming. New hybrid seedlings are normally derived from crosses of two high-quality parental varieties with different characteristics. In general, breeding programs are designed to improve the size and color of the flowers, as well as other characteristics such as longevity, stalk, length, leaf shape, ease of cultivation, or disease resistance (Tang and Chen 2007).

The crossing of orchids has economic importance due to the variety of colors, different flower size and flower shape (Hartati 2009). The result of crossing between swamp orchid (*Phaiussps*), one of the endangered species of orchids, and two native species of India, *Phaius tankervilleae* (Banks ex l'Heritier) Bl and *Phaius flavus* (Blume) Lindl, showed that crossability between species leads to new hybrids, which have petals and sepals different in color and size from the female parent (Devades *et al.* 2019). In a research program, compatibility between 23 species and 14 hybrids of *Dendrobium* was studied (Devades *et al.* 2016). The pod setting in the species by species crosses was only 8.97% in the direct crosses and 18.75% in the reciprocal crosses. On the other hand, the rate of pod formation was 34.37% in the direct species × hybrids crosses and 50% in their reciprocal combinations. In another study, seven commercial *Phalaenopsis* hybrids were cross-pollinated with each other. The cross-fertilization rate was 76.7%.

Also, 19 new hybrids were produced from these crossings (Lesar *et al.* 2012).

Hicks (2000) stated that a plant with smaller flowers should be used as a female plant and a plant with larger flowers as a male plant. Pollen of smaller flowers, when germinating on the stigma of a larger flower, may not develop a pollen tube long enough to reach the egg cell in the ovarian of the larger flowers.

The purpose of this study was to evaluate five *Phalaenopsis* varieties under self-pollination conditions and also as the female or male parents in the crosses for six phenological and morphological traits.

Material and Methods

To compare five different *Phalaenopsis* varieties as male or female parents and the effect of gender on different traits after pollination, a factorial experiment was designed based on a completely randomized design with three replications in a greenhouse of Fardis town in the Alborz province, Iran, from 2018-2019 growing season. The varieties as females were the levels of the first factor, and as males were the levels of the second factor. The *Phalaenopsis* varieties under study were as follows: Nottingham (W), Bucharest (R), Memphis (P), Dubrovnik (Y) and Andorra (K). The greenhouse had a temperature range of 20-27 °C, the humidity of 80% and light of 2500 lx. To pollinate the orchid varieties, an orchid pollination syringe was invented (Patent number: 100033). The syringe consisted of a plastic body, two replaceable toothpicks as pollination needles, a needle adjustment screw, a chassis with a 30°

angle from the syringe body and a light-angle adjustment screw. Plants were pollinated by self and cross-pollination. After the toothpick strikes the male organ in the orchid flower, it is sucked into the inner space of the syringe by the piston, and therefore, the possibility of falling to the ground and becoming contaminated is reduced. Also, the syringe is easily pressed into the female organ (whether in the self-pollination or cross-pollination conditions) and thus pollination is done. The measured characteristics were as follows: time to the first pollination (TFP), when wilting of the petals was visible, time to the first sign of capsule swelling (TCS), capsule length (CL) in centimeters, the weight of the full capsule (WFC) in grams, the weight of the empty capsule (WEC) in grams, the weight of seeds in each

capsule (WSC) in grams (the difference between WFC and WEC).

After analysis of variance of the data, the means were compared by Duncan's multiple range test using the SAS software.

Results and Discussion

Time until the first pollination signs (TPS)

TPS varied in different cultivars. The differences among male parents ($p \leq 0.05$) and the male by female interaction ($p \leq 0.01$) were significant on TPS. However, the differences among female parents were not significant. Bucharest as the male parent showed the signs of petal-wilting later than other varieties (6.63 days, which was significantly different from Nottingham as the earliest variety (5.92 days) (Figure 1).

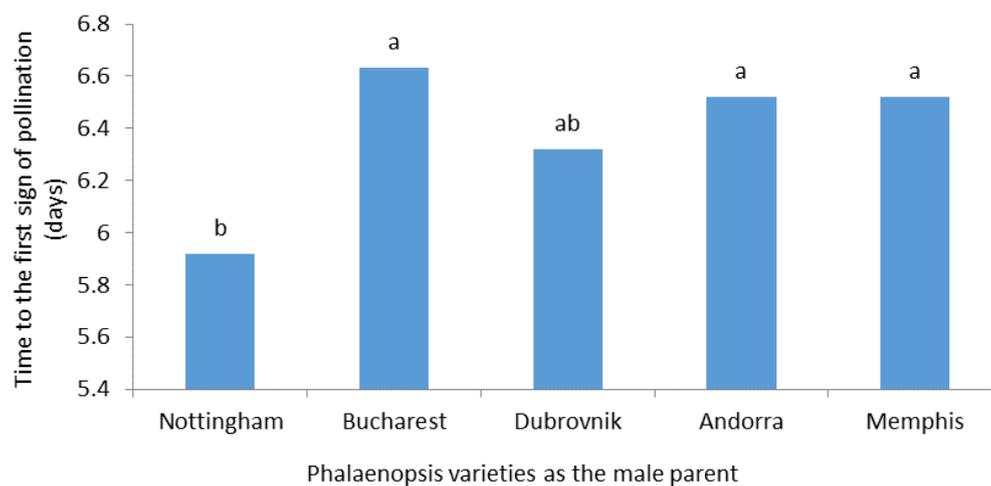


Figure 1. Time until the first pollination of the Phalaenopsis varieties as the male parent.

Comparing the TPS of the five self-pollination and 20 cross-pollination states showed that Nottingham had significantly lower TPS (4.6 days) than other states at the self-pollination condition. After that, Andorra × Memphis and

Bucharest × Andorra with 5.8 days were better than the rest; however, they were not significantly different from some other combinations. Petals displayed signs of wilting later in Nottingham × Andorra, Memphis × Dubrovnik and Bucharest ×

Table 1. Means for various pollination states (self-pollination and cross-pollination) for the *Phalaenopsis* characters under investigation.

Pollen recipient varieties	Characteristics	Pollen donor varieties				
		Nottingham	Dubrovnik	Bucharest	Memphis	Andorra
Nottingham	TPS	4.6 ^d	6.17 ^{abc}	6.00 ^{bc}	6.00 ^{bc}	7.40 ^a
	TCS	13.60 ^l	18.00 ^{fghi}	22.00 ^{bc}	17.80 ^{ghi}	24.20 ^a
	WFC	9.66 ^a	6.65 ^{efgh}	5.54 ⁱ	8.30 ^{bc}	6.39 ^{fgh}
	WEC	6.08 ^a	4.16 ^{ghij}	3.47 ^m	4.96 ^{bcd}	4.33 ^{fghi}
	WSC	3.58 ^a	2.49 ^{ef}	2.07 ^g	3.34 ^{ab}	2.06 ^g
	CL	11.04 ^a	8.27 ^{bc}	5.21 ^{klm}	8.61 ^b	5.96 ^{ghi}
Dubrovnik	TPS	6.20 ^{abc}	6.20 ^{abc}	6.00 ^{bc}	6.80 ^{abc}	6.00 ^{bc}
	TCS	15.80 ^k	19.20 ^{efgh}	19.50 ^{ef}	15.80 ^{jk}	15.80 ^{jk}
	WFC	7.97 ^{cd}	6.13 ^h	6.16 ^h	8.67 ^b	8.08 ^{cd}
	WEC	4.69 ^{cdef}	3.61 ^{lm}	4.14 ^{ghijk}	5.27 ^b	4.84 ^{bcd}
	WSC	3.28 ^{abc}	2.52 ^e	2.05 ^{gh}	3.40 ^{ab}	3.24 ^{abc}
	CL	8.00 ^c	5.31 ^{ijklm}	6.74 ^{def}	8.82 ^b	8.37 ^{bc}
Bucharest	TPS	6.60 ^{abc}	6.80 ^{abc}	7.20 ^{ab}	6.80 ^{abc}	5.80 ^c
	TCS	19.20 ^{efgh}	22.80 ^{ab}	15.80 ^{jk}	20.40 ^{de}	20.60 ^{cde}
	WFC	6.30 ^{gh}	5.29 ⁱ	6.94 ^{ef}	5.22 ⁱ	6.62 ^{efgh}
	WEC	4.15 ^{ghij}	3.63 ^{lm}	4.39 ^{efgh}	3.56 ^m	3.91 ^{ijklm}
	WSC	2.15 ^{fg}	1.66 ^h	2.55 ^e	1.66 ^h	2.71 ^{de}
	CL	5.91 ^{ghij}	5.20 ^{klm}	6.36 ^{efg}	5.03 ^m	5.65 ^{ijklm}
Memphis	TPS	6.80 ^{abc}	7.20 ^{ab}	6.60 ^{abc}	6.20 ^{abc}	6.80 ^{abc}
	TCS	19.6 ^{ef}	16.80 ^{ijk}	15.80 ^{jk}	19.20 ^{efgh}	17.60 ^{hi}
	WFC	6.75 ^{efg}	7.11 ^{2e}	6.684 ^{efgh}	7.118 ^e	6.46 ^{fgh}
	WEC	3.846 ^{ijklm}	4.09 ^{ghijkl}	3.912 ^{hijklm}	4.566 ^{defg}	3.88 ^{ijklm}
	WSC	2.904 ^{cde}	3.02 ^{2bcd}	2.772 ^{de}	2.552 ^e	2.58 ^e
	CL	5.8 ^{ghijk}	6.306 ^{efgh}	6.996 ^d	6.856 ^{de}	5.62 ^{ijklm}
Andorra	TPS	6.00 ^{bc}	6.40 ^{abc}	6.20 ^{abc}	5.80 ^c	7.00 ^{abc}
	TCS	19.40 ^{efg}	19.8 ^e	17.40 ^{ij}	21.8 ^{bcd}	16.00 ^{jk}
	WFC	6.396 ^{fgh}	6.314 ^{gh}	6.356 ^{gh}	5.312 ⁱ	7.678 ^d
	WEC	3.756 ^{ijklm}	3.47 ^m	3.648 ^{klm}	3.532 ^m	5.072 ^{bc}
	WSC	2.64 ^{de}	2.844 ^{de}	2.772 ^{de}	1.78 ^{gh}	2.606 ^e
	CL	6.158 ^{fghi}	5.706 ^{hijkl}	7.078 ^d	5.088 ^{lm}	6.078 ^{ghi}

Means within each trait with the same letter(s) are not significantly different at the 5% probability level according to Duncan's multiple range test.

Bucharest (Table1).

Time until the first signs of capsule swelling (TCS)

The effect of male and female parents and their interaction on TCS was significant ($p \leq 0.01$). Nottingham was a better variety either as a female or male parent under self-pollination (16.76 and 15.68 days, respectively) and had significantly lower values than other varieties (Figures 2 and 3).

Table 1 shows the data about TCS values for different self-pollination and cross-pollination states. Self-pollination of Nottingham showed the earliest sign of capsule swelling (13.6 days) and Dubrovnik \times Nottingham, Bucharest \times Bucharest, Dubrovnik \times Memphis, Memphis \times Bucharest and Dubrovnik \times Andorra equally ranked second in earlier capsule swelling (15.8 days). Nottingham \times Andorra had the longest TCS (24.2 days), however, it was not significantly different from the Bucharest \times Dubrovnik. Self-pollination of

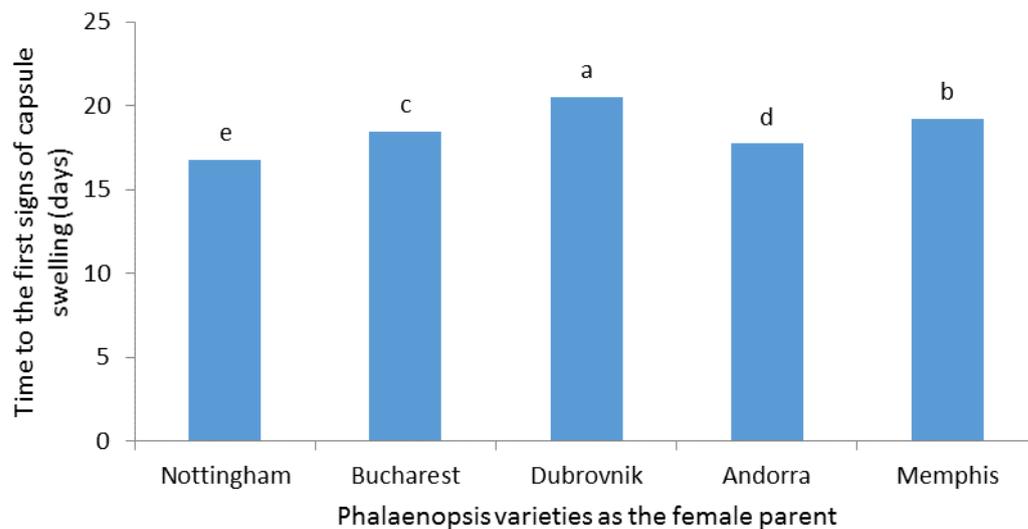


Figure 2. Time until the first signs of capsule swelling of the Phalaenopsis varieties as the female parent.

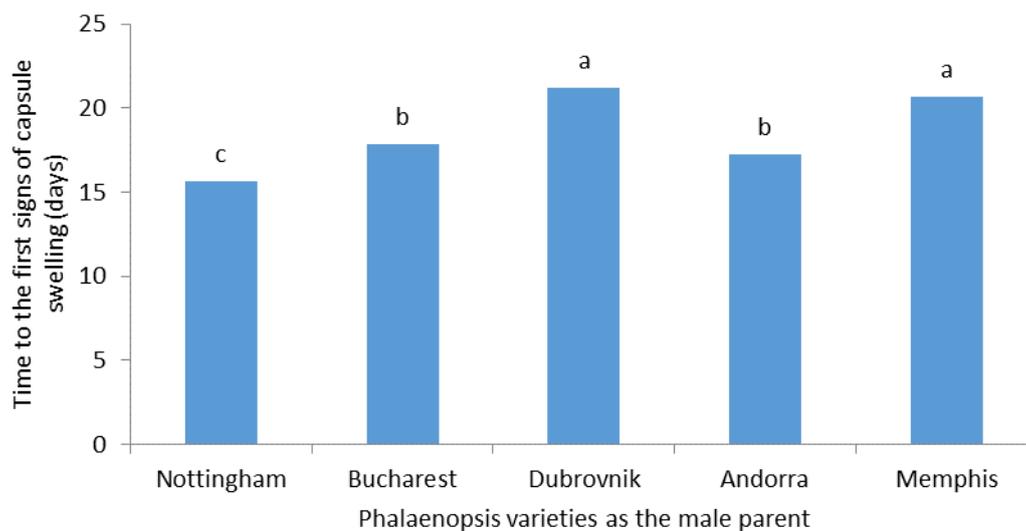


Figure 3. Time until the first signs of capsule swelling of the Phalaenopsis varieties as the female parent.

Bucharest and Nottingham (15.8 and 13.6 days, respectively) caused the earlier capsule swelling and consequently, seed setting than their corresponding hybrids Nottingham \times Bucharest and Bucharest \times Nottingham (22 and 19.2 days, respectively). On the other hand, opposite conditions happened concerning Dubrovnik and Memphis, and self-pollination caused capsules to

swell later than their corresponding crosses. Also, the cross of Memphis \times Nottingham had higher TCS than Nottingham. Dubrovnik had a TCS value of 19.2 days when self-pollinated, while its value reduced by crossing to Nottingham [Dubrovnik \times Nottingham (15.8 days)]. In other words, crossing improved this trait in the Dubrovnik variety, but the crossing was not

beneficial for the Nottingham variety and caused a decline in its TCS.

Weight of full capsule (WFC)

The results of data analysis showed that the effect of female and male parents and their interaction was significant on WFC ($p \leq 0.01$). According to

Figures 4 and 5, Nottingham had the highest WFC both as the female and the male parent (7.51 and 8.54 g, respectively). Memphis had the lowest WFC as the female parent but was not significantly different from the Bucharest and Dubrovnik varieties. The lowest WFC belonged to Dubrovnik (5.5 g) as the male parent (Figure 5).

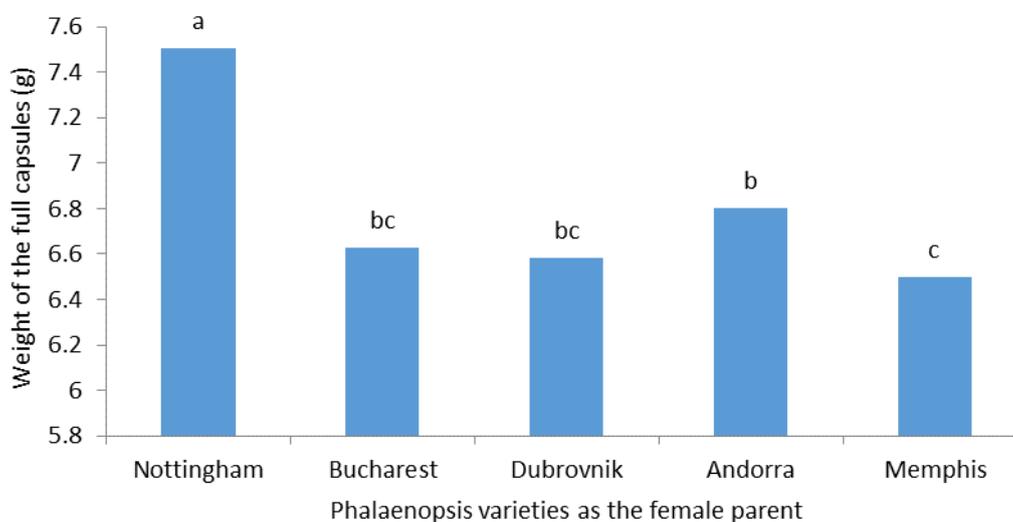


Figure 4. Weight of the full capsule of the Phalaenopsis varieties as the female parent.

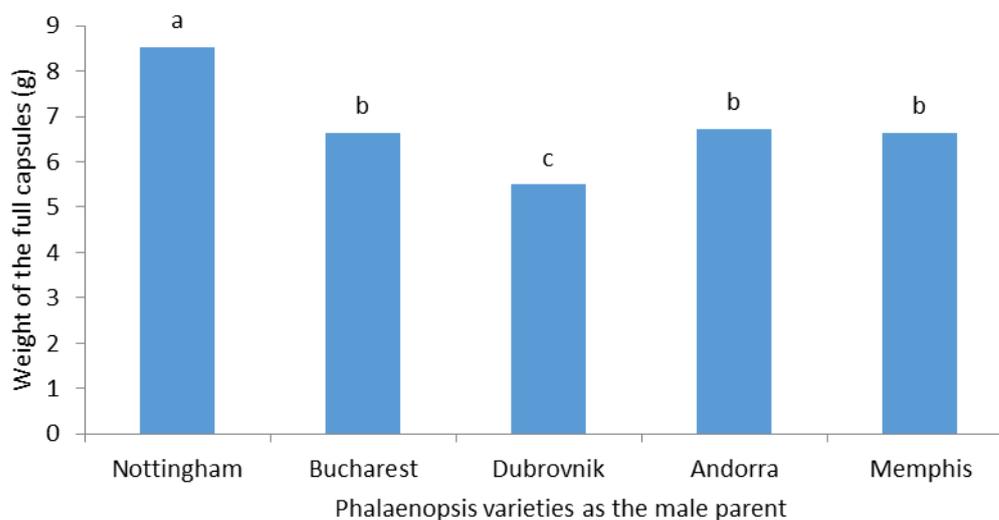


Figure 5. Weight of the full capsule of the Phalaenopsis varieties as the male parent.

Nottingham acquired the highest WFC (9.66 g) under self-pollination conditions as compared to other combinations (Table 1). After Nottingham, the Dubrovnik \times Memphis cross had the highest WFC (8.67). Bucharest \times Dubrovnik (5.29 g), Andorra \times Memphis (5.31 g) and Nottingham \times Bucharest (5.54 g) showed the lowest WFC than other treatments. The crossing of Memphis \times Andorra and Andorra \times Memphis (6.46 and 5.31 g) decreased WFC as compared to their parents Andorra (7.68 g) and Memphis (7.12 g) under self-pollination conditions. Therefore, larger capsules were obtained when these varieties were self-pollinated. On the other hand, self-pollination of Dubrovnik and Memphis showed lower capsule weight (6.13 and 7.12 g) than the Dubrovnik \times Memphis (8.67 g) cross (Table 1) so cross-pollination between these varieties was beneficial as compared to their self-pollination. Also, the cross Dubrovnik \times Nottingham and (as

the worst and best variety in terms of WFC) showed that cross-pollination improved this trait as compared to the inferior parent (Dubrovnik) and decreased it compared to the superior parent (Nottingham). So cross-pollination with Nottingham (as the male parent) can improve FWC in Dubrovnik (as the male parent). On the other hand, the Andorra \times Memphis and Memphis \times Andorra crosses showed significantly lower WFC (5.31 and 6.46 g respectively) than their parents [Andorra (7.68 g) and Memphis (7.12 g), respectively]. In other words, cross-pollination between Andorra and Memphis was not suitable concerning this trait (Table 1).

Weight of the empty capsule (WEC)

Effects of different varieties as female and male parents and their interaction on EWC were significant ($p \leq 0.01$). Based on Figures 6 and 7, Nottingham had the highest WEC either as the

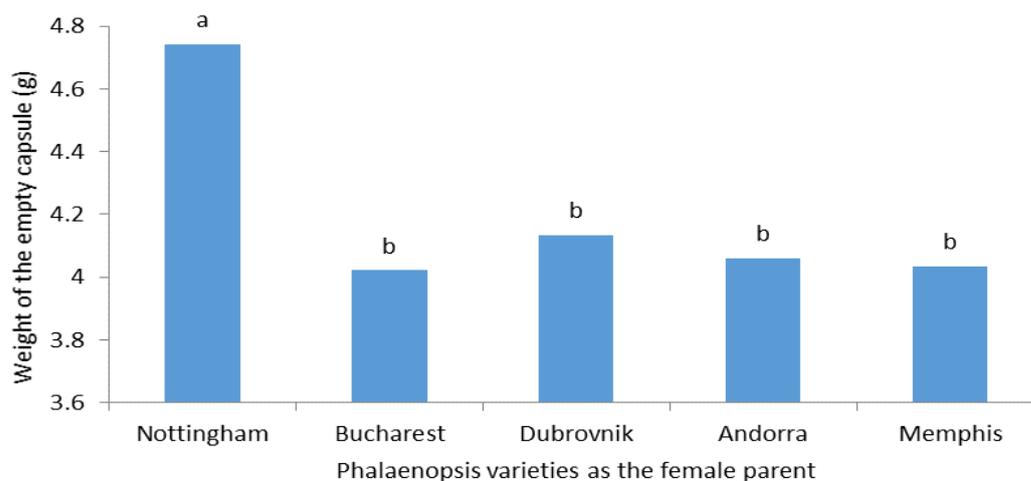


Figure 6. Weight of the empty capsule of the Phalaenopsis varieties as the female parent.

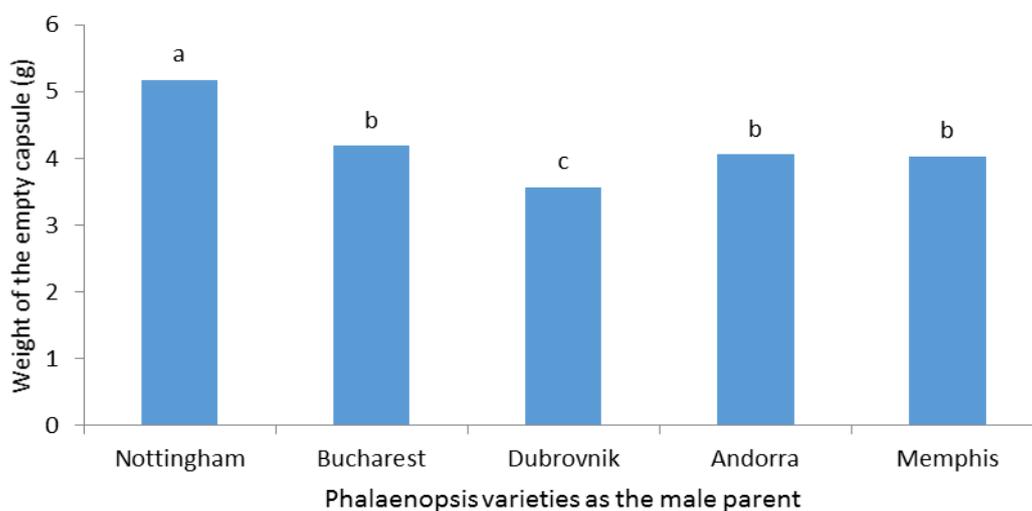


Figure 7. Weight of the empty capsule of the *Phalaenopsis* varieties as the male parent.

female parent (4.74 g) or as the male parent (5.17 g). Other varieties as female parents were significantly lower than Nottingham for WEC but they were not significantly different from each other. Among the male parents, Dubrovnik showed the lowest WEC (3.56 g).

Nottingham, when self-pollinated, had the highest WEC (6.08) among all treatments Table 1). After Nottingham, Dubrovnik \times Memphis (5.27 g), Andorra \times Andorra (5.07 g) and Nottingham \times Memphis (4.96 g) had higher WEC too, although not significantly different from some other treatments. Nottingham \times Bucharest had the lowest WEC (3.47 g). Dubrovnik \times Nottingham and Nottingham \times Dubrovnik (4.69 and 4.16 g) had significantly lower WEC than the Nottingham parent (6.08 g) and significantly higher WEC than the Dubrovnik parent (3.61 g). In other words, cross-pollination of Dubrovnik with Nottingham improved its WEC either as the female or as the male parent.

The weight of seeds in the capsule (WSC)

Effects of the females, males and their interaction were significant on WSC ($p \leq 0.01$). Nottingham and Andorra as the female parent (2.763 and 2.74 g) had the highest amount of WSC than other varieties but they were not significantly different than Bucharest. As the male parent, Nottingham showed the highest WSC (3.37 g) and Dubrovnik the lowest WSC (1.94 g) among treatments (Figures 8 and 9).

Self-pollination of Nottingham resulted in the highest WSC (3.58) but this value was not significantly different from those of Dubrovnik \times Memphis (3.402 g), Nottingham \times Memphis (3.34 g) and Dubrovnik \times Nottingham (3.24 g). The crossing of Nottingham as the female parent with Dubrovnik as the male parent, which have the highest and lowest WSC, respectively, did not improve this trait over the parents. However, cross-pollination between Dubrovnik and Memphis (i.e. Memphis \times Dubrovnik with 3.02 g

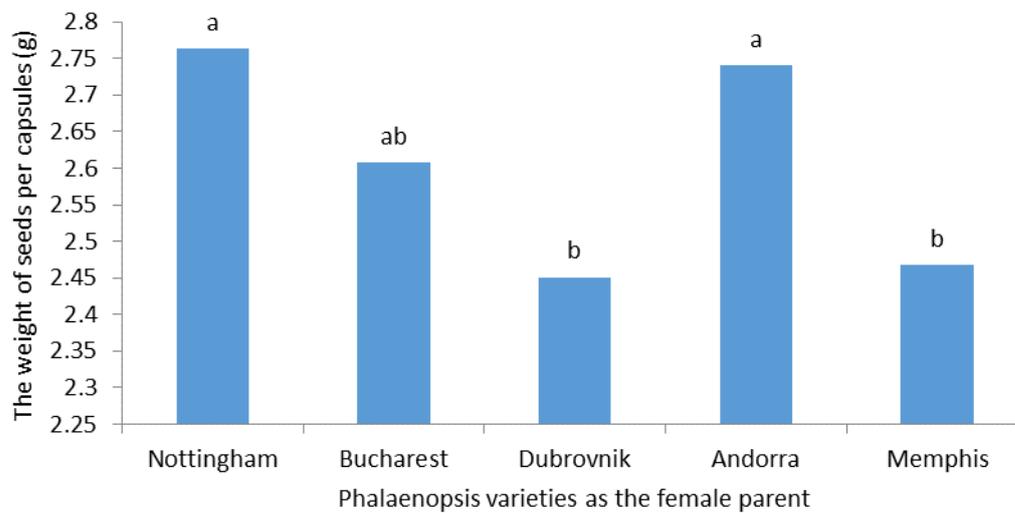


Figure 8. The weight of seeds per capsule in the Phalaenopsis varieties as the female parent.

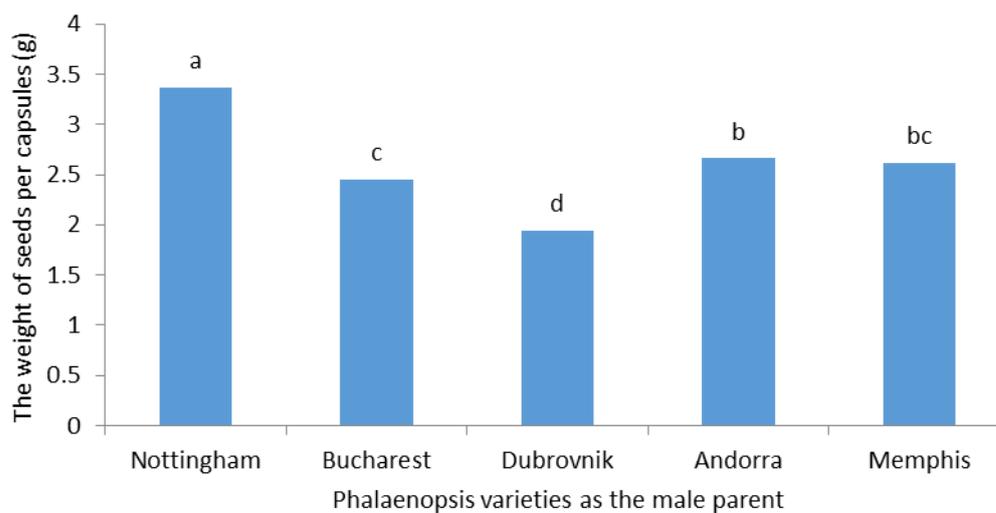


Figure 9. The weight of seeds per capsule in the Phalaenopsis varieties as the male parent.

WSC and Dubrovnik \times Memphis with 3.4 g WSC) decreased WSC as compared to Dubrovnik (3.52 g) and increased WSC as compared to Memphis (2.55 g). This means that cross-pollination can be used in the Memphis variety for improving seed yield. Cross-pollination of Nottingham with Andorra was not effective for increasing seed yield over the parents. Although

Hicks (2000) indicated that the parent with a bigger flower should be used as the pollen donor but we did not obtain this result about the Nottingham variety that had larger flowers than the other four varieties.

Capsule length (CL)

The result of data analysis showed that the effect

of females, males and their interaction were significant ($p \leq 0.01$) on WSC. Nottingham either as the female or the male parent showed significantly longer capsules than other varieties. Bucharest, Andorra and Memphis (with 6.719, 6.386 and 5.996 cm CL, respectively) had higher values than Dubrovnik (5.17 cm) as the male parent Figures 9 and 11).

Self-pollination of Nottingham resulted in the highest CL (11.042 cm) among other self-pollination or cross-pollination states. After Nottingham, Dubrovnik \times Memphis (8.82 cm), Nottingham \times Memphis (8.61 cm), Dubrovnik \times Andorra (8.37 cm), Nottingham \times Dubrovnik (8.27 cm) and Dubrovnik \times Nottingham were significantly better than other treatments. Comparison of CL in Bucharest \times Nottingham (5.91 cm) and Nottingham \times Bucharest (5.21 cm) showed a decrease in this trait compared with their parents, Nottingham (11.04 cm) and Bucharest (6.36 cm), however, the decrease in

Bucharest \times Nottingham (5.91 cm) was not significant as compared to Bucharest parent. This means that the capsule length was larger under self-pollination than the cross-pollination in these orchid varieties. On the other hand, Nottingham \times Dubrovnik and Dubrovnik \times Nottingham (with 8.27 and 8 cm CL, respectively) had higher CL than Dubrovnik (5.31 cm) and lower CL than Nottingham (11.04 cm). CL in self-pollination of Bucharest (6.36 cm) and Andorra (6.08 cm) was lower than the Andorra \times Bucharest cross (7.08 cm) and higher than the Bucharest \times Andorra (5.65 cm) cross. This means that the cross of Bucharest with Andorra was favored over the self-pollination of both parents when Bucharest was used as the male parent.

According to Hick (2000), if the plant with larger flower used as the female parent and the plant with the smaller flower used as the male parent, the pollen may not grow long enough in the larger flower to reach the ovarian, but in this

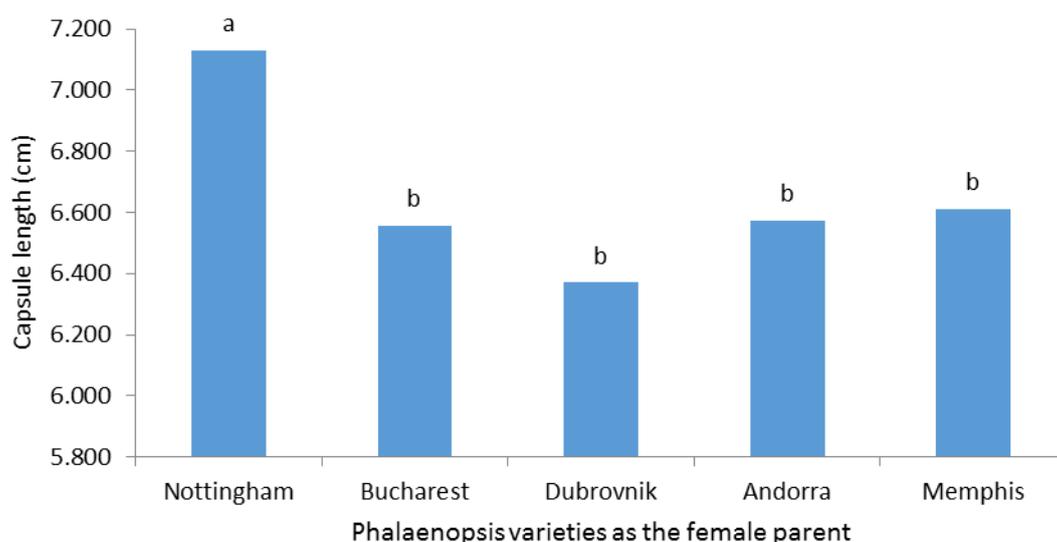


Figure 10. The capsule length of the Phalaenopsis varieties as the female parent.

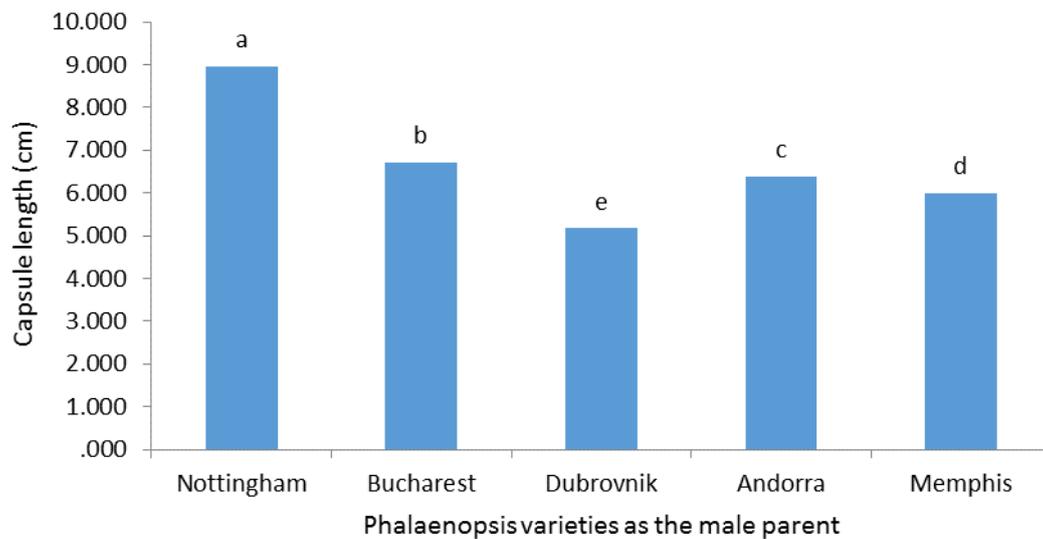


Figure 11. The capsule length of the *Phalaenopsis* varieties as the male parent.

research all of the crosses between the different flower sizes (Nottingham with large flowers and Dubrovnik with smaller flowers than others) produced capsules and seeds. Therefore, further studies are needed to clarify about the effect of flower size on the success or failure of the pollen tube growth and fertilization in *Phalaenopsis* orchids.

Conclusion

The results in this research showed that in general, Nottingham and Dubrovnik were the superior and weaker varieties, respectively either as the female or male parents and also under self-pollination conditions. Based on our results, a special variety can be used in a cross-pollination according to the

desired trait. Cross-pollination improved some traits between some varieties as compared to self-pollination and the opposite happened in other varieties. Therefore, according to the importance of the desired trait in the production of *Phalaenopsis* orchids, which consider the higher seed yield and also the shortest time to fill the capsule, the best variety can be selected as the male or female parent to be used in the self- or cross-pollination conditions.

Conflict of Interest

The authors declare that they have no conflict of interest with any organization concerning the subject of the manuscript.

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انتخاب حالات مناسب گرده افشانی از نظر صفات فنولوژیک و فیزیولوژیک در پنج رقم فالانوپسیس

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چکیده

در این تحقیق پنج رقم ارکیده فالانوپسیس (Nottingham, Memphis, Dubrovnik, Bucharest, Andorra) برای بررسی برخی صفات در پنج حالت خودگرده افشانی و ۲۰ حالت دگرگرده افشانی مورد استفاده قرار گرفت. آزمایش در گلخانه‌ای با دمای ۲۷-۲۰ درجه سانتی‌گراد، ۸۰٪ رطوبت و ۲۵۰۰ لوکس نور در سال زراعی ۹۸-۱۳۹۸ اجرا گردید و از یک سرنگ ابداعی برای تلقیح گل‌های ارکیده استفاده شد. بررسی ارقام از نظر شش صفت فنولوژیک و مورفولوژیک نشان داد که رقم Nottingham در حالت خودگرده افشانی بهتر از سایر ارقام و نیز برتر از کلیه تلاقی‌ها بود. تأثیر هر دو عامل مادری و پدری و اثر متقابل آن‌ها روی کلیه صفات، به غیر از مدت زمان ظهور اولین علائم تلقیح که در آن اختلاف بین والد‌های مادری معنی‌دار نبود، معنی‌دار شد. به طور کلی رقم Nottingham به عنوان رقم برتر تقریباً در همه صفات و رقم Dubrovnik به عنوان رقم ضعیف‌تر در اکثر صفات هم به عنوان والد پدری و هم به عنوان والد مادری شناخته شدند. دگرگرده افشانی والدین در مقایسه با خودگرده افشانی در صفات مختلف نتایج متفاوتی داشت. برای مثال در مورد صفت مدت زمان ظهور اولین علائم متورم شدن کپسول، تلاقی‌های Nottingham × Memphis و Memphis × Nottingham سبب پر شدن دیرتر کپسول نسبت به والد Nottingham گردیدند. تلاقی Dubrovnik × Nottingham نیز سبب پر شدن سریعتر کپسول نسبت به والد Dubrovnik شد. نتایج بررسی وزن بذور در هر کپسول به عنوان یک صفت مهم نشان داد که در تلاقی Dubrovnik × Nottingham وزن بذور در هر کپسول نسبت به خودگرده افشانی Dubrovnik افزایش یافته است. همچنین دگرگرده افشانی برای افزایش وزن بذور در هر کپسول در تلاقی Nottingham × Andorra مناسب نبود. از نظر طول کپسول نیز برای مثال در تلاقی Nottingham × Bucharest کپسول‌های کوتاه‌تری نسبت به خودگرده افشانی این والد‌ها به دست آمد. بنابراین، با توجه به اهمیت صفت مورد نظر در کارهای تولیدی، می‌توان از دگرگرده افشانی به عنوان روشی علاوه بر تولید گل با رنگ و شکل تقریباً متفاوت نسبت به والدین، برای بهبود آن صفت نسبت به حالت خودگرده افشانی یک والد یا هر دو والد استفاده کرد.

واژه‌های کلیدی: تشکیل بذور؛ طول کپسول؛ گل ارکیده فالانوپسیس؛ وزن بذور؛ وزن پر کپسول.