ACTA SCIENTIARUM POLONORUM

Acta Sci. Pol. Hortorum Cultus, 16(2) 2017, 149–160

www.acta.media.pl ISSN 1644-0692

ORIGINAL PAPER

Accepted: 20.01.2017

THE EFFECT OF THE CUTTING METHOD ON ROOTING OF *Dahlia pinnata* Cav. CUTTINGS

Jerzy Hetman, Sylwia Łukawska-Sudoł, Krystyna Pudelska✉, Marzena Parzymies

University of Life Sciences in Lublin

ABSTRACT

Dahlias are propagated through stem cuttings. In the years 2003–2005, in a glasshouse of the Experimental Station in Felin, University of Life Sciences in Lublin, the research was conducted to evaluate rooting of different types of dahlia cuttings. The studied *Dahlia pinnata* cultivars were: 'Berliner Kleene', 'Gea', 'Orange' and 'Orietta'. Six types of cuttings were tested: cuttings with heel, without heel, tip ones, tip long ones, lateral and middle ones. The cuttings excision was started when sprouting shoots had 5–7 pairs of leaves. The tip part with 2–3 pairs of leaves was cut off, leaving at least 2 pairs of leaves on the stem (tip cuttings). After about 2 weeks, in the nodes, new shoots start to arise, which might be used as cuttings when they form 2–3 pairs of leaves. When the tip cuttings are excised, new shoots will sprout directly from a tuber. They might be excised with a part of a tuber as cuttings with heel or without it – cuttings without heel. It is also possible to place tuberous roots into a glasshouse early, let the sprouting shoots form 6–8 pairs of leaves, and then excise longer then before tips with 3–4 pairs of leaves (long tip cuttings). The remaining, middle parts of the stems with 2 pairs of leaves, might be also used as lateral cuttings. Different types of cuttings were used and all of them rooted very well. No matter the type of cutting, their survival exceeded 90%. The types of cuttings did not significantly affect the percentage of rooted cuttings. However, the intensity of taking the roots depended on the cutting method. The growth started the earliest in case of cuttings with heel and tip ones. Plants formed from these types of cuttings characterized with the highest weight of the underground part as well. During the three years of the experiment, the highest mean weight of the above ground part was observed in case of tip and long tip cuttings.

Key words: dahlia, cutting method, types of cuttings, rooting, tubers effectiveness

INTRODUCTION

Dahlias are propagated vegetatively and generatively. The easiest method of vegetative propagation of dahlia, recommended especially in an amateur cultivation, is division of tuberous roots. A large-scale propagation aims at obtaining the most plants in the ossible shortest time, so that the cuttings are usually used.

Propagation through cuttings is extremely effective for many ornamental or nursery plants species [Ochoa et al. 2000, Cameron et al. 2001, Krzymińska and Czekalski 2002, Kolasiński 2005]. This method guarantees obtaining a large amount of equal plant material, in terms of size and quality [Langeslang 1989, De Hertogh and Le Nard 1993, Clenet 1995, Chmiel 2000, Jerzy i Krzymińska 2011]. It is also used for propagation of dahlia. Soft cuttings of dahlia are usually obtained through excision of sprouting shoots with a piece of root tuber – these are so called cuttings with heel. They should be 6–8 cm long with 2–3 pairs of healthy, undamaged leaves [Chmiel 2000; Jerzy and Krzymińska 2011].

✉kpudelsk@autograf.pl

The quality of cuttings depends on, among other things, condition and health of mother plants. Vegetative propagation might cause transferring pathogens, including viruses, what directly worsens the quality of yield, while the disinfection of reproduction material significantly increases the cost of cultivation [Winiarczyk et al. 2014]. Selected roots of dahlia for stock nurseries must be completely free from viruses, bacterial diseases and insects [De Hertogh and Le Nard 1993]. De Hertogh and Le Nard [1993] note that this method of da hlia propagation is ineffective. According to Escher [1983], the number of soft shoots sprouting from the tubers of dahlia which are suitable for cuttings ranges from 15 to 50, and moreover, there is always a risk to damage neighbouring buds which are able to produce successive cuttings.

The research conducted in the Institute of Ornamental Plants and Landscape Architecture (currently the Department of Ornamental Plants and Landscape Architecture), of the University of Life Sciences in Lublin, proved that there is a possibility to use other types of cuttings, apart from the ones with heel. The cuttings might be broken out without a piece of a tuber, they are so called cuttings without heel, they might be also cut with the tip part of the main stem with at least 4–5 pairs of leaves (apical cuttings) or longer shoot with at least 5–6 pairs of leaves (apical long cuttings). Moreover, the leaf two-node cuttings left after taking an apical part (so called middle cuttings) and the ones growing from axils of leaves of the main shoot left after cutting the tip (lateral cuttings) might also be used. The results allowed to conclude that the types of cuttings other than traditional ones with heel, did not significantly influence the percentage of rooted plants [Pudelska 2000, Pudelska et al. 2015]. The ability to form a rooting system by cuttings depends on many factors, both endogenous and exogenous, such as a growing phase of mother plants, quality of shoots selected for cuttings or physiological processes in a cutting, like a balance between photosynthesis and transpiration [Biran and Halevy 1973, Cuijpers 1995, Hartman et al. 1997, Serek et al. 1998, Krajnc et al. 2002, Szabo et al. 2014]. The most important factor is temperature. The temperature of a substrate during rooting should be 22–23°C, while an air temperature 2–3°C lower. It is advised not to water the cuttings that have not formed roots yet, as the water excess causes rotting. To prevent cuttings from wilting, it is necessary to mount low foil tunnels or install automatic dispersion to keep a stable air humidity. The cuttings form roots from 3 to 4 weeks [Jerzy and Krzymińska 2011].

Substances influencing a process of adventitious roots development in cuttings are auxins. They are formed endogenously in leaves and buds of plants, and then they are transported basipetal, what means they are accumulated in lower parts of cuttings [Jerzy and Krzymińska 2011]. An auxin is essential to induce adventitious roots meristems on stems. However, an auxin itself is not involved in a process of forming new roots primordia, but activates existing ones or starts forming the new ones, activating their mitotic abilities and stimulating their development [Świstowska and Hetman 2004]. The endogenous auxins include indoleacetic acid (IAA) and indole-3-butyric acid (IBA). Their content in tissues decides about the ability of cuttings to root. Rooting might be also enhanced through application of auxins from the outside, both endogenous and synthetic ones. One of more important synthetic auxin is naphthaleneacetic acid (NAA) [Jerzy and Krzymińska 2011].

A research conducted by Pudelska and Hetman [2001] proved that the choice of substrate and stimulator containing auxins, decided about the rooting, quality of rooting system and a quality of dahlia cuttings. Very good results were obtained while using a rooting powder contaning 0.2% NAA and fungicides, which improved both quality of the rooting system and a quality of cuttings. Fungicides, such as Kaptan 50WP, used in combination with an auxin, improve rooting of cuttings [Hocking and Thomas 1979, Bojarczuk 1984, Czekalski 1988]. However, the effect of these substances depends on their concentration and conditions of rooting. Too high concentration of fungicides, especially in high temperature, might have toxic properties [Pudelska and Hetman 2001].

A substrate for rooting of soft cuttings should be light, of low density, with good air-water characteristics, high porosity, permeability, but at the same time able to retain water easily available for plants [Hetman 1993]. Assurance of good soil porosity guaran-

tees proper aeration, that is a sufficient number of capillaries for transport, what allows natural drainage of water excess from watering [Reinikainer 1993]. Pudelska and Hetman [2001] recommend a mixture of sphagnum peat and pine bark or sphagnum peat with sand or perlite as the best substrate for dahlia cuttings.

The aim of the research conducted in the years 2003–2005 was to estimate the most effective method of obtaining soft cuttings of dahlia, in order to produce the higher number of good quality plants

MATERIALS AND METHODS

The plant material to prepare cuttings were tuberous roots of mother plants of four cultivars of *Dahlia pinnata*: 'Berliner Kleene', 'Gea', 'Orange' and 'Orietta'. 'Gea' and 'Orietta' are cultivars of Polish origin, from dr Wieslaw Legutko Breeding and Seed Company Ltd. in Smolice, while 'Berliner Kleene' and 'Orange' are Dutch cultivars. During winter, the tuberous roots were stored in the temperature of 4–8°C and 80% humidity. Each year, in the beginning of February, the roots were transported to a glasshouse and planted into trays filled with sphagnum peat, limed to pH 5.6 and enriched with 2 $g \cdot dm^{-3}$ Azofoska (1 N : 0,5 P_2O_5 : 1,4 K_2O). Before planting, the roots were treated with 0.5% powdered Kaptan 50WP (containing fungicide and Kaptan 50WP 50%), while trays were disinfected with a detergent. Roots were planted in a way that a root crown was above a ground. The trays were placed on the tables in the glasshouse in the air temperature 18–20°C and systematically watered. The sprouting shoots were cut as following:

Type I – cuttings with heel (stem soft cuttings with 2–3 pairs of leaves excised with a piece of tuber);

Type II – cuttings without heel (stem soft cuttings with 2–3 pairs of leaves excised without a piece of tuber);

Type III – tip cuttings (stem soft cuttings with 2–3 pairs of leaves, excised from shoots with 4–5 pairs of leaves);

Type IV – long tip cuttings (stem soft cuttings with 3–4 pairs of leaves, excised from shoots with 5–6 pairs of leaves);

Type V – lateral cuttings (stem soft cuttings with 2 pairs of leaves growing from leaf axils after decapitation);

Type VI – middle cuttings (stem soft cuttings excised from the central part of stem after decapitation).

Each year, the cuttings were excised successively as new shoots sprouted, till the 25th of April. A cutting was conducted with a scalpel disinfected with 70% of methyl alcohol. The cuttings were treated with a mixture of 0.2% NAA and fungicide (Kaptan 1%) and placed in 4.5 × 4.5 cm multipots filled with a mixture of sphagnum peat, sand and lime (1 l : 1 l : 1 g). The multipots were placed on the tables in the glasshouse. The air temperature during rooting was 18–19°C and the soil temperature was 22–23°C. The tables were covered with a foil tunnel to ensure the right air humidity. During a whole rooting period, the cuttings were regularly misted, sprayed with fungicides on a preventive basis, and shaded with a nonwoven fabric when the sunshine was high.

After about 5 weeks from cuttings preparation, the evaluation of rooting of different types of cuttings of all four cultivars was done. The soil remains were exactly washed out, the underground part was cut off and the above and underground parts of cuttings were weighed separately. The underground part consisted of roots with the ending of shoots they had sprouted from. The number of leaves on each cutting was counted, the above ground part and the roots were measured. All remaining cuttings were planted into soil each year, at the beginning of June and the percentage of well established plants was estimated.

The experiment was set up completely randomly, according to the triple classification. The obtained results of the measurements were analyzed statistically with the use of analysis of variance for triple classification. The significance of differences between the means were established according to the Tukey's confidence intervals at the level of significance = 0.05.

RESULTS

During the three years of research, the highest mean weight of the under ground part formed cut-

tings with heel and tip ones. Their weight was on average 1.6 g. The lowest weight of the underground part was noted for lateral cuttings – 0.7 g (tab. 1).

Taking into consideration a type of cutting and the cultivar, the highest mean weight of the underground parts characterized tip and middle cuttings of the 'Orange' cultivar. Definitely the lowest weight characterized lateral cuttings of the 'Berliner Kleene' and 'Gea' cultivars. As for the interaction of the type of cutting and years, the highest mean weight of the underground part had the cuttings with heel in the year 2003, while the lowest one was noted for the lateral cuttings in 2004.

The highest mean weight of the underground part was observed in 2003 – 1.5 g. Whereas the weight of cuttings in the remaining years did not differ significantly and was 1.1 g in 2004 and 1.2 g in the year 2005.

In relation to cultivars, the highest weight characterized cuttings of all types of the 'Orange' cultivar – 2.4 g, while the lowest one was noted for 'Berliner Kleene' ones (0.8 g).

Looking at a whole experiment, in relation to the type of cutting – cultivar – year interaction, the highest weight of the underground part had lateral cuttings of the 'Orange' cultivar in the year 2003. Their mean weight was 3.6 g. The lowest weight characterized lateral cuttings of the 'Berliner Kleene' cultivar in the years 2003 and 2005 – 0.02 g.

The highest mean weight of the above ground part in all three years of the experiment had the long tip cuttings – 2.0 g and a similar, high weight was noted for tip cuttings – 1.9 g and middle cuttings –1.8 g. The lowest weight of the above ground part characterized cuttings without heel. Their weight was 1.1 g (tab. 2).

Taking into consideration the type of cutting and the cultivar, the highest mean weight of the above ground part had long tip cuttings of the 'Orange' cultivar – 4.1 g. The lowest weight was observed in case of lateral cuttings of the remaining three cultivars: 'Berliner Kleene', 'Gea' and 'Orietta' (0.8 g) and middle cuttings of the 'Gea' cultivar, with the same weight.

Looking at the interaction of a method of cutting – years, the highest mean weight of the above ground part characterized long tip cuttings – 2.4 g, then middle and tip ones – 2.3 g and 2.2 g in the year 2003, respectively. The lowest weight was noted for lateral cuttings in the year 2004 – 0.9 g.

In case of cultivars, the highest weight was noted for cuttings of the 'Orange' cultivar – 2.6 g, while the lowest one – 'Berliner Kleene' (1.1 g).

The highest weight of the above ground part was observed for cuttings of the 'Orange' cultivar: 3.1 g in 2003, 2.1 g in 2004 and 2.7 g in 2005. Definitely lower weight had cuttings of the 'Berliner Kleene' (1.1 g in the years 2003 and 2005, 1.0 g in 2004) and 'Gea' cultivars (1.2 g in 2003, 0.8 g in 2004 and 1.0 g in 2005).

Looking at a whole experiment and the interaction between the type of cutting, cultivar and years, the highest weight of the above ground part characterized long tip cuttings of the 'Orange' cultivar in the year 2003. Their mean weight was 4.4 g. The lowest weight had lateral cuttings of the 'Gea' cultivar in 2004.

In all three years of the experiment, the highest were plants obtained from long tip cuttings (8.8 cm). The lowest one were obtained from leaf axils (so called lateral ones) – 6.3 cm (tab. 3).

Taking into consideration the type of cutting and the cultivar, the highest (14 cm) were long tip cuttings of the 'Orange' cultivar. The lowest were lateral cuttings of the 'Berliner Kleene' and 'Gea' cultivars – 4.8 cm.

In the interaction between the type of cutting and years, the highest were the long tip cuttings in the year 2003 (9.1 cm), while the lowest were lateral ones in 2005 – 5.6 cm.

Definitely the highest (7.8 cm) were the cuttings in the year 2003, while the lowest ones in 2005 – 6.8 cm. In case of cultivars, the highest were the cuttings of the 'Orietta' cultivar – 9.3 cm, and the lowest of the 'Gea' cultivar – 5.3 cm.

Looking at the whole experiment, the interaction between the type of cutting, cultivar and years showed that the highest were cuttings cut from a top part of the shoot, with 5–6 pairs of leaves, so called long tip

Table 1. The underground weight (g) of dahlia cuttings after rooting (A × B × C, 2003–2005 means)

Years (A)	Cultivar (B)	Type of cutting (C)						Means A × B
		with heel	without heel	tip	long tip	middle	lateral	
2003	Berliner Kleene	2.6 a–f	2.1 b–j	1.3 f–p	0.9 i–p	0.08 p	0.02 p	1.2 C
	Gea	1.6 d–n	1.0 h–p	1.6 d–n	1.0 h–p	0.2 p	0.08 p	0.9 CD
	Orange	2.8 a–e	2.3 a–h	2.8 a–e	2.5 a–g	3.0 abc	3.6 a	2,8 A
	Orietta	0.8 j–p	1.2 g–p	1.6 d–n	1.2 g–p	1.4 f–p	1.0 h–p	1.2 C
2004	Berliner Kleene	1.7 c–m	1.5 e–o	1.1 h–p	1.0 h–p	0.2 p	0.08 p	0.9 CD
	Gea	1.0 h–p	0.5 ł–p	1.1 h–p	0.9 i–p	0.1 p	0.06p	0.6 D
	Orange	1.8 c–ł	1.9 b–l	2.9 a–d	1.9 b–l	3.0 abc	1.3 f–p	2.1 B
	Orietta	0.7 k–p	0.7 k–p	1.0 h–p	0.8 j–p	0.7 k–p	0.4 nop	0.7 CD
2005	Berliner Kleene	2.2 b–i	1.5 e–o	0.7 k–p	1.3 f–p	0.08 p	0.02 p	0.9 CD
	Gea	1.2 g–p	1.6 d–n	1.2 g–p	1.1 h–p	0.1 p	0.1 p	0.9 CD
	Orange	2.0 b–k	1.4 f–p	3.2 ab	1.8 c–ł	2.6 a–f	1.7 c–m	2.1 B
	Orietta	0.8 j–p	0.7 k–p	0.8 j–p	1.2 g–p	0.7 k–p	0.3 nop	0.7 CD
Means C		1.6 A	1.3 AB	1.6 A	1.3 AB	1.0 CD	0.7 D	
Means B × C								means B
Berliner Kleene		2.2 ABC	1.7 C–F	1.0 F–I	1.1 FGH	0.1 KL	0.02 L	1.0 B
Gea		1.3 EFG	1.0 F–I	1.3 EFG	1.0 F–I	0.1 KL	0.06 L	0.8 B
Orange		2.2 ABC	1.9 CDE	2.9 A	2.1 BCD	2.8 AB	2.2 ABC	2.4 A
Orietta		0.8 G-K	0.8 G–K	1.1 FGH	1.1 FGH	0.9 G–J	0.6 G–L	0.9 B
Means A × C								means A
2003		2.0 A	1.6 ABC	1.8 AB	1.4 A–E	1.2 C–G	1.2 C–G	1.5 A
2004		1.3 B-F	1.1 C–H	1.5 A–D	1.2 C–G	1.0 C–I	0.4 I	1.1 B
2005		1.5 A-D	1.3 B–F	1.5 A–D	1.3 B–F	0.9 E–I	0.5 HI	1.2 B

$NIR_{0.05}$ for A = 0.1, for B = 0.2, for C = 0.3, for AB = 0.5, for AC = 0.6, for BC = 0.7, for ABC = 1.3

Table 2. Fresh weight (g) of the above ground part of dahlia cuttings after rooting (A × B × C, 2003–2005 means)

Years (A)	Cultivar (B)	Type of cutting (C)						Means A × B
		with heel	without heel	tip	long tip	middle	lateral	
2003	Berliner Kleene	1.7 j–m	0.9 łm	1.0 lłm	0.8 m	1.4 j–m	0.7 m	1.1 EF
	Gea	0.8 m	1.0 lłm	1.4 j–m	1.7 j–m	1.0 lłm	1.2 k–m	1.2 EF
	Orange	2.2 g–ł	1.1 k–m	3.3 a–h	4.4 a	4.3 ab	3.4 a–g	3.1 A
	Orietta	1.1 k–m	1.6 j–m	3.1 a–i	2.7 d–j	2.3 f–l	0.8 m	1.9 CD
2004	Berliner Kleene	0.8 m	1.5 j–m	0.9 łm	0.7 m	1.0 lłm	0.9 m	1.0 EF
	Gea	1.0 lłm	0.8 m	0.7 m	1.1 k–m	0.8 m	0.5 m	0.8 F
	Orange	1.1 k–m	1.1 k–m	3.6 a–f	4.0 a–d	1.4 j–m	1.3 k–m	2.1 C
	Orietta	1.1 k–m	1.3 k–m	2.4 e–k	1.5 j–m	1.8 i–m	0.9 m	1.5 DE
2005	Berliner Kleene	1.7 j–m	1.3 k–m	0.8 m	1.1 k–m	1.1 k–m	0.9 łm	1.1 EF
	Gea	1.5 j–m	1.1 k–m	1.1 k–m	0.9 łm	0.8 m	0.6 m	1.0 EF
	Orange	0.8 m	1.1 k–m	2.4 e–k	4.1 abc	4.0 a–d	3.7 a–e	2.7 AB
	Orietta	0.9 łm	1.1 k–m	1.5 j–m	1.8 i–m	1.2 k–m	0.6 m	1.2 EF
Means C		1.2 D	1.1 D	1.9 AB	2.0 A	1.8 ABC	1.3 D	
Means B × C								means B
Berliner Kleene		1.4 FGH	1.2 FGH	0.9 H	0.9 H	1.1 GH	0.8 H	1.1 C
Gea		1.1 GH	1.0 H	1.1 GH	1.2 FGH	0.8 H	0.8 H	1.0 C
Orange		1.4 FGH	1.1 GH	3.1 BC	4.1 A	3.2 B	2.8 BCD	2.6 A
Orietta		1.0 H	1.3 FGH	2.3 CDE	2.0 DEF	1.8 EFG	0.8 H	1.5 B
Means A × C								means A
2003		1.4 C–F	1.1 F	2.2 ABC	2.4 A	2.3 AB	1.5 C–F	1.8 A
2004		1.0 F	1.2 EF	1.9 A–D	1.8 A–E	1.2 EF	0.9 F	1.3 C
2005		1.2 EF	1.2 EF	1.5 C–F	2.0 ABC	1.8 A–E	1.4 C–F	1.5 B

$NIR_{0.05}$ for A = 0.1, for B = 0.2, for C = 0.3, for AB = 0.5, for AC = 0.6, for BC = 0.8, for ABC = 1.3

Table 3. The height (cm) of the above ground part of dahlia cuttings after rooting (A × B × C, 2003–2005 means)

Years (A)	Cultivar (B)	Type of cutting (C)						Means A × B
		with heel	without heel	tip	long tip	middle	lateral	
2003	Berliner Kleene	8.0 f–p	5.5 k–p	5.3 k–p	5.6 k–p	5.3 k–p	5.3 k–p	5.8 FG
	Gea	5.5 k–p	7.0 h–p	5.3 k–p	5.5 k–p	5.1 ł–p	4.2 op	5.4 G
	Orange	11.0 a–h	7.0 h–p	7.8 f–p	13.8 ab	10.4 b–i	8.7 d–n	9.8 ABC
	Orietta	6.5 i–p	9.4 c–l	12.3 a–e	11.5 a–g	12.8 a–d	9.1 c–ł	10.3 A
2004	Berliner Kleene	6.0 j–p	6.8 h–p	5.1 ł–p	6.1 j–p	4.0 p	4.1 op	5.4 G
	Gea	6.0 j–p	6.1 j–p	5.6 k–p	4.4 op	5.4 k–p	5.0 ł–p	5.4 G
	Orange	7.0 h–p	7.0 h–p	8.0 f–p	13.2 abc	9.0 c–m	5.5 k–p	8.3 CDE
	Orietta	9.1 c–ł	7.9 f–p	11.5 a–g	9.0 c–m	11.9 a–f	11.9 a–f	10.2 AB
2005	Berliner Kleene	6.4 i–p	5.5 k–p	5.2 l–p	6.5 i–p	6.5 i–p	5.1 ł–p	5.9 FG
	Gea	5.6 k–p	5.5 k–p	5.0 ł–p	4.7 nop	5.2 l–p	5.1 ł–p	5.2 G
	Orange	6.5 i–p	7.0 h–p	6.3 i–p	15.0 a	9.5 c–k	7.9 f–p	8.7 A-D
	Orietta	7.7 f–p	8.3 e–o	7.8 f–p	10.0 b–j	6.4 i–p	4.3 op	7.4 DEF
Means C		7.1 BC	6.9 BC	7.1 BC	8.8 A	7.6 B	6.3 C	
Means B × C								means B
Berliner Kleene		6.8 F-K	6.0 H–K	5.2 JK	6.1 F–K	5.3 JK	4.8 K	5.7 C
Gea		5.7 H-K	6.2 F–K	5.3 JK	4.8 K	5.2 JK	4.8 K	5.3 C
Orange		8.1 B-H	7.0 F–K	7.4 E–J	14.0 A	9.6 B–E	7.4 E–J	8.9 AB
Orietta		7.8 D-I	8.5 B–F	10.5 B	10.1 BCD	10.3 BC	8.4 B–G	9.3 A
Means A × C								means A
2003		7.8 A-E	7.2 A–G	7.7 A–F	9.1 A	8.4 ABC	6.8 C–G	7.8 A
2004		7.0 B-G	6.9 C–G	7.6 A–G	8.2 A–D	7.6 A–G	6.6 C–G	7.3 AB
2005		6.5 C-G	6.6 C–G	6.1 EFG	9.0 AB	6.9 C–G	5.6 G	6.8 B

$NIR_{0.05}$ for A = 0.5, for B = 0.7, for C = 0.9, for AB =1.6, for AC = 2.0, for BC = 2.4, for ABC = 4.2

Table 4. Length (cm) of roots of dahlia cuttings after rooting (A × B × C, 2003–2005 means)

Years (A)	Cultivar (B)	Type of cutting (C)						Means A × B
		with heel	without heel	tip	long tip	middle	lateral	
2003	Berliner Kleene	12.8	13.5	15.0	14.0	2.3	0.0	9.6 FG
	Gea	11.2	12.0	10.5	11.1	5.4	2.6	8.8 G
	Orange	18.6	24.5	19.8	18.5	22.5	26.1	21.6 A
	Orietta	11.1	18.2	16.1	16.1	21.1	10.5	15.5 D
2004	Berliner Kleene	9.3	12.5	9.5	13.6	4.5	1.6	8.5 G
	Gea	14.6	8.3	7.8	14.8	3.3	0.0	8.1 G
	Orange	22.3	23.8	19.0	22.0	24.0	18.1	21.5 AB
	Orietta	11.1	12.7	14.5	12.4	18.4	9.6	13.1 DE
2005	Berliner Kleene	14.6	13.5	14.1	11.0	1.6	0.0	9.1 G
	Gea	12.8	10.3	10.3	12.8	2.6	2.8	8.6 G
	Orange	16.8	21.6	20.8	23.3	16.8	18.1	19.6 ABC
	Orietta	11.5	13.3	14.4	17.5	10.7	9.0	12.7 DEF
Means C		13.9 A–D	15.4 AB	14.3 ABC	15.6 A	11.1 E	8.2 F	
Means B × C								means B
Berliner Kleene		12.2 G–M	13.1 G–K	12.8 G–Ł	12.8 G–Ł	2.8 R	0.5 R	9.1 C
Gea		12.9 G–L	10.4 H–O	9.5 J–Q	12.9 G–L	3.8 R	1.8 R	8.6 C
Orange		19.2 A–F	23.3 A	19.8 A–E	21.2 AB	21.1 ABC	20.8 A–D	20.9 A
Orietta		11.2 H–N	14.7 E–J	15.0 E–I	15.3 E–H	16.7 B–G	9.7 I–P	13.8 B
Means A × C								means A
2003		13.4 A–J	17.0 A	15.3 A–D	14.9 A–E	12.8 A–K	9.8 G–M	13.9 A
2004		14.3 A–H	14.4 A–G	12.7 A–L	15.7 ABC	12.5 A–Ł	7.3 M	12.8 AB
2005		13.9 A–I	14.7 A–F	14.9 A–E	16.1 AB	7.9 ŁM	7.5 M	12.5 B

$NIR_{0.05}$ for A = 1.2, for B = 1.6, for C = 2.1, for AB = 3.5, for AC = 4.6, for BC = 5.4, for ABC = 9.4

Table 5. Number of leaves of dahlia cuttings after rooting (A × B × C, 2003–2005 means)

Years (A)	Cultivar (B)	Type of cutting (C)						Means A × B
		with heel	without heel	tip	long tip	middle	lateral	
2003	Berliner Kleene	5.6 j–r	4.3 m–r	4.6 ł–r	4.3 m–r	4.3 m–r	3.3 pr	4.4 G
	Gea	5.3 k–r	5.0 l–r	5.6 j–r	5.3 k–r	2.6 r	5.0 l–r	4.8 G
	Orange	11.3 a–d	10.3 a–g	9.6 a–i	11.3 a–d	9.6 a–i	6.3 h–r	9.7 ABC
	Orietta	7.6 d–n	9.6 a–i	13.3 a	12.3 abc	11.3 a–d	8.3 d–ł	10.4 A
2004	Berliner Kleene	5.0 l–r	6.0 i–r	5.0 l–r	4.0 n–r	4.6 ł–r	5.6 j–r	5.0 G
	Gea	5.6 j–r	5.6 j–r	4.3 m–r	3.0 pr	3.3 pr	5.0 l–r	4.5 G
	Orange	9.0 a–k	10.6 a–f	10.3 a–g	11.3 a–d	9.3 a–j	7.3 e–o	9.6 A–D
	Orietta	10.0 a–h	8.3 d–ł	12.6 ab	10.3 a–g	10.6 a–f	8.0 d–m	10.0 AB
2005	Berliner Kleene	4.6 ł–r	5.3 k–r	6.3 h–r	3.6 opr	4.6 ł–r	4.6 ł–r	4.8 G
	Gea	5.3 k–r	5.0 l–r	4.3 m–r	2.6 r	3.3 pr	5.6 j–r	4.3 G
	Orange	8.3 d–ł	10.3 a–g	9.0 a–k	10.0 a–h	10.3 a–g	6.6 g–p	9.1 A–F
	Orietta	8.3 d–ł	8.6 c–l	11.0 a–e	11.3 a–d	9.0 a–k	9.0 a–k	9.5 A–E
Means C		7.1 BCD	7.4 AB	8.0 A	7.4 AB	6.9 B–E	6.2 E	
Means B × C								means B
Berliner Kleene		5.1 L–N	5.2 L–N	5.3 LŁM	4.0 ŁMN	4.5 ŁMN	4.5 ŁMN	4.7 C
Gea		5.4 LŁ	5.2 L–N	4.7 L–N	3.6 ŁMN	3.1 N	5.2 L–N	4.5 C
Orange		9.5 B–H	10.4 A–D	9.6 B–G	10.8 ABC	9.7 B–F	6.7 I–L	9.5 AB
Orietta		8.6 D–J	8.8 C–I	12.3 A	11.3 AB	10.3 A–E	8.4 D–K	10.0 A
Means A × C								means A
2003		7.5 A–D	7.3 A–D	8.3 A	8.3 A	7.0 A–D	5.7 D	7.3 A
2004		7.4 A–D	7.6 ABC	8.0 AB	7.1 A–D	7.0 A–D	6.5 A–D	7.3 A
2005		6.6 A–D	7.3 A–D	7.6 ABC	6.9 A–D	6.8 A–D	6.5 A–D	6.9 A

$NIR_{0.05}$ for A = 0.5, for B = 0.6, for C = 0.8, for AB = 1.4, for AC = 1.8 for BC = 2.2, for ABC = 3.8

cuttings, of the 'Orange' cultivar in the year 2005 (15.0 cm). Significantly the lowest (4.0 cm) were middle cuttings of the 'Berliner Kleene' cultivar in 2004.

In all three years of the experiment, the longest roots formed long tip cuttings (15.6 cm), while the shortest ones were noted in case of lateral ones (8.2 cm) (tab. 4).

Taking into consideration the type of cutting and cultivar, definitely the longest roots were noted in case of cuttings without heel of the 'Orange' cultivar (23.3 cm), while the shortest ones were middle ones of the 'Berliner Kleene' cultivar – 0.5 cm.

The longest roots formed cuttings in the year 2003, their mean length was 13.9 cm. The length of the roots of cuttings in the remaining years did not differ significantly and was 12.8 cm in the year 2004 and 12.5 cm in 2005. In case of cultivars, the longest roots characterized cuttings of the 'Orange' cultivar – 20.9 cm, while the shortest ones 'Gea' cultivar – 8.6 cm.

Looking at the whole experiment and the interaction between the type of cutting, cultivar and the years of the experiment, the longest roots were noted in case of lateral cuttings of the 'Orange' cultivar in the year 2003 (26.1 cm). The shortest roots were observed in case of lateral cuttings of the 'Berliner Kleene' cultivar in 2004 and middle ones of the same cultivar in 2005 (1.6 cm).

During the measurements conducted in the years 2003 and 2005, it was noticed that plants formed from lateral cuttings of the 'Berliner Kleene' had no roots formed, only the healed wound left after cutting with visible callus tissue in their lower part could be observed. The same situation was noticed in the year 2004 in case of plants formed from 'Gea' lateral cuttings.

In all three years of the experiment, the most leaves formed tip cuttings – 8 on average. The least leaves formed lateral cuttings – 6.2 (tab. 5).

Taking into consideration the type of cutting and cultivar, definitely more leaves were noted in case of tip cuttings of the 'Orietta' cultivar – 12.3. The least leaves were noted in case of middle cuttings of the 'Gea' cultivar – 3.1.

The number of leaves did not differ significantly in the years of the experiment and was 7.3 in 2003 and 2004, and 6.9 in 2005. In case of cultivars, the most leaves characterized 'Orietta' cultivar – 10. Similar number of leaves was noted for the 'Orange' cultivar – 9.5 on average.

Looking at a whole experiment and the interaction between the type of cutting, cultivar and the years, the most leaves were observed in case of cuttings excised from the top of stem with 3–4 pairs of leaves, so called tip cuttings, of the 'Orietta' cultivar in the year 2003. Their mean number was 13.3. The least leaves was noted in case of the middle cuttings of the 'Gea' cultivar in the year 2003 (2.6).

DISCUSSION

In a large scale, commercial production, dahlias are propagated mainly through stem cuttings [Grabowska et al. 1987, Chmiel 2000]. Most authors [Rzepecka-Żelechowska and Żelechowski 1986, Grabowska et al. 1987, Chmiel 2000] recommend to excise the cuttings with heel with a part of base crown tissue from the roots. However, this method is ineffective. The experiments conducted by Pudelska [2000], Hetman and Pudelska [2006] and Pudelska et al. [2015] proved that other methods of cutting might be used which allow to enhance the productiveness of dahlia nurseries.

Hetman and Pudelska [2006] in the experiments on rooting of different types of soft cuttings of dahlia proved that dahlia cultivars characterize with a very high differentiation in intensity of forming shoots proper for cuttings and the effectiveness of rooting. The percentage of cuttings that formed roots ranged between 78 and 85. In the cited experiments there wasn't an automatic regulation of the rooting conditions.

In the presented experiment, over 90% of cuttings formed roots Types of cuttings did not significantly influence the percentage of rooted cuttings. However, the intensity of forming the roots depended on the method of cutting. While observing the cuttings during rooting, it was noted that growth started the earliest in case of cuttings with heel and tip ones. These cuttings characterized with the highest weight of the above ground part as well. It means the process of roots forming in case of this type of cuttings started

the earliest. It appears that rooting would amount even to 100% in optimal conditions, which are automatically regulated temperature, light, air and soil humidity. According to Sochacki [2010], dahlias cuttings root very well in optimal conditions. However, the process of producing roots by cuttings depends, to a large degree, on conditions, which are air and soil temperature and humidity [Jerzy and Krzymińska 2011].

The type of cutting influenced morphological features of the obtained plants. During all three years of the experiment, the highest mean weight of the above ground part was noted in case of tip and long tip cuttings. Such results are correlated with the higher weight of the cuttings at the moment of excision from mother crowns, in comparison to the cuttings obtained from lateral shoots or the ones without heel.

Grabowska et al. [1987] and De Hertogh and Le Nard [1993] state that the best term to establish a nursery of dahlia is at the turn of February and March. On the basis of own experiments it might be noted that cuttings obtained from the leaves axils (lateral ones) and from the central part of the stem (middle ones) form roots longer, so that the dahlias tuberous roots should be placed in a glasshouse at the beginning of February and exposed to light in order to hasten shoots sprouting, which would be earlier available for rooting.

The results obtained in the presented experiment as well as in the previous research of the authors, allow to estimate the recommendations on methods of dahlia cuttings excision to obtain maximum effectiveness of mother plants. To obtain the highest possible number of cuttings, dahlias roots should be placed in a glasshouse at the beginning of February in optimal conditions to start vegetation. So far, the most often advised date to establish nurseries is the turn of February and March [Grabowska et al. 1987, De Hertogh and Le Nard 1993]. Cuttings should be excised when sprouting shoots achieve 5–7 pairs of leaves. Then the top part with 2–3 pairs of leaves should be cut off, leaving at least 2 pairs of leaves on the stem. After around 2 weeks, in leaves axils new shoots start to be visible, which, after forming 2–3 pairs of leaves, might be used as cuttings. Just after taking top cuttings, new shoots will sprout directly from mother roots. It is also possible, if the roots are early placed in a glasshouse, to allow the stem form 6–8 pairs of leaves, and then cut longer tip cuttings with 3–4 pairs of leaves. The remaining, middle part with 2 pairs of leaves, might also be used. The stem will still have the remaining 1–2 pairs of leaves from which axils new shoots will grow, which after further 2–3 weeks might be used as lateral cuttings. This method of cutting allows to obtain 100 or more cuttings from one, well branched tuberous roots, from February till the end of April.

CONCLUSIONS

1. With the use of different types of stem cuttings there is a possibility to enhance effectiveness of *Dahlia annabilis* propagation.

2. The highest effectiveness of mother crowns might be obtained when tip cuttings with 2–3 pairs of leaves are excised from stems with 5–6 pairs of leaves, and then two-node middle cuttings are taken. From the nodes of the remaining stem with 1–2 pairs of leaves new shoots will arise, which might be excised as lateral cuttings when they form 2–3 pairs of leaves.

3. Cuttings excised in different ways root very well, however the process of forming the roots runs in a different rate, depending onthe type of cutting and a cultivar. Roots are formed the fastest on the cuttings with heel and the tip ones, while the latest they are observed in case of lateral cuttings.

4. Plants obtained from different types of cuttings after 5 weeks of rooting, adapt well when planted into the ground.

REFERENCES

Biran, I., Halevy, A.H. (1973). The relationship between rooting of Dahlia cuttings and the presence and type of bud. Physiol. Plant., 28, 244–247.

Bojarczuk, K. (1984). Wpływ czynników zewnętrznych oraz niektórych związków chemicznych na ukorzenianie sadzonek różaneczników. Arbor. Kórn., 29, 143–169.

Cameron, R.W.F., Harrison-Muray, R.S., Ford, Y.Y., Judd, H. (2001). Ornamental shrubs: Effects of stockplant

management on the rooting and establishment of cuttings. J. Hort. Sci. Biotech., 76, 489–496.

Clenet, G. (1995). Las Dahlias. Rustica, 9–10.

Cuijpers, L.H.M. (1995). Growth regulation of *Chrysanthemum*, *Pelargonium*, *Begonia* and *Kalanchoe* using temperature pretreatment of stockplants. Acta Hort., 378, 97–104.

Chmiel, H. (2000). Uprawa roślin ozdobnych. PWRiL Warszawa, 332–336.

Czekalski, M. (1988). Rozmnażanie bugenwilli gładkiej przez sadzonki pędowe. Ogrodnictwo, 7, 29–31.

De Hertogh, A.A., Le Nard, M. (1993). The physiology of flower bulbs. Elsevier, 273–283.

Escher, F. (1983). Schnittblumenkulturen. Verlag Eugen Ulmer, Stuttgart, 590.

Grabowska, B., Krause, J., Mynett, K. (1987). Uprawa cebulowych i bulwiastych roślin ozdobnych. PWRiL Warszawa, 46–62.

Hartman, H.T., Kester, D.E., Davies, F.T., Geneve, R.L. (1997). The biology of propagation by cuttings. Plant Propagation. Principles and Practices. Chapter 10. Prentce-Hall, Inc. Englewood Cliffs, New Jersey, 07632, 277–328.

Hetman, J. (1993). Nowe komponenty podłoża do ukorzeniania sadzonek goździka. Materiały konferencyjne: Postępowanie w uprawie goździków. Łódź, 16 – 22.

Hetman, J., Pudelska, K. (2006). Ukorzenianie różnych typów sadzonek zielnych kilku odmian dalii zmiennej (*Dahlia pinnata* Cav.) Zesz. Probl. Post. Nauk Rol., 510, 195–202.

Hocking, P.J., Thomas, M.B. (1979). Efect of IBA in combination with Thira captan and benomyl on the rooting four ornamental species. New Zeland J. Exp. Agric., 7, 263–269.

Jerzy, M., Krzymińska, A. (2011). Rozmnażanie wegetatywne roślin ozdobnych. PWRiL Poznań.

Kolasiński, M. (2005). Ukorzenianie metasekwoi chińskiej (*Metasequoia glyptostroboides* Hu & W.C. Cheng) w zależności od ich typów. Zesz. Probl. Post. Nauk Rol., 504, 407–414.

Krajnc, A.U., Turinek, M., Ivančič, A. (2002). Morphological and physiological changes during adventitious root formation as affected by auxin metabolism: Stimulatory effect of auxin seaweed extract treatment. Agricultura, 1, 17–27.

Krzymińska, A., Czekalski, M. (2002). Kwitnienie młodych krzewów różaneczników rozmnożonych za pomocą sześciu typów sadzonek. Zesz. Probl. Post. Nauk Rol., 483, 133–139.

Langeslang, J.J.J. (1989). Teelen Gebruiksmogelijkheden van Bijgoedgwassen. Tweede Uitgave. Minisgelijkheden van Landbouw, Natuurbeheeren Visserijen Consulentschap Algemence Dienst Bloombollenteelt, Lisse. The Netherlands, 273 (in Dutch).

Ochoa, J., Bañon, S., Fernández, J.A., González, A., Franco, J.A. (2000). Influence of cutting position and rooting media on rhizogenesis in oleander cuttings. Acta Hort., 541, 135–145.

Pudelska, K. (2000). Opracowanie technologii produkcji roślin dalii (*Dahlia* × *cultorum* Thorsr. et Reis) do uprawy w pojemnikach i na kwietnikach. Sprawozdanie merytoryczne. Projekt badawczy nr PB 5.PO6.C.007.11. The Library of the Department of Ornamental Plants and Landscape Architecture, University of Life Sciences in Lublin.

Pudelska, K., Hetman, J. (2001). Wpływ podłoża i preparatów zawierających NAA na ukorzenianie sadzonek zielnych kilku odmian dalii ogrodowej. Annales UMCS, Horticultura, 9, 9–15.

Pudelska, K., Hetman, J., Łukawska-Sudoł, S., Parzymies, M. (2015). The efficiency of mother crowns and quality of soft cuttings of a few dahlia cultivars. Acta Sci. Pol. Hortorum Cultus, 14(3), 189–200.

Reinikainer, C. (1993). Choice of growing media for pot plants. Acta Hort., 324, 357–360.

Rzepecka-Żelechowska, K., Żelechowski, W. (1986). Byliny nie zimujące w gruncie. Krajowa Rada Związku Działkowców, Warszawa, 11–21.

Serek, M., Prabucki, A., Sisler, E., Andersen, A.S. (1998). Inhibitors of ethylene action effect final quality and rooting of cuttings before and after storage. HortSci., 33, 153–155.

Sochacki, D. (2010). Dalie. Wyd. Działkowiec Sp. z o.o. Warszawa.

Szabo, V., Nemeth, Z., Sarvari, A., Vegvari, G., Hrotko, K. (2014). Effects of biostimulator and leaf fertilizers on *Prunus mahaleb* L. stockplants and their cuttings. Acta Sci. Pol. Hortorum Cultus, 13(6), 113–125.

Świstowska, A., Hetman, J. (2004). Wpływ auksyn na ukorzenianie mikrosadzonek i adaptację roślin *Columnea hirta* Klotzsch et. Hanst. Część II. Następczy wpływ w uprawie szklarniowej. Acta Sci. Pol. Hortorum Cultus, 3(2), 239–248.

Winiarczyk, K., Solarska, E., Sienkiewicz, W. (2014). Prevalence of infections with onion yellow dwarf virus, leek yellow stripe virus and garlic common latent virus in plants from the genus *Allium*. Acta Sci. Pol. Hortorum Cultus, 13(3), 123–133.