Scientific Papers. Series B, Horticulture. Vol. LXVIII, No. 2, 2024
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

INFLUENCE OF THE ULTRASOUND ON THE SOWING QUALITY OF SNAPDRAGON (*ANTIRRHINUM MAJUS* L.) SEEDS

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Abstract

The main goal of the present study was to establish the effect of ultrasound on the sowing parameters of snapdragon (Antirrhinum majus L.) seeds. Experiments were carried out with three varieties snapdragon. The seeds were sonicated with ultrasound for 2, 4, 6 and 8 minutes. The following parameters were investigated: germination energy, germinability, Mean germination time, Uniformity of germination, length of embryo root and hypocotyls, and fresh weight of the sprouts. The sowing parameters were improved from each duration of ultrasound treatment. The best results for germination and in most of the parameters were found about treatment with 6 minutes. The high correlation between the length of hypocotyls and embryo root and fresh weight was established. Polynomial regression with a high determination coefficient was registered.

Key words: *seeds, energy of germination, germination, mean germination time, seedlings.*

INTRODUCTION

Snapdragon is a flower crop widely used for landscaping open areas. It is applied often for small and courtyard gardens. The ornamental value of the species is determined by the specific flower structure and many different colors (Huxley & Griffiths, 1992). In addition, its flowering is long-lasting, throughout the growing season, which makes it extremely suitable for permanent landscaping. It is pointed out that in the Mediterranean region, it is even a perennial crop (Shafique et al., 2011).
A positive side of snapdragon is the considerably long flowering period and the duration of preservation in good condition of the individual flowers. Although originally intended only for landscape use in parks and open public spaces as flower beds or borders, it has recently been grown for cut color (Sanderson & Martin, 1984). Various groups of cultivars have been developed and flowering can be regulated by temperature and light conditions (Ball, 1991; Rogers, 1992).
However, the species is characterized by relatively low seed viability and a long period of germination and emergence (Kabatliyska, 2005). In this regard, studies have been conducted to stimulate the vital processes of seeds by using various agents. Kang and Choi (2006) applied soaking of snapdragon seeds for two days in GA_3 solutions of different concentrations, pointing out that the application of 200 $ml.L^{-1}$ demonstrated the strongest stimulating effect. Similar experiments with GA_3 were conducted also by Bhargava et al. (2015). Additionally, these authors tested other chemical treatments with KNO_3 and KH_2PO_4 and bio-priming with *Trichoderma harzianum* and *Bacillus subtilis*. The greatest positive influence on the life processes of the seeds of this species is found in bio-priming, with an increase in germination by 20%. Contradictory results in the treatment of snapdragon seeds with chemical agents, and in particular with GA_3, were reported by Kepczynski (1979), indicating that a stimulatory effect was not reported in all cases.
The use of physical agents is another direction to improve the sowing qualities of the seeds of *Antirrhinum majus* L. The application of variable temperatures has a very high acceleration on the germination (Geo, 1991). Armitage (1991) also points out the influence of different temperature conditions on the improvement of seed viability. Research on the pre-sowing stimulation of snapdragon seeds is limited, and the application of some methods and agents is lacking. This determined the purpose of the study.

The main goal of the present study was to establish the effect of ultrasound on the sowing parameters of snapdragon (*Antirrhinum majus* L.) seeds.

MATERIALS AND METHODS

The experiments were carried out with three snapdragon varieties - as follows Apple Blossom, Sonnet Carmine and Orange Wonder. The seeds were treated with ultrasound in the Scientific laboratory of the Department of Horticulture at the Agricultural University - Plovdiv, Bulgaria. The tested periods of sonication were 2, 4, 6 and 8 minutes. As a control were used not treated seeds. Ultrasonic bath Nahita, model 620-1 of the company Auxilab, S.L. from Spain was applied for sound treatment. This aparate are characterized with the following parameters: frequency 40 KHz, volume 0.6 L.

After treatment, the seeds were placed in Petri dishes with a diameter of 10 cm. On the bottom of the Petri the filter paper Watman 1 moistened with 5 ml of water was set up. The 100 seeds in four replicates were put in Petri dishes for the establishment of their viability parameters. The germination energy (first count) and germination (final count) were determined, according to the requirements of ISTA (2013), as germinated seeds were counted daily. The time to germination of 50% of the seeds (T_{50}) was calculated by the equation of Farooq (2005). Mean germination time (MGT) and uniformity of germination (described by Panayotov, 2015) were determined. At the time of the germination establishment, the lengths of the embryo root and the hypocotyls were measured. These measurements were done on ten seedlings from the 4 replicates. The weight of the all developed sprouts in the four repetitions was established also in this moment and recalculated for one sprout.

The results were processed to ANOVA, and the correlation and regression analyses also were carried out (Fowel & Cohen, 1992).

RESULTS AND DISCUSSIONS

Germination energy, as an indicator that is taken into account in an earlier period of germination, provides information about the number of seeds that have higher vitality and in which the germination processes proceed more quickly (Panayotov, 2015). The data are shown in Table 1. The control seeds of the three tested cultivars had relatively similar germination energy. The application of ultrasound causes significant changes in this indicator, both depending on the variety and the duration of processing. The strongest effect of ultrasound treatment was found in the Apple Blossom variety, where even the weakest sonication of 2 minutes increased the germination energy by approximately 10%, while in the other two varieties, the changes in this variant were within about 3%. As the duration of the ultrasound processing increased to 6 minutes, the germination energy increased constantly, then decreased, but its values remained higher than the control, except for those of the Orange Wonder variety, where a stronger inhibition was observed. The highest germination energy, almost 21% above the control, was reported for Apple Blossom seeds and reached 71.33%. In the other two varieties, especially in Sonnet Carmine, the improvement of this parameter is weaker. The main indicator of the vital status of seeds, which most fully reflects their properties and standardizes quality, is germination (Black et al., 2006). It follows a similar trend as germination energy. As the sounding time increases, its values increase relatively evenly. The strongest influence, compared to the control, was reported for the varieties Orange Wonder and Apple Blossom, where even with the weakest treatment, germination increased by approximately 8.0%. Snapdragon seeds are initially characterized by a not particularly high germination rate (Bhargava et al., 2015).

With the help of ultrasound, seed viability was significantly improved, with the highest results obtained at the 6-minute variant for all three cultivars. The highest germination rate was observed in the Apple Blossom variety - 78.3%, followed by Orange Wonder with 74.6%. The data of germination energy are with statistical significance. At this duration of seed treatment with ultrasound, Panchev (2023) also obtained a high stimulatory effect in the seeds of decorative plants. There are different opinions about how ultrasound affects the seeds. One of the reasons for the increase in germination according to López-Ribera & Vicient (2017) and Aladjadjiyan (2007) is that when ultrasound is applied, the pores of the seed coat are open more. Close to this view is the conclusion of Nogueira et al. (2024) who pointed out that the effect of ultrasound treatment was due to the stimulation of the uptake of water and oxygen by the seeds and also of their metabolism. The authors emphasized that research on the influence of ultrasound at the biochemical and molecular level is limited, but one of the possible reasons for its effect is the degradation of starch and stimulation of the action of the enzyme α-amylases in the endosperm.

Table 1. Viability parameters of snapdragon seed after treatment with ultrasound

Vari-ants	Germination energy (%)			Germination (%)			$T_{50\%}$ germination (days)		
	Apple Blossom	Sonnet Carmine	Orange Wonder	Apple Blossom	Sonnet Carmine	Orange Wonder	Apple Blossom	Sonnet Carmine	Orange Wonder
Control	50.2	50.6	53.3	62.2	53.3	55.6	7.93	8.52	9.46
2 min	60.5	53.3	56.7	69.3	58.6	63.3	7.46	8.24	8.41
4 min	64.0	54.6	60.5	68.4	60.6	66.6	7.46	8.16	7.62
6 min	71.33	55.3	64.9	78.3	68.3	74.6	7.12	8.16	7.33
8 min	56.5	52.3	38.3	63.0	57.3	58.2	7.73	8.73	8.73
LSDp= 0.05%	6.5	4.0	5.8	4.8	4.4	6.1	1.1	1.4	1.3

The indicated changes in germination are also observed through the established regression relationships (Figure 1). For the three varieties, this dependence is polynomial. The coefficients of determination are high R^2=0.56 (Apple Blossom), R^2=0.67 (Sonnet Carmine), and R^2=0.72 (Orange Wonder). Using this coefficient, the influence of the factorial variable on the percentage of variance of the outcome variable can be assessed. This study shows that between 56% and 72% of cases of sonication, the observed changes in snapdragon seed germination will produce.

The influence of ultrasound on the germination time of 50% of the seeds, which is another important indicator for assessing their vital state, is weaker and a well-expressed varietal response is observed. In the Apple Blossom cultivar, it ranged from 7.93 days for the control to 7.12 days at 6 minutes. Within approximately 8 days, this indicator changes with Sonnet Carmine, and even at 8 minutes there is a slight increase. Better results were observed for Orange Wonder, especially for the 4 and 6-minute variants, with the required time for 50% of the seed germination decreasing by 1.84 and 2.13 days, respectively. The effect of snapdragon seed treatment on variation in 50% germination time was also reported by Bhargava et al. (2015).

Another important indicator for evaluating the sowing qualities of the seeds is the mean germination time (Table 2). It shows the average number of days for a seed to germinate (Trayanov, 2021). In summary, it can be stated that this time for the tested variants and varieties is more than 2 days. Sonication improved this trait except at 8 minutes for Sonnet Carmine and Orange Wonder cultivars. The least time for germination of one seed was obtained after treatment with 6 minutes of ultrasound - 1.98 days and 1.95 days, respectively, for Apple Blossom and Orange Wonder, the difference with the control being 0.43 and 0.97 days. Seed uniformity also reflects the impact of ultrasound on germination processes Its values are relatively low, which once again shows that snapdragon seeds have lower vital parameters. In untreated seeds, it is between 4.11% (Orange Wonder) to 5.29% (Sonnet Carmine). After the application of ultrasound, it increased uniformly in all variants and all varieties and reached maximum values at 6 minutes. The strongest improvement with 2.41% was registered with Orange Wonder, followed by Sonnet Carmine with 1.76%.

The morphological development of the sprouts gives additional insight into the vital status of the seeds.

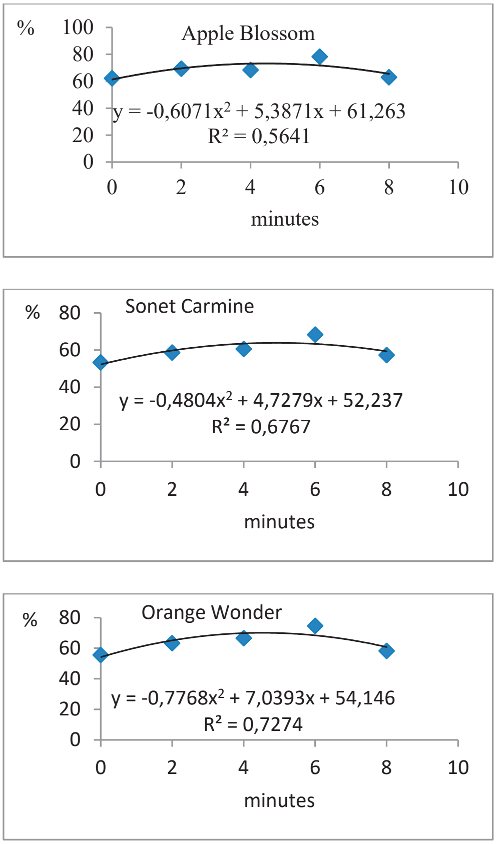

Figure 1. Regression dependence of germination and the duration of ultrasound treatment of snapdargon seeds

On the other hand, fresh mass is often used as an indicator of establishment the of seed vigor (Panayotov, 2015). The data are presented in Table 3. The length of the embryo root changes as a result of the action of ultrasound. For all variants tested, it increased to 6 minutes, with values ranging from 0.79 cm to 1.42 cm, respectively, for Apple Blossom and Sonnet Carmine. The differences compared to the control were 0.63 and 1.22 cm. At 8 min application, inhibition was reported, but the values were significantly higher than untreated seeds.

Table 2. Sowing indexes of snapdragon seed after treatment with ultrasound

Vari-ants	Mean germination time (days)			Uniformity of germination (%)		
	Apple Blossom	Sonnet Carmine	Orange Wonder	Apple Blossom	Sonnet Carmine	Orange Wonder
Control	2.41	2.71	2.32	5.10	5.29	4.11
2 min	2.36	2.48	2.40	5.79	5.38	5.47
4 min	2.27	2.40	2.53	6.24	5.71	5.69
6 min	1.98	2.21	1.95	6.66	7.05	6.52
8 min	2.32	2.84	2.72	5.81	6.48	4.75
LSDp= 0.05%	0.8	1.1	1.3	1.4	1.1	1.0

The hypocotyl is characterized by a much longer length and the stimulating effect is stronger. Under the influence of ultrasound, the sprouts develop long hypostyles. Growth is uniform up to 8 minutes of sonication. Sprouts from seeds treated for 8 minutes are characterized by the greatest length.

Table 3. Morphological characteristics of snapdragon seed after treatment with ultrasound

Variants	Length of embryo root (cm)			Length of hypocotyl (cm)			Fresh weight of one sprout (mg)		
	Apple Blossom	Sonnet Carmine	Orange Wonder	Apple Blossom	Sonnet Carmine	Orange Wonder	Apple Blossom	Sonnet Carmine	Orange Wonder
Control	0.76	0.55	0.56	2.96	3.00	3.33	0.10	0.08	0.09
2 min	0.99	0.73	0.68	3.23	3.20	3.53	0.11	0.10	0.11
4 min	1.09	1.15	1.98	3.46	3.43	4.26	0.12	0.11	0.11
6 min	1.39	1.74	1.82	3.70	3.66	5.33	0.13	0.14	0.13
8 min	0.79	1.42	1.15	4.40	4.26	5.46	0.12	0.12	0.07
r*							0.76	0.97	0.48
r**							0.77	0.69	0.34
LSDp= 0.05%	0.4	0.7	0.6	1.2	1.3	1.0	0.5	0.4	0.3

r* - correlation between fresh weight and length of embryo root; r** - correlation between fresh weight and length of hypocotyl.

The longest are those of the Orange Wonder variety - 5.46 cm or 2.13 cm more than the control, followed by that of Apple Blossom with a length of 4.40 cm. Fresh weight varies within narrower limits and differences between cultivars are insignificant. They range from 0.07 mg at 8 minutes for Orange Wonder to 0.14 mg at 6 minutes for Sonnet Carmine. A strong positive correlation was found between seedling fresh weight and embryo root and hypocotyl length with coefficients of r=0.76 and r=0.77 for Apple Blossom and r=0.97 and r=0.69 for Sonnet Carmine, respectively. In Orange Wonder, these correlations are also positive but weak.

CONCLUSIONS

Sonication has a significant effect on the sowing qualities of snapdragon seeds. A well-manifested cultivar response is observed. Treatments with 6 min of sonication increased the most germination energy and germination, with differences from the control reaching 20% in Apple Blossom variety. A polynomial regression, with high coefficients of determination, was found between the duration of the treatment and germination.

The germination time of 50% of the seeds, mean germination time and uniformity of germination are improved, with the highest effect observed in the 6-minute varinats. The morphological development of the sprouts was best when using 6 minutes of ultrasound, and positive correlations were established between their length and weight.

It is recommended to apply sonication for 6 minutes to improve the sowing qualities of snapdragon seeds.

ACKNOWLEDGEMENTS

This scientific work was carried out with the help of the Research Fund of the Agricultural University - Plovdiv, Bulgaria under Project 17-12

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