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Article

Osmotic potential of nutrient solution in snapdragon growth and quality

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Abstract

On the market, there are cultivars of snapdragon flowers that belong to a particular series and group, depending on the range of nocturnal temperature they tolerate; however, even within the same series, the cultivars may have different responses to a defined environment and management. The research aimed to compare different osmotic potentials of the nutrient solution on the growth and quality of snapdragon (*Antirrhinum majus* L.), cultivars Red and Rose, during the autumn-winter cycle in Nayarit. The treatments were obtained through a 5 x 2 factorial arrangement; the factors were the osmotic potential (-0.036, -0.054, -0.072, -0.09, -0.108 MPa) and the cultivar (Red and Rose). These were established in September 2018 in Xalisco, Nayarit. The design of the experiment was completely randomized with 15 replications. The variables evaluated were stem length and diameter, total fresh biomass, dry leaf and stem biomass, SPAD readings, dry root biomass, root volume, spike length, dry spike biomass, number of buds and flowers, days to flowering, and days to harvest. The osmotic potentials of -0.036 and -0.054 MPa obtained the highest values in the different growth variables; these were the most suitable for greater growth and production of cut snapdragon flowers. It was also observed that, in the growth variables, the Rose cultivar stood out and was classified in the special category; on the other hand, Red was harvested earlier and classified in the sophisticated category, under the conditions of the experiment.

Keywords:

Antirrhinum majus, cultivars, nutrition.

Introduction

In Mexico, floriculture has been a relevant activity for small producers and large companies, mainly in the international market for cut flowers, due to the high value of production (FND, 2014). In 2016, there was a 25% increase in the production of different ornamental plants in the country because of the demand, including cut flowers (gladioli, chrysanthemum, and rose), and production was concentrated mainly in the State of Mexico, Puebla, Morelos, and Mexico City (SAGARPA, 2017).

It was also observed that flowers, in addition to their decorative use, are used to season dishes, in the pharmaceutical, gastronomic, and cosmetic industries, a situation that contributes to the increase in demand, which helps the floricultural activity to become an activity that generates higher income and more opportunities for the rural sector (Franzen *et al*., 2019).

In Nayarit, the agricultural sector has focused on producing sugarcane, beans, jicama, and tropical fruits, while flower production is almost non-existent; nevertheless, there is a constant demand for cut flowers all year round and at peak sales dates. For this reason, florists obtain the cut flowers from the leading producing states; however, due to the distance and transportation, the quality and life in the vase decrease, and the costs rise. Given this, it is necessary to promote the production of cut flowers in the state of Nayarit in order to meet the demand, offer production alternatives to the producer, and provide higher quality flowers to the consumer.

An option for this purpose is the cultivation of snapdragon (*Antirrhinum majus* L.). This crop can be grown year-round, has brightly colored flowers, and adapts to various climates. New snapdragon cultivars are constantly being put on sale, such as Red and Rose, with an intense and striking color that corresponds to group 2, 3 for summer production. This crop is rarely produced in Mexico, which is attributed to the lack of information on its cultivation and conservation, leaving it out of the main species of importance in Mexico (SIAP, 2016).

The production of ornamental plants can be carried out in hydroponics, where the formulation of the nutrient solution may be different for a particular species (Jiménez-Peña *et al*., 2019); in addition, the climate, season of the year, and other factors are also considered. Some studies with flowers where nutrient solutions with different concentrations were used are those by Jiménez-Peña *et al*. (2019) in different species of orchids in gerbera(Urbina-Sánchez *et al*., 2011), where they studied the direct effect and interactions of the factors: osmotic potential and concentration of $NH4^+$ in the nutrient solution. The objective was to compare different osmotic potentials of the nutrient solution on the growth and quality of snapdragon (*Antirrhinum majus* L.), cultivars Red and Rose, during the autumn-winter cycle in Nayarit.

Materials and methods

The research was conducted in a greenhouse with a plastic cover and anti-aphid mesh walls with a height of 5 m, in Xalisco, Nayarit. The minimum and maximum temperature was 22 and 38 °C, minimum and maximum relative humidity was 35 and 45%, and the average radiation was 462 mol m^{-2} s^{-1}. The proposed treatments were derived from the combination of the osmotic potential (OP) of the nutrient solution (Mpa) (-0.036, -0.054, -0.072, -0.090, -0.108) with two snapdragon cultivars (Red and Rose from the Monaco series, PanAmerican Seed®).

The Monaco series is tolerant of the warm autumn conditions, without flowering fast, with average stem height ranging from 99 to 152 cm (PanAmerican-Seed, 2019). Sowing was carried out on September 20, 2018, in 200-cavity expanded polystyrene trays filled with the mixture of peat moss and vermiculite (Sunshine®); one seed was placed per cavity. The trays were irrigated with Steiner's 25% solution; the volume of water was 500 to 600 ml per tray, with one to two irrigations per day, according to the growth of the seedling and the climate.

The seedling with a height of 15 cm was transplanted in black grow bags 20 x 15 cm 25 days after sowing. These contained red tezontle with a particle size of 1 to 3 mm. The plants were irrigated with Steiner's (1984) solution with the OP depending on the treatment. A leachate volume of 20% was considered; the number of irrigations varied from 1 to 3, with a volume of 300 to 400 ml, according to the climate condition and the plant's phenological stage.

Nutrient solutions with different OP were obtained by increasing nutrient concentrations adjusted, where the content of the different ions of the water was considered, which had 0.2 dS m^{-1}. Nutrient solutions were kept at pH 6 using 1N H_2SO_4 for adjustment. Magnesium sulfate®, potassium sulfate®, potassium nitrate®, calcium nitrate®, and monopotassium phosphate® were used in the preparation of the nutrient solutions. The micronutrients were supplied with the product Kelatex®, based on 3 ppm Fe in solution.

The plant was trained with a support consisting of a plastic mesh with an opening of 10 x 10 cm. Preventive control of pests and diseases was carried out with 20 x 20 cm yellow traps. The flower stems were harvested when one of the treatments had 50% open flowers, according to Larson's (2004) quality categories (Table 1).

Table 1. Quality categories in snapdragons, traits with minimum values.

Category	Fresh biomass (g)	Stem length (cm)	No. of flowers open
Special	71- 113	91	15
Sophisticated	43-70	76	12
Extra	29-42	61	9
First	14-18	46	6

Larson (2004).

Variables evaluated in the aerial and root parts

Stem length (cm), with a tape measure, from the substrate level, every ten days; the stem diameter (mm) was obtained with a Truper® vernier, 10 cm above the substrate level, every ten days; total fresh biomass (TTFB), dry leaf and stem biomass (g) (DLB, DSB), fresh material was weighed, then placed in a kraft paper bag and placed in an air-circulation oven (FE-294®) at 60 °C to constant weight, then weighed with an electronic scale (GX-2000®) at 55-57 DAT (days after transplantation); SPAD readings, they were obtained with a SPAD 502 (Minolta LTD) on three leaves of the middle part of the plant at 55-57 DAT.

Dry root biomass (g) (DRB), at the time of harvest, the fresh root (without substrate particles) was placed in a paper bag to be dried in an air-circulation oven at 60 °C to constant weight, then weighed on an electronic scale; root volume (cm^3) (RV), the fresh root was introduced into a graduated cylinder with water to record the displaced volume, based on Archimedes' principle; spike length (cm) (SL), from the base of the spike to the last closed bud, obtained with a tape measure.

Dry spike biomass (g) (DSpB), the spike was separated from the stem at the time of harvest, 55-57 DAT, and placed in a paper bag that was placed in an air-circulation oven at 60 °C to constant weight, then weighed on an electronic scale; number of flowers and buds (NF, NB), the number of flowers fully opened and the closed flower buds in the same spike were also counted; days to flowering (DF), the number of days from transplanting to the appearance of the buds on the spike with a size of 0.5 cm; days to harvest (DH), the days from transplanting to cutting the spike were counted, this was done when the first treatment presented spikes with 50% of florets and 50% of buds, approximately.

The experimental design was completely randomized with a 5 x 2 factorial arrangement. The first factor was the osmotic potential of the nutrient solution and the second factor was the cultivar, which gave rise to 10 treatments, which had 15 replications. Analysis of variance was applied to the data with the statistical program SAS version 9.0 (SAS, 2002), and the means were compared using Tukey's test ($p \leq 0.05$). The experimental unit consisted of a plant in a pot.

Results and discussion

According to the statistical analyses, no interactions were found between the osmotic potential and cultivar factors, so the results were explained only in terms of the osmotic potential factor and the cultivar factor.

Effect of osmotic potential factor

During the production cycle, stem length or plant height showed no difference ($p\leq$ 0.05) due to the osmotic potential (OP) factor on the different sampling days (Table 2). According to the literature, there was controversy with other authors since, in Peruvian lily (*Alstroemeria hybrida* L.) cv. Monalisa, Sánchez-García *et al*. (2004) found a higher height with an OP of -0.072 MPa compared to -0.092 MPa.

Table 2. Stem length of snapdragon flowers in (cm), cultivars Red and Rose, irrigated with Steiner's nutrient solution at different osmotic potentials.

Factor	DAT					
	10	20	30	40	50	55-57
OP (MPa)						
-0.036	21.14 a	33.57 a	51.35 a	68.27 a	89.97 a	109.25 a
-0.054	21.02 a	33.36 a	49.95 a	67.72 a	89.3 a	110.37 a
-0.072	20.35 a	32.36 a	49.27 a	65.82 a	87.87 a	106 a
-0.09	20.63 a	32.8 a	49.87 a	65.65 a	87.17 a	105.75 a
-0.108	20.83 a	33.83 a	50.27 a	67.65 a	86.82 a	104 a
HSD	1.32	2.16	2.94	5.04	5.56	10.14
Cultivar						
Rose	21.37 a	34.41 a	50.82 a	66.41 a	88.06 a	109.25 a
Red	20.21 b	32.02 b	49.47 b	67.64 a	88.4 a	104.9 b
HSD	0.597	0.96	1.31	2.25	2.48	4.34
CV	5	5.09	4.59	5.89	4.93	4.07

Values with the same letter are statistically equal (Tukey, $p\leq$ 0.05); DAT= days after treatment; HSD= honest significant difference; CV= coefficient of variation; OP= osmotic potential.

In tulips (*Tulipa gesneriana* L.) cv. Golden Apeldoorn, a higher plant height was obtained with the solution at -0.036 MPa, in contrast to the solutions at -0.018 MPa and -0.072 MPa (Rodríguez-Mendoza *et al*., 2011). This indicates that each species or cultivar has a different response in plant height due to the effect of osmotic potential.

In relation to the stem diameter (Table 3), it was observed that at 30 and 40 DAT, the lowest value was obtained with the osmotic potential of -0.108; nevertheless, at 50 and 55-57 DAT, the osmotic potentials of -0.072, -0.09, and -0.0108 MPa showed the smallest diameter, smaller by 6 to 7.3% on average compared to the osmotic potentials of -0.036 and -0.054 MPa. This is similar to Urbina-Sánchez *et al* (2014) results; they reported a larger stem diameter of lilies (*Lilium* spp.) with an osmotic potential of 0.24 atm (-0.024 MPa), compared to 0.48 atm (-0.048 Mpa).

Table 3. Stem diameter of snapdragon plants in (mm), cultivars Rend and Rose, irrigated with Steiner's nutrient solu tion at different osmotic potentials.

Factor	DAT					
	10	20	30	40	50	55-57
OP (MPa)						

Factor	DAT					
	10	20	30	40	50	55-57
-0.036	2.39 a	3.33 a	4.17 a	4.8 a	6.85 ab	6.85 ab
-0.054	3.58 a	3.25 a	4.17 a	4.74 a	6.98 a	6.98 a
-0.072	2.6 a	3.35 a	4.06 ab	4.68 a	6.4 b	6.4 b
-0.09	2.45 a	3.11 a	4.02 ab	4.55 ab	6.47 b	6.47 b
-0.108	2.45 a	3.34 a	3.8 b	4.3 b	6.38 b	6.38 b
HSD	2.05	0.29	0.31	0.34	0.49	0.49
Cultivar						
Rose	2.68 a	3.26 a	3.97 b	4.53 b	6.67 a	6.67 a
Red	2.71 a	3.29 a	4.12 a	4.69 a	6.56 a	6.56 a
HSD	0.91	0.13	0.14	0.15	0.22	0.22
CV	7.73	7.15	6.06	5.8	5.84	5.84

Values with the same letter are statistically equal (Tukey,$p \leq 0.05$); DAT= days after transplantation; HSD= honest significant difference; CV= coefficient of variation; OP= osmotic potential.

The lowest total fresh biomass was obtained with the osmotic potential of -0.108 MPa, followed by -0.09 and -0.072 MPa. Dry leaf biomass reached the lowest value with the OP of -0.108 MPa, smaller by 28.6 to 37.04%, while dry stem biomass was lower by 27.57 to 36.54% compared to -0.036, -0.054, -0.072, -0.09 MPa (Table 4). Rojas-Velázquez *et al*. (2013) reported that dry snapdragon leaf and stem biomass was the lowest at -0.072 MPa in the nutrient solution, compared to -0.036, -0.054, and -0.09 MPa.

Table 4. Variables of stem, leaves, and root of snapdragon plants, cultivars Red and Rose, irrigated with Steiner's nutrient solution at different osmotic potentials at 55-57 DAT.

Factor	TTFB (g)	TTDB	DLB (g)	DSB (g)	SPAD	DRB (g)	RV (ml)
OP (MPa)							
-0.036	77.61 a	21 a	4.35 a	11.45 a	66.25 b	1.6 a	7.52 ab
-0.054	76.62 a	21.43 a	4.51 a	11.61 a	66.05 b	1.65 a	9.93 a
-0.072	70.17 ab	20.02 a	4.31 a	10.7 a	67.05 ab	1.43 ab	7.19 b
-0.09	69.99 ab	19.34 ab	4.23 a	10.05 ab	68.62 a	1.39 ab	6.55 b
-0.108	57.75 b	16.86 b	3.44 b	8.41 b	68.77 a	1.14 b	6.45 b
HSD	12.75	3.13	0.72	1.92	2.34	0.32	2.6
Cultivar							
Rose	72.58 a	21.25 a	4.66 a	11.47 a	68.86 a	1.68 a	8.06 a
Red	68.28 a	18.21 b	3.68 b	9.41 b	66.58 b	1.21 b	7 a
HSD	5.45	1.34	0.3	0.82	1.04	0.13	1.11
CV	7.77	6.82	7.44	7.93	2.39	9.59	14.84

Values with the same letter are statistically equal (Tukey, $p \leq 0.05$); HSD= honest significant difference, CV= coefficient of variation; TTFB= total fresh biomass; TTDB= total dry biomass; DLB= dry leaf biomass; DSB= dry stem biomass; DRB= dry root biomass; RV= root volume; DAT= days after transplantation; OP= osmotic potential.

Nonetheless, Flores-Ruvalcaba *et al*. (2004) found that the dry stem and leaf biomass of chrysanthemum (*Dendranthema* x *grandiflora* L.) was lower with an OP of -0.018 MPa, compared to -0.027, -0.036, -0.045 MPa. From the results of stem length, stem diameter, and dry leaf and stem biomass, it was deduced that each species has a different response to the osmotic potential of the nutrient solution.

SPAD readings at 55-57 DAT recorded the highest values at -0.072, -0.09, and -0.108 MPa (Table 4). In plants of tulip cv. Golden Apeldaron, Rodríguez-Mendoza *et al*. (2011) found higher values of SPAD readings with the solution at 100% concentration (-0.072 MPa) compared to that of 50%

(-0.036 MPa). This coincided with the experiment conducted in this study, where SPAD readings were higher with higher osmotic potentials.

SPAD readings are positively correlated with chlorophyll content and, therefore, with N content in plant tissue, as shown by various reports, such as that by Fernández-Delgado *et al*. (2021). N is one of the most studied elements in plant cultivation since it increases growth; however, at specific concentrations, it decreases dry biomass, as pointed out by Castillo-González *et al*. (2018), who evaluated from 50 to 600 mg L^{-1} of N in lisianthus cv. Echo Blue (*Eustoma grandiflorum* L.) and found that in doses greater than 150 mg L^{-1} or less than 100 mg L^{-1}, the dry biomass of leaves and stem and the N content of the plant decreased.

This helps to explain the results in relation to these variables of the aerial part in snapdragon due to the higher osmotic potential, which implied a higher concentration of N. Dry root biomass obtained a lower value with osmotic potentials of -0.072, -0.09, and -0.108 MPa, between 19.7 and 21.73%, compared to -0.036 and -0.054 MPa; root volume was 34.54% lower compared to -0.054 MPa (Table 4). In snapdragons, Potomac series, cv. Rose, Rojas-Velázquez *et al*. (2013) found lower dry biomass at -0.09 MPa compared to -0.036, -0.056, -0.072, and -0.108 MPa in winter, although no difference was observed in summer.

In crops of lisianthus cv. Echo Blue, the highest dry root biomass was obtained with 250 mg L^{-1} of N and with doses higher or lower than this, the dry biomass decreased (Castillo-González *et al*., 2018). Nevertheless, in other crops, the effect of osmotic potential level on root biomass is not reported, such as Miranda-Villagómez *et al*. (2014), who reported no differences in the dry root biomass of freesia (*Freesia* x *hybrida*) plants with different concentrations of nutrient solutions at 25, 50, 75, and 100% (-0.018, -0.036, -0.054, and -0.09 MPa).

The higher biomass and root volume of snapdragons with the lowest osmotic potentials (-0.036 and -0.054 MPa) can be related to a condition of lower stress due to the lower concentration of salts, which facilitates the greater absorption of nutrients, according to Castillo-González *et al*. (2018), and can also be linked to a lower concentration of N. The lowest spike length was at -0.036 MPa, 14.7% lower compared to -0.108 MPa and 17% lower compared to -0.054 MPa (Table 5). Nevertheless, Miranda-Villagómez *et al*. (2014) reported for freesia (*Freesia* x *hybrida*) plants, longer spike length with the nutrient solution of 25% (-0.018 MPa) compared to 100% (-0.09 MPa).

Table 5. Spike variables in snapdragon plants, cultivars Red and Rose, irrigated with Steiner's nutrient solution with different osmotic potentials.

Factor	SL (cm)	DSpB	NB	NF	DF (nd)	DH (nd)
OP (MPa)						
-0.036	28 b	5.19 a	14.87 ab	20.1 b	43.57 a	55 a
-0.054	33.25 a	5.3 a	16.39 ab	20.2 b	44.46 a	55 a
-0.072	30.5 ab	5.01 a	17.12 a	17.5 b	44.28 a	57 a
-0.09	31.75 ab	5.05 a	14.75 ab	21 ab	45 a	55.5 a
-0.108	32.83 a	5.01 a	12.87 b	23.75 a	43.57 a	56 a
HSD	4.1	0.84	3.6	3.5	3.3	3.33
Cultivar						
Rose	31.93 a	5.11 a	15.8 a	17.4 b	47.64 a	59 a
Red	30.6 a	5.11 a	14.6 a	23.9 a	40.41 b	52.4 b
HSD	1.81	0.36	1.54	1.51	1.48	1.5
CV	7.6	7.1	10.19	7.34	7.04	6.5

Values with the same letter are statistically equal (Tukey, $p \leq 0.05$); HSD= Honest significant difference; C.V.= coefficient of variation; nd= number of days; SL= spike length; DSpB= dry spike biomass at harvest; NB= number of buds; NF= number of flowers; DF= days to flowering; DH= days to harvest; O.P.= osmotic potential.

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The dry biomass of snapdragon spikes was the same in all treatments ($p \leq 0.05$) (Table 5). This differed from other studies, such as that by Urbina-Sánchez *et al*. (2014), who obtained higher biomass of 'Marlon' lily inflorescences with the OP of 0.24 atm (-0.024 MPa) compared to 0.48 and 0.72 atm (-0.048 and -0.072 MPa). Rojas-Velázquez *et al*. (2013) reported that the dry biomass of snapdragon spikes was higher at -0.036 and -0.09 MPa, in contrast to -0.054, -0.072, and -0.108 MPa.

Regarding the number of buds in the spike (Table 5), in general, it was observed that it was 7.38% lower with the OP -0.108 MPa; on the other hand, the number of fully open flowers was higher with the OP of -0.108 and -0.09 MPa, which meant between 26.32 and 51.37% more compared to the OP of -0.036, -0.054, and -0.072 MPa. Fertilization or nutrition and other factors, such as water and temperature, influence the induction of flowering (Cho *et al*., 2018).

On the other hand, through photosynthesis, sugars are produced in the leaves (source) and then translocated to the demanding organs or tissues (flowers and fruits); sugars regulate various processes in the plant, such as flowering (Sami *et al*., 2016; Hyo *et al*., 2020). In the research, solutions with -0.108 and -0.09 Mpa presented higher SPAD readings, so it is inferred that this caused more open flowers.

About the above, Rojas-Velázquez *et al*. (2013) recorded the highest number of open flowers of snapdragon cv. Rose with the OP of -0.09 and -0.108 MPa, compared to those with lower osmotic potential. On the other hand, Miranda-Villagómez *et al*. (2014) reported a higher number of freesia flowers with the 25% nutrient solution (-0.018 MPa) compared to the solutions with -0.036, -0.054, and -0.072 MPa.

Concerning the days to flowering and harvest, no differences were found (*p*# 0.05) due to the effect of osmotic potential. Flores-Ruvalcaba *et al*. (2004) indicated a reduction in the number of days to harvest in chrysanthemum cv. Polaris White as the OP increased, where 0.045 MPa obtained the lowest number of days to harvest in contrast to the OP of 0.018 MPa. From the above, it was deduced that some species are more sensitive than others to osmotic potential, which affects their production cycle.

According to Larson (2004), the quality characteristics of snapdragons to be classified into one of the categories include between 6 and 15 open flowers, stem length between 46 and 91 cm, and fresh biomass between 14 and 113 g. Based on the total fresh biomass, the special category was reached with the OP of -0.036 and -0.054 Mpa, while at a more negative OP, the plants reached the category of sufficient (Table 1).

Effect of cultivar factor

The Rose cultivar recorded the highest value at harvest in the variables of plant height, dry leaf biomass, dry stem biomass, days to flowering, days to harvest, and SPAD readings, while the Red cultivar had a higher number of fully opened florets (Table 2, 3, 4, 5). The differences in the variables between cultivars are attributed to the genotype; Rodríguez-González *et al*. (2011) mention that the genotype-by-environment interaction is significant, so the genotype behaves differently according to the environment.

Therefore, the study of materials contributes to the choice of a certain place and condition. Vásquez *et al*. (2021) evaluated eight varieties of sunflower (*Helianthus annuus* L.) in two cycles, August-November 2020 and December-March 2021, and they observed heterogeneous morphology in the first cycle, while, in the second cycle, they found significant differences in their morphological behavior, which evidenced the effect of the environment on the expression of the phenotype; in both cycles, the Moonwalk variety was the one with the highest germinative earliness and the shortest time to physiological maturity.

Purbiati and Santoso (2007) reported differences among 10 varieties of rose bushes (*Rosa hybrida* L.) that were grown in the same environment, where the 'Pergiwo' rose bush obtained the highest value in height compared to 'Pergiwati'; they also observed greater dry biomass of leaves and stem

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in poinsettia (*Euphorbia pulcherrima* W.) 'Rehilete' compared to 'Valenciana' (Galindo-García *et al*., 2015).

No differences were found in spike length (*p*# 0.05) between cultivars, nor in the number of buds (Table 5). Miranda *et al*. (2007) reported that snapdragon spike length was longer in the Maryland Yosemite Pink cultivar compared to White/Ivory; the number of flowers was also higher in Maryland Yosemite Pink compared to Maryland Flamingo. Therefore, the present study does not agree with the authors in the referred variables since they found differences between cultivars.

At harvest, the Rose cultivar yielded higher dry root biomass compared to the Red cultivar. Galindo-García *et al*. (2015) reported higher dry root biomass of 'Rehilete' poinsettia in contrast to 'Valencia', which is similar to the present research. In general, the introduction of new cultivars as well as new varieties to a region opens the door to greater commercialization, as well as an adaptation of new species, so it is important to study their behavior and agronomic management (Cruz-Castillo and Torres-Lima, 2017).

As Miranda *et al*. (2007); Reyes-Montero *et al*. (2009) found differences in the different snapdragon varieties; this is due to the groups to which they belong, where each group manifests optimal development in different conditions of climate, solar radiation, temperature, and daylight hours.

Comparison of different variables evaluated in snapdragons according to specifications

According to the technical data sheet of PanAmerican-Seed (2019), the stem length of the cut snapdragon should be in a range of 99 to 152 cm, and the harvest time should be from 56 to 126 days maximum; the plant height in the present work was between 100 and 110 cm and the harvest time was between 87 to 94 days at harvest.

Table 1 shows the minimum characteristics for that snapdragon quality category. According to this, the Rose cultivar (72.58 g, length of 109.25 cm, and 17.4 florets) reached the special category; the Red cultivar obtained good height, with 68.28 g, 104.9 cm, and 23.9 florets and was placed in the sophisticated category. For this reason, it is recommended to conduct further research, particularly for the snapdragon flower of the Red cultivar, in order to achieve the special category.

Conclusions

The osmotic potentials of -0.036 and -0.054 MPa are the most suitable for the Rose and Red snapdragon cultivars since the highest growth and quality were obtained under the research conditions. The osmotic potentials of -0.09 and -0.108 Mpa increased the number of open flowers. The Rose cultivar showed higher growth than the Red cultivar and was classified with the special category; the Red cultivar was earlier for harvest and fell into the sophisticated category.

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