Journal of Ornamental Plants
*Available online on: www.jornamental.iaurasht.ac.ir*
*ISSN (Print): 2251-6433 ISSN (Online): 2251-6441*
*Research Paper*

# Study of *Aloysia citrodora* Growth as an Ornamental-Medicinal Plant in Substrates Containing Natural and Synthetic Superabsorbents

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Received: 10 March 2020 Accepted: 28 March 2020
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Abstract

In this study, we investigated the effects of organic waste and moisture superabsorbent on the amount of available water and delay in moisture equivalent of permanent wilting point (PWP) in soil. In the first phase (soil incubation phase), 12 treatments were studied in a completely randomized design at the Soil Science Laboratory of Science and Research Branch, Tehran. The treatments consisted of 5 and 10% compost (mixture of municipale waste compost and cow manure); 5, 15 and 30 g/kg soil of zeolite and 2, 4 and 8 g/kg soil of moisture superabsorbents (A200). In the second phase (greenhouse phase), three treatments with the highest delay in permanent wilting point with a control treatment were selected as planting media and in a factorial experiment based on randomized complete block design, we studied the effect of planting substrate (four substrates) and irrigation period at three levels (48, 72 and 120 hours) on Aloysia citrodora growth. The results showed that the highest amount of FC moisture equivalent was related to the treatment with 8 g superabsorbent per kg soil. The highest delay in the permanent wilting point was for 8 g superabsorbent per kg of soil with a delay of 682 h. The highest total fresh weight of plant was observed in the treatment of 10 g of zeolite per kg of soil and 48 hours irrigation round with a mean of 9.47 g. In the superabsorbent treatment, leaf dry weight was higher than the control in 3 irrigation rounds. In general, the results showed that the addition of superabsorbent to the soil by delaying the plant's wilting point could save water use by increasing irrigation rounds.

**Keywords:** Field capacity, Moisture curve, Municipale waste compost, Permanent wilting point.

## INTRODUCTION

Drought is considered as one of the most important factors in reducing agricultural production potential (Jazaeri Nushabadi and Rezaei, 2007). Developing drought-tolerant cultivars can be beneficial in such areas. Reducing water loss and increasing irrigation efficiency has always been a concern of researchers and agricultural experts (Tommasini *et al*., 2008). Management practices and applying advanced techniques for conserving soil moisture is an appropriate way to exploit water resources (Haghighat *et al*., 2017). One of the ways for agricultural researchers is to use soil ammendments and additives materials. Some materials, such as plant residues, manure, compost, and superabsorbent polymer hydrogels can store different amounts of water and increase the ability to absorb, retain, and store water in the soil. The water stored in these materials is released into the soil at times of water shortage and used by the root of the plant (Chatzopoulos *et al*., 2000).

The application of superabsorbent polymers can increase the amount of water holding capaciy in the soil, and at times of drought, supply the need water to plant (El-Hady and Wanas, 2006; Mohammadi Torkashvand and Shadparvar, 2013). In terms of structure, polymers are synthetic organic compounds that are synthetically produced and made of potassium polyacrylate and polyacrylamide copolymers and able to rapidly absorb and store water up to several times their volume in contact with water and increase water holding capaciy in the soil and finally promote plant growth by reducing drought stress. These materials are odorless, colorless and free of polluting soil, water, and plant tissue (Roshan, 2002). Studies by the German Environment Agency and other countries have shown that the use of these materials has no harm to humans, plants, soil and the environment. The use of this polymer can increase the irrigation round. These materials, when mixed with granular substrates used in non-soil systems, can improve the physical texture of the substrate and increase water holding capacity (Ganji Khoramdel, 2002; Akhter *et al*., 2004; AL-Harbi *et al*., 1999; Guilherme *et al*., 2015), increase in root access to water and nutrients (El-Hady and Wanas, 2006), reduction in drought stress (Arbona *et al*., 2005) and yield per unit water and fertilizer. Hence, they can improve plant water and nutrient use efficiency (Behbahani *et al*., 2005; Anupama *et al*., 2005; El-Hady and Wanas, 2006; Syvertsen and Dunlop, 2004).

Manure is another soil additive that increases soil moisture storage capacity and improves soil granularity and physical properties, while increasing soil fertility and crop yield, thus improving water use efficiency (Guilherme *et al*., 2015; Mohammadi Torkashvand *et al*., 2015a).

Both organic and chemical fertilizers are needed in order to provide suitable conditions for plant growth. The traditional organic fertilizers, in addition to having no adverse effect, increase soil humus and maintain it at a suitable level. The organic fertilizers with producing humus reduce adverse effects of chemical fertilizers and increase the efficiency of fertilizer use (Shata *et al*., 2007). The organic matter increases the amount of nutrients needed by plants including phosphorus, potassium, iron, zinc and copper in the soil and increases the ability of some nutrients to be available by the plant (Bresso *et al*., 2001; Soumare *et al*., 2002).

Zeolites are among the most important amendments. Adding zeolite to soil is one of the effective ways to reduce the effects of water shortage on crop production (Gholizadeh *et al*., 2010). Zeolites are aluminosilicates that, in addition to having the ability for moisture storage (Khashei Suiki and Ahmadee, 2015; Kazemian, 2004), provide nutrients to improve plant growth (Ahmadee *et al*., 2014; Shiranrad *et al*., 2011). On the one hand, the abundance of zeolite resources in Iran has made it widely used in agriculture (Khashei Suiki and Ahmadee, 2015).

Paradlo *et al*. (2009) investigated the effect of grape pulp compost and vermicompost on soil physical properties at 4, 8 and 16% of dry soil weight during an incubation experiment. They concluded that the organic matter resulted in a significant increase in soil strength, soil water holding capacity and aggregate size. Camberato *et al*. (2006) used organic waste in paper industry to improve soil physical properties and fertility and found that its use results in increased soil organic matter, agglomeration, water storage capacity and CEC. In an experiment, 6 superabsorbents of zero, 1, 2, 3, 4 and 5 g/kg soil and four irrigation rounds with 10, 14, 18 and 22 days were applied on forage maize SKC 704 cultivar under greenhouse conditions. According to the results, the application of superabsorbent had a positive effect on the traits such as plant height and dry matter accumulation and with increasing irrigation rounds, the effect of superabsorbent and its higher values was more significant (Allah Dadi, 2002). Karimi *et al*. (2012) studied yield and yield components of sunflower under drought stress with the application of zeolite and recommended the use of zeolite to enhance the yield of this plant.

*Aloysia citrodora* is a shrub 1.5–2 m height, long, angular and branched, with simple, coarse, full leaves, apex, and complex with 3-4 bright green leaves. Since there is a great potential for producing *Aloysia citrodora* seedlings in the country, rapid growth and development of its cultivated area can lead to an economic development in the medicinal-ornamental plant industry. The purpose of this study is to determine a culture medium with adequate water storage potential for the growth of *Aloysia citrodora*.

## MATERIALS AND METHODS

### Incubation phase

The soil of an area of Khomein, Iran, with light texture was selected and transferred to laboratory. The soil was spread in laboratory media and after drying, it was passed through a 2 mm sieve and prepared for testing. Hydrometric method was used to measure soil texture (Page, 1986). The municipalmunicipal waste compost was prepared from Isfahan municipal waste recycling plant. The synthetic superabsorbent used in this study is Stocosorp $A_{200}$.

At the first stage, an incubation experiment was performed to investigate the delay in moisture coefficient of permanent wilting and the amount of water available to the soil. The experiment was performed in a completely randomized design with 9 treatments, 3 replications and a total of 27 soil samples. The treatments applied at incubation stage were:

1. Control;
2. Zeolite 5, 15 and 30 g/kg soil;
3. Equal mixture of municipalmunicipal waste compost and cowmanure compost at 5 and 10% (Weight);
4. Use $A_{200}$ superabsorbent 2, 4 and 8 g/kg soil.

Hamblin (1981) filter paper and empirical equation were used to determine the moisture equivalent of field capacity and permanent wilt (Abdollahian Noghabi and Baradaran, 2002). After determining moisture coefficients of field capacity and permanent wilting point, the amount of water available and delayed at the permanent wilting point, top superabsorbent and zeolite treatment and an organic treatment were compared to the control in a greenhouse experiment to study irrigation rounds.

### Determination of moisture equivalent to field capacity and permanent wilting point

The most important parameter measured in the experiment was determining the moisture content of treatments at field capacity (FC) and permanent wilting point (PWP), which is required to determine soilmatric potential ($\varphi_m$). The direct measurement of soil moisture characteristic curve is costly and time consuming and requires special laboratory equipment. For this reason, in recent years, many efforts have been made to estimate it accurately with acceptable soil properties without the need for direct measurement (Khodaverdilo and Homaei, 2002). Currently, in order to determine the soil moisture curve, pressure plate method is common. Although, this method is accurate, it requires expensive equipment, it is only used in well-equipped soil and irrigation laboratories. Filter paper method is a simple, inexpensive, and practical method, even for large samples (Hamblin, 1981). In order to determine the soil moisture curve with the filter paper method, a precision scale with 0.001 g accuracy, Whatman No. 42 filter paper and oven at 100°C are required. The basis of this work is that in soil samples with the same weight (about 100 g soil passed through 2 mm sieve), different and distinct amounts of distilled water are added and soil moisture samples with a permissible surface area are allowed to contact Wattman No. 42 filter paper for 48 hours to achieve a moisture balance (Abdollahian and Noghabi, 2002). In this case the matrix potential of the wet soil sample (soil suction) is equivalent to matric potential of filter paper. Therefore, if matric potential of filter paper is estimated using Hamblin (1981) empirical equation according to equation (1), matric potential of the wet soil sample will be obtained.

$$Ln = (10\ \varphi_m) = -\ 2.397 - 3.683\ Ln\ (F/100) \qquad (1)$$

So, in this equation:
$\varphi_m$ = Filter paper matric potential in $m_{pa}$;
F = Weight moisture content of filter paper.

In order to obtain the soil moisture curve, about 2 kg of each treatment was taken and dried after passing through 2 mm sieve inside an oven at 105°C. 100 g of soil was weighed and 5, 7.5, 10, 12.5, 15, 17.5, 20, 22.5, 25, 27.5 and 30 ml of water was added to each 100 g soil, respectively. The soil was thoroughly mixed with water so that moisture distribution in the soil was completely uniform. The special metal containers were used to place the soil and filter paper. In each container, we placed 3 filter papers weighing exactly 0.001 g so that each filter paper was between two layers of soil. After 48 hours, wet filter paper was removed from the metal container and weighed accurately using a scale. Weight moisture content of filter paper was calculated and $\varphi_m$ was calculated using equation (1). By obtaining and expressing $\varphi_m$ in bar, moisture content of treatments at suction was 0.3 and 15 bar (FC and PWP equivalent, respectively).

**Time to moisture equivalent of permanent wilting point**

With having FC moisture equivalent and wilting point moisture equivalent, all treatments were followed carefully to reach the wilting point. After saturating the soil, moisture content for the first, second and third observations was reduced every 12 hours, approaching moisture equivalent to the wilting point of the moisture measurement intervals, to obtain the exact time to reach PWP in hours. Thus, saturation time of the soils until the moisture equivalent of PWP was calculated. A delay in permanent wilting point was obtained from the difference between treatment time to the permanent wilting point and the same time in the control treatment.

**Greenhouse phase**

In May 2017, after preparing a plant sample from Mahalat Flower and Plant Research Center, cuttings were prepared from Aloysia citrodoraand transplanted in pots of size 4 with a weight of 2.5 kg soil. After soil incubation and studying soil physical properties, 4 treatments out of 9 treatments were selected based on the maximum time to reach wilting point and used for planting. The treatments include:

1. Soil (control);
2. 80% soil + 20% cow manure and municipal waste compost;
3. 10 g of zeolite per kg of soil (25 g per pot);
4. 3 g of superabsorbent per kg soil (7.5 g per pot).

For irrigation of the plant, irrigation water was used by spraying with one liter per pot at each irrigation round.

Irrigation periods include:

1. 48 hours;
2. 72 hours;
3. 120 hours.

The greenhouse phase was carried out in a factorial experiment based on randomized complete block design with two factors of planting (4 treatments) and irrigation (3 rounds) with 3 replications and a total of 36 pots.

After harvesting the pots, plant fresh weight, leaf dry weight, root fresh weight and the number of lateral branches were measured by a digital scale.

In order to measure nutrients, 0.9 g of salicylic acid was dissolved in 30 ml of water and gently 150 cc of concentrated sulfuric acid (96%) was added. After acids mixture was prepared, the leaves and stems of the plant were thoroughly powdered in the mill, then 0.3 g of each sample was poured into a 50 ml balloon and 3 ml of acids mixture was added to it. This solution was kept for two days to make it digestible and black in color. After two days, 6 drops of 30% oxygenated water were added to each sample. The solutions obtained from each sample were heated by shof balloon and, upon observation, removed the first boiling solution and waited for it to cool. We added 6 drops of 30% oxygenated water again and boiled the solution. This was repeated until the solution turned pale yellow. The solution of each sample was then reached 50 ml volume by distilled water, then passed through Wattman No. 42 filter paper and kept in plastic containers with a lid as a plant extract. Atomic absorption device of Razi Laboratory of Azad University of Science and Research Branch was used to measure iron and zinc.

The data were analyzed using software MSTATC and SAS, Duncan test was used for the mean comparison and diagrams were plotted using software Excel.

## RESULTS AND DISCUSSION

### Analysis of data variance

Table of data analysis of variance (Table 1) shows that incorporation of different amounts of organic waste and superabsorbent in soil on soil physical properties including FC moisture equivalent content, permanent wilting point, available water percentage, and time to permanent wilting point was significant at 1% level.

Table of variance analysis of plant traits (Table 2) shows that total plant fresh weight, leaf fresh weight, leaf dry weight, root fresh weight, Fe and Zn affected by planting substrate were significant at 1% level. Also, all traits were significant at 1% level under irrigation rounds. The interaction between planting substrate and irrigation round was significant at 1% level for all traits.

Table 1. Results of analysis of variance of data on effects of treatments on soil physical properties.

| S.o.V | df | MS | | | |
|---|---|---|---|---|---|
| | | Percentage of moisture equivalent FC | moisture equivalent of permanent wilting point | Percentage of available water | Time to permanent wilting point |
| Treatment | 11 | 38.9** | 24.6** | 18.2** | 528.4** |
| Error | 22 | 0.21 | 1.1 | 0.08 | 2.1 |
| CV | | 16.2 | 8.1 | 9.6 | 12.3 |

*, ** and $^{ns}$: Significant at $P < 0.05$, $P < 0.01$ and insignificant, respectively.

Table 2. Analysis of variance of traits of *Aloysia citrodora* and amount of Fe and Zn affected by irrigation and planting substrate.

| S.o.V | df | MS | | | | | |
|---|---|---|---|---|---|---|---|
| | | Total fresh weight of plant | Leaf fresh weight | Leaf dry weight | Root fresh weight | Fe | Zn |
| Substrate | 3 | 17.4** | 32.69** | 1.97** | 0.19** | 18582** | 73.8** |
| Irrigation round | 2 | 13.59** | 2.86** | 0.16** | 0.61** | 61591** | 71.0** |
| Substrate×Irrigation | 6 | 10.65** | 0.85** | 0.05** | 0.09** | 7015** | 159.9** |
| Error | 24 | 0.63 | 0.15 | 0.01 | 0.01 | 108 | 28.2 |
| CV | | 7.5 | 18.6 | 15.2 | 14.9 | 7.8 | 10.4 |

*, ** and $^{ns}$: Significant at $P < 0.05$, $P < 0.01$ and insignificant, respectively.

Table 3. Effects of treatments on moisture equivalent of field capacity (FC) and permanent wilting point (PWP) and available moisture and time to reach permanent wilting point.

| | Treatment | | Moisture equivalent of field capacity (FC) (%) | Moisture equivalent of permanent wilting point (PWP) (%) | Available moisture (%) | Time to reach permanent wilting point (hrs) |
|---|---|---|---|---|---|---|
| 1 | Control | | 20.5 a | 13.1 cd | 7.4 c | 140 d |
| 2 | Zeolite g/kg soil | 5 | 22.0 bc | 13.4 bcd | 8.6 cd | 152 cd |
| 3 | | 15 | 23.4 b | 13.6 bcd | 9.8 bc | 212 bc |
| 4 | | 30 | 25.6 ab | 13.6 bcd | 12.0 ab | 260 bc |
| 5 | Compost (%) | 5 | 25.1 ab | 15.0 ab | 10.1 bc | 286 bc |
| 6 | | 10 | 26.8 a | 14.8 abc | 12.0 ab | 304 b |
| 7 | Superabsorbent $A_{200}$(g/kg soil) | 2 | 22.4 b | 13.8 bc | 8.6 cd | 175 c |
| 8 | | 4 | 25.5 ab | 13.6 bcd | 11.9 abc | 364 b |
| 9 | | 8 | 27.2 a | 14.2 abc | 13.0 a | 682 a |

## Incubation phase

### The effect of treatments on FC and PWP

Table 3 shows that the highest content of FC moisture equivalent was related to the superabsorbent treatment of 8 g/kg soil with 27.2% moisture content. The treatment of 10% municipal waste compost and cow manure and the treatment of 30 g zeolite per kg soil with 26.8 and 25.6% FC moisture content showed the highest values after treatment No. 9, respectively.

The use of municipal waste compost increased FC moisture equivalent compared to the control. Municipal waste compost treatments (treatments 5 and 6) increased FC moisture equivalent content with increasing the percentage of waste so that in this group treatment 5, with 5% waste compost, had the lowest FC and treatment 6 with 10% waste compost showed the highest FC. Increasing different amounts of zeolite increased FC moisture equivalent compared to the control. In the group of zeolite treatments (treatments 2, 3 and 4), FC content increased with increasing percentage of zeolite. The use of superabsorbents had a significant effect on all treatments compared to the control. Increasing the amount of superabsorbent increased FC moisture equivalent content so that among the treatments of this group, treatment 7 (2 g superabsorbent / kg soil) and treatment 9 (8 g superabsorbent / kg soil) had the highest FC moisture equivalent content.

Treatment 2 (5 g zeolite per kg soil) had the highest amount of PWP moisture equivalent. The increase in moisture content of FC and PWP in soils after application of amendments is due to the increase in organic carbon content and the formation of gels resulting from decomposition of organic residue and microbial secretion. This is consistent with Emerson (1995). Emerson (1995) reported that with increasing organic matter in grassland, moisture content in FC and PWP increased. They stated that regardless of the amount of clay, as the amount of organic carbon increased, moisture storage capacity of the gels formed by the decomposition of organic residue and microbial secretion increased. It seems that in addition to organic carbon, particle size distribution, pore size distribution, and aggregate size distribution also increased FC and PWP moisture equivalent content in soils that is consistent with Wu *et al.* (1990).

**The effect of treatments on available water**

Table 3 shows that the highest amount of water available was for treatment 9 (8 g superabsorb / kg soil) with 13% moisture followed by treatment 4 (30 g zeolite per kg soil) with 12% moisture, treatment 6 (10% municipal waste compost) with 12% moisture and treatment 8 (4 g superabsorbent per kg soil) with 11.9% moisture. In the group of zeolite treatments (treatments 2, 3 and 4), increasing the amount of zeolite increased available moisture content. In the group of municipal waste compost treatments (treatments 5 and 6), available water content increased with increasing the percentage of municipal waste compost. In the superabsorbent group (treatments 7, 8 and 9), available moisture content increased as the amount of superabsorbent increased.

The ability of superabsorbents to absorb water increased available water content. The increase in water content available through the use of superabsorbents is also consistent with Akhter *et al.* (2004) and Patil *et al*. (2011). The effect of hydrogel (superabsorbent) on water storage in sandy and sand loam soils and its effect on barley, wheat and chickpea growth were investigated by Akhter et al. (2004) in Pakistan. The results showed that water storage capacity increased linearly (R = 0.988) with increasing 0.1, 0.2 and 0.3% hydrogel to soil. In a long-term experiment (28 years), Morlat and Chaussod (2008) investigated the effect of various organic amendment on the chemical, physical, and biological properties of sandy soil. The effects of annual application of pruned and crushed vineyard shoots (2 ton / ha fresh weight), cow manure (10 and 20 ton / ha fresh weight) and crushed mushroom compost (8 and 16 ton/ha fresh weight) compared to the control were examined. The results showed that water storage capacity increased and bulk density reduced.

**The effect of treatments on time to permanent wilting point (PWP)**

Table 3 shows that all treatments had a significant difference with the control treatment. The maximum time to permanent wilting point (PWP) was for treatments 9 (8 g superabsorbent / kg soil), 8 (4 g superabsorbent / kg soil) and 6 (10% waste compost) with values of 682, 364 and 304 hours, respectively. In all groups of treatments (zeolite, municipal waste compost, and superabsorbent), time to permanent wilting point (PWP) increased with increasing values.

The organic waste increased the amount of water available and reduce the time to wilting point by reducing evaporation and increasing water holding capacity. This is consistent with Ebrahimi *et al*. (2003), Reddy and Reddy (1998). The superabsorbent polymers, because of their ability to absorb high amounts of water, act as small water tanks and can make water available for plants and delay the wilting point. This is consistent with the theory of many researchers. Gehring and Lewis (1980) investigated the effect of Vitra hydrogel (a superabsorbent) and pot size on wilt and moisture stress of *Zinnia elegans* and *Petroselinum crispum*. The results showed that increasing the amount of hydrogel delayed the time to wilting point. Wang and Gregg (1990) in a study investigated the effect of hydrogel on the growth and wilt of three ornamental plants. The results showed that hydrogel had no beneficial effect on plant growth but increased the time required to reach the wilting point by three days. Haghighat *et al*. (2017) showed hat the most significant delays in PWP coefficient (at 1% level) in 50% municipal wastes compost and 16 g/kg superabsorbent respectively with a delay of 19 and 30 days were obtained.

## Greenhouse phase

According to data of interaction between irrigation round and planting substrate (Table 4), the highest total fresh weight of plant was observed in treatment 3 (10 g zeolite per kg soil) and 48 hours irrigation round with a mean of 9.47. The superabsorbent treatment increased total fresh weight of the plant by increasing the irrigation round from 48 hours to 120 hours and was equivalent to 48 hours irrigation roundat 120 hours. It is expected that with increasing irrigation round to 10-12 days (240-288 h) superiority of the superabsorbent treatment becomes more significant.

Table 4. Mean interaction of irrigation round and planting substrate on growth and uptake of iron and zinc.

| No. | Planting Substrate composition | Irrigation (h) | Plant total fresh weight | Leaf fresh weight | Leaf dry weight | Root fresh weight | The number of sub-branches | Iron | Zic |
|---|---|---|---|---|---|---|---|---|---|
| | | | (g) | | | | | (mg per pot) | |
| 1 | Soil (control) | 48 | 4.67 cd | 0.74 de | 0.20 c | 0.49 c | 3 c | 270 b | 68 a |
| | | 72 | 6.48 bc | 1.17 cd | 0.32 bc | 0.60 bc | 7 ab | 281 b | 55 abc |
| | | 120 | 5.97 cd | 0.58 cde | 0.17 c | 0.39 cd | 7 ab | 257 bc | 55 abc |
| 2 | 80% soil + 20% cow manure and municipal waste compost | 48 | 7.66 b | 1.13 cd | 0.31 bc | 0.80 b | 8 a | 184 d | 47 bc |
| | | 72 | 6.15 bc | 1.04 cde | 0.28 bc | 0.53 c | 5 b | 164 d | 56 abc |
| | | 120 | 3.14 e | 0.27 e | 0.08 d | 0.17 d | 8 a | 154 de | 53 bc |
| 3 | 20 grams of zeolite per kilogram of soil | 48 | 9.47 a | 1.5 cd | 0.41 b | 1.23 a | 4 bc | 351 a | 66 a |
| | | 72 | 5.87 cd | 0.96 de | 0.27 bc | 0.70 b | 6 ab | 292 b | 55 abc |
| | | 120 | 4.24 cde | 0.63 de | 0.19 c | 0.48 c | 4 bc | 236 c | 46 bc |
| 4 | 3 g of superabsorbent per kg of soil | 48 | 9.34 a | 4.31 a | 1.05 ab | 0.77 b | 6 ab | 254 bc | 51 bc |
| | | 72 | 7.03 bc | 5.98 a | 1.50 a | 0.42 c | 5 b | 277 b | 58 ab |
| | | 120 | 9.44 a | 3.8 ab | 1.00 ab | 0.44 c | 5 b | 112 e | 57 ab |

Regarding leaf fresh weight, in all irrigation rounds, this trait was higher in superabsorbent treatment than control treatment. In treatment 2 (20% cow manure and municipal waste compost) at 48 h irrigation round, leaf fresh weight with a mean of 1.13 g was higher than the control treatment with this irrigation round. In treatment 3 (10 g zeolite per kg soil) at 48 and 120 h irrigation rounds, leaf fresh weight was higher than the control treatment. Regarding leaf dry weight, the interaction between irrigation round and planting substrate was significant. In the superabsorbent treatment, leaf dry weight was higher than control. The highest root fresh weight was for zeolite treatment and irrigation round of 48 hours. Results of Mohammadi Torkashvand *et al*. (2016) showed that the greatest weight of shoot dry matter of *Lysimachia nummularia* cv. Aurea was obtained in 30% municipal waste compost treatment and rice wastes treatment in 36 hours irrigation period, but at 168 hours period, dry matter decreased and the greatest dry matter was obtained from superabsorbent treatment.

The mean number of sub-branches shows that the highest number of sub-branches was related to treatment 2 (20% cow manure and municipal waste compost) at 48 and 120 hours irrigation rounds with a mean of 8. The highest iron content was for treatment 2 (20% cow manure and municipal waste compost) and irrigation round of 72 hours with a mean of 292.3. The study results show that adding superabsorbent to soil by delaying plant wilting point can save water by increasing irrigation round.

The interaction between irrigation round and planting substrate had a significant difference with the control treatment in most of measured traits. At 120 h irrigation round, the superabsorbent treatment played a significant role in comparison with the other irrigation rounds and control treatment, but it seems that water stress with irrigation round of up to 120 h is not sufficient to observe the effect of superabsorbent polymers on plant growth. So, according to the study results, irrigation round can be extended to more than one week (10-12 days). *Aloysia citrodora* is irrigated once every 2 days in the greenhouse. The use of superabsorbent polymers with increasing irrigation rounds can reduce costs and increase water use efficiency. In general, considering the economic conditions, application of 3 g of superabsorbent polymer per kg soil with 10-12 days irrigation round can be recommended for *Aloysia citrodora*. In this case, it is expected to produce higher quality plants compared to the control during the irrigation round of 10-12 days.

Jandaghian (1996) in a study using polyacrylamide superabsorbent in Philodendron culture medium showed that by increasing the amount of superabsorbent from zero to 50% volume, plant height, the number of leaves, leaf surface area, fresh and dry weight of shoot and fresh and dry weight of root increased.

Regarding treatments containing municipal waste compost, treatment 2 (70% soil + 30% municipal waste compost) and treatment 3 (70% soil + 20% manure + 30% municipal waste compost) significantly increased dry weight and the number of knots compared to the control. This increase can be due to the increase in organic matter and the provision of adequate nutrients in the soil and, on the other hand, the improvement of water storage capacity and soil physical properties (Almasian *et al*., 2006; Mohammadi Torkashvand *et al*., 2015a and b; Ashoorzadeh *et al*., 2016). Moldes *et al*. (2007) reported that municipal waste compost can provide all macro nutrients needed for plant growth and thereby improve plant yield.

As the irrigation rounds increased, the level of growth traits reduced. Under moisture stress conditions, leaf water reduced and water relationships change before ionic changes (Munns and James, 2003). The plants show tolerance to stress conditions by reducing osmotic potential and making inorganic and organic solutions in the cell, which is called osmotic regulation. Under these conditions, water and osmotic potential of the plant become more negative and pressure potential increases due to the absorption of water under increasing salt conditions (Rivelli *et al*., 2002).

Closure of stomata is a response to mechanism stress to reduce water loss from plant tissues (Paranychianakis and Chartzoulakis, 2005; Tardieu, 2005), but if this persists for a long time, may due to a reduction in carbon dioxide fixation, the rate of photosynthesis is greatly reduced (Tardieu, 2005). The reduction in photosynthesis results in a reduction in plant growth. Stress reduces longitudinal growth and is directly related to water potential. Growth occurs only under conditions of water availability and potential. The study results show that adding superabsorbent to soil by delaying plant wilting point can save water use by increasing irrigation rounds. In this study, by adding superabsorbent to soil, most of the measured criteria were increased, which is consistent with the results of Jandaghian (1996), Huttermann *et al.* (1999), Martinez *et al*. (2001), Mohammadi Torkashvand *et al*. (2012) and Mohammadi Torkashvand and Shadparvar (2013) in different plants.

According to the results, it is recommended to use moisture absorbers as a mixture to increase soil water storage capacity and delay in permanent wilting point. The interaction of 3 g of superabsorbent and irrigation round of more than 10 days (more than 240 hours) should be studied on growth factors of *Aloysia citrodora* and the effect of superabsorbent, irrigation round and salinity stress on growth factors of *Aloysia citrodora*.

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**How to cite this article:**

Marashi, M., Ghasedi, S. and Seyed Nasir, S. 2020. Study of *Aloysia citrodora* Growth as an Ornamental-Medicinal Plant in Substrates Containing Natural and Synthetic Superabsorbents. *Journal of Ornamental Plants,*10(2), 121-133.

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