EFFECT OF SODIUM POLYACRYLATE ON GROWTH AND FLOWER PRODUCTION OF PETUNIA UNDER WATER STRESS CONDITION

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Abstract: Water stress is considered as one of the most important abiotic factors that adversely affect flowers morphology and quality flower production, through altering the growth, physiology and metabolic activities of plants. In order to overcome the adverse effect of water stress, an experiment was designed to assess individual and combine effect of sodium polyacrylate (SP_0 (soil without sodium polyacrylate, SP_1 (90% soil + 10% sodium polyacrylate), SP_2 (70% soil + 30% sodium polyacrylate) and SP_3 (50% soil + 50% sodium polyacrylate)) and irrigation interval i.e. W_0 (half day), W_1 (1day interval), W_2 (2 days interval) and W_3 (3 days interval) on growth and flowering related attributes of petunia at Ornamental Horticulture Nursery, The University of Agriculture, Peshawar in February 2019.The results indicated that use of (30% of sodium polyacrylate + 70% soil) significantly reduced days to flowering and increased number of flowers and size of flower. Moreover, highest number of leaves, number of branches, taller plant, highest value of root length and root volume were recorded in the plants planted in soil supplemented with (10% sodium polyacrylate + 90% soil). The irrigation interval after 3 days produced earlier flowering, increased the number of flowers and size of flower. Similarly, numbers of leaves plant-1, number of branches plant-1, plant height, root length, root volume were enhanced in petunia plants irrigated with 2 days interval. The interactive effect of sodium polyacrylate also significant effect morphological and flower related attributes of petunia. Based on the results, it was concluded that SP_2 (70% soil + 30% sodium polyacrylate) with irrigation interval of 3 days for reproductive attributes of petunia and for vegetative growth SP_1 (90% soil + 10% sodium polyacrylate), with 2 days of irrigation interval is recommended.

Keywords: Abiotic stress, Sodium polyacrylate, Hydrogels, Water Holding Capacity, Percolation

INTRODUCTION

Changing climatic patterns and high demand of water for industrial and domestic use, there is pressure to minimize water application to ornamental plants by local authorities (Arnell, 1998). With increase in the population of world, the increase in efficiency of agricultural water use is very critical for generation in future. Innovation in science and technology is very important for planning and managing the problems regarding water storage globally (Howell, 2001).On the other hand abiotic stress known to be the most important limiting environmental factor for plant growth is drought stress (Boyer, 1982). Bedding plants are a popular feature in the urban landscape, being widely used in public parks, town centers, and private gardens (as planted plants but also in containers and hanging baskets). In light of changing climatic patterns and a greater demand for water for domestic and industrial use (Arnell, 1998), there is pressure on local authorities to minimize irrigation applied to ornamental plants. As a consequence, bedding plants are being replaced in many landscapes by more xerophytic but often less colorful species, many of which rely on foliage rather than flowers for their display (Franco et al., 2006). Without a doubt, water deficit stress is one of the leading limitations to photosynthesis and plant primary productivity (Elshibli et al., 2016). For that reason, the prompt and timely evaluation of water status in plants through the use of physiological plant measurement sensors (i.e. canopy temperature/reflectance, sap flow, stem variation) has proven useful in irrigation control (Seelig et al., 2009).

Water is an important component for plant production and growth, water is available in soil but leach down due to percolation depends on soil types. By reducing percolation of water and more water availability for plant roots could be achieved by adding some polymers. According to a study, the application of polymer (polyacrylic acid) enhances soil water stable aggregate content by 17.27% averagely, density reduced by 11.18%, and soil water holding capacity increased by 2.8 times (Feng, 2006). In 1970s, super absorbent polymer was used for the first time commercially, later on super absorbent polymer were used in sanitary napkins in 1978 by Park Davis. European used super absorbent polymer for the first time in a baby diaper during 1982. The expansion of this material and research greatly led to the development of ultra-thin baby diapers. Polymers are available in the form of crystals or tiny beads by different names i.e., root watering crystals, super absorbent polymers and drought crystals are called hydrogels, they have huge capacity of retaining water and make it available accordingly when required by plants over time (Henderson and Hensley, 1985; Ingram and Yeager, 1987; Wang and Boogher, 1987; Wang and Gregg, 1990).

Scientists revealed that the addition of polymer into soil could increase the particle's bonding force which is easy to disperse, and produce larger aggregate structure, specifically the aggregate ratio of particles larger than 1 mm increased rapidly (Yuan Xuefeng, 2005). Furthermore, it also enhances the growth and rooting of plants, as a result improves their quality and yield (Al-Darby, 1996). It might retain the organic matter in the soil and has the ability to adapt rapidly to an environment characterized by alternating wet and dry conditions (Arbona *et al*., 2005; Bai *et al*., 2010). Moreover, hydrogel accumulation enhanced water retention characteristics of soils and results in the interruption and arrival of permanent percentages of wilting under severe evaporation (Taylor and Halfacre, 1986).

In ornamental crop production good watering practice is an important factor for reducing leaching of nutrients. (Briggs *et al*., 1998; Lea-Cox and Ross, 2001; Tyler *et al*., 1996). Previous studies shows that these materials are very functional under partial water conditions (Wang and Gregg, 1990). Roots have the ability to extract water from the crystal bead and chain of hydrogels (Ingram and Yeager, 1987). Hydrogels has the ability to enhance soil physico-chemical properties like structural stability, water holding capacity and soil productivity (Hedrick and Mowry, 1952; Johnson, 1984; Guilherme *et al*. 2015).

Good irrigation management is an important best management practice in ornamental crop production, reducing runoff of nutrient and pesticide-rich water from production sites (Briggs et al., 1998; Lea-Cox and Ross, 2001; Tyler et al., 1996). Better control of irrigation has other benefits as well as better plant quality, more compact plants (Burnett and van Iersel, 2008), and reduced damage from root pathogens (Powell and Lindquist, 1997). In order to overcome these problems, an experimental study was planned to check the response of sodium polyacrylate on morphological and flower related attributes of petunia plant with the following objectives: (i) to investigate the effect of different concentration of sodium polyacrylate on quality flower production of petunia under stress condition (ii) to determine the best irrigation interval in term of producing quality flower production.

MATERIALS AND METHODS

Experimental site and design

An experiment entitled "Effect of sodium polyacrylate (hydrogel) on growth and quaity flower production of Petunia under water stress" was conducted at Ornamental Nursery, Department of Horticulture, The University of

Agriculture Peshawar (34°01'22.1" North and 71°28'43.0" East) during winter 2019. Complete Randomized Design (CRD) with two factors having three repetition were used during experimentation. The treatments comprised of sodium polyacrylate (SP_0 (soil without sodium polyacrylate, SP_1 (90% soil + 10% sodium polyacrylate), SP_2 (70% soil + 30% sodium polyacrylate) and SP_3 (50% soil + 50% sodium polyacrylate)) and irrigation interval i.e. W_0 (half day), W_1 (1day interval), W_2 (2 days interval) and W_3 (3 days interval). Dry baby diapers were dipped in container full of water for 10 minutes to absorb water efficiently. Socked hydrogel were taken from diaper and mixed into the soil with different concentrations. The combination of soil was Garden soil + Silt + Leaf mould at ratio 1:1:1. Pots were filled with mixed soil containing hydrogel. Petunia seedlings were transferred from seedling pots to individual pots and each pot had different concentration of sodium polyacrylate (hydrogel) mixed with soil in different ratios (Bouranis *et al*., 1995).

Data Collection

Data was collected on morphological and flower related attributes of petunia.Number of leaves and number of branches of each plant were counted from randomly selected plants and their average were calculated for five plants from each replication in each treatment. The height of plant was measured by measuring tape from soil to highest tip of the plant in centimeter and then means of each plant were calculated. Total days were counted from planting date to first flower, of five randomly selected plants from each replication and their average were calculated. After every 3rd day, number of flower were counted of each treatments, from first flowering till fading of the plant and their means were interpreted. Flower size data were measured with the help of ruler in centimeter from the five selected plants in each replication and average was calculated. In the five randomly selected plants of each treatment the root length was measured by using measuring tape from the base of the root to tip of the roots and means were calculated. Water displacement method was used for calculation of root volume of randomly five selected plants and then their average were calculated.

Statistical Procedure

The data taken for different variable were subjected to Analysis of Variance (ANOVA) of Statistical software package (Statistix 8.1, Inc, Tallahassee FL, USA) suitable for Completely Randomized Design and LSD test ($P \leq 0.05$) were used for means comparision by using.

RESULTS AND DISCUSSION

Days to flowering

It is obvious from (Table 1) that Sodium polyacrylate and irrigation interval significantly influenced days to flowering of petunia . The early flowering (11.58) was recorded in SP_2 (70% soil + 30% sodium polyacrylate), while more days (14.33) was observed in plant recieved 50% sodium polyacrylate + 50% soil medium. Regarding irrigation interval, petunia plant received irrigation after 3 days interval produced earlier flowering (11.25), whereas maximum days to flowering (15.58) was recorded in half day irrigation interval. (Table 1). Early flower initiation in 3 days of irrigation interval might be due to water stress which turns plant from vegetative growth to reproductive growth as result initiate early flower prodcution. Similar findings were also recorded by (Kiyotoshi, 2016) who reported that plant switch from vegetative growth to reproductive due to stress condition.While using of more sodium polyacrylate resulted maximum vegetative growth due to more retention of water by hydrogel.Similar results were also observed by Anupama *et al* (2017) reported that 0.5% hydrogel, had fastest growth and reached the transplantable stage in (18 days) as compared to (control: 28 days). While at 1.0% treatment seedling growth took 20 days, and treatment with 1.5% and 2.0% took 22 days in onion. The importance of water stress was also examined by Razmjoo et al. (2008), who found that the number of flowers produced by *Matricaria chamomile* decreased with long interval irrigation. Similar effects of water stress on flower production have also been observed in crops. Passioura (2006) observed that water deficit greatly affected crop productivity, especially when it occurred at the flowering stage.

Number of leaves plant^{-1}

The statistical analysis of data revealed that number of leaves plant^{-1} was significantly influenced by sodium polyacrylate, irrigation interval and their interactions (Table 1). The maximum number of leaves plant^{-1} (42) wer recorded in plants supplied with 10% of sodium polyacrylate, while lowest value of number of leaves plant^{-1} (24) was recorded in plant received 50% of sodium polyacrylate with soil medium. Similarly maximum number of leaves (46) were noticed in irrigation interval of 2 days compared to number of leaves (29) observed in half days irrigation interval, respectively (Table 1). The interaction between sodium polyacrylate and irrigation interval revealed that maximum number of leaves (55) was observed in SP_1 (90% soil + 10% sodium polyacrylate) and irrigated after 2 days interval. While plant treated with 50% of sodium polyacrylate + 50% soil and irrigated twice a day produced number of leaves plant^{-1} (19.67) (Fıgure 1). Maximum number of leaves per plant might be due to enough moisture available in the soil for plants to uptake more nutrients from soil which resulted more growth and thus produced highest number of leaves. Similar results were observed by (Manassah et al.,1981). Mixing of 30% sodium polyacrylate in soil had best result which might be due to the fact that surrounding soil around the root zone of plants starts to dry up, however hydrogel releases water and nutrients to plant roots. These results are in accordance with the finding of (Khadem *et al*., 2010) who reported that hydrogel polymer application to the soil enhanced the accessibility of water in the substrate, increase the leaf chlorophyll and leaf water content, improving plant growth, minimize nutrient leaching and helps to improve penetration of the soil. While the interaction of 30% sodium polyacrylate with 2 days irrigation interval shows best results which might be due to sufficient water availability, because every plant has its own requirement of irrigation (Anonymous, 2014).

Number of branches plant^{-1}

Number of branches of petunia significantly influenced by sodium polyacrylate, irrigation interval and their interaction (Table 1). The highest number of branches (4.58) was recorded in SP_1 (90% soil + 10% sodium polyacrylate), while lowest number of branches plant^{-1} (3.75) was observed in SP_3 (50% soil + 50% sodium polyacrylate). Regarding irrigation interval, plant irrigated with 2 days interval attained maximum number of branches plant^{-1} (4.83), whereas minimum number of branches (3.25) were recorded in irrigation interval of half day (Table 1). The interaction between sodium polyacrylate and irrigation interval revealed that maximum number of branches (5.33) was observed in SP_1 (90% soil + 10% sodium polyacrylate) and irrigated after 2 days compared to SP_3 (50% soil + 50% sodium polyacrylate) and irrigated twice a day produced minimum number of branches plant^{-1} (2.33). (Fıgure 1). Maximum number of branches per plant might be due to enough moisture available in soil for plants to uptake maximum nutrients from soil which resulted more number of branches. Similar findings were also noticed by Hossain *et al*. (2013), they stated that number of branches was significantly affected by irrigation. Mixing of 30% sodium polyacrylate had best results might be due to presence of hydrogel in sodium polyacrylate. The present study revealed that the application of hydrogel had significant impact in improving the number of branches per plant (Trisha-Roy *et al.*, 2019). Similar studies were in line with Francesco *et al*. (2015) who reported that application of hydrogel and controlled water stress enhanced branching and number of leaves, many folds in tomato crop. Hydrogel releases water and nutrient to the plants when surrounding soil around root zone of plants starts to dry up, plant growth is mainly a utility of fertilizer and water for prolonging the survival of plants under drought conditions (Huttermann *et al*.,1999).

Plant height (cm)

It is obvious from Table 1 that there is highly significant differences between the treatments and their interaction. The highest value of plant height (19.33cm) was recorded in SP_1 (90% soil

+ 10% sodium polyacrylate), while lowest value of plant height (16.08 cm) was observed in SP_3 (50% soil + 50% sodium polyacrylate). Regarding irrigation interval, taller plant (20.25 cm) was observed in petunia plant irrigated with 2 days interval, whereas minimum plant height (15.08cm) was observed by half day irrigation interval (Table 1). The interaction between sodium polyacrylate and irrigation interval revealed that maximum value of plant height (22.33cm) was observed in SP_1 (90% soil + 10% sodium polyacrylate) with irrigation interval of 2 days as compared to plant height (12.67cm) observed in petunia plant treated with 50% of sodium polyacrylate + 50% soil and irrigated twice a day (Figure 1). Maximum plant height might be due to more water availability by sodium polyacrylate which has the ability to retain water as result plant turn into vegetative growth. Water concentration affects the plant height because more transpiration from surface area of plant lose more water (Ray and Sinclair, 1998). Maximum plant height were observed in 2 days irrigation interval along with the use of 10% sodium polyacrylate mixed in the soil due to sufficient water availability. The hydrogel increase efficient water consumption, decreasing irrigation costs and increasing irrigation intervals, also, implement soil's water holding capacity and soil porosity, providing plants with eventual moisture and nutrients as well as enhancing plant viability and ventilation and root development which provides a conducive atmosphere for better growth of plants and finally increases crop yield. Similar findings were reported by Francesco *et al*. (2015) who reported that cucumber cultivation in hydrogel results in higher plant (180cm and 158cm), moreover 50% of sodium polyacrylate had more water but the plants gained shorter height which might be due more moisture and nutrients depletion, correlating with the findings of Oad *et al*. (2001) who reported that plant attain less height due to competition of moisture, space and nutrients. The decrease in leaf growth might be attributed by reduction in cell elongation that led to the minimize cell turgidity, cell volume and eventually the cell growth.

Number of flowers plant^{-1}

Data presented in Table 1 indicated that sodium polyacrylate, irrigation interval and the interaction of both significantly influenced the number of flowers per plant. Among the different concentration of sodium polyacrylate, maximum number of flowers (16) was recorded in using SP_2 (70% soil + 30% sodium polyacrylate) compared to SP_3 (50% soil + 50% sodium polyacrylate that produced minimum number of flowers plant^{-1} (12). Similarly in different irrigation intervals, highest number of flowers plant^{-1} (17) were recorded in irrigation after 3 days, while minimum number of flowers plant^{-1} (7) were observed in half day interval (Table 1). The interaction between sodium polyacrylate and irrigation interval revealed that maximum value of number of flowers plant^{-1} (21.33) was observed in using 30% of sodium polyacrylate + 90% soil with irrigation interval of 3 days,while minimum number of flowers plant^{-1} (7.33) treated with 50% of sodium polyacrylate + 50% soil and irrigated twice a day (Fıgure 2). Maximum number of flowers per plant might be due to required water availability to plant, while the rest of the applications were leads to over watering and too much water keeps the soil wet constantly which leads to lack of oxygen present in the spaces between the soil particles which ultimately reduced their growth, by 1 day irrigation interval or irrigation twice in a day. Our results are confirmed by previous studies of (Hong, 1970) who reported that in amaryllis the maximum flowers plant^{-1} were recorded by irrigation interval of 10 days, while irrigation interval of 5 days produced less number of flowers. Use of 30% sodium polyacrylate produced maximum flowering yield might be due to hydrogel. Similar studies regarding hydrogel by (Trisha *et al*., 2019) reported that hydrogel supplimented soil improved the yield grain in wheat up to 51%.

Flower Size (cm)

The analysis of variance revealed highly significant differences among the treatments and their interaction (Table 1.). The highest value of flower size (5.77cm) was recorded in SP_1 (90% soil + 10% sodium polyacrylate) , while lowest value of flower size (5.05 cm) was observed in plant recieved (50% of sodium polyacrylate+50% soil medium). Irrigation interval after 3 days showed maximum flower size (5.78 cm), whereas minimum flower size (5.11 cm) was recorded by half day irrigation interval, (Table 1). The interaction between sodium polyacrylate and irrigation interval revealed that maximum value of flower size (6.40cm) was observed in using 30% of sodium polyacrylate + 70% soil with irrigation interval of 3 days, While plant treated with 50% of sodium polyacrylate + 50% soil and irrigated twice a day attained minimum flower size (4.43cm) (Fıgure 2). Maximum flower size of petunia plant might be due to sufficient water availably to plant because plant takes nutrients from soil through water and more nutrients leads to increase the flower size. Similar findings were also recorded by Koksal (2011) who reported that nutrients are transported through water. While the 50% sodium polyacrylate had more water but excessive water leads to reduce the oxygen availability to roots which directly affected the plant growth and flowers size. Similar findings were also reported by Anupama (2005) who reported that chrysanthemum seedlings planted in soil mixed with hydrogel up to 0.5% wt/wt increased the flower size and number of flower as compared to control treatments.

Root Length (cm)

The analysis of data showed that root length was significantly influenced by sodium polyacrylate, irrigation interval and their interactions (Table 1). Among the different concentrations, longer root (10.42) was observed SP_1 (90% soil + 10% sodium polyacrylate), while minimum root length (7.17cm) was noticed in SP_1 (50% soil + 50% sodium polyacrylate). Regarding irrigation, maximum root length (10.25 cm) was observed by applying irrigation after 2 days, while minimum root length (7.50 cm) was recorded by applying irrigation twice a day (Table 1). The interaction between sodium polyacrylate and irrigation interval revealed that maximum length of root (12 cm) was observed in using 10% of sodium polyacrylate + 90% soil with irrigation interval of 2 days compared to plant treated with 50% of sodium polyacrylate + 50% soil and irrigated twice a day attained minimum root lenght (4.33cm) (Fıgure 2). The maximum root length ware recorded by irrigation interval of 2 days might be due to sufficient water availability to roots of the petunia plant. Similar results were reported by Nelson (1998) who stated that efficient irrigation management had affect not only preserve moisture, but also increase the root growth, plant growth and affect plant quality in commercial production.The plants that were planted in 50% sodium polyacrylate had more water capability but the results were minimum in the irrigation interval twice a day, might be the reason of excessive water. Similar studies reported that, due to excess irrigation, root growth might be limited or restricted by oxygen diffusion rate while under limited irrigation, root growth and development may be less due to lack of water or high soil strength (Klepper, 1991). The hydrogel particles are also taken as "miniature water reservoir" in the soil and water will be detached from these reservoirs upon the root mandate through osmotic pressure difference.[10] Due to the respectable volume reduction of the hydrogel as water is released to the plant, hydrogel creates at intervals the soil, free pore volume providing further space for air and water infiltration, storage and root growth (Miliani et al., 2017).

Root Volume (ml)

The analysis of data showed that root volume was significantly influenced by sodium polyacrylate, irrigation and interactions of both (Table 1). Among the different concentrations, maximum root volume (1.14 ml), was observed in SP_1 (90% soil + 10% sodium polyacrylate) ,while minimum root length (0.97 ml) was noticed in SP_3 (50% soil + 50% sodium polyacrylate). Regarding irrigation, maximum root length (1.10 ml) was observed by applying irrigation after 2 days, while minimum root length (0.84 ml) was recorded by applying irrigation twice a day (Table 1). The interaction between sodium polyacrylate and irrigation interval revealed that maximum root volume (1.33ml) was observed in using 10% of sodium polyacrylate + 90% soil with irrigation interval of 2 days compared to plant treated with 50% of sodium polyacrylate + 50% soil and irrigated twice a day attained minimum root lenght (0.57ml) (Fıgure 2). Maximum root volume by 2 days irrigation interval might be due to proper and required availability of water to roots of the petunia plant. Similar results were observed by (Dimitrios *et al.*, 2014) that the increase of irrigation rate had significant effect on volume and density of the root system, while other root characteristics associated with the yield of the plants. Moreover 50% of sodium polyacrylate had minimum value might be the reason of time of irrigation (Anonymous, 2014). However maximum root volume might be due to excessive water, because 50% sodium polyacrylate had more capacity to retain more water. Similar findings were also observed by (Ghasemi and Khushkhui, 2018) reported that roots, shoots and flowers of chrysanthemum enhanced by using hydrogel in soil under drought stress. uses of hydrogels improving plant viability, seed germination, ventilation and root development mainly under arid environments, additionally, with respect to the growth of the plant, it's been noticed that there's a significant increase in the growth of the plants when usage of the hydrogel

CONCLUSION

Sodium polyacrylate is a cross-linked hydrophilic polymer that can swell up in water to hundreds of times its dry weight. The effectiveness of hydrophilic polymers in enhancing soil water retention or in increasing yield is dependent on formulation and soil type. Our results indicated that quality flower production was recorded in SP_1 (10% sodium polyacrylate and 90% soil substrates). While reproductive growth (flower number, size) shows best results by the use of 10% sodium polyacrylate mixed with 90% soil from the rest of the treatments. Increasing irrigation interval significantly reduced quality of petunia flower and other morphological attributes.

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Table 1. Growth and flower production related traits of petunia as influenced by sodium polyacrylate and irrigation intervals

Treatments	Days to flowering	No. of leaves plant^{-1}	No. of leaves plant^{-1}	Plant height (cm)	No. of flowers plant^{-1}	Flower size (cm)	Root length (cm)	Root volume (ml)
Sodium polyacrylate (%) (S.P)								
Control	14.00ab	37.08b	3.92b	17.08bc	13.58bc	5.32b	9.00b	0.88b
10	13.00b	41.83a	4.58a	19.33a	15.83ab	5.74a	10.42a	1.14a
20	11.58c	41.25a	4.42a	18.50ab	16.17a	5.77a	10.08a	1.09a
30	14.33a	24.42c	3.75b	16.08c	12.67c	5.05b	7.17c	0.79b
LSD≤ 0.05	0.84	2.82	0.43	0.89	1.70	0.20	0.81	0.06
Irrigation intervals (days) (I.I)								
Twice a day	15.58ab	28.58	3.25	15.08c	11.00c	5.11c	7.50	0.84c
1	13.58b	32.75c	4.25	17.17b	14.08b	5.38	8.92b	0.95bc
2	12.50c	45.67a	4.83	20.25a	16.08b	5.61	10.25a	1.10a
3	11.25a	37.58b	4.33	18.50b	17.08	5.78a	10.00a	1.01ab
LSD≤ 0.05	0.84	2.82	0.43	0.89	1.70	0.20	0.81	0.06
Interaction								
S.P×I.I	NS	Figure 1	Figure 1	Figure 1	Figure 2	Figure 2	Figure 2	Figure 2

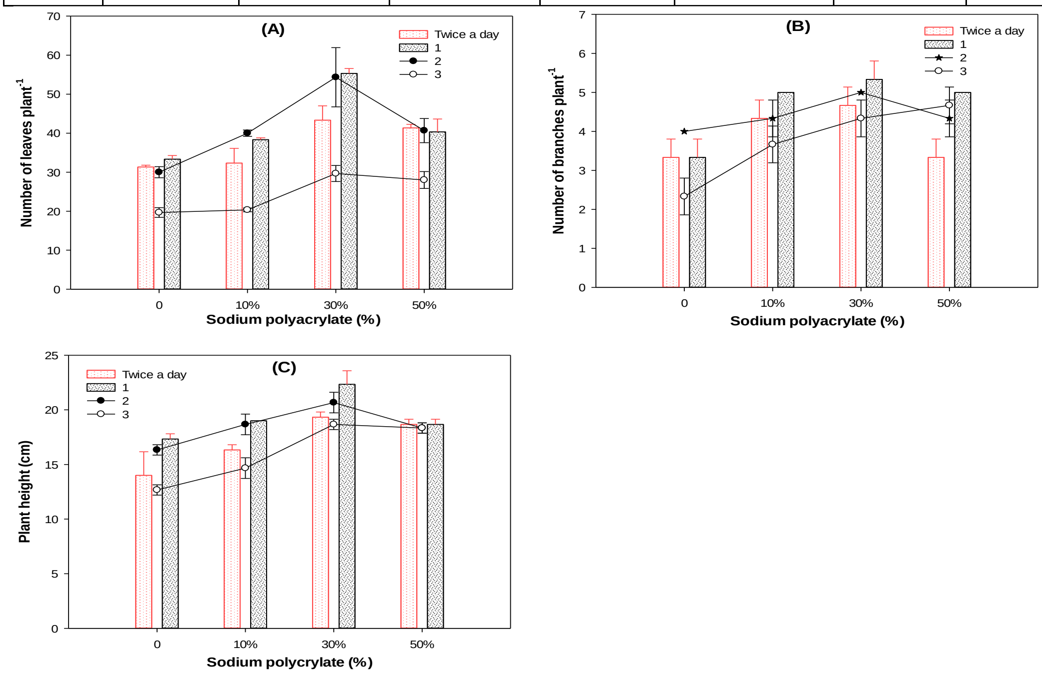

Figure 1. Growth and flower production related traits of petunia as influenced by interaction of sodium polyacrylate and irrigation interval

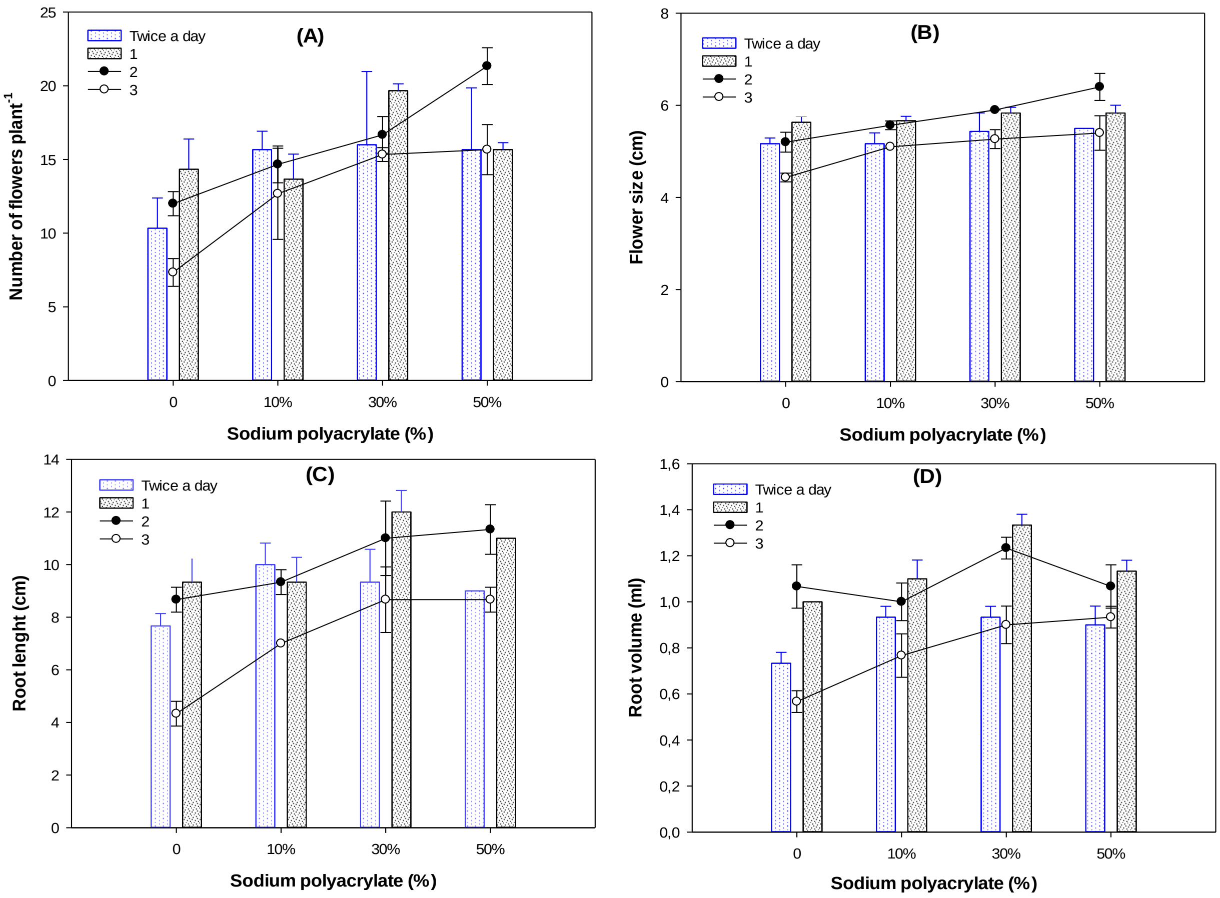

Figure 2. Growth and flower production related traits of petunia as influenced by interaction of sodium polyacrylate and irrigation interval