Iranian Polymer Journal
15 (9), 2006, 715-725

Available online at: http://journal.ippi.ac.ir

Effects of a Hydrophilic Polymer on the Field Performance of an Ornamental Plant (*Cupressus arizonica*) under Reduced Irrigation Regimes

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Received 16 April 2006; accepted 15 August 2006

ABSTRACT

The objectives of this study are to evaluate the effects of a hydrophilic polymer (Superab A200) on the growth indices of an ornamental plant (*Cupressus arizonica*) under reduced irrigation regimes in the field and on the soil water retention curve in a laboratory. The RETC computer programme was used for obtaining optimum model parameters. Superab A200 in two levels, 4 and 6 g/kg, were mixed with two soil textures of clay and sandy loam, respectively. The results of the soil water retention model showed that, Superab A200 caused the residual water content (θ_r) and saturated water content (θ_s) to increase. Air entry value (h_b) was observed to decrease in the clay and increase in the sandy loam. The results of the statistical analysis showed that there is a significant difference between samples containing Superab A200 and without hydrophilic polymer (the control) and the levels of polymer application. Available water content increases 2.3 fold of the control at maximum, with hydrophilic polymers application of 6 g/kg in sandy loam soil. The field trials were conducted as a split plot on the random complete blocks design in which the main plot treatments were two irrigation regimes consisting 33% and 66% evapotranspiration (ET_c) and two sub-plot treatments were soils containing 4 and 6 g/kg hydrogel, respectively. The control blocks had no hydrophilic polymer and irrigated with 100% ET_c. The results indicated that plant height, shoot diameter and length of green, are the same in treatments containing 4 and 6 g/kg Superab A200 and receiving irrigation water 66% ET_c with the control. Thus, application of 4 and 6 g/kg hydrophilic polymer reduced the required water to 1/3 of the control. Application of Superab A200 can result in significant reduction in the required irrigation frequency particularly for light soil texture. This is an important issue in arid and semi-arid regions of the world.

Key Words:

soil water retention models;
RETC computer programme;
hydrophilic polymer;
Cupressus arizonica;
hydrogel.

INTRODUCTION

The term hydrophilic cross-linked polymer or hydrogel itself is rather generic referring to hydrogels used in oil recovery [1], to medical grafting supplements [2], in clarification of potable and waste water, dewatering sludges, mining separations, food processing, personal care products, and laboratory supplies [3] as well as in agriculture.

Special hydrogels i.e., superabsorbents absorb and store water hundreds times of their own weights [4-6]. Their performance is determined by the chemistry and formation conditions of hydrophilic polymer and the chemical composition of the soil solution or irrigation water. Water held in the expanded hydrogel is intended as

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a soil reservoir for maximizing the efficiency of plant water uptake. Three classes of hydrophilic polymers commonly used can be generally classified as natural polymers, semi-synthetic and synthetic polymers [7]. Synthetic hydrophilic polymers usually consist of polyacrylamides (PAM) and polyvinyl alcohols [7]. Fully synthetic polymers are chemically cross-linked to prevent them from dissolving in solution. The uncross-linked PAM is effectively used for soil erosion control, sediment reduction in surface waters, and earthen canal bed stabilization.

Much works have been done in floriculture with hydrophilic polymers (hydrogels) to describe their effect on water holding capacity of media in pot-grown crops [8-10]. Hydrophilic polymer networks have been reported to improve aeration and drainage of the medium [11], improve market life of container grown plants [8,9,11], and seed coating [12].

Hydrophilic polymers potentially influence infiltration rates, density, soil structure, compaction, soil texture, aggregate stability, crust hardness [13,14], and evaporation rates [15]. Gehring and Lewis [10] reported that moisture stress of plants decreased by incorporation of a hydrophilic polymer into the medium. Wallace and Wallace [16], have stated that generally the most favourable results for seed emergence and water infiltration came from an anionic polymer where, a cationic polymer was less effective.

Hydrophilic polymers have been used to establish tree seedlings and transplanted in the arid regions of Africa and Australia to increase plants survival [17-20]. Specht and Harvey-Jones (2000) found that less drought tolerant tree species had a much more favourable response to the incorporation of hydrophilic polymers [17]. In a trial when irrigation was stopped for a few as six days all of the control seedlings died compared to 57% and 71% survival rate in the hydrogel amended soil [20]. *Pinus halepensis* (Aleppo pine) doubled its survival rates in 0.4% hydrogel soil compared to no hydrogel amendments [6]. The hydrogel also allowed for 19 days passing drought [6]. *Pinus pinea* (umbrella pine or Italian stone pine) seedlings survived 1.4 to 2.0 times longer, with applications of hydrogels, compared to the trials with no hydrogels in the field production [18]. *Pinus halepensis* also had increased adventitious root growth along with increased overall plant mass when hydrogel was added to the medium [6]. Dehgan et al. [21] indicated that foliage plants like *Photinia fraseri* (Fraser photinia) responded in increased mass to the addition of hydrogels into the medium. Hydrophilic polymers usually have some effects on plant establishment, with the greatest benefit for hydrophilic plants planted in dryer conditions. *Fesstuca arundinacea* (Tall fescue) benefited from pre-seeding incorporation of hydrophilic polymers into the soil [22]. The soil required large amount of hydrogel (greater than 1% of soil volume) to achieve a beneficial response from *Fesstuca arundinacea* in greenhouse [22]. Fry and Butler [22] concluded that greater amounts were needed to achieve the same response in the outdoor environment. *Pyracantha cocinnea* (scarlet firehorn) and *Rhododendron sp.* (azalea) had increased survival and increased dry weights in container production when a hydrophilic polymer was incorporated into the medium [23]. Drought sensitive plant, such as *Petunia parviflora* (petunia), responded well to the hydrogels in dry conditions and increased flower numbers and dry weights [24]. Responses of moisture-requiring plants to the hydrogels have been inconclusive and sometimes negative when used in field and container productions. In a container production of *Betula pendula* (European birch), hydrogel addition into the medium has shown the reductions in overall plant mass and the amount of water available in the plants [25]. After further investigation, the lack of water availability could be attributed to the amounts of soluble salts in the medium [25]. Wang [26] found that *Codiaeum variegatum* (croton), *Dieffenbachia sp.* (dumb cane) and *Hibiscus rosta-sinensis* (hibiscus) show no visible size difference when hydrophilic polymers were used compared to when they were not used. The effects of different cultivation methods with addition of either organic mulch or a hydrophilic polymer (aquasorb), on seeding emergence of seven indigenous plant species were evaluated in South Africa by Witbooi and Esler in 2004 [27]. Seedling emergence was higher in areas where seed and aquasorb were used together.

Allahdadi et al. [28], in 2005 studied the impact of Superab A200 on drought stress of soybean (*Glycine max L.*). In this field trial, the different rates of Superab A200: 0.75, 150 and 225 kg/ha were obtained along with irrigation intervals of 6, 8, and 10 days on yield and yield components and some physiological characteristics of soybean. The results showed that the highest yield and yield components obtained from 6 days irrigation interval and 225 kg/ha. The number of pod per main stem and branches, percentage of seed oil and nodule dry weight were increased with application of 150 kg/ha Superabsorbent polymer (SAP). Also, the longest irrigation interval without application of SAP produced the lowest yields and yield components [28].

Viero et al. [29] conducted a field trial in 2002 with the primary objective of being able to successfully extend the planting period within which *Eucalyptus grandis clones* could be planted. This was done by testing tree growth and survival by the addition of a soil-amended hydrogel (Stockosorb 400K) and comparing it to traditional water planting methods. There was a highly significant ($p<0.01$) interaction between hydrogel and water, which had a positive impact on both transplant survival and growth. Also, there was significant difference between water only treatments when compared with all levels of hydrogel; with the hydrogel treatments performing significantly better.

The relative effectiveness of the hydrophilic polymers depends upon chemical properties of the hydrophilic polymer, such as molecular weight, and the hydrophilic polymer properties tend to have differing effects on various soil properties.

The Arizona Cypress

Cupressus arizonica is a versatile, fast growing evergreen tree and has shown characteristics which are promising afforestation planting in both arid and semi-arid areas. Traditionally, *Cupressus arizonica* has been used for landscaping and Christmas trees and more importantly, for erosion control and windbreaks [30].

Cupressus arizonica is a dominant tree in the landscape of many cities in arid and semi-arid areas of Iran particularly in the green belt zone of cities. Much efforts and costs have been allocated for maintenance and irrigation of this sort of trees by tankers. Hence it is important to find proper solutions to reduce irrigation frequency and as a result to minimize the cost of irrigation.

To the knowledge of authors no data is available in the literature to study the effects of a hydrophilic polymer amendment on the field performance of *Cupressus arizonica* under deficit irrigation. In addition, there is no information indicating the ability of a widely used computer programme (RETC) to verify the changes of soil hydraulic properties (θ_s, θ_r, α, AWC) due to incorporating a hydrophilic polymer to the soil. Hence, the purpose of this study is to investigate the application of a cross-linked hydrophilic polymer on soil water retention characteristics using the RETC computer programme in the laboratory trial and the effects of a hydrophilic polymer amendment on the field performance of *Cupressus arizonica* under reduced irrigation regimes.

EEPERIMENTAL

Materials and Methods

For laboratory experiments, two soils, classified as clay and sandy loam, were used in this study. The sandy loam and clay samples were collected from the upper soil layer (0-30 and 30-60 cm) in Bakhtiar-Dasht area and Research Station of Mahmoud-Abad, respectively, both located in the west of Isfahan, in central Iran. The soil samples were air-dried, mixed, crushed and sieved to < 2 mm particle size. The physical and chemical characteristics of the soils are shown in Table 1.

The soil amendment used was a hydrophilic polymer, Superab A200, produced by Rahab Resin Co. Ltd., under license of Iran Polymer and Petrochemical Institute. The chemical structure of Superab A200 is shown in Figure 1.

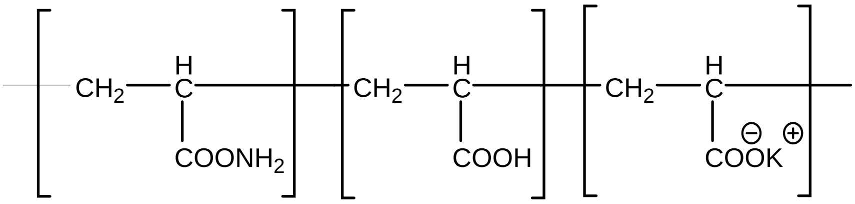


Figure 1. The chemical structure of Superab A200.

Table 1. The physical and chemical characteristics of the soils.

Soil texture	Depth (cm)	Soil particles (%)			ρ_s* (cm^3/cm^3)	ρ_b** (cm^3/cm^3)	pH	EC (dS/m)	K (ppm)
		Clay	Silt	Sand					
Sandy loam	0-30	15.2	32.4	52.3	1. 19	2.69	6.7	4.1	11.8
	0-60	18	25.4	56.6	1.22	2.69	7.1	4.8	16
Clay	0-30	53	26	21	1.41	2.7	7.7	2.5	21.8
	0-60	48	27	25	1.38	2.6	7.9	2.8	18.7

(*): ρ_s the soil actual density, (**): ρ_b the soil bulk density.

Table 2. The properties of Superab A200.

Properties		
Water content (%)		5-7
Density (g/cm^3)		1.4-1.5
pH		6-7
Grain size (ì m)		50-150
Maximum durability (year)		7
Water uptake capacity (g/g)	Distilled water	220
	Tap water	190
	NaCl 0.9%	45

The properties of Superab A200 are shown in Table 2.

Laboratory Experiments

The soil water characteristics were determined in the laboratory using a pressure plate apparatus (soil moisture, ELE model) as shown in Figure 2.

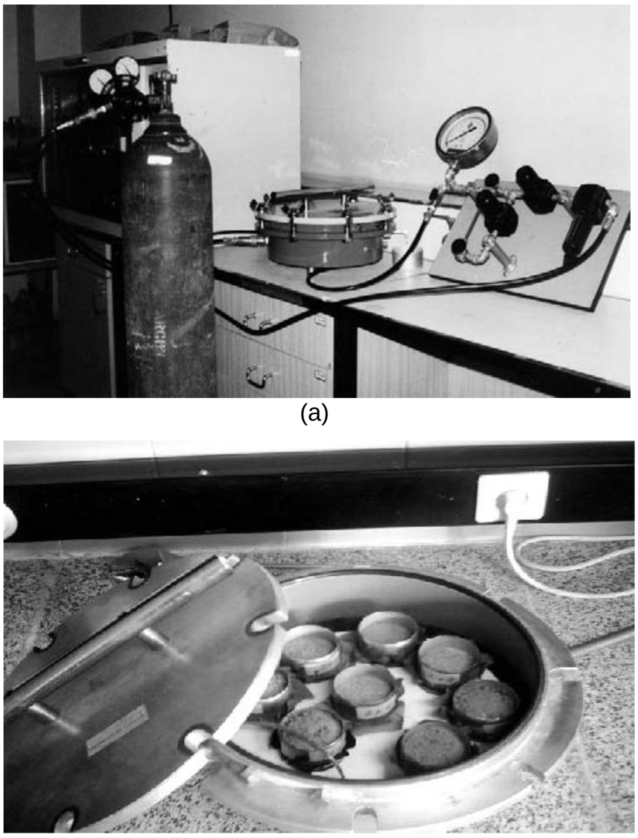
Triplicates samples of each soil containing different amounts of hydrophilic polymers in dry form (4 and 6 g/kg soil), were placed in the pressure plate in three retaining rings (65 mm diameter and 30 mm height) and saturated with tap water (EC=0.2 dS/m) overnight. The desired pressure (0, 0.3, 1, 3, 5 and 15 bar) was then applied until outflow ceased and the soil water was considered to be in equilibrium with the applied pressure. The gravimetric water content for each treatment was determined by oven drying. The soil volumetric water content was then determined by multiplying the gravimetric water content by the ratio of the soil bulk density (listed in Table 1). The computer programme, RETC [31] was used for obtaining optimal model parameters for non-linear equations with multiple parameters. The parameters are deemed optimal in the sense that they provide the minimum least-square error between the estimated and measured values. The RETC programme used the parametric models of Van Genuchten, eqn (1), and Brooks-Corey, eqn (2), to represent the soil water retention curve.

$$\Theta = \theta_r+(\theta_s - \theta_r)[1+(\alpha\ h)^n]^{-m} \qquad (1)$$

$$\Theta = \theta_r+(\theta_s - \theta_r)\ (\alpha\ h)^{-\lambda} \qquad (2)$$

where Θ, θ_s, θ_r, α , h, λ, and n and m are the soil volumetric water content, the saturated water content, the residual water content, the inverse of air entry value, the soil matric suction, the pore size distribution index, and the fitting coefficients, respectively.

Available water content (AWC) is the amount of water released by a soil between field capacity (FC) and permanent wilting point (PWP). AWC was calculated by subtraction of FC and PWP (AWC = FC - PWP). The term implies that the available water can be used by plants. FC is defined as the amount of water retained by a soil after it has been wet thoroughly and drainage has become negligible. The soil water content at FC is for practical purposes and the upper limit of soil water availability has been related to a suction of 0.3 bar (300 kPa). The permanent wilting point of a soil is generally defined as the soil water content below which plants wilt permanently. This point has generally been given as the lower limit of soil water availability and has been related to a suction of 15 bar (1500 kPa).



(a)

(b)

Figure 2. Pressure plate apparatus: (a) whole system (b) soil samples placed in the pressure plate.

Field Experiments

The field trials were conducted in Research Station of Mahmoud-Abad located in Isfahan, central Iran (longitude 51º, 35 E and latitude 33E, 47´ N). The average annual rainfall average at the nearest station (Isfahan University of Technology) is 134 mm and the average of air temperature is 17.0ºC. The experimental site has an arid climate and is 1580 m above sea level.

The field trials were conducted as a split plot on the random complete blocks design in which the main plot treatments were two irrigation regimes consisting 33%, 66% ET_c and two sub-plot treatments were soil containing 4 and 6 g/kg hydrogel, respectively. The amounts of hydrogel addition were selected according to the previous experiments [32]. The control blocks had no hydrophilic polymer and irrigated with 100% evapotranspiration (ET_C). Seedlings of 1-year-old, *Cupressus arizonica* were transplanted in small dicked basins with 3 m distances from each other. Inside each dicked basin a hole (80 mm diameter and 60 mm depth) was digged and seedling was placed in the centre of the hole until the hole filled with mixture of soil and polymer, along with an untreated control (no hydrogel).

The soil around the roots was made firm by hand. The experiment was conducted at three replications. Crop water requirement was computed based on water use efficiency, the root depths of plant and the moisture deficiency of soil for different stages of growth and irrigation was applied to meet 33%, 66% and 100% ET_c. ET_c was calculated based on class A pan data as follows [33]:

$$ET_0=K_{pan}(E_p) \tag{3}$$

$$ET_c=K_c\ ET_0 \tag{4}$$

where ET_0 is potential evapotranspiration from a reference crop, K_{pan} is pan coefficient and E_p is evaporation from pan and K_c is a dimensionless plant coefficient. Based on local experiments, and K_{pan} and K_c were set at 0.7 and 1, respectively.

It should be mentioned that irrigation regimes conducted after 2 weeks from establishment of plants. The growth indices of *Cupressus arizonica* including height, shoot diameter and length of green were measured in the beginning of planting and 12 months later, at the end of experiment.

Multiple comparisons by Post Hoc least significant difference (LSD) test and analysis of variance for the various treatments were done by the statistical analysis package SAS™ [34].

RESULTS AND DISCUSSION

Saturated Water Content (θ_s)

For each soil texture, Superab A200 application increased volumetric water content (Table 3). The increase in θ_s is proportional to the proportion of hydrophilic polymer application. The maximum value of θ_s is related to 6 g/kg. The results indicate that in sandy loam soil, the value of θ_s is 1.9 fold that of control at maximum. In clay soils, the value of θ_s is 1.3 fold that of control at maximum compared to the control.

Residual Water Content (θ_r)

The variations of (θ_r) in each soil texture are shown in

Table 3. Estimation of water retention parameters by RETC model.

Amount of polymer addition (g/kg)	Sandy loam			Clay		
	θ_r* (cm^3/cm^3)	θ_s** (cm^3/cm^3)	α*** (1/cm)	θ_r (cm^3/cm^3)	θ_s (cm^3/cm^3)	α (1/cm)
4	16.76	62.54	0.25	23.82	74.20	0.010
6	26.98	72.73	0.064	29.46	80.09	0.013
Control (without polymer)	5.05	37.57	1.09	20.35	61.15	0.007

(*) :θ_r the residual water content; (**): θ_s the saturated water content; (***): α the inverse of air entry value.

Table 3. The value of θ_r is increased with polymer addition and increasing polymer application. The increase of θ_r in sandy loam soil was found to be more than the other and 5.3 fold that of the control. This could most likely be attributed to sandy loam having less cation holding capacity compared with the other soil texture. As a result the expansion of polymers and associated water adsorption are increased. The increase of θ_r in clay soil was 1.5 fold that of the control at maximum, with application of 6 g/kg.

Air Entry Value

Commonly the WRC changes sharply with air entry value ($h_b=1/\alpha$). Due to larger pore geometry in sandy loam soils, water is released under lower matric suction. In other words the value of α, is high. The values of α in sandy loam and clay for control are 1.09 and 0.007, respectively. As Table 3 shows, adding and increasing the amount of Superab A200 in sandy loam reduced the largest pores in the soils and the pressure required for water expulsion is increased. Consequently the value of α, is reduced. In clay control soil the air entry value was seen to be increased, i.e. α, is decreased. Hydrophilic polymer addition to these soils may open the media, by forcing soil particles apart, increasing aeration. Hence less pressure is needed to desorb water and the value of α is increased.

Water Retention Characteristic Curve

There is a statistically significant difference (95% confidence level) between Superab A200 application without (control) and the amount of polymer application in each soil texture and soil matric suction. The maximum increase obtained at an application level of 6 g/kg (Figures 3 and 4).

Available Water Content

There is a statistically significant difference (95% confidence level) between the amount of Superab A200 application, samples (4 and 6 g/kg), and samples containing polymers and those without polymers (control) in two soil textures. The values of volumetric water content at FC and PWP compared to the control are shown in Figures 3 and 4 for two soils. The results indicate that the volumetric water content at FC for sandy loam is increased 2.3-2.8 fold that of the

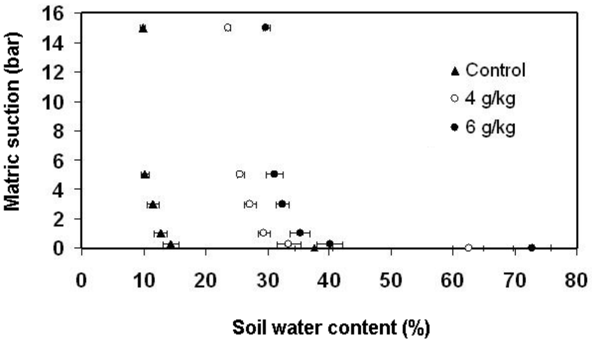


Figure 3. Water retention characteristic curves in sandy loam soil due to application of Superab A200.

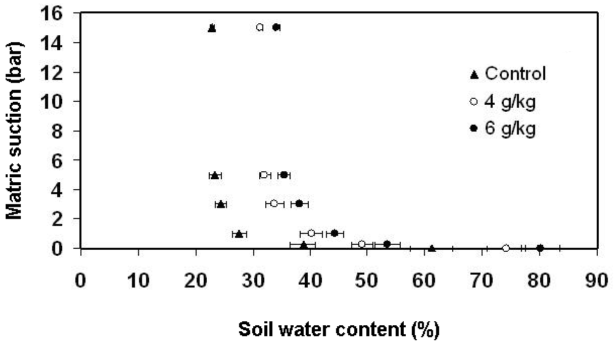


Figure 4. Water retention characteristic curves in clay soil due to application of Superab A200.

Table 4. Volumetric water content (%) at AWC in soils compared to the control.

Sandy loam		
Control	Amount of polymer addition (g/kg)	
	4	6
4.54	9.84	10.33
Clay		
15.90	17.89	19.40

control by adding 4-6 g/kg hydrophilic polymers, respectively. The related values for PWP are 2.4-3 fold that of the control. The volumetric water content at FC for clay is increased 1.3-1.4 fold that of the control by adding 4-6 g/kg Superab A200, respectively. The related values for PWP are 1.4-1.5 fold that of the control.

The values of available water content (AWC=FC-PWP) compared to the control are shown in Table 4 for two soils. In sandy loam soil AWC would be 2.2 and 2.3 fold that of the control by adding 4-6 g/kg polymer, respectively. In clay soils, AWC is 1.1-1.2 fold by adding 4-6 g/kg polymer compared to the control (Table 4). As the results of AWC indicated incorporation of hydrophilic polymer revealed better performance in sandy loam compared to the clay soils which is due to low cationic exchange capacity of coarse textured sandy loam soils. The same trends were obtained by Abedi-Koupai and Sohrab [32]. They incorporated 4 and 6 g/kg of a hydrophilic polymer (PR3005A) with the same chemical structure with Superab A200 into the sandy loam and clay. In sandy loam soil AWCs were 2.2 and 2.5 fold that of the control by adding 4 to 6 g/kg PR3005A, respectively. In clay soil, however, AWC was 1.4-1.7 fold compared to the control by adding 4 to 6 g/kg PR3005A.

Number of Days to Reach PWP

There were marked responses in the number of days to PWP as a result of polymer application and increases in polymer concentration (Figure 5). Samples containing 6 g/kg polymer had the maximum period to reach PWP (22 days) compared to the control samples (12 days).

The results seem to coincide with that of Johnson [35]. He mixed sand with different cross-linked polyacrylamides so as to produce a polymer concentration range of 0-2 g/kg. The results indicated that all polymers tested increased FC for coarse sand, by 171-402%. Also, he showed that the PWP of the control sand was reached between 2-3 days, in comparison to 6-7 days for 1 g/kg polymer treated sand and between 9-10 days for 2 g/kg polymer treated sand.

Enhancement of the number of days to the onset of wilting has been reported previously in growing systems amended with hydrophilic polymers [10,36]. Also, Sharma (2004) stated that hydrogel amendment reduced drought stress in plants of *Asclepias incarnata* and *Gaillardia grandiflora*. Time to wilting was longer for plants growing in amended soil [37].

Frequency of irrigation can be determined by dividing the amount of water to be depleted from the soil by the consumptive use per day. Hence, due to the linear dependency of the frequency of irrigation to the AWC, the increasing of AWC is proportional to the frequency of irrigation. This is an important issue

Table 5. Analysis of variance of the growth indices of *Cuypressus arizonica.*

Variable factor	Degree of freedom	Least square average		
		Height (mm)	Shoot diameter (mm)	Green length (mm)
Replicate	2	1.96	0.97	52.45
Irrigation regime (I)	1	158.36**	26.22**	1912.31**
Different combinations (C)	5	15.1**	4.39**	146.32**
I×C	5	3.62	1.75	28.2
Control against combinations	1	37.05	35.26	287.21

** Significant ($p<0.01$).

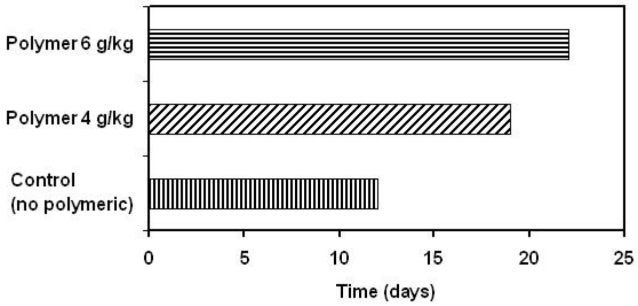


Figure 5. Number of days to reach PWP due to application of 4 and 6 g/kg Superab A200.

where irrigation water is scarce commodity and the cost of irrigation maintenance must be reduced.

Effects of Polymer Amendment on Growth Indices

The data were subjected to an analysis of variance to determine the effect of irrigation regimes, polymer addition, amount of polymer and interaction between them (Table 5).

Height

The results show that there are significant ($p < 0.01$) effects of irrigation regime on the height. Multiple comparisons by Post Hoc Least Significant Difference (LSD) test indicated, there is a significant effect of 66% ET_c on the growth indices compared with 33% ET_c (Table 6). The maximum effect of polymer addition on the height is related to 6 g/kg. However, there is no significant difference between polymer application of 4 and 6 g/kg with 66% ET_c and untreated control (100% ET_c). Thus, the application of 4 g/kg Superab A200 could reduce the required water to the level of 33% less than that of the control.

Table 6. Comparison of average growth indices for *Cupressus arizonica* under reduced irrigation regimes and polymer amendment.

Index	Control	66% ET_C		33% ET_C	
		4 g/kg	6 g/kg	4 g/kg	6 g/kg
Height	7.63^a	6.65^{ab}	7.50^a	2.40^{cd}	3.66^{bc}
Shoot diameter	4.80^a	3.20^a	4.26^a	0.76^b	1.22^b
Green length	5.15^a	1.74^{ab}	4.08^a	N^*	N^*

No significant difference ($p<0.05$) between the treatments with the same sign.

*: indicates no green length.

Shoot Diameter

The results show that there are significant ($p < 0.01$) effects of irrigation regime on the shoot diameter. Multiple comparisons by Post Hoc least significant difference (LSD) test indicated, there is a significant effect of 66% ET_c on the shoot diameter compared with 33% ET_c (Table 6). The maximum effect of polymer addition on the shoot diameter is related to 6 g/kg. However, there is no significant difference between polymer application of 4 and 6 g/kg with 66% ET_c and untreated control (100% ET_c). Thus, application of 4 g/kg Superab A200 could reduce the required water to the level of 33% less than that of the control.

Length of Green

The results show that there are significant ($p < 0.01$) effects of irrigation regime on the length of green (height less than the stem of plant). Multiple comparisons by Post Hoc least significant difference (LSD) test indicated that there is a significant effect of 66% ET_c on the length of green compared with 33% ET_c (Table 6). The maximum effect of polymer addition on the length of green is related to 6 g/kg. However, there is no significant difference between polymer application of 4 and 6 g/kg with 33% and 66% ET_c and untreated control (100% ET_c). Thus, application of 4 g/kg Superab A200 could reduce the required water to the level of 66% less than that of the control. The results coincide with that of the Allahdadi et al. [38]. They studied the impact of Superab A200 on Zea mays yield and yield components. They reported there was no significant difference between polymer application of 200 kg/ha along with the irrigation intervals of 7 days and untreated control with the irrigation intervals of 3 days. Also, Sharma [37] stated that plants growing in hydrogel amended soil had more water available (reflected in higher stomatal conductance and higher leaf water potential) for longer period of time compared to control plants as a result frequency of irrigation may be reduced. Increase in plant growth may also be due to increased nutrient retention in hydrogel-amended substrate [39]. However no fertilizer was applied to plant in the present study.

The results seem to concord with that of Gollagan

[19,20]. *Eucalyptus microtheca* (Eucalyptus) was planted in Sudan with PAM and PVA hydrogels incorporated into sandy soil. The trials involving *Eucalyptus microtheca* were performed in the absence of irrigation, the survival rate of the trees doubled compared to trials with no hydrogels amendment [19, 20]. In situations with reduced irrigation rates, the survival rate was 1.4 and 1.6 times better with a hydrogel amendment.

Performance of Superab A200 was assessed by soil hydraulic properties (θ_s, θ_r, α, AWC) in the laboratory trial and measuring of plant growth indices in the field trial. A similar and clear trend exists between the field and laboratory results, however no such clear trends in response to increasing polymer concentration were seen in the measures of plant growth indices. This may be attributed to the fact that, relationships between root growth and polymer-held moisture are complex. Therefore, there is a need for further investigation in this regard.

CONCLUSION

Incorporation of hydrophilic polymers may be summarized as having the following effect on soil water retention characteristics:

- The variations of soil hydraulic properties due to addition of Superab A200 represented much clear by using RETC computer programme.
- Increase of saturated and residual water content in the range of soil matric suction studied (0-15 bar).
- Release of water at low matric suction particularly for clay soil texture.
- Application of high levels of Superab A200 addition in sandy loam soil enhanced available water content approximately 2.3 fold compared to that of the control.
- The number of days to permanent wilting point and growth indices is independent estimates of plant performance. There were marked responses in the number of days to permanent wilting point as a result of polymer application. However, higher application rates of polymer could not be justified in practice. Application of 4 g/kg Superab A200 had a proper performance for *Cupressus Arizonica* and reduced the required water at least 1/3 of the control.

Thus, application of hydrophilic polymers can result in significant reduction in the required irrigation frequency particularly for light soil texture (such as sandy soil). This is an important issue in arid and semi-arid regions of the world where irrigation water is scarce commodity, short-term drought is a possible cause of plant losses, and where the cost of irrigation maintenance must be minimized.

ACKNOWLEGMENTS

The authors would like to appreciate financial support of this research project by Management and Programming Organization of Iran, and Parks and Landscape Organization of Municipality of Isfahan.

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