The Study of Deficit Irrigation for Forest Plantation in Semiarid Areas

Seyed Mohammad Hosseini^{1,*}, Achim Dohenbusch², Alois Skoupy¹, Rokhsareh Armoon³, Jan Macku¹

¹Faculty of Forestry and Wood Sciences, Czech University of Life Sciences Prague, Czech Republic

²Faculty of Forest Ecology, George-August University of Göttingen, Germany

³Faculty of Humanities, Science and Research Branch Islamic Azad University, Iran

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Abstract The climate situation is one of the main factors for developing of green spaces in semiarid regions, because the first priority of people for available water will be for living and agricultural products. In such big semiarid zones in the world, each year different projects are launched in order to reduction of irrigation costs and development of green spaces. The objective of this research was to find a practical way for afforestation development and optimal and viable solution for creation and irrigation of planting in semiarid zones. This research has been continued for 1 year and 4 broadleaves and 4 confers were evaluated under 5 treatments by the use of superabsorbent material, bearing the trade market as Stockosorb 300. The results of the research proved that the type of treatment which had been employed had a positive effect on the aliveness of the saplings with reduction of minimum 50% water irrigation for many species. The statistical analyses indicated tree species under treatments are significantly different that *Robinia pseudoacaccia* proved to be the best species and *Cupressus sempervirens* the worst.

Keywords Afforestation, Reforestation, Super Absorbent, Semi-arid, Irrigation

1. Introduction

According to the climatologic categorizations, Iran has arid climate and the average annual precipitation in this country is less than 250 mm. It should be mentioned that such precipitation usually occurs in rain showers which cause sheet washings and surface erosion.

On the other hand, desertification, expansion of deserts and movement of blowing sands (dunes) are turning into a thorny and insurmountable problem of the country.

No doubt, soil stabilization and development of planting are one of the appropriate ways to tackle the problem and

prevent furtherance of it. To accomplish this important objective, arid and semiarid countries of the world have resolved to search and devise new ways of planting which bear lower costs of irrigation.

Using hygroscopic polymers in the plantation of saplings is one the novel methods which have been adopted in the recent years. These hydrophilic polymers are capable of absorbing a plenty of water (as much as 100 times their weight) and turn it into a gelatinous material and in water shortage (deficit) and during dry spells, the plant is gradually provided with the water stored in the polymer.

Scientific research on hydrophilic polymers has been initiated since the late 1980s. It was the early 1990s that most countries, particularly those which has vast arid regions such as Africa, South America, the Middle East, and the Far East, got better acquainted with hydrophilic polymers.

Since it is a long time that hygroscopic polymers (Hydrogel) are produced in the world and Iran as well, extensive research have been carried out on them and some of such research findings are striking.

Woodhouse & Johnson (1991) indicates that the endurance of the super absorbent polymers ranges from 2 years for sandy soil structure to 4 years for clay soil structure¹⁰.

The research conducted by Hatterman, et al (1997-1999) showed that when stockosorb polymer is mixed with soil, the more the percentage of such a polymer increases in the soil, the more the moisture storage of the soil will become. Their research demonstrated that in case the polymer was applied to the soil is 4 weight percent, after passage of 17 days, all 45 seeds which had been planted remained alive; as for the mixture of 0.2%, 23 remained alive and as to the control treatment it was 17³.

Ganji, N. (1378) studied the effect of 0, 0.2, 0.1, 0.05, and 0.3 weight percent of the super absorbent polymer PR3005A on some of the physical properties of soil such as water conservation property and porosity of two types of soil textures: loam and sandy loam. The results revealed that, from among the different percentages of the super absorbent

polymer, the 0.3 weight percent was the most effective in enhancing the porosity of the soil. In the sandy loam, the 0.2 and 0.3 weight percent were the most effective in enhancing the total porosity of the soil. With increasing the amount of the polymer applied, moisture conservation capacity of the soils tested was also increased and such an increase was more in sandy loam².

Allahdadi studied the effect of Superab 100 on the growth and efficiency of the field corns in 2002. The results indicated positive effects of the larger amounts of super absorbent on the properties which were under study, especially the height of the field corns and the dry biomass of these plants¹. The aforesaid papers together with the other papers cited in this research all suggest that the effect of Hydrogel on the aliveness of different types of plant species, with regard to their edaphic and climatic conditions, varies to a great degree⁴⁻⁹.

The harmful effects of super absorbent polymers (SAPs) on ecosystem, animals and vegetables are not significantly clear yet and there not side effects evidences up to now. More studies are recommended.

In a city like Tehran, with a population of 10 million and an area of 730 km², with the adverse conditions resulting from air pollution of it, and having semiarid climate, each year different projects are launched in order to plant thousands of saplings whose viability and maintenance require continual irrigation. For instance, during spring and summer they are irrigated more than 30 times. Irrespective of the problems and difficulties involved in irrigating the environs of Tehran – problems that are immensely important and must be studied separately – the volume of the water consumed for this purpose and its ecologic value are of utmost importance for the population and the municipal authorities. Grasping the importance of this problem, the

Municipality of Tehran in collaboration with Kharazmi University, George-August University of Gottingen and Czech University of Life Sciences has launched a joint research project. A test plot was designated for the project in which 8 tree species, in the form of 5 treatments, were planted.

2. Materials and Methods

2.1. The Area under Study

The research was conducted in an area situated at 15 kilometers to the east of Tehran (Figure No. 1). This area lies at 35° 49' 82" longitude and 51° 30' 383" latitude. It is situated at an altitude of 1857 meters; its general aspect is southeastward and the average slope is 12%. By the use of the data which had been collected by the nearest weather station (situated at a 10-kilometer distance of the area under study during the past 50 years) the average rain fall per year was 384 mm. The specifications of the soil are in table 1. This area comprises low hills of limestone formation, semi-deep soil without salinity or alkalinity; there are average amounts of gravels and cobbles both on the surface of and in the depth of the soil and it has sparse bushy vegetation. The soil temperature regime of the area is Mesic. There are parts where the mean annual temperature of the soil is between 8 and 15 degrees Centigrade and the difference of the summer average and the winter one, in a soil depth of 50 centimeters, is over 5 degrees Centigrade. The soil moisture regime of the area is dry xeric and its moisture control regime, in over 90 consecutive days of during 4 months commencing from summer, is dry.

Table 1. Summary of soil specifications

Depth (Cm)	Soil texture	Soil structure	Soil electrical conductivity (EC: d s m-1)	Calcium carbonate (%)e	Phosphor (ppm)	Nitrogen (%)	Potassium (ppm)	pH
0-20	loam	Granular	0.44	11.7	22.8	0.11	620	7.2
20-60	Clay Loam	Massive	0.29	15.8	19.6	0.05	200	7.4
60-110	Sandy Loam	Massive	0.22	19.6	20.8	0.03	40	7.4

Figure 1. the geographical location of the area under study

2.2. The Research Method

8 tree species that are common in the plantings of the city of Tehran, including 4 conifers and 4 broadleaves, were employed in this research. The broadleaved species planted are as follows: Robinia (*Robinia pseudoacaccia*), Ailanthus (*Ailanthus altissima*), Maple (*Acer negundo*), and Olive (*Olea eurpea*); the coniferous species planted are as follows: Pine (*Pinus eldarica*), Thuja (*Thuja orientalis*), Zarbin (*Cupressus arizonica*), and Silver tree (*Cupressus sempervirens*). All of these saplings were two years old and had been grown up in a plantation at 50 kilometers of Tehran (the city of karaj). The plot was 2500 m² in area (50 × 50 meters) and the distance between the saplings is 2 meters and the dimensions of each pit is 35 × 30 × 30 cm. 60 saplings of each species were planted in this plot and the total number of the saplings is 480. 1.5 meter high metal mesh fences were erected around the plot using wooden posts so as to keep livestock and small rodents off the plot.

The hygroscopic polymer utilized in this plot has the trade

name of Super Absorbent A300. Approximately 1250g of this substance was added to 100 liters of water, after being mildly stirred, the gel in question was obtained and, at the time of planting, applied to the soil around the roots of the saplings (Stocksorb A 300 stores hundreds of times its weight in water, on demand, as soil conditions turn dry, nutrient-rich water is released to the plant root zone where it's most needed).

Five treatments were employed in this research as follows:

- Treatment No. 1: mixture of Hydrogel, soil, and sawdust
- Treatment No. 2: mixture of Hydrogel, soil, and manure
- Treatment No. 3: control treatment which only includes the bed-soil without any additional substance
- Treatment No. 4: Hydrogel treatment, in this treatment Hydrogel is the only substance added to the soil
- Treatment No. 5: Hydrogel treatment and cobbles,

this treatment is similar to Treatment No. 4, however, the only dissimilarity is that: after planting, the surface of the soil, especially around the stem of the saplings, is covered with cobbles.

Meteorological equipment was installed in the plot including: pluviometer, minimum thermometer, maximum thermometer, thermometer, and soil thermometer which were placed at a depth of 15 cm. During the growing season accompanied with the warm spell, the status of aliveness of the saplings was measured at some intervals using the following method:

- Succulent saplings
- Semi-succulent saplings
- Saplings which are withering
- Dead saplings

The data collected about the measurement factors were integrated during the research period and, using statistics software such as SPSS, were also analyzed.

3. Data Analysis

Regarding the relative difference which exists during the growing season in the climatic conditions of Tehran, the results obtained from the research were examined in two separate points of time:

3.1. Three Months after Planting

Regarding climatic conditions of Tehran in the spring, there may be intermittent patchy rain during this period which is adequate to help the saplings stay alive. According to the statistics, during this season there was an average rainfall of 350 mm in five times and therefore no irrigation was carried out at this stage of measurement. According to the evaluation conducted until this stage, 71% of the saplings remained alive. Among the tree species planted, Robinia, with 87% aliveness, holds the top rank and the ranks of remaining species in descending order are as follows: Maple, Olive, Zarbin, Pine, Silver Tree, Thuja, and Ailanthus (Figure 2).

The data measured and analyzed in terms of succulence show that Robinia falls into the category of “very succulent”, which outnumbers other tree species with 42% of the very succulent saplings; by contrast, Pine with 15% of very succulent saplings has the fewest number in this regard. Under the category of “succulent”, the number of Maple, with a broad difference from the tree species second to it, is the greatest of all (50%) and Silver tree holds the lowest rank (9%). Under the category of “withered saplings”, Silver Tree and Pine have respectively the most and the least percentage of the saplings (27% vs. 15%). Under the category of “dead saplings” the highest percentage appertains to Ailanthus (38%) and the lowest belongs to Robinia (13%). Table 1 shows the condition of the saplings in the 4 growing states based on the species.

Figure 2. Percentage of the alive and dead saplings after three months of planting

Figure 3. Aliveness situation of the saplings based on the species

3.2. Six Months after Planting

The second growing season (summer) was the beginning of the warm and dry spell during which rainfall lessened to the extent that no rainfall was recorded during this season. During this stage of measurement, when the indications of stress and water deficit emerged on the leaves of the saplings, each sapling was irrigated by 5 liters and the irrigation operations were conducted in five stages. At the end of this dry and warm season the research revealed that 49% of the total saplings became dead and among which percentage Robinia had the least mortality (33%) and Silver Tree had the most mortality (63%) (Figure 4).

Zarbin and Robinia have the maximum number (percentage) of the “very succulent” saplings, but, the minimum number under this category appertains to Pine.

Although a high percentage of the saplings of Silver Tree were dead, a noticeable percentage of the saplings of the species are very succulent. In other words, the number of “withered saplings” and of “succulent saplings” is very small; however, the number of those saplings of this species which fall into the category of “very succulent” is substantial. In the succulent stage Olive as well as Robinia has the largest number and Silver Tree as well as Ailanthus have the smallest number. The frequency of Robinia saplings in each of the “very succulent”, “succulent”, and “withered” stage was the most of all the species and noticeable. In the “withered” stage Maple with 5% has the largest number among the other species. As mentioned earlier, Silver Tree has the smallest number (percentage) at this stage of aliveness.

Figure 4. Percentage of the alive and dead saplings after six months planting

Figure 5. Aliveness of the saplings based on the species

Table 2. Table of analysis of variance which compares all of the treatments in Jajroud after three months of planting

Status	Sum of Square (SS)	Degree of Freedom (df)	Mean Square (MS)	F	P
Between Groups	98.229	4	24.557	21.327	0.000
Within Groups	546.938	475	1.151		
Total	645.167	479

Figure 6. The percentage of the alive and dead saplings in the said treatments after three months of planting

4. Results

4.1. Three Months after Planting

The analysis of the information obtained after three months of planting shows that, statistically, there is a significant difference among the treatments at the statistic levels of 1% and 5%. Comparing Treatment No. 1 with the other treatments indicates that there is a significant statistical difference between this Treatment and the other treatments; however, there is no significant difference between Treatment No. 2 and Treatment No. 4 at this stage but they make a significant difference with the other treatments. Treatment No. 3 (control treatment) has a significant difference with the other treatments and it shows the effect of the other treatments on aliveness of the saplings. Treatment No. 4 has a significant difference with the other treatments, except for Treatment No. 2. Treatment No. 5 is almost the same as other treatments by comparison.

As it has been shown in the above Figure, Treatment No. 1 and Treatment No. 2 are the best treatments at this stage and also are the most effective treatments in terms of aliveness of the saplings after three months of planting. Treatment No. 5 is a little superior to Treatment No. 4 and the difference between them is statistically significant. The condition of the

control treatment shows that approximately 58% of the total saplings planted in this treatment are dead and the remaining 42% of the total saplings managed to survive until this stage of collecting statistics because of the following factors: the soil moisture of winter, patchy rains, and the relatively low temperature of spring.

4.2. Six Months after Planting

The analysis of the information obtained from data analysis at the second phase of statistics collecting shows that there is a generally significant difference among the treatments.

Comparison of Treatment No. 1 with the other treatments indicates a significant statistical difference in them. Comparison of Treatment No. 2 with the other treatments shows that this treatment statistically differs from the other ones except for Treatment No. 4. There is a significant statistical difference between Treatment No. 3 (control treatment) and the rest, except for Treatment No. 4. Treatment No. 4 shows a statistical difference only with Treatment No. 1 and no statistical difference with the rest. Treatment No. 5 shows a statistical difference with Treatment No. 1 as well as Treatment No. 3 and no statistical difference with the others.

Table 3. Table of analysis of variance which totally compares all of the treatments in Jajroud after six months of planting

Status	Sum of Square (SS)	Degree of Freedom (df)	Mean Square (MS)	F	P
Between Groups	90.783	4	22.696	19.997	0.000
Within Groups	539.115	475	1.135		
Total	629.898	479

Figure 7. The percentage of alive and the dead saplings in the said treatments after six months of planting

5. Conclusions

Regardless of the percentage and number of the living and dead saplings, it is particularly noteworthy that the saplings managed to survive the very inhospitable and harsh climatic conditions of 2008 – which has been one of the driest years of Iran for the past 70 years. Although these saplings were irrigated in several stages with a specified volume of water, the endurance and strength of these species in relation to water deficit as well as making use of auxiliary treatments played a key role in protracting their life span. Treatment No. 1 and Treatment No. 2 are the best among the other treatments in this plot. Accordingly, I conclude from this research that utilization of Hydrogel together with other materials such as sawdust and manure has considerable effects on aliveness of the saplings.

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