© 2020 Journal compilation
https://biotaxa.org./mjbs
DOI:10.22353/mjbs.2020.18.15
Volume 18(2), 2020

Mongolian Journal of Biological Sciences

ISSN 1684-3908 (print edition)
MJBS
ISSN 2225-4994 (online edition)

Original Article

The Effect of Different Watering Regimes on the Growth of Trees and Shrubs in Desert Regions of Mongolia

Byambadorj Ser-Oddamba[1,2], Akhmadi Khaulenbek[3], Lunten Janchivdorj[3], Ochirbat Batkhishig[3], Byung Bae Park[1,*] and Nyam-Osor Batkhuu[2,*]

[1]*Laboratory of Silviculture, Chungnam National University, Daejeon 34134, Republic of Korea,*
[2]*Laboratory of Forest Genetics and Ecophysiology, National University of Mongolia,*
Ulaanbaatar 14201, Mongolia,
[3]*Institute of Geography and geoecology, Mongolian Academy of Sciences,*
Ulaanbaatar 15170, Mongolia.

Abstract

Key words: Growth, seedling, irrigation, Greenbelt, Dalanzadgad

Received: 09 Apr. 2019
Accepted: 13 Jan. 2020

***Correspondence:**
batkhuu@num.edu.mn
bbpark@cnu.ac.kr

The selection of tree species resistant to drought, cold, salt and other natural and anthropogenic stressors is important for the success of afforestation processes especially when these take place in desert and semi-desert regions of Mongolia. The seven woody species (*Tamarix ramosissima*, *Ulmus pumila*, *Elaeagnus moorcroftii*, *Hippophae rhamnoides*, *Caragana microphylla*, *Armeniaca sibirica*, *Amygdalus pedunculata*) were grown under four different watering regimes and nine years of continuous monitoring conducted on the growth performances. All measured growth traits (root collar diameter, stem height, and survival rate) showed significant differences between treatments and species. The best performance of stem height and root collar diameter was observed in *T. ramosissima* and *E. moorcroftii* whereas *A. pedunculata* presented be lowest values. *Ulmus pumila*, *E. moorcroftii* and *T. ramosissima* showed the highest survival rate compared with all other species. However, control plants showed a 0% survival rate in 2016. Date presented here suggest that native species are characterized by the best adaptive characteristics compared to non-native species, which species are the best candidates to be used for afforestation processes of desert and semi-deserts areas.

Cite this paper as: Ser-Oddamba, B., Khaulenbek, A., Janchivdorj, L., Batkhishig, O., Park, B. B. & Batkhuu, N. 2020. The effect of different watering regimes on the growth of trees and shrubs in desert regions of Mongolia. *Mong. J. Biol. Sci.*, 18(2): 55–64.

Introduction

Mongolia occupies a large area of 1.565.000 km^2 (52°06'-41°32'N, 87°47'-119°54'E). It could be considered to be primarily a mountainous country mixed with steppe on average altitude of 1580 m above sea level, and with a variation obscillating between 533 and 4355 m a.s.l.. The relief is very complicated with latitudinal climate zones mixed with altitudinal gradients, particularly in the West of the country. Mongolia is placed in the center of the Asian continent and this fact explains its extreme continental climate and very low precipitation regime. The absolute temperatures vary from -50°C in winter to 40°C in summer. The maximum annual precipitation is near 250-300 mm in the north, or at elevations over 3000 m a.s.l, but it decrease to 100-150 mm in the south, to a final value of less than 50 mm normally recorded in the Trans-Altai Gobi deserts (Vostokova *et al*., 1995). Mongolia is the termination of Asia's monsoon climate zone, so about 50-70% of overall precipitations occur during the summer. Thus, in short the specific climatic features of Mongolia are: a) aridity in all regions (particularly in southern and western regions); b) continental climate with extreme period of cold and heat; c) inclusion of the frontier between the Siberian taiga coniferous forests and the Eurasian steppes.

Although population has increased rapidly over the last century its density is still very low, with an overall population of 3.2 million (NSO, 2019). This fact explains why still less than 1% of Mongolia's territory has been converted into farmland with a landscape that remains pristine (Hilbig, 1995; Vostokova & Gunin, 2005). However, an increasing negative environmental degradation is rapidly taking place in the country, and this fact calls for the implementation of a legal and economic national framework which puts together the need of facilitate the social development with a strict respect of the major ecological drivers essential to ensure the protection of Mongolia territory. In fact, the primary mid-term strategies of the Government are timed to protect the native characteristics of the country, to adapt economic leverage for environmental protection, and to increase expenditure aimed to rehabilitate a specific territory on the basis of preliminary ecological and economic assessment procedures.

On the basis of the above considerations, there is no need to further stress the role played by a natural resourse such as water for the conservation of Mongolia territory. Therefore, the need to manage reasonably the use of this natural resource, it requires to understand better the relationship existing between plants (taken as single individual and/or as plant community) and water. Water is a factor essential to enable plant's life and development as it represents both a nutrient carrier and an important factor to enable the photosynthesis process. Plant productivity depeds upon water availability and this explain why crop plants need regular irrigation and even spraying with water. Water deficiency in plants affects negatively a number of vital processes of plant metabolism with consequences on yield at both qualitative and quantitative level (Olszewska *et al*., 2010). However, when considering water stress, it is necessary to consider that this event could depend from both an excel or a shortage of this resource. (Dąbrowska *et al*., 2010; Tavarini *et al*., 2011; Chenafi *et al*., 2013; Razouk *et al*., 2013). At the same extent as water and minerals are also important as water for the process of photosynthesis. From these considerations emerges that more attention should be paid to ensure a reasonable and sustainable water management which includes attention for water management during crop farming (Kang *et al*., 2002).

The adoption of a "limited irrigation" approach in agro-forestry is based on the fact that the level of water available to plants must be put in strict relationship with the need to ensure a good crop growth. Such approach has become more important in recent in years especially in places where water resources are limited. Studies on the effects of limited irrigation show that crop yield can be largely maintained at high rate and product quality can sometimes be improved while substantially reducing the irrigation volume used (Li, 1982; Shan, 1983; Fapohunda *et al*., 1984; Sharma *et al*., 1986; Singh *et al*., 1991; Zhang *et al*., 1999). Desert plants, like any other plants, need water to grow and their survival, which are often at risk especially when they grow in an arid environment despite these plants present often specific morphological and physiological adaptations aimed to limit water losses for transpiration. Desert plants retain moisture in their tissues by limiting water loss through their leaf epidermis. Many plants accomplish this by adapting the size, sheen, or texture of their leaves. Small leaves or spines limit the amount of surface area exposed to the drying heat and in this way they limit their loss of water due to transpiration. *Acacia erioloba, Faidherbia albida, Euclea pseudebenus* and *Tamarix usneoudes* are example plants that reduce the leaf surface to limit loss of water. Typical adaptations are presence of thick cuticles; presence of a pubescence that forms a thicker boundary layer on the leaf surface; presence of sunken stomata; formation of tissues to store succulent (large amounts of water) (Rabas & Martin, 2003). In addition to such features desert plants develop longer roots to reach the groundwater table. Plants absorb water from soil through a tension pressure difference between the water in the soil and the water in the root tissues. The pressure required to exude water from the leaf is defined as the difference water potential between the leaf and its surrounding atmosphere (Savage *et al*., 1983).

The need to protect Mongolia's territory from desertification explains the attempt undergoing in the last decades to afforestate arid and semi-arid lands (Batkhuu *et al.,* 2013). On the basis of all considerations mentioned above, it is clear that the selection of species to be used for the afforestation purposes must look primarily to select plant species that are tolerant to drought, cold, salt and the other natural and anthropogenic stressors. The study presented here aims to investigate the growth performance of a number of tree species which have been selected on the basis of their adaptation to grow in arid regions. In particular, objectives of this study were: 1) to test the efficiency of different watering regimes in ensuring the growth of selected species; 2) to suggest the adaptation of the best tree species as a suitable candidate for a successful afforestation attempt of desert and semi-desert areas of Mongolia

Material and Methods

Experimental site.

The experimental site selected for this research was located at the Korea-Mongolia joint "Greenbelt" plantation established in Dalanzadgad soum, Umnugobi province, 575 km south of Ulaanbaatar, Mongolia (Fig. 2). The geographical position is at 43°36'12″N, 104°21′22″E, with an elevation of 1468 m. The area considered to be in an arid region with a mean annual temperature of 4.5°C (mean temperature in July 20°C, in January -18°C) and average annual precipitation ranging between 100–150 mm. The vegetative season usually starts in May or June in coincidence with the onset of the summer rains and it ceases at the end of September with the first upcoming frost events (The National Agency for Meteorology and Environmental Monitoring of Mongolia). Climate data collected during the research period and average precipitation is 123 mm (Fig. 1b).

The desert region where the experimental site is located presents a high level of degradation due to the car-traffic and livestock grazing pressure. The soil is covered by a feather grass-onion community with pea shrubs and eurotea. The percentage of grass covering the region is around 69.7% with onions (*Allium polyrrhizum, A. mongolicum)* covering 10% of it, whereas 5% is covered by feather grass (*Stipa gobica, S. glareosa)* and 34% is covered by *Oxytropis aciphylla, Convolvulus ammanii, Peganium nigellastrum,* and annual plants as *Artemisia pectinata, Chenopodium aristatum, Earagrostis minor, Pappophorum borealis* (Batkhuu *et al.,* 2012). Soil is classified as Gobi Brown soil. The main characteristics of this soil are: 1) low organic content; 2) alkaline soil reaction; 3) stony sandy loamy texture; 4) a high carbonate content. However, within the experimental fields there is

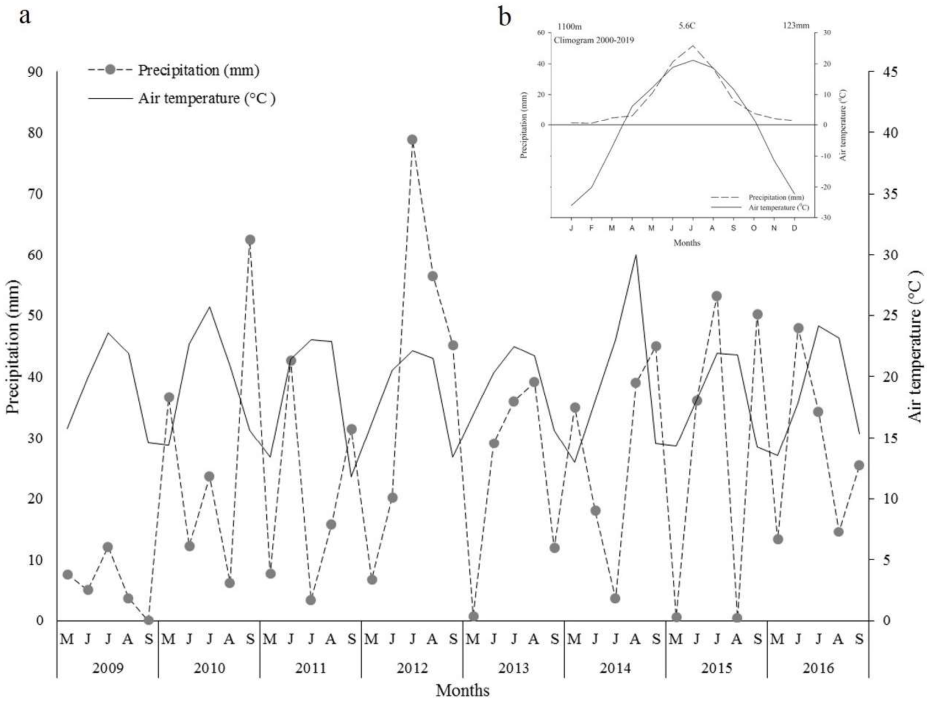

Figure 1. Inner panel (a) Monthly average air temperature and precipitation vegetation seasons the 2009–2016 experimental period; (b) Monthly average air temperature and precipitation for the period 2000-2016.

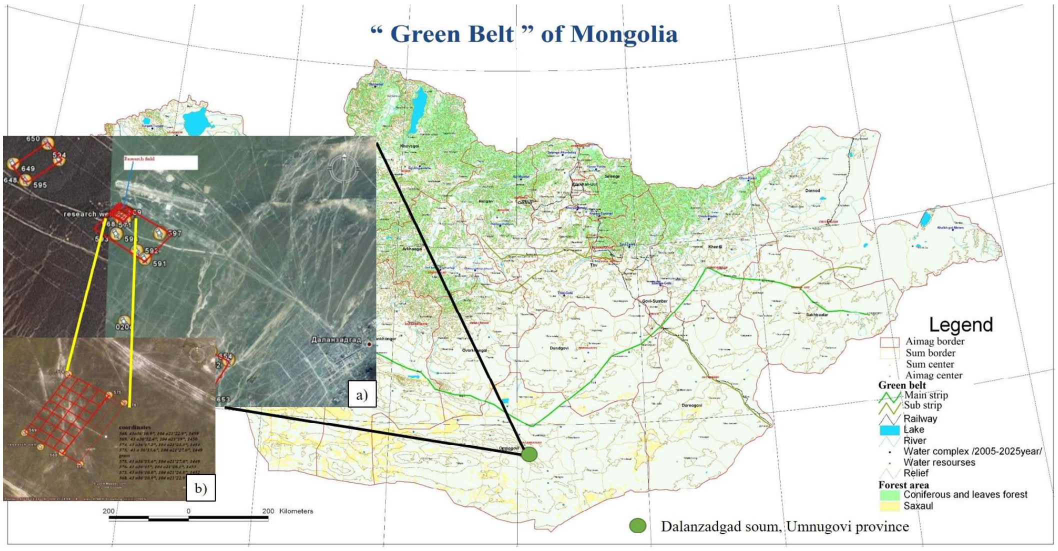

Figure 2. Location of the experimental site: a) Nursery site; b) Tree planted of the experimental site design.

the distinguished occurrence of soil with variable properties in topsoil thickness, presence of stones, and carbonate content (Batkhuu *et al.,* 2012).

Experimental design.

For this experiment we used two-years-old seedlings belonging to seven different species: (*Tamarix ramosissima* L., *Ulmus pumila* L., *Elaeagnus moorcroftii* Wall., *Hippophae rhamnoides* L., *Caragana microphylla* Lam., *Armeniaca sibirica* L., *Amygdalus pedunculata* Pall.) (Table 1). The seedlings grown in the nursery were planted in holes having a size of 60-70 cm of depth and a diameter of 50-60 cm. The holes were filled with a mixture of soil and fertilizer. At time of transplanting sufficient irrigation was given to individual trees with water emitters (Emitter with CNL Compensating Non-Leakage (CNL) Button Dripper) capable of delivering 1 gph (4 lt/-1). Emitters were placed at a distance of 10 cm from seedling axis. Seedlings were irrigated initially until soil stabilization and then drip irrigation treatments were applied according to four different watering regimes: rainfall (control), rainfall+84 mm tree^{-1} yr^{-1} (4l/h watering rate), rainfall+168 mm tree^{-1} yr^{-1} (8l/h watering rate), rainfall+252 mm tree^{-1} yr^{1} (12l/h watering rate). Total area of experimental site measured: 1.75 hectare each plot had a size of 25 x 25 m. Overall number of plots was 28 with a 4 m distance between trees. The distance between tree rows was of 2 m; 36 seedlings were planted in each plot (Fig. 2) (Batkhuu *et al.,* 2013; Ser-Oddamba, 2012).

Growth measurement.

The stem growth was measure as: height (H), root collar diameter (RCD). Measurements were taken at the end of each vegetative season, between 2009-2016. Seedling height (cm) was measured from the RCD to the tip of the young shoot and diameters were measured by using a digital Vernier caliper (Bluebird, NA500-200S, China) (Thompson and Schultz, 1995) at the base

Table 1. Tree and shrub species used for the experiments.

Tree species	Age	Seedling		
		H*	DBH*	LGT*
Tamarix ramosissima Ledeb.	2	83.63	0.77	34.48
Ulmus pumila L.	2	51.35	0.44	37.15
Caragana microphylla (L.) DC	2	40.92	0.34	35.85
Elaeagnus moorcroftii L.	2	52.13	0.53	33.52
Armeniaca sibirica (L.) Lam	2	85.18	0.37	24.71
Amygdalus pedunculata Pall.	2	37.28	0.56	29.03
Hippophae rhamnoides L.	2	39.43	0.38	21.9

Note: H- Average stem height; RCD*- Mean root collar diameter; LGT*- Mean root length;*

of the stem and plant height was measured with a ruler (Basic aluminum Staff TS5-5MD, Korea).

Statistical analysis.

Statistical analysis was computed by using the package SAS version 9.4 software (SAS Institute Inc., Cary, North Carolina, USA). Two-way analysis of variance (ANOVA) with Duncan's multiple range test (DMRT) was used for multiple comparisons.

Results

The statistical analysis conducted on our trait measurements showed that there were significant differences between the tree species, treatments, and tree species x treatment when for both H and RCD were measured over all the duration of the experiment ($p<0.0001$), (Table 2).

Data shown in Table 3 indicated that the seedlings presented a relatively uniform size at the time of planting, whereas considerable differences emerged after eight vegetable seasons with highest values when trees and shrubs were treated with watering regimes (Table 3). In the control seedlings, *T. ramosissima* preseted the highest H value (75.4±2.91 cm) whereas maximum value (0.6 cm) of RCD for this tree species was observed in 2009 (Table 3).

In 2016, the highest H values were found in plants treated with 12l/h watering regime. In particular: *H* values were 8.6% higher than 4l/h whereas RCD was 16% higher in *T. ramosissima*; in *E. moorcroftii* values were 15.7% for H and of 6.5% for RCD higher than 4l/h watering regimes. Also in *A. sibirica* and *H. rhamnoides* values increased of 24.1% for H, and of 49.6% for RCD, 28.8% for H and of 56.4% for RCD under 12l/h watering regime comparing than 4l/h, respectively. Moreover, during the interval from 2009 to 2016, *T. ramosissima's* height were increased by 107% and RCD 154.2% in 12l/h treatment and *E. moorcroftii's* height were increased by 228.4% and RCD 410%, and *A. sibirica's* height were increased by 391.7% and RCD 546.7% comparing than 4l/h watering regime. In *H. rhamnoides*'s H increased of 394.9% and RCD 870%, respectiverly (Table 3).

In *U. pumila*, the highest H value was recorded in plants undergoing a 4l/h watering regimes in 2016, with a 6.7% increment of H in respect to 12l/h. In analogy, also RCD presented an increment of 11.7. In the case of *U. pumila's* treated with 4l/h watering regime in the period 2009-2016, we observed that H values showed a 154% increase in respect to the initial value whereas for RCD the increase was of 533.3% (Table 3).

In *C. microphylla*, the highest H value was recorded in 2016 with 8l/h of watering regime with a 12.6% increment in respect to 4l/h watering regime. In regard of RCD the highest value was observed when 4l/h watering regime was applied with a 3% increament in respsect to the value showed with 12l/h watering regime. Therefore, in the case of *C. microphylla's* value of H between the period 2009 to 2016 increased by 228.4% with 8l/h treatment whereas RCD increased by 410% in 4l/h watering regime.

In *A. pedunculata*, the highest H values were observed in 8 l/h watering regime with an increament of 143.1% from 2009 to 2016 whereas RCD the increment was of 551.1% (Table 3). In our experiment, we made the assumption that the influence of competing vegetation was considered to be of a trascurable level.

At the beginning of experiment (2009), 1008 seedlings were planted and the survival rate (Table 4) was 60% at the end of the first vegetative season (2009). In spring 2010, all dead seedlings were replaced and this fact enabled to obtain an overall survival rate of 53.9% after nine vegetative seasons (last measurement were completed in September 2016). The considerable decrease of survival rate was correlated to the lowest survival rate of *A. pedunculata* (2.1%). In regard of *U. pumila* and *E.*

Table 2. Repeated measures analysis of variance for transformed heights and RCD from all measurement dates, showing sources of variance, degrees of freedom for numerator (DF) and F ratios (F value) and their probabilities (Pr).

Source	DF	H (cm)		RCD (cm)	
		F Value	Pr>F	F Value	Pr>F
Treatment	2	17.76	<0.0001	7.68	0.0005
Species	6	108.19	<0.0001	76.94	<0.0001
Treatment*species	10	1.1	0.3577	6.07	<0.0001

Table 3. Effects of treatments (cont, 12 l/h, 8 l/h, 4 l/h) on H and RCD at three measurement dates (by each species).

		Height, cm							
No	Species	Control		12 l/h		8 l/h		4 l/h	
		2009	2016	2009	2016	2009	2016	2009	2016
1	*T. ramosissima*	75.4±2.91b	-	128.8±6.18a	267.5±8.6a	124.9±6.44a	252.6±10.2a	134.5±5.41a	246.3±8.4a
2	*U. pumila*	29.4±1.96b	-	65.74±3.31b	192.2±7.5c	78.27±2.89c	197.1±6.8bc	80.6b±2.9	205.1±6.8b
3	*C. microphylla*	34.17±2.58b	-	39.5±3.13d	144.1±6.4d	47.4±2.18d	155.7±4.6d	53.01d±2.8c	138.2±3.5d
4	*E. moorcroftii*	58.85±3.71a	-	60.4±2.76c	221.6±5.7b	80.9±2.53c	216.3±6.5b	69.6±3.41c	191.4±5.85c
5	*A. pedunculata*	17±0.0b	-	-	-	31.5±4.2e	76.6±3.8e	-	-
6	*A. sibirica*	-	-	86.25±6.75b	151.3±3.8d	99.4±5.49b	141.9±4.7d	84.6±3.25c	121.9±5.3e
7	*H. rhamnoides*	-	-	37.3±1.77d	184.6±4.91c	41.3±2.38de	171.4±6.1cd	37.8±1.86e	143.23±4.8d

		RCD, mm							
No	Species	Control		12 l/h		8 l/h		4 l/h	
		2009	2016	2009	2016	2009	2016	2009	2016
1	*T. ramosissima*	0.6±0.03a	-	1.29±0.07a	3.28±0.18bc	1.04±0.04a	2.99±0.16b	1.09±0.04a	2.82±0.21b
2	*U. pumila*	0.28±0.02a	-	0.67±0.04bc	5.22±0.23ab	0.69±0.03b	5.1±0.16a	0.9±0.03ab	5.7±0.21a
3	*C. microphylla*	0.3±0.02a	-	0.3±0.03d	2.22±0.24c	0.4±0.02c	2.33±0.14c	0.47±0.02c	2.4±0.14c
4	*E. moorcroftii*	0.43±0.03a	-	0.7±0.04b	4.99±0.17a	0.98±0.04a	5.07±0.28a	1.1±0.26a	4.76±0.23a
5	*A. pedunculata*	0.2±0.0a	-	-	-	0.43±0.1c	2.8±0.5c	-	-
6	*A. sibirica*	-	-	0.62±0.07bc	4.01±0.18ab	0.68±0.04b	3.28±0.14b	0.68±0.04cb	2.68±0.12c
7	*H. rhamnoides*	-	-	0.5±0.03cd	4.85±0.27ab	0.48±0.03c	4.8±0.2a	0.47±0.03c	3.1±0.16bc

Note: Means with different letters are significantly different according to Duncan's Multiple Range Test (DMRT) at 5% level.

moorcroftii, our data show that the highest (100%) survival rates were always observed in 8l/h and 4l/h watering regimes. Independently from the tree species considered, control plants showed a 0% survival rate at the end measurements of 2016 and the lower survival among all the species and the watering regime considered were found in *A. pedunculata*.

Discussion

The growth parameters (H and RCD) measured in this work show the occurrence of differences in the response of the various plant species considered to the different watering regimes tested. These different responses suggest that it exists among the species with different capability to adapt to the same experimental condition. The quantitative and qualitative variations of the trait value measured during the experiment duration indicate also that probably the species-specific adaptation to the experimental condition changes with the time. In particular, our work show clearly when treated with 12l/h watering regime almost all the plant species tested show a very good growth performance with the lowest growth performance occurring with 4l/h watering regime. Thus, our results confirm the data present in literature which indicate that drought is the most important limiting factor of plant growth and productivity (see aslo Alizadeh *et al.,* 2011; Yassir *et al*. 2012; Hussein & Hussein, 1983; Wahba *et al.,* 1990).

In literature it has been suggested that the response of crop tree to water stress and to

Table 4. Survival rate of species, % (by treatment).

№	Species	Control		12 l/h		8 l/h		4 l/h	
		2009	2016	2009	2016	2009	2016	2009	2016
1	*T. ramosissima*	83.3	-	83.3	86	91.7	97.2	100	100
2	*U. pumila*	13.9	-	75	89	100	100	100	100
3	*C. microphylla*	75	-	94.4	42	100	80.6	97.2	86.1
4	*E. moorcroftii*	47.2	-	41.7	94	91.7	100	86.1	100
5	*A. pedunculata*	2.8	-	-	-	11.1	8.3	-	-
6	*A. sibirica*	-	-	22.2	39	88.9	80.6	69.4	72.2
7	*H. rhamnoides*	-	-	33.3	75	91.7	83.3	97.2	77.8
Mean		31.74	0	49.99	60.7	82.1	78.6	78.56	76.6

variations in mineral fertilization depend on several factors, including the species specifity and the tree age. It has been shown that both stresses induce an overall decrease of CO2 assimilation (Šircelj *et al.,* 2007; Alizadeh *et al.,* 2011; Jaroszewska *et al.,* 2011; Xu & Leskovar, 2014) with a decrease in the yield due to a reduction of photosynthesis intensity. Furthermore, it is known that even a small decrease of the water content taking place in leaves in consequence of water shortage in the soil leads to a strong growth inhibition and a consequent decrease in the yield (Starck, 2002; Olszewska & Grzegorczyk, 2013). The data presented here suggest that an early morphological response to drought stress could be responsible for the onset of a avoidance mechanism which affects plant growth as demonstrated by a measurable reduction of H and RCD traits. In fact, the occurrence of a growth reduction has been clearly showed here with data referring to *T. ramosissima*, *E. moorcroftii, A. sibirica* and *H. rhamdoines.* Our results are consistent with numerous previous studies, which report the same type of response in different plant systems (e.g. Amdt *et al*., 2001; Li, 2000; Yin *et al*., 2004; Zhang *et al*., 2004).

Difficult to interpret is the fact that *U. pumila* plants show the highest H value in 4l/h watering regimes instead of 12l/h as all the other plants tested. The indication emerging from this work in regard to *U. pumila* agrees with the suggestion advanced by Park (2015) that this plant is tolerant to cold-, drought- and burial-stresses. Other authors have proved that water use efficiency of *U. pumila* increases under water stress condition (Valladares *et al.,* 2005). Furthermore, Xu and Zhou (2008) showed that an early response to drought stress of this plant was a reduction in leaf area and plant growth with consequent reduction of their transpiration and increase in water use efficiency. The data obtained by us suggest that 15 days watering interval is not enough to induce water stress to the in *U. pumila* seedlings under the non-fertilized condition when they are transplanted in the sand soil. The interpretation is that *U. pumila* seedlings watered every 15 days maintain their growth and photosynthetic performance at least for one vegetative season without the need of any additional nutrient supply.

Seedling survival is a fundamental issue when considering an intervention of afforestation and reforestation (Pinto *et al*., 2011). Some studies reported that plant growth and seedling mortality were correlated with water and nutrient stress (Wei *et al*., 2017). In our work we also found a similar result where seedling survival rate of *U. pumila* increases when we improve the water content in the soil.

All the properties mentioned above in regard of *U. pumila* probably explain why this plant seems to be particularly adapt to live on arid terrain where few other broadleaved trees can survive (Shi *et al*., 2004; Dulamsuren *et al*., 2005; Park *et al*., 2012). For this reason, it seems reasonable to us to candidate this tree species as the most idoneous tree to be used for the rehabilitation of arid and semi-arid areas, where there is the need to combat a danger of desertification advancement (Dulamsuren *et al*., 2004, 2009; Shi *et al*., 2004; Valladares & Sánchez-Gómez, 2006).

Further take-home messages emerge from our work as the need to understand preliminarily what is the effects of watering regimes on plant performance when the use of watering regime is necessary to support an attempt to rehabilitate a land. This type of knowledge is necessary to achieve a more efficient and sustainable use of water in these processes of environmental restoration. Moreover, it emerges also that we cannot overlook the fact that the response of plants to the environmental conditions, especially to the water availability, occurs primarily through the action of root system. Unfortunately in this work we have not examined the response of the root system to watering regimes but it is clear that if we want a complete understanding of their reaction of a plant to different water regimes we need to investigate also the response of the root system. The probable importance of studies concerning the roots emerges in this work when we observe an adaptation of plants to the experimental conditions during the duration of our experiment. An interpretation of this adaptation could be based upon the probable response of the root system which is known to be characterized by a considerable level of plasticity (Grime *et al.,* 1991; Sun & Chen, 2000).

Conclusion

This long term study at the Dalanzadgad soum, Umnugovi province, demonstrated that watering regimes affect a different level growth and survival rate of a number of plant species.

In particular, we demonstrate that plant growth depends directly upon watering regime used. The control plant species survival rate shows that only rainfall is not enough to plant growth in desert area. Date presented here suggest that native species (*T. ramosissima, E. moorcroftii, U. pumila)* are characterized by the interesting adaptive properties to water shortage compared to other non-native species. All these species could be used for afforestation purposes in desert or semi-desert lands. In particular, the better suitability of *U. pumila* to play this role should be considered.

Acknowledgements

This study was supported by the Mongolia-Korea Joint "Greenbelt" Plantation Project, Korea Forest Service, Republic of Korea. We thank members of Laboratory of Forest Genetics and Ecophysiology, National University of Mongolia for their help in field survey and plant material collections, and special thanks for Prof. Donato Chiatante (Department of Biotechnology and Life Science, University of Insubria, Italy), who helped us in revising early draft of this paper and provided valuable advices.

References

Alizadeh, A., Alizade, V., Nassery, L. & Eivazi, A. 2011. Effect of drought stress on apple dwarf rootstocks. *Technical Journal of Engineering and Applied Science*, 1(3): 86–94.

Amdt, S. K., Clifford, S. C., Wanek, W., Jones, H. G. & Popp, M. 2001. Physiological and morphological adaptations of the fruit tree Ziziphus rotundifolia in response to progressive drought stress. *Tree Physiolilogy,* 21: 705–715.

Batkhuu, N., Akhmedi, Kh., Batkhisihg, O., Janchivdorj, L., Bayasgalan, D., Tsagaantsooj, N. & Ser-Oddamba, B. 2013. Report of Korea – Mongolia joint Greenbelt project. 164 pp.

Batkhuu, N., Akhmedi, Kh., Batkhisihg, O., Janchivdorj, L., Bayasgalan, D., Tsagaantsooj, N. & Ser-Oddamba, B. 2012. Report of Korea – Mongolia joint Greenbelt project. 99 pp.

Chenafi, A., Monney, P., Ceymann, M., Arrigoni, E. & Boudoukha, A, 2013. Influence of regulated deficit irrigation for apple trees cv. 'Gala' on yield, fruit quality and water use. *Revue Suisse de Viticulture Arboriculture, Horticulture*, 45(2): 92−101.

Dąbrowska, J., Ropek, M. & Kołton, A. 2010. Wpływ stresu wodnego na aktywność fotosynte-tyczną poisencji (*Euphhorbia pulcherrima Wild. ex Klotzsch*). Proceedings V Krakow Conference of Young Scholars, September 23–25, Krakow, pp. 213−221.

Dulamsuren, C., Kamelin, R. V., Cvelev, N. N., Hauck, M. & Mühlenberg, M. 2004. Additions to the flora of the Khentej, Mongolia, Part 2. *Willdenowia*, 34: 505–510.

Dulamsuren, C., Hauck, M. & Muhlenberg, M. 2005. Ground vegetation in the Mongolian taiga forest-steppe ecotone does not offer evidence for the human origin of grasslands. *Applied Vegetation Science,* 8: 149–154.

Dulamsuren, C., Hauck, M., Nyambayar, S., Osokhjargal, D. & Leuschner, C. 2009. Establishment of *Ulmus pumila* seedlings on steppe slopes of the northern Mongolian mountain taiga. *Acta Oecologica* 35: 563-572.

Fapohunda, H. O., Aina, P. O. & Hossain, M. M. 1984. Water use–yield relations for cowpea and maize. *Agricultural Water Management*, 9: 219–224.

Grime, J. P., Campbell, B. D., Mackey, J. M. L. & Crick, J. C. 1991. Root plasticity, nitrogen capture and competitive. In: Atkinson A, (ed.): Plant Root Growth: An Ecological Perspective. Oxford: Blackwell Scientific Press, pp. 381-397.

Hilbig, W. 1995. The Vegetation of Mongolia. SPB Academic Publishing, Amsterdam.

Hussein, F. & Hussein, F. A. 1983. Effect of irrigation on growth, yield and fruit quality of dry dates grown at Asswan, pp. 168-173. In: *Proceedings of the First Symposium* on *the Date Palm*. Saudi Arabia.

Jaroszewska, A., Podsiadło, C. & Kowalewska, R. 2011. Analiza wykorzystania wody przez wiśnię, wróżnych warunkach wodnych inawozowych. Infrastr. *Ekologia Terenów Wiejskich*, 6: 165−173.

Kang, S., Zhang, L., Liang, X., Cai, X. & Gu, B. 2002. Effects of limited irrigation on yield and water use efficiency of winter wheat in the Loess Plateau of China. *Agricultural Water Management*, 55(3): 203−216.

Li, C. 2000. Population differences in water-use efficiency of *Eucalyptus microtheca* seedlings under different watering regimes. *Physiologia Plantarium*, 108: 134–139.

Li, Y.S. 1982. Evaluation of field soil moisture condition and the ways to improve crop water use efficiency in Weibei region. *Journal of Agronomy in Shaanxi Province*, 2: 1–8.

NSO. 2019. National Statistics office of Mongolia. https://www.en.nso.mn/. [accessed December 2019].

Olszewska, M., Grzegorczyk, S., Olszewski, J.A. & Bałuch-Małecka, A, 2010. Porównanie reak-cji wybranych gatunków traw na stres wodny. Łąkarstwo *w Polsce* (Grassland Science in Poland), 13: 127−136.

Olszewska, M., Grzegorczyk, S. 2013. Oddziaływanie stresu wodnego na wybrane gatunki traw uprawianych na glebie organicznej. *Fragmenta Agronomia*, 30(3), 140−147.

Park, Y. D., Lee, D. K., Batkhuu, N., Jamsran, T., Combalicer, M. S., Park, G. E. & Woo, S. T. 2012. Woody species variations in biomass allocation, photosynthetic WUE and carbon isotope composition under natural drought condition in Mongolia. *Journal of Environmental Science and Management*, Special Issue 1: 29-37.

Park, G. E. 2012. Morphological and Physiological Characteristics of Siberian Elm (*Ulmus pumila* L.) under Various Water Conditions. Doctoral dissertation. Seoul National University. Republic of Korea.

Pinto, J. R, Marshall, J. D, Dumroese, R. K., Davis, A. S., Douglas, R. & Cobos, D. R. 2011. Establishment and growth ofcontainer seedlings for reforestation: A function of stocktype and edaphic conditions. *Forest Ecololgy and Management,* 261: 1876–1884

Rabas, A. R. & Martin, C. E. 2003. Movement of Water from Old to Young Leaves in Three Species of Succulents. *Annals of Botany*, 92(4): 529–536. https://doi.org/10.1093/aob/mcg171

Razouk, R., Ibijbijen, J., Kajji, A. & Karrou, M. 2013. Response of peach, plum and almond to water restrictions applied during slowdown periods of fruit growth. *American Journal of Plant Sciences*, 4: 561−570.

SAS Institute Inc. 2013. SAS® 9.4 Statements: Cary, NC, USA, SAS Institute Inc.

Savage, M. J., Wiebe, H. H. & Cass, A. 1983. In situ field measurement of leaf water potential using thermocouple psychrometers. *Plant Physioligy*, 73(3): 609-13.

Šircelj, H., Tausz, M., Grill, D. & Batic, F. 2007. Detecting different levels of drought stress in apple trees (*Malus domestica* Borkh.) with selected biochemical and physiological parameters. *Scientia horticulturae*, 113: 362−369.

Ser-Oddamba, B. 2012. Species Selection for Reforestation in Arid and Semiarid Regions of Mongolia. (The Effects of watering and Fertilizer). Master Thesis. National University of Mongolia, Ulaanbaatar, Mongolia.

Shan L. 1983. Plant water use efficiency and dryland farming production in Northwest of China. *Newsletters of Plant Physiology*, 5: 7–10

Sharma, P. N. & Alonso Neto, F. B. 1986. Water production function of sorghum for Northeast Brazil. *Agricultural Water Management*, 11: 169–180.

Shi, L., Zhang, Z. J., Zhang, C. Y. & Zhang, J. Z. 2004. Effects of sand burial on survival, growth, gas exchange and biomass allocation of *Ulmus pumila* seedlings in the Hunshandak Sandland, China. *Annals of Botany,* 94(4): 553-560.

Singh, P. K., Mishra, A. K. & Imtiyaz, M. 1991. Moisture stress and the water use efficiency of mustard. *Agricultural Water Management*, 20: 245–253.

Sun, S. C. & Chen, L. Z. 2000. A preliminary study on the ecological responses of seedlings to drought and simulated defoliation in Quercus liaotungensis (in Chinese). *Acta Ecol Sinica*, 2000, 20(5): 893-897.

Starck, Z. 2002. Mechanizmy integracji procesów fotosyntezy i dystrybucji biomasy w niekorzystnych warunkach środowiska. *Zeszyty Problemowe Postepow Nauk Rolniczych*, 481: 111−123.

Tavarini, S., Gil, M. I., Tomas-Barberan, F. A., Buendia, B., Remorini, D., Massai, R., Degl' Inno-centi, E. & Guidi, L. 2011. Effects of water stress and rootstocks on fruit phenolic composition and physical/chemical quality in Suncrest peache. *The Annals of Applied Biology*, 2: 226-233. http://onlinelibrary.wiley.com/doi/10.1111/aab.2011.158.issue-2/issuetoc226−233.

Thompson, J. R., & Schultz, R. C. 1995. Root system morphology of *Quercus rubra* L.

planting stock and 3-year field performance in Iowa. *New Forests*, 9(3): 225–236. https://doi.org/10.1007/BF00035489

Valladares, F. & Sánches-Gómez, D. 2006. Ecophysiological traits associated with drought in Mediterranean tree seedlings: Individual responses versus interspecific trends in eleven species. *Plant Biology,* 8: 688-697.

Valladares, F., Dobarro, I., Sánches-Gómez, D. & Pearcy, R. W. 2005. Photoinhibition and drought in Mediterranean woody saplings: scaling effects and interactions in sun and shade phenotypes. *Journal of Experimental Botany,* 56: 483-494.

Vostokova, E. A. & Gunin, P. D. Eds. 2005. Ecosystems of Mongolia, Atlas. Russian Academy of Sciences, Moscow.

Vostokova, E. A., Gunin, P. D. & Rachkovskaja, E. I. 1995. Ecosystems of Mongolia. Nauka, Moscow. (in Russian)

Wahba, S. A., Abdel Rahman, S. I., Tayal, M. Y. & Matyn, M. A. 1990. Soil moisture, salinity, water use efficiency and sunflower growth as influenced by irrigation, bitumen mulch and plant density. *Soil Technology,* 3: 33- 44.

Wei, J., Liu, G., Liu, D. & Chen, Y. 2017. Influence of irrigation during the growth stage on yield and quality in mango (*Mangifera indica* L). PLoS ONE 12(4): e0174498. https://doi.org/,10.1371/journal.pone.0174498

Xu, Z. & Zhou, G. 2008. Responses of leaf stomatal density to water status and its relationship with photosynthesis in a grass. *Journal of Experimental Botany,* 59: 3317-3325.

Xu, D.I. & Leskovar, C. 2014. Growth, physiology and yield responses of cabbage to deficit irrigation. *Horticultural Science*, 41(3): 138−146.

Yassir, M. I., Amir, B. S., Ali, M. E. & Mohammed, E. 2012. Effect of Irrigation Water Management on Growth of Date Palm offshoots (*Phoenix dactylifera*) under the River Nile State Conditions. *University of Khartoum journal of Agricultral Science,* 20: 275-285.

Yin, C., Duan, B., Wang, X. & Li, C. 2004. Morphological and physiological responses of two contrasting Poplar species to drought stress and exogenous abscisic acid application. *Plant Science,* 167: 1091–1097.

Zhang, H., Wang, X., You, M. & Liu, C. 1999. Water-yield relations and water use efficiency of winter wheat in the North China Plain. *Irrigation Science*, 19: 37–45.

Zhang, X, Zang, R. & Li, C. 2004. Population differences in physiological and morphological adaptations of *Populus davidiana* seedlings in response to progressive drought stress. *Plant Science*, 166: 791–797.

*****