INTERNATIONAL JOURNAL OF PLANT, ANIMAL AND ENVIRONMENTAL SCIENCES

IJPAES

Volume-3, Issue-1, Jan-Mar-2013 ISSN 2231-4490

Coden : IJPAES www.ijpaes.com

Received: 11th Jan-2013 *Revised: 23rd Jan-2013* *Accepted: 25th Jan -2013*

Research article

EVALUATION OF THE PHYSIOLOGICAL AND GROWTH RESPONSE OF *JUNIPERUS PROCERA* HOCHST. EX ENDLICHER TO SOME TYPES OF MICROCATCHMENTS

Ibrahim Mohamed Aref [1]; Hashim Ali El Atta[*1]; Thobayet Alshahrani[1]; Abdul Rahman Alazba[2]; Abdalla Ismail Ahmad[1]

[1]Range and Forestry Applied Research Unit, Dept. of Plant Production, King Saud University, Riyadh, Postal Code 11451, P.O. Box 2460, Saudi Arabia.

[2]Dept. of Agric. Engineering, King Saud University, Riyadh, Postal Code 11451, P.O. Box 2460, Saudi Arabia.

*Corresponding Author: Email: hmabu@ksu.edu.sa Mobile: +966500778916

ABSTRACT: *Juniperus procera* Hochst. ex Endlicher forests and woodlots are the dominant species at ≥ 1600 m.a.s.l. in southwestern Saudi Arabia. The species has been declining progressively in many parts of the world mainly due to drought, increased runoff and soil erosion. This study was designed to investigate the effect of improving rainwater harvesting by some types of microcatchments (repaired terraces and semi-circular bunds) on leaf water potential, chlorophyll content and photosynthetic gas exchange of *J. procera*. The study was carried out for one year in Al Souda National Park (southwestern Saudi Arabia: 18° 17´ 59´´ N 42° 21 47´´ E). Microcatchments constructed were ten terraces repaired by using stones and soil, four semi-circular and four quadrangular bunds in addition to control site with no intervention. After one year leaf water potential, chlorophyll content and gas exchange were measured. The results revealed that *J. procera* growing inside microcatchments had significantly more LWP, chlorophyll a and b, net photosynthetic and respiration rates and stomatal conductance than control. Growth performance of seedlings grown inside microcatchments increased significantly in terms of diameter, height and survival as compared to control.
Keywords: Microcatchments; *Juniperus procera*; Leaf water potential; chlorophyll; Photosynthetic gas exchange.

INTRODUCTION

Juniperus procera Hochst. ex Endlicher are the dominant forest and woodlands species at ≥ 1600 m.a.s.l. in southwestern Saudi Arabia. These forests and woodlands provide wood and non-wood forest products, grazing, beekeeping and protection of watersheds. In such mountainous terrain, terraces have been the means for rainwater harvesting. Like many parts of the world agricultural activities have been practiced in the terraced areas. Most of these terraces were destroyed and abandoned following a shift in the economy probably due to the increasing oil explorations [1]. Consequently, a widespread die-back and general deterioration of *J. procera* have been reported [2] [1]. The frequency of abandoning agricultural land in the Middle East has been increasing. Soil compaction and the limited vegetation cover caused the formation of soil crusts which were characterized with low infiltration and runoff [3]. In *J. procera* National Parks Soil depth decreases dramatically with increasing distance from juniper trees [2]. Terraces are important tools for rainwater harvesting in southwestern Saudi Arabia, whereas their destruction increased soil loss, surface runoff, and bulk density and reduced infiltration. Junipers growing along intact terraces showed better performance [1]. In southeastern Spain terraces increased plant growth by reducing runoff [4]. Middle East and North Africa countries are extremely dry with very limited freshwater [5]. In arid and semi-arid areas the high rate of evaporation usually happens in growing seasons, and characterized by heavy rain-storms which made the soil unable to absorb the large amount of water in such a short period of time which resulted in high surface runoff.

Terracing has been reported as causing positive effects by reducing runoff coefficient and soil loss, and maintaining soil moisture content. Runoff and soil loss in terraces in Likhu Khola drainage basin, Middle Hills, Nepal in the majority were lower than the rates that commonly perceived in other areas in the Middle Hills of the Himalaya [6]. Gradually constructed contour terrace in a hilly terrain in northern China increased crop production by 37.1% [7]. Scarcity of rains and erosion are serious problems threatening plantations in dry climates. This is the exact situation in the Juniper ecosystem in Sarawat Mountains in Saudi Arabia. One of the well established practices in South-eastern Spain for tree planting is terracing in semi-arid climates [4].

Water stress is the single most important environmental problem that critically affects plant growth and development particularly in arid regions [8]. Plant response to water stress is complex and depends on many factors [9] [10].
The objective of the present study was to evaluate the effect of some types of microcatchments on leaf water potential, chlorophyll content, and photosynthetic gas exchange of *J. procera*.

MATERIALS AND METHODS

The Study Area

The study area was selected and demarcated in Al Souda National Park (southwestern Saudi Arabia: 18° 17′ 59′′ N 42° 21 47′′ E). The study area (4 ha) was fenced by iron poles and wire mesh. Al Souda National park (Aseer region) was chosen because it is characterized by heavy yearly traffic including both vehicles and humans especially in summer time (June-September). Apparently there is severe soil compaction, little or nil regeneration by *J. procera*. It also contains abandoned terraces and a wide spread mortality of Juniper trees. As such it represents a good site for intervention and improvement of rainfall harvesting which is the core objective of the current study. Most forests in the study area contained old, abandoned and damaged terraces.

Construction of Microcatchments

Two types of microcatchments were constructed inside the fenced area as means for rainwater harvesting as follows:
Repair of damaged terraces: A total of 10 damaged terraces which have slope angels less than 10º were selected [6]. The selected terraces were treated as follows

- Six were repaired by maintenance of the terrace wall (using stones in the study area), sub-soiled and ploughed.

- Four were left damaged (control).

Construction of semicircular bunds: Four semi circular soil bunds around groups of juniper trees (5-10 trees) were constructed from earth. The radius of the bund was 3-5 m and 0.5-1 m high. Each bund was left open against the direction of the slope to allow entrance of rainwater. Excess water will overflow on the sides when the bunds are fully filled with water. The soil hard crust was broken mechanically. Dead and dying branches of *J. procera* were removed.

Construction of quadrangular bunds

Quadrangular bunds (1 x 1 m) were constructed inside semi-circular bunds. A total of 120 two-year-old *J. procera* seedlings were planted in quadrangular bunds in such a way that the depth of the bund after planting was 20 cm to act as a small catchment. A similar number of seedlings were planted in control area. The seedlings were monitored for one year by the measurement of height, diameter and survival.
Control: The control site was at the immediate vicinity outside the fenced area. No intervention was done and the site was left as it was. It was composed of severely damaged terraces that hardly harvested any rainwater.

Assessment of Leaf Water Potential (Ψw)

Ψw was measured as an indicator to the level of water stress. From each site needle samples were taken from four randomly selected seedlings, saplings, mature and over mature *J. procera*. From each tree needle samples were taken from three branches at different positions (top, middle and bottom). Prior to measurements, needle samples were washed with a small amount of water to remove adhering dust and other contaminants.
Needle samples assigned for water potential measurements were immediately wrapped with well moistened tissue paper and then immediately the samples were kept in tightly closed polythene bags to avoid water loss from the samples and the samples were stored in a fridge until measurements.

Before measuring the needle water potential, samples were abraded with sandpaper on the needle cuticle to speed equilibration and to get more accurate results. Following abrasion, samples were dried with a tissue paper to remove any excess water. Then, leaf water potential was measured by Dew point PotentiaMeter (Decagon devices, Inc., Washington, USA).

Chlorophyll Content

Needle samples of *J. procera* were collected from different microcatchments from trees at different developmental stages (seedlings, saplings, mature and overmature). From each age a small twig consisting of several needles was detached from the leading shoot at the tips of healthy trees. For each sample 100 mg needle tissues were incubated in 2 ml N, N-Dimethylformamide, extra pure solution in a test tube for extraction. Samples were kept in darkness by wrapping with aluminum foil and stored in a fridge for 48 hours. Each sample was then transferred to a cuvette. The Chlorophyll content was measured by using Thermo Scientific GENESYS™ 10 Scanning UV/Visible Spectrophotometer (Genesis 10-S, Thermo Fisher Scientific, Madison, USA). Prior to measurement a blank reading was taken for standardization at 664 nm then chlorophyll a and b were measured at the wave lengths of 664 and 646 nm, respectively for each sample. Chlorophyll content was measured in three replicates for each tree age.

Photosynthetic Gas Exchange

To assess the impact of water stress conditions on the photosynthetic efficiency of the *J. procera* trees photosynthetic gas exchange measurements were performed for plants inside and outside the microcatchments. In each location six plants were randomly selected for each tree age (seedlings, saplings, mature and over-mature trees) from healthy plants. Photosynthetic gas exchange measurements were taken under light conditions (before noon) using a handheld photosynthesis system (CI–Handheld Photosynthesis system, CID, Inc., Camas, U.S.A).In each measurement, a fully-expanded needle at the top of a well-developed twig at the middle of the plant was assigned for gas exchange measurement. The needle was inserted inside the leaf chamber and then photosynthetic gas exchange parameters were measured. These measurements were replicated 5 times/plant/location.

Seedlings performance and survival

Growth parameters and the survival rate of *J. procera* seedlings planted in quadrangular bunds constructed inside semi-circular bunds improved significantly (P = 0.0001) as compared to those planted in the control sites (Table 6) and the values were 7.0 and 4.8 cm for diameter (45.8% increase), and 46.3 and 24.8 cm for height (86.7% increase), respectively. Also the survival rate of seedlings was 86.8 and 55.4% (56.7% increase) in seedlings grown inside semi-circular bunds and in control sites, respectively (Table 6). These results are in line with those of Bastida et al. [4] who reported a better growth of plants in repaired terraces in Spain. This might be attributed to improved chlorophyll content and leaf water potential in microcatchments as compared to control.

Statistical Analysis

Data were statistically analyzed by variance analysis (ANOVA) and T-test and means were separated by LSD test of significance (P=0.05) using SAS statistical package [11].

RESULTS AND DISCUSSION

Leaf Water Potential (Ψw)

Microcatchments significantly (P < 0.0001) increased (Ψw) of needles as compared to control (Table 1). Leaf water potential was -1.79, -1.2, - 2.33 and -5.77 MPa in junipers growing in semi-circular bunds, quadrangular bunds and repaired terraces and control site, respectively (Table 2). Although the problem of decline *of J. procera* has been reported globally, yet no mitigation and/or recovery of these forests and woodlots exist.

The results of the present study showed that rainwater harvesting by microcatchments may contribute significantly to solving this problem. In the present study, microcatchments significantly and positively affected Ψw , chlorophyll content, net photosynthetic and transpiration rates and stomatal conductance of naturally growing *J. procera* in south west Saudi Arabia. In contrast, junipers in the control site recorded severe water stress indicated by the low leaf water potential, comparatively least chlorophyll content, net photosynthetic and transpiration rates and stomatal conductance. The overall result was a significant drop in net photosynthetic rate. The relationship between water and Ψw has been reported by several investigators. A reduction in (Ψw) of Peach as a result of water stress was reported [12]. Moderate and severe water stress (Ψs= –0.51 and –1.22 MPa, respectively) caused a decrease in Ψw of tomato plants and the decrease was more in severely as compared to moderately stressed plants [13].

Table 1. Effect of microcatchments on leaf water potential ANOVA

Source	DF	SS	MS	F value	P
Model	3	94.8	47.4	12.01	0. .0001
Error	137	540.7	3.9		

$R^2 = 15$ %

Table 2. Effect of microcatchments on leaf water potential

Type of catchment	Mean (Ψw) (MPa)
Semi-circular bunds	-1.79 a*
Quadrangular bunds	- 1.2 a
Repaired terraces	- 2.33 a
Control	-5.77b

*Means followed by the same letter are not significantly different at P=0.05

Chlorophyll Content

Chlorophyll a increased significantly (P < 0.0001) in trees in microcatchments as compared to control (Table 3). Mean chlorophyll a was 2.3 mg g^{-1} in needles from juniper trees growing in microcatchments and 2.6 mg g^{-1} in seedlings grown in quadrangular bunds, whereas it was approximately 50% less (1.3 mg $g^{-1)}$ in trees in the control site (Table 4). Similarly, junipers in microcatchments had significantly (P < 0.0001) more chlorophyll b as compared to control (Table 5). Mean chlorophyll b was 1.0, 0.95 and 1.2 mg g^{-1} in needles from juniper trees growing in repaired terraces, semi-circular and seedlings grown in quadrangular bunds, respectively (Table 6), whereas it was approximately 50% less (0.51 mg $g^{-1)}$ in trees in the control site (Table 6). Chlorophyll reduction results are in line with those of other investigators. A reduction of chlorophyll content of *Withania somnifera* (medicinal plant) occurred due to water stress [14]. However, treatment of stressed plants with mycorrhiza increased chlorophyll content. Water stress caused reduction in total chlorophyll and protein content of rain fed rice [15]. Drought stress significantly decreased chlorophyll a, chlorophyll b and total chlorophyll content of three cultivars of chickpea [16]. Gholamin and Khatnezhad [17] investigated the effect of drought stress on chlorophyll fluorescence and chlorophyll content of leaf in five maize genotypes. The authors showed that drought had reduced chlorophyll content and fluorescence as well as grain yield. Chlorophyll content was reduced by varying degrees in *Avena* species cultivars as a result of moisture stress at vegetative and flowering stages [18]. Water stress also significantly reduced chlorophyll a, chlorophyll b, total chlorophyll and net photosynthesis of oriental lily plants [19].

Table 3. Effect of microcatchments on chlorophyll a content ANOVA

Source	DF	SS	MS	F value	P
Model	3	23.3	11.65	58.12	0.0001
Error	99	19.85	0.20		

$R^2 = 54$ %

Table 4. Effect of microcatchments on chlorophyll a content

Type of catchment	Mean chlorophyll a mg g^{-1}
Repaired terraces	2.3 a*
Semi-circular bunds	2.3 a
Quadrangular bunds	2.6 a
Control	1.30 b

*Means followed by the same letter are not significantly different at P=0.05

Table 5. Effect of microcatchments on chlorophyll b content ANOVA

Source	DF	SS	MS	F value	P
Model	3	5.09	2.54	32.57	0.0001
Error	99	19.85	0.20		

R^2 = 40 %

Table 6. Effect of microcatchments on chlorophyll b content

Type of catchment	Mean chlorophyll a mg g^{-1}
Repaired terraces	1.0 a*
Semi-circular bunds	0.95 a
Quadrangular bunds	1.2 a
Control	0.51 b

*Means followed by the same letter are not significantly different at P=0.05

Photosynthetic Gas Exchange

Net photosynthetic rate: The results showed that junipers grown in microcatchments produced significantly (P = 0.001) more net photosynthesis on average (1.58 µmol m^{-2} s^{-1}) than Junipers in the control site (0.29 µmol m^{-2} s^{-1}) (Table 7).

Transpiration rate: Similarly transpiration rate was significantly (P = 0.0001) more in junipers grown in microcatchments (0.38 mmole m^{-2} s^{-1}) than in those in control (0. 09 mmole m^{-2} s^{-1}) (Table 8).

Stomatal conductance: Stomatal conductance was significantly (P = 0.0001) higher (6.10 mmole m^{-2} s^{-1}) in junipers grown in microcatchments than in those in control (1.41 mmole m^{-2} s^{-1}) (Table 9). Water deficit was reported to reduce stomatal conductance and net photosynthetic rate of common bean [20]. It has been established that plant growth performance is greatly influenced by shortage of water [21]. The reduction in net photosynthesis was attributed to stomata closure in water stressed *Incarvillea delavayi* plants [22]. Also water stress may increase oxygenase activity of RuBP carboxylase/oxygenase (Rubisco) leading to a reduction in carboxylation efficiency. Bendevis [23] found that gas exchange of both Ashe juniper (*Juniperus ashei* Bucholz) and live oak (*Quercus virginiana* P. Mill.) declined as a result of water limitation on Edwards Plateau, Texas and that juniper was more affected than oak. Drought stress caused a decrease in transpiration rate as well as net photosynthesis with an overall reduction in total biomass of *Populus davidiana* seedlings [7]. Reduced leaf stomatal conductance and transpiration rate with a consequent decline in photosynthetic rate were reported in Soybean (*Glycine max*) [24].

Table 7. Effect of microcatchments on net photosynthesis

Type of catchment	Mean net photosynthesis (µmol m^{-2} s^{-1})	T-value	P
Microcatchments	1.38	3.77	0.001
Control	0.29		

Table 8. Effect of microcatchments on transpiration rate

Type of catchment	Mean transpiration rate (mmole m^{-2} s^{-1})	T-value	P
Microcatchments	0.38	5.06	0.0001
Control	0.09		

Table 9. Effect of microcatchments on stomatal conductance

Type of catchment	Mean stomatal conductance (mmole m^{-2} s^{-1})	T-value	P
Microcatchments	6.1	5.59	0.0001
Control	1.4		

Table 10. Growth performance and survival of *J. procera* seedlings

Location	Mean diameter (cm)	Increase (%)	T-value	P
QSCB*	7.0	45.8	11.0	0.0001
Control	4.8			
	Mean Height (cm)			
QSCB	46.3	86.7	7.4	0.0001
Control	24.8			
	Seedlings survival (%)			
QSCB	86.8	56.7		
Control	55.4			

*Quadrangular inside semi-circular bunds

Seedlings performance and survival

Growth parameters and the survival rate of *J. procera* seedlings planted in quadrangular bunds constructed inside semi-circular bunds improved significantly (P = 0.0001) as compared to those planted in the control sites (Table 10) and the values were 7.0 and 4.8 cm for diameter (45.8% increase), and 46.3 and 24.8 cm for height (86.7% increase), respectively. Also the survival rate of seedlings was 86.8 and 55.4% in seedlings grown inside semi-circular bunds and in control sites (56.75 increase), respectively (Table 6). These results are in line with those of Bastida et al. [4] who reported a better growth of plants in repaired terraces in Spain. This might be attributed to improved soil and water conservation in microcatchments.

CONCLUSIONS

In conclusion, microcatchments improved the physiological performance of *J. procera* as indicated by a significant increase in Ψw, chlorophyll content, net photosynthetic and transpiration rates and stomatal conductance as compared to control.Also seedlings growth (diameter and height) and survival increased remarkably.

ACKNOWLEDGEMENT

The authors are much indebted to the National Plan for Sciences Technology and Innovation for sponsoring this study as part of Project No. 09-WAT 668-02. Special thanks to Ahmed Al-Khazim, Director of the programme, King Saud University, Kingdom of Saudi Arabia.

REFERENCES

[1] El Atta HA and Aref IM. 2010. The effect of terracing on rainwater harvesting, regeneration and growth of Juniperusus procera Hochst. ex Endlicher on the Sarawat mountains in south western Saudi Arabia. Inter. J.Biodiv.Conserv. 1(5): 119-128.

[2] Barth H J and Strunk H. 2000. The dieback phenomenon of Juniperus procera at the Al Souda family park. Report to Deutsche Forschungs Gemeinschaft (DFG), National Commission for Wildlife Conservation and Development (NCWCD). Riyadh.

[3] Lesschen J P, Cammeraat L H and Nieman T. 2008. Erosion and terrace failure due to agricultural land abandonment in a semi-arid environment. Earth Surf. Proc. 33 (10): 1574 – 1584.

[4] Bastida F, Moreno JL, Hernández T and García C. 2007. The long-term effects of the management of a forest soil on its carbon content, microbial biomass and activity under a semi-arid climate. Appl. Soil Ecol. 37 (1-2): 53-62.

[5] Qadir MA, Bahri T, Sato A and Al-Karadsheh E. 2010. Wastewater production, treatment, and irrigation in Middle East and North Africa. Irrig.Drain.Sys. 24:37–51.

[6] Gardner RAM and Gerrard AJ. 2003. Runoff and soil erosion on cultivated rainfed terraces in the Middle Hills of Nepal. Appl. Geog. 23:23-45.

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

[8] Boyer JS. 1982. Plant productivity and environment. Sci. 218: 443 – 448.

[9] Bray EA. 1997. Plant responses to water deficit. Trends Plant Sci. 2 (2): 48 – 54.

[10] Chaves MM, Pereira JS, Maroco J, Rodriues M.L. Ricardo, CPP, Osorio ML, Carvalho I and Faria T. & Pinheiro C. 2002. How plants cope with water stress in the field: Photosynthesis and growth. Annal. Bot. 89: 907 – 916.

[11] SAS. 1997. SAS Institute Inc., Cary, North Carolina. [12] Steinberg SL, Mcfarland MJ and Mille JC. 1989. Effect of Water Stress on Stomatal Conductance and Leaf Water Relations of Leaves Along Current-Year Branches of Peach.

[13] Zgallaï H, Kathy S and Raoul L. 2006. Effects of different levels of water stress on leaf water potential, stomatal resistance, protein and chlorophyll content and certain anti-oxidative Enzymes in tomato plants. J. Integ. Plant Biol. 48(6): 679–685

[14] Haripriya M, Vijaya T and Mouli KC. 2010. Effect of water stress on growth, metabolic activities of Withania sominefera-an important phytoceutical plant: Ameliorative effects of VAM. J. Global Pharm. Tech. 2(3): 112-116.

[15] Sikuku PA, Netondo GW, Onyango JC and Musyimi DM. 2010. Chlorophyll fluorescence, protein and chlorophyll content of three Nerica rain fed rice varieties under varying irrigation regimes. ARPN J. Agric. Biol.l Sci. 5 (2): 19-25.

[16] Mafakheri AB, Siosemardeh PC, Bahramnejad Y, Struik T and Sohrabi S. 2010. Effect of drought stress on yield, proline and chlorophyll contents in three chickpea cultivars. Australian J. Crop Sci. 4(8): 580-585

[17] Gholamin R and Khayatnezhad M. 2011. The effect of end season drought stress on the chlorophyll content, chlorophyll fluorescence parameters and yield in maize cultivars. Sci. Res. Essay 6 (25): 5351 – 5357.

[18] Pandey HC, Baig MJ and Bhatt RK. 2012. Effect of moisture stress on chlorophyll accumulation and nitrate reductase activity at vegetative and flowering stage in Avena species. Agric. Sci. Res. J. 2(3): 111-118.

[19] Zhang YJ, Xie ZK, Wang YJ, Su PX, An LP and Gao H. 2012. Effect of water stress on leaf photosynthesis, chlorophyll content, and growth of oriental lily. Russian J. Plant Physiol. 58(5): 844-850.

[20] Santos MG, Ribeiro RV, Machado EC and Pimentel C. 2009. Photosynthetic parameters and leaf water potential of five common bean genotypes under mild water deficit. Biol. Plant. 53 (2): 229-236

Australian J. Plant Physiol. 16(6): 549 – 560

[21] Xu Z, Zhou G and Shimizu S. 2010. Plant responses to drought and rewatering. Plant Sig. Behav. 5 (6): 649 – 654

[22] Cai YF, Zhang SB, Hu H and Li SY. 2010. Photosynthetic performance and acclimation of Incarvillea delavayi to water stress. Plant Biol. 54 (1): 89 – 96.
[23] Bendevis MA. 2006. Comparison of photosynthetic responses of Ashe juniper and live oak on the Edwards Plateau, Texas. Master's thesis, Texas A&M University.
[24] Ohashi YN, Nakayama H, Saneoka T and Fujita K. 2006. Effects of drought stress on photosynthetic gas exchange, chlorophyll fluorescence and stem diameter of soybean plants. Biolo. Plant. 41:133–137