

Effects of film-bottomed treatment on seedling emergence and growth of *Caragana korshinskii* in arid northwestern China

X. Zhou¹, Y. Yan¹, Ch. Wan³, H. Wang⁴, L. Wu⁴, Y. Wang⁵, J. Ren²

¹Forest Inventory and Planning Institute of Gansu Province, Lanzhou, P.R. China

²College of Pastoral Agriculture Science and Technology, Lanzhou University, Lanzhou, P.R. China

³Department of Natural Resources Management, Texas Tech University, Lubbock, Texas, USA

⁴Forestry College of Gansu Agricultural University, Lanzhou, P.R. China

⁵Jing Tai Station of Desert Control, Gansu province, P.R. China

ABSTRACT

A field study was conducted to study the effectiveness of film-bottomed treatment (FBT) on the seed germination and seedling establishment of *Caragana korshinskii* Kom. in the arid Hexi Corridor of northwestern China in 2007 and 2008. The experiment involved three different depths of film-bottomed treatments (DFBT) (80, 90 and 100 cm) and a control with twelve replications in each treatment. Soil moisture, seedling emergence percentage, leaf characteristics, shoot height, main root length, basal diameter, biomass, biomass allocation, as well as root system distribution, were studied and were found to be significantly higher with FBT in respect to the check (CK) values. Soil moisture content increased with depths of film-bottomed treatments. Our study demonstrates that *C. korshinskii* can be grown successfully using FBT in arid areas and 90 cm DFBT gives the maximum growth-promoting effect.

Keywords: arid area; *Caragana korshinskii* Kom.; film-bottomed treatment; Hexi corridor; northwestern China

Shrub shelterbelt is an important element of man-made oasis ecosystems in arid northwestern China, where the ecological environment is fragile and blown sand is a serious hazard (Evans and Thames 1981, Zhang 1999). In the most part of the Hexi Corridor of China, surface and groundwater resources are often either unavailable or too saline and brackish for irrigation. Precipitation is the major water source for plant growth. Annual precipitation in this region ranges from 183.6 to 157.3 mm, with 70% falling between June and September. Water availability is a crucial factor in the establishment of oasis ecosystems (Evans and Thames 1981, Zhang 1999). Furthermore, most sandy soils in this region have low water- and nutrient-retention capacities (Tao and Ren 2004, Zhou et al. 2007). Loss of water and

nutrients from soil also influences revegetation process (Guo et al. 2007).

Caragana korshinskii is a drought resistant shrub widely used for vegetation rehabilitation in arid regions of China as: (i) it facilitates transition from shifting dune to sandy grassland; (ii) it helps restore soil nutrients by fixing atmospheric nitrogen; (iii) it can form shrub shelterbelts for farmland or artificial grassland; and (iv) it can serve as a supplementary source for livestock (Hansson et al. 1995). Due to scarce precipitation and dry climate, the establishment and growth of *C. korshinskii* is often impaired by water shortage (Li et al. 2006). The film-bottomed planting method, using plastic film as a leak-proofing material under sandy soil, can effectively alleviate soil water stress, keep soil from puddling

Supported by The Global Environment Fund Program of China, Project No. GEF-0P-12.

and packing together, and prevent loss of water and nutrients (Tao and Ren 2004, Zhou et al. 2007). In this study, the effects of FBT on the seed germination and growth of *C. korshinskii*. The optimum depth of FBT for establishment of *C. korshinskii* shelterbelts is also determined.

MATERIALS AND METHODS

Study site. The study was carried out at the Experimental Station of the State Key Laboratory of Arid Agro-ecology, Gansu Agriculture University, on the southern fringe of the Tengger Desert (37°26'N, 103°45'E, 1665 m above sea level), a transitional zone between desert and oasis. The climate is arid with annual precipitation of 183.6 mm, mean annual temperature of 8.2°C, the mean annual effective accumulated temperature of 2988.7°C, and mean annual wind velocity of 3.5 m/s, the average daily evaporation during the time of experiment was 3038.5 mm. The soil is sandy, being classified as Gray Desert soil (Xiong and Li 1987) with low organic matter content. Total nitrogen (N), total phosphorus (P), available P and K, and water-soluble salinity are shown in Table 1 (Zhou et al. 2007).

Field layout and experimental details. A field experiment was conducted during the 2007 and 2008 growing seasons (from April to October). *C. korshinskii* was sown on April 10, 2007 at a sowing rate of 36 seeds/m² (sowing width 15 cm × spacing 15 cm). The experiment consisted of three levels of DFBT (80, 90 and 100 cm) and a check (CK) with twelve replications for each treatment.

FBT was applied in each treatment plot, which was situated in the middle of a cropland. Each treatment plot was 20 × 20 m, divided into subplots of 4 × 4 m. A treatment plot was established by digging a 20 × 20 m pit, with all residual roots,

and then lining the bottom and sidewalls of the pit with a plastic film (0.05 mm thick) before backfilling the pit with the original sandy soil (Tao and Ren 2004, Zhou et al. 2007). At the same time, the subplots were separated from one another by a buffer strip 1 m wide, and there was a similar buffer strip 0.5 m wide. Before sowing, fungicides and insecticides were applied for disease and insect control, and weeds were manually removed throughout the growing season. At 30 days after seedling emergence of *C. korshinskii*, many seedlings were died. Through soil test and plant diagnosis, the soil nutrition scarcity resulted in the seedling death, because the sandy soil has lower total N and P, and available P and K. Thus, the additional fertilization was supplied at different levels and the minimum amount of fertilizer application obtained. Therefore, 50 kg P/ha, 25 kg K/ha and 40 kg N/ha were applied manually to all subplots.

Soil moisture content. During the experimental period, neutron probe access tubes (Frequency Domain Reflectometry (FDR) ATS1 PR1/4, Delta-T Devices Ltd., UK) with a diameter of 4 cm were installed in the center of each subplot to the depth of 60 cm. Soil moisture content was measured with a FDR Profile Probe on 5 consecutive days at 4 day-intervals. The neutron probe access tubes were installed at each subplot from 5 cm to 60 cm below soil surface, using a 10 cm interval for the depths of 0 to 20 cm and 20 cm interval for the depths of 40–60 cm.

Seedling emergence percentage and growth characteristics. In the present study, the effect of FBT on seedling emergence percentage was investigated by counting the emergence number of seeds germinated 14 days after sowing (DAS).

All plants were harvested and separated into root and shoot in 60 DAS and 150 DAS. The root

Table 1. Some chemical characteristics of soil (0–60 cm depth) at the experimental site in 2007

Soil characteristics	Value
pH (CaCO ₃)	7.8
Organic matter (%)	2.61
Total N (g/kg)	0.27
Total P (g/kg)	0.65
Available P (mg/kg)	3.08
Available K (mg/kg)	4.62
Water-soluble Cl (%)	0.21

Table 2. LSD multiple comparison test of soil moisture content between different DFBT and CK for two growing seasons in the Hexi Corridor

	X ₃	X ₂	X ₁	CK
X ₃		0.252	0.0001	0.0001
X ₂			0.0001	0.0001
X ₁				0.0008
CK				

DFBT – depth of film-bottomed treatment; X₁ – 80 cm DFBT; X₂ – 90 cm DFBT; X₃ – 100 cm DFBT; CK – check

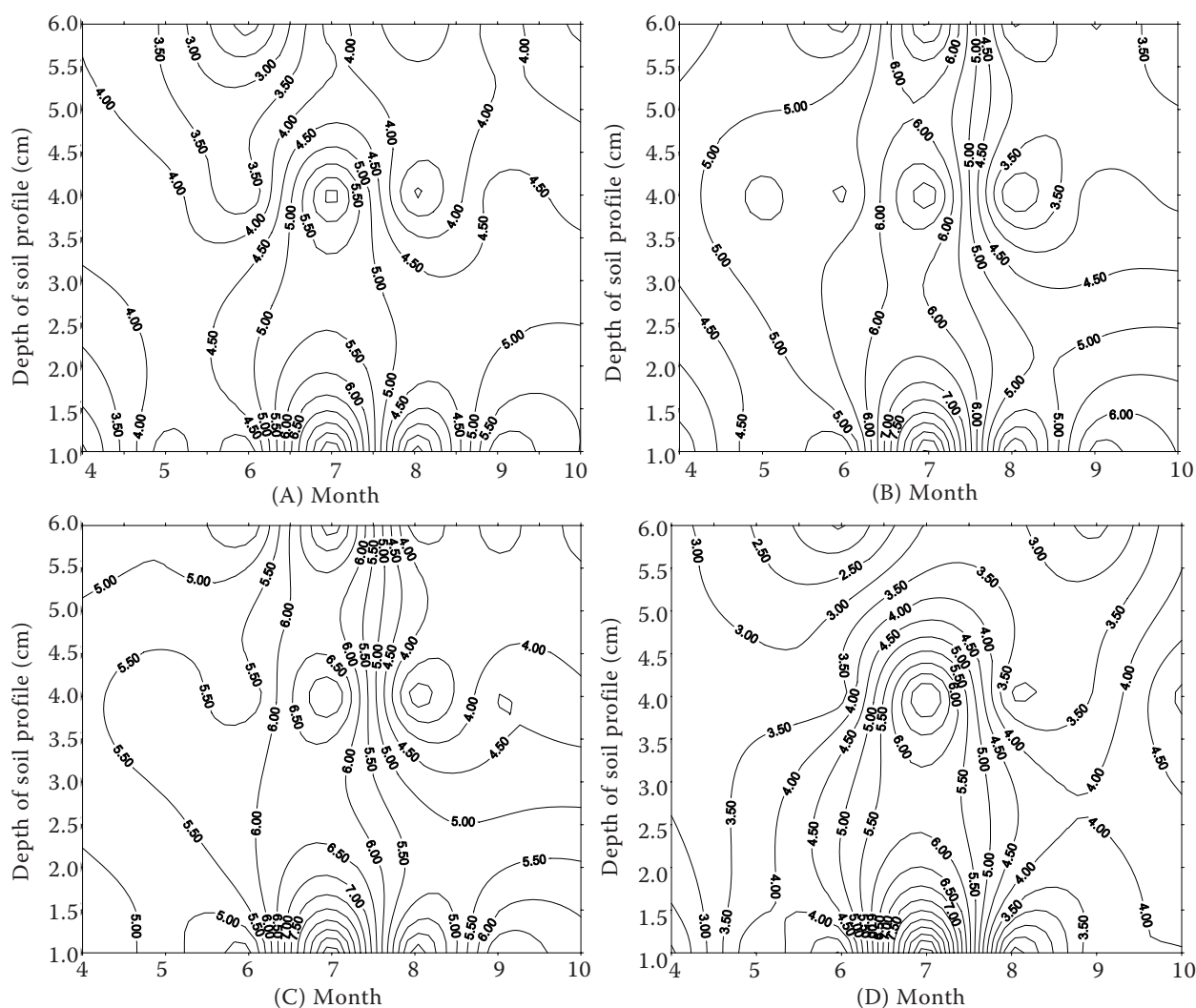


Figure 1. Contour plot of mean soil moisture content of treatment plots in 2007 and 2008. (A) 80 cm DFBT; (B) 90 cm DFBT; (C) 100 cm DFBT; (D) the check plot

material was separated according to soil depths of 0 to 10, 10 to 20, 20 to 40 and 40 to 60 cm. The fresh weight of shoot and root was determined soon after destructive harvesting. To obtain the dry biomass, the fresh root and shoot were oven-dried at 85°C for 48 h and then weighed. The distribution parameters of dry biomass were calculated according to Beadle (1993).

Leaf area was measured by Laser Area Meter CI-203 (CID, Inc., USA). Leaf area ratio and leaf area index (LAI) were calculated, according to Hughes and Freeman (1967).

Statistical analyses. The statistical analysis software SAS (SAS Institute, 2001) was used to analyze the data. The ANOVA procedure was used to evaluate the significance of each treatment on germination rate and growth of *C. korshinskii* in a randomized complete block design with twelve replications. Treatment means were separated

by the least significance difference (LSD) test. All significant differences are reported at the $P = 0.0001$ level.

RESULTS

Soil moisture content. Soil moisture declined during *C. korshinskii* growth season from April to October (Figure 1) (Surfer V5.0.1). However, FBT retarded water loss through reduced soil percolation and significantly improved soil water content when compared with CK (one-way ANOVA: $F_3 = 30.011$, $P < 0.0001$). Significant difference in water content was found among all treatment comparisons except for comparison between 90 cm and 100 cm DFBT (Table 2).

Seedling emergence percentage. FBT improved the seedling emergence percentage of *C. korshinskii*

Table 3. Seedling emergence percentage of *C. korshinskii* determined by ANOVA in 2007 and 2008

Year	DFBT			CK	F-value	P
	X ₁	X ₂	X ₃			
2007	41.57 ^c	62.01 ^a	58.52 ^b	20.54 ^d	81.26	0.0000
2008	34.06 ^c	54.76 ^b	56.11 ^a	15.76 ^d	47.80	0.0000
Mean	37.81 ^c	58.37 ^a	57.31 ^b	18.15 ^d	69.01	0.0000

DFBT – depth of film-bottomed treatment; For each component the mean values with the same superscript letters among species are not significantly different at 1% level of probability ($n = 360$); LSD – multiple comparison test; X₁ – 80 cm DFBT; X₂ – 90 cm DFBT; X₃ – 100 cm DFBT; CK – check

through increased soil water availability. Compared with CK, mean emergence percentage of *C. korshinskii* in 80 cm, 90 cm and 100 cm DFBT increased by 19.66%, 40.22% and 39.16%, respectively (Table 3). The emergence percentage was also significantly different among various DFBT. The highest emergence percentage in 2007 was observed at 90 cm DFBT ($F_3 = 81.26$, $P < 0.0001$); while the highest

emergence percentage in 2008 was at 100 cm DFBT ($F_3 = 47.80$, $P < 0.0001$).

Leaf characteristics. Leaf characteristics also differed among the treatments (one-way ANOVA: leaf number: $F_3 = 86.94$, $P < 0.0001$ at 60 DAS, $F_3 = 185.42$, $P < 0.0001$ at 150 DAS; leaf area: $F_3 = 35.41$, $P < 0.0001$ at 60 DAS, $F_3 = 167.80$, $P < 0.0001$ at 150 DAS; leaf area ratio $F_3 = 110.09$,

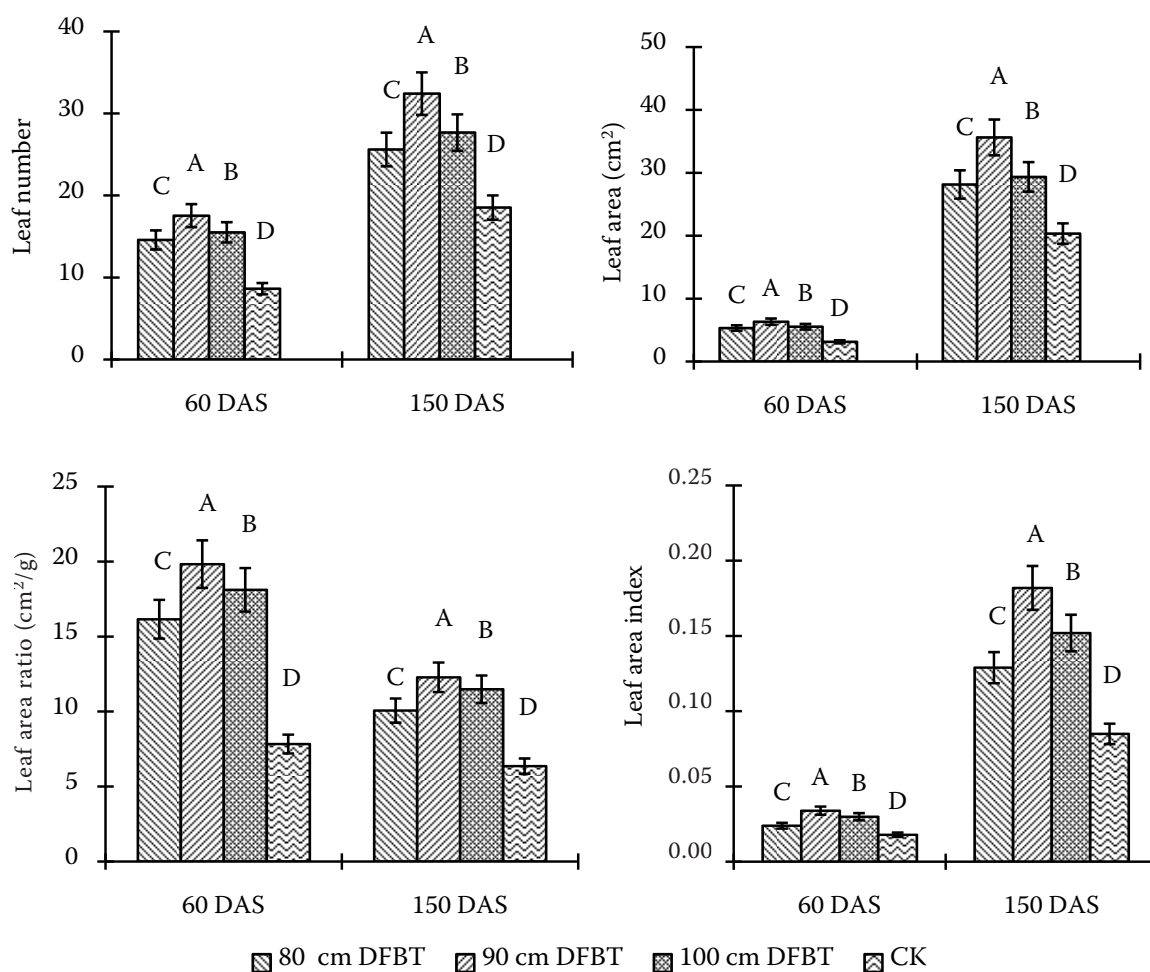


Figure 2. Changes in leaf characteristics of *C. korshinskii* with DFBT. Boxes represent means and error bars represent ± SE of the means ($n = 480$). Values with different letters are significantly different at the 0.0001 level (LSD – multiple comparison test)

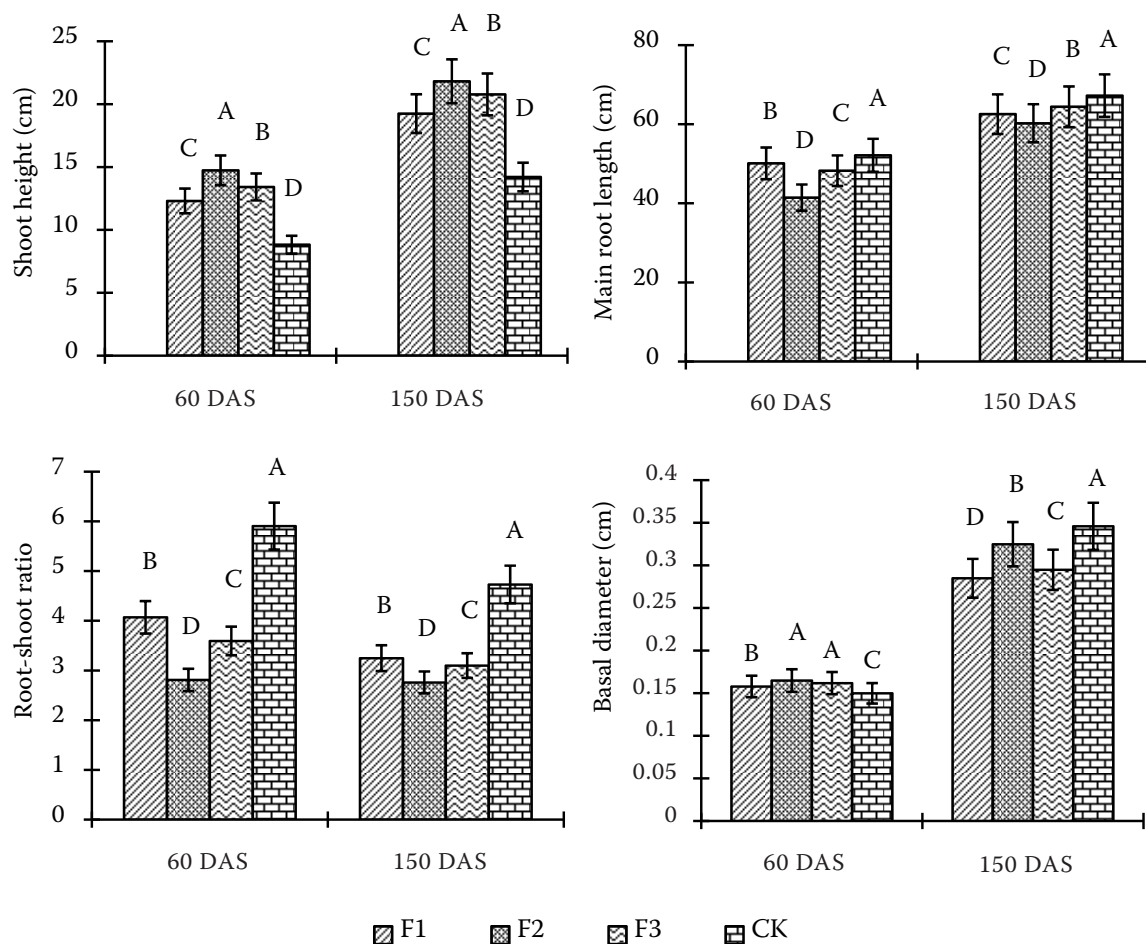


Figure 3. Seedling height, main root length, root-shoot ratio and basal diameter of *C. korshinskii* with DFBT. Boxes represent means and error bars represent \pm SE of the means ($n = 480$). Values with different letters are significantly different at the 0.0001 level (LSD multiple comparison test)

$P < 0.0001$ at 60 DAS, $F_3 = 3944.240$, $P < 0.0001$ at 150 DAS; LAI: $F_3 = 42.51$, $P < 0.0001$ at 60 DAS, $F_3 = 158.32$, $P < 0.0001$ at 150 DAS). Leaf number, leaf area, leaf area ratio and LAI of *C. korshinskii* were the highest at 90-cm DFBT among all treatments (Figure 2).

Shoot height, main root length, root-shoot ratio and basal diameter. Compared with CK, FBT had a marked effect on shoot height, main root length, root-shoot ratio and basal diameter of *C. korshinskii*. Furthermore, shoot height, main root length, root-shoot ratio and basal diameter were significantly different among all treatments (one-way ANOVA: shoot height: $F_3 = 86.15$, $P < 0.0001$ at 60 DAS, $F_3 = 94.96$, $P < 0.0001$ at 150 DAS; main root length $F_3 = 58.61$, $P < 0.0001$ at 60 DAS, $F_3 = 46.63$, $P < 0.0001$ at 150 DAS; root-shoot ratio $F_3 = 206.38$, $P < 0.0001$ at 60 DAS, $F_3 = 92.45$, $P < 0.0001$ at 150 DAS; basal diameter $F_3 = 58.27$, $P < 0.0001$ at 60 DAS, $F_3 = 160.58$, $P < 0.0001$ at 150 DAS).

FBT significantly increased the shoot height and basal diameter as compared to CK, and the largest shoot height and basal diameter always occurred with 90 cm DFBT at 60 DAS and 150 DAS. In contrast, the largest main root length and root-shoot ratio were always found at CK during the study period (Figure 3).

Biomass. FBT significantly increased shoot dry weight and total weight. The maximum always occurred at 90-cm DFBT, while the minimum always occurred at CK (Figure 4).

Each biomass parameter varied with a similar pattern among different treatments (Figure 4). Following are the summaries for the data set ($n = 280$) during the *C. korshinskii* growing season: shoot dry weight: $F_3 = 78.19$, $P < 0.0001$ at 60 DAS, $F_3 = 84.29$, $P < 0.0001$ at 150 DAS; root dry weight: $F_3 = 110.58$, $P < 0.0001$ at 60 DAS, $F_3 = 63.29$, $P < 0.0001$ at 150 DAS; total weight: $F_3 = 16.24$, $P < 0.0001$ at 60 DAS, $F_3 = 78.517$, $P < 0.0001$ at 150 DAS. The response of plant biomass

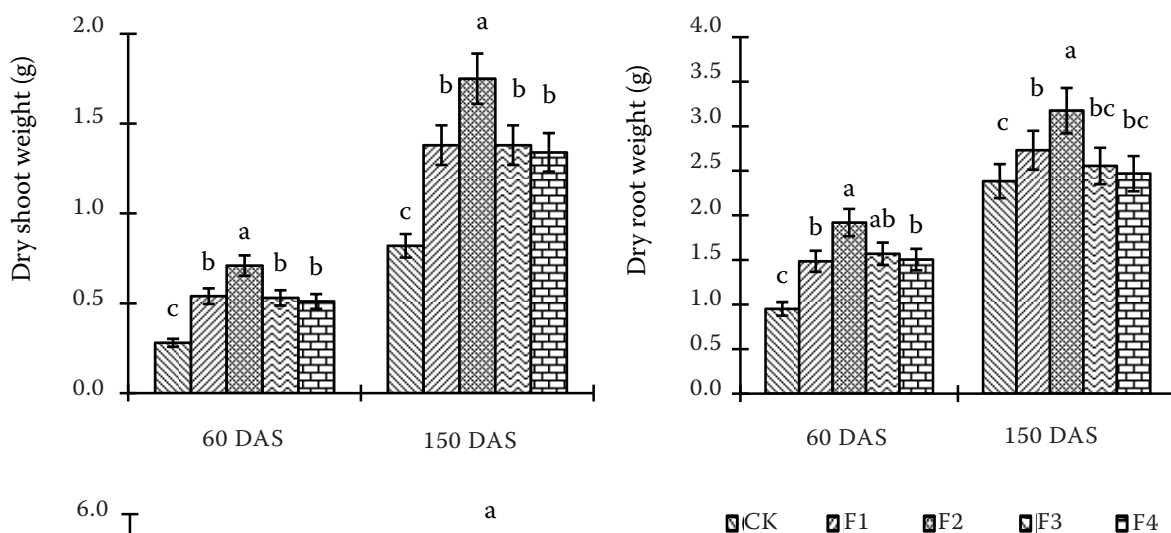


Figure 4. Biomass of *C. korshinskii* with DFBT. Boxes represent means and error bars represent \pm SE of the means ($n = 280$). Values with different letters are significantly different at the 0.0001 level (LSD multiple comparison test)

to DFBT was very similar to that of shoot and basal diameter of *C. korshinskii* (Figure 4).

In the current study, the percentage of root dry weight for the soil layers of 0 to 10 cm and 20 to 40 cm at CK was 28.30% and 32.80%, respectively. However, the percentage of root dry weight for the soil layer of 10 to 20 and 20 to 40 cm at FBT was higher, 36.84% and 34.30%, respectively (Table 4).

DISCUSSION

Several studies have shown that FBT can effectively keep soil from puddling and packing together and to prevent loss of water and nutrients, resulting in improved soil water and nutrient status (Tao and Ren 2004, Zhou et al. 2007). This, in turn, improves the growth parameters of *C. korshinskii* such as seed germination, leaf characteristics, shoot height, basal diameter, above- and below-ground biomass.

Seedling establishment is often constrained by inadequate precipitation in arid northwestern China (Li et al. 2006). Seedling emergence of *C. korshinskii* increased by 18% when the soil

water content in the layer of 0 to 10 cm increased by only 2% (Sun et al. 2004). In the current study, the water content in the layer of 0 to 10 cm at CK was 3.41% and corresponding emergence rate was 20.83%. In comparison, the water content in the layer of 0 to 10 cm at FBT was higher than 4.92%, and the emergence rate was more than 44.17%. The highest emergence rate occurred when the depth of FBT was 90 cm.

Physiological and structural adaptations of plant to desert environment are crucial for plant survival (Misra and Misra 1991, Ni and Pallardy 1991). Plants must develop stress avoidance mechanisms to cope with water deficit (Misra et al. 2002). Leaf growth is the most sensitive response to water stress. Soil water stress impairs the physiological functions and biomass production of plants due to low carbon assimilation as a result of decreased leaf size, leaf area, and leaf number (Misra et al. 2002). The reduction in leaf area with increasing water stress also enabled the plants to reduce water consumption and to be more capable of tolerating prolonged drought (Kozłowski et al. 1991). The data in our study demonstrated how *C. korshinskii* plant responded to water deficit and they are in

Table 4. Root vertical distribution of *C. korshinskii* at 150 DAS (g, %)

Type	Depth of soil profile (cm)										
	0–10					10–20					
	X ₁	X ₂	X ₃	CK	F-value	X ₁	X ₂	X ₃	CK	F-value	
Dry weight	(g)	0.38 ^c	0.50 ^b	0.36 ^d	0.54 ^a	57.05	0.89 ^b	1.19 ^a	0.91 ^b	0.47 ^c	44.86
	(%)	16.31 ^b	16.18 ^c	14.57 ^d	28.57 ^a	43.51	38.19 ^a	38.51 ^a	36.84 ^b	24.87 ^c	36.28
Type	20–40					40–60					
	X ₁	X ₂	X ₃	CK	F-value	X ₁	X ₂	X ₃	CK	F-value	
	(g)	0.85 ^c	1.06 ^a	0.89 ^b	0.62 ^d	170.91	0.21 ^d	0.34 ^a	0.31 ^b	0.26 ^c	47.62
(%)	36.48 ^a	34.30 ^b	36.03 ^a	32.80 ^c	268.55	9.01 ^d	11.00 ^c	12.55 ^b	13.76 ^a	119.38	

X₁ – 80 cm DFBT; X₂ – 90 cm DFBT; X₃ – 100 cm DFBT; CK – check. For each component the mean values with the same superscript letters among species are not significantly different at 1% level of probability ($n = 480$) (LSD multiple comparison test).

agreement with Guo et al. (2007), Misra (1994) and Misra et al. (2002).

The seedlings from 90 cm FBT had greater ($P < 0.0001$) biomass (4.93 g dry weight per seedling) than the seedlings from the other treatments at 150 DAS. In comparison to 90 cm FBT, the biomass from CK was by 29.94% lower, and that from 100 cm FBT was by 25% lower.

In our study, higher root to shoot ratio at CK was probably due to a higher allocation of assimilates to the root system under increasing soil water deficit. This is in accordance with Pallardy and Rhoads (1993), Misra (1994), and Lu and Zhang (1999). Decreased assimilate accumulation in leaves as a result of water stress may be attributed to the reduced carbon and nitrogen metabolism and leaf senescence, which is also considered as drought avoidance mechanism (Misra et al. 2002). In the present study, the root system of *C. korshinskii* at CK was mainly distributed in the surface soil layer of 0 to 10 cm and 20 to 40 cm and with FBT it was mainly distributed in the soil layer of 10 to 40 cm during the seedling stage (1-year old). This could be attributed to a higher water content at the deeper soil layers with FBT due to reduced water percolation.

With respect to interdependence between fertilizer and seedling growth, we will continue field experiment and research, summarize theory and practice to serve people in arid region.

Acknowledgments

The authors extend their sincere appreciations to Prof. Liu Qianzhi from the Gansu Agricultural

University for his suggestions, and thank Su Wanhong, and Sun Hanguo from the Jing Tai Station of Desert Control, Gansu province for their field assistance.

REFERENCES

- Beadle C.L., Ludlow M.M., Honeysett J.L. (1993): Water relations. In: Hall E.O., Scurlock J.M.O., Bolhar-Norderkamp H.R. (eds.): Photosynthesis and Production in a Changing Environment: A Field and Laboratory Manual. Chapman & Hall, London, 113–128.
- Evans D.D., Thames J.L. (1981): Water in Desert Ecosystems. Dowden, Hutchinson and Ross, Inc., Stroudsburg, Academic Press, New York.
- Guo W., Li B., Zhang X., Wang R. (2007): Architectural plasticity and growth responses of *Hippophae rhamnoides* and *Caragana intermedia* seedlings to simulated water stress. *Journal of Arid Environments*, 69: 385–399.
- Hansson A.C., Aifen Z., Andren O. (1995): Fine-root production and mortality in degraded vegetation in horqin sandy rangeland in Inner-mongolia, China. *Arid Soil Research and Rehabilitation*, 9: 1–13.
- Hughes A.P., Freeman P.R. (1967): Growth analysis using frequent small harvest. *Journal of Applied Ecology*, 4: 553–560.
- Kozlowski T.T., Kramer P.J., Pallardy S.G. (1991): The Physiological Ecology of Woody Plants. Academic Press, San Diego.
- Li X.Y., Gao Y.S., Xu H.Y., Liu L.Y. (2006): Growth of *Caragana korshinskii* using runoff-collecting microcatchments under semiarid condition. *Journal of Hydrology*, 328: 338–346.
- Lu C., Zhang J. (1999): Effects of water stress on photosystem II photochemistry and its thermostability in wheat plants. *Journal of Experimental Botany*, 50: 1199–1206.
- Misra A.N. (1994): Pearl millet (*Pennisetum glaucum* L.R.Br.) seedling establishment under variable soil moisture levels. *Acta Physiologiae Plantarum*, 16: 101–103.

- Misra A.N., Biswal A.K., Misra M. (2002): Physiological, biochemical and molecular aspects of water stress responses in plants, and the biotechnological applications. The National Academy of Sciences, India, 72. B (II): 115–134.
- Misra A.N., Misra M. (1991): Physiological responses of pearl millet to agroclimatic conditions. In: Prakash R., Ali A. (eds.): Environmental Contamination and Hygiene, Jagmandir Books, New Delhi, 165–175.
- Ni B.R., Pallardy S.G. (1991): Response of gas exchange to water stress in seedlings of woody angiosperms. Tree Physiology, 8: 1–9.
- Pallardy S.G., Rhoads J.L. (1993): Morphological adaptations to drought in seedling of deciduous angiosperms. Canadian Journal of Forest Research, 23: 1766–1774.
- Ren J., Tao L., Liu X.M. (2002): Effect of different microhabitats and stand age on survival of introduced sand-fixing plants. Journal of Arid Environments, 51: 413–421.
- Statsoft, Inc (2001): SAS for Windows 8.0. SAS Institute Inc., Cary, NC.
- Sun J., Peng X.Y., Sun Y.H., Guo F. (2004): Study on test of caragana seed bud bursting. Agro-forest. Sciences and Technology Qinghai, 3: 51–52.
- Surfer version 5.01, 1993–1994, Gold Software Inc.
- Xiong Y., Li Q.K. (1987): China Soil. Science Press, Beijing.
- Zhang G.S. (1999): Seasonal change for Mao Wusu sand area aeolian sandy soil mechanical composition and moisture content. Journal of Desert Research, 19: 145–149.
- Zhou X.L., Wang H., Chen Q.G., Ren J.Z. (2007): Coupling effects of depth of film-bottomed tillage and amount of irrigation and nitrogen fertilizer on spring wheat yield. Soil and Tillage Research, 94: 251–261.

Received on October 21, 2009

Corresponding author:

Prof. Hui Wang, Gansu Agricultural University, Forestry College, Lanzhou 730070, P.R. China
phone: + 86 138 9313 9076, fax: + 86 931 4683 362, e-mail: atbeijing2008@gmail.com
