Annals of Arid Zone 38(1): 37-44, 1999

Growth of *Prosopis cineraria* on Microcatchments in an Arid Region

G.N. Gupta, N.K. Limba and Sarita Mutha
Arid Forest Research Institute, New Pali Road, Jodhpur 342005, India

Abstract: The influence of different *in situ* water harvesting structures (microcatchments) on establishment and growth of *Prosopis cineraria* (*khejri*) was studied on a flat sandy aridisol. Water harvesting structures included 45 x 45 x 45 cm pits (control), saucer pit having 2.5 m diameter, ring pit, trench cum mound, trench and mound and deep ploughing + pitting. Trees attained highest growth in ring pit followed by trench and mound and saucers after 57 months of planting. Biomass production from tree prunings was 6-9 times higher in ring pits, trench and mound and saucers as compared to the control. Plant survival improved from 30% in the control to 86-97% in these microcatchments. Soil moisture storage was 39-51% higher in ring pit, trench and mound and saucers as compared to the control. Since the cost of planting in ring pits was 60% higher than in the control, adoption of trench and mound structures and saucers is recommended which cost respectively, 21% and 27% more than the control.

Key words: *Prosopis cineraria*, microcatchments, growth, survival, soil moisture, leaf water potential.

Khejri (*Prosopis cineraria*) is an important multipurpose tree species of arid region giving fodder, fuel, timber, edible pods and the much needed shade to desert inhabitants. It is the most preferred species in agroforestry plantations in arid regions owing to its beneficial effects on the agricultural crops. However, its establishment and growth is very slow, primarily due to inadequate availability of moisture. Its fast growth under irrigated conditions in IGNP command area of the Indian arid zone indicates the potential of this species to establish and grow faster if moisture availability is enhanced (Upadhyay, 1991). Microcatchment water harvesting (MCWH) is known to improve soil moisture storage and prolong the period of moisture availability and enhance several folds the growth of agricultural, horticultural and forest crops in arid and semi-arid regions (Evenari *et al.*, 1968; Sharma *et al.*, 1982; El Amami, 1983; Roberts, 1985; Critchley, 1987; Moald, 1984; Rodrigues and Yameogo, 1988; Roose, 1997; Finkel and Finkel, 1987; Urkurkar *et al.*, 1985; Boers *et al.*, 1986; Reiz *et al.*, 1988; Carter and Miller, 1991). Rainfall in the Indian arid zone is low and erratic and is received in a few showers of high intensity, resulting in runoff losses to the tune of 25-40%. As high as 85% runoff has been recorded in a single event from a bare land (Singh, 1980). Sometimes the winter rains produce substantial runoff. These losses could be minimised by using suitable *in situ* water harvesting techniques, so that most of the rain water is stored in the vicinity of tree roots to facilitate better tree growth. A few studies have demonstrated tremendous influence of MCWH on the growth of trees (Sheikh, 1982; Gupta, 1994, 1995; Gupta *et al.*, 1995). A field experiment was conducted in order to find out the most suitable technique of *in situ* rain water harvesting for better growth of *P. cineraria* on a sandy plain. The paper presents the results on the effectiveness of different techniques of microcatchment water harvesting (MCWH) on soil moisture storage and growth of *P. cineraria.*

Materials and Methods

A field experiment was conducted at the experimental farm of Arid Forest Research Institute, Jodhpur, during 1992-97. According to the US soil taxonomy the soil of the site is loamy, mixed, hyperthermic family of Camborthids, having thick layer of calcium carbonate at 75 cm depth. The soil has pH 7.8, organic carbon 0.18% and soil moisture retention 10% at 0.03 MPa and 2% at 1.5 MPa. The mean annual rainfall (average for 1988 to 1997) is 433 mm and mean annual pan evaporation 2796 mm. Thus, severe water deficit conditions dominate the region. The mean monthly minimum temperature varied from 9.0 to 29.0°C and mean monthly maximum temperature from 23.8 to 42.6°C during the experimental period.

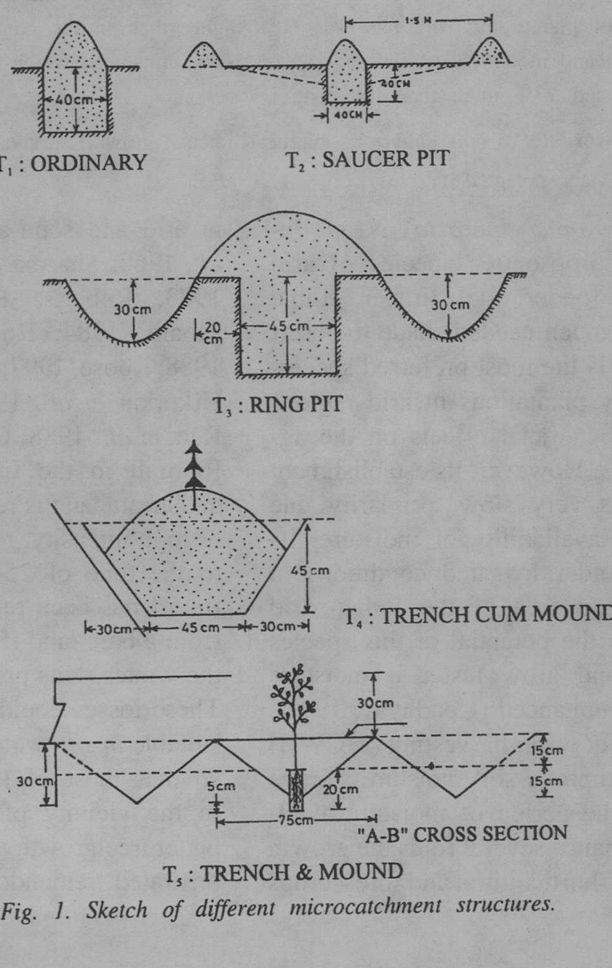

Fig. 1. Sketch of different microcatchment structures.

Table 1. Growth and leaf water potential of P. cineraria, 57 months after planting, as affected by different treatments of in-situ rain water harvesting

Treatments	Growth (cm)		Leaf water potential (MPa)		
	Height	Girth	February 1996	March 1996	March 1997
Control	223	16.2	-6.78	-7.32	-5.40
Saucers	302	21.4	-6.25	-7.05	-5.14
Ring pits	323	20.8	-6.12	-7.45	-5.50
Trench-cum-mound	281	18.0	-6.38	-6.65	-5.67
Trench and mound	319	22.6	-6.38	-6.38	-4.83
Deep ploughing + pitting	279	20.8	-6.52	-6.78	-5.14
C.D. at 5%	57	1.9			

The experiment comprised of six treatments of *in situ* MCWH methods, which were T_1: ordinary pit of size 45 x 45 x 45 cm (control), T_2: saucer pit of 2.5 m diameter, T_3: ring pit, T_4: trench-cum-mound, T_5 : trench and mound, and T_6: deep ploughing + pitting (Fig. 1). Each treatment was taken in triplicate and the experiment was laid in Randomised Block Design. There were 12 trees in each plot at 3 x 3 m spacing. Six-month-old seedlings of *P. cineraria* (*khejri*) were planted on 30th July, 1992. A basal application of 3 kg FYM and 10 g di-ammonium phosphate per pit was mixed with the pit soil just before planting. Water harvesting structures were made before planting. Solution of chloropyrophos was added @ 0.2% to all the seedlings in the month of September 1992, and was repeated after a year to control the termite attack, which is a common problem in this region. Three supplementary

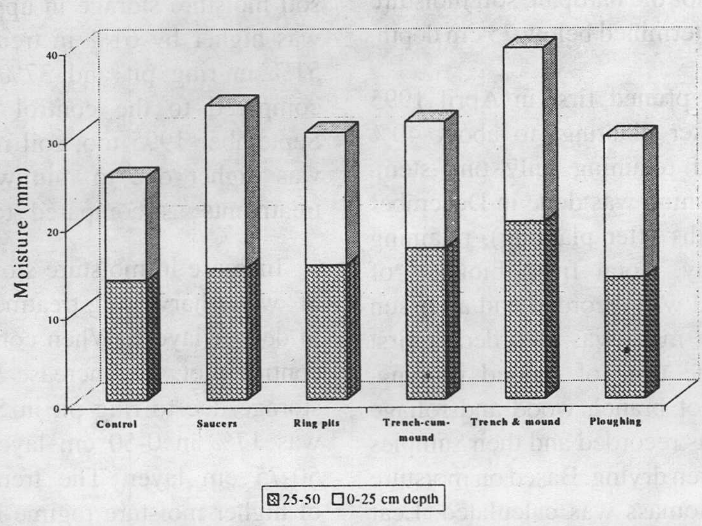

Fig. 2. Soil moisture storage as affected by different in situ water harvesting treatments.

Table 2. Biomass yield (dry, q ha^{-1}) from the prunings of P. cineraria due to different treatments of in situ rain water harvesting treatments

Treatment	At 33 months	At 54 months		
	Total biomass	Bench wood	Foliage	Total biomass
Control	2.2	2.47	0.19	2.66
Saucers	21.0	14.54	2.31	16.85
Ring pits	19.1	18.80	2.04	20.84
Trench-cum-mound	8.0	13.24	0.93	14.17
Trench and mound	18.5	20.65	2.69	23.34
Deep ploughing + pitting	5.9	19.72	1.11	20.83

waterings of 10 L each were given to each plant in the months of November, April and June, in the first year only.

Height of *P. cineraria* was recorded quarterly from August 1992 to December 1998. Collar circumference of trees was recorded six monthly from December 1994 to December 1996. Soil moisture was determined gravimetrically in 0-25, 25-50 and 50-75 cm layers at different periods and stages of tree growth. From each plot, 3 samples, 15 cm away from the tree, were taken. Because of the hardpan, soil moisture could not be determined below 75 cm depth.

Trees were pruned first in April 1995 (33 months after planting) to about 40% of canopy and retaining only one stem. The second pruning was done in December 1996 (54 months after planting), retaining 50% of canopy. Total fresh biomass of pruned material was recorded and after sun drying, the dry mass was recorded at first pruning. At the time of second pruning, fresh biomass of branch wood and foliage of each plot was recorded and their samples collected for oven drying. Based on moisture content, dry biomass was calculated. Leaf water potential was determined by HR 33T Dew Point Microvoltmeter at 14 hrs in February 1996, March 1996 and March 1997. Cost of planting due to different treatments was also calculated.

Results and Discussion

Soil moisture

Water harvesting treatments resulted in significantly higher moisture storage than in the control plot (Fig. 2). In October 1992, soil moisture storage in upper 50 cm layer was 38 mm in ring pit and 34 mm in trench and mound as against 27.3 mm in control plot. In September 1994, soil moisture storage in upper 75 cm layer was higher by 61% in trench and mound, 51% in ring pit and 37% in saucers, as compared to the control (64.7 mm). In September 1995 too, soil moisture storage was higher due to rain water harvesting treatments as compared to the control.

Increase in moisture storage, as a result of water harvesting treatments, was higher in deeper layers. When compared with the control plot, the increase in the moisture storage due to ring pit in September 1994 was 17% in 0-50 cm layer and 111% in 50-75 cm layer. The trend is indicative of higher moisture regime in deeper layers (75 cm layer) under microcatchment structures as compared to the control. This is also evident from continuance of better

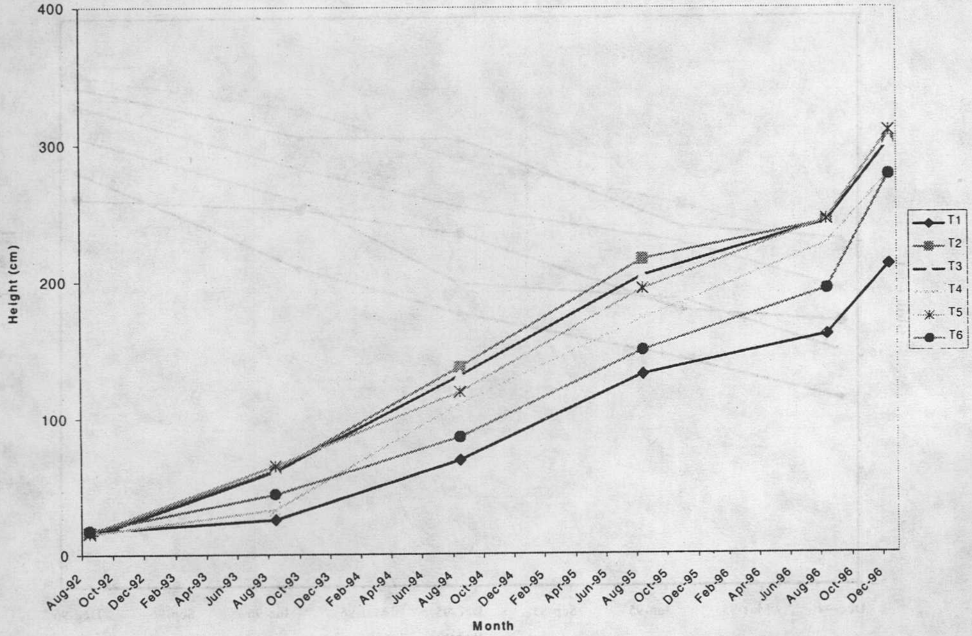

Fig. 3. Height of P. cineraria plants as affected by different in situ water harvesting treatments.

tree growth on microcatchments than the control, during the most dry period of May-June, when moisture availability in upper 75 cm layer is almost below wilting point.

Leaf water potential

Leaf water potential (LWP), which is indicative of leaf moisture stress, vary much during the experiment (Table 1). Inspite of the much higher crown spread of trees in microcatchments than in the control plot, the LWP was at par in all the treatments. This is indicative of the higher moisture availability to the trees in microcatchments.

Plant survival

Plant survival, after 3 years of planting, was only 30% in the control, whereas, in microcatchments, it was nearly three fold, i.e., 97, 87 and 86% in saucer, trench and mound and ring pit, respectively. Deep ploughing improved the plant survival to 78%. Survival of plants due to trench-cum-mound structure was 50%.

Tree growth

There was dramatic improvement in the growth of *P. cineraria* due to different treatments of MCWH. Rate of increase was particularly higher in the initial period of tree establishment. Tree height was higher by 221% in saucers and 124% in trench and mound and ring pits, as compared to that in the control plot at 18 months of age (Fig 3). Collar girth of trees at 30 months of age was 15.2 cm in ring pits, 14.8 cm in saucers and 13.0 cm in trench and mound, which were higher by 85, 80 and 59%, respectively, as compared to the

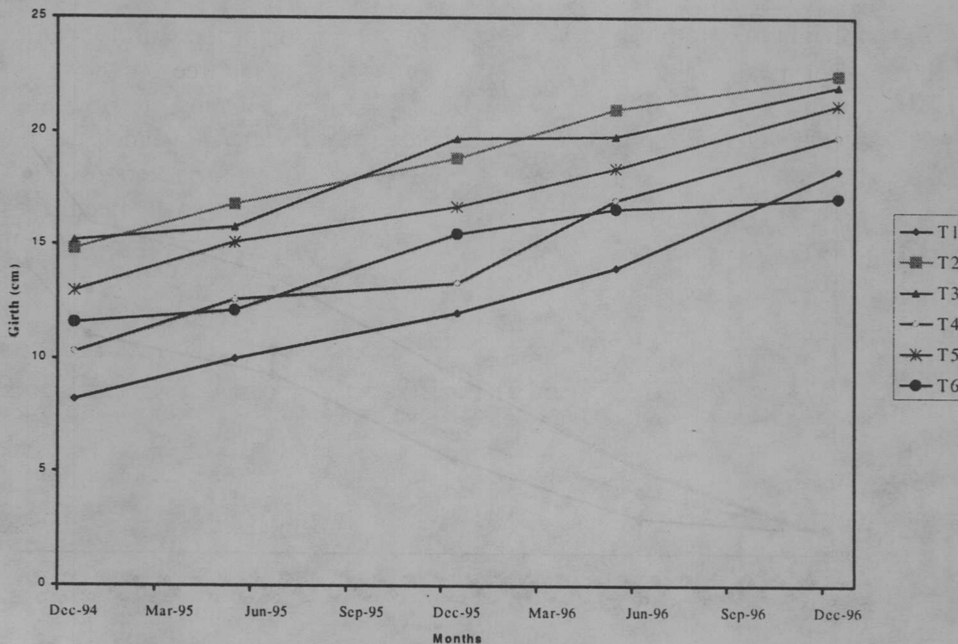

Fig. 4. Girth of P. cineraria as affected by different in situ water harvesting treatments.

control plot (8.2 cm) (Fig 4). After 57 months of planting trees had 323 cm height and 20.8 cm collar girth in ring pit, 319 cm height and 22.6 cm collar girth in trench and mound, and 302 cm height and 21.4 cm collar girth in saucers, as compared

Table 3. Cost[+] of planting (Rs. ha^{-1}) under different rain water harvesting treatments

	Control	Saucers	Ring pits	Trench-cum-mound	Trench-cum-mound	Deep ploughing + pitting
Land clearing and ploughing	340	340	340	340	340	680*
Pitting (Rs. 0.75 pit^{-1})	825	–	–	–	–	825
Planting (Rs. 0.25 $plant^{-1}$)	275	275	275	275	275	275
Farm yard manure (3 kg pit^{-1}; @ Rs. 100 t^{-1})	335	335	335	335	335	335
Water harvesting structure	–	1900	3300	1650	1500**	–
Aldrin, Rs. 250 L^{-1} (@ 2 L ha^{-1})	500	500	500	500	500	500
Weed clearing (Twice a year)	500	500	500	500	500	500
Watering (three $year^{-1}$)	1200	1200	1200	1200	1200	1200
Total cost of plantation (Rs. ha^{-1})	3975	5050	6350	4800	4950	4315
Increase (%) in cost over control	21	27	60	21	17	9

– Planting space 3 x 3 m; * Cost of deep ploughing; ** By tractor, whereas, other structures could be made manually; + base price, 1992 (planting year).

to 223 cm height and 16.2 cm collar girth in the control plot (Table 1).

Biomass production

Biomass yield of the pruned material was 6-8 folds higher in microcatchments than in the control. At the first pruning, total biomass yield was maximum in saucers (21.0 q ha^{-1}), followed by ring pits (19.1 q ha^{-1}) and trench and mound (18.5 q ha^{-1}), as compared to 2.2 q ha^{-1} in the control. At second pruning, maximum biomass yield was on trench and mound (23.34 q ha^{-1}), followed by ring pits (20.84 q ha^{-1}) and saucers (16.85 q ha^{-1}), as compared to 2.66 q ha^{-1} in the control plot (Table 2).

Cost considerations

Cost of planting *khejri* on sandy plain soil of Indian arid region in western Rajasthan under different water harvesting treatments is given in Table 3. The increase in cost of planting was 60% in ring pits, 21% in trench and mound and 27% in saucers as compared to the control plot. Considering the very high increase in the planting cost, ring pits are not recommended for raising *khejri*. Wherever tractor facilities are available, trench and mound structures are recommended as microcatchments. In the areas where manual labour is cheaper and easily available, saucers are recommended, which have added advantage of employment generation.

The study *amply* demonstrates the benefits of *in-situ* water harvesting techniques in desert afforestation. In flat topography with about 433 mm per annum rainfall and loamy sand soil, techniques such as ring pits, trench and mound, and saucers of 2.5 m diameter caused dramatic improvement in the tree growth. Considering the cost of planting, trench and mound structures are recommended for areas with tractor facility and saucers for areas where manual labour is easily available. These practices will facilitate speedy establishment of plants and will give them good initial boost to develop into healthy vigorously growing stands in subsequent years, besides imparting to resistance to droughts and famines, which are frequent in the Indian arid zone. Adoption of water harvesting techniques will generate employment. Such activities could easily be taken up under famine work.

Acknowledgement

Authors express their grateful thanks to Director, AFRI, Jodhpur, for his encouragement and providing necessary facilities.

References

Boers T.M., de Graaf, M., Feddes, R.A. and Ben. Asher J. 1986. A linear regression model combined with a soil water balance model to design microcatchments for water harvesting in arid zones. *Agriculture Water Management* 11: 187-206.

Carter, D.C. and Miller, S. 1991. Three years experience with on-farm water catchment water harvesting system in Botswana. *Agriculture Water Management* 19: 191-203.

Critchley, W.R.S. 1987. Some lessons from water harvesting in Sub-Saharan Africa. *Report from a workshop held at Baring, Kenya, 13-17 October, 1986*. World Bank, Eastern and Southern Africa Projects Department, Washington DC, U.S.A.

El-Amami, S. 1983. *Les amenagements hydrauliques traditionels en Tunisia. Centre de Recherche du Genie Rural, Tunis, Tunisia.*

Evenari, M., Shanan, L. and Tadmor, N.H. 1968. Runoff farming in the desert. I. Experimental layout. *Agronomy Journal* 60(1): 29-38.

Finkel, H.J. and Finkel, M.L.1987. Engineering measures: Water harvesting. In *Semi-arid Soil and Water Conservation* (Eds. H.J. Finkel, M. Finkel and Z. Naveh), pp. 93-101. CRC Press Inc., Florida, U.S.A.

Gupta, G.N. 1994. Influence of rain water harvesting and conservation practices on growth and biomass production of *Azadirachta indica* in Indian desert. *Forest Ecology and Management* 70: 329-339.

Gupta, G.N. 1995. Rain water management for tree planting in Indian desert. *Journal of Arid Environments* 31: 219-235.

Gupta, G.N., Limba, N.K. and Gupta, P.K. 1995. Micro-catchment water harvesting for raising neem in arid region. *Indian Forester* 121: 1022-1032.

Klemm, W. and Prinz, D. 1989. Utilization of factor "soil" through runoff farming - A case study from Mali. *Natural Resources and Development Institute for Scientific Co-operation, Germany*, 76-88.

Moald 1984. Runoff harvesting for crop, range and tree production in BPSAAP-area. *BPSAAP Interim Report*, ch 12, pp. 78-113.

Reiz, C., Maulder, P. and Begemann, L. 1988. Water harvesting for plant production. *World Bank Tech Paper 91*, Washington, D.C., U.S.A.

Roberts, M. 1985. Fuel and fodder project, Baringo district. *Progress report*, November 1983-March 1985.

Rodrigues, L. and Yameogo, C. 1988. *Projects de recherche development a l'ord du Yatenga Rapport d'activities 1987. ORD du Yatenga*, Burkina Faso.

Roose, E. 1977. *Erosion et ruissellement en Afrique de l'Ouest vingt annees de mesures en petites parcelles experimentales.* ORSTOM Travaux et Documents No. 78.

Sharma, K.D, Pareek, O.P. and Singh, H.P. 1982. Effect of runoff concentration on growth and yield of Jojoba. *Agriculture Water Management* 5: 73-85.

Sheikh, M.I. 1985. Tree planting in arid and semi-arid lands. *Progressive Farming* 5(5): 40-43.

Singh, R.P. 1980. Runoff management and recycling of water in arid zons. *ICAR Summer Institute on Management of Arid Zones of India.*

Upadhyaya, A.K. 1991. Shelter belt plantations effectively check sand deposition in Indira Gandhi Canal. *Indian Forester* 117(7): 511-514.

Urkurkar, J.S, Sastri, A.S.R.A.S. and Chandrawansi, B.R. 1985. Rainfall harvesting for rainfed rice cultivation. *Inernational Rice Newsletter.*