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In-situ Moisture Conservation in Polyethylene Bags for Afforestation in Dry Regions

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Abstract

A study was conducted at the WRRI-NARC, Islamabad under controlled conditions of rainfall and high temperatures to simulate hot-arid environment for establishment of plants like *Eucalyptus camaldulensis and Acacia arabica* in plastic bags with an objective to reduce volume of water required for establishment and to achieve higher survival rates. The results indicated that number of irrigations were reduced to half under bags of 20"x30" size compared to control and volume of water used, was reduced by 60-70 per cent. The irrigation interval was almost doubled in 20"x30" polyethylene bags compared to control. The volume of water per irrigation also reduced by 27-55 per cent, reducing the irrigation cost considerably. The peak daily reference crop evapotranspiration (ETr) of 9.41 mm/day was observed during June. Water requirement was reduced to about 1/4th of the ETr in plastic bags compared to about 3/4th of the ETr in control. The increase in water use efficiency for plastic bags was 4-5 times that of the control. Plastic bag of 20"x30" size resulted in 16 per cent increase in growth for *Eucalyptus*. The increase was around 59 per cent for Kikar under bag size of 18"x24" compared to control.

Introduction

Pakistan's Agriculture represents a complex and climatically diversed system with rainfall of less than 100 mm to about 1500 mm in the foot hills and mountains (Ahmad, 1994). The total area of the country is placed at 79.61 million hectares of which only 21.59 million hectares are cultivated and 3.62 million hectares are under forests. The rest 54.40 million hectares constituting almost 70 per cent of the total area is dry and commonly known as the arid zone of the country (Agricultural Statistics, 1996-97).

The arid areas are characterized by drought and severe moisture stress. The rainfall is erratic and poorly distributed. Afforestation is not encouraging, for plant survival rate is poor. Losses are serious i.e. evaporation and un-necessary transpiration especially. Hence, there is great potential to establish forest plants because there is lack of proper and cost-effective moisture conservation practices.

The survival rate of any plantation effort is dependent on the availability of water to the plants especially during the establishment phase. If the planting season is dry, the survival rate of plantation is sometimes less than 10 per cent (WRRI, 1995).

Pakistan has a forest capital growing on less than 5 per cent of its area. With population of 130 million mounting at an alarming pace of 3.1 per cent per year, the existing forest resource is in advanced stage of degradation due to multiplicity of rights in mountain forests and incessant grazing. The irrigated plantations and riverain forests are beset with the problem of low productivity. The mangrove, juniper and chalghoza forest ecosystems are in critical state (IUCN, 1995). To arrest the degradation of the existing forests and reduce dependence on imported forest products, need is being felt to enhance the forestry resource base to the optimum level by encouraging farm forestry even in the arid regions through water conservation and better plant survival.

This study was conducted under controlled conditions to develop cost effective technique for water conservation in polyethylene bags for establishment of forest plants. As a case study *eucalyptus camaldulensis* and *Accacia Arabia* were selected. This technique was tested in the semi arid environments of NWFP to raise eucalyptus plants in degraded and eroded lands with a survival rate of 99 per cent by planting them inside micro-catchments (eye-brow terraces) using plastic bag technology (Badruddin *et al.*, 1994).

Materials and Methods

This study was initiated at the WRRI-NARC, Islamabad, under controlled conditions of rainfall and high temperatures to simulate hot-arid environment for establishment of plants like *Eucalyptus camaldulensis* (sufaida) and *Acacia Arabica* (kikar) in plastic bags. White polyethylene film bags of 20 micron thickness which can hold about 30-50 kg of soil and costing about Rs.1 per bag were used to establish the forest plants.

Two sizes of bags i.e. 18" x 24" and 20" x 30" were tested for water conservation and growth response of the plants and the results were compared with the control. The study was conducted in an experimental design CRD with three replicates for each plant. Irrigation interval, growth and daily temperature were observed and recorded for the study period, as input data for detailed analysis. A 6-inches from the top was left in each bag and rest was filled with soil. The physico-chemical analysis of the soil is given in Table 1.

Irrigation Scheduling: Irrigation scheduling is the process of when to irrigate and how much water to apply. The permanent wilting point (PWP) was based on 50 per cent of the field capacity (FC). (Doneen *et al.*, 1984). The amount of water per irrigation was 2.5 litre,4.0 litre and 5.5 litre for bag size of 18"x24", 20"x30" and the control respectively. Irrigations were scheduled at close to wilting point of the plants. Thus irrigation scheduling was based on plant appearance and this criteria was practiced for the whole study period. Data for the irrigation interval was recorded irrigating all the three replicates within one treatment on the same day.

Table 1: Physico-chemical analysis of the soil.

	Properties	Values		
a) Physical analysis				
Mechanical Analysis				
	Clay (%)	17		
	Silt (%)	62		
	Sand (%)	21		
	Textural class	Silt loam		
Bulk Density (g cm^{-3})				
	Plastic bags	1.12		
	Control	1.45		
Water Retention				
(% on dry mass basis)				
	FC	16.79		
	PWP	8.395		
	AW (FC-PWP)	8.395		
b) Chemical Analysis				
NPK (mg kg^{-1})				
	Soil depth	N	P	K
	0-6"	2.40	40.2	92
	7"-12"	1.37	14.2	72
	13"-18"	1.03	3.0	32

Water-use Efficiency: Water-use efficiency (Eu) is based on dry plant weight produced by a unit volume of water. After 268 days of data, *Acacia* and *Eucalyptus* plants were harvested. Dry bio-mass was determined by oven-drying the samples. Irrigation water needed till the harvest was known. The water-use efficiency was determined in gm/litre units, i.e.

$$Eu = \frac{\text{Dry plant weight (gms)}}{\text{Volume of water (1)}}$$

Estimation of Reference Crop Evapotranspiration (Etr): Islamabad lies at an altitude of 510 m from the mean sea level with latitude as 33° 42' North and longitude as 73° 08' East (Siddiqi, 1992). Reference crop evapotranspiration (ETr) was calculated by the temperature based Hargreaves (1985) method. Hargreaves *et al.* (1985) developed the original Hargreaves (1975) equation in the following form:-

$$ETr = 0.0023 * Ra * (TD)^{0.5} (T + 17.8)$$

where

Etr = Reference Crop Evapotranspiration in mm;

Ra = Extra terrestrial radiation received at the top of th atmosphere, mm;

TD = Difference between mean monthly maximum an minimum temperature, °C.; and T = Mean a temperature in °C.

The required observed data is temperature, therefore, dai temperature data of maximum and minimum was record and mean maximum, mean minimum and mean dai temperature of every month was calculated for the stu period. The extra- terrestrial radiation, Ra for Islamabad w interpolated (Doorenbos *et at.*, 1977).

Results and Discussion

Based on data collection of daily temperature, month growth and irrigation interval, the results were obtained terms of water savings, irrigation interval, growth, referen crop evapotranspiration and water use efficiency. All th results are based on 268 days of data for *Eucalyptus* an Acacia after which they were harvested for bio-mass an water use efficiency.

Water Savings and Irrigation Interval: The results indicat that the number of irrigations and volume of water requir for establishment reduced significantly. The number irrigations were reduced to half under bags of 20"x30" si compared to control. Similarly volume of water used w also reduced by 60-70 per cent. The irrigation interval w almost doubled in 20"x30" polyethylene bags compared control. For example for *Eucalyptus* it was increased fro 13-24 days to 27-60 days. This will reduce the irrigati cost to less than half in addition to higher survival rate The volume of water per irrigation also reduced by 27-5 per cent which further reduce the irrigation cost as water at premium in arid environment (Table 2).

In arid and semi arid regions where the rainfall is erratic an poorly distributed, water from rainfall of 250-500 mm in year is lost for economic use by plant interception, run-o evaporation, transpiration and deep percolation, there m be even less effective rainfall. In such areas water is limiting factor and 60-70 per cent savings means mo water for more plantation bringing profitability to the farm and improving ecology of these regions. Water savin coupled with longer irrigation intervals would save tim labour and money reducing the irrigation cost which is major input.

Reference Crop Evapotranspiration (Et,l): The climatic da of controlled conditions were collected and Hargrea (1985) method was used to predict monthly reference cr evapotranspiration. This indicates the actual environm where the study was conducted. The peak daily referen crop evapotranspiration of 9.41 mm/day was obser

Table 2: Volume per irrigation, number of irrigations, range of irrigation interval (II) and the percent savings in polyethylene bags

Treatment	Volume/ irrig. (l)	No. of irrig.		II (Days) *		% savings	
		Euc.	Kikar	Euc.	Kikar	Euc.	Kikar
Control	5.5	15	10	13-24	26-33	-	-
20"x30"	4.0	7	6	27-60	40-72	66.06	56.36
18"x24"	2.5	13	8	14-39	26-56	60.60	63.64

* The lower limits were recorded in summer months and the higher in winter.

Table 3: Monthly and mean daily reference crop evapotranspiration using Hargreaves (1985) method.

Months	Monthly Et_r (mm)	Mean daily ET_r (mm)
Dec., 1996	78.4	2.53
Jan., 1997	76.2	2.46
Feb., 1997	93.7	3.35
Mar., 1997	145.4	4.69
Apr., 1997	170.4	5.68
May, 1997	250.0	8.06
Jun., 1997	282.3	9.41
Jul., 1997	255.3	8.24
Aug., 1997	252.6	8.15
Sep., 1997	201.9	6.73
Oct., 1997	139.6	4.50
Nov., 1997	93.6	3.12
Dec., 1997	70.5	2.27

ring June which is quite comparable to arid environments Table 3).

hile in control the water applied was about 47-70 per nt of the ET_r, it was only about 21-24 per cent of the ET_r 20"x30" bags and 22-36 per cent of the ET_r in 18"x24" gs. Water requirement was reduced to about 1/4th of the r in plastic bags compared to about 3/4th of the ET_r in ntrol. Plantation in plastic bags offers a solution to mbat the problem of high evapotranspiration and low nfall in dry regions (Table 4).

e 4: Irrigation as % of the ET_r, for different treatments

	Treatments	Total ET_r (mm)	Total Irrigation (mm)	Irrigation as % of ET_r
alyptus	Control	1602	1129	70.48
	20"x30"	1602	388	24.22
	18"x24"	1602	577	36.02
r	Control	1602	753	47.00
	20"x30"	1602	333	20.76
	18"x24"	1602	355	22.17

wth, bio-mass and water use efficiency: The growth in size of 20"x30" resulted in an increase of more than 16 cent compared to control, for eucalyptus. For kikar the ase in growth under bag size of 18"x24" is about 59 cent that of the control (Table 5). The results for dry ass reveals that the average dry mass of kikar was 24 gm, 220.22 gm and 386.08 gm for control, 20"x30" bag and 18"x24" bag respectively. For Eucalyptus it was 345.90 gm, 437.33 gm and 295.48 gm for control, 20"x30" bags and 18"x24" bag, respectively. The small bag (18"x24") provided better moisture and nutrients conservation for Acacia resulting in more dry bio-mass (386.08 gms). In case of *Eucalyptus* the bag size of 20"x30" provided favourable conditions of moisture and nutrients resulting in better bio-mass (437.33 gm).

Table 5: The average heights gained, bio-mass and water use efficiency

Plants	Treatments	Plant height (cm)	Bio-mass (gm)	Water use efficiency (gm/l)
Eucalyptus	Control	192.33	345.90	4.19
	20"x30"	223.67	437.33	15.62
	18"x24"	208.00	295.48	9.09
Kikar	Control	117.00	210.24	3.82
	20"x30"	123.67	220.22	9.18
	18"x24"	186.00	386.08	19.30

The water-use efficiency for Acacia was about 5 times in 18"x24" bag compared to control and double compared to 20"x30" bag. For Eucalyptus it was about 4 times in 20"x30" compared to control and close to double compared to 18"x24". In terms of water use efficiency Acacia performed better in 18"x24" bag (Table 5) and *Eucalyptus* in 20"x30" bag. The average is based on three replicates and the coefficient of variation ranged from 3 - 10 per cent for the plant height and 2 - 9 per cent for bio-mass and water use efficiency, respectively.

Conclusions

A brief description of the conclusions made from this study is given as under:

- Analysis of variance for the plant heights shows that the plant factor is highly significant, while for bio-mass and water use efficiency, the combined effect of plant and moisture conservation is highly significant, all at 5 per cent and 1 per cent level of significance.
- The water saving is in the order of 60-70 per cent in the plastic bags. The volume of water required for establishment can be reduced to about 1/4th of the ETr in plastic bags compared to about 3/4th of the ETr in control.
- The growth was significantly increased in plastic bags in terms of height. The water-use efficiency increased to

about 4-5 times that of the control.

- There were less frequent irrigations in plastic bags increasing the irrigation interval. The irrigation interval was almost doubled in 20"x30" bag.
- In terms of water saving, growth, bio-mass and water-use efficiency, Kikar performed better in bag size of 18"x24" with almost the same number of irrigations as that of the control.
- Eucalyptus performed better in bag of 20"x30" size in terms of water saving, growth, bio-mass and water use efficiency and the irrigation interval was doubled compared to control.

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