BIOMASS PRODUCTION AND REHABILITATION OF DEGRADED LANDS IN ARID ZONE

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PREFACE

Harsh environment and excessive anthropogenic activitiy are the causative factors responsible for the degradation of land, water and vegetation resources of the arid regions. In India about 175 million hectares of area suffer from varying degrees of degradation and are getting further degraded due to one or more forces of degradation. During the last few decades the demand for grain, fodder, fuel wood and water has increased in the arid regions due to ever increasing human and livestock population. As a result of this there has been an excessive ground water use, deforestation, over grazing of pastures, excessive cultivation of even the marginal lands and thus degradation. Of late it has been realized to reverse these trends. For that a project entitled, "Biomass production and rehabilitation of degraded lands" was sanctioned by Department of Land Resources, Ministry of Rural Development of Government of India. Under this project, efforts were made to develope technologies of rainwater harvesting particularly land shaping/catchment construction, construction of multi-purpose tankas, pasture development, development of alternative farming systems like agroforestry, agri-horticulture and silvi-pasture, conservation farming, minimum tillage etc. for rehabilitating degraded lands. These have been tried, tested and demostrated in cluster of villages around Barmer with ever lasting impact, which helped in mitigating the effect of recurring droughts, and provided sustainabilitiy to the region to a great extent. I am sure the information on these aspects provided in this report will be of great use to all those associated with the development of degraded arid lands.

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INTRODUCTION

Arid zone occupies about 32 million hectares, which is about 12 per cent of the country's geographical area. Out of this about 62 per cent is in the State of Rajasthan. The total area covered by degraded lands in Rajasthan is 19.9 million hectares and is mostly spread over northwest parts of the State. The main causes of land degradation are:

Improper cultivation practices

Deforestation

Over grazing

Over utilization of resources without undertaking appropriate soil and water conservation measures

Industrial expansion

Diversion of productive land for non-agriculture uses

Poor management of irrigation and chemical fertilizers.

Soil degradation means partial or total loss of soil either quantitatively or qualitatively or both as a result of factors mentioned above. These lands therefore, need to be appropriately put in the productive phase and also new land are to be protected from being degraded.

The project work on technology for biomass production and reclamation of degraded lands in arid zone, sanctioned by Department of Land Resources, Ministry of Rural Development was undertaken in village Kalyanpur (Distt. Barmer). The project was executed for six years from 1994-95 to 1999-2000 at a total grant of Rs. 9.55 lakhs. In village Kalyanpur 15 sites having total area of 300 ha was taken up for research cum developmental works, with the following objectives.

- Development of water harvesting systems for improved crop production and tree establishment.
- Development of integrated farming systems,i.e. Agroforestry, Agri-horticulture, Silvi-pasture etc
- Development of energy and other economic plantation and unconventional crops.

SITE SELECTION AND CHARACTERISTICS

Reconnaissance survey of Barmer district was conducted. Initially four sites i.e. Parlu, Kotada, Kalyanpur and Thob were selected. Information regarding land use pattern, cropping pattern and distribution of wastelands in Barmer district is presented in tables 1 to 3. Final selection of village Kalyanpur (Figure 1) was made on the basis of problems of the area, its demonstration value and farmer's willingness to participate. The basic information about the village is presented in table 4. In all 15 sites having about 300 ha area were finally selected for the developmental work.

Table 1: Average values (1991-1996) cropped area and production distribution in Barmer district.

Crops	Area (ha)	Production (m.tons)
A. CEREALS		
Bajara	1065514	98628.4
Jowar	1644	201.2
Maize	35	6.8
Wheat	14362	10412.8
Barley	132	150.3
B. PULSES		
Gram	1687	1085.0
Other Kharif pulses	197071	20734.0
C.COMMERCIAL CROPS		
Sesamum	10797	825.4
Rape & Mustard	12829	11015.7
Lin seed	19	26.7
Castor seed	1478	452.6
Chillies	156	10.2
Potatoes	1.4	0.4
Cotton	123	10.8
Tabacco	2.6	0.4

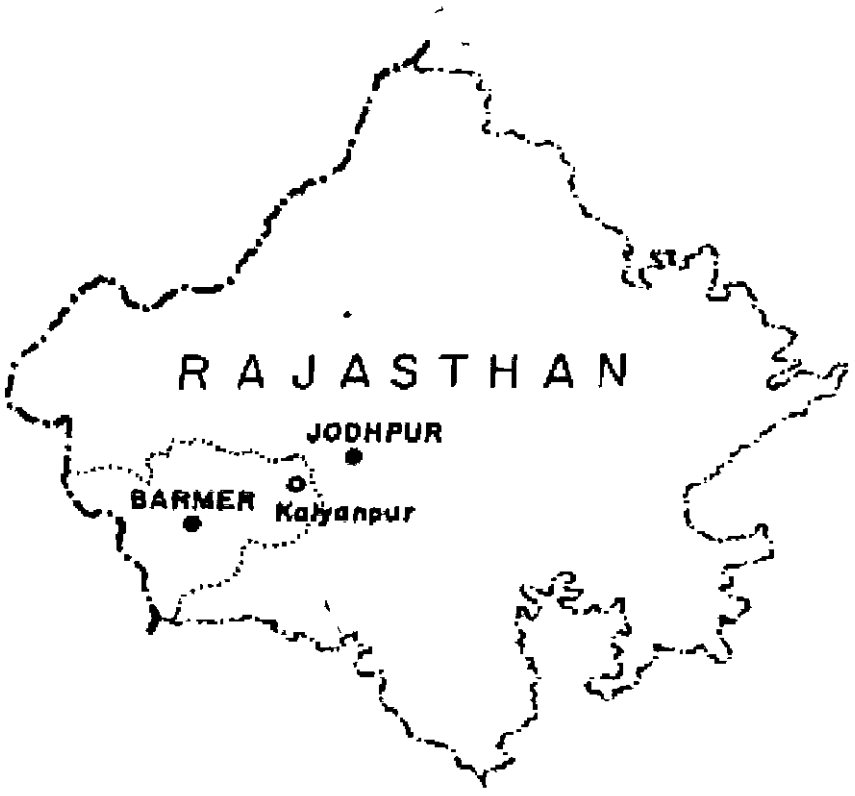

Fig.1: Geographical location of Kalyanpur village

Table 2: Land use pattern in district Barmer

Land Use	Area(ha)	Percentage
Forest	24020	0 85
Land put to non agriculture use	67691	2.40
Barren and uncultivated land	132244	4.69
Other uncultivated land exculding fallow land	209548	7.44
Cultiwable waste	280967	9.97
Fallow Land	609572	21 64
Net sown area	1493290	53 01

Table 3: Distribution of wasteland in district Barmer

Type of wateland	Area(ha)	Percentage
Sandy Waste	362202	72.17
Saline Waste	14326	2.88
Stony Waste	7629	1 52
Gravelly Waste	78734	15 34
Rocky Waste	4315	0.86
Rocky and Stony Waste	12593	2.51
Stony and Gravelly Waste	21172	4.23
Rocky and Gravelly Waste	-	-
Stone Waste with open scrub	722	0.14
Rocky and Gravelly Waste with open scrub	181	0.07
TOTAL	501974	100.00

Table 4: Basic information about village Kalayanpur, District Barmer (as on 1991)

Total Area	3928.02 ha
Total Population	2793
No. of families	440
Education facilities	One high Secondary School and one adult literacy centre.
Medical	One primary health sub centre.
Source of drinking water	Tap water, well water, tanks
Post and Telegraph	One Post and Telegraph Office
Culturalble Wasteland	256.08 ha
Area not available for cultivation	142.46 ha

TOPOGRAPHY AND CLIMATE

Topographical survey of the sites was conducted at 40x40 m grid and contour map was prepared at 1 m vertical interval. Soil survey of the area was also conducted to assess the problems and potential of the site for developmental work. Based on topographical survey and soil type, different land use systems were planned and executed. The total area of different project sites was about 300 ha with 15 farmer's land holdings. The climate of the project area is characterized by highly erratic rainfall, extreme variations in diurnal and annual temperature and high evaporation. Day temperature in summer may range from 40 to 45°C, strong wind regime from April to June cause dust storms. The average annual rainfall in area ranges from 200 to 250 mm mostly from July to September. The potential evapo-transpiration is between 1500-2000 mm $year^{-1}$. Sowing rains of monsoon may occur 15 days in advance or delayed by a month and the withdrawal of monsoon can be early by 20 to 25 days. Regular early, mid-season or late droughts are the usual phenomena of the region. The project site in general has N-W slope of about 5 %. The runoff from the entire catchment of one farmer's field accumulates at extreme lowest area forming a 'Khadin' system. Entire runoff occurs in the form of overland flow causing sheet erosion in the upper reaches.

SOIL AND VEGETATION

Soils in the project area are mainly sand to loamy sand with depth varying from 30-50 cm. In the low lying area, soils are sandy loam to loam and depth varies from 60 to 100 cm. Soil crusting is the major problem during kharif season which hampers proper seed germination of the major crops and grasses. Fertility status of soil under different farming systems is presented in table 5. Common perennial natural vegetation of the area comprises of *Zizyphus nummularia, Salvadora oleoides, Prosopis cineraria, Acacia tortilis* and *Capparis decidua*. The dominant seasonal ground flora comprises of *Cyperus* sp., *Cenchrus biflorus, Crotolaria* sp. and *Tribulus terrestris*.

Table 5 : Soil fertility under various systems in the project area.

Systems	0.C (%)	Av.K ($Kgha^{-1}$)
Silvi-pasture	0.156	324
Pasture	0.131	331
Agri-horticulture	0.600	336
Arable farming	0.073	238

RESEARCH AND DEVELOPMENTAL ACTIVITIES

Field studies for development, refinement and demonstration of technology for biomass production and rehabilitation of degraded arid lands were conducted during 1994 to 1999. Different integrated farming systems viz. Silvi-pasture, Agri-horticulture, Energy and Economic plantation were developed for different soil and land use conditions and are discussed as under.

PASTURE AND SILVI-PASTURE SYSTEMS

Since livestock husbandry occupies the most important place in the economy of the arid region and frequent droughts result in loss of livestock owing to the shortage of fodder sources. Nutritious, balanced and adequate feeding of animals is a major limiting factor in realising increased livestock production. Grasses are ideally suited for the desert eco-system. They not only provide a permanent source of forage which is so important for animal husbandry, but also help to conserve the soil from the ever increasing hazard of wind erosion. The importance of grasses to this region, therefore, can not be over emphasized. Therefore pasture was established in the project area from the point of view of continuous supply of quality fodder (Fig. 2). It is necessary that pasture programme is also strengthened by raising fodder tree and shrub species. Introduction of suitable tree species will not only provide nutritionally better quality fodder during the lean period, but will also be useful in nitrogen build up in the soil and serve as shade tree for grazing animals. In addition, fodder trees and shrubs will ameliorate the micro-climate conditions and thereby improve condition for better regeneration of grasses. Silvi-pasture system was established during kharif season of 1995 and 1999 at different farmer's fields.

Pasture Establishment Technology

The technology for pasture establishment consists of cleaning the area from the unwanted plants by proper soil working, followed by sowing of *Cenchrus ciliaris* grass (strain 358) immediately after first effective shower by mixing moist sandy soil three to four times the volume of seed. The mixture of soil and seed were drilled uniformly behind cultivater in lines 50 cm apart in 8 to 10 cm deep furrows at a depth of not more than 2-3 cm under the soil. Pelleted seed sowing is also practical. These are prepared by mixing seeds of grass, cow dung, clay and sand in proportion (by volume) 1:1:3:1 using sufficient quantity of water for preparing round pellets (of the size of about 0.5 cm diameter). The pellets containing 2 to 3 spikelets are dried and

Fig.2 : *Cenchrus ciliaris* pasture raised on the wasteland

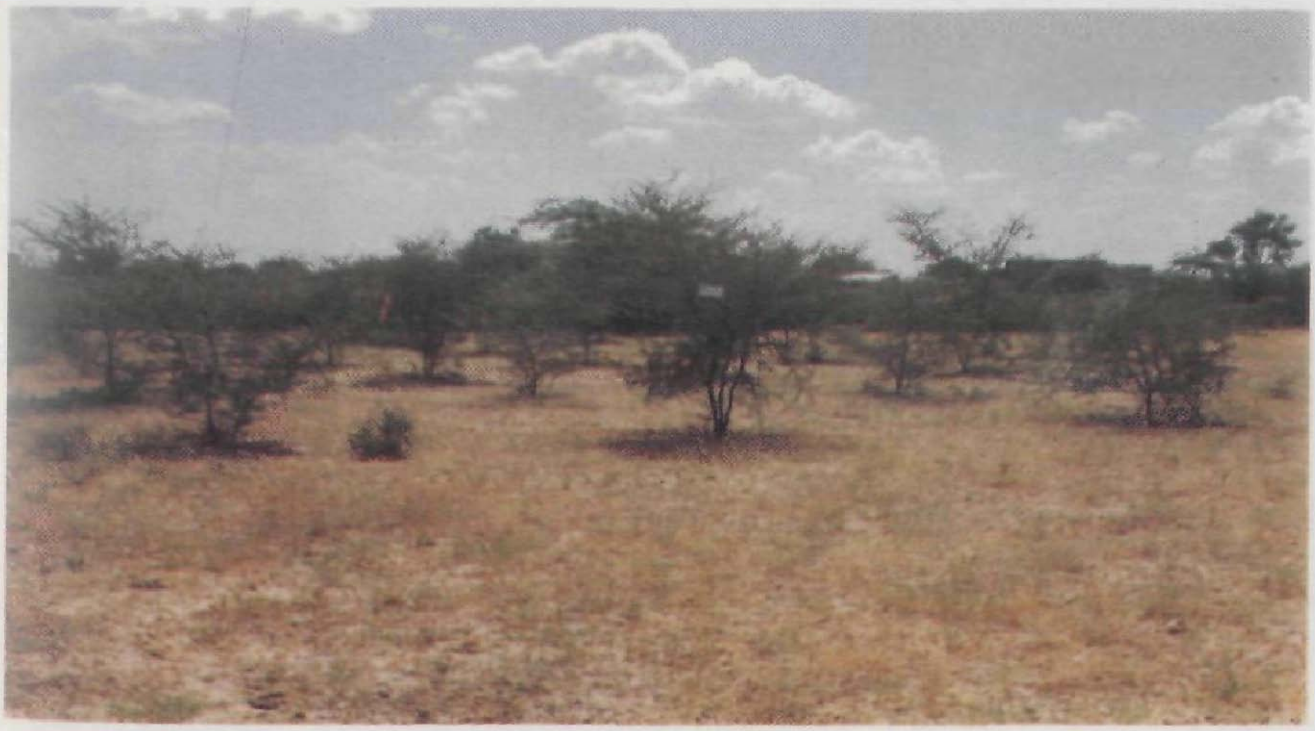

Fig.3: Energy plantation raised on waste calcareous land

stored. The pellets are sown in lines 50 cm apart and placed 1-2 cm deep below the soil surface. Sowing operations are carried out immediately after first effective monsoon rain and also a cuple of days before expected rains.

The programme of Silvi-pasture establishment was undertaken in about 50 hactare area in five years period. Observation of growth parameters of *Cenchrus ciliaris* recorded during different years are presented in table 6:

Table 6: Performance of *Cenchrus ciliaris* grass

Year	Height (cm)	Spike length (cm)	Plant population (000 ha^{-1})	Basal diameter (cm)	Canopy diameter (cm)	Seed weight kg ha^{-1}	Dry fodder yeild kg ha^{-1}
1995	80.5	10.1	43.8	18.7	27.7	90.6	1228.1
1996	83.7	11.0	106.3	14.1	23.9	106.3	1509.4
1997	101.3	10.7	117.2	19.2	29.8	92.2	2695.4
1998	82.6	10.0	84.1	18.2	28.0	86.0	1290.7
1999	88.9	9.8	96.3	19.9	31.3	81.0	1495.4

The degraded lands rehabilitated through pasture establishment and managed properly are potential source of nutritious forage for livestock and good source of grass seed production. This gave net return of Rs. 4964 ha^{-1} as per economics of the model on Silvi-pasture (Annexure I).

The fodder tree species such as *Prosopis cineraria, Colophospermum mopane, Hardwickia binata* and *Zizyphus rotundifolia* were successfully established in pasture land, at 20 m. row to row distance and 5 m. tree to tree distance.

ENERGY PLANTATION

The tree plantation constitutes a basic national resource of vital economic importance. The immense protective and ameliorative role conferred on the environment by trees needs no emphasis. While the area under trees is shrinking and getting decimated at an alarming rate, the demand for timber, fuel wood and various other forest produce is increasing and the gap between demand and supply is widening. The energy crises arising out of diminishing supply and high cost of fossil fuels has created additional demand of firewood as energy source. Various industries depend upon trees for their raw materials. So unless the forest wealth is carefully

maintained, properly developed and effective measures taken, we may soon face an energy crisis.

With the objective to make the farmer self-sufficient for his requirements of fuel, fodder and timber etc. Some tree seedlings of *Acacia tortilis, Acacia nilotica, Albizzia lebbeck, Dalbergia sissoo* and *Tecomella undulata* were planted on wasteland or marginal lands in soils having a calcareous layer (murrum) near the surface (depth 10-20 cm) (Fig. 3). At such sites, round pits (60 x 60 cm) at 5 x 5 m spacing were dug manually. With the onset of monsoon 450 seedlings of above five species (30 seedlings of each species) in three replication were planted in July 1995

Table 7: Performance of different tree seedlings

Tree Species	1995	1996	1997	1998	1999	Mean
Acacia tortilis						
Height (cm)	59.7	115.6	146.9	194.6	224.3	148.2
Canopy (cm)	14.8	38.9	115.2	134.4	141.3	88.9
Acacia nilotica						
Height (cm)	48.2	103.3	154.7	187.2	205.6	139.8
Canopy (cm)	13.5	35.7	116.2	136.4	135.6	87.5
Albizzia lebbeck						
Height (cm)	40.8	90.0	110.6	147.0	167.4	111.1
Canopy (cm)	7.9	20.1	53.3	61.5	66.4	41.8
Dalbergia Sissoo						
Height (cm)	34.3	69.8	87.1	130.3	147.2	93.7
Canopy (cm)	6.9	24.3	52.6	65.7	70.7	44.0
Tecomella undulata						
Heigth (cm)	38.0	65.8	91.1	116.0	126.8	87.5
Canopy (cm)	13.2	22.7	70.2	79.8	81.6	53.5

The five years growth data after planting showed maximum height and canopy of *Acacia tortilis* seedling followed by *Acacia nilotica*. Both *A. tortilis* and *A. nilotica* performed better than other species (Table 7).

In the year 1998, 240 plants of *Acacia senegal* with different soil profile treatments were successfully established in area having shallow soils. Performance of plants in terms of height and survival was recorded and is presented in table 8.

Table 8: Survival and height of *A. senegal* under different treatments.

Treatments	1998		1999	
	Height (cm)	Survival %	Height (cm)	Survival %
T_1 - Pit having murrum	27.0	80	38.9	80
T_2 - Pit having 1/2 loamy sand +1/2 murrum	28.5	80	42.5	80
T_3 - Pit having loamy sand	29.6	81	46.3	81
T_4 - Pit having loamy sand +FYM (5kg)	33.6	80	53.4	80

It has been found that plants grown in pits having loamy sand soil and manure treatment attained the maximum height (53.4 cm) in 12 months period.

At an other site during 1999, tree seedlings of three species of *Albizzia lebbeck*, *Albizzia amara* and *Azadirachta indica* were planted by giving fortnightly irrigation (15 litres) with rain harvested water. During the first year of establishment of these tree species the maximum height was attained in *Albizzia lebbeck* (154.2 cm).

Termite damage was observed in plantation from time to time. Specially in the western Rajasthan due to poor soil fertility, deficient soil moisture and other environmental causes, termite infestation to plantation is severe and some times total loss of plantation has been observed. The infestation is observed on root, stem and bark of the plant. Chlorpihyriphos 20 EC was used for control of termites on plantation.

AGRI-HORTICULTURE

- Horticulture plays a significant role in wasteland development, because fruit crops once established become a permanent source of income and impart stability to agriculture especially in arid and semi-arid regions.

- In addition to bearing fruits, some plants which need pruning provide additional income through fuel wood and fodder.

- Fruit trees are efficient in resource conservation and utilisation.

Most potential fruit crop for arid region is ber (*Zizyphus mauritiana*). It is a quite hardy and can withstand drought, salinity and saline irrigation water. It requires only a few irrigations for establishment. Therefore, plants of grafted ber were planted in 1995 at three sites at 10 x 5 m and 10 x 10 m spacing. At one site in 1995, the soil of the planting pit was treated with a polymer Jalshakti (50 g), FYM (5 kg), composite material (bentonite + guargum 50 g) and mulch. Jalshakti and composite material were applied near root zone of plants. Weeding, irrigation, pruning and protection were given to plantation from time to time. Height variations in ber plants under different treatments during 1995 to 1998 were recorded (Table 9).

Table 9: Performance of *Zizyphus mauritiana* (ber) under different treatments.

Treatments	Height (cm)				Mean
	1995	1996	1997	1998	
Jalshakti (JS)	49.2	71.8	85.9	92.8	74.9
FYM	34.9	70.2	76.1	85.3	66.6
Composite material (CM)	45.4	68.0	72.8	81.4	66.9
Mulch (M)	51.6	71.1	78.4	86.9	72.0
FYM + JS	40.6	85.8	91.6	99.6	79.4
M + JS	55.3	74.4	95.4	99.6	81.2
FYM + Composite material	43.4	74.5	88.5	97.0	75.9
M + Composite material	52.4	68.6	90.9	97.7	77.4
FYM + M	50.4	77.9	84.4	91.0	75.9
Control	43.0	66.7	67.2	73.5	62.6

Ber plants attained greater height (99.6 cm) when treated with Jalshakti and either FYM or mulch.

In the agri-horticulture system, improved varieties of Mung bean (S-8), Moth bean (Maru moth and RMO-40) and clusterbean (Maru guar) were grown in between the ber with about 40-50% increase in yield over local varieties. Beside the grain yield from crops, the system provided the overall net return of Rs. 20,000 ha^{-1} (Annexure II).

During the year 1997, 800 plants of grafted Aonla were planted at eight different sites on farmers field. This plant has a vast scope of growing on wastelands. It is the richest and cheapest source of vitamin C among fruits. This plant has capacity to tolerate high level of salinity in soil as well as in water. It starts fruiting after three years and has potential to produce about 100-150 kg of fruit $plant^{-1}$. These plants

were planted at 10 x 5 m spacing with fortnightly irrigation from rain harvested water

UNCONVENTIONAL ECONOMIC CROPS

Some of the unconventional crops like Senna (*Cassia angustifolia*) and Mehandi (*Lawsonia alba*) were introduced in the area with the objectives of efficient utilisation of resources and the improvement of economic condition of the farmer.

Senna

Senna is perennial crop and stands for 5-7 years. This plant is well known for its medicinal properties and is highly drought resistant, evergreen shrub (Fig.4). The plant can thrive on a wide range of well drained sandy soils to heavy clays including even coarse gravelly soils. Deep sand (depth more than one meter) and sand dunes have been found best for its long tap root development and good branching. Before sowing, the soil should be made free from weeds. Seed rate of 8-10 kg ha^{-1} has been found adequate for good plant population. The best time of sowing is during 15th July to last week of August. The sowing can be done at 30 x 30 cm spacing at a depth of 2-3 cm. It can also be broadcasted followed by harrowing. The leaves are the main economic part of plant. The cutting should be done when the leaves contain high sennocides. This stage comes after flowering when leaves become bluish green. Four cuttings can be done in a year. After cutting the twigs are spread in sunlight for 1-2 days to reduce the moisture content. Thereafter heap of one meter height is made. It is turned upside down after every 2 days until the leaves become brittle but remain green because green colour fetches good price in market. After drying leaves are separated from the twig by soft beating.

The crop which is grown for quality seeds should be harvested after the pods are matured. The mature dark brown pods are collected and seed can be threshed out easily by rubbing the pods.

About 800-1000 kg ha^{-1} dry leaves can be obtained in one year. Seed yield of 400-450 kg ha^{-1} can be obtained from a crop grown for seed.

In terms of economics this crop is highly remunerative and the earning can be between Rs. 10,000 to 13,000 ha^{-1} $year^{-1}$ without the use of costly inputs like water, fertilizer and pesticides etc.

Senna leaves are used in preparing drugs in Unani, Ayurvedic and Allopathic systems against constipation. The trials conducted at Kalyanpur from 1996-1999 have shown very encouraging results on leave and seed production (Table 10).

Table 10: Dry leaves and seeds production of Senna.

Years	Production (Kg ha^{-1})	
	Dry Leaves	Seed
1996	143.3	87.5
1997	530.0	290.0
1998	512.5	407.5
1999	495.0	327.5
Mean	420.2	278.1

Mehandi

In Rajasthan Mehandi has been in cultivation for centuries particularly at Sojat in Pali district the main production centre. It has assumed importance as an important export item to the countries of middle east in addition to the west including U.K. and U.S.A.

Perennial plant of Mehandi stands for 15-20 years. In general, it is grown on soils of widely variable texture varying from sand to clay loam. However, it grows better in soils having medium to moderately fine texture ranging from sandy loam to clay loam with better moisture retention in sub soil. It tolerate little alkalinity in soil. Propagation is done by seeds and cutting. Propagation by seed is common. Seeds are sown in nursery beds and then transplanted. Seeds are first soaked in water for few days for sprouting (with frequent change in water) and then sown in seed beds during March-April. About 4-5 kg seeds are required to cover an area of one hectare. In the month of July-August when seedlings are of 45 to 60 cm height, transplantation of seedlings is done in the fields after cutting out the superflous roots and shoots. Plant spacing may vary from 15 to 30 cm. The field is occasionally hoed and weeded. Once established, these plants continue to grow, flourish and yield successive crops of leaves for several years. Traditionally no irrigation no fertilizer or even no manure is given to this crop in this region. The crop survives even during severe drought conditions.

From second year onwards the crop is harvested regularly by cutting the twigs twice in a year. One cutting is done in March-April while the other is done in November-December. The harvest of November-December alone accounts for 60-80 percent of the total annual yield.

Fig.4: A flowering senna crop on the waste land

Fig.5: Plantation of Mehandi crop at farmer's field

The plants are cut close to the ground. The cut twigs are dried in shade and leaves separated by simple beating on ground. The yield of dry leaves during first 2-3 years may be low varying from 200 to 800 kg ha^{-1}. It may increase later to 1000 to 2000 kg ha^{-1}.

Cost of initial plantation comes to about Rs. 4000-4500 ha^{-1}. Weeding and hoeing operations may cost annually around Rs. 1000 to 1250 ha^{-1}. Harvesting inclusive of two cuttings may annually cost Rs.1000 to 2000 ha^{-1} depending on the crop growth. Thus the total cost of cultivation of Mehandi comes about Rs. 6000 to 7750 ha^{-1} with average dry leave production of about 500 kg ha^{-1}; sold at the rate of Rs.35 kg^{-1}, an income of Rs. 17500 ha^{-1} can be obtained. The profit Rs.17500-7500 = Rs.10000 ha^{-1} from second year onwards is raised to 15000 ha^{-1}, because there will no expenditure on plantation from second year onwards.

With high returns commercial cultivation of Mehandi is attracting the attention of more and more farmers every year and covering more and more cultivable area from crop lands.

It is a hardy shrub and can with stand adverse climate conditions. Its plantations can also act as anti-erosion measure on slopping lands. Therefore, there is an immense scope of plantation mehandi on, degraded wastelands (fig. 5). The results of the studies from 1996-1999 presented in table 11 show high dry matter production in shallow soils (depth 30 cm) of Kalyanpur in Barmer district.

Table 11: Dry leaves production of Mehandi at different soil depth.

Soil depth (cm)	Dry leaves production (kg ha^{-1})				Mean
	1996	1997	1998	1999	
0	73.0	275.0			174.0
30	111.3	481.3	377.5	358.5	332.15
100	99.5	343.8			221.65

ARABLE CROPPING

The production of crops occupies the foremost place in arid agriculture. The techniques of growing crops successfully by utilising the potentialities of soil and climate to the best advantage is, therefore of prime importance to every farmer. Suitable dryland crops and their varieties which match the rainfall pattern of the region and efficiently use the rainfall and stored soil moisture like pearlmillet (HHB-60, HHB-67), mung bean (S-8, K-851), moth bean (Marumoth, RMO-40) and clusterbean (Maruguar and RGC 936) have been identified.

During the kharif seasons improved varieties of different crops were grown in areas having relatively less problem of soil degradation. During rabi, crops were grown in the low-lying area on conserved soil moisture. Farmers in the area grow local varieties of crops which yields very low. Seeds of improved varieties of different crops were given to farmers and trials were conducted on their fields. The performance of these crops is presented in Table 12:

Table 12: Performance of improved varieties of different crops.

Crop	Yield (kg ha $^{-1}$)									
	1995		1996		1997		1998		1999	
	Grain	*Straw*	*Grain*	*Straw*	*Grain*	*Straw*	*Grain*	*Straw*	*Grain*	*Straw*
Kharif										
Clusterbean										
RCG	447	597								
Navin	483	645								
Maru guar	574	891	1003	1719	1035	1953	678	1568	511	1402
RGC 936									530	1453
Local	434	478	788	1550	830	1700	538	1344	413	1238
Mung bean										
S-8			1449	3978	1205	3425	561	2989	553	2892
K-851									587	3006
Local			954	3492	763	3035	344	2281	294	2406
Moth bean										
Maru Moth	183	1284	484	1516	753	1998	260	1340	197	1075
RMO-40									263	1344
Local	133	1273	413	1225	663	1800	219	925	169	969
Pearlmillet										
HHB-60							978	5565	730	5072
HHB-67									690	5000
Local							544	3856	531	3844
Sesame										
RT-46					678	7735	288	4355		
Local					456	4781	231	3763		
Groundnut										
	954	2554								
Rabi										
Gram										
Treatment										
N_0P_0	759	1170								
N_0P_{30}	818	1297								
N_1P_0	856	1323								
N_1P_{30}	955	1445								

Pearlmillet

Pearlmillet (*bajra*) is one of the most important millet crops of the region as evident from cropping pattern in district Barmer. It is grown in 10.65 lakh ha area in Barmer. Beside the grain plant stalks are used to feed cattle or used for thatching purpose. Farmers grow local variety which yield low. Improved varieties HHB-60 and HHB-67 of pearlmillet are short duration varieties and mature in 65-70 days. These varieties tolerate the drought and produce higher yields than local variety (Fig. 6). Therefore farmers of this region prefer both the varieties.

Clusterbean

The farmers in the area grow local variety of guar which yields very low. During 1995, three varieties of guar namely RCG, Navin and maru guar were taken in about 5 ha area and yields were compared with local variety. All three varieties gave higher yield than the local variety. Amongst the improved varieties, maru guar yielded highest followed by Navin and RCG. Maru guar produced 32% more yield as compared to local variety. Looking to the performance of maruguar, seeds of this variety were distributed to different farmers from 1996 onwards for growing in their fields. RGC 936 variety of cluster bean was also tried during 1999 which produced at par with maruguar.

Mung bean

Mungbean S-8 variety gave 52%, 58%, 63% and 88% higher yield as compared to the local variety during 1996 to 1999 respectively. The S-8 variety of mungbean was much liked by the farmers of the area (Fig. 7) because on an average it gave 50-60% higher yield than the local variety.

Moth bean

Improved variety of moth (maru moth) was grown from 1995 to 1999. A comparison of maru moth with local variety showed bigger and bold grain and higher yields of maru moth variety as compared to local one. RMO-40 variety of moth bean tried during 1999 was also liked by the farmers because it tolerates the drought conditions and mature early in 62-65 days only. Yield of Maru moth ranged from 183 to 753 kg ha^{-1}.

Sesame

During 1997 and 1998 sesame variety RT-46 was grown in the area. It performed very well and yielded 678 kg ha^{-1} in 1997, but its yield was less 288 kg ha^{-1} in 1998 due to drought conditions. Its over all performance was, however, better than the local variety.

Groundnut

This crop was introduced in Kalyanpur area for the first time in 1995. In low lying area where runoff water either does not accumulate or recedes early, there is generally sufficient profile moisture to meet the crop water requirement. In order to make effective use of this profile moisture, possibility of raising groundnut crop was explored and results were quite encouraging with grain yield as much as 954 kg ha^{-1}.

Gram

In the low lying areas where water accumulates during rainy season and remain standing it is not possible to raise a kharif crop. After the standing water subsides the farmers grow mustard and gram crops during the rabi season with the objective to utilize conserved moisture. A field trail was conducted in rabi season of 1995 in replicated randomized block design using two levels of nitrogen (0 and 10 kg ha^{-1}) in combination with phosphorus (0 and 30 kg P_2O_5 ha^{-1}). The fertilizers were applied before sowing. Higher yields of grain and straw of gram were attained with the application of 30 kg P_2O_5 ha^{-1} over control. The yield, in control were of the order of 759 kg ha^{-1} grain and 1170 kg ha^{-1} in straw. Application of 10 kg N ha^{-1} in combination with 30 kg P_2O_5 ha^{-1} increased the grain and straw yields by 25% and 23% respectively over control.

WATER HARVESTING

About 90-95% area of Barmer district depends upon monsoon rain for crop, vegetation and plant production. Average annual rainfall in this region is low (250 mm) and highly erratic in distribution. Uncertainty in occurrence of rainfall leads to low yields and frequent crop failures. Under these circumstances water harvesting attains prime importance. Water harvesting can be broadly classified in two categories:

(i) In-situ water conservation

The in-situ methods of water conservation during kharif season have been found to be successful for the field crops as well as the orchard. About 300 ber plants

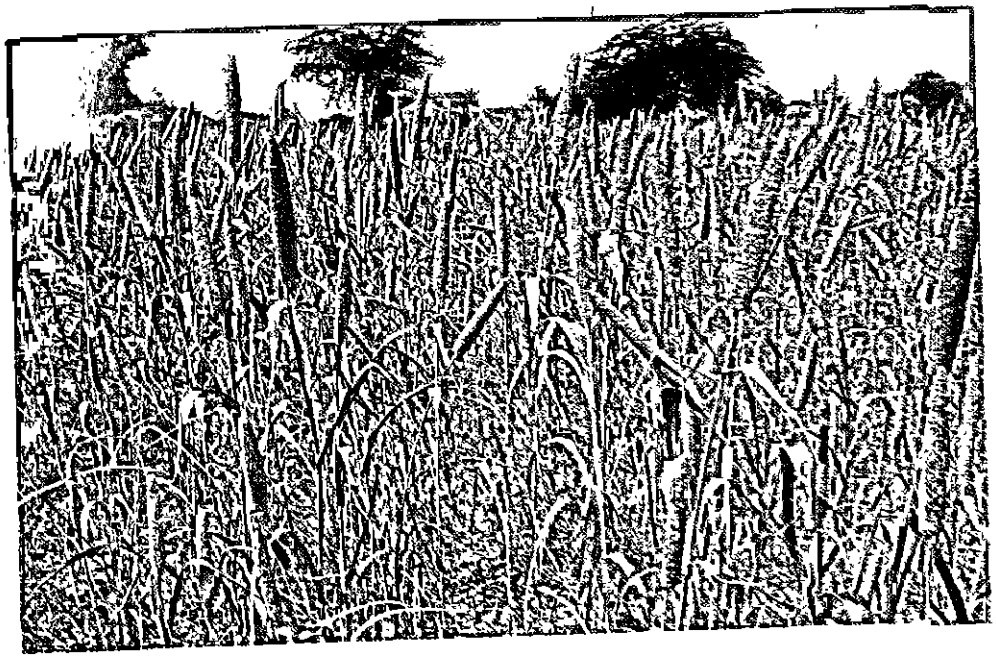

Fig.6: Improved Pearlmillet crop at Farmer's field in Kalyanpur

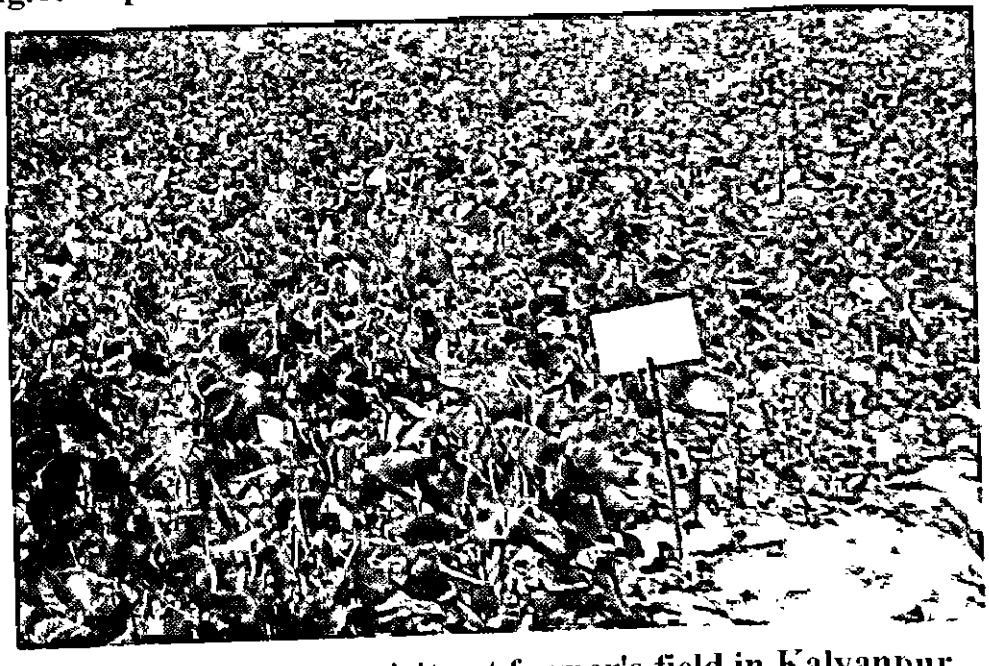

Fig.7: Mung S-8 varielty at farmer's field in Kalyanpur

were established by using micro-catchment of water harvesting at the spacing of 10 x 5 m. For establishment of ber plants, water harvesting system of circular and elliptical catchment (area, 7.07 sq. m) were designed with used sand filled polythene bags, stone waste, marble waste and newspaper as lining material to induce runoff. The growth of plants was found to be higher with water harvesting in comparison to the field plantation. The height of plants was higher by 33.3%, 25.0%, 25.0% and 8.3% in stone, marble, newspaper and polythene lining as compared to unlined control. The height of plants in the unlined control was higher by 26.3% than the normal field plantation (Table 13). The soil temperature at peak hours (13.30 hr) at surface and at 10 cm depth was 1-2°C less in the catchment than that in the field out side the catchment.

Table 13: Effect of various water harvesting treatments on growth parameters of ber plants.

Treatments	% increase over field plants		
	Height	Branch No.	Leaf area (cm^2)
Field plants	-	-	-
Control (unlimited)	26.3	100.0	29.9
Stone lined	68.4	242.8	377.6
Marble lined	57.9	71.4	86.2
Newspaper lined	57.9	100.0	67.8
polythene	36.8	92.8	39.6

Bunding and vegetative barriers

Bunding and vegetative barriers of *Lasiurus sindicus, Sachrum munja* and *Cassia angustifolia* were established at a horizontal interval of 30 m and pearlmillet crop were sown on farmers field during 1998. The cumulative rainfall at the time of sowing was 105.0 mm after which no significant rainfall was received. Moisture observations in 60 cm profile were taken at 15 days interval after sowing. The moisture data revealed 36.5%, 72.0% and 54.2% higher moisture storage as compared to control (36.9 mm/60 cm) in *C. angustifolia, L. sindicus* and *S. munja* respectively. The uniformity coefficient of moisture distribution in the plot size of 125 x 30 m was 91.9, 99.0 and 94.4% in *C. angustifolia, L. sindicus* and *S. munja* respectively. On the average the yield of pearlmillet was 39.1% higher than the control (4.6 q ha^{-1}).

In another trial bunding and vegetative barrier of *Cenchrus ciliaris* were tried and were found very effective in intercepting runoff and improving profile moisture storage in cultivated field having 1-2 percent slope with 40 percent increase in yield of mung bean and moth bean (Fig. 8).

(ii) Ex-situ water harvesting

In the view of scarcity of water, it was proposed to construct water harvesting ponds (Tankas) of 50 m^3 capacity at different locations in farmers field. It was envisaged that the water stored through these structures will be used to raise different plantations (Fig. 9). After initial survey 12 such water harvesting ponds of 50 m^3 capacity were constructed in the farmer's fields at potential water harvesting locations. To ensure farmers participation in the developmental process and as a part of agreement, farmers contributed 40% of the cost of construction of tanka in terms of labour and materials. With the onset of monsoon all these tankas were full to their capacity thereby created a reliable source of water for plants, human and livestock. With the ensured availability of water from these tankas energy and economic plantations, fodder trees, Ber, Anar and Aonla orchard were developed at different locations. To prevent entry of silt in tankas through flowing water different type of silt traps were constructed at inlets. Observations on traditional and improved silt traps showed improved silt traps to be more effective in controlling silt over traditional type of silt traps.

The baffle type silt trap with a colleetion area of 5625 cm^2 reduced the suspended silt load of surface runoff by 1.4 gl^{-1} for a rainfall event of 86.0 mm whereas for the same event, the conventional pit type trap with an equal collection area collected silt load at the rate of 0.74 gl^{-1}. For the rainfall event of 24.0 mm the values were 5.5 gl^{-1} and 3.75 gl^{-1} for baffle and pit type traps respectively. Although for high flows the quantum of silt reduction was less in both silt traps, the baffle type collected 89.1% more silt than pit type.

HYDROLOGICAL MODELLING

In the project area system of localized ground water recharge, with a perched ground water table was studied. The top surface (0-30 cm) soil of the area is sandy-gravelly with high hydraulic conductivity (K_s = 2.6 m day^{-1}). However, below the surface, the soil is very compact and clayey (K_s = 0.5 m day^{-1}). While, the surface soil is very conducive to surface run-off generation, the subsurface restricting layer causes the water to remain stagnant for 6-7 months. The first aquiclude in the study area was found to be at 29.13 m deep from the surface. Hence, the subsurface strata, because of high fillable porosity permits formation of a perched water table, with sufficient storage to supply the year round water. The aquifer transmissivity (T) was established as 4.561 m^2 day^{-1}. The arrival rate of water (V_a) from recharge basin at water table was 0.2 m day^{-1} The fluctuation of water table due to the varying equation

Fig.8: Bunding and vegetative barrier of *Cenchrus ciliaris*

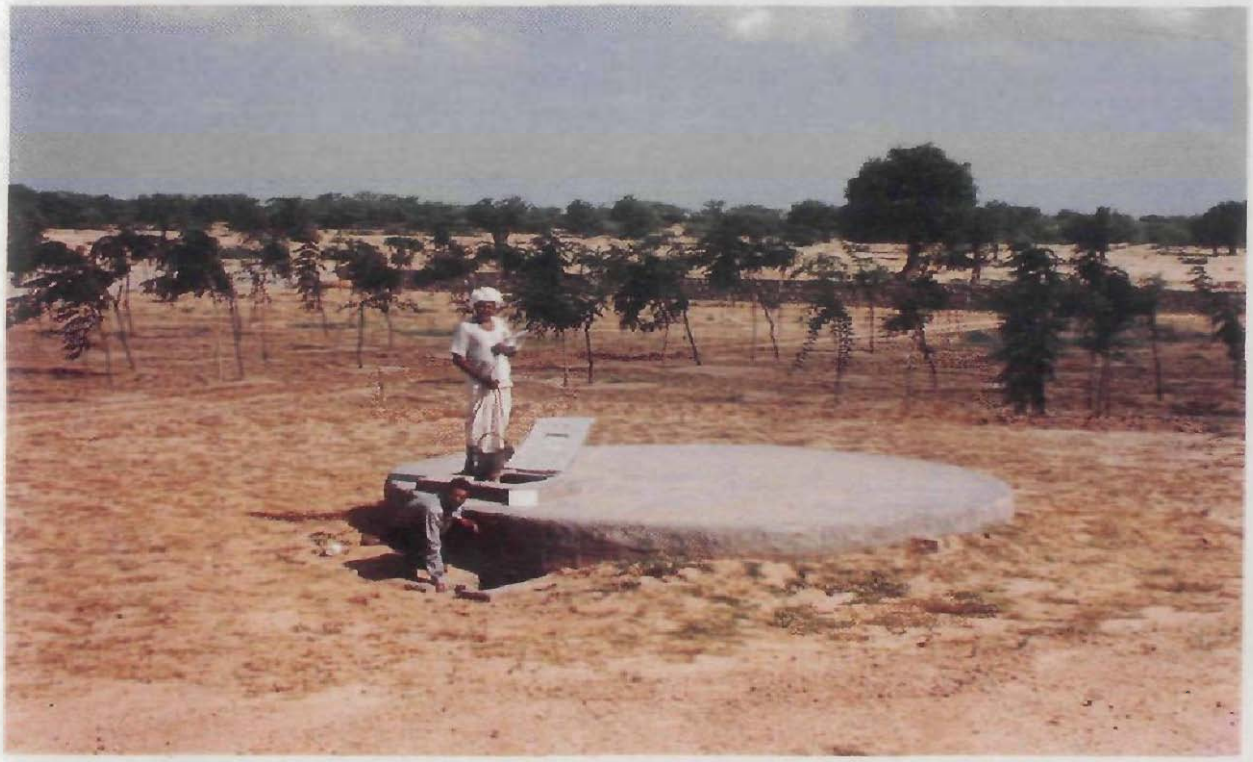

Fig.9: Improve multi purpose tanka and plantation raised with harvested water

was used to predict the rise and fall of ground water mound under the recharge basin.

$$h_t - H = V_a t/4f \{F[(W/2+x)n, (L/2+y)n] + F[(W/2+x)n, (L/2-y)n] + F(W/2-x)n, (L/2+y)n] + F(W/2-x)n, (L/2-y)n]\}$$

Where, h_t is the height of water table above impermeable layer at time t, H is the original height of water table, t is the time since start of recharge, n is the aquifer parameter, and F is the aquifer function and depends on the geometry of the recharge basin. The observed and estimated values of water table show that the fluctuation of water table due to recharge has close prediction. This equation can be applied to evaluate the suitability of certain aquifers (with known aquifer parameter n) for recharge and to determine the best layout of infiltration basin.

Surface and subsurface hydrological phenomena

Studies were conducted on the predictability of Green and Ampt's infiltration equation on the basis of soil physical characteristics of seven catchments of varying area. Five rainfall events mainly contributed to the corresponding water harvesting ponds. The runoff collected in the ponds was recorded for each event of rainfall. The Green and Ampt's equation for unsteady rainfall intensities was applied to each catchment condition for the estimation of rainfall excess converted to surface runoff. The data revealed that prediction of runoff was quite satisfactory (Table 14).

The ground water recharge studies showed that the size of recharging mound was 29.44 m following the heavy rainfall (86.0 mm) of June 10,1998. The mound subsequently subsided and finally levelled of at 10.63 m, thereby causing an effective recharge of 1.45 m from a total seasonal (June-October) rainfall equal to 228.0 mm.

Table 14: Event-wise surface runoff and its predicted value for different sizes of catchment areas.

Date	Rainfall (mm)	Pond location and catchment area (m^2)													
		1		2		3		4		5		6		7	
		400		390		730		390		750		550		390	
		Obs.	Pred.	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.
10.06.98	86.0	78.1	77.2	72.4	73.4	62.6	60.6	55.4	53.1	66.5	66.0	70.4	69.1	71.5	69.8
02.07.98	24.0	07.2	07.2	06.7	06.4	05.3	05.3	-	-	05.5	05.6	06.0	05.6	06.7	06.2
24.08.98	21.0	05.9	05.6	05.6	06.2	03.9	03.8	05.4	05.1	04.2	03.9	04.0	03.4	05.7	05.1
19.09.98	33.0	13.2	14.5	14.5	13.5	12.5	11.9	13.2	13.0	11.9	12.0	11.6	12.3	13.5	13.0
16.10.98	39.0	17.5	17.1	17.1	16.9	14.8	14.5	15.6	15.9	14.0	13.6	13.6	13.9	16.2	16.6

NURSERY RAISING AT FARMERS FIELD

A nursery was raised at farmers field with 5000 plants of four species *Acacia senegal, Tecomella undulata, Colophospermum mopane* and *Hardwickia binata*. The seedlings of four species were given four treatments of light exposure with the help of nylon net of different porosities. These seedlings were raised under shades of net. Observation on the effect of shade on the growth of seedlings of three months of age was recorded (Table 15).

Table 15: Effect of shade on the growth of seedlings.

Plant species/ Shade %	Plant height (cm)				No. of leaves			
	75%	50%	25%	Control	75%	50%	25%	Control
Acacia senegal	10.2	12.4	13.3	7.2	6	7	6	4
Colophospermum mopane	16.2	18.6	14.2	11.3	7	8	7	5
Hardwickia binata	11.1	14.4	12.6	9.5	4	4	4	2
Tecomella undulata	10.3	13.3	8.7	5.8	9	10	7	4

The results of the studies showed that 50% light interception to be the best for growth of all four species of nursery plants. All the shade treatments were found better over control (open without shade). Watering was given to the plants in shade treatments with rain harvested water from tankas at an interval of 3 to 5 days while in control (open without shade) daily watering was required for survival of seedlings.

The objective of this study was to conserve water by reducing evapotranspiration losses, to make farmers self-sufficient for his requirements of seedlings and also for income generation through sale of nursery seedlings.

STABILIZATION OF SAND DUNES/HUMMOCKS

Blowing sand from nearby sand dunes/hummocks creat enormous problems for agricultural lands. The technique of sand dune stabilization has been developed by sowing of grasses and senna (Sonamukhi) and transplanting of tree seedlings of *Acacia tortilis, Acacia nilotica* and *Acacia senegal* at the onset of monsoon. This system has been found quite effective in controlling sand drift.

Senna is perennial crop and stands for 5-7 years. It is highly drought resistant. Deep sand (depth more than one meter) and sand dunes have been found effective for its long tap root development and good branching. Similarly grasses are ideally suited for soil conservation and wind erosion control.

Trees planted at 10 x 5 m spacing in between senna and grasses stabilized sand dunes/hummocks beside improving the environment and economy of the farmers.

OTHER ACTIVITIES

Organisation of field day

In view of creating awareness among farming community regarding various development activities of the project, a farmers training cum-field day was organised on 20th September 1997 at one of the beneficiary farmers field in Kalyanpur. Besides scientists about 300 farmers, school children and others of nearby villages actively participated in the programme. Visit of the farmers to the project site was arranged. Farmers were shown different systems i.e. agri-horticulture, silvi-pasture, energy plantation and water harvesting (Tankas) and cultivation of improved varieties of kharif crops. Farmers appreciated performance of improved varieties of mung bean, moth bean and clusterbean. Farmers showed keen interest in cultivation of mung bean S-8 variety. Besides they were also shown the plantation of some unconventional economic crops like Sonamukhi and Mehandi. Farmers showed keen interest in construction of water harvesting ponds (Tanka) at their fields with the assistance from NWDB. Farmers were also given training for grafting of budded ber. Expert scientists of different discipline from the institute attended the problems of the farmers and tried to solve them. On this occasion a quiz was organised for school children to create awareness about different type of soils, their properties and behaviour.

Training programmes organized:

The following training programmes were organized at farmer's field during 1999-2000.

Integrated pest management	26.04.1999
Afforestation and nursery raising techniques	25.05.1999
Sand dune stabilization and wind erosion control	30.06.1999
Dryland crop production and nutrient management	30.07.1999
Soil and water conservation techniques	07.08.1999
Pasture and silvi-pasture system	30.09.1999
Cultivation of unconventional crops	22.11.1999
Horticulture and processing	22.11.1999
Mushroom cultivation	14.01.2000
Animal husbandry and livestock management	29.02.2000

Expert scientists of the institute of different disciplines imparted training to the farmers. Each training was organised at farmer's fields so that maximum farmers could be benefited by the programmes. In each training programme about 50 to 100 farmers of Kalyanpur and nearby villages actively participated.

Distribution of seed and seedlings

Seeds of improved varieties of crops viz. pearlmillet, mungbean, mothbean, clusterbean, sesame, groundnut etc. were distributed to farmers in the villages. Farmers were also educated about the improved package of practices. Grass seeds and seed of some economic crops like Sonamukhi and Mehandi were distributed. About 10000 plants of *Acacia senegal*, *Acacia tortilis*, *Azadirachta indica*, *Albizzia lebbeck* etc. were also distributed to farming community for field and boundary plantation.

PUBLICATION

Following research paper, popular articles and technical extension brouchers were published out of the studies conducted under this project. These are:

Research Papers

Gupta, J.P., S.S. Rathore and B M. Sharma (1997). Technology for greening sandy wastelands The Kalyanpur experience. Paper presented on Symposium in RAMOECOS organised by CAZRI, Jodhpur March 3-5, 1997. Published in Management of Arid Ecosystem. A.S. Faroda, N.L. Joshi, S. Kathju and Amal Kar (Eds.) p. 499-504.

Gupta, J.P., P.R. Ojasvi and R.K. Goyal (1997). Rehabilitation of degraded land in arid eco-system. Paper presented in National Symposium on Public Participation in Environmental Protection organised by Deptt. of Zoology, J.N.V. University, Jodhpur December 22-23, 1997.

Rathore, S.S. and J.P. Gupta (2001). Technology approach for rehabilitating degraded arid lands. Paper presented in Symposium on Impact of Human Activities on Thar Desert Environment; organised by Arid Zone Research Association of India, Jodhpur, February 15-17, 2001.

Popular Articles

Rathore, S.S. and Gupta, J.P.(1999). Shuska kshetro mein kharif ki pramukh faslo ki unnat kheti. Vishwa Krishi Sanchar 2 (1): 38-40.

Gupta, J.P., A.P. Jain, S.S. Rathore and R.K. Goyal (1999). Shuska kshretro mein samanvit snasadan prabandhan apanakar utpadakta badhaye. Vishwa Krishi Sanchar 2 (3):50-51 & 83.

Rathore, S.S. and J.P Gupta (2000). Guar va moth adhik utpadan prodyogiki. Vishwa Krishi Sanchar 2 (11-12): 85.

Technical extension brochures

Rathore, S.S. and J.P. Gupta (2000). Charagah and van-charagah vikas.

Rathore, S.S. and J.P. Gupta (2000). Guar paramparik phasalo ki kheti.

Sharma, B.M and J.P. Gupta (2000). Khad avam urvarko ka upyog.

Sharma, B.M. and J.P. Gupta (2000). Shasya Vaniki.

Goyal, R.K. and J.P. Gupta (2000). Marusthal mein mrada va jal sanrakshan.

Goyal, R.K., J.K. Lohia and J.P. Gupta (2000). Bahu-udhesya unnat tanka.

Vyas, N.L., Arun Kumar and J.P. Gupta (2000). Maru kshretro mein khumbi ki kheti.

Annexure I

Economics Analysis of Silvi-pasture Model

Expenditure ha^{-1}		**Rs.**
I. Pasture establishment		
Field preparation and grass seedings		
Three tractor operations (for removal of unwanted vegetation, through soil working and grass seeding) required 8 hours @ Rs 100 hr^{-1}.		800
12 labourers for cleaning of area and sowing of grass seed @ Rs 44 day^{-1}		528
Input cost		
Grass seed 5 kg @ Rs 150 kg^{-1}	750	
Fertilizer (40 kg N + 20 kg P_2O_5)	400	
Miscellaneous	100	1250
Maintenance and other recurring expenditure		
Post planting cultivation once in season, two tractor hour @ Rs. 100 hr^{-1}.	200	
two labourers @ Rs 44 day^{-1}	88	
Other recurring expenditure	70	
		358
Seed collection and forage harvest cost		
Seed collection cost (Average production 30 kg ha^{-1}) 15 labourers @ Rs. 44 day^{-1}	660	
Grass harvesting cost (Average production 2500 kg ha^{-1}) 10 lab @ Rs. 44 day^{-1}	440	
		1100
II. Establishment of fodder plant in pasture		
Digging of pits, weeding, irrigation etc. required 20 labourers @ Rs. 44 day^{-1}		880
Seedling 100 @ Rs. 3 plant^{-1}	300	
Fertilizer	100	
		400
Harvest of forage and fuel 5 lab @ Rs. 44 day^{-1}	220	
		220
Total Expenditure		**5536.00**

Return ha^{-1}

Grass seed (30 kg ha^{-1}) sold @ Rs. 150 kg^{-1}	4500
Grass fodder (2500 kg ha^{-1}) sold @ Rs. 2 kg^{-1}	5000
Green fodder from tree seedling (5 kg from each tree) 100 x 5 = 500 kg sold @ Rs. 2 kg^{-1}	1000
Total Return	**10500.00**

Net profit: 10500-5536 = Rs. 4964 ha^{-1}

Annexure II

Economics Analysis of Agri-horticulture Model

Expenditure ha^{-1}

I. Establishment of Ber orchard	**Rs.**
Layout 2 labourers @Rs. 44 day^{-1}	88
Fencing cost	700
Digging pits and planting cost etc. 15 labourers @ Rs. 44 day^{-1}	660
Input cost	
Seedling (100 no.) @ Rs. 7 seedling^{-1}	700
FYM one trolly	500
Pond silt one trolly	300
Fertilizer	500
Insecticide and pesticide	1,000
Labour for irrigation, weeding, watch ward, picking of fruit, pruning and other miscellaneous charges 75 labourers @ Rs. 44day^{-1}	3300
II Cultivation of crops (Mung bean, Moth bean, Clusterbean) ha^{-1}	
Two tractor operations for field preparation and sowing of crop required for 5 hours @ Rs. 100 hour^{-1}	500
20 labourers for sowing, weeding, harvesting of crops @ Rs. 44 day^{-1}	880
Input cost	
Kharif legume 15 kg @ Rs. 25 kg^{-1}	375
Fertilizer and FYM	500
Total Expenditure	**10000.00**

Returns ha^{-1}

		Rs.
Fruit yield plant^{-1}: 20 kg Total yield ha^{-1} (100 plants): 2000 kg Total returns @ Rs. 10 kg^{-1}		20000
Crop production 5 q ha^{-1} sold @ Rs. 2000 q^{-1}		10000
	Total Return	**30000**

Net profit: Rs.30000-Rs.10000 = Rs.20000 ha^{-1}