CHAPTER -1

SODIC VERTISOLS OF SOUTH - WEST MADHYA PRADESH - AN OVERVIEW

Degradation of soil physical and chemical environment is a serious problem in India. When we talk of degraded land we must also know ideal soils. It actually helps us in understanding degraded land. The ideal soil for agricultural production is better understood by following attributes.

- Neutral in reaction.
- Capable of supplying adequate quantities of essential plant nutrient.
- Capable of supporting biological process with adequate soil organic matter.
- Well drained and well aerated, with capacity to store soil moisture to support crop growth.
- Sufficiently deep with no impediment to root growth.
- Located on gently sloping sites.

Any inadequacy or lack in one or more of the above attributes would render a soil problematic or degraded and decrease its productive potential. Looking at the fast shrinking per capita arable land, Government of India is increasingly felt need to give strong emphasis to management and reclamation of degraded land in its various programmes. As per Agricultural Statistical Compendium (1992) the per capita available agricultural land during 1951 was 0.41 ha which was reduced to 0.20 ha by 1991 and 0.16 ha by 2001. Genesis, nature and occurrences of degraded lands differ region to region, which necessitates location specific monitoring and utilization of these soils. These sodic Vertisols possess unique physico -chemical characteristics under semi -arid climate with erratic rainfall of 500-800 mm per annum and inadequate irrigation facilities. Under the situation common reclamation methods such as sub -surface drainage, leaching and flushing of salt, chemical amelioration etc were tried by SAS Project Indore and it was observed after several years of experiments that aforesaid measures did not prove feasible proposition to effectively reclaim these soils. The only option then left with is provision of surface drainage through various means along with reuse of harvested runoff to control sodicity build-up and improvement in production.

Extent of sodic soils

The salt affected soil encompasses 8.5 million ha in India (Singh, 1992) under contemporary and secondary salinization in arid and semi- arid regions out of which 2 million ha is under Vertisols and associated soils. An area of 0.242 million ha is reported to exist in Madhya Pradesh, afflicted with salt problem which is about 2.63 % of the total waste land area. The reconnaissance soil survey, reported that about 34000 ha is affected by salinity and sodicity problems in black soil regions of Madhya Pradesh. Approximately 21965 ha were observed to have salt problems due to natural causative factors in black soils of Malwa and Nimar regions of southwest Madhya Pradesh.

Characteristics of sodic vertisols

The sodicity and salinity problems are observed in Vertisols and associated soils of Nimar and Malwa regions of Madhya Pradesh. The area represents a case of contemporary sodicity developed due to combination of factors like basaltic parent material, low and basin topography poor drainage and semi-arid climatic conditions exist together. The area is having moderate rains of 500 – 800 mm annually along with inadequate irrigation facilities. Basu (1950) opined that it is the basic nature of the parent material, aridity of the climate, nearness to sub-soil water, poor drainage condition and topography that are responsible for development of the sodic problem in Vertisols and associated soils. Most of the area under black soils falls in semi- arid tropics with low leaching intensity and alternate wet and dry seasons. Thus the climate conditions are favourable for the build-up of salt in the root-zone to a level detrimental to normal plant growth particularly under restricted condition. Vertisols are potentially saline/ alkaline in compacted sub-surface horizons (Murthy et al., 1991). Due to compacted sub-surface horizons coupled with low infiltration characteristics the black soils are prone to sever erosion and exhibits as high as 40 % runoff and soil loss to the tune of 60 Mg per ha per year (Sharma et al., 1991). In black alkali soils the ESP beyond 10 leads to sever structural degradation (Gupta and Verma, 1983) due to high degree of clay dispersion. The dispersed clay clogs the pores and induced increased water retention (Sharma et al., 1984) at all suctions. With increasing ESP the rate of drying front declines and moisture changes in lower layer are much slower. With higher water retention and increasing alkali contents, deep cracks do not develop in sodic Vertisols (Sharma, 1998, Verma and Sharma, 1998) which is a qualifying characteristic of Vertisols.

Status of common reclamation methods

The aforesaid typical physico-chemical characteristics of sodic Vertisols put question mark on effectiveness of commonly used reclamation methods to manage these soils. The SAS Project, Indore tried various commonly used reclamation methods such as leaching and flushing, chemical amelioration, sub-surface drainage etc in these soils and after a several years of experiments it was concluded that above methods are not feasible proposition to reclaim and manage these soils. The status of various tried measures is as discussed below.

Leaching and flushing

The unique physico-chemical properties render salt leaching difficult (Verma et al., 1989) unless their physical conditions are improved first with the addition of suitable amendments (Yadav, 1981) which again requires ample amount of water for dissolution, soil reaction, leaching and flushing. Availability of ample water is a constraint due to inadequate and meager irrigation facilities. The ground water is also depleting alarmingly in the region. Thus the situation stresses the need of harvesting of excess runoff water for recycling specially in sodic Vertisols Agri- ecosystem.

Chemical amelioration

Chemical amelioration of the layer has very little effect on sub-soil sodicity, which restricts deep percolation. After incorporation of chemical amendments the improvement in physico- chemical properties is limited to only the depth of mixing of amendments. Untreated layer creates obstruction to in-flowing water. This not only adds as impediments to root growth but also causes development of perched water table following rains or irrigation thereby reducing seedling emergence and crop stand through inducement of oxygen stress in root zone. Even the ameliorated plough layer lacks adequate aeration porosity because of high clay content and residual sodicity. Thus under semi-arid climate condition the up-land kharif crops grown in such soils can be considerably mitigated by providing economically viable means of drainage (Sharma et al., 2000).

Sub-surface drainage

Sub-surface drainage system installed in alkali soils of Nimar region of Madhya Pradesh (during 1970-1971) became non-functional after few years of installations. The excavation of drains showed complete choking of tiles in both lateral and collector with sediments of fine silt and clay particles. The sediment has been transported due to movement of water to the drain and got entrapped there. The filter materials used were found unable to restrict the entry of fine suspended particles. It was interesting to note that just above the drains pipe a 30 cm high and 100 cm vide envelope of filter material of coarse sand could not arrest the clay particles from entering the drain pipe along with draining water. Ranade et al., 1995 assessed the cause of failure sub–surface drainage system. It was observed that filter efficiency of the system can be improved to some extend by increasing the fineness of the filter materials. Further it was observed that discharge rate decreased significantly with time and this might have lead to failure of drainage. Therefore only option left with is surface drainage system through various means along with harvesting of excess drainage water for recycling to improve crop production. To design appropriate means of surface drainage and runoff harvesting system one is required to monitor series of hydrologic data such as rainfall, runoff and soil loss on small agricultural watershed basis in sodic black soils.

Quality of drained water

The growing environment consciousness and enactment of several laws and regulations to maintain the quality of water emphasize the need to assess quality of effluent runoff of salt affected fields to ensure recycling of the same in agriculture along with on spot conservation (Dutt, 1994). For achieving the goal of water quality management and water pollution control a reliable database is always mandatory.

Finally, the overview calls for conducting research in sodic black soil conditions on various aspects like surface drainage design criteria, method of irrigation and quality of water in fruit plants recommended for sodic black soils, on form water harvesting, assessing and conserving natural resources, comparing various land configurations rainfall-runoff relationship, drip fertigation with marginally saline water, hydrological behavior of some grass species planted in sodic Vertisols, performance of primary treatment measures of waste water and approach to design wetlands for waste water treatments. The research work carried out on above aspects during a decade or so in sodic black soils and its counterpart under the auspices of SAS Project has been discussed in this bulletin.

CHAPTER 2
DRAINAGE CRITERIA

2.1 Evaluating surface drainage need in sodic black soils

Agricultural land drainage is an important aspect of farming. The purpose of agricultural land drainage is to remove excess surface water adequately enough for the needs of the crops for which drainage system should be properly designed. The proper design of the drainage work depends on estimation of the suitable value of drainage coefficient. Different crops have different degree of tolerance to excess water conditions. The excess surface water therefore has to be removed from the cropland within such times that the crops are not damaged due to excess water conditions. Therefore physical tolerance to excess water condition becomes an advantageous factor in agricultural land and drainage designs since runoff water can be removed at a much smaller rate than peak. A smaller rate of water removal results in much smaller dimensions of the drain, thereby reducing cost of drainage system. Battacharya (1982) opined that consecutive day's rainfall analysis is more relevant for ascertaining suitable value of drainage coefficient to arrive at proper design of agricultural land drainage and it should be followed in command areas. Higher the recurrence interval, higher the design rainfall value, implying more cost of the project with less risk of failure. Failure in agricultural sense is loss of production. An average failure of 5 to 10 years is generally acceptable for agricultural land drainage since cropping pattern in area changes fast (Anonymous. 1980). With the above back ground an attempt has been made in this study to evaluate drainage need in sodic black soils of south – west Madhya Pradesh to arrive at suitable values of drainage need for proper design of surface drainage structures.

The daily rainfall data of 11 years period (1989-1999) recorded at Barwaha Farm was subjected to depth-duration frequency analysis to work out consecutive days maximum rainfall at various recurrence interval of 2, 5, 10 and 20 years. The year wise maximum consecutive days rainfall was worked out by maximum total technique described by Kesseler and Raad (1974) from daily rainfall record of 11 years. Plotting positions were obtained by Weibul formula. The Gumble distribution is fitted to rainfall data by using frequency factor technique. The frequency factor (k) is a function of recurrence interval (years) and the type of probability distribution to be used. The fitted equation by frequency factor is expressed as;

$$X = \bar{X} + \sigma k$$

Where X = a variate
$\bar{X}$ = mean
σ = Standard deviation
k = frequency factor

The frequency factor (k) can be determined by empirical formula proposed by Fuller for frequency analysis for maximum annual rainfall as follows;

$$k = 0.8 / CV \log T$$

Where $CV = \sigma / \bar{X}$
T is recurrence interval (years)

Agricultural land drainage need is determined by subtracting basic infiltration value from consecutive day's rainfall. The basic infiltration rate was ascertained by developed equation for soils having different ESP levels. Verma and Sharma (2000) reported that basic infiltration at > 35 ESP becomes almost negligible in sodic black soils. The drainage need for different ESP level soils for various recurrence interval were estimated by considering the fact that soils are saturated and therefore evapotranspiration, raindrop interception etc are negligible as for as drainage is concerned. Information on consecutive day's rainfall for various recurrence interval, basic infiltration and drainage need were developed in this study. The details of developed information are discussed as below.

Consecutive day's rainfall analysis

Year wise maximum consecutive days rainfall values were ascertained by maximum total technique from daily rainfall data of 11 years period (1989-1999) recorded at research farm, Barwaha of the project and are shown in Table 2.1.1 along with probabilities of their occurrences.

Table 2.1.1. Consecutive day's rainfall in ascending order along with probability

S No.	Consecutive days rainfall (mm)				Probability
	1	2	3	4	
1	178.4	294.2	299.4	302.0	0.083
2	178.2	243.0	271.0	281.5	0.166
3	157.0	216.0	220.0	245.7	0.250
4	135.5	206.8	208.4	232.0	0.333
5	123.5	194.0	199.5	211.6	0.416
6	101.0	180.0	194.0	194.0	0.500
7	91.0	171.8	165.9	176.0	0.583
8	78.0	121.0	164.0	170.0	0.666
9	75.0	117.0	158.0	168.0	0.750
10	62.0	110.0	140.6	148.6	0.833
11	62.0	67.0	67.0	76.8	0.910
ΣX^2	157874.3	379675.37	435336.34	482976.9	-
ΣX	1235.6	1921.3	2085.8	2205.2	-
$\bar{X}$	112.327	174.663	189.618	200.47	-
σ_{X-1}	43.683	66.40	63.11	63.948	-
C_V	0.3888	0.3801	0.3328	0.3189	-

The consecutive days rainfall values for 1, 2. 3 and 4 days period were worked out by fitted equations obtained by frequency factor method as discussed in technique section. The fitted equations obtained in terms of recurrence interval (T) in years are shown in Table 2.1.2.

Table 2.1.2. Fitted equations for various consecutive days' rainfall.

Period in days	Fitted equations
1	$X_1 = 112.327 + 89.98 \log T$
2	$X_2 = 174.663 + 139.95 \log T$
3	$X_3 = 189.618 + 151.7 \log T$
4	$X_4 = 200.47 + 169.42 \log T$

Where X_1 represents 1-day period rainfall and T for recurrence interval in years.

From the above fitted equations of Table 2.1.2 consecutive days maximum rainfall values were computed for recurrence interval of 2, 5. 10 and 20 years and the same are shown in Table 2.1.3.

Table 2.1.3. Consecutive day's maximum rainfall for various recurrence intervals (in years)

S. No.	Period in days	Consecutive days maximum rainfall (mm) for R. I.			
		2	5	10	20
1	One	139	175	224	229
2	Two	216	272	314	356
3	Three	235	295	341	386
4	Four	248	318	369	420

Basic infiltration with ESP

The transient infiltration measurement in field plots with differential ESP levels reveals that the rates and cumulative infiltration is considerably reduced with increase in soil ESP in sodic black soils. The infiltration study was conducted by SAS project and relationship developed between time (minutes) and cumulative infiltration (mm) at various ESP levels are shown as below (Table 2.1.4**)**.

Table 2.1.4. Infiltration equation developed at various ESP levels in sodic black soils

Sr. No.	ESP levels	Developed equations
1	10	$I = 5.7\ t^{0.5}$
2	15	$I = 5.7\ t^{0.36}$
3	22	$I = 4.9\ t^{0.31}$
4	> 35	Approached to almost 0*

- Verma and Sharma, (2000).

The cumulative infiltration and rate were worked out using above developed equations and computed values are shown in Table 2.1.5.

Table 2.1.5. Cumulative infiltration (mm) and Rate mm/hr at various ESP levels

S. No.	Time (minutes)	Infiltration at various ESP levels.					
		ESP- 10		ESP - 15		ESP – 22	
		Cumulative	Rate	Cumulative	Rate	Cumulative	Rate
1	60	44.15	-	24.89	-	17.43	-
2	120	62.44	18.29	31.94	7.05	21.61	4.16
3	180	76.47	14.03	36.96	5.02	24.51	2.9
4	240	88.33	11.83	40.19	4.03	26.79	2.28
5	300	98.73	10.43	44.42	3.43	28.71	1.92
6	360	108.15	9.42	47.44	3.02	30.38	1.67
7	720	152.94	-	60.88	-	37.66	-
8	780	157.13	4.19	62.66	1.76	38.61	0.95
9	1360	211.74	-	76.95	-	46.08	-
10	1440	216.29	4.55	78.14	1.18	46.69	0.62

11	1500	220.76	4.47	79.29	1.15	47.29	0.6
12	1560	225.13	4.37	80.42	1.13	47.87	0.58
13	1620	229.42	4.29	81.52	1.10	48.43	0.56
14	1680	233.63	4.21	82.60	1.08	48.98	0.55
15	1740	237.76	4.13	83.65	1.05	49.51	0.53
16	1800	241.83	4.07	84.67	1.02	50.04	0.53

It is obvious from table 2.1.6 that infiltration rate decreases sharply with increase in ESP. The basic infiltration rate observed at ESP levels 10. 15 and 22 are 4 mm/hr, 1 mm/hr and 0.5 mm/hr respectively. While Vera and Sharma (2000) and many others reported that basic infiltration rate beyond ESP 35 becomes almost negligible. So basic infiltration rates (mm/hr) obtained from Table 2.1.5 are summarized in Table 2.1.6.

Table 2.1.6. Basic infiltration rates obtained at ESP levels

S. No.	ESP levels	Basic infiltration rates
1	10	4
2	15	1
3	22	0.5
4	> 35	Approaches to 0

Drainage need in sodic soils

Drainage need is governed by the factors like recurrence interval, crop tolerance to excess water condition and ESP levels of soil. So considering aforesaid factors drainage need is worked out by subtracting basic infiltration from designed consecutive days rainfall values and obtained values of the same are shown in Table 2.1.7.

Table 2.1.7. Estimated drainage need in sodic black soils

Sr. No.	**I_b (mm/hr)**	**Drainage need in (mm/day) for consecutive days rainfall of various R.I. (years)**											
		1 day			**2days**			**3 days**			**4 days**		
		5	**10**	**20**	**5**	**10**	**20**	**5**	**10**	**20**	**5**	**10**	**20**
1	0	175	224	229	136	157	178	99	114	129	80	93	105
2	1	151	200	205	112	133	154	75	90	105	56	69	81
3	2	127	176	181	88	109	130	51	66	81	32	45	57
4	3	103	152	157	64	85	106	27	42	57	8	21	33
5	4	79	128	133	40	61	82	-	18	33	-	-	9
6	5	55	104	109	16	37	58	-	-	9	-	-	
7	6	31	80	85	-	13	34	-	-	-	-	-	
8	7	-	56	61	-	-	10	-	-	-	-	-	
9	8	-	32	37	-	-	-	-	-	-	-	-	
10	9	-	-	-	-	-	-	-	-	-		-	

The values of drainage need shown in above table reveal that crops grown in sodic black soils having ESP > 10 may necessarily have to be provided with surface drainage system and there is enough runoff potential to harvest for later use in the area. The runoff potential also increases with increase in ESP of soils and it would be maximum beyond 35 ESP. The drainage need as per ESP level of sodic black soils, crop tolerance and recurrence interval can easily be found out from table 8.The drainage needs computed are summarized in Table 2.1.8.

Table 2.1.8. Some of the values of drainage need for different ESP soils

ESP	I_b (mm/hr)	Drainage need (mm / day)											
		1 Day CT*			2 days CT			3 days CT			4 days CT		
		5**	10	20	5	10	20	5	10	20	5	10	20
10	4	79	128	133	40	61	82	27	42	33	32	21	33
15	1	151	200	205	112	133	154	75	90	105	56	69	81
22	0.5	163.5	212	217	124	145	166	87	102	117	68	81	93
> 35	0	175	224	229	136	157	178	99	114	129	80	93	105

* Indicates crop tolerance to excess water condition.
** Figure in 3 rd row of the table shows recurrence interval in years'

It is obvious from table 2.9 that in sodic black soils having ESP > 10 the drainage need for crops having crop tolerance 1 day, varies between 175 – 79 mm/day, 224 – 128 mm/day and 229 – 133 mm/day for recurrence interval 5, 10 and 20 years respectively. In the same way drainage need for crops having crop tolerance two days varies between 136–40 mm/day, 157-61 mm/day and 178 –82 mm/ day for recurrence interval of 5, 10 and 20 years respectively. Similarly value of drainage need for 3 days and 4 days crop tolerance can be obtained as between 99–27 mm/day 114–42 mm/day, 129–33 mm/day and 80–33 mm/day, 93- 21 mm/day, 105–33 mm/ day respectively for 5, 10 and 20 recurrence interval.

Conclusion

The study therefore deals with an approach to arrive at suitable value of drainage need in sodic black soils. The study has developed equation to estimate 1, 2, 3 and 4 consecutive day's rainfall for various recurrence intervals. The transient infiltration measured at differential ESP levels and used to develop relationship between cumulative infiltration and time .The basic infiltration rate observed from developed equation are 4, 1, 0.5 and 0 mm / hr at ESP levels of 10, 15, 22 and 35 or above respectively. The estimated value of drainage needs reveals that crops grown in sodic black soils having ESP greater than 10 may necessarily have to be provided with surface drainage system and there is enough runoff potential to harvest the same for later use. The runoff potential enhances with increase in ESP levels and it would be maximum beyond 35 ESP. Study also suggests drainage need values between 175 – 79, 224 – 128 and 229- 133 mm / day for recurrence interval of 5, 10 and 20 years respectively in soils having ESP 10 or more in case of crops with 1 day crop tolerance to excess water condition. Similarly values of drainage need ranges are (136–40, 157–61, 178–82 mm / day), (99-27, 111-42, 129-33 mm / day) and (80-33, 93-21, 129—33 mm/day) for crops having crop tolerance to excess water condition as 2, 3 and 4 days respectively. Finally it is concluded that depending upon crop grown, ESP of soils and recurrence interval adopted a suitable value of drainage need could be arrived at for proper design of surface drainage in sodic black soils of south – west Madhya Pradesh.

2.2 Crop tolerance to excess water condition in sodic black soils

It has been reported for sodic Vertisols that feasibility of proper drainage is only possible through various means of surface drainage systems. It was also reported that significant yield improvement observed after adoption of surface drainage in sodic black soils. Agricultural land drainage is an important aspect of farming. The purpose of agricultural land drainage is to remove excess surface water adequately enough for the needs of the crops for which drainage system should be properly designed. The proper design of the drainage work depends on estimation of the suitable value of drainage coefficient. Different crops have different degree of tolerance to excess water conditions. The excess surface water therefore has to be removed from the cropland within such times that the crops are not damaged due to excess water conditions. Therefore physical tolerance to excess water condition becomes an advantageous factor in agricultural drainage design since runoff water can be removed at a much smaller rate than peak. A smaller rate of water removal results in much smaller dimensions of the drain, thereby reducing cost of drainage system. With the above back ground an attempt has been made in this study to evaluate the crop tolerance of cotton to excess water condition in sodic black soils.

The cotton crop is a most adopted choice of the farmers of the area and therefore selected for study. To determine the crop tolerance of cotton to excess water condition, submergence for period of 1 to 4 days was observed at various growth stages of the crop. The growth stages considered were (S_1) – sowing to emergence (7 days after sowing), (S_2) – after 15 days of sowing, S_3 – flowering after 45 days from sowing and (S_4) – square stage after 80 days from sowing and (S_0) as control i.e. no submergence. Similarly period of submergence is represented by D_1, D_2, D_3 and D_4 as 1, 2. 3 and 4 days submergence, respectively. Vikram variety of cotton was sown on 4 th of July 2000. All recommended package of practices for growing cotton in sodic black soils were adopted. Experiment is conducted at 3 ESP levels i.e. 25 35 and 45. The other details of the experiment are as follows.

Treatments

Main plot treatment	- Natural soil ESP (25, 35 and 45)
Sub-treatment	- 4 growth stages (S1, S_2, S_3 and S_4)
	- 4 submergence periods ($D1_,$ D_2, D_3 and D_4)
Design	- RBD with 3 replication
Plot size	- 2m x 1m

Crop tolerance to excess water condition

The data on yield reductions were observed under the influence of submergence for different period of time (1, 2. 3 and 4 days) at various growth stages of Cotton crop (variety – Vikram) at three of the locations having ESP levels of 25, 35 and 42. However, yield reduction could not be observed because this year is exceptionally scanty rainfall year and therefore crop could not survive to the last due to acute shortage of water. Instead of yield only per plant biomass could be recorded. The treatment wise per plant biomass recorded at various ESP levels of 25, 35 and 42 are shown in table 1, 2 and 3, respectively.

It is obvious from Tables 2.2.1, 2.2.2 and 2.2.3 that in case of all the ESP levels (25, 35 and 42) there was reduction in per plant biomass over control. It implies that there is reduction in yield of the cotton under the influence of continuous prevailing excess water conditions because of the obvious fact that yield of any crop follow the same trend as that of its biomass yield . At ESP 25 reduction in per plant biomass over control was as high as 44% and as low as 10 %. At ESP 35 it was around 53% and 17% and at ESP 42 it was around 66% and 20 %. At ESP 25 difference in plant bio-mass reduction over control is significant at 0.05 confidence level, while at ESP 35 this difference was nonsignificant. In case of ESP 42 this difference is significant at 0.01 confidence level. Study also indicates that higher the ESP of soil more will be the yield reduction. The sowing to emergence growth stage (S_1) appears to be vulnerable stage in case of all the ESP of soils. To arrive at concrete conclusion about permissible crop tolerance to excess water condition and vulnerable growth stage this experiment is required to be conducted at least in two years in future. The study also indicates that two to three days period may be considered as crop tolerance period to excess water condition for cotton crop in sodic black soil.

Table 2.2.1. Biomass reduction per plant under different period of submergence at ESP 25

S. No,	Treatments	Per plant biomass in (g)			Mean	Reduction (%)
		R_1	R_2	R_3		
1	Control (C)	44	45	47	45.33	-
2	S_1D_1	21	19	30	23.18	40.50
3	S_1D_2	22	50	25	32.40	16.92
4	S_1D_3	36	29	20	28.38	27.21
5	S_1D_4	17	20	29	21.92	43.79
6	S_2D_1	21	25	20	22.14	43.23
7	S_2D_2	37	36	17	29.67	23.91
8	S_2D_3	37	22	11	22.93	41.19
9	S_2D_4	29	22	14	21.7	44.35
10	S_3D_1	37	19	12	23.16	40.59
11	S_3D_2	32	33	28	31.20	19.99
12	S_3D_3	18	33	28	26.64	31.67
13	S_3D_4	21	43	38	33.92	13.01
14	S_4D_1	21	36	27	28.01	28.17
15	S_4D_2	38	44	22	34.72	10.96
16	S_4D_3	47	37	50	44.42	13.89
17	S_4D_4	30	57	45	43.86	12.47
	CD 5%	NS				

Table 2.2.2. Biomass reduction per plant under different period of submergence at ESP 35

S. No,	**Treatments**	**Per plant biomass in (g)**			**Mean**	**Reduction (%)**
		$\mathbf{R_1}$	$\mathbf{R_2}$	$\mathbf{R_3}$		
1	Control (C)	40	39	38	39.00	
2	S_1D_1	20	18	23	20.24	48.10
3	S_1D_2	18	17	20	18.22	53.28
4	S_1D_3	11	29	14	18.10	53.58
5	S_1D_4	09	33	17	19.53	49.91
6	S_2D_1	13	43	41	32.23	17.35
7	S_2D_2	10	45	38	30.98	20.55
8	S_2D_3	10	53	29	30.76	21.11
9	S_2D_4	17	60	29	35.33	9.40
10	S_3D_1	17	15	29	20.06	48.54
11	S_3D_2	27	18	22	22.59	42.07

12	S_3D_3	31	20	23	24.70	36.66
13	S_3D_4	19	21	25	21.84	43.98
14	S_4D_1	26	21	25	23.95	38.57
15	S_4D_2	21	19	35	24.92	36.10
16	S_4D_3	20	23	42	28.21	27.64
17	S_4D_4	17	29	40	28.60	26.64
	CD 5 %	7.74				

Table 2.2.3. Biomass reduction per plant under different period of submergence at ESP 42

S. No,	Treatments	Per plant biomass in (g)			Mean	Reduction (%)
		R_1	**R_2**	**R_3**		
1	Control (C)	30	29	31	30.00	-
2	S_1D_1	17	21	17	18.76	51.83
3	S_1D_2	21	17	26	20.85	46.53
4	S_1D_3	23	17	29	22.75	17
5	S_1D_4	13	14	12	12.00	66.75
6	S_2D_1	16.	21	29	22.20	43.07
7	S_2D_2	25	18	37	26.66	31.62
8	S_2D_3	30	23	40	30.83	20.94
9	S_2D_4	24	20	19	23.93	38.63
10	S_3D_1	18	13	14	14.90	61.79
11	S_3D_2	25	15	30	23.46	39.82
12	S_3D_3	17	20	17	18.46	52.64
13	S_3D_4	27	20	24	23.53	39.65
14	S_4D_1	16	17	14	15.46	60.34
15	S_4D_2	25	18	34	26.73	34.01
16	S_4D_3	13	25	14	17.5	55.12
17	S_4D_4	14	16	23	17.56	54.12
	CD 1 %	8.07				

Conclusion

Study indicates that higher the ESP of soil more will be the yield reduction. The sowing to emergence growth stage (S_1) appears to be vulnerable stage in case of all the ESP of soils. The study also indicates that two to three days period may be considered as crop tolerance period to excess water condition for cotton crop in sodic black soil and may be used as drainage criteria for the provision of the surface drainage.

CHAPTER 3
RESEARCH UNDER RAINFED CONDITIONS
3.1 Assessing and conserving natural resources

Contemporary salt affected soils have not been utilized for crop production due to various constraints (Prasad, 1988). In black soils the main problem is sodicity due to which the soils are difficult to manage through conventional agro-techniques. Soil sodification induces higher swelling and water retention on surface; consequently the plant available water, soil permeability and infiltration are adversely affected (Sharma et. al, 1998). Such sodic black soils have unique potential to retain water on surface due to their negligible infiltration rate (Gupta and Verma, 1983). In rainfed semi-arid conditions about 40 – 50% of precipitation is lost through runoff due to slow infiltration rate in black soils. The vagaries of the problem are further intensified under black sodic soil conditions where infiltration rate is almost negligible and water dispersible clay is about 40% leading to higher runoff and loss of nutrients. It has been established that increased soil sodicity enhances soil dispersion and reduces soil aggregation to a greater degree that may cause severe soil and nutrient loss during runoff. Introduction of various land configurations may provide sufficient barrier for checking soil loss by controlling runoff. For normal black soil Raise and sunken Bed land configuration has been suggested for improving drainage and water storage under high rainfall situation (Gupta et. al, 1978). This system has also given higher yields of karif crops under rainfed Agri – ecosystem in dry land agriculture (Gupta and Sharma, 1990). Raise and sunken bed land configuration has been adopted at Soil Salinity Research Station Barwaha (Distt. Khargone) has given constantly encouraging results in sodic black soils in improving physical-chemical properties and crop yields (Anonymous, 1998-99). Moreover the other land configuration e.g. Broad Bed and Furrow, Ridge and furrow etc. have resulted in reducing runoff in normal soil may also prove better in sodic black soils. With above background, study is planned to explore suitability of various land configurations for controlling runoff by monitoring rainfall and associated runoff events under various land configuration systems in rainfed sodic black soil condition. Study will also use recorded data to develop the best-fit equation for tried land configurations to predict runoff in sodic black soils. It will save energy and time in recording runoff otherwise.

A field experiment in sodic black soil was conducted at Soil Salinity Research Station, Barwaha (Khargone) M.P to explore suitability of various land configurations for controlling runoff by monitoring rainfall and associated runoff events under various land configuration systems in rainfed sodic black soil condition. The experimental area (76^0 00’ 46” E and 22^0 14’ 36” N) is laying south of Vindhyan ranges about 3 k.m. north of river Narmada at an elevation of 185 m above MSL in agro climatic zone XI - Nimar Valley (agro-ecology region 5) .The climate of the area is semi–arid sub-tropical monsoon type which remains mostly dry except during monsoon period (June–September). About 92% of the mean annual precipitation (700 mm) is received during monsoon months. The experimental soil belongs to fine smectitic hyperthematic family of Typic Heplusterts – sodic phase (clay 55%, silt –36%, sand 9%).The different land configurations were formulated with the help of tractor driven implements with a slope of 0.3 % to save the crop from temporary submergence. The MB plough and chiseler were used for this purpose. The cotton crop was planted on different configurations while paddy was planted in sunken bed only. Runoff potential were quantified for various land configurations with the help of multi-slot divisors prepared by Central Institute of Agricultural Engineering, Bhopal. Four land configurations viz. Raised-Sunken Bed (RSB) – (1:1), Broad Bed and Furrow(BBF) - (100cm beds with 30cm furrow in alternate), Ridge and Furrow (RF) - (30cm each) and Flat Bed (F) – (with general slope of 0.3%) were prepared in the plot measuring 30 x 4.5 m^2 in the month of June 2002 (Fig. 1). Multi-slot divisors having 11 slots were installed at lower end on ground level in the plots of BBF, R&F and Flat land configurations. Whereas in case of Raised – Sunken Bed system the multi-slot divisor was installed at the height of 30 cm so as to store water up to 30 cm for growing successful paddy crop. Cotton crop was raised in all land configurations except sunken beds where paddy crop was planted. Recommended package and practices were adopted for raising cotton and paddy crops. The rainfall and associated runoff data recorded during 2003-04 and 2004-05 were used to fit linear, logarithmic, polynomial, power and exponential equations. Rainfall-runoff data recorded during 2002-03 was used to test validity of the best-fitted equation.

Rainfall-runoff relationship

Rainfall and associated runoff events under various land configuration in sodic black soils having ESP 25 were recorded during the period 2002-03 to 2004-05 and are shown in Table 3.1.1.During Monsoon (2002-03 to 2004-05) 15, 12 and 14 rainfall-runoff events were recorded with receipt of 400mm, 490mm and 442.9 mm rainfall. It is clear from Table 3.1.1 that during the year 2002-03 the recorded runoff yield was 33.39%, 53.88%, 57.19% and 61.97%in RSB, BBF, RF and F respectively. Similarly, runoff yield recorded during year 2003-04 and 2004-05 were 35.58%, 59.19%, 64.5%, 57.3% and 31.47%, 53.23%, 58.82%, 62.18% respectively. During three years period, every year minimum runoff occurred in RSB and maximum in F. The recorded rainfall-runoff data (3 years average) reveals order of suitability of land configuration for controlling runoff as RSB > BBF > RF > F with runoff values as 33.48%, 56.80%, 58.37% and 62.88% out of 444.3 mm rainfall respectively. Recorded runoff data are indicative of the fact that Sunken and raise bed land configuration is markedly effective in controlling runoff among tried land configurations. The control of runoff is necessary to control soil and nutrients loss in sodic soils. Higher the runoff more will be the soil and nutrient loss in turn, because sodic soil is more water dispersible.

The rainfall-runoff data recoded during 2003-04 and 2004-05 (26 events) was used to fit various curves viz. linear, polynomial, logarithmic, power and exponential. Equations of the fitted curves along with coefficient of determination are shown in Table 3.1.2 for different land configurations. The best-fitted equation in case of RSB is logarithmic with maximum R^2 = 0.509. The reason to this poor fitness may be due to its configuration, as the system operates as a pond with over flow device with a sill height at 30 cm above bed level. Thus any runoff can occur only after filling in the empty volume. Similarly best fit equation in case of BBF, RF and F are polynomials with R^2 = 0.9228, 0.9116 and 0.9115 respectively. Rainfall data recorded in the year (2002-03) was used to test goodness of fit of best-fit equations. The graphical representations (Fig. 2) of predicted (using best fit relation, Table 3.1.2) and observed values of runoff show reasonably close match in all the tried land of configurations. Hence the developed rainfall-runoff relationships can be successfully used for predicting runoff from recorded rainfall in case of various land configurations in sodic black soils.

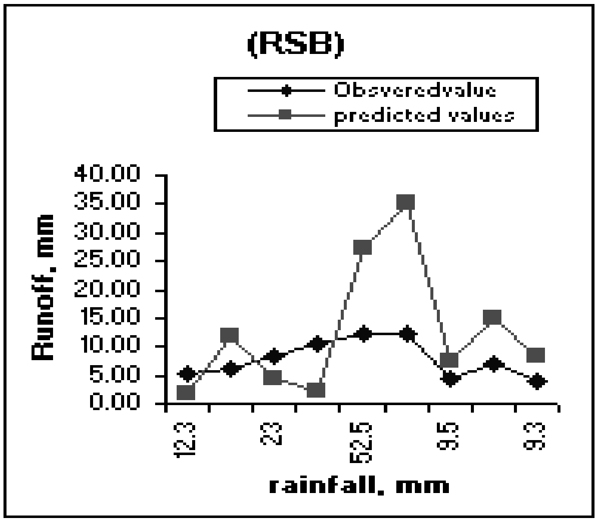
Table 3.1.1. Rainfall and associated runoff under land configurations in sodic black soils

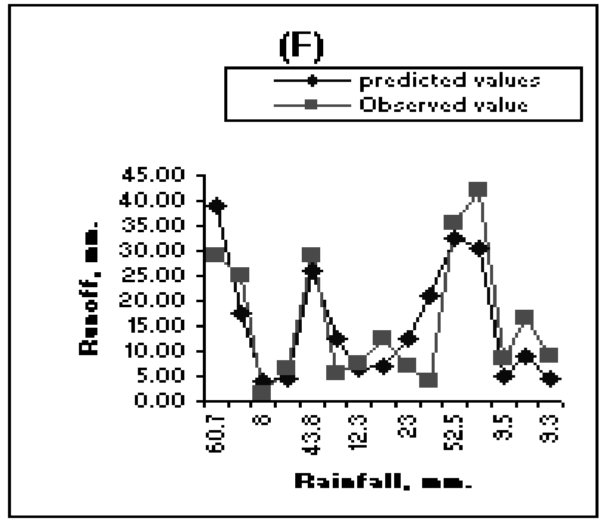
Event	Date	Rainfall (mm)	Runoff Percentage							
			RSB		BBF		R&F		Flat	
			mm	%	mm	%	mm	%	mm	%
2002-03										
1st	26/06/02	60.7	-	-	25.00	41.19	26.00	42.83	29.00	47.78
2nd	27/06/02	31.0	-	-	20.00	64.52	22.20	71.61	24.80	80.00
3rd	28/06/02	8.0	-	-	01.00	12.50	01.30	16.25	1.50	18.75
4th	30/06/02	9.4	-	-	05.20	55.32	05.66	60.24	6.40	68.09
5th	21/07/02	43.8	-	-	23.80	54.34	26.20	59.82	29.20	66.67
6th	06/08/02	23.0	-	-	04.50	19.57	04.80	20.87	5.40	23.48
7th	19/08/02	12.3	01.76	14.31	05.60	45.53	06.35	51.63	7.30	59.35
8th	20/08/02	14.0	11.76	84.00	11.90	85.00	12.30	87.86	12.70	90.71
9th	24/08/02	23.0	04.20	18.26	05.60	24.35	06.20	26.96	7.10	30.87
10th	01/09/02	36.5	02.10	05.75	03.20	08.77	03.40	09.32	3.80	10.41
11th	02/09/02	52.5	27.20	51.81	30.00	57.14	31.60	60.19	35.50	67.62
12th	03/09/02	49.5	35.00	70.71	36.70	74.14	38.10	76.97	42.00	84.85
13th	04/09/02	9.5	07.60	80.00	07.90	83.16	08.20	86.32	8.60	90.53
14th	05/09/02	17.5	15.00	85.71	15.80	90.29	15.90	90.86	16.40	93.71
15th	06/09/02	9.3	08.40	90.32	08.60	92.47	08.80	94.62	9.00	96.77
Total		400.0	113.02	33.39	204.81	53.88	217.01	57.12	238.70	61.97
2003-04										
1st	23/6/.03	36.0	00.00	00.0	11.73	32.59	09.87	27.43	08.80	24.44
2nd	05/7/03	43.0	00.00	00.0	15.25	35.47	14.18	32.97	10.85	25.24
3rd	25/7/03	17.5	00.00	00.0	08.80	50.29	10.56	60.34	11.73	67.05
4th	26/7/03	20.0	00.00	00.0	12.91	64.53	08.80	44.00	13.69	68.44
5th	27/7/03	101.5	29.92	29.48	69.43	68.40	73.53	72.44	70.40	69.36
6th	25/8/03	62.0	19.07	30.75	38.62	62.29	41.07	66.24	41.07	66.24
7th	28/8/03	09.5	00.73	07.72	04.30	45.29	06.84	72.05	04.11	43.23
8th	20/9/03	59.4	27.72	46.67	34.22	57.61	44.00	74.07	36.18	60.91
9th	25/9/03	96.5	50.75	52.59	79.20	82.07	70.40	72.95	63.55	65.86
10th	27/9/03	12.5	10.58	84.60	08.80	70.40	09.78	78.22	07.82	62.58
11th	29/9/03	23.3	20.23	86.82	15.32	65.77	19.41	83.31	15.32	65.77
12th	30/9/03	08.8	07.77	88.33	06.65	75.56	07.92	90.00	05.87	66.67
Total		490.0	166.8	35.58	305.2	59.19	316.4	64.5	289.70	57.3
2004-05										
1	26.7.04	28.4	00.0	0.0	07.7	27.2	08.3	29.3	08.8	31.0
2	29.7.04	16.0	02.0	12.7	05.6	35.2	06.5	40.3	06.8	42.2
3	30.7.04	26.4	07.7	29.3	12.8	48.3	13.9	52.6	14.9	56.3
4	31.7.04	27.5	09.3	33.7	14.3	51.8	15.1	54.8	15.8	57.3
5	5.8.04	54.0	16.9	31.4	27.0	50.0	28.4	52.6	29.6	54.7
6	6.8.04	27.5	12.9	47.0	16.5	60.0	17.6	63.8	18.9	68.7

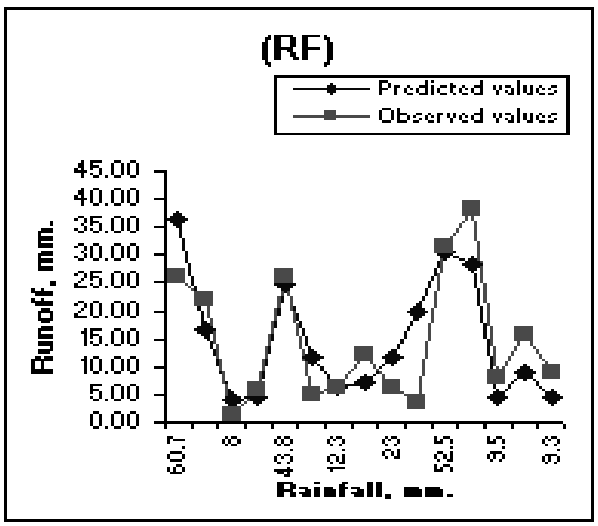
7	7.8.04	69.6	20.0	28.8	42.4	60.9	51.2	73.6	52.6	75.5
8	8.8.04	17.5	08.8	50.2	12.0	68.6	13.2	75.4	13.9	79.3
9	12.8.04	25.0	13.6	54.5	16.3	65.1	18.0	72.0	20.3	81.0
10	14.8.04	11.0	01.8	16.5	06.7	60.7	07.7	69.5	08.9	80.5
11	23.8.04	39.2	10.0	25.6	13.4	34.1	14.6	37.3	15.2	38.8
12	24.8.04	04.5	02.9	64.0	03.1	68.3	03.2	70.0	03.3	73.3
13	25.8.04	15.7	09.8	62.2	10.1	64.0	10.5	66.9	11.0	70.2
14	26.804	54.6	11.5	21.0	30.0	54.9	33.4	61.1	35.7	65.4
15	7.10.04	26.0	12.1	46.5	18.1	69.5	19.1	73.3	20.0	77.0
Total		442.9	139.4	31.47	235.8	53.23	260.5	58.82	275.4	62.18
Three years average		444.3	148.1	33.48	252.4	56.80	259.3	58.37	279.4	62.88

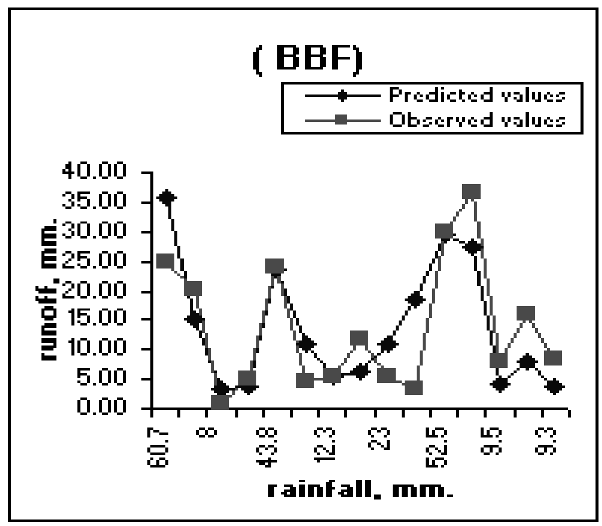
Table 3.1.2. Rainfall-runoff relationships for land configurations in sodic black soils

S. No.	**Type of Eq.**	**Fitted equation**	**Coefficient of determination (R^2)**
1. Raise & Sunken Bed land configuration			
1.1	Linear	$Y = 0.2027 X$	0.1251
1.2	Logarithmic	$Y = 4.7555 \ln (X) – 6.4542$	0.509
1.3	Polynomial	$Y = 0.0027 X^2 + 6.4542 X$	0.4699
1.4	Power	$Y = 0.3989 X^{0.8484}$	0.4115
1.5	Exponential	$Y = 3.0205 e^{0.00205X}$	0.2752
2. Broad Bed and Furrow land configuration			
2.1	Linear	$Y = 0.6217 X$	0.8816
2.2	Logarithmic	$Y = 20.63 \ln (X) –47.611$	0.6718
2.3	Polynomial	$Y = 0.0032 X^2 + 0.3939 X$	0.9228
2.4	Power	$Y = 0.4246 X^{1.0413}$	0.6865
2.5	Exponential	$Y = 4.3544 e^{0.0311X}$	0.7002
3. Ridge & Furrow land configuration			
3.1	Linear	$Y = 0.6262 X$	0.8906
3.2	Logarithmic	$Y = 20.319 \ln (X) – 45.982$	0.6888
3.3	Polynomial	$Y = 0.0022 X^2 + 0.4677 X$	0.9116
3.4	Power	$Y =0.5524 X^{0.8837}$	0.6936
3.5	Exponential	$Y =4.995 e^{0.0293X}$	0.7034
4. Conventional Flat land configuration			
4.1	Linear	$Y = 0.6722 X$	0.8887
4.2	Logarithmic	$Y = 21.759 \ln (X) – 49.249$	0.679
4.3	Polynomial	$Y = 0.0027 X^2 + 0.4789 X$	0.9155
4.4	Power	$Y = 0.5995 X^{0.9764}$	0.6545
4.5	Exponential	$Y = 5.2925 e^{0.0293X}$	0.6739









Sediment loss

The data regarding total loss of sediment (Table3.1.3) during 2003-07 showed that maximum loss of sediments was 28.68, 20.02, 29.9 & 22.37 t ha^{-1} in flat land configuration and minimum in RSB as 9.59, 1.64, 1.30 and 3.85 t ha^{-1} (Table 3..1.3) during the years 2003-04, 2004-05,2005-.06 and 2006-07 respectively. The sediment loss from field was markedly reduced by adoption of different land configurations. There was 60.5 and 85.2 % reduction in loss of sediments due to adoption of raised – sunken bed system, in two years respectively. BBF and R&F system were not so effective in checking sediment losses. This was due to reason that soil was loosened to a great extent during the preparation of ridge and furrow (R&F) system.

Nutrient loss

The yearly total nutrient (nitrogen and potassium) loss estimated through sediments is presented in Table, 3.1.3 Maximum loss of nitrogen was 27.06, 19.49,10.20 & 32.85 kg ha^{-1} in flat land configuration and minimum in RSB as 1.048,2.63,4.04 and 4.24 kg ha^{-1} (Table 3..1.3) during the years 2003-04, 2004-05,2005-.06 and 2006-07 respectively. However, nitrogen losses of 9.27 & 28.30 and 7.45 & 23.79 kg ha^{-1} were observed in BBF and RF land configuration during the year 2005-06 & 2006-07 respectively. It implies that RSB was found markedly effective in controlling nutrient losses. Similarly, Maximum potassium loss was 47.91, 32.40, 9.54 and 48.93 kg ha^{-1} in flat land configuration and minimum in RSB as 1.73, 2.63, 3.78 and 6.30 kg ha^{-1} during the years 2003-04, 2004-05,2005-.06 and 2006-07 respectively. (Table 3.1.3). However, potassium loss of 6.97 & 38.60 kg ha^{-1} and 8.67 & 44.47 kg ha^{-1} were observed in BBF and RF land configurations during the year 2005-.06 and 2006-07 respectively.

Table: 3.1.3. Sediment and nutrient losses from different land configurations in sodic soil

Land	2003-04	2004-05	2005-06	2006-07
Sediment loss (t ha^{-1})				
R-S Bed	09.59	1.64	1.30	3.85
BBF	18.792	24.88	2.40	18.90
R&F	24.656	28.99	22.37	2.99
Flat	28.687	20.02	29.9	22.37
Nitrogen (kg ha^{-1})				
R-S Bed	1.048	2.63	4.04	4.24
BBF	19.489	22.91	7.45	23.79
R&F	22.639	27.81	9.27	28.30
Flat	27.067	19.89	10.20	32.85
Potassium (kg ha^{-1})				
R-S Bed	1.736	2.63	3.78	6.30
BBF	31.261	36.65	6.97	38.60
R&F	35.032	49.53	8.67	44.47
Flat	47.914	32.40	9.54	48.93

Runoff conservation

Study on performance of different land configuration for controlling runoff in sodic black soils reveals that runoff yields recorded were 116.17, 206.6, 217.05 & 238 mm from raise and sunken bed (RSB), broad bed furrow (BBF), ridge furrow (RF) and flat (F) land configurations respectively out of 400 mm rainfall recorded in 15 events (Table 3.1.4). The RSB system conserved 66 % rainfall over flat system whereas BBF and RF conserved 14 % and 7.2 % respectively. The results are suggestive that amongst different land configuration RSB is markedly effective in controlling and conserving runoff water, which in turn may reduce soil erosion as well as nutrient loss in sodic black soils.

Table 3.1.4. Recorded runoff (mm) under various land configurations in sodic black soils

S. No.	Date of event	Rainfall (mm)	Runoff depth (mm) under land configuration			
			RSB	BBF	RF	F
1st	26.06.02	60.70	0	25.00	26.00	28.64
2nd	27.06.02	31.00	0	20.00	22.20	24.80
3rd	28.06.02	08.00	0	1.00	1.30	1.50
4th	30.06.02	09.40	0	5.20	5.70	6.40
5th	21.07.02	43.80	0	23.80	26.20	29.20
6th	06.08.02	23.00	0	4.50	4.80	5.40
7th	19.08.02	12.30	01.76	5.60	6.35	7.42
9th	20.08.02	14.00	11.76	11.90	12.30	12.70
10th	24.08.02	23.00	4.20	5.60	6.20	7.10
11th	01.09.02	36.50	2.10	3.20	3.40	3.80
12th	02.09.02	52.50	30.35	30.00	31.60	35.50
13th	03.09.02	49.50	35.00	36.70	38.10	42.00
14th	04.09.02	09.50	7.60	7.90	8.20	8.60
15th	05.09.02	17.50	15.00	15.80	15.90	16.40
16th	06.09.02	09.30	8.40	8.40	8.80	9.00
Total		**400.00**	**116.17**	**204.60**	**217.05**	**238.46**
Water conserve			**283.83**	**119.54**	**182.35**	**170.14**
% Water conserve over F			**66.82**	**14.92**	**7.20**	**-**

Crop Yield

The crops at soil ESP of 40 and 55 failed completely during growth stage and there was only partial success at soil ESP of 25 and 30 due to poor rains and its erratic distribution and increase in moisture stress with increase in soil ESP. The yield data recorded at soil ESP of 25 and 30 are presented in Table 3.1.5 which was very poor in general regardless of treatments and soil ESP .The yield difference due to adoption of various land configurations were not prominent. However crop yields were low at soil ESP of 30 as compared to soil ESP of 25.

Table3.1.5.Crop yield (Cotton & Paddy in kg ha^{-1}) recorded at soil ESP of 25 and 30 under different land configurations

S.No.	Land configuration	ESP-30		ESP-25	
		Cotton	Paddy	Cotton	Paddy
		2002-03			
1	Raised &-Sunken Bed	155.2	336.7	302.0	1354.0
2	BBF	155.0	-	373.0	-
3	R&F	180.8	-	345.0	-
4	Flat	234.7	-	326.6	-
		2003-04			

1	Raised &-Sunken Bed	26.9	1250	255.9	1336.2
2	BBF	60.6	-	111.1	-
3	R&F	80.8	-	-138.0	-
4	Flat	166.7	-	200.0	-

CONCLUSION

Looking to the physico-chemical properties of sodic black soils, a field experiment was carried out to test suitability of various land configurations in controlling runoff yield in sodic black soils under rainfed condition during Monsoon 2002-05. The recorded rainfall-runoff data reveals order of suitability of land configuration for controlling runoff as RSB > BBF > RF > F with runoff values as 33.48%, 56.80%, 58.37% and 62.88% out of 444.3 mm rainfall respectively. It implies that RSB is markedly effective for controlling runoff among tried land configurations. The study further reveals that the best fitted equation is logarithmic with R^2 value as 0.509 in case of RSB for predicting runoff from rainfall. Similarly, the best fitted equations were polynomials in case of BBF, RF and F with R^2 values as 0.9288, 0.9116 and 0.9115 respectively. The graphical representations of predicted and observed values of runoff show reasonably close match in all the tried land configurations. Hence the developed rainfall-runoff relationships can be successfully used for predicting runoff from recorded rainfall in case of various land configurations in sodic black soils. The results are suggestive that amongst different land configuration RSB is markedly effective in controlling and conserving runoff water, which in turn may reduce soil erosion as well as nutrient loss in sodic black soils. Assessed agricultural drainage needs can be utilized successfully for designing the surface drainage in sodic black soils

3.2 Water harvesting in sodic soils

The black saline-alkali soils generally persist in the areas having low rainfall and insufficient irrigation facilities. The reclamation of such soils requires ample water for leaching/ flushing after incorporation of chemical amendments, which is tedious and slow in absence of irrigation water. Owing to negligible infiltration rate such soils retain water on surface, which hampers agricultural operations and ultimately further reduced productivity. As such harvesting of surface water by utilizing higher runoff potential of sodic black soils is a must to improve production therein. Black sodic soils are potentially saline / alkaline in compacted sub-surface horizons (Murthy et. al. 1981). Due to compacted sub-surface horizons coupled with low infiltration these soils exhibits as high as 40% runoff (Sharma 1994). The black soils having ESP beyond 10 leads to sever structural degradation (Gupta and Verma, 1983) due to high degree of clay dispersion. Dispersed clay clogs the pores and induced increased water retention on surface. Deep cracks do not develop in sodic black soils because of higher water retention capacity and alkali contents which otherwise a qualifying characteristics of black soils (Sharma and Verma.1998).

Above physico-chemical properties make sodic soil potentially high to yield more runoff, which can be utilized for improving production by giving supplemental irrigation. The above situation stresses the need of harvesting excess runoff for recycling especially in sodic Vertisols agri-ecoystem under rainfed condition by harvesting the same in small dug out pond. Thus a study was conducted to assess performance of a small dug out pond constructed across an ephemeral stream along with quantifying runoff potential and infiltration under differential ESP levels in contemporary sodic black soil.

To assess drainage need daily rainfall data of 11 years period (1989 to 1999) recorded at Barwaha Farm and was subjected to depth duration frequency analysis to work out consecutive day's maximum rainfall for 5, 10 and 20 years recurrence interval. Agricultural drainage need was assessed by subtracting basic infiltration value from consecutive day's rainfall. The basic infiltration rate was ascertained by developed equation for soils having differential ESP. Verma and Sharma (2001) reported that basic infiltration at 35 ESP becomes almost negligible in sodic black soils. Drainage need was assessed by considering the fact that soils are saturated and therefore evapotranspiration, raindrop interception etc are negligible as far as drainage is concerned.

To utilize the harvested runoff water a dugout pond of size 35 x 17 x 2 m was constructed in sodic black soils of Research Farm Barwaha. Daily rainfall, evaporation and change in depth of stored water in pond was recorded for dates on which there was neither any flow observed in stream nor any irrigation was given from stored water. For the recorded events average evaporation, rainfall and change in depth of water in pond was calculated to find out percolation per day. Yield of paddy (IR-6) and Cotton (Vikram) were also recorded for the period of non-irrigation and irrigation to compare yield improvement. In this study, information was developed on consecutive day's rainfall for various recurrence intervals, basic infiltration, drainage need, water harvesting in small dug out pond, percolation loss, crop yield and siltation in pond etc. The details of developed information are discussed as below.

Consecutive day's rainfall analysis:

Year wise maximum consecutive day's rainfall values were ascertained by maximum total technique from daily rainfall data of 11 years period (1989-1999) recorded at research farm, Barwaha of the project and are shown in Table 3.2.1 along with probabilities of their occurrences.

Table 3.2.1. Consecutive day's rainfall in ascending order along with probability

S No.	Consecutive days rainfall (mm)				Probability
	1	2	3	4	
1	178.4	294.2	299.4	302.0	0.083
2	178.2	243.0	271.0	281.5	0.166
3	157.0	216.0	220.0	245.7	0.250
4	135.5	206.8	208.4	232.0	0.333
5	123.5	194.0	199.5	211.6	0.416
6	101.0	180.0	194.0	194.0	0.500
7	91.0	171.8	165.9	176.0	0.583
8	78.0	121.0	164.0	170.0	0.666
9	75.0	117.0	158.0	168.0	0.750
10	62.0	110.0	140.6	148.6	0.833
11	62.0	67.0	67.0	76.8	0.910
ΣX^2	157874.3	379675.37	435336.34	482976.9	-

ΣX	1235.6	1921.3	2085.8	2205.2	-
$\bar{X}$	112.327	174.663	189.618	200.47	-
σ_{X-1}	43.683	66.40	63.11	63.948	-
C_V	0.3888	0.3801	0.3328	0.3189	-

The consecutive days rainfall values of table 3.2.1 were used to fit equations to obtain design value of maximum rainfall of 1, 2. 3 and 4 days period in terms of recurrence interval (T) in years. The fitted equations obtained in terms of recurrence interval (T) in years are shown in Table 3.2.2.

Table 3.2.2. Fitted equations for various consecutive days' rainfall

Period in days	Fitted equations
1	$X_1 = 112.327 + 89.98 \log T$
2	$X_2 = 174.663 + 139.95 \log T$
3	$X_3 = 189.618 + 151.7 \log T$
4	$X_4 = 200.47 + 169.42 \log T$

Where X_1 represents 1- day period rainfall and T recurrence interval in years.

From the above fitted equations consecutive days maximum rainfall values were computed for recurrence interval of 2, 5. 10 and 20 years and the same are shown in Table 3.2.3.

Table 3.2.3. Consecutive day's maximum rainfall for various recurrence intervals (in years)

S. No.	Period in days	Consecutive days maximum rainfall (mm) for R. I.			
		2	**5**	**10**	**20**
1	One	139	175	224	229
2	Two	216	272	314	356
3	Three	235	295	341	386
4	Four	248	318	369	420

Basic infiltration with ESP

The transient infiltration measurement in field plots with differential ESP levels reveals that the rates and cumulative infiltration are considerably reduced with increase in soil ESP in sodic black soils. The infiltration study was conducted by SAS project and relationships developed between time (minutes) and cumulative infiltration (mm) at various ESP levels are shown as below.

Table 3.2.4. Infiltration equation developed at various ESP levels in sodic black soils

Sr. No.	ESP levels	Developed equations
1	10	$I = 5.7\ t^{0.5}$
2	15	$I = 5.7\ t^{0.36}$
3	22	$I = 4.9\ t^{0.31}$
4	> 35	Approached to almost 0*

- Verma and Sharma, (2000).

The cumulative infiltration and rate were worked out using above developed equations and computed values are shown in Table 3.2.5.

Table 3.2.5. Cumulative infiltration (mm) and Rate mm/hr at various ESP levels

S. No.	Time (minutes)	Infiltration at various ESP levels.					
		ESP- 10		ESP - 15		ESP – 22	
		Cumulative	Rate	Cumulative	Rate	Cumulative	Rate
1	60	44.15	-	24.89	-	17.43	-
2	120	62.44	18.29	31.94	7.05	21.61	4.16
3	180	76.47	14.03	36.96	5.02	24.51	2.9
4	240	88.33	11.83	40.19	4.03	26.79	2.28
5	300	98.73	10.43	44.42	3.43	281	1.92
6	360	108.15	9.42	47.44	3.02	30.38	1.67
7	720	152.94	-	60.88	-	37.66	-
8	780	157.13	4.19	62.66	1.76	38.61	0.95
9	1360	211.74	-	76.95	-	46.08	-
10	1440	216.29	4.55	78.14	1.18	46.69	0.62
11	1500	220.76	4.47	79.29	1.15	47.29	0.6
12	1560	225.13	4.37	80.42	1.13	47.87	0.58
13	1620	229.42	4.29	81.52	1.10	48.43	0.56
14	1680	233.63	4.21	82.60	1.08	48.98	0.55
15	1740	237.76	4.13	83.65	1.05	49.51	0.53
16	1800	241.83	4.07	84.67	02	50.04	0.53

It is obvious from table 5 that infiltration rate decreases sharply with increase in ESP. The basic infiltration rate observed at ESP levels 10, 15, 22 and 35 are 4 mm/hr, 1 mm/hr, 0.5 mm/hr and almost negligible respectively. While Verma and Sharma (2000) and many others reported that basic infiltration rate beyond ESP 35 becomes almost negligible. So basic infiltration rate (mm/hr) obtained from Table 3.2.5 is summarized in Table 3.2.6.

Table 3.2.6. Basic infiltration rates obtained at ESP levels

S. No.	ESP levels	Basic infiltration rates (mm/hr)
1	10	4
2	15	1
3	22	0.5
4	> 35	Approaches to 0

Drainage need

The estimated value of surface drainage need as shown in Table 3.2.7 reveals that crops grown in sodic black soils having ESP greater than 10 may necessarily have to be provide with surface drainage system and there is enough run off potential to harvest the same for later use. The run off potential enhances with increase in ESP levels and it would be maximum beyond 35 ESP. In sodic black soils having ESP greater than 10, the drainage needs for crops with one day tolerance period vary between 175-79, 224-128 & 229-113 mm per day for recurrence interval of 5,10 & 20 years respectively. Similarly drainage need values for crops with 2,3 & 4 days tolerance period vary as (136-40, 157-61, 178-82 mm per day), (99-3, 114-10, 105-12 mm per day) and (80-0, 93-0,93-0 mm per day) respectively. For proper designing the surface drainage in sodic black soils assessed drainage needs can be utilized successfully.

Table 3.2.7. Estimated drainage need (mm / day) in sodic black soils

S. No.	I_b (mm/hr)	Drainage need in for consecutive days rainfall of various R.I. (years)											
		1 day			2days			3days			4days		
		5	10	20	5	10	20	5	10	20	5	10	20
1	0	**175**	**224**	**229**	**136**	**157**	**178**	**99**	**114**	**129**	**80**	**93**	**105**
2	1	151	200	205	112	133	154	75	90	105	56	69	81
3	2	127	176	181	88	109	130	51	66	81	32	45	57
4	3	103	152	157	64	85	106	27	42	57	**8**	21	33
5	4	**79**	**128**	**113**	**40**	**61**	**82**	**3**	**18**	**33**	-	-	**12**
6	5	55	104	109	16	37	58	-	-	9	-	-	-
7	6	31	80	85	-	13	34	-	-	-	-	-	-
8	7	-	56	61	-	-	10	-	-	-	-	-	-
9	8	-	32	37	-	-	-	-	-	-	-	-	-
10	9	-	-	-	-	-	-	-	-	-	-	-	-

Water harvesting:

Harvesting surface runoff water in small farm pond can play important role in alleviating drought in these areas. A dug out water harvesting pond of size 35 X 17 X 2 m was constructed across the ephemeral stream running across the research farm Barwaha having sodic black soil. The constructed pond is of 1190 m^3 storage capacity. The objective of the pond is to collect 2m deep runoff water during flow in stream for subsequent life saving irrigation to paddy (IR-36) in sunken and cotton (Vikram) on raised bed under Sunken and Raise bed system with 7.5 m width in 1:1 ratio.. The stored water could manage to deliver 4380 mm depth of water for irrigating 1.34 ha. Paddy and 0.082 ha. Cotton. (Table 3.2.8).

Table 3.2.8. Details of life saving irrigation through pond water along with yield

S. No.	Details of Irrigation				
	Land configuration	Date	Area (m^2)	Depth (mm)	Crop
1	RSB – I	8.7.2001	2160	380	Paddy
2	RSB – I	1.8.2001	2160	500	Paddy
3	RSB – I	9.7.2001	2160	500	Paddy
4	RSB – I	4.11.2001	450	200	Paddy
5	RSB – I	5.112001	600	300	Paddy
6	RSB – II	16.7.2001	1350	200	Paddy
7	RSB – II	30.8.2001	1350	500	Paddy
8	RSB – II	2.11.2001	750	400	Paddy
9	RSB – II	3.11.2001	700	400	Paddy
10	RSB – III	19.7.2001	825	300	Paddy
11	RSB – III	2.8.2001	825	350	Paddy
11	RSB – IV	31.8.2001	825	100	Paddy

12	Set furrow	1.9.2001	825	250	Cotton
Total			**14785**	**4380**	

Daily rainfall, evaporation and change in depth of stored water in pond was recorded for dates on which there was neither any flow observed in stream nor any irrigation was given from stored water and are shown in Table 3.2.9. For the recorded events average evaporation, rainfall and change in depth of water in pond was calculated to find out percolation per day. On an average percolation loss in pond was observed as 0.034 m^3 per day per m^2 wetted area of pond during dry spell. Within two years of time pond depth reduce to 1.65 m. from 2 m. initial storage depth due to siltation, which undermined the capacity of pond from 1190 m^3 to 981.52 m^3.

Table 3.2.9 Daily evaporation, rainfall and depth of water level in pond (all in mm).

S. No.	Date	Evaporation	Rainfall	Depth of water	Change in depth
1.	23.06.01	8.0	-	1650	-
2.	24.06.01	9.00	-	1600	50
3.	25.06.01	9.00	-	-	-
4.	26.06.01	10.50	-	1500	100
5.	27.06.01	10.50	-	-	-
6.	28.06.01	10.50	-	1400	100
7.	29.06.01	11.50	-	1350	50
8.	30.06.01	11.00	-	1300	50
9.	01.07.01	11.00	3	1250	50
10.	04.07.01	06.00	-	1150	-
11.	05.07.01	06.00	-	1100	50
12.	06.07.01	06.00	-	1050	50
13.	07.07.01	05.00	-	1000	50
14.	20.10.01	4.50	-	1550	-
15.	22.10.01	4.50	-	1500	50
16.	24.10.01	4.50	-	1450	50
17.	26.10.01	4.50	-	1400	50
18.	17.08.01	3.00	-	1650	-
19.	18.08.01	3.50	-	1600	50
20.	23.08.01	3.00	-	1450	-
21.	24.08.01	3.00	-	1400	50
22.	Total	144.50	3	-	800
Av. percolation (mm/day) - 800+3-144.5 / 16 = 41.2 mm / day (0.034 m^3/ m^2/day					

Recycling and yield improvement

The yield data recorded during the non- irrigation (1995 and 1996) and irrigation period (1999-2000) are shown in Table 10. During the year 1999-2000, water harvesting was done in constructed small dugout pond and its recycling too was introduced in sunken and raised bed system of width 7.5 m in 1:1 ratio. This year crop faced a temporary drought condition during 31^{st} and 35^{th} SMW and two irrigations of 10 cm depth each were provided from harvested water of dugout pond. Yield recorded during 1995 and 1996 are without the provision of recycling of harvested water because of non-construction of dug out pond. As a result of recycling of harvested water synergistic yield improvement was observed. The yield of paddy in sunken increased by 81% and cotton in raised bed by 64% (Table 3.2.10).

Table 3.2.10. Yield under Raise and Sunken Bed System with harvested water

S. No.	**Crops**	**Variety**	**Recorded yield in Kg Ha^{-1}**					
			Without irrigation			**With irrigation**	**Increase**	**% Increase**
			! 995	**1996**	**Mean**	**1999-2000**		
1	Paddy	IR-6	2558	1684	2121	3845	1724	81
2	Cotton	Vikram	490	435	462	764	299	64

Conclusion

Harvesting surface runoff water through the black saline-alkali soils generally persists in the areas having low rainfall and insufficient irrigation facilities. The conservation of water through water harvesting is a must to improve or rather to take production in such soils. As such study is carried out on performance of small dug out pond in contemporary sodic black soils along with assessment of its runoff potential and infiltration characteristics. The study reveals that basic infiltration rate decreases sharply with increase in ESP. The basic infiltration rate observed at ESP levels 10, 15, 22 and 35 are 4 mm/hr, 1 mm/hr, 0.5 mm/hr and almost negligible respectively. It implies that sodic black soils do have higher runoff harvesting potential and better storage as compared to its counter parts. The estimated value of surface drainage need suggests that crops grown in sodic black soils having ESP greater than 10 may necessarily have to be provide with surface drainage system and there is enough run off potential to harvest the same for later use. The run off potential enhances with increase in ESP levels and it would be maximum beyond 35 ESP. In sodic black soils having ESP greater than 10, the drainage needs for crops with one day tolerance period vary between 175-79, 224-128 & 229-113 mm per day for recurrence interval of 5,10 & 20 years respectively. Similarly drainage need values for crops with 2,3 & 4 days tolerance period vary as (136-40, 157-61, 178-82 mm per day), (99-3, 114-10, 105-12 mm per day) and (80-0, 93-0,93-0 mm per day) respectively. For proper designing the surface drainage in sodic black soils assessed drainage needs can be utilized successfully. Runoff harvesting in small dugout farm pond can play important role in alleviating drought and improving crop of paddy and cotton in sodic black soil areas. A dug out water harvesting pond of size 35 X 17 X 2 m was constructed across the ephemeral stream running through the research farm Barwaha having sodic black soil. The constructed pond is of 1190 m^3 storage capacity. The stored water could manage to deliver 4380 mm depth of water for irrigating 1.34 ha. paddy and 0.082 ha. cotton. This irrigation in turn showed improvement in the yield of paddy and cotton by 81% and 64 % respectively. On an average percolation loss in pond was observed as 0.034 m^3 per day per m^2 wetted area of pond during dry spell. Within two years of time pond depth reduced to 1.65 m. from 2 m. initial storage depth due to siltation, which undermined the capacity of pond from 1190 m^3 to 981.52 m$^{3.}$

CHAPTER 4
RESEARCH UNDER IRRIGATED CONDITIONS
4.1 Drip fertigation with marginally saline well water

A large chunk of area (18 million ha) under Vertisols in Central India is known to occur with scarcity of water in semi-arid and arid regions which stressed the need to utilize the irrigation water judiciously. Method of irrigation can play vital role in achieving high effectiveness of water use. Most of the farmers in India are still practicing surface irrigation. However drip irrigation is fast expanding technology in modern irrigated agriculture. Irrigation done so far in India and abroad has shown that this method leads to not only appreciable saving of irrigation water but also resulted in achieving higher crop yields as compared to conventional methods (INCID, 1994).Vertisols are potentially saline soils and having poor hydraulic properties (Murthy *et. al*, 1981). These soils pose problem of salinity when irrigated with marginally saline waters (Anonymous, 1997-98). The physical properties of the soil starts deteriorating even at low salinity of irrigation waters (Verma, *et. al*, 1993) The accumulation of water soluble salts in the root zone also hinders crop production (.Verma, *et. al*, 2006). While visiting the area it has been noticed that some progressive farmers of Nimar valley (Agro-climatic zone - 11) and Malwa Plateau (Agro-climatic zone - 10) started growing vegetable crops through use of drip system for irrigation and fertigation to achieve targeted yield. The salt efflorescence has been observed within area commanded by drip irrigation (Bagda Khurd and Padali villages). As such, study is planned to monitor the effect of marginally saline water and drip fertigation on vegetable production in Vertisols at Farmers field of Bagda Khurd village, Bedia, Tehsil, Khagoan district, Madhya Pradesh.

The study was carried out during 2006-10 to monitor effect of drip fertigation with marginally saline well water on salinity and economics of horticultural crops grown in Vertisols at farmer's field of Bagda khurd village of Bedia tehsil, Khargone Distt, Madhya Pradesh. Farmer grew Capsicum, chilli, tomato, ladyfinger, water melon in the year 2006-07, bitter gourd, potato, chilli, Onion in the year 2007-08, tomato, bitter gourd, garlic in the year 2008-09 and tomato bitter gourd during the year 2009-10. The crops were planted on ridges with recommended package of practices. Periodically soil samples were taken at the interval of 15 days for all the crops at sampling points viz. on drippers, between two consecutive drippers, 15 cm away from dripper (side of dripper) and 30 cm away from dripper (Side of ridge). The collected samples were analyzed for pH and EC. The soil samples were taken from sampling depths of 0-5 cm, 5-15 cm and 15-30 cm at each sampling points. The farmer is using water of two existing wells of his field for irrigating crops. Well water samples were analyzed as per standard methods to ascertain quality of water used for irrigation. The water of both the wells was found marginally saline with EC value 0.92 and 1.15 dS/m. The limits of EC (dS/m) for classification of irrigation water prescribed by USDA, 1954 are 0.25, 0.25 to 0.75, 0.75 to 2.25

and 2.25 for safe, probably safe, marginal and unsuitable categories respectively. To work out economics of growing different crops information on marketable yield, cost of cultivation including drip installation cost and prevailing market rates was also collected. The collected information was used to find out B:C ratio for different crops grown. The soils of study area classified as fine montmorillonitic hyperthermic family of typic heplusterts with particle size distribution as clay > 55%, silt > 30% and sand < 15%. Study area comes under Semi-arid sub-tropic climate with annual rainfall range of 600-800mm. Among the various crops grown by the farmer the details of results of one of the Tomato (Abhinav) crop are discussed as sample example in respect of EC, quantification of irrigation water, water use efficiency and B:C ratio etc. Similar procedure was followed for other crops grown and abstracted results are discussed.

Tomato (Abhinav)

Tomato (Abhinav) crop was sown on 15th of November 2009 in 1.5 acres of area. The crop was planted on ridges with recommended package of practices. The soil samples were drawn from 0-5 cm, 5-15 cm and 15-30 cm at each sampling point (viz. on drippers, between two drippers, side of the ridge, side of dripper) at the interval of 15 days on six consecutive instances (1st, 2nd 3rd, 4th 5th, and 6th) and analyzed for EC and pH. The data indicates that EC (salt concentration) increased with number of irrigations applied (Table 4.1.1). Maximum EC was observed at sampling point between drippers followed by side of the ridge. The minimum values were recorded at sampling point on drippers. Average values of EC were recorded 0.40, 0.46, 0.55, 0.64, 0.0.69 and 0.35 dS/m in case of on drippers sampling point for 1st, 2nd , 3rd , 4th , 5th , and 6th sampling respectively. EC increases as we move away from the drippers i.e. side of the ridge, side of the dripper and between drippers. The difference between maximum and minimum average value of EC were 0.29 dS/m, 0.41dS/m, 0.50 dS/m and 0.43dS/m on the sampling location viz. on drippers, between two drippers, side of the ridge, side of dripper respectively. Recorded EC values also indicate that higher salt accumulation was observed on sampling points side of ridge, side of drippers and between drippers as compared to sampling point "on drippers" in case of all the crops. It implies that salt accumulation was more as we move away from drippers and it was maximum on Sampling point "side of the ridge". Reduction in EC values after 5th sampling is due to surface irrigation given to the crop.

Table 4.1.1. Recorded values of EC (dS/m) and pH in Tomato (ES) crop (Abhinav) (2010)

Sampling Point.	**Depth, cm**	**1st EC**	**2nd EC**	**3rth EC**	**4rth EC**	**5th EC**	**6th EC**
On dripper	0-5	0.33	0.44	0.56	0.71	0.7	0.29
On dripper	15cm	0.48	0.48	0.57	0.62	0.73	0.38
On dripper	30	0.38	0.46	0.53	0.59	0.63	0.38
Average		**0.40**	**0.46**	**0.55**	**0.64**	**0.69**	**0.35**
Between drippers	0-5	0.78	0.96	1.11	1.16	1.21	0.58
Between drippers	15cm	0.35	0.45	0.51	0.74	0.18	0.41
Between drippers	30	0.32	0.43	0.69	0.78	0.49	0.53
Average		**0.48**	**0.61**	**0.77**	**0.89**	**0.63**	**0.51**
Side of ridge	0-5	0.39	0.56	0.76	0.89	1.09	0.47
Side of ridge	15cm	0.47	0.54	0.66	0.78	0.86	0.56
Side of ridge	30	0.4	0.57	0.61	0.74	0.81	0.64

Average		**0.42**	**0.56**	**0.68**	**0.80**	**0.92**	**0.56**
Side of Drip	0-5	0.43	0.51	0.75	0.88	0.91	0.53
Side of Drip	15cm	0.42	0.48	0.58	0.66	0.76	0.59
Side of Drip	30	0.42	0.49	0.61	0.73	0.89	0.67
Average		**0.42**	**0.49**	**0.65**	**0.76**	**0.85**	**0.60**

Quantification of irrigation

The depth of irrigation water applied during crop period to Tomato (Abhinav) crop was worked out and the details are shown in Table 4.1.2. The quantity of irrigation water per dripper came around 174 liters for Tomato (Abhinav) crop. This quantity 174 L is multiplied by total Nos. of drippers (57600) used per ha divided by area to work out depth of irrigation in cm/ha. The depth of irrigation for Tomato (Abhinav) crops came around 100 cm which was used for computing water use efficiency later on.

Table 4.1.2. Details of quantity of irrigation water applied in tomato (Abhinav)

Month	No. of	Discharge	Period of	Quantity of	Quantity of
1	**2**	**3**	**4**	**5 = (2*3*4)**	**6**
December 08	8	1.3	2	21	12
January 08	8	1.3	2	21	12
February 08	10	1.3	2	26	15
March 08	10	1.3	2	26	15
April 08	15	1.3	2	40	23
May 08	15	1.3	2	40	23
Total	**66**	**1.3**	**2**	**174**	**100**

Economics

Area distribution, along with marketable yield, yield per ha and wholesale rate of tomato (Abhinav) crop are shown in Table 4.1.3. The crop wise cost of production as per actual, gross return and calculated B:C ratio are shown in Table 4 . The gross return was calculated by considering marketable yield per ha and prevailing whole sale marketable price at that time at the market. The cost of production includes cost of installation of drip system and the cost of cultivation as per actual starting from field preparation to till crop is finally reached to market. The B;C ratio of Tomato (Abhinav) crop came around 2.15 (Table 4) indicates that growing Tomato (Abhinav)l crop with drip fertigation in black soils is an economically viable venture.

Table 4.1.3. Area and yield of tomato under drip fertigation with well water

S. No.	Name of crop	Area, ha	Marketable yield, t	Yield, t/ha	Wholesale rate, Rs./t
1	Tomato (Abhinav)	0.6	24.6	41	5000

Table 4.1.4. Economic of tomato under drip fertigation with marginally saline well water

S.	Name of crop	Cost of production, Rs./ha	Gross return, Rs./ha	Net	B:C

No.				return	ratio
1	Tomato (Abhinav)	95000	205000	110000	2.15

Water Productivity

The water productivity (WP) worked out for tomato (Abhinav) crops are shown in Table 4.1.5.The WP was obtained as 4.10 q ha $^{-1}$cm $^{-1}$ in case of crop Tomato (Abhinav)

Table 4.1.5 .WP and B: C ratio of Tomato under drip fertigation with well water

S. No.	Crops	Water, cm ha $^{-1}$	Yield, q/ha	WP, q ha $^{-1}$cm $^{-1}$
1	Tomato (Abhinav)	100	410	4.10

Similar procedure was followed in case of all other crops grown and only abstracted results are discussed.

Effect on Salinity

The Average values of EC for soil depth 0-30 cm recorded during the year 2006-07, 2007-08 and 2008-09 are shown in Table 4.1.6. It is clear from the Ec data that EC increases as the number of irrigation applied progresses in case of all the crops grown. For example average values of EC were recorded (0.40, 0.38 and 0.50 dSm^{-1}) in case of Capsicum crop “on drippers” sampling point for 1st 2nd and 3rd sampling respectively. The EC values indicate that there was an increase in average values of EC within 15days and 30 days period at sampling points on drippers and similar trend observed in all the crops and sampling points. The study further reveals that higher salt accumulation was observed on sampling points side of ridge, side of drippers and between drippers as compared to sampling point “on drippers” in case of all the crops. It implies that salt accumulation was more as we move away from drippers and it was maximum on side of the ridge.

Table 4.1.6. Average Value of EC for 0-30 cm profile depth recorded during years

Crop	Sampling pts.	Recorded EC (dS/m) at various Sampling No.					
		1st	2nd	3rd	4rth	5rth	6rth
		2006- 07					
Capsicum	On dripper	0.40	0.38	0.50	-	-	-
	Between drippers	0.62	0.65	0.66	-	-	-
	Side of ridge	0.30	0.52	0.83	-	-	-
	Side of drippers	0.4	0.83	0.89	-	-	-
Chilli	On dripper	0.53	0.59	0.61	-	-	-
	Between drippers	0.62	0.65	0.66	-	-	-
	Side of ridge	0.52	1.12	0.73	-	-	-
	Side of drippers	0.82	0.89	0.96	-	-	-

Tomato	On dripper	0.42	0.72	0.33	-	-	-
	Between drippers	0.80	1.33	0.68	-	-	-
	Side of ridge	0.67	0.99	0.68	-	-	-
	Side of drippers	0.37	0.42	0.55	-	-	-
Lady fingure	On dripper	0.46	0.58	0.35	-	-	-
	Between drippers	0.64	0.83	0.62	-	-	--
	Side of ridge	0.56	0.32	0.61	-	-	-
	Side of drippers	0.38	0.53	0.59	-	-	-
Water Melon	On dripper	0.48	0.31	0.37	-	-	-
	Between drippers	0.51	0.34	0.78	-	-	-
	Side of ridge	0.39	0.51	0.69	-	-	-
	Side of drippers	0.50	0.62	0.74	-	-	-
2007- 08							
Bitter Gourd	On dripper	0.49	0.48	0.50	1.07	0.62	0.51
	Between drippers	0.69	0.50	0.69	0.96	0.75	0.74
	Side of ridge	0.68	0.74	0.56	3.35	1.11	0.65
	Side of drippers	0.86	0.45	0.64	0.98	0.81	0.36
Potato	On dripper	0.48	0.56	0.70	0.81	0.82	0.55
	Between drippers	0.65	0.55	0.58	0.93	0.86	0.68
	Side of ridge	0.74	0.61	0.93	0.97	1.25	0.73
	Side of drippers	0.82	0.77	0.45	0.93	0.96	0.65
Chilli	On dripper	0.53	0.39	0.73	0.91	0.91	0.74
	Between drippers	0.37	0.33	0.77	1.29	0.83	1.29
	Side of ridge	0.38	0.22	1.00	0.86	0.77	0.75
	Side of drippers	0.75	0.86	0.66	1.73	0.73	0.75
Onion	On dripper	0.55	0.42	0.91	0.96	0.83	0.72
	Between drippers	0.87	0.99	0.83	1.22	0.75	0.87
	Side of ridge	0.45	0.54	0.63	1.61	0.84	0.86
	Side of drippers	0.71	0.83	0.77	1.45	0.86	0.79
2008- 09							
Tomato (Abhishek)	On dripper	0.38	0.47	0.60	1.05	0.63	0.51
	Between drippers	0.43	0.52	0.71	1.00	0.63	0.74
	Side of ridge	0.51	0.61	0.86	1.63	1.11	0.65
	Side of drippers	0.33	0.46	0.71	0.99	0.69	0.60
Tomato (Abhinav)	On dripper	0.35	0.52	0.63	1.06	0.68	0.68
	Between drippers	0.31	0.55	0.76	1.02	0.59	0.68
	Side of ridge	0.45	0.67	0.85	1.54	0.81	0.65
	Side of drippers	0.41	0.56	0.77	0.98	0.72	0.54
Bitter gourd	On dripper	0.57	0.67	0.77	0.99	0.62	0.60
	Between drippers	0.57	0.70	0.85	1.23	0.86	0.74
	Side of ridge	0.40	0.68	0.85	1.52	1.11	1.01
	Side of drippers	0.55	0.66	0.91	1.28	0.81	0.72
Garlic	On dripper	0.45	0.55	0.69	0.83	0.54	0.65
	Between drippers	0.41	0.59	0.81	1.06	0.74	0.85
	Side of ridge	0.64	0.90	1.06	1.75	1.11	1.02
	Side of drippers	0.58	0.82	0.94	1.21	0.81	0.92

Water productivity and economics

The water productivity worked out for different crops are shown in Table 4.1.7.The highest WP was obtained as 8.5 q /ha/ cm in case of potato crop with B:C ratio 2.25 and lowest was with the chili crop as 0.58 q/ ha/ cm . Next to Potato crop was water melon which gave WP as 6.03 q ha $^{-1}$cm $^{-1}$ with the highest B:C ratio of 3.2. The overall WP came around 3.31 q/ ha/ cm with the B: C ratio of 2.21 for all the crops grown on by the farmer. The highest B: C ^{ratio} of 3.50 was obtained in Garlic crop and next to it was in water melon crop as 3.20. The lowest was obtained in case of Onion and Capsicum crops as 1.25 and 1.60. B:C ratio is more than one in all the crops grown which implies that drip fertigation with marginally saline well water for cost intensive cultivation of horticultural crops in Vertisols under sub tropic semi-arid climate is a feasible and economically viable proposition.

Table 4.1.7. WP and B: C ratio of vegetable under drip fertigation with well water

S. No.	Crops	Water, cm ha $^{-1}$	Yield, q/ha	WUE, q/ ha/ cm	B:C ratio
1	Potato	053	450	8.50	2.25
2	Water melon	053	320	6.03	3.20
3	Chili	120	070	0.58	1.94
4	Capsicum	120	080	0.67	1.60
5	Lady finger	053	210	3.96	2.10
6	Bitter Guard	120	350	2.92	3.11
7	Onion	053	250	4.72	1.25
8	Tomato	075	410	5.47	2.16
9	Garlic	076	180	2.37	3.50
Total		**647**	**2140**	**3.31**	**2.21**

Quality of irrigation water

The vegetable crops grown in study area were irrigated by water of 2 open wells existing in the farmer's holding. The water samples of these two wells were collected and analyzed in SAS project lab for quality parameters and same are presented in Table 4.1.8. It is obvious that water used for irrigation as well as fertigation is marginally saline in nature.

Table 4.1.8. Recorded quality parameters of well water used for irrigation

Parameters	Unit	Results	
		Well 1	**Well 2**
pH		8.16	8.01
EC	dS/m	0.95	1.15
Calcium	meL^{-1}	6.60	8.00
Magnesium	meL^{-1}	1.40	1.80
Sodium	meL^{-1}	1.33	1.62
Potassium	meL^{-1}	0.02	0.00
Carbonate	meL^{-1}	0.20	0.00
Bicarbonate	meL^{-1}	5.60	6.80
Chloride	meL^{-1}	2.40	3.40
Sulphate	meL^{-1}	1.00	0.94
Rasidual Sodium Carbonate	meL^{-1}	Nil	Nil
Sodium adsorption Ratio	(mmolL^{-1})$^{1/2}$	0.66	1.14

Conclusion

A study was carried out during 2006-10 to monitor effect of drip fertigatoin with marginally saline well water on salinity and economics of horticultural crops grown in Vertisols at farmer's field of Bagda khurd village of Bedia tehsil, Khargone Distt, Madhya Pradesh. The study reveals that EC increases as number of irrigation applied progresses in case of all the crops grown. In case of Tomato (Abhinav) crop average values of EC were recorded 0.40, 0.46, 0.55, 0.64, 0.0.69 and 0.35 dS/m on sampling point on-dripper for 1st, 2nd , 3rd , 4th , 5th , and 6th sampling respectively. Similar trend has been observed with all the crops grown. EC increases as we move away from the drippers i.e. side of the ridge and between drippers. The minimum values were recorded at sampling point on drippers. The difference between maximum and minimum average value of EC were 0.29 dS/m, 0.41dS/m, 0.50 dS/m and 0.43dS/m on the sampling locations viz. on drippers, between two drippers, side of the ridge, side of dripper respectively. Recorded EC values also indicate that higher salt accumulation was observed on sampling points side of ridge, side of drippers and between drippers as compared to sampling point "on drippers" in case of all the crops. It implies that salt accumulation was more as we move away from drippers and it was maximum on Sampling point "side of the ridge". Growing horticultural crops with drip fertigation with marginally saline well water in Vertisols is a feasible and economically viable venture as indicated by B: C ratio. B: C ratio obtained is greater than 1 in case of all grown crops. The highest B:C ratio of 3.50 was obtained in Garlic crop and next to it was in potato crop as 3.20. The lowest was obtained in case of onion and capsicum crops as 1.25 and 1.60. The lowest B:C ratio was obtained in case of Capsicum. It may be due to the reason that capsicum crop was adversely affected in later stage by salinity increase with frequency of drip fertigation. The highest water productivity (WP) was obtained as 8.5 q ha $^{-1}$cm $^{-1}$ in case of potato crop with B: C ratio 2.25 and lowest was with the chili crop as 0.58 q ha $^{-1}$cm $^{-1}$. Next to Potato crop was water melon which gave WP as 6.03 q ha $^{-1}$cm $^{-1}$ with the B: C ratio of 3.2. Bitter Gourd crop gave WP as 2.92 q ha $^{-1}$cm $^{-1}$ with 3.11 B: C ratio. In conclusion, the study indicates that drip fertigation with marginally saline well water for cost intensive cultivation of horticultural crops in Vertisols under sub-tropic semi-arid climate is a feasible and economically viable proposition. Drip fertigation with marginally saline water showed salt accumulation in irrigated area around drippers as number of irrigation applied progresses. The salt accumulation can be duly taken care of by simply practicing one surface irrigation after a period of 75-90 days or may be by Monsoon rain in natural course.

4.2 Irrigation in fruit plants

A large chunk of area under Sodic black soils do persist in Central India and it is known to occur with scarcity of water in arid and semi-arid regions. It stresses the need to utilize the irrigation water judiciously. Method of irrigation can play vital role in achieving high effectiveness of water use. Most of the farmers in India are still practicing surface irrigation. However drip irrigation is fast expanding technology in modern irrigated agriculture. Irrigation done so far in India and abroad has shown that this method leads to not only appreciable saving of irrigation water but also resulted in achieving higher crop yields as compared to conventional methods (INCID, 1994).Vertisols are potentially saline soils and having poor hydraulic properties (Murthy *et. al*, 1981). The capital-intensive reclamation of sodic black soils calls for utilizing such untapped lands through horticultural plantation. Ber, Sapota and Pomegranate are the recommended horticultural trees for sodic black soils. A study is therefore planned to compare performance of three fruit trees Ber (Banarsi Kadka), Sapota (Kalipatti) and Pomegranate (Ganesh) transplanted during July to Sept. 2005. Three irrigation systems viz. Check basin, Drip and embedded pipe (100 mm dia. perforated vertical PVC pipe of length 40cm) were adopted with two qualities of water (normal and diluted distillery waste water).Sharma *et al* (2007) reported embbeded pipe system (pipe diameter 100 mm and length 40 cm) markedly effective in sodic black soil to irrigate new Aonla tree plantation and therefore it has been cosidered under the study. The study was carried out in sodic black soils of Salinity Research Station, Barwaha.Three types of fruit plants Ber (Banarsi Kadka), Sapota (Ganesh) and Pomegranate (Kalipatti) were transplanted. These plants were transplanted as per the recommended methods. Pits of size 45 x 45 x 45 cm were dug and filled with excavated soils mixed with gypsum @ 100% 0f GR along with FYM before filling to the pit. The normal practice of irrigation (twice in a month) was adopted to irrigate the planted saplings. The various irrigation treatments were super imposed after getting established grafted Ber (Banarsi Kadaka).Two different quality irrigation waters i.e. Best Available water (BAW) and Spent Wash Diluted Water (1:30) were used for irrigation (as per treatments). 12 plants of each fruit plants were irrigated by each irrigation method and quality of irrigation water. Two bio metric parameters i.e. thickness and height was recorded every year since planting. The month wise details of quantity of irrigation water actually applied were recorded in each treatment. The EC, SAR and RSC of normal water were 0.5 dS/m, 1.1 (mmol/L)½ and 0.0 me/L respectively. However the EC, SAR and RSC of diluted spent wash (1:30 ratio) were 0.93 dS/m, 7.3 (mmol/L)½ and 0.0 me/L respectively. The conceptual sketch of embedded pipe irrigation system is shown below aong with its advantages.

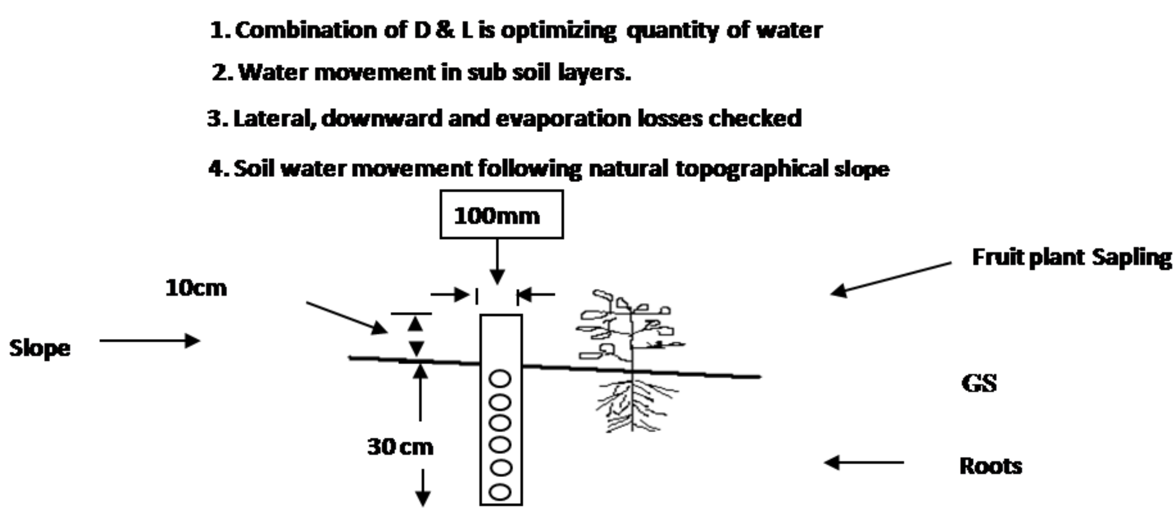


Fig 1. Conceptual sketch of irrigation arrangement

Scheduling of irrigation

1 x 1 m sized check basins were constructed around transplanted fruit plant sapling and per irrigation 7 cm irrigation water was applied. Irrigation was scheduled on the basis of 0.5 IW /

CPE ratio. In drip method irrigation was scheduled alternate day and quantity of irrigation water applied according to following relationship.

$$V = Ep \times Kp \times Kc \times Ai$$

The value of Kc for fruit crop was determined as 0.76. The irrigation was given by pressure Non- compensating drippers of 4 LPH discharge at operating pressure of 1kg / cm^2. The PVC rigid pipe piece with length 40 cm and external dia. 110 mm imbedded 30 cm in soil and having perforations facing towards plant. Per irrigation 3.25 liter of water was applied by filling pipe ones. Irrigation was scheduled alternate day.

Quantification of irrigation

The month wise details of quantity of irrigation water actually delivered during 2006 under Check basin, Imbedded pipe and Drip irrigation in Sapota, Ber and Pomegranate are given in Table 4.2.1 . It is clear that 1610, 376 and 480 liters of irrigation water per plant per year applied during 2006 in irrigation method check basin, imbedded pipe and drip respectively. It implies that there was 76% and 70% irrigation water saving in case of imbedded pipe and drip irrigation respectively over check basin irrigation.

Table 4.2.1. Details of irrigation delivered during 1st year of planting

S.No.	Months	Details of Irrigation requirement								
		Check Basin			Imbedded Pipe			Drip		
		Nos.	Qntity.	Total, L	Nos.	Qntity.	Total, L	Nos.	Qntity. (L)	Total,
Sapota (Kalipatti) Sown on 28rth July 2005										
1	January 06	2	70	140	15	3.14	47	15	3.93	60
2	February06	2	70	140	15	3.14	47	15	3.93	60
3	March 06	3	70	210	15	3.14	47	15	3.93	60
4	April 06	4	70	280	15	3.14	47	15	3.93	60
5	May 06	4	70	280	15	3.14	47	15	3.93	60
6	June 06	4	70	280	15	3.14	47	15	3.93	60
7	July 06	-	-	0	-	-	0	-	-	0
8	August 05	-	-	0	-	-	0	-	-	0
9	Sept. 05	-	-	0	-	-	0	-	-	0
10	October 05	-	-	0	-	-	0	-	-	0
11	Nov. 05	2	70	140	15	3.14	47	15	3.93	60
12	Dec. 05	2	70	140	15	3.14	47	15	3.93	60
Total		**23**		**1610**	**120**		**376**	**120**		**480**
Zuzuba (Banarsi Kadka) sown on 1st August 2005										
1	January 06	2	70	140	15	3.14	47	15	3.93	60
2	February06	2	70	140	15	3.14	47	15	3.93	60
3	March 06	3	70	210	15	3.14	47	15	3.93	60
4	April 06	4	70	280	15	3.14	47	15	3.93	60
5	May 06	4	70	280	15	3.14	47	15	3.93	60
6	June 06	4	70	280	15	3.14	47	15	3.93	60
7	July 06	-	-	0	-	-	0	-	-	0
8	August 05	-	-	0	-	-	0	-	-	0
9	Sept. 05	-	-	0	-	-	0	-	-	0
10	October 05	-	-	0	-	-	0	-	-	0

11	Nov. 05	2	70	140	15	3.14	47	15	3.93	60
12	Dec. 05	2	70	140	15	3.14	47	15	3.93	60
Total		**23**		**1610**			**376**			**480**
Pomegranate (Ganesh), sown on 3rd September 2005										
1	January 06	2	70	140	15	3.14	47	15	3.93	60
2	February06	2	70	140	15	3.14	47	15	3.93	60
3	March 06	3	70	210	15	3.14	47	15	3.93	60
4	April 06	4	70	280	15	3.14	47	15	3.93	60
5	May 06	4	70	280	15	3.14	47	15	3.93	60
6	June 06	4	70	280	15	3.14	47	15	3.93	60
7	July 06	-	-	0	-	-	0	-	-	0
8	August 06	-	-	0	-	-	0	-	-	0
9	Sept. 05	-	-	0	-	-	0	-	-	0
10	October 05	-	-	0	-	-	0	-	-	0
11	Nov. 05	2	70	140	15	3.14	47	15	3.93	60
12	Dec. 05	2	70	140	15	3.14	47	15	3.93	60
Total		**23**		**1610**			**376**			**480**

Similarly as above, the details of water expense as per actual has been worked out for the 2007 and the same are abstracted in Table . It is clear from the data of the Table that 1610, 376 & 480 liters (2006) and 2790, 1115 and 1480 liters (2007) of irrigation water per plant per year applied during the study period (Table 4.2.2) in irrigation method check basin, imbedded pipe and drip respectively. Study reveals there was substantial saving of irrigation water in embedded pipe method followed by drip as compared to Check basin method.

Table 4.2.2. **Water requirement (L/plant/year) under different method of irrigation**

Year	**Check Basin**		**Imbedded Pipe**		**Drip**	
	Nos.	**Qntity. (L)**	**Nos.**	**Qntity. (L)**	**Nos.**	**Qntity. (L)**
2006	23	1610	120	376	120	480
2007	31	2790	120	1115	120	1480

Change in Bio-metric parameters

(i) thickness

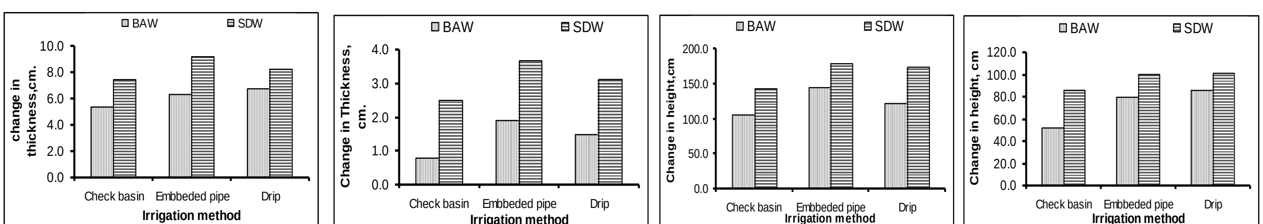
The change in average thickness was worked out by considering average thickness of plants under each treatment at the time of planting and after 1 and 2 year of planting (Table 4.2.3). Better growth in terms of thickness was observed in case of embedded pipe and drip irrigation as compared to check basin in all the fruit plants. The data also revealed that the change in thickness was more in case of irrigation by diluted spent wash as compared to irrigation by best available irrigation water (Fig.1&2).

(ii) Height

The change in average height was also worked out by considering average height of plants under each treatment at the time of planting and after 1 & 2 year of plating (Table 4.2.3). Better growth in terms of height was observed in case of embedded pipe and drip irrigation as compared to check basin in all the fruit plants. It is also seen that change in height was more in case of irrigation by spent wash diluted water as compared to irrigation by best available irrigation water (Fig.3&4) .

Table 4.2.3. Change in thickness and height of fruit trees in different method of irrigation

Method	Change in thickness (cm)			Change in height (cm)		
	Ber	Sapota	Pomegranate	Ber	Sapota	Pomegranate
Best available water -2006						
Check basin	0.81	0.42	0.52	33.0	13.3	25.4
Embedded pipe	1.21	0.83	0.67	51.9	22.5	26.3
Drip	1.21	0.81	1.05	51.9	20.8	43.9
Diluted spent wash (Spent wash : Water : : 1:30)- 2006						
Check basin	0.65	0.50	0.48	19.0	21.0	26.0
Embedded pipe	0.95	0.87	0.94	38.0	23.0	34.0
Drip	0.71	0.78	0.76	25.0	25.0	28.0
Best available water -2007						
Check basin	2.8	3.0	0.7	115.8	52.3	45.4
Embedded pipe	6.4	3.9	4.3	144.8	79.6	113.7
Drip	6.7	4.4	1.5	122.2	86.1	79.8
Diluted spent wash (Spent wash : Water : : 1:30)- 2007						
Check basin	4.6	2.6	2.5	143.7	86.0	51.4
Embedded pipe	9.2	4.3	3.7	178.6	101.0	105.1
Drip	8.2	5.2	3.1	173.3	102.0	104.7



Comparison of change in thickness and height of plants under different methods of irrigation and quality of water

Conclusion

A large chunk of area under Sodic black soils do persist in Central India and it is known to occur with scarcity of water in arid and semi-arid regions. It stresses the need to utilize the irrigation water judiciously. Method of irrigation can play vital role in achieving high effectiveness of water use. The capital-intensive reclamation of sodic black soils calls for utilizing such untapped lands through horticultural plantation. Ber, Sapota and Pomegranate arê the recommended horticultural trees for sodic black soils. A study was therefore carried out during the years 2006 and 2007 to compare performance of three fruit trees Ber (Banarsi

Kadka), Sapota (Kalipatti) and Pomegranate (Ganesh) grown in sodic soil environment under the influence of three irrigation systems viz. Check basin, Drip and embedded pipe (100 mm dia. perforated vertical PVC pipe of length 40cm) with two qualities of water (normal and diluted spent wash water). The study reveals that 1610, 376 & 480 liters (2006) and 2790, 1115 and 1480 liters (2007) of irrigation water per plant per year applied during the study period in irrigation method check basin, imbedded pipe and drip respectively. Better growth in terms of thickness and height was observed in case of embedded pipe and drip irrigation system as compared to check basin in all the fruit plants. The study further revealed that the change in thickness and height was more in case of irrigation by diluted spent wash as compared to irrigation by best available irrigation water. Finally, study reveals that embedded pipe irrigation method (having pipe diameter 100 mm and length 40 cm) followed by drip irrigation are observed markedly effective and promising in performance as compared to conventional check basin method in terms of saving of irrigation water and improvement in Bio-metric parameters for growing Ber sapota and pomegranate fruit plants with spent wash diluted (1:30) water in sodic soil environment. The data also revealed that the change in thickness and height was more in case of irrigation by diluted spent wash as compared to irrigation by best available irrigation water.

4.3 Establishing new aonla tree plantation

As a part of arid and semi-arid landscape, contemporary salt affected soils are known to occur with inadequate irrigation facilities. These lands have not been utilized for crop production due to various constraints (Prasad 1988). In black soils the main chemical degradation problem is of sodicity due to which the soils are inherently difficult to manage through conventional agro-techniques. Soil sodification induces higher swelling and water retention. Consequently the plant available water, soil permeability and infiltrability are adversely affected (Sharma *et al.* 1998). It renders the soil unfit for cultivation. Reclamation of such lands for crop productions requires provision of chemical amendments, irrigation facilities and on farm drainage, which is capital-intensive activity. Qadir and Oster (2002) reported that reclamation has become costly for subsistence farmers in developing countries because of increase in cost of amendments due to greater industrial usage and reduction in government subsidy. In order to utilize such untapped lands plantation of trees might be one of the easiest rescues after adopting suitable technology (Yadav 1981). Trees in general known to be more tolerant to adverse soil condition than most agriculture crops (Manjunath *et al.*, 2002)

Amongst fruit plants Aonla (A*mblica officinalis*) is one of the recommended horticultural plants for sodic soils. It is a hardy species and requires low and frequent irrigation, especially in sodic black soils. The conventional irrigation methods like surface, sprinkler and drip are not effective due to very low infiltration rate and high percentage of dispersible clay. Therefore need is felt to evolve suitable low cost unconventional methods of irrigation for establishing new tree plantation in sodic black soils. With this background, certain unconventional irrigation arrangement were thought of for irrigating new Aonla seedlings for their establishment in sodic black soils and performance of the same are evaluated and compared with conventional surface irrigation check basin in terms of water saving, biometric parameters and survival percentage.

A field experiment in sodic black soils was conducted at Soil Salinity Research Station, Barwaha (Khargone) M.P. during the year 2002-2003 to study the effect of unconventional irrigation method as compared to conventional method of irrigation check basin in new Aonla tree plantation. Under the study 8 arrangements of unconventional irrigation (T_1 - T_8) were tried and compared with check basin treatment (T_9), as control. The details of various proposed irrigations arrangements are as follows.

T_1 – The PVC pipe having 100 mm dia and 40 cm length embedded 30 cm in soil with perforation facing towards plantation.

T_2 - The PVC pipe having 100 mm dia. and 62.5 cm length embedded 52.5 cm in soil with perforation facing towards plantation.

T_3 - The PVC pipe having 75 mm dia. and 40 cm length embedded 30 cm in Soil with perforation facing towards plantation.

T_4 - The PVC pipe having 75 mm dia. and 62.5 cm length. embedded 52.5 cm in soil with perforation facing towards plantation.

T_5 - The PVC pipe having 50 mm dia. and 40 cm length embedded 30 cm in soil with perforation facing towards plantation.

T_6 - The PVC pipe having 50 mm dia. and 62.5 cm length embedded 52.5 cm in soil with perforation facing towards plantation.

T_7 - The PVC pipe having 25 mm dia. and 40 cm length embedded 30 cm in soil with perforation facing towards plantation.

T_8 - The PVC pipe having 25 mm dia. and 62.5 cm length embedded 52.5 cm in soil with perforation facing towards plantation.

T_9 – Check basin (control).

The embedded pipes were wrapped with locally available coir material. The conceptual sketch of unconventional irrigation arrangement is shown in Fig. 1. The plant saplings of four varieties of *Amblica Officinalis* namely Krishna, kanchan, NA-10 and NA-7 were planted on 14th of October 2002 following RBD with 5 replications. Row-to- row and plant-to-plant distances were kept uniform for all the four varieties as 5m x 4.5 m respectively. The recommended package of practice was adopted. The performance of each variety was evaluated under each irrigation treatment in terms of saving of irrigation water, survival percentage, and plant height and collar thickness or diameter.

Field experiment was conducted at Salinity Research Station, Barwaha in sodic black soils to study the effects of unconventional irrigation arrangements as compared to conventional method of irrigation check basin in new Aonla plantation. There are 8 arrangements of unconventional irrigation (T_1 to T_8) tried and compared with check basin treatment (T_9) which is control. Various details of results are discussed as below.

Saving of Irrigation Water

Aonla is a hardy plant and requires low and frequent irrigation, especially in sodic black soils. Irrigation was therefore applied 4 times in a month at regular interval in each of the treatment (T_1 to T_9). In check basin 5 cm depth of irrigation was applied. In case of (T_1 to T_8) volume of water applied is equal to volume of installed pipe. The details of pipe dimension, volume of water per irrigation, No. of irrigation, total volume of water applied per month per plant and saving of water over check basin method are shown in Table 4.3. 1.

Table 4.3.1. Saving of water under irrigation treatments in Aonla in sodic black soils

S. No.	Treatments	Volume of water/ irrigation (m^3)	No. of Irrigation / plant/ month.	Quantity		
				(m^3)	(l)	% Saving

1	T_1 – L - 40, D -100	0.0063	4	0.025	25.12	69
2	T_2 – L - 62.5, D - 100	0.0098	4	0.039	39.25	51
3	T_3 – L – 40, D -75	0.0053	4	0.021	21.20	74
4	T_4 – L - 62.5, D - 75	0.0083	4	0.033	33.12	59
5	T_5 – L - 40, D - 50	0.0031	4	0.013	12.56	84
6	T_6 – L - 62.5, D - 50	0.0049	4	0.020	19.63	75
7	T_7 – L – 40, D - 25	0.0010	4	0.004	03.93	95
8	T_8 - L - 62.5, D - 25	0.0015	4	0.006	06.13	92
9	T_9 - Basin (control)	0.0200	4	0.080	80.00	-

L – Length, D – Diameter and l - Liters

It is obvious from the above data that there is marked reduction in amount of irrigation water applied in case of each of the unconventional method as compared to check basin method in which 80 liters of irrigation water was applied per month per plant. In case of T_1, T_2 and T_3 there is 69%, 51% and 74% saving in irrigation water over check basin. Apart from saving in irrigation water, assessment of effect of irrigation methods on biometric parameters like height, thickness and survival of plant was also studied to adjudge effective method.

Thickness of Plant

Thickness of plants in terms of diameter at stump height was recorded at the time of plantation and after one year of plantation. The details of thickness are shown in Table 4.3.2.

Table 4.3.2. Plant thickness as influenced by different management of irrigation

S. No.	Treatment	Thickness (cm)				
		Kanchan	Krishna	NA-10	NA-7	Mean
1	T_1 – L - 40, D -100	1.60	1.28	1.54	1.40	**1.46**
2	T_2 – L - 62.5, D - 100	1.48	1.26	1.60	1.06	**1.35**
3	T_3 – L – 40, D -75	1.50	1.56	1.22	1.06	**1.34**
4	T_4 – L - 62.5, D - 75	1.62	1.22	1.18	1.44	**1.37**
5	T_5 – L - 40, D - 50	1.64	1.40	1.45	1.20	**1.42**
6	T_6 – L - 62.5, D - 50	1.16	1.60	1.56	1.06	**1.35**
7	T_7 – L – 40, D - 25	1.10	1.67	0.88	1.30	**1.24**
8	T_8 - L - 62.5, D - 25	0.84	1.10	1.14	1.32	**1.10**
9	T_9 - Basin (control)	1.64	1.19	0.89	1.51	**1.31**

The data reveals that the mean highest growth in terms of stump diameter was observed as 1.46 cm in case of T_1 than that of 1.31 cm in check basin. The mean growth in diameter was observed lowest incase of T_7 and T_8. It is also observed that increase in thickness of plant diameter was observed lowest in case of CB and it was maximum in case of T_1, T_4 and T_5 irrespective of species. In rest of the treatments increase in thickness is marginally better than CB but lower than T_1 T_4 and T_5.

Height of Plantation

Observations on height of plant were also recorded before and after one year of plantation and are shown in Table 4.3.3.The data on plant height reveals that increase in height of plants was observed lowest in case of CB as 90 cm and maximum in T_1, T_3 and T_4 as 97.25 cm, 101.5 cm and 100 cm, respectively. In rest of the treatments it is marginally better over CB except T7 and T8 with the lowest growth in height. All the verities have shown better growth in height in treatments T_1, T_3 and T_4.

Table 4.3.3. Plant height as influenced by different management of irrigation

S. No.	Treatment	Plant height (cm)				
		Kanchan	**Krishna**	**NA-10**	**NA-7**	**Mean**
1	T_1 – L - 40, D -100	099	097	089	104	**097.25**
2	T_2 – L - 62.5, D - 100	110	080	098	075	**090.75**
3	T_3 – L – 40, D -75	097	128	084	097	**101.50**
4	T_4 – L - 62.5, D - 75	107	092	105	096	**100.00**
5	T_5 – L - 40, D - 50	113	081	100	078	**00930**
6	T_6 – L - 62.5, D - 50	074	107	105	084	**092.50**
7	T_7 – L – 40, D - 25	070	091	073	090	**081.00**
8	T_8 - L - 62.5, D - 25	068	078	092	081	**079.75**
9	T_9 - Basin (control)	103	086	059	112	**090.00**

Survival Percentage

Treatment wise varietals survival percentage is shown in Table 4.3.4. The survival percentage in Kanchan, Krishna, NA10 and NA 7 observed were 70, 90, 90 and 90 percent, respectively in CB, which is minimum in comparison to other treatments except T_7 and T_8 with mean survival as 75 and 95, respectively. Percent survival in T_1, T_2 T_3 and T_4 are between 100 %, which is highest irrespective of variety.

Table 4.3.4. Survival of Aonla under the influence of various irrigation treatments

S. No.	Treatment	Survival %				
		Kanchan	**Krishna**	**NA-10**	**NA-7**	**Mean**
1	T_1 – L - 40, D -100	100	100	100	100	100
2	T_2 – L - 62.5, D - 100	100	100	100	100	100
3	T_3 – L – 40, D -75	100	100	100	100	100
4	T_4 – L - 62.5, D - 75	100	100	100	100	100
5	T_5 – L - 40, D - 50	100	100	080	100	100
6	T_6 – L - 62.5, D - 50	100	100	100	100	100
7	T_7 – L – 40, D - 25	060	060	080	100	**075**
8	T_8 - L - 62.5, D - 25	080	080	100	100	**095**
9	T_9 - Basin (control)	070	090	090	090	**085**

Water expense

The amounts of irrigation water given season wise to each plant in liters during the years (2005-05 and 2006-07) are abstracted Table 4.3.5. It is clear from the data that 882 & 1050 liters of irrigation water per plant per year was required during 2005-06 & 2006-07 respectively in irrigation arrangement (T_1) while in case of Check Basin (CB) it was quantified as 1260 and 1470 liters. It implies that there was around 30 % saving of irrigation water in T_1 over CB conventional method of irrigation.

Table 4.3.5. Yearly and seasonal water requirement in liters per plant under embedded pipe (T_1) and check basin (CB) method of irrigation

S. No.	Season	Months	No. of irrigation	Depth of irrigation (mm)		Total quantity of irrigation.		% Saving
				CB	T1	CB	T1	
1	Winter	Jan.-Mar.	7	60	42	420	294	
2	Summer	Apr.-Jun.	12	60	42	720	504	
3	Rainy	Jul.-Dec.	2	60	42	120	84	
Total – 2005			**21**			**1260**	**882**	**30**
Yearly increase (%)						**20**	**20**	
1	Winter	Jan.-Mar.	7	70	50	490	350	
2	Summer	Apr.-Jun.	12	70	50	840	600	
3	Rainy	Jul.-Dec.	2	70	50	140	100	
Total – 2006			**21**			**1470**	**1050**	**28.6**
Yearly increase (%)						**16.7**	**19.0**	

Changes in thickness and survival

The biometric parameter (recorded in the month of December) i.e. thickness at stump height was recorded during the year 2005-06 and 2006-07 for all the 4 varieties of Aonla (Table 4.3.6). The thickness was 3.36, 3.46, 4.72 & 2.64 cm (2005-06) and 4.92, 3.90, 6.68 and 5.22 cm 2006-07) in case of aonla plant varieties viz. Krishna, Kanchan and NA -10 except NA-7 respectively when irrigated by method T_1. However, it was 2.84, 2.64, 0.58 & 2.22 cm (cm) and 2.18, 1.60, 2.70 and 4.14 cm (2006-07) in case of check basin method of irrigation. The data on survival percentage revealed that survival percentage was 80 % (Kanchan and Krishna), 100 % (NA-10) and 60 % (NA-7) under T_1 while in case of CB survival was around 40 % which is the lowest one. Among the tried various combinations of internal diameter and length of pipe, the combination of 100 mm internal diameter pipe with 40 cm length (embedded 30 cm in soil with perforation facing towards plantation) appears markedly effective and promising over other tried combinations in establishing new Aonla tree plantation in sodic black soils on the basis of marked saving in irrigation water, better survival and improved growth of plants.

Table 4.3.6. Change in thickness (cm) and survival (%)

Pipe length	ID	Thickness (cm)	Survival (%)

pipe (mm)		Krishna	Kanchan	NA-10	NA-7	Krishna	Kanchan	NA-10	NA-7
				2005-06					
40.0	100	3.36	3.46	4.72	2.64	80	80	100	100
62.5	100	4.08	2.44	5.08	3.82	80	80	80	80
40.0	75	3.28	3.76	1.8	2.32	80	80	60	80
62.5	75	3.02	3.64	1.32	3.96	80	80	80	80
40.0	50	4.06	2.48	2.62	1.92	80	80	80	100
62.5	50	2.38	2.22	3.04	1.56	80	80	40	60
40.0	25	1.04	2.28	0.64	4.3	40	60	40	60
62.5	25	0.38	1.82	1.2	4.94	40	60	40	60
C. Basin (control)		2.84	2.64	0.58	2.22	40	40	20	60
				2006-07					
40.0	100	4.92	3.90	6.68	5.22	80	80	100	60
62.5	100	3.10	2.80	7.42	1.82	80	80	100	80
40.0	75	3.62	2.66	2.52	2.72	80	80	60	80
62.5	75	3.38	3.56	1.96	4.42	80	80	40	80
40.0	50	3.64	2.96	2.40	1.92	80	60	60	60
62.5	50	4.00	4.32	4.10	2.26	60	60	80	40
40.0	25	0.22	1.64	0.58	4.20	40	60	40	60
62.5	25	1.30	2.02	1.80	4.44	40	60	40	60
C. Basin (control)		2.18	1.60	2.70	4.14	40	40	40	40

I D – Internal diameter in mm

Conclusion

The capital-intensive reclamation of sodic black soils calls for utilizing such untapped lands through horticultural plantation. Aonla (*Amblica Officinalis*) is one of the recommended horticultural trees for sodic soils. The conventional irrigation methods like surface, sprinkler and drip are not effective in sodic black soils due to low infiltration and higher percentage of dispersible clay. In order to evolve suitable low cost unconventional method of irrigation for establishing new tree plantation in sodic black soils, a study is planned to compare performance of the proposed unconventional method with conventional check basin method in sodic black soils at Salinity Research Station, Barwaha during 2002-03. Study reveals that unconventional irrigation arrangement T_1 (pipe dia. 100 mm and length 40 cm) is observed markedly effective in performance as compared to conventional check basin method. There is a reduction in amount of irrigation water by 69% as compared to conventional check basin method in which 80 liters of irrigation water was applied per month per plant. Apart from saving of irrigation water the survival rate of new tree plantation was 100% as compared to 85% in check basin besides the improved growth in terms of plant height and thickness of collar diameter as 97.25 cm and 1.46cm, respectively than that of 90cm and 1.31 cm in check basin method. Finally, present investigation insinuates that unconventional irrigation arrangement T_1 (The PVC pipe having 100 mm diameter 40 cm length. embedded 30 cm in soil with perforations facing towards plantation) appears to be effective and promising among various tried arrangements over check basin method in establishing new Aonla tree plantation in sodic black soils on the basis of marked saving in irrigation water, better survival and improved growth of plants.

CHAPTER 5
HYDROLOGICAL BEHAVIOR OF GRASS SPECIES

The grasses play a vital role in soil and water conservation. Soil conserving capacity depends upon the grass species, particularly their root behavior and canopy development. In black alkali soils mechanical measures bunding is expensive (Gupta and Ranade, 1988) and unstable due to deterioration in soil structure. There is growing awareness to opt for vegetative measures, since the development of vegetative cover during rains strongly influences soil loss (Wischmeier and Smith, 1978). Easily propagated grass species with extensive root system may be used as vegetative hedges to reduce runoff and soil loss. But little information is available on their rooting pattern. The present study was planned to assess suitability of certain grass species as vegetative barriers for enhancing in situ conservation of water and to observe roots' growth and distribution pattern of these grass species in sodic black clay soils of Nimar region. Attempts were also made to develop a dynamic root development Model for these species.

The investigation was initiated in April 2001 at Soil Salinity Research Station, Barwaha (76^0 0' 27"E and 22^0 14' 48" N) district Khargone, Madhya Pradesh.The experimental soil belongs to order Vertisols (Haplusterts - Sodic phase) with high CEC 40cmol (p+) kg^{-1}, ESP (40.0 ± 2.0), low ECe (0.9 to 1.4 dSm^{-1}) and moderate pH (8.2-8.4). The soil is clay in texture (clay 54.6%, silt 34.4% and sand 11.0%) with almost negligible steady state infiltration rate (terminal rate). The bulk density of plough layer soil (0-15 cm) is in the range of 1.40 to 1.45 Mgm^{-3}. The grasses were transplanted with uniform population in all the main plots (except control) with land slope of about 0.3% during July 2001. The experiment design is RBD with three replication and six treatments. The six treatments were five grass species viz. Marvel grass (*Dichanthium annulatum*), Para grass (*Brachiria mutica*), Vetiver grass (*Vetiveria zizinoides*), Karnal grass (*Diplachne fusca*) and Napier grass (*Penisetum perpurium*) and control. In order to provide protection against fungal infestation the root portion of each slip was dipped in the 0.5% solution of Bavistin for 15 minutes. The slips were transplanted at specified distance interval (30x30 cm) in plots measuring 21.0 x 4.5 m and basal application of urea (50 kg N ha^{-1}), Super phosphate (40 kg P_2O_5 ha^{-1}) and Zn SO_4 (25 kg ha^{-1}) has been applied at planting. One plot in each replication has been kept fallow as check.

Grasses were tested for hydrological aspects after one year of transplanting. The lower end of the plot has been provided with multi-slot divisor prepared by Central Institute of Agricultural Engineering, Bhopal (M.P). The collected runoff samples were analyzed for sediment and nutrient loss. Infiltration rate was measured by placing double ring infiltrometers in different treatments permanently in one of the replication. After the steady state condition the intake rate was measured.

Root growth and proliferation of the grass species was monitored through monoliths of 50 x 50 x 10 cm layer wise excavation to a depth of their penetrations. Roots were being recovered by washing away of soil. The total roots recovered after washings were collected from each plots in different sections at 10 cm interval. Fresh root weights was recorded and mean root diameter were measured with the help of screw gauge by taking randomly ten roots from each layers and then weighted over all the depths of root recovery. The wet roots obtained were immersed in a measuring cylinder to record the volume of fresh roots. Roots were then dried in oven at 80^0C and dry root weight be recorded. Root biomass density (g cm^{-3}) for each grass species at different time interval was calculated by considering the volume of 50x50x50 cm^3 size monolith. Soil binding capacity of the roots was calculated by
the method described by Bhimaya *et al*. (1956).

$$F = V/ r^2$$

Where ' F' is binding factor,
'V' is volume of roots (cm^3), and
'r' is average radius of roots (mm)

Survival of grasses

The date of planting and survival percentage recorded after a month of transplanting are reported in table 5.1. The highest survival was recorded in Para grass (94%) which was significantly higher than marvel (87%), Vetiver (67%) and Karnal grass (63%). The lowest survival was recorded with Panicum (10%) after three times of transplanting thus it was replaced by Napier on 11th August 2001. The survival of Napier (recorded later on) was satisfactory (72%). Ashok Kumar and Abrol (1986) evaluated the tolerance of several forage grasses under green house and field conditions and reported the tolerance in the order of Karnal grass, Rhodes grass, Gatton panic, Bermuda grass and Para grass.

Table 5.1. Date of transplanting & survival percent of different grasses

S. No.	Name of grass	Date of transplanting	Survival percent	Remark (rank)
1.	Marvel grass	26/6/2001	87	2
2.	Vetiver grass	4/7/2001	67	3
3.	Para grass	5/7/2001	94	1
4.	Panicum grass	6/7or14/7or27/7/2001	10	Failed
5.	Karnal grass	9/7/2001	63	4
6.	Napier grass	11/8/2001	72	(in lieu of Panicum)
SEm ±			0.67	
CD at 0.05			2.21	

Infiltration

The infiltration rate (Table 5.2) improved markedly after 42 months of grass planting this may be attributed to exude generated by roots, uptake of sodium and disintegration of roots biomass in soil. Ashok Kumar and Abrol (1979) observed improvement in soil properties by growing five grasses (Hybrid Napier, Para grass, Setaria grass, Guinea grass and Bermuda grass). They recorded highest infiltration rates in the plots having Bermuda grass followed by Para grass. Deep penetration of grass root also improves infiltration rate of soil. Similar results were reported by Mishra *et al.* (1995).

Table 5.2. Infiltration rate (mm h^{-1}) as influenced by different grasses.

Months	Marvel	Para	Vetiver	Karnal	Napier	Control
6	0.11	0.22	0.21	0.l3	0.09	0.11
12	0.07	0.13	0.12	0.09	0.14	0.09
18	0.19	0.09	0.09	0.13	0.04	0.06
24	0.18	0.27	0.31	0.12	0.10	0.06
30	0.20	0.23	0.36	0.23	0.18	0.10
36	0.20	0.26	0.32	0.24	0.12	0.14
42	0.18	0.22	0.26	0.20	0.16	0.12

Runoff

The runoff data (Table 5.3) recorded with the help of multi-slot devisor showed that maximum seasonal (total) runoff occurred from control plot and it was reduced with plantation of marvel, Para and Vetiver grass. The runoff was 59.8% in the plots having no vegetation and was reduced to 32 % in the plot planted with Marvel grass after a year of grass plantation in first season. Among various grasses Marvel was most effective in checking runoff (27.8%) as compared to control plot and followed by Para (20.5%) and Vetiver (19.0%). This effectiveness for reduction in runoff in Napier (10.7%) plot was lower among all the grasses. This may be attributed to root behaviors and its soil binding capacity of the grasses. The grasses with thinner roots (Marvel) and surface proliferations had higher effectiveness in checking of runoff and improving internal drainage. Mishra *et al.* (1995) also reported that Vetiver and Marvel grasses are most suitable grasses to protect soil from runoff even in normal soils. As compared to control the magnitude of run-off was lowered in second and third years of plantation than first year. The runoff quantity was also regulated by amount of rainfall its intensity and antecedent soil moisture content being its function. The runoff was higher when amount of rain, intensity and antecedent soil moisture was higher.

Table 5.3. Effect of different grasses on runoff (%) after one year of plantation

Event	Date	Rainfall (mm)	Runoff Percentage					
			Marvel	Para	Vetiver	Karnal	Napier	Control
2002-03								
1st	26/06/02	60.7	30.1	33.3	32.3	31.9	34.4	42.8
2nd	27/06/02	31.0	6.4	24.1	26.9	34.1	38.3	78.1

3rd	28/06/02	8.0	3.4	6.9	5.8	15.1	13.1	18.6
4th	30/06/02	9.4	4.1	10.5	4.7	9.4	25.7	69.1
5th	21/07/02	43.8	16.1	14.6	20.6	42.2	30.1	66.3
6th	06/08/02	23.0	3.6	3.1	7.2	3.4	3.7	23.0
7th	19/08/02	12.3	8.9	9.8	13.4	7.2	20.6	58.1
8th	20/08/02	14.0	23.6	19.6	71.5	37.7	84.9	91.1
9th	24/08/02	23.0	18.2	44.9	20.6	54.1	79.4	27.3
10th	01/09/02	36.5	8.1	48.8	18.7	36.2	41.6	9.6
11th	02/09/02	52.5	46.1	68.1	64.1	61.4	65.8	59.5
12th	03/09/02	49.5	67.1	71.6	63.6	60.4	64.6	66.4
13th	04/09/02	9.5	83.4	69.5	78.7	63.7	40.5	91.5
14th	05/09/02	17.5	84.9	81.7	88.0	91.8	96.2	96.8
15th	06/09/02	9.3	75.7	86.3	95.8	89.9	96.9	98.2
Total		**400.0**	**32.0**	**39.3**	**40.8**	**42.6**	**49.1**	**59.8**
				2003-04				
1st	23/06/03	36.0	2.9	1.6	3.0	2.3	2.4	2.4
2nd	05/07/03	43.0	3.2	6.1	4.4	7.4	2.8	12.0
3rd	25/07/03	17.5	11.0	17.0	13.2	13.8	11.9	15.1
4th	26/07/03	20.0	31.9	47.9	33.0	38.2	39.9	67.7
5th	27/07/03	101.5	28.0	30.3	24.2	27.4	29.5	29.9
6th	25/08/03	62.0	38.7	41.5	37.8	41.5	37.1	41.9
7th	28/08/03	9.5	38.2	41.7	78.7	79.9	82.2	77.6
8th	20/09/03	59.4	51.3	50.4	48.3	46.7	52.6	38.3
9th	25/09/03	96.5	31.5	28.7	29.0	28.7	32.4	31.9
10th	27/09/03	12.5	46.6	55.4	60.7	63.4	67.8	69.5
11th	29/09/03	23.3	36.8	50.5	38.5	42.3	43.7	58.1
12th	30/09/03	8.8	46.3	53.8	67.5	77.5	83.8	85.0
Total		**490.0**	**30.5**	**35.4**	**36.5**	**39.1**	**40.5**	**44.1**
				2004-05				
1st	26/07/04	28.4	4.8	3.2	2.8	3.8	2.6	2.8
2nd	29/07/04	16.0	26.2	26.8	28.6	29.2	32.3	28.4
3rd	30/07/04	26.4	28.4	39.2	42.3	44.4	48.5	52.3
4th	31/07/04	27.5	33.2	42.8	48.8	46.5	49.3	51.8
5th	05/08/04	54.0	11.3	22.5	32.5	36.5	38.3	39.7
6th	06/08/04	27.3	31.4	32.6	36.4	38.6	48.8	52.6
7th	07/08/04	69.6	55.3	52.3	54.3	55.3	65.3	68.3
8th	08/08/04	17.5	58.4	56.4	58.5	58.2	68.4	72.3
9th	12/08/04	25.0	28.4	32.8	34.4	36.8	34.3	46.5
10th	14/08/04	11.0	23.5	27.5	27.6	35.6	38.6	49.4
11th	23/08/04	39.2	18.4	16.2	14.2	18.2	22.4	23.8
12th	24/08/04	4.5	28.3	36.3	38.5	42.3	38.5	39.5
13th	25/08/04	15.7	36.4	42.5	44.6	46.4	52.3	54.8
14th	26/09/04	54.6	33.2	34.2	28.4	32.3	30.3	31.4
15th	07/10/04	26.0	23.5	25.8	22.5	21.6	19.5	18.4
Total		**442.7**	**29.4**	**32.7**	**34.3**	**36.4**	**39.3**	**42.1**

Soil Loss

Total sediment loss (Table 5.4) during 1st, 2nd and 3rd year was highest from control (8.54, 2.87 & 2.76 t ha^{-1}, respectively) and lowest (2.94, 1.34 & 1.26 t ha^{-1}) from the plot where Marvel grass was planted. The sediment losses were less than 40% during second year which further reduction in third year even in control plots. This may be attributed to establishment of grasses and no tillage operations. The sediment loss from field was effectively checked through plantation of grasses in comparison to fallow land. There was 65.6, 53.3 & 54.3 % reduction in sediments loss due to plantation of Marvel grass, 57.9, 53.3& 51.1 % with Para grass in first, second and third years respectively as compared to control plot. It was lowest in field where Napier (13.3, 24.0 & 24.6 %) grass was planted. The root of grasses form dense base at soil surface and thereby retards runoff and soil loss (Mishra *et al.* (1995). The lowest soil conservation with Napier grass was due to reason that it was badly damaged during the each summer and took some time to revive again after rains. The soil losses in all three years were always highest during first event of runoff and there was reduction in its magnitude with the progress of time. There was reduction in sediment loss (more than 50%) from field of all the grasses but it was less (only 25%) in the plots of Napier and control either due to establishment of planted or natural grasses or reduction in number of events during second year.

Table: 5.4. Effect of different grasses on control of sediments losses (t ha^{-1})

Event	Rainfall Intensity	Sediments loss (t ha^{-1})					
		Marvel	**Para**	**Vetiver**	**Karnal**	**Napier**	**Control**
2002-03							
1st	Fast	1.680	1.830	1.630	1.660	2.710	3.690
2nd	Fast	0.130	0.410	0.400	0.390	0.460	1.200
3rd	Slow	0.021	0.031	0.022	0.060	0.110	0.260
4th	Slow	0.009	0.031	0.022	0.049	0.095	0.106
5th	Fast	0.290	0.161	0.273	0.646	0.573	1.829
6th	V. Slow	0.005	0.002	0.121	0.009	0.107	0.428
7th	Fast	0.002	0.018	0.026	0.014	0.062	0.092
8th	Slow	0.091	0.047	0.175	0.006	0.538	0.264
9th	Fast	0.128	0.116	0.222	0.259	0.390	0.091
10th	Slow	0.174	0.340	0.179	0.248	0.891	0.053
11th	Fast	0.146	0.165	0.469	0.341	0.571	0.207
12th	Fast	0.062	0.108	0.507	0.181	0.669	0.205
13th	Slow	0.084	0.035	0.068	0.025	0.024	0.015
14th	Fast	0.082	0.136	0.063	0.058	0.138	0.068
15th	Fast	0.039	0.068	0.041	0.031	0.072	0.036
Total		**2.943**	**3.498**	**4.218**	**3.977**	**7.410**	**8.544**
2003-04							
1st	Fast	0.015	0.011	0.031	0.056	0.014	0.173
2nd	Fast	0.019	0.018	0.168	0.129	0.199	0.234
3rd	Slow	0.051	0.060	0.089	0.131	0.086	0.151
4th	Slow	0.040	0.037	0.057	0.084	0.211	0.198
5th	Fast	0.307	0.341	0.616	0.578	0.814	0.772
6th	Slow	0.131	0.162	0.203	0.136	0.079	0.190
7th	Fast	0.068	0.085	0.131	0.027	0.079	0.084
8th	Fast	0.444	0.278	0.518	0.261	0.292	0.438
9th	Fast	0.190	0.364	0.108	0.046	0.240	0.548

10th	Slow	0.036	0.022	0.064	0.068	0.067	0.036
11th	Slow	0.040	0.015	0.019	0.017	0.090	0.035
12th	V.Slow	0.003	0.007	0.014	0.003	0.010	0.009
Total		**1.344**	**1.400**	**2.018**	**1.536**	**2.181**	**2.868**
2004-05							
1st	Fast	0.262	0.252	0.332	0.262	0.442	0.582
2nd	Fast	0.128	0.118	0.224	0.124	0.148	0.214
3rd	Slow	0.034	0.044	0.058	0.048	0.076	0.084
4th	Slow	0.034	0.044	0.052	0.044	0.068	0.072
5th	Fast	0.174	0.178	0.284	0.184	0.236	0.342
6th	Slow	0.044	0.054	0.084	0.064	0.132	0.182
7th	Fast	0.032	0.042	0.044	0.040	0.064	0.072
8th	Slow	0.032	0.042	0.044	0.040	0.064	0.072
9th	Fast	0.114	0.114	0.222	0.122	0.134	0.264
10th	Slow	0.064	0.074	0.098	0.084	0.108	0.142
11th	Fast	0.058	0.078	0.108	0.084	0.124	0.148
12th	Fast	0.058	0.058	0.084	0.064	0.114	0.128
13th	V.Slow	0.028	0.032	0.054	0.038	0.068	0.074
14th	Fast	0.084	0.098	0.108	0.104	0.132	0.184
15th	Fast	0.114	0.124	0.142	0.134	0.172	0.204
Total		**1.260**	**1.352**	**1.938**	**1.438**	**2.082**	**2.764**

Rooting Pattern

Data on root development observed quarterly upto age of 21 months is presented in Table 5.5. A Root development by length, volume and root biomass was high in Vetiver, Para and low in Napier. However, root thickness was higher in Vetiver as compared to others at all stages. Increasing trends were observed in root length, root biomass and volume with advancement of time but it was at higher magnitude only up to 6 months and after that increase was marginal stabilizing after 15 months. It indicates development of finer roots in latter stage of growth. At all the stages after planting, maximum root biomass was recorded with Para grass and Vetiver followed by Karnal and lowest with Napier grass. The higher and almost equal root length was observed in Vetiver and Para (68cm). R root length of grasses did not increase in the same proportions as biomass but followed the same order. Root diameter also revealed same trend. Root moisture content, which remained between 60 to 80 per cent, was almost constant at all stages of growth.

The root binding capacity computed with the data of total volume of roots, mean radius and binding capacity at seven stages of growth revealed that Para grass had the maximum binding capacity followed by Marvel and Vetiver. This may be attributed to the presence of finer roots in Para and Marvel grass, Total root volume of each grass increased with advancement of growth. The binding capacity of roots of all the grass species increased with increasing age of the grasses up to 9 months owing to increase in root volume and finer roots. Average root radius normally increased with the increasing age and higher root radius was observed for Vetiver, Para and Napier at all stages of growth.

Table 5.5. Root parameters recorded for different grasses during 21 months after planting

Grass	Months	Penetration	Radius	Biomass	Volume (cc)	Soil binding
Marvel	3	33.0	0.26	5.33	20.0	295.90
	6	40.6	0.24	7.20	30.0	520.80
	9	43.5	0.26	7.80	31.7	468.90
	12	47.0	0.30	7.50	33.0	366.70
	15	47.0	0.30	8.40	34.8	386.70
	18	47.3	0.31	9.70	35.7	371.50
	21	47.4	0.31	12.74	35.9	373.57
Para	3	56.5	0.43	5.92	29.0	156.80
	6	64.2	0.30	24.00	110.0	1222.20
	9	65.2	0.29	27.40	110.0	1308.00
	12	67.3	0.36	27.70	117.0	902.80
	15	67.5	0.44	30.70	120.0	619.80
	18	67.8	0.57	31.80	125.5	386.30
	21	68.0	0.59	35.57	126.4	363.11
Vetiver	3	46.0	0.76	7.08	38.0	65.80
	6	47.3	0.46	18.80	90.0	425.30
	9	48.0	0.43	19.30	92.7	501.40
	12	59.0	0.49	22.80	111.0	462.30
	15	62.0	0.55	36.70	120.0	396.70
	18	63.3	0.69	47.30	134.4	282.30
	21	67.2	0.69	48.81	135.2	283.97
Karnal	3	20.5	0.28	1.77	5.0	63.80
	6	32.7	0.30	2.40	8.0	88.90
	9	35.7	0.19	2.90	15.8	437.70
	12	37.6	0.31	4.50	25.0	260.10
	15	38.2	0.32	5.50	25.3	247.10
	18	38.7	0.33	6.50	28.4	260.80
	21	39.2	0.35	12.55	29.2	238.37
Napier	3	10.0	0.41	0.12	1.0	6.00
	6	24.2	0.20	0.40	5.0	125.00
	9	47.0	0.48	4.90	13.0	56.40
	12	47.2	0.48	4.30	13.2	57.30
	15	48.0	0.48	5.20	14.4	62.50
	18	48.2	0.49	5.60	15.2	63.30
	21	48.1	0.50	6.41	15.7	62.80

Prediction of Root Biomass Density

The data on root biomass recorded at different time interval were used to develop a dynamic root development model that can be used for prediction under such soil and water conditions. The data on root biomass density against different time interval are depicted in Table 5.5. Based on such data the root dynamic models for each grass species were developed.

Progressive root growth of different grass species expressed as root biomass density (RBD g cm^{-3}) at different time interval were recorded and fitted to a logistic growth function of following nature:

$$Y = a / 1 + e^{b + cx}$$

Whereby is the predicted RBD (g m^{-3})
x is the time interval
a is the maximum value of the parameter

b and c are regression coefficients

The logistic growth function was best fitted in the grass species Vetiver grass (*Vetiveria zizinoides*), Marvel grass (*Dichanthium annulatum*), Karnal grass (*Diplachne fusca*), Napier grass (*Penisetum perpurium*) and Para grass (*Brachiria mutica*). Based on the observed data, the following equations were developed for different grass species:

S. No.	**Name og grass**	**Developed eq.**	**R^2**
1	Vetiver (*Vetiveria zizinoides*)	$Y = 11507 / 1 + e^{4.81-0.30X}$	0.4974
2	Marvel (*Dichanthium annulatum*)	$Y = 87.30 / 1 + e^{-0..27 - 0.32X}$	0.5155
3	Karnal (*Diplachne fusca*)	$Y = 174.93 / 1 + e^{2.26-0.32X}$	0.5251
4	Napier (*Penisetum perpurium*)	$Y = 43.18 / 1 + e^{3..16-2.72X}$	0.4846
5	Para (*Brachiria mutica*)	$Y = 253.33/ 1 + e^{-0..50-1.20X}$	0.5443

The equations developed from observed data for prediction of root biomass density compute a very close value (Table 5.6) and it can be used for predicting root biomass in sodic clay soils. The higher 'a' value of Vetiver and Para clearly showed that these grasses are more effective in penetrating black alkali soils as compared to other grasses.

Table 5.6. Observed and predicted values of root biomass density at different time intervals

Growth (months)	**Marvel**		**Para**		**Vetiver**		**Karnal**		**Napier**	
	O*	**P***	**O**	**P**	**O**	**P**	**O**	**P**	**O**	**P**
3	56.6	68.3	42.6	42.5	14.2	12.3	0.96	0.12	47.4	84.1
6	150.4	92.3	57.6	49.5	19.2	16.5	3.20	17.5	192.0	157.4
9	154.4	124.5	62.4	56.3	23.2	21.9	39.2	16.9	219.2	214.4
12	182.4	167.8	62.4	62.4	36.0	28.4	39.2	39.2	221.6	240.2
15	292.6	225.9	67.2	67.7	44.0	37.5	41.6	42.9	245.6	249.2
18	315.0	303.6	77.6	72.2	52.0	47.8	44.8	43.2	254.4	252.1
21	390.5	407.0	101.9	75.8	100.4	59.8	51.3	43.2	284.6	252.9

O* Observed value P* Predicted value

Conclusions

In a field study five grass species viz. Marvel grass (*Dichanthium annulatum*), Para grass (*Brachiria mutica*), Vetiver grass (*Vetiveria zizinoides*), Karnal grass (*Diplachne fusca*) and Napier grass (*Penisetum perpurium*) were evaluated to assess their suitability as biological reclaiming agent and vegetative barriers for reclaiming as well as reducing soil erosion and enhancing in situ water conservation in a moderate sodic clay soil . The study reveals that lowest soil loss and runoff were observed from the plots planted with Marvel grass. From the point of view of fodder and commercial value; the order (decreasing) of performance for adoption of these grasses for sodic vertisols was Marvel, Para, Napier, Karnal and Vetiver. Rooting pattern of these five grass species were found to form the dense base at soil surface thereby retarding the runoff. Equations have been developed to estimate their root biomass density during growth for two years. These equations can be considered valid for such soils under rainfed conditions. It can be concluded from the study that planting of grasses like Marvel, Para and Karnal in sodic clay soils protect natural resources (sediment and nutrient losses) and are helpful in reclaiming these soils. The root growth equations developed from data are useful for prediction of root biomass production with interval of time under similar conditions and soils.

CHAPTER 6
WASTE WATER TREATMENT

6.1 Primary treatment measures of wastewater for agriculture

In arid and semi-arid regions of the world water is becoming increasingly scarce. Malwa region of south-west Madhya Pradesh, having semi-arid sub-tropic climate, is no exception to it. This region is facing acute shortage of irrigation water due to depleting ground water as well as erratic and inadequate rainfall. Whenever good quality of water becomes scarce water of marginal quality will have to be considered for use in agriculture. In Malwa region irrigation in crops especially in summer vegetables is practiced on substantial area with raw and concentrated wastewater flowing through natural course. With current emphasis on environment hazards and pollution issues, there is an increasing awareness of the need to dispose of wastewater safely and beneficially. Here the need of wastewater treatments realized. The properly treated wastewater alleviates the problem of soil and water pollution.

Wetlands are now recognized as an accepted, cost effective and eco-technology in developing countries of the world (Reddy and Gale, 1994) for secondary treatment of wastewater used in agriculture. There are currently thousands of constructed and natural wetlands worldwide receiving and treating variety of municipal, industrial and urban wastewater.(Kandle and knight, 1996). It has also been reported (Billore, 1999) that wetlands require effective and reliable pre-treatment of wastewater before it actually discharge into main wetland body for secondary treatment. Primary treatment of wastewater is prerequisite for its secondary treatment (Pascard, 1992). Therefore study is planned to evaluate performance of primary treatment measures of wastewater used in agriculture in Malwa region of south-west Madhya Pradesh to assess the individual contribution of primary treatment measures to control present contamination in terms of total suspended solids (TSS) and biological oxygen demand (BOD) as measure of degradable organic matter. This study will also be of help to select efficient and cost effective locally available material for filtration of wastewater as primary treatment.

The study is carried out in Malwa region of southwest Madhya Pradesh in Central India. Study area is situated between 23^0 30'to 24^0 10' N and $70^0$10' to 77^0 10' E along with the altitude range of 450 to 75 m from mean sea level.. The climate is semi-arid sub-tropic. The average rainfall varies from 800 to 200 mm. More than 90% rainfall comes through southwest monsoon from June to late August or early September. The maximum temperature during summer reaches up to 45^0C and minimum during winter up to 4^0C. Average relative humidity ranges from 80 to 70%. Predominant soil group is medium black soil s.

Under the study the primary treatment measures viz. settlement and filtration were evaluated. For the purpose wastewater samples were collected from two location namely sewage farm Ujjain and Darjikaradiya village, Indore where wastewater irrigation in agriculture is being practiced by the farmers. While collecting, wastewater samples were screened. These screened samples were subjected to 24 hours settlement and then quality parameters like EC. PH, TSS and BOD were recorded before and after settlement. For the evaluation of performance of primary treatment measures removal efficiency were worked out for TSS and BOD load as follows

$$\text{TSS Removal Efficiency} = \frac{\text{TSS before settlement} - \text{TSS after settlement}}{\text{TSS before settlement}}$$

$$\text{BOD reducing Efficiency} = \frac{\text{BOD before settlement} - \text{BOD after settlement}}{\text{BOD before settlement}}$$

Similarly for evaluation of filtration measure vertical section having 40 cm length and 12 cm diameter were maintained for each filtration material in permeameters pipe. Wherever more than one filtration materials were used those were placed one over another serially. Various filtration materials and their combination used are as follows

1. Coarse Sand (CS)
2. Fine Sand (FS)
3. Metal (M) (It is same as building material used for concreting)
4. Charcoal (Ch) (it is wood charcoal available in local market)
5. M+FS (2:1)
6. M+CS (2:1)
7. M+Ch (2:1)
8. M+CS+Ch (4:1:1)
9. M+CS+Ch (4:2:1)

Then measured value of 500 ml of raw wastewater sample are allowed to pass through each maintain section of filter material in permeameters pipe. Then time to travel section of filter material by wastewater is recorded as retention time. Time to total recovery was also recorded. The quality parameters viz. EC, pH, TSS and BOD were also recorded before and after filtration through each filter material. The value of EC and pH were recorded with the help of EC and pH meter respectively. Available concentration i.e. TSS in wastewater samples was determined by standard evaporating dish method as difference of residue left after evaporation of unfiltered (TS) and filtered (TD). BOD as measure of degradable organic matter present in wastewater samples is determined by Standard Modified Winkler's Iodometric method.

Broadhead (1983) while studying drain envelope material and particle size distribution opined that filter criteria are based on pore size distribution. As such particle size distribution of locally available filter material was also done by passing the known quantity of material through standard screen having BS No. 4, 10, 20, 40, 80, 200 and 400 with size 4, 1.6, 0.8, 0.4, 0.2 0.08 and 0.04 mm respectively to find out prominent particle size and uniformity coefficient. Kumbharre, reported computation of uniformity coefficient (Uc) of material based on particle size distribution, as follows

$$Uc = \frac{D_{10}}{D_{60}}$$

Where, D_{10} denotes particle size of filtration material at which 10% particles have smaller size.

D_{60} denotes particle size of the filter material at which 60% particles have smaller size.

The prize of each filter material was also obtained from the local market to compare the cost to find out cost effective material. Primary treatment is a pre-requisite for secondary treatment of wastewater by wetland. The primary treatment measures commonly practiced are screening, settlement and filtration etc. In this study performance of primary treatment measures settlement and filtration were evaluated after screening wastewater samples. For the study wastewater samples were collected from two source sites namely Sewage Farm, Ujjain and Darjikaradiya village, Indore.

Performance of settlement measure

Settlement is one of commonly used primary treatment measures. To evaluate performance of settlement measure the quality parameters like EC, pH, TSS and BOD were recorded before and after settlement of 24 hours of wastewater samples. The recorded values of quality parameters like EC, pH, TSS and BOD for both of the sites are shown in Table 6.1.It is evident from Table 1 that samples originally having pH, EC, TSS and BOD as 8.9, 5.7 mmhos, 2197 Mgl $^{-1}$ and 1865 Mgl $^{-1}$ respectively was collected from natural course at sewage farm, Ujjain. This wastewater sample is allowed to settle for 24 hours and again its pH, EC TSS and BOD were recorded as 8.6, 4.9 mmhos. 1810 Mgl $^{-1}$ and 1700 Mgl $^{-1}$ respectively. The above values of TSS and BOD were used to find out removal efficiency as discussed in previous section. The worked out values of removal efficiency indicate that primary treatment measure settlement alone has reduced the contamination (TSS) by removal efficiency of 17% and BOD with 10%. To corroborate the above results samples were also collected from another site Darjikaradiya and it is allowed to settle for 24 hours. Then values of quality parameters before and after settlement were recorded and are shown in Table 1. In case of wastewater samples of Darjikaradiya site the TSS and BOD removal efficiencies were observed as13% and 11% respectively, which corroborates the result obtained for wastewater samples of sewage farm Ujjain.The above results reveal that primary treatment measure settlement of 24 hours alone has reduced the contamination (TSS) by 13 to 17% and BOD by 10 to 11% removal efficiency. EC and pH values also declined marginally as a result of settlement.

Table 6.1. Quality parameters before and after settlement

S.No.	Particulars of sites and samples	Quality Parameters					
		EC (mmhos)	pH	TSS		BOD	
				Mgl $^{-1}$	%R	Mgl $^{-1}$	%R
1.	(i)Before settlement	8.9	5.7	2197	-	1865	-
	(ii) After settlement	8.6	4.9	1810	17	1700	1
2.	Before settlement	7.6	3.1	2690	-	1810	-
	After settlement	7.3	2.4	2336	11	1600	11

% R indicates removal efficiency in percentage.

Performance of filtration measure

Filtration is also one of primary treatment measures commonly used in which wastewater is allowed to pass through body or section of filtration material like coarse sand, fine sand, metal charcoal and combination of these material to reduce TSS and BOD load The quality parameters of wastewater samples of Sewage Farm Ujjain were recorded before and after filtration through various materials and shown in Table 6.2. It is obvious from Table 6.2 that among various filtration materials tried, coarse sand observed most effective in reducing contamination (TSS) with removal efficiency of 45% which is highest among all other filter materials tried. It also reduces the degradable organic matter (BOD) by 30% removal efficiency, which is reasonably good efficiency. Next to Coarse sand was Metal + Coarse sand combination (2:1) with TSS removal efficiency as 40% and removal efficiency as 16%. Locally available charcoal appeared to enhance the contamination rather than reducing the same. It may be due to some sorts of contamination present in locally available material. The quality parameters obtained in case of wastewater samples of Darjikaradiya are also shown in Table 6.3 and value of TSS removal efficiency corroborates the same finding as obtained in case of Sewage Farm Ujjain. It is obvious from the EC and pH values obtained and shown in Table 6.2 and 6.3 that there is reduction in pH and EC values in case of all the filtration materials except Charcoal. Reason may be due to availability of bad quality of Charcoal in local market. Observation of EC and pH values implies that filtration alone does marginally control alkaline reaction and salt load carried by wastewater,

Table 6.2. Quality of wastewater of Sewage Farm Ujjain before and after filtration

S No.	Filter Material	Quality Parameters					
		PH	EC (mmhos)	TSS		BOD	
				Mgl $^{-1}$	% R	Mgl $^{-1}$	% R
1	Fine Sand	8.5	2.1	1360	25	1300	28
2	Coarse Sand	8.7	2.4	991	45	1190	30
3	Metal	8.8	2.3	1627	15	1480	18
4	Charcoal	7.9	7.4	6741	-	1200	29
5	M+FS (2:1)	8.3	2.4	1490	18	1100	35
6	M+CS (2:1)	8.6	2.5	1080	40	1430	16
7	M+Ch (2:1)	8.0	4.5	1743	4	1378	19
8	M+CS+Ch (4:2:1)	8.4	4.8	1666	8	1070	37
9	M+CS+Ch (4:1:1)	8.8	4.2	1968	-	900	47

Table 6.3 Quality Parameters of Darjikaradiya site before and after filtration

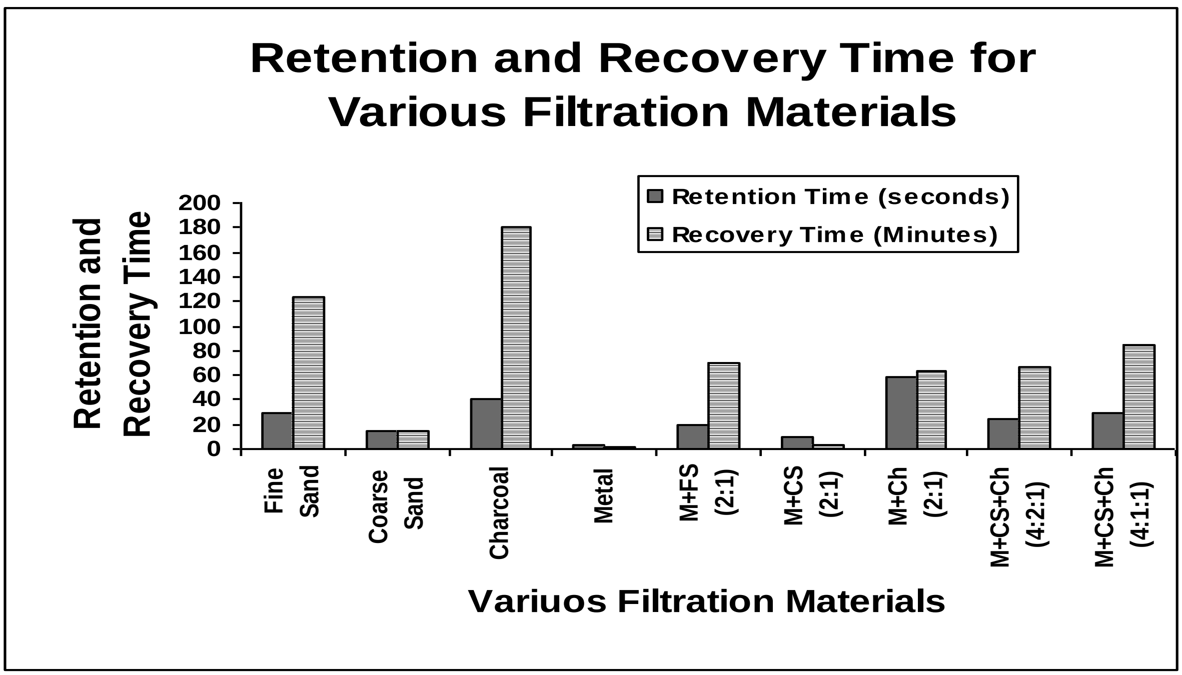
S No.	Filter Material	Quality Parameters			
		pH	EC (mmhos)	TSS	
				Mgl $^{-1}$	% R
1	Fine Sand	7.7	3.1	1760	24
2	Coarse Sand	7.4	2.6	1880	45
3	Metal	7.3	3.1	2100	10
4	Charcoal	7.1	18.9	8760	-
5	M+FS (2:1)	7.3	2.8	1930	17
6	M+CS (2:1)	7.4	2.8	1390	40
7	M+Ch (2:1)	7.3	7.8	2250	4
8	M+CS+Ch (4:2:1)	7.5	6.7	2160	8
9	M+CS+Ch (4:1:1)	7.2	5.9	2540	-

Retention, Recovery and Uniformity Coefficient of filtration material

A measured quantity of 500 ml wastewater samples was allowed to pass through each filtration material section maintained in permeameter pipe. Then time to travel the section of each filtration materials i.e. retention time was recorded. Time of total recovery of wastewater after filtration was also recorded in case of each material and is shown in Table 6.4. Table 6.4 indicates that minimum retention time was observed in case of metal as 4 seconds. Next to it was 9 seconds in case of metal + coarse sand (2:1). While it was 15 seconds in case of Coarse Sand. Maximum retention time was observed 59 seconds and 41 seconds in case of metal + charcoal (2:1) and Charcoal sole respectively. Exactly similar trend was observed in case of recovery time. Retention and recovery time of various filtration materials can be seen at a glance in bar diagram shown below in figure. It is obvious from the diagram that there is variation in both retention and recovery time of various filtration material. However, trend is similar in case of both retention and recovery time.

Table 6.4. Recovery and retention time of filtration material

S. No.	Filtration Material	Retention time (seconds)				Recovery time (minutes)			
		R_1	R_2	R_3	Mean	R_1	R_2	R_3	Mean
1	Fine Sand	29	30	31	30	125	120	124	124
2	Coarse Sand	14	15	16	15	15	15	18	14
3	Charcoal	45	37	40	41	180	184	178	181
4	Metal	4	5	3	4	2	1	1	1.5
5	M+FS (2:1)	18	20	19	19	70	69	71	70
6	M+CS (2:1)	9	8	10	9	4	5	3	4
7	M+Ch (2:1)	60	57	60	59	60	65	67	63
8	M+CS+Ch (4:2:1)	23	25	24	24	69	65	67	67
9	M+CS+Ch (4:1:1)	32	28	30	30	83	80	85	85



Particle size distribution analysis

The locally available filtration materials were analyzed for particle size distribution and details of screen numbers, size, material retained on screen, D_{10}, D_{60} and Uniformity Coefficient are mentioned in Table 6.5. It is clear from Table 6.5 that dominating particle size in case of metal is 4mm, which accounts for 94.8% with uniformity coefficient 49% as highest. In case of coarse sand it was 1.6 mm and 0.8 mm accounting for 37.4 % and 47.4% respectively with UC as 25%. Similarly, the value for Fine sand and Charcoal are 0.4 mm and 0.2 mm accounting for 38.30% and 28% respectively.

Table 6.5. Details of particle size distribution analysis of filtration materials

S. No.	BS No. of Screens	Size of Screens (mm)	Material retained on screen (gms)			
			M	**CS**	**FS**	**Ch**
1	4	4	948	51	16	14
2	10	1.6	45	370	16	220
3	20	0.8	5	474	170	281
4	40	0.4	2	72	389	99
5	80	0.2	0	20	389	101
6	200	0.08	0	13	10	102
7	400	0.04	0	0	10	83
D_{10} (mm)			4	0.8	0.4	0.4
D_{60} (mm)			1.6	0.2	0.08	0.04
Uc = $D_{`10}$ / D_{60} (%)			40	25	20	10

Comparison of retention time, recovery time, Uniformity Coefficient and cost

Retention time, recovery time, Uniformity Coefficient and cost of various filtration materials available in local market are abstracted in Table 6.6. The Table 6.6 shows that retention time increases with decrease in value of Uc of filtration materials. It was 4 seconds as minimum for metal having Uc 40% as highest. While it was maximum 41 seconds for charcoal having minimum Uc as 10%. Similar trend was observed in case of recovery time as well. If cost of filtration materials shown in Table 7 are compared than Coarse sand appeared to be cheapest one with minimum cost of Rs.250 /- per m^3 and therefore considered cost effective in comparison to Metal. Fine sand and Charcoal. Above exercise suggests that coarse sand is considered to be the best filtration material for primary treatment of wastewater in Malwa region of south-west Madhya Pradesh because it is efficient in reducing available contamination (TSS) and degradable organic matter (BOD) with highest removal efficiency and at the same time it is also cost effective among other filtration material tested.

Table 6.6. Uc, retention time, recovery time and cost of filtration material

S. No.	**Filtration Material**	**Uc (%)**	**Retention time (seconds)**	**Recovery time (Minutes)**	**Cost (Rs. / m^3)**
1	Metal	40	4	1.5	400
2	Coarse sand	25	15	14	250
3	Fine sand	20	30	124	300
4	Charcoal	10	41	181	500

Conclusions

Owing to the scarcity of water, wastewater irrigation to agricultural crops is in vogue. Growing awareness about environmental hazards calls for treatment of this wastewater to alleviate problem of soil and water pollution. The study reveals that settlement for 24 hours alone can remove available contamination (TSS) by 13% to 17% and degradable organic material

(BOD) by 10 to 11% removal efficiency. Among various filtration materials coarse sand is found not only the cost effective but also most effective in removing available contamination (TSS) by highest removal efficiency of 45%along with 30% BOD load reducing efficiency. Settlement and filtration both measures do marginally control alkaline reaction of wastewater (pH) along with salt concentration (EC). Retention and recovery times also decrease with increase in uniformity coefficient of filtration material. Finally it is concluded that settlement for 24 hours and filtration through coarse sand after screening wastewater are to be adopted as primary treatment measures to reduce contamination and degradable organic matter along with marginal control of EC and pH of wastewater used in agriculture in Malwa region of south-west Madhya Pradesh in central India

6.2 Approach to design wet- land for secondary treatment of sewage water stream of size 60,000 liters. / day.

Approach

Staff members, Daily College, Indore approached to SAS Project Indore for solving the problem of sewage water irrigation to lawns and gardens by domestic waste generated to the tune of 60,000 liters / day at the campus. The irrigation by untreated wastewater poses problem of order and pollution. Use of domestic wastewater is only choice for maintaining garden and lawn of campus due to scarcity of good quality water.

For the purpose primary and secondary treatment screening by 25 – 50 mm and 0.8 mm sized screen, then settling in tank and filtration by passing through boulders barrier are suggested to reduce debris in waste water. Thereafter it is allowed to entered into wet – land for further treatment. In this study optimum size of wet – land is being ascertained with available information. The study is aimed to compile available information and use the same for design of wetland to assess its adequacy for designing wetland The details of design approach are discussed as below.

Dimensions of wetland pond

1. Quality of generated domestic wastewater at campus is around 60,000 liters per day or 0.0007 cumec.
2. This 60,000 liters per day quality of domestic wastewater has to be treated by three Nos. wet – lands.
3. So, load for each wet – land is 1/3 rd i.e. 20,000 liters per day.
4. Dimensions of each wet - land has to be design for 20,000 liters per day load.
5. In wet – land water has to be passed through sand body, which is medium for building bio film. Here it is required to take into consideration the porosity of sand body as 40 %. So for retaining 20 m^3 of wastewater in wet – land , the actual volume of wet – land should be 2.5 times the volume of water to be treated (20 m^3 per day) i.e 50 m^3 per day. So, volume of each wet – land should be 50 m^3 per day for 1day period.
6. design of wet – land:

(i) Rate of generated wastewater - $20\ m^3$ per day.
(ii) Volume of wet – land pond - $20\ m^3$.
(iii) Taking into consideration porosity of sand as 40 % the actual volume of wet - land to retain $20\ m^3$ wastewater. = $50\ m^3$.

Dimension of wet – land pond having trapezoidal section

(a) Volume of trapezoidal pit is given by - $V = d / 2 (A_l + Au)$

Where,

V = Volume of pond ($50\ m^3$)
D = depth of pond (0.8 m).
A_l = area of lower surface (m^2).
Au = area of upper surface (m^2)

(b). Au = Lu * Wu = 20 * 3.5 = $70\ m^2$

Where,

Lu = length of pond at upper surface.
Wu = Width of pond at upper surface.

(c) $A_L = L_l * W_l$ = 19 * 3 = $57\ m^3$

Where,

L_l = Length of pond at lower surface.
W_l = Width of pond at lower surface.

(d). V = 0.8/2 (70 + 57) = $50.8\ m^3$

The dimensions of wetland pond enough to retain $20m^3$ wastewater every day are as below.

Lu = 20 m. Wu = 3.5 m,
L_l = 19 m, W_l = 3.5 m,
D = 0.8.

Note: Wet land pond pit of above mentioned dimensions should be dug up to depth of 0.3 – 0.4 m depth and dug earth should be used in making bund of 0.4 m height around the wet land pond pit, so that total depth of is 0.8 m . There is no need to dug earth up to 0.8m depth.

Design of settling tank

(i). Stream size of generated domestic waste is 0.0007 cumec.
(ii). To allow 2 hours settling time implies that settling tank should be of such size that it should be filled in 2 hrs. with 0.0007 cumec stream size.

Volume of tank = Stream size * time
= 0.0007 cumec * 2 * 3600 sec.
= $5.04\ m^3$

for above volume, dimensions of tank by trial and error should be arrived at

V = 2m *2m *1.5m = $6m^3$

Screen size

In text reference screen size suggested are as follows..
(i) 25 mm to 50 mm.
(ii) 0.8 mm.

Diameter of pipe:

(a) Flow through pipe is governed by continuity equation.

$Q = a * v$

Where,

Q = Discharge rate.

A = Area.

V = Velocity.

So,

$A = Q / v = 0.0007 / 0.01 = 0.07\ m^2$

$A = \pi d^2$

$d = (a / \pi)^{½} = (0.07 / \pi)^{½} = 0.149$ m. = 15 cm.

CHAPTER 7
ORP ON SUBSURFACE DRAINAGE

The Operational Research Project (ORP) experimental site was located at the Govt. Agriculture Farm, Gohad (Distt. Bhind). The area experiences water table at around 1m depths from ground surface during pre monsoon period, reaching to surface during monsoon and irrigation period. The soils are sodic sandy loam with 37.3% sand, 36.4% silt and 26.3% clay. The quality of sub-surface water is also sodic, which can not be used for irrigation. The crop yield is poor to nil. A field experiment under ORP trail was laid out in the year 2004 to investigate the performance of sub-surface drainage in such sodic sandy loam soil.

The critical water table depth for cereal crops in sandy loam soils varies between 0.6 m to 0.8 m (Kamara. and Roa., 1992). As per recommendation of SAS project, Indore, it should be around 1.5 – 2.0m for black soils. Looking to the geometry of the field and the recommendation of SAS project, Indore (1984) the spacing between the lateral drains was kept 18m. The layout details are given in Fig. 1.

The sub-surface drainage was installed before start of monsoon with PVC perforated pipe surrounded by filter of 2 to 6 mm sized mineral envelope of 5 cm thickness. The drained and adjacent undrained fields were cropped with Til (Variety – TKG – 55) and Wheat (HD – 4672) in *Kharif* and *Rabi* respectively during 2004. During the year 2005 – 06 the drained and adjacent undrained fields were cropped with Pearl millet (Variety – JBG - 3) and Bengal gram (PG –5) in *Kharif* and *Rabi* respectively. Bajara crop was sown on 11 July 2005 and Wheat crop on 18 December 2005. The full-recommended package of practice was adopted. The results of study are discussed as below.

(a) Chemical Properties

The soil sample were collected for 0 to 90 cm depth at a interval of 15 cm depth under drained and undrained condition and were analyzed in SAS Project lab to record chemical properties. The values of various chemical properties recorded under drained and undrained areas are shown in Table 7.1, which reveal improvement of these properties due to drainage.

Table 7.1. Values of chemical properties of soils under drained and undrained conditions

S. No.	Sampling depth, cm	Drained					Undrained				
		pH	EC dSm^{-1}	ESP, (%)	CEC, C. mol. $P^{(+)}$ kg^{-1}	Ex. Na C.mol. $P^{(+)}$ kg^{-1}	pH	EC dSm^{-1}	ESP, (%)	CEC, C. mol. $P^{(+)}$ kg^{-1}	Ex. Na C.mol. $P^{(+)}$ kg^{-1}
1	0-15	7.8	0.93	42.2	9.0	3.8	9.1	2.03	53.3	9.2	4.9
2	15-30	7.1	1.67	44.1	14.3	6.3	9.2	1.90	56.9	14.6	8.3
3	30-45	7.6	1.90	35.4	22.3	7.9	9.3	2.40	44.5	22.7	10.1
4	45-60	7.9	1.60	33.3	24.3	8.1	9.3	1.99	46.1	24.3	11.2
5	60-90	8.2	1.47	42.2	21.8	9.2	9.5	2.42	54.7	22.1	12.2
Average		**7.7**	**1.51**	**39.4**	**18.34**	**7.06**	**9.28**	**2.15**	**51.9**	**18.58**	**9.28**

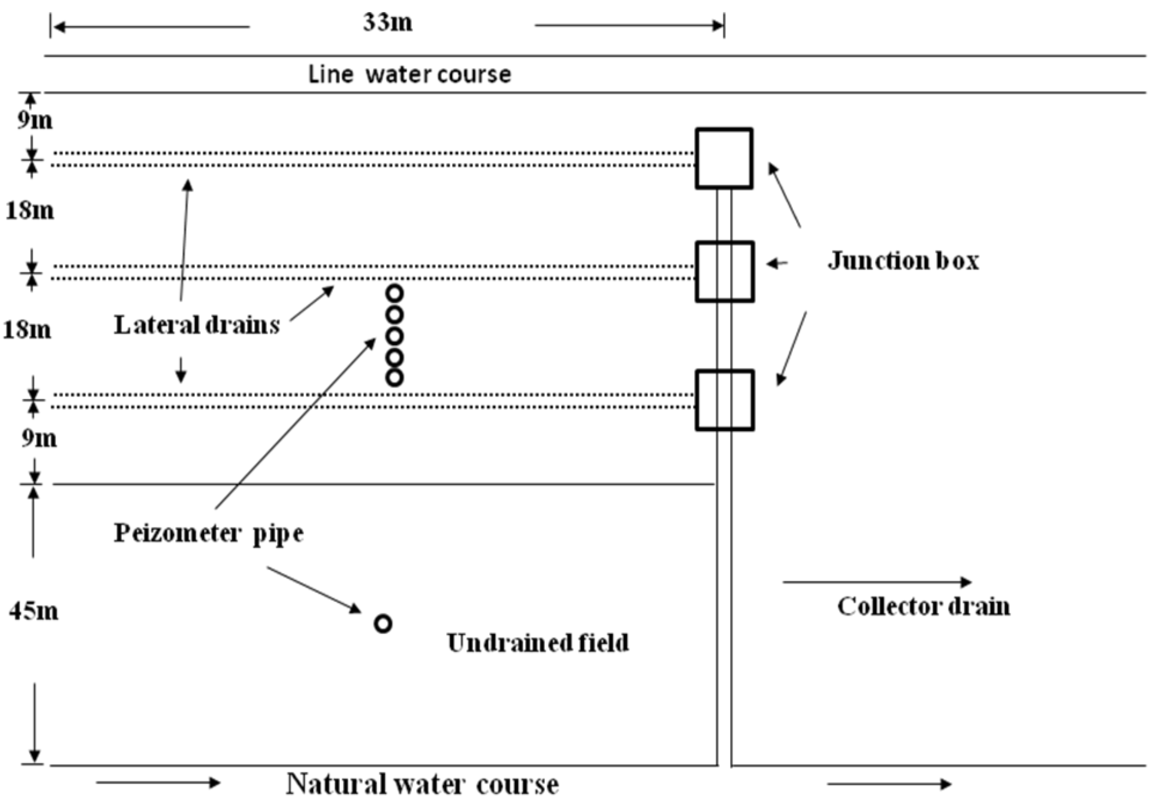


Fig. 1 Layout plan of installed sub-surface system drainage

Cost

The details of cost of installation of sub-surface drainage in 33m by 57m sized field with around 100m lengths of laterals and 100 m collector drains. The cost of installation came around Rs. 12900/- as given in Table 7.2. This land reclamation Programme has generated 40-man days employment to local personals and also created awareness among them and farmers of the area about sodicity and its solution sub-surface drainage.

Table 7.2. Details of Installation of sub-surface drainage

S. No.	Material/ items of works	Quantity	Rate	Amount, Rs.

1	Sand	1 m^3	Rs. 600 /- per m^3	600
2	Metal	3 m^3	Rs. 700 /- per m^3	2100
3	Cement	3 bags	Rs. 140 /- per bag	420
4	Bricks	300	Rs.200 /- per 100 Nos.	600
5	Pipe	200 m	Rs. 33 /- per m length	6600
6	Labour	40 man days	Rs. 64.73 /- per man days	2600
Total cost of installation for 33 x 57 m sized field				12900

Yield

As a result of installation of sub surface drainage system the yield of different crops and their comparison with the yield from undrained area are shown in Table 7.3. The study reveals that provision of sub surface drainage in sodic sandy loam soils improves the yields of Til (TKG – 55), Wheat (HD – 4672), Pearl millet (JVB – 3) and Bengal Gram (PG – 5) over undrained condition by 15, 12, 19 and 18 % respectively with 500 kg/ha, 1400 kg/ha, 530 kg/ha and 1180 kg/ha yield levels.

Table 7.3. Yield of crops under drained and undrained conditions in sodic soils

S. No.	Crop grown	Season / year	Crop Yield (kg/ha)		
			Drained	Undrained	% Increase
1	Til (TKG – 55)	Kharif (2004 - 05)	500	425	15
2	Wheat (HD – 4672)	Rabi (2004 – 05)	1400	1250	12
3	Pearl millet (JVB – 3)	Kharif (2005 - 06)	530	444	19
4	Bengal Gram (PG – 5)	Rabi (2005 – 06)	1180	1003	18

(d) Water Table

Water table in piezometers installed up to 1m depths could be recorded on 5th of October 2005 under drained and undrained conditions. The water table depth observed was 65 cm from ground surface in undrained field while at the same time no water table was observed in drained field up to 1m depth in installed piezometer pipes. The observation indicates clearly control of water table in drained plot as compared to undrained plot.

Conclusion

A sub-surface drainage system using corrugated perforated PVC pipe was installed in a plot area of 33 x 60 m size with 100 m lateral drain and 100m collector drain having surrounded by a 5 cm thick envelope of 2-6 mm sized mineral components. The lateral drains were installed at 18 m spacing and 0.6m depth and collector was at a depth of 0.7m. The study reveals that provision of sub surface drainage in sodic sandy loam soils improves the yields of Til (TKG – 55), Wheat (HD – 4672), Pearl millet (JVB – 3) and Bengal Gram (PG – 5) over undrained condition by 15, 12, 19 and 18 % respectively with 500 kg/ha, 1400 kg/ha, 530 kg/ha and 1180 kg/ha yield levels. Study further indicates control in pH, EC and ESP in drained condition as compared to undrained condition. The average values of pH, EC and ESP observed were 7.7, 1.51 dSm^{-1} and 39.4% in drained field as compared to 9.28, 2.15 dSm^{-1} and 51.9% in undrained field. The water table depth observed was 65 cm from ground surface in undrained field while at the same time no water table was observed in drained field up to 1m depth in installed piezometer Study also indicates improvement in pH, EC and ESP of soils in drained condition as compared to undrained condition. The cost of installation of sub-surface drainage system came around Rs. 12900/-.

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