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Estimation of seepage loss from canal by inflow-outflow method & comparative study of canal lining materials (A case study of NLBC, Malegaon, Tal-Baramati)

[1] S.A. Birajdar, [2] P.T. Nimbalkar, [3] Y.R. Sawant, [4] P.D. Pawar

[1] Research scholar, Bharati Vidyapeeth Deemed University College of Engineering Pune, Maharashtra, India.
[2] Professor, Bharati Vidyapeeth Deemed University College of Engineering Pune, Maharashtra, India.
[3] Assistant Engineer Grade-1, Pandare Irrigation Subdivision, Malegaon Colony, Tal-Baramati, Dist-Pune, Maharashtra, India
[4] Assistant Professor, Bharati Vidyapeeth Deemed University College of Engineering, Pune, Maharashtra, India.

Abstract
Irrigation is main factor for agricultural production. Our aim is to increase agricultural yield by increasing area under irrigation. It is very important to see that more water available for irrigation is completely used as far as possible to avoid water loss during conveyance through canal. Seepage loss is major water loss during transit. Main purpose of this paper is to calculate seepage from earthen canal & apply appropriate lining material on canal to prevent this loss. Inflow-Outflow is the best method to measure seepage loss accurately. Study was undertaken at reach no 2 from mile 19/4 to mile 42 of Nira Left Bank Canal off taking from Vir dam. According to study, it was found that 2.55 TMC/34.96km water is lost due to seepage. Comparative study of canal lining material has been proposed for NLBC to save seepage losses. Concrete canvas-8mm is the most effective & long life lining material, which saves 95-100% water lost by seepage alone as compare to cement concrete.

Keywords: Seepage, Inflow-Outflow, Cement concrete, concrete canvas.

1. Introduction
Water has been said that the "oil of the 21st century" -- a commodity whose availability and quality may be subject to both known and unknown influences. Day-by-day, the scarcity of water has been felt worldwide due to ever-increasing demand for industrial, municipal and other users, besides agriculture. Agricultural use of water accounts for nearly 70% of the water used throughout the world, and the majority of this water is used for irrigation. Irrigation is main factor to boosts agricultural production. In India, 91.6% of the water is used for irrigation purpose as compared to 84% in Asia & 71% in the world (Irrigation in Asia, Water Reports No.18, and 2014-15). The irrigated area in the country was 22.6 Mha in 1950-51; today it has reached to 70 Mha. Since the food production was much below the requirement of the country, due attention was paid for expansion of irrigation. The ultimate irrigation potential of India has been estimated as 140 Mha. Out of this, 76 Mha would come from surface water and 64 Mha from ground water resources. The volume of water used for irrigation by the last century was 300 BCM of surface water and 128 BCM of groundwater out of 428 BCM. The estimates indicate that by the year 2025. The water requirement for irrigation would be 561 BCM for low demand scenario and 611 BCM for high demand scenario. These requirements are likely to further increase to 628 BCM for low demand scenario and 807 BCM for high demand scenario by 2050. Therefore, in order to meet food grain requirements and to bring maximum area under cultivation, the water resources are to be managed efficiently.

Seepage is defined as "the process of downward lateral movement of water into soil from source of supply such as irrigation canal". Seepage loss is depending upon Permeability of soil, Area and shape of canal wetted perimeter, Water depth in the canal, Location of ground water table, Constructions on ground water flow, location of wells, rivers, drains, impermeable boundary conditions, Soil suction zone in between ground water level and ground level, Viscosity of flowing water (neglected), Salinity of available water, Sedimentation and size distribution, Life of canal. According to different research it was observed that average seepage loss was 20-50 percentages in conveyance [3]. More seepage loss contributes water logging of lands & higher salt concentration in soils due to this problems crop production will be reduced. Number of methods is adopted for controlling seepage loss like soil compaction, lining of canal, replacement of canal by close conduit. Lining of irrigation canal is the simplest & most effective method for saving water & land in irrigated area [5].

Keeping in view that practicability, the losses through unlined reach no 2 from mile 19/4 to mile 42 under command area of Nira Left Bank Canal irrigation project was undertaken with following objectives.

1. To determine the rate of seepage losses at a limited section of NLBC.
2. To check out the conveyance efficiency of limited section of NLBC
3. Comparative study of canal lining material (Cement concrete & concrete canvas).

2. Study Area
Nira irrigation project consist of Bhatghar dam on Yelwandi River of 665.79 Mcum capacity of live storage & Vir dam on Nira River of live storage capacity 266.45 Mcum. Nira Left Bank Canal & Nira Right Bank Canal is off take from Vir dam. NLBC is consist of 89 distributaries with a total length of 153 Km. NLBC is completely unlined. There are four reaches in NLBC that are canal head to mile 19/4, mile 19/4 to mile 42, mile 42 to mile 77, mile 77 to tail. For further study of water loss & their controlling methods that is lining

the canal studies case study of reach no 2 from mile 19/4 to mile 42 of Nira Left Bank Canal irrigation system in Malegaon-Pandare subdivision, Tal-Baramati, Dist-Pune (Maharashtra). This reach is consisting of 26 distributaries with a total length of 34.96km. This reach having full supply capacity 827 cusecs & design discharge capacity 945 cusecs. There are perennial crops in the command area of the Nira Left Bank Canal. Huge plantation along the canal is done. No thick forest is near any component of this project. Wheat, Javari, Sugarcane are major crops of the NLBC command area. There are 4 sugar factories, 2 wineries & number of small agro based industries in the command area of NLBC. In addition to this NLBC supplies drinking water to Baramati & Walchandnagar Municipal Corporation and 118 small villages. Presently the entire economy & social life of 118 villages depend on water supply of NLBC.

3. Data Utilised

Climatic data

Nira River is a right bank tributary of Bhima River. The basin in its upper reaches is hilly and becomes flatter in tail portion. High intensity of rainfall about 6800 mm is received in the hilly area in Nira Sub basin which reduces to 500 mm on D/S area. It is tapped by Nira Major Project in its upper reaches. The Nira Left Bank canal is lies in between 18^0 7' 05" N latitude &74^0 05' 05" E longitude, starts from Vir Dam. At present NLBC is functioning up to 153 Km catering irrigation facilities to the crop area of 27328 Hectors in the culturable area of 68767 Hectares and gross command area of 81381 hectors from year 1887.

Availability of water

The actual tank gauge data is available at Bhatghar dam site and Vir dam site for more than 40 years. According to the available data the yield available at Vir and Bhatghar dam are as below. Hence the 75% available yield for Nira Canal System at Vir dam is 59.669 TMC

Cropping pattern

At reach no2 of NLBC about 90% area of cultural command area was sugarcane & 10% area by other crop.

Discharge data

Year wise discharge data from 2011 to 2015 is collected from Malegaon-Pandhare irrigation subdivision, Tal-Baramati.

Fig 1: Map identified the reach no.2 from mile 19/4 to mile 42 of NLBC.

4. Methodology

1. Measurement of seepage loss by inflow-outflow method.

We have used this method for estimation of seepage losses. This method involves measuring the amount of water flows into a channel at upstream of the section and amount which flows out at the downstream of the section. The loss is the difference between upstream & downstream section of channel. The measurement can be either of total volumes of water or if the channel is flowing steadily with its little change in the measured flow rate at either end directly of flow rates. To measure steady state seepage losses in a channel section, the flow measurement devices will be installed at the beginning and end of the channel section. The same type and size of device will be used if possible. The flow should be monitored in both devices until the steady flow is obtained. In order to measure discharges at head and tail, Standing Wave flume was placed in a straight section of channel in the centre & parallel to the direction of flow. The bottom and sides of flume were sealed to avoid leakage and the inside bottom of flume was cleaned from any sediment of trash to get precise gauge reading. The upstream reading was taken as h_u and the downstream reading was taken as h_d. These values were then converted to flow values by using the appropriate tables from discharge measurement manual by irrigation department in Pandhare subdivision, Baramati. Seppage loss was estimated by following formulas [6].

Determination of seepage rate per unit length of channel:

$$Qs = \frac{Qu-Qd}{L}$$

Where: -

Q_s = loss rate LPS/100 meter length

Q_u = Flow rate in the upstream side of canal (LPS)

Q_d = Flow rate in the downstream side of canal (LPS)

L = Length of the channel between the measurements per100 m

Determination of percent seepage loss

% loss = $Qs = \frac{Qu-Qd}{Qu}$ x100

Determination of losses (% per 100m)

Losses (% per 100m) = $[(Q_u - Q_d)/Q_u \times 100] \times (100/L)$ = (% losses/total length) x 100

Determination of conveyance efficiency

Conveyance efficiency = 100 - water loss percentage.

Table 1: Inflow-Outflow test on reach no 2 from mile19/4 to mile42 of Nira Left Bank Canal

Year	Section length (L)m	Water use for irrigation (LPS)	Q_u (LPS)	Q_d (LPS)	$Qs = \frac{Qu - Qd}{L/100}$ (LPS/100m)	Q_s (cusecs/100m)	Q_s m^3/sec/100m
2011-12	34,960	10,86,932	58,52,644	47,65,712	3109.07	111.04	3.11
2012-13	34,960	8,41,652	54,88,980	46,47,328	2407.47	85.98	2.41
2013-14	34,960	9,48,612	56,99,064	47,50,452	2713.42	96.90	2.71
2014-15	34,960	7,31,780	51,53,988	44,22,208	2093.19	74.75	2.09

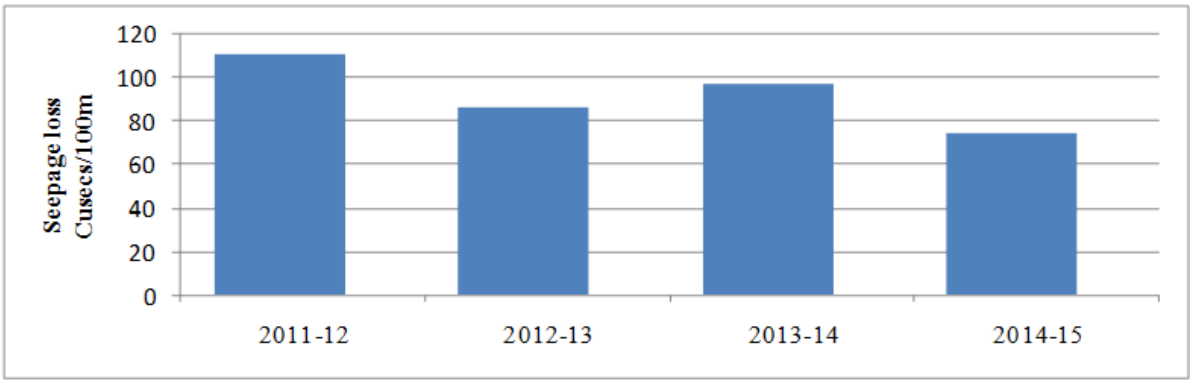

Fig 2: Year wise seepage losses in cusecs/100m at reach no2 of NLBC.

Table 2: Conveyance efficiency of section from mile19/4 to mile42 of NLBC.

Year	Distance (m)	Discharge in m^3/sec		Water loss Q_s (m^3/sec)	Q_s (LPS)	Q_s (cusecs)	Q_s Cusecs Per 100m	Water loss % age	Conveyance efficiency (%) C.E.=100- W.L.%
		Q_u	Q_d						
2011-12	34,960	5,852.644	4,765.712	1,086.932	10,86,932	38,819	111.03	18.57	81.43
2012-13	34,960	5,488.980	4,647.328	8,41.652	8,41,652	30,059	85.98	15.33	84.66
2013-14	34,960	5,699.064	4,750.452	9,48.612	9,48,612	33,879	96.90	16.64	83.36
2014-15	34,960	5,153.988	4,422.208	7,31.78	7,31,780	26,135	74.75	14.19	85.80

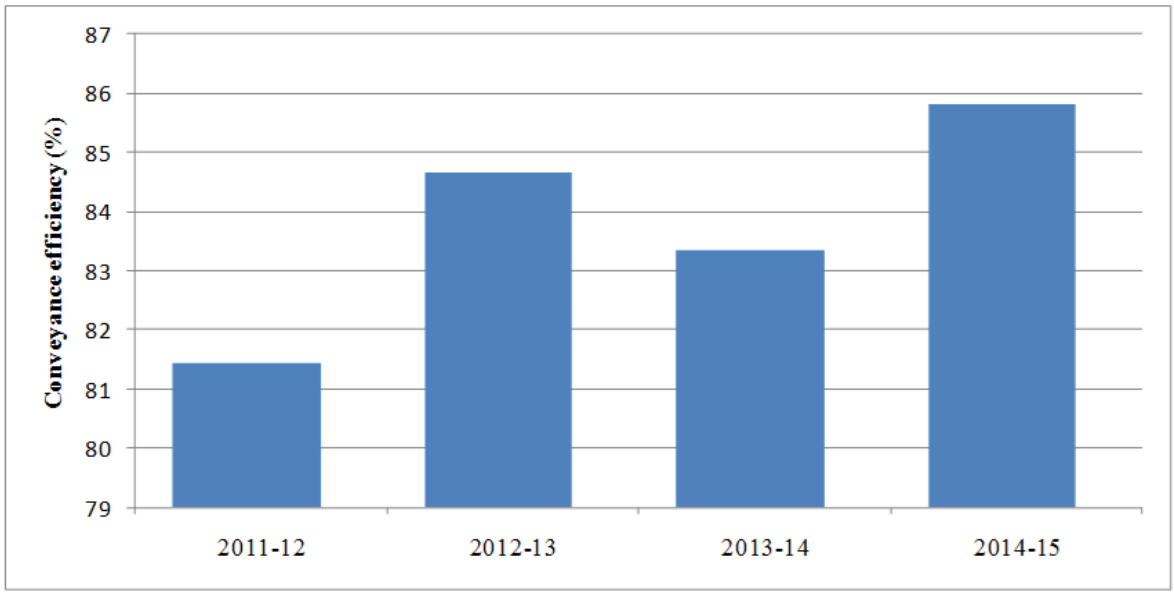

Fig 3: Year wise conveyance efficiency at reach no2 of NLBC.

Table 3: Seasonally variations of mean seepage at reach no 2 from mile19/4 to mile42 of NLBC from 2011 to 2015.

Year	Section length L (m)	Discharge (cusecs)								
		Kharif			Rabbi			Hot Weather		
		Q_u	Q_d	Water use for irrigation	Q_u	Q_d	Water use for irrigation	Q_u	Q_d	Water use for irrigation
2011-12	34960	62094	51566	10528	86184	69604	16580	60745	49029	11711
$Qs = \frac{Qu - Qd}{L/100}$ (Cusecs/100m)		30.11			47.42			33.51		
2012-13	34960	52473	45291	7182	84632	72187	12445	58930	48498	10432
$Qs = \frac{Qu - Qd}{L/100}$ (Cusecs/100m)		20.54			35.59			29.84		
2013-14	34960	68957	59314	9643	73232	59464	13768	61349	50881	10468
$Qs = \frac{Qu - Qd}{L/100}$ (Cusecs/100m)		27.58			39.38			29.94		
2014-15	34960	56311	50224	6087	69019	58976	10075	58741	48736	10005
$Qs = \frac{Qu - Qd}{L/100}$ (Cusecs/100m)		17.41			28.73			28.62		

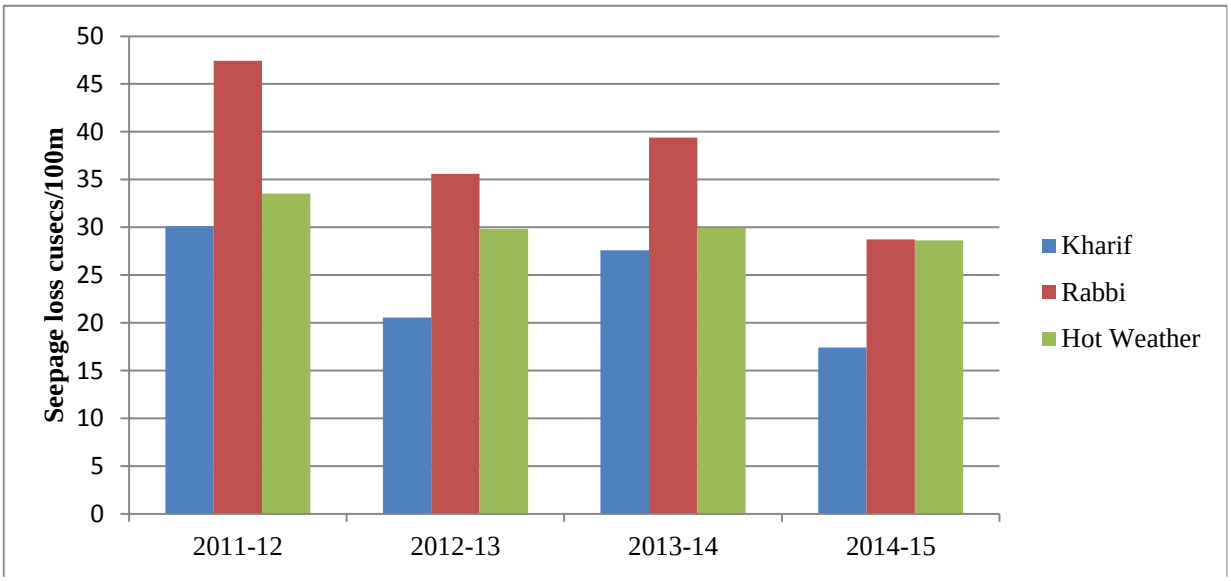

Fig 4: Season wise seepage losses (Cusecs/100m) at reach no2 of NLBC from 2014 to 2015.

2. Comparative studies of proposed cement concrete (10cm) lining & concrete canvas (8mm) lining apply at reach no 2 of NLBC

The principle of conservation requires that full use be made of available water supplies the most amount of water lost through seepage during conveyance in the canals. Seepage losses are control by soil compaction, lining the canal, replacing by piping. An avoidable seepage loss from unlined canal system not only entail appropriate wastage of investment made on the construction of dam to collect water, and it is distribute canal system to particular farm field. For further investment is made for controlling waste of water, so that water logging created in the canal irrigated areas. Lining is the best solution because it helps conserve the costly impounded water otherwise lost during conveyance due to high seepage losses in unlined section. In India different type of canal lining materials are used like rigid lining, flexible lining & combination lining. In this study proposed canal lining is carried out to reduce the seepage loss from reach no 2 of NLBC. This study gives comparative study of cement concrete & concrete canvas based on cost analysis & their properties. Estimation of cement concrete lining is carried out as per RSR Pune 2013-14. Estimation of concrete canvas is carried out that cost per square meter is 4890Rs including supply, providing & fixing of CC-8mm as provided by M/S Sanbros spares private limited Nagpur[7]. Comparison of the two different estimated annual costs of types of lining material shown in following table.

Table 4: Comparing Estimated Annual Cost of Lining.

Sr. No.	Type of work	Cost of proposed lined canal per Km	
		Cement Concrete	Concrete Canvas
1	Total net cost	9815680	133758407
2	Life	50	50
3	Salvage value	2453920	33439602
4	Total depreciation during life	7361760	100318805
5	Annual depreciation charge	147235	2006376
6	Annual interest charge	490784	6687920
7	Annual maintenance charge	98157	1337584
8	Total annual cost (5+6+7)	736176	10031880

Table 5: Comparative study of Concrete Canvas & Cement Concrete.

Concrete Canvas	Cement Concrete
CC is available in man portable roll for applications with limited access.	It is not available in man portable volume for applications with limited access
The fibre reinforcement prevents cracking, absorb energy from impacts and provide a stable failure mode.	Cement concrete possesses low tensile strength, so that cracks are developed
In comparison to cement concrete thickness of CC lining slim	Thickness of cement concrete is more than CC
In this lining joints & grooves are in proper distance, so that coefficient of friction is low	In this lining joints & grooves are more, so that coefficient of friction is high.
CC has a low alkaline reserve, a low washout rate and a low carbon footprint, so that it is environmental friendly	If soluble salt is present in concrete then it may leads to efflorescence when comes in contact with moisture, So that it is not environmental friendly
CC having higher flow rate & conveyance efficiency, because geo-textile fibre is laid on top & bottom	It having low flow rate & conveyance efficiency due to high friction as compared to CC.
CC can be rapidly applied by hand with no specialist equipment with low period.	Cement concrete is applied slowly with high period by using specialist equipment
It has more life than cement concrete with higher initial cost.	It has less life as compared to CC though initial cost is less
CC having minimal training for installation	Cement concrete required more trained workers for installation.

Table 6: Comparative study of addition potential due to the lining the reach no2 from mile 19/4 to mile 42 of NLBC.

Season	Existing		Cement concrete 10cm lining		Concrete Canvas 8mm lining	
	TMC	ICA (Ha)	TMC	ICA (Ha)	TMC	ICA (Ha)
Kharif	0.72	2037	1.33	3762	1.44	4074
Rabbi	1.14	2574	1.91	5403	2.05	5799
Hot Weather	0.92	2603	1.7	4809	1.84	5205
Total	2.78	7214	4.94	13974	5.33	15078

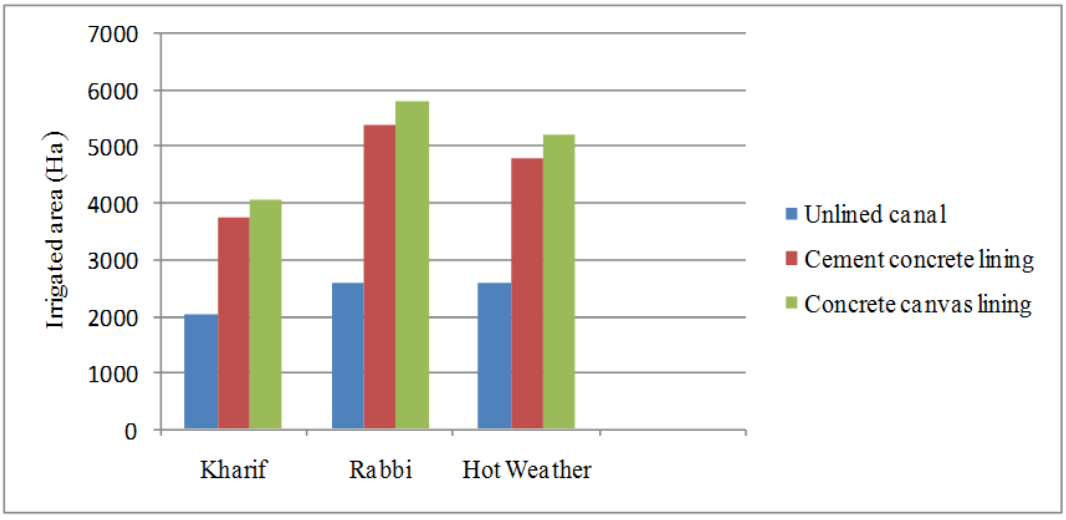

Fig 5: Comparative study of additional potential at reach no 2 of NLBC.

5. Result & Discussion

This chapter deals with results obtained from case study carried out at reach no 2 from mile 19/4 to mile 42 of NLBC. In inflow-outflow method discharge data is collected from Malegaon-Pandhare subdivision by using this year wise data seepage loss was estimated. From table no1 loss of water in the reach no2 of NLBC was 111.04, 85.98, 96.90, 74.75 Cusecs/100m obtained in 2011-12, 2012-13, 2013-14, 2014-15 years respectively. The average seepage loss was 2.55 TMC/34.96km obtained in earthen reach no 2 of NLBC in

respective years. Conveyance efficiency of reach no 2 of NLBC is 85.80% higher in 2014-15 as compared to other respective years as shown in table no 2 & figure 3. According to study it was conclude that seepage rate is higher in Rabbi Season due to high flow period from 2011 to 2015 as shown in table no 3 & figure 4. According to study it was conclude that higher additional potential is occurred after lining the reach no 2 of NLBC by Concrete Canvas -8mm as shown in table no 4-6 & figure 5.

6. Conclusions

Following concluding remark could be drawn from findings of the present study.

1. Increased canal capacity will introduce greater flexibility in operation and will make normal canal closures possible. This will permit normal canal maintenance work, which is not possible as of today.
2. With the increased capacity of canal the rotation period of Kharif and Rabi seasons will be reduced from about 45 days to 21 days. This will enable supply of water to crops at their appropriate stages of growth, which is not possible at present. This will increase crop yields and hence agricultural production and farmer's benefits.
3. 2.55TMC (95-100%) water will be saved due to Concrete canvas lining without loss at reach mile 19/4 to mile 42.With these improvements the losses to the canal will be reduced and more water will be available for irrigation. Thus, additional 2037Ha in kharif, 3225Ha in Rabbi & 2602Ha in Hot Weather irrigation is also expected without any additional drawls from storage. Over all 7864 ha additional area will be irrigated as compared to cement concrete.
4. Increase in the No. of rotation in each season: Theoretically it is necessary to provide 15 days rotation at an interval of not more than 21 days in a Year. However considering the old age of the system & status of the system it is not possible to achieve this. After lining the canal by concrete canvas-8mm no of crop rotation increased, that is 4 rotations in kharif, 3 rotations in Rabbi, 2 rotations in Hot Weather.

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