PERFORMANCE EVALUATION OF SOME LINED WATERCOURSES OFF-TAKING FROM MUBARAK WAH IN DISTRICT TANDO MOHAMMAD KHAN, PAKISTAN

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ABSTRACT: *A study was conducted on six watercourses in the command area of Mubarak Wah falling in the hydraulic boundaries of Phulleli Canal and administrative boundary of district Tando Mohammad Khan. The selected watercourses have different length, design, discharge, gross command area (GCA), cultivable command area (CCA), relative elevation, cropping pattern, cropping intensity and crop yield etc. from each other. Two watercourses from each head, middle and tail reach of the Mubarak Wah were selected to evaluate their performance with an aim to have reach-wise performance evaluation of selected watercourses under study. Pygmy current meter was used to measure discharge in lined portion of the watercourse whereas cut-throat flume was used in unlined portion of the watercourses. Inflow outflow method was used to measure conveyance efficiency. The increase in cropping intensity and yield are the water saving indicators which were observed by conducting farmers' interviews. The results showed an increase in conveyance efficiency about 96.55 to 98.25% and the cropping intensity was increased by about 6.27 to 9.26% in Rabi and 6.11 to 9.88% in Kharif season. While annually the cropping intensity increased by 12.41 to 17.71%. The results further showed an increase of 4.69 to 5.73% in yield of cotton 4.07 to 5.76% in sugarcane and 4.87 to 6.73% in wheat. It was observed that the lining of watercourses has improved the overall conveyance efficiency resulting an increase in cropping intensity and cropping yield. Therefore it is suggested that the watercourses should be lined throughout irrigated areas. In Pakistan watercourses improvement is up to 30% of total length of watercourses. It should be extended to 100% length of watercourse for increasing conveyance efficiency, cropping intensity as well as yield of major crops.*

Key words: watercourse, yield, seepage, conveyance efficiency, cropping intensity

INTRODUCTION

Water is often considered as a fundamental resource for sustainable agriculture development in arid and semi-arid regions of the world. The demand of irrigation water is increasing with time for both agricultural and non-agricultural purposes. The main reason of increasing demand of water is the rapid population growth and shifting to water to industrialization resulting the reduction in share of agriculture. Efficient water conservation and management practices should be used for sustainable food supply and increasing crop production to overcome scarcity even in high rainfall areas [1].

Pakistan situated in arid and semi-arid climatic conditions. Increasing demand of food and fiber to fulfill human needs are forcing for proper usage and management of Available Water resources. The per capita availability of fresh water in Pakistan was 5650 m^3 in 1951, which decreased to 1000 m^3 in 2010 and is projected to go down to 800 m^3 by the year 2025, if population continues to grow with the present rate. Apart from surface water, the usable groundwater is also depleting day by day as a result the water table has gone down to a undesirable extent in many areas of the country [2]. Therefore canal water is used to irrigate crops as well as to fulfill the demands of domestic and industries.

Sindh is the second largest province of Pakistan according to population. The province covers an area of 140,900 km2 and population about 43.42 million including the population of Karachi. Poverty alleviation in Sindh province is mainly dependent on irrigated agriculture as 70% population is inhibited in rural areas and their main source of livelihood is agriculture. According to Water Apportionment Accord (WAA), 60.47 BCM water is available for Sindh province which require maximum conservation. Irrigated agriculture is dependent on available water resources of 60.47 BCM which is scarce in Sindh [3].

However, Sindh province is facing severe conditions, conveyance, application and water use efficiencies, inequity, inadequacy and non-reliability in water distribution system are at critical levels as compared to other provinces of Pakistan. The overall irrigation efficiency is 45- 50% Pakistan Water Partnership (PWP) report [4] which is alarming sign particularly for those whose economy is largely dependent on irrigated agriculture. The Sindh province has 3 major barrages, 14 main canal commands and draws about 54 to 60.47 billion cubic meter of water annually. The canal system has an aggregate length of 19066 km (11916 miles) serving a gross command area (GCA) of 5.71 million hectare (14.09 million acres). There are 46699 watercourses which have aggregate length of about 120,000 km (75000 miles), from which 29,492 watercourses have been improved under various programs/projects including by the government's own funding under National Program for Improvement (NPIW) of Water Courses. The World Bank so far has funded two SOFWM Projects (original 4 year project covering 4,355 watercourses and another 1,421 watercourses under the current 2.5 year additional funding project to SOFWM-AF). Thus about 17,207 watercourses are remaining for improvement in Sindh [5]. The growth in agriculture sector and its increasing commercial orientation resulted increase in cropping intensity, crop diversification and shift to high yielding hybrid varieties that consume more water.

Sindh has over 5.8 million hectares of irrigated land, and over 800,000 farms. Major crops include cotton, rice, sugarcane, and wheat. Sindh is also a major horticulture producing area of Pakistan. The average farm size is small, and over 93 percent have less than 7 ha, and these represent 64 percent of total farm area. However, land ownership is skewed in favor of large holders. Larger farms (greater than 7 ha) account for only 7 percent of the total number of farms, but nearly 36 percent of the total farm area. The land tenure system in Sindh has regulated ownership, tenancy, and inheritance rights. About 50 percent of the farms, representing about 59 percent of the total farm area, are operated by owners, while 42 percent of the farms, representing 29 percent of the total farm area, are operated by tenants/sharecroppers. The remaining 8 percent of the farms, representing 12 percent of the total farm area, are operated by owners-cum-tenants.

To embark upon these problems, the Government of Sindh with the support of Government of Pakistan launched and completed several projects related to On Farm Water Management aimed at improving the irrigation efficiency and crop productivity though integrated interventions of the projects in the province. (i.e., Sindh On-Farm Water Management Previous Schemes, Sindh On-Farm Water Management Project Original, Sindh On-Farm Water Management- Additional Financing Project, National Program for Improvement of Watercourses). In all these projects the scope of lining was 30%. (Operation & maintenance irrigation manual volume – I).

Mangrio *et al*. [6] conducted an experiment to evaluate the conveyance efficiency of lined watercourses. The results revealed that the conveyance efficiency of watercourses increased by 8% with 30% lining of total length of watercourse which saved 14.13 ha-m water to cultivate 7 hectares more land. The cropping intensity has also increased by about 29 % in Rabi and 12 % in Kharif seasons.

Ahmed *et al.* [7] conducted a study to assess the conveyance losses/efficiency of lined watercourses. The results showed that after lining of watercourses conveyance losses decreased and conveyance efficiency increased. The results also showed higher crop yields due to lining of watercourse.

Mohammad [8] mentioned that channels lining remove large part of water losses and increase the yield of crops. Dilawar et al. [9] conducted a case study to assess irrigation water losses at various locations of selected watercourses in Warsak Lift Canal System. They found 50 to 60% of losses while severe crop losses were found at the end the extent of three fourth of the crop production.

Khan et al. [10] conducted a case study to assess irrigation water losses at various locations of selected watercourses. It was found that the conveyance losses ranged from 50 to 60%. They further recommend that the existing watercourses should be lined to save more water.

Asadullah *et al*.[11] conducted an experiment on earthen watercourses to assess water losses and conveyance efficiency. According to the results average water loss was 30.9% and conveyance efficiency was 69.10% in earthen watercourse.

Zaheeruddin *et al*. [12] found that On-Farm Water Management project phase-III was perceived as successful in renovating the watercourses, maximizing the cropping intensities, and producing better yields of the major crops.

Mirani *et al*. [13] conducted an experiment to determine effect of lining of watercourses on water losses and conveyance efficiency. They concluded that after lining of watercourses the water losses reduced from 25.85 to 1.61, 13.82 to 1.36, 36.46 to 1.36 and 39.84 to 1.63 % and conveyance efficiency improved by 37.85%. They recommended that to obtain maximum conveyance efficiency, the watercourse lining should be on top priority.

Qurban *et al.* [14] conducted an experiment to evaluate the impacts of watercourse improvement on watercourse No. 52810-L located at Shahkot Distributory. The results showed that conveyance losses were found 41% comprising 19.5% on main watercourse and 21.5% on farmer's branch. Improvement of only main watercourse reduced the losses from 19.5% to 9.75% but from the unimproved farmer's branches, the losses were increased from 21.5% to 24.5%. After the improvement of total system, i.e main and farmer's branches a saving of 50% of losses was observed.

Keeping in view the present study is aimed at evaluating performance of six lined watercourses with reference to assess increase in: conveyance efficiency, cropping intensity and crop yield for selected watercourses off-taking from Mubarak Wah in district Tando Mohammad Khan improved/lined under Sindh On Farm Water Management-Additional Financing Project.

Material and Methods

Study Area

This study was carried on six lined watercourses on Mubarak Wah located in District Tando Mohammad Khan improved under Sindh On-Farm Water Management- Additional Financing (SOFWM-AF) Project. Two watercourses from each head, middle and tail reach of the Mubarak Wah were selected to evaluate their performance with an aim to have reach-wise performance evaluation of selected watercourses under study. The description of each selected / sample watercourse is narrated in subsequent paragraphs and their salient features are portrayed in Table 3.1.

Description of selected watercourses

3-R Mubarak Wah

3-R Mubarak Wah off takes from head reach of Mubarak Wah at 1.0 RD (reduced distance), which carries the designed discharge of 163 LPS to serve about 63.26 hectares of land. The total length of watercourse is 2000 m out of which 600 m are lined and 1400 m are unlined.

4-AR Mubarak Wah

It off takes from head reach of Mubarak Wah at 2.50 RD, carrying a designed discharge of 90 LPS to serve 31.18 hectares of land. The total length of watercourse is 945 m out of which 284 m are lined and 661 m are unlined.

18-CL Mubarak Wah

18-CL Mubarak Wah off takes from mid reach of Mubarak Wah at 20.80 RD, carrying a designed discharge of 204 LPS to serve 89.47 hectares of land. The total length of watercourse is 2460 m out of which 738 m are lined and 1722 m are unlined.

19-L Mubarak Wah

It off takes from mid reach of Mubarak Wah at 22.0 RD, carrying a designed discharge of 65 LPS to serve 21.54

hectares of land. The total length of watercourse is 1330 m out of which 339 m are lined and 931 m are unlined.

45-R Mubarak Wah

This watercourse off takes from tail reach of Mubarak Wah at 44.10 RD, carrying a designed discharge of 282 LPS to serve 96.44 hectares of land. The total length of watercourse is 3200 m out of which 960 m are lined and 2240 m are unlined.

46-R Mubarak Wah

This watercourse off takes from tail reach of Mubarak Wah at 44.20 RD, carrying a designed discharge of 158 LPS to serve 53.85 hectares of land. The total length of watercourse is 3200 m out of which 960 m are lined and 2240 m are unlined.

Conveyance losses

Conveyance losses in a particular reach / system is defined as the ratio of flow leaving the reach (outflow) and the flow entering the reach / system (inflow). Mathematically conveyance losses expressed as:

Q1 – Q2 = Loss in lined section
Q3 – Q4 = Loss in unlined section
Q1 – Q4 = Cumulative losses in w**c**

Conveyance Efficiency

Conveyance efficiency in a particular reach / system is defined as the ratio of flow leaving the reach (outflow) and the flow entering the reach / system (inflow) and is expressed in percent. Mathematically conveyance efficiency denoted by E_c is expressed as:

$$E_c = \frac{Q_o}{Q_i} \times 100$$

Where:

E_c = conveyance efficiency (%)
Q_o = outflow rate (LPS)
Q_i = inflow rate (LPS)

In order to estimate conveyance efficiency of lined and unlined portions of watercourse the inflow and outflow method was used. The flow rate of lined portion of watercourse was measured using current meter and flow rate of unlined portion of watercourse was measured by Cut-throat Flume.

Inflow-outflow Method

The most accurate technique for measuring conveyance losses from an irrigation channel is inflow-outflow method using existing irrigation structures for discharge measurement. The conveyance losses can be evaluated for each reach knowing flow entering the reach and flow leaving the reach under consideration.

There are several methods / techniques to record inflow and outflow rate, however the most popular methods widely used in the field are flow measurement through current meters/pygmy meters and cut-throat flumes.

To conduct the inflow outflow method the watercourse length was divided into two portions. First portion comprised lined section whereas second portion was unlined section. The lined section was further subdivided in two reaches and unlined section was also divided in two reaches (AB, BC). The discharge measurements were carried out at head-tail of each portion of lined and unlined section. Two current meters were used in lined portion and one Cut-throat Flume were used on the tail reach of unlined portion to take measurements at different locations simultaneously.

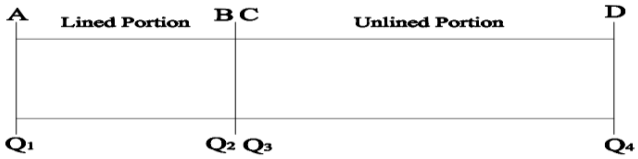

Fig. 3.1 Layout of Watercourse

Flow entering in the lined section was termed as inflow (Q1) and flow leaving the lined section was termed as outflow (Q2). Flow leaving the lined section and entering in unlined portion was termed as inflow for unlined portion (Q3) and the flow at the tail end of unlined portion of watercourses was outflow (Q4).

Conveyance efficiency for a particular reach was determined by using equation narrated above.

Thus, the conveyance efficiency in lined section of the watercourse was determined as

$$(Q_2 \div Q_1) \times 100$$

Thus, the conveyance efficiency in unlined section of the watercourse was determined as

$$(Q_4 \div Q_3) \times 100$$

The overall conveyance efficiency of the watercourse was determined as

$$(Q_4 \div Q_1) \times 100$$

Cropping intensity and crop yield

The water saving was calculated from discharge data analysis in relation to increase cropping intensity and crop yield by conducting interview from farmers. The command areas of selected watercourses was different in nature in terms of length, design, discharge, gross command area (GCA), culturable command area (CCA), relative elevation, cropping pattern, cropping intensity, crop yield etc. Following relation was used to calculate the cropping intensity is (OFWM Field manual [15]).

$$CI = \frac{CA}{CCA} \times 100$$

Where:

CI = Cropping intensity (%)
CA = Cropped area (ha)
CCA = Cultivable command area (ha)

The yield is ultimate outcome which improves the economy of the grower. Though the increase in quantum of water through lining of watercourses is not a sole factor to accelerate the per hectare yield of crops but even then optimal supply of water to the field makes difference at certain level to enhance yield potentials. The studies will be carried out to record the yield of 3 major crops comprising wheat, cotton and sugarcane on six improved/lined watercourses off-taking from Mubarak Wah.

To evaluate the cropping intensity and yield of major crops (Wheat, Cotton and Sugarcane), the crop data was retrieved from a sample of farmers falling on the command of six watercourses under study. The data pertaining to crop area

before and after lining of the watercourses under study will be obtained through interviews from farmers.

The sample of farmers for recording the data was done in such a way that at least 50% of total farmers of the watercourses were covered so as to get good representative data for analytical analysis.

A questionnaire has been developed to retrieve the crop and crop yield data from respondents / farmers of the watercourses improved under study before and after improvement / lining. This data was critically analyzed to assess the impact of lining on cropping intensity and yield of major crops. Filled questioner details of 71 farmers are presented in this study.

Results

The research study was conducted on six watercourses in the command area of Mubarak Wah, falling in the hydraulic boundaries of Phuleli canal and administrative boundary of district Tando Mohammad Khan.

Conveyance Losses

The study was taken in hand to record the impact of lining of watercourse on the conveyance efficiency in the post-improvement scenario after lining.

The conveyance losses ranged from 1.75 to 3.45% in lined portion of watercourses and from 22.62 to 28.80% in unlined portion of watercourses. Whereas overall losses ranged from 24.42 to 31.03 % as shown in Table 2.

Conveyance efficiency

The data in Table 3 shows that the conveyance efficiency from lined portion of watercourses ranged from 96.55 to 98.25% and from unlined portion ranged from 71.20 to 77.38%. Whereas overall efficiency ranged from 68.97 to77.58 %.

Cropping intensity

To obtain cropping intensity 71 farmers were interviewed. The watercourse wise farmer's details are given in Table 4.

Rabi Season

Cropping intensities for Rabi season before and after lining of watercourses are shown in Table 5 which indicates that cropping intensity of watercourses before improvement ranged from 76.17 to 88.33 %. While after improvement the cropping intensity ranged from 84.52 to 95.82 %. This showed an increase of 6.27 to 9.26 % in cropping intensity after improvement of watercourses.

Kharif Season

Table 6 shows the cropping intensity for Kharif season before and after lining of watercourses. Table indicates that cropping intensity of watercourses before lining ranged from 73.95 to 86.56 %. While after improvement the cropping intensity ranged from 83.31 to 94.54 %. The result showed an increase of 6.11 to 9.88 % in cropping intensity after improvement of watercourses.

Annual cropping intensity

Annual cropping intensity before and after lining of watercourse is shown in Table 7. Table shows that cropping intensity of watercourses before improvement was 150.12 to 173.13 %. While after improvement of watercourse the cropping intensity was 167.83 to 190.35 %. This shows an increase of 12.41 to 17.71 % annually after improvement of watercourses.

Crop Yield

To collect crop yield, 71 farmers were interviewed. The watercourse wise farmer's details are given in Table 4.

Cotton: Yield of cotton before and after lining of watercourse is shown in Table 8. The table shows that yield of cotton before improvement was 553.85 to 575.82 kg/ha. While after improvement the yield was 583.43 to 605.13 kg/ha. This shows an increase of 26.37 to 32.48 kg/ha (4.69 to 5.73 %) after improvement of watercourses.

Sugarcane

Yield of sugarcane before and after lining of watercourse is shown in Table 9. Table shows that yield of sugarcane before improvement was 12514.79 to 13703.30 kg/ha. While after improvement the yield was 13183.43 to 14263.74 kg/ha. This shows an increase of 560.44 to 736.26 kg/ha (4.07 to 5.76 %) after improvement of watercourses.

Wheat

Yield of wheat before and after lining of watercourse is shown in Table 10. Table shows that yield of wheat before improvement was 474.73 to 506.59 kg/ha. While after improvement the yield was 506.59 to 536.26 kg/ha. This shows an increase of 23.93 to 31.95 kg/ha (4.87 to 6.73 %) after improvement of watercourses.

Table 1. Salient features of selected / sample watercourses.

Sr. No	Name of Watercourse	Reach	C.C.A (ha)	Sanction Discharge (LPS)	Total Length (m)	Lined Length (m)	Unlined Length (m)
1	3-R Mubarak Wah	Head	63.26	163	2000	600	1400
2	4-AR Mubarak Wah	Head	31.18	90	945	284	661
3	18-CL Mubarak Wah	Mid	89.47	204	2460	738	1722
4	19-L Mubarak Wah	Mid	21.54	65	1330	339	931
5	45-R Mubarak Wah	Tail	96.44	282	3200	960	2240
6	46-R Mubarak Wah	Tail	53.85	158	3200	960	2240

Table 2. Conveyance losses from lined and unlined portions of watercourses

S. #	Name of W/C at Mubarak Wah	Lined Portion				Unlined Portion				Overall (lined & unlined)		
		Length	Inflow Q1	Outflow Q2	Losses	Length	Inflow Q3	Outflow Q4	Losses	Inflow Q1	Outflow Q4	Losses
		m	LPS	LPS	(%)	m	LPS	LPS	(%)	LPS	LPS	(%)
1	3-R	600	148	143	3.38	1400	143	106	25.87	148	106	28.4
2	4-AR	284	86	84	2.33	661	84	65	22.62	86	65	24.4
3	18-CL	738	184	180	2.17	1722	180	134	25.56	184	134	27.2
4	19-L	339	57	56	1.75	931	56	43	23.21	57	43	24.6
5	45-R	960	197	191	3.05	2240	191	136	28.80	197	136	32.0
6	46-R	960	145	140	3.45	2240	140	100	28.57	145	100	31.0

Table 3. Conveyance efficiency (CE) of lined and unlined portions of watercourses

S. #	Name of Watercourse at Mubarak Wah	Lined Portion				Unlined Portion				Overall (Lined & Unlined		
		Length	Inflow Q1	Outflow Q2	CE	Length	Inflow Q3	Outflow Q4	CE	Inflow Q1	Outflow Q4	CE
		m	LPS	LPS	(%)	m	LPS	LPS	(%)	LPS	LPS	(%)
1	3-R	600	148	143	96.62	1400	143	106	74.13	148	106	71.62
2	4-AR	284	86	84	97.67	661	84	65	77.38	86	65	75.58
3	18-CL	738	184	180	97.83	1722	180	134	74.44	184	134	72.83
4	19-L	339	57	56	98.25	931	56	43	76.79	57	43	75.44
5	45-R	960	197	191	96.95	2240	191	136	71.20	197	136	69.04
6	46-R	960	145	140	96.55	2240	140	100	71.43	145	100	68.97

Table 4. Watercourse wise number of farmers interviewed

S. #	Name of Watercourse	No. of Farmers Interviewed
1	3-R Mubarak Wah	14
2	4-AR Mubarak Wah	14
3	18-CL Mubarak Wah	13
4	19-L Mubarak Wah	12
5	45-R Mubarak Wah	9
6	46-R Mubarak Wah	9
	Total	71

Table 5. Cropping intensity before and after lining of watercourses in Rabi season

S. #	Name of Watercourse	Area under crops (hectare) Rabi Season						
		C.C.A	Before lining		After lining		Increased	
			Area	Intensity	Area	Intensity	Area	%
1	3-R Mubarak Wah	3.24	2.63	81.98	2.92	90.58	0.29	8.60
2	4-AR Mubarak Wah	5.75	4.74	84.71	5.18	91.56	0.43	6.86
3	18-CL Mubarak Wah	5.33	4.52	86.56	5.01	95.82	0.50	9.26
4	19-L Mubarak Wah	6.28	5.09	81.65	5.50	87.92	0.40	6.27
5	45-R Mubarak Wah	5.35	3.64	76.17	4.14	84.52	0.49	8.34
6	46-R Mubarak Wah	4.72	4.09	88.33	4.45	94.63	0.36	6.30

Table 6. Cropping intensity before and after lining of watercourses in Kharif season

S. #	Name of Watercourse	Area under crops (hectare) Kharif Season						
		C.C.A	Before lining		After lining		Increased	
			Area	Intensity	Area	Intensity	Area	%
1	3-R Mubarak Wah	3.24	2.63	81.98	2.92	90.58	0.29	8.60
2	4-AR Mubarak Wah	5.75	4.74	83.75	5.29	93.33	0.55	9.58
3	18-CL Mubarak Wah	5.33	4.52	86.56	4.95	94.54	0.44	7.97
4	19-L Mubarak Wah	6.28	5.06	79.98	5.63	89.87	0.57	9.88
5	45-R Mubarak Wah	5.35	3.60	73.95	4.11	83.31	0.52	9.36
6	46-R Mubarak Wah	4.72	3.42	78.15	3.73	84.26	0.31	6.11

Table 7. Annual cropping intensity before and after lining of watercourses

S. #	Name of Watercourse	Annual Cropping Intensity (%)						
		Kharif Season		Rabi Season		Annually		% Increased
		Before lining	After lining	Before lining	After lining	Before lining	After lining	
1	3-R Mubarak Wah	81.98	90.58	81.98	90.58	163.96	181.16	17.20
2	4-AR Mubarak Wah	83.75	93.33	84.71	91.56	168.46	184.89	16.43
3	18-CL Mubarak Wah	86.56	94.54	86.56	95.82	173.13	190.35	17.23
4	19-L Mubarak Wah	79.98	89.87	81.65	87.92	161.63	177.79	16.16
5	45-R Mubarak Wah	73.95	83.31	76.17	84.52	150.12	167.83	17.71
6	46-R Mubarak Wah	78.15	84.26	88.33	94.63	166.48	178.89	12.41

Table 8. Yield of cotton before and after lining of watercourse

S. #	Name of Watercourse	Yield of Cotton (kg/ha)			
		Before Lining	After Lining	Increase in Yield	(%)
1	3-R Mubarak Wah	558.24	584.62	26.37	4.69
2	4-AR Mubarak Wah	575.82	604.40	28.57	4.94
3	18-CL Mubarak Wah	553.85	583.43	29.59	5.37
4	19-L Mubarak Wah	566.67	598.72	32.05	5.73
5	45-R Mubarak Wah	572.65	605.13	32.48	5.57
6	46-R Mubarak Wah	562.39	593.16	30.77	5.47

Table 9. Yield of sugar cane before and after lining of watercourses

S. #	Name of Watercourse	Yield of Sugar Cane (kg/ha)			
		Before Lining	After Lining	Increase in Yield	(%)
1	3-R Mubarak Wah	12802.20	13538.46	736.26	5.76
2	4-AR Mubarak Wah	13703.30	14263.74	560.44	4.07
3	18-CL Mubarak Wah	12514.79	13183.43	668.64	5.35
4	19-L Mubarak Wah	13230.77	13871.79	641.03	4.85
5	45-R Mubarak Wah	12991.45	13658.12	666.67	5.10
6	46-R Mubarak Wah	13418.80	14034.19	615.38	4.55

Table 10. Yield of wheat before and after lining of watercourses

S. #	Name of Watercourse	Yield of Wheat (kg/ha)			
		Before Lining	After Lining	Increase in Yield	(%)
1	3-R Mubarak Wah	474.73	506.59	31.87	6.68
2	4-AR Mubarak Wah	506.59	536.26	29.67	5.91
3	18-CL Mubarak Wah	475.74	507.69	31.95	6.73
4	19-L Mubarak Wah	489.74	516.67	26.92	5.52
5	45-R Mubarak Wah	492.31	516.24	23.93	4.87
6	46-R Mubarak Wah	492.31	521.37	29.06	5.94

DISCUSSION

The canal irrigation system in the Indus Basin of Pakistan is facing a number of operational problems resulting in high degree of losses of water during conveyance of irrigation water to agricultural lands. These water losses result in constrained water supplies of canal water in the Indus Basin. Water losses from these canals have major impacts on surface water supplies and needs management, and must be minimized, if not altogether eliminated. This is perhaps the most cost-effective method of augmenting water supplies. The primary and secondary canals of the irrigation system of the Indus Basin are looked after by the provincial Irrigation Department whereas, the construction of tertiary canals (watercourses) and their operation and maintenance is the sole responsibility of the farmers. Because of inadequate technical skills and lack of motivation of farmers, these watercourses have been deteriorated, resulting in excessive conveyance losses. Keeping in view the importance of lining of watercourse; the present study was conducted to evaluate performance of six lined watercourses with reference to

increase in: conveyance efficiency, cropping intensity and crop yield. The results of the present research work are shown in previous chapter while the discussion on the results is given in this chapter.

Conveyance Losses

The conveyance losses decreased from lined portion of watercourse as compared to unlined portion of watercourse. It might be due to high seepage from bed and banks of the unlined portion of watercourse. These results are in accordance with those of Ahmed *et al.*, Arshad *et al.* and Khan *et al.* who studied the water losses at various locations of selected watercourses. Thus it was found that the conveyance losses were minimized after improvement of watercourse. The lining of watercourse can effectively save the water losses.

Conveyance Efficiency

Conveyance efficiency of lined portion was increased as compared to unlined portion of all selected watercourses after lining. The reason of the less conveyance efficiency of unlined portion of watercourses is absolutely due to vegetation, improper alignment of watercourses and rodent affect. Thus the conveyance efficiency has improved by lining of the watercourse. Similar findings have also been adduced in a study carried out by Ahmed *et al.* , Sultan *et al.* , Asadullah *et al.* and Mirani *et al.* [7, 11, 13 & 17] . They concluded that the lining of watercourses increased the conveyance efficiency in India and Pakistan respectively, thus also recommended to obtain maximum conveyance efficiency, the watercourse lining should be on top priority

Cropping intensity

The results reveal that the cropping intensity increased after lining in both seasons as compared to before lining of watercourse. The annual cropping intensity was also recorded higher after lining of watercourse.

This increasing trend in cropping intensity was mainly due to lining which brought more land under cultivation. These results are supported by Fawad *et al.*, Zaheeruddin *et al.* and Naeem *et al.* [12, 18 & 19]. They reported that cropping intensity was increased after lining of watercourse, they also concluded that the farmers of the area brought more land under cultivation with saved water.

Crop Yield

The yield of cotton, sugarcane and wheat before and after lining of selected watercourse were increased. The result indicates that the yield of crops increased after lining as compared to before lining of watercourses. This increase in yield of crops was mainly due to efficient supply of water to field after lining of watercourse. Similar findings have also been cited in a study carried out by Ahmed *et al.*, Fawad *et al.* and Mohammad [7, 8 & 18]. They concluded that channels lining removed large part of water losses and increased the yield of crops and producing better yields of the major crops.

CONCLUSIONS

From the foregoing research study following conclusions have been drawn:

- The conveyance losses of lined portion of watercourses were 1.75 to 3.45 % while the conveyance losses of unlined portion of watercourses were 22.62 to 28.80 %.
- The conveyance efficiency of lined portion of watercourses was 96.55 to 98.25 % while the conveyance efficiency of unlined portion of watercourses was 71.20 to 77.38 %.
- The cropping intensity has been increased by about 6.27 to 9.26 % in Rabi and 6.11 to 9.88 % in Kharif season while it increased by 12.41 to 17.71 % annually.
- The results showed an increase in yield of major crops; cotton 4.69 to 5.73 %, sugarcane 4.07 to 5.76 % and wheat 4.87 to 6.73 %.

Suggestions / Recommendations

From the study, the following suggestions have been put forth:

- The lining of watercourses has improved the cropping intensity and crop yield. Therefore it is suggested that the watercourse lining should be continued in all irrigated areas.
- In Pakistan watercourse improvement is limited up to 30% of total length of watercourses. It should be extended to 100 % length of watercourse.

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