1.2 Cotton water consumption rates and irrigation regime

1.2.1 General comments

On the irrigation regime and water consumption rates study the research results from 7 projects were presented, including 4 projects in Uzbekistan and 3 projects in Tadjikistan. At the same time, 3 projects from Uzbekistan included research of cotton field water consumption (total evaporation formation) during growing period with thermal balance method using electronic thermal balancing (T6-72), type AFNII. There were the following projects:
1st - NISTO (experimental station on irrigation technique by SANIIRI) located in Zangiata district, Tashkent province;
2nd - G.Goulyam state farm, SANIIRI (Syrdarya province);
3rd - state farm N24 in Karshi steppe.

At the same time, moisture changes before and after irrigation, field water balances as well as meteorological elements and crop growth and development processes were studied in these plots.

In collective farm Khalkabad water consumption rate and irrigation regime study was conducted with generally used procedure through selection of optimal pre-irrigation moisture in given calculated layer depending on crop development phase, i.e. moisture deficit in the calculated layer while changing capacity of the latter according to crop growth and development phases.

All experiments for irrigation regime study in Tadjikistan were conducted with generally used procedure by means of selection of different options of pre-irrigation moisture in given calculated layer depending on crop growth and development phases. However, these experiments have methodological differences:
first experiment - purely irrigation regime with different pre-irrigation moisture in given calculated layer against FFC by crop development phases;
second experiment - one range of moisture against FFC and changing the calculated layer within a big range;
third experiment - changing amount of mineral fertilizers depending on crop development phases.

Such differences in methodological approach complicate preparation of relevant recommendations.
In Tadjikistan two plots are located in the Vaksh valley of Hissar district, altitude is 600-800 m, and one plot - in Leninabad province on foothills.

1.2.2 Cotton irrigation regime

For the irrigation regime and water consumption rates study the research results from 7 projects were presented, where, as it was mentioned above, water consumption rate was studied with thermobalancograph. Experiments in other 4 pilot projects on cotton irrigation regime were conducted in the following way: in 2 plots (collective farm “Khalkabad”, Khorezm province - 1.06.U and collective farm “Kommunizm”, Kumgargansky district, Khatlan prov-

ince - 1.01Tad) - according to generally used methodology; and in other 2 plots (particularly, Lenin collective farm, Khodjekent district - 1.04) - study of mineral fertilizes portion effect on yield and water consumption rates. In plot of SPA "Zemledelie", Tadjikistan, 1.06Tad, influence of changes in given calculated layer on irrigation norm, depth of irrigation and on cotton yield was studied.

Due to this fact, analysis of research results is carried out with regard to these methodological differences and uses information from relevant publications.

Plot 1.06.U (collective farm "Khalkabad") is located within hydromorphous regime of soil formation with groundwater level of 0,5-1,5 m, while plot 1.01.Tad (collective farm "Kommunizm") is located within automorphous regime, where groundwater level does not influence soil moisture. In "Khalkabad" soils consist of stratified loam and clay sediments up to 1,5m and sands below. Collective farm "Kommunizm" has light gray soils. Experiments in both plots were conducted in 5 options: first - control one; second - selection of different pre-irrigation moisture against FFC with regard for rooting system growth from 0,5 to 1,0 m.

In "Khalkabad" (1.06.U) the following rates of pre-irrigation moisture against FFC were determined: 60-70-60% with the scheme of watering 1-2-0; 70-70-60% with the scheme 1-2-0; 70-80-60% with the scheme 2-3-0; and 80-80-60% with the scheme 2-3-0 (first watering is water recharge).

In collective farm "Kommunizm" (1.01.Tad) irrigation regime for the control option followed recommendations adopted in the Republic of Tadjikistan. Other options had the following moisture against FFC: 60-60-60%; and 70-70-80%, the last option used discharge mass curve recommended by Kh.D.Domuladjanov. Irrigation stream varied within 0,4-0,6l/sec in "Dehkanabad" plot and within 0,15-0,05l/sec in "Kommunizm" plot, while lengths of furrows were 100-150m and 200-250m, respectively.

In "Khalkabad" water was supplied within certain time periods with depth of irrigation equal to 700-1100 m^3/ha. Irrigation norms ranged by options from 3950 m^3/ha (2nd option: pre-irrigation moisture was 70-70-60% against FFC) to 4650 m^3/ha (5rd option: pre-irrigation moisture was 70-80-60% against FFC). Yield ranged from 3.2 c/ha (control option) to 44,4 c/ha (4th option: moisture was 70-80-60% against FFC).

In collective farm "Kommunizm" under automorphous conditions depth of irrigation ranged from 770 m^3/ha during germination-flowering up to 1230 m^3/ha during flowering-ripening. Irrigation norms varied from 7691 m^3/ha (70-70-60% against FFC) to 8483 m^3/ha (2nd option - 70-70-60% against FFC). In control option irrigation norm accounted for 8190 m^3/ha. Following the irrigation regime the lowest yield (31,5-35,5 cwt/ha) was gathered in control option, while the highest one (44,3 c/ha) was gathered in 4th option with the scheme of watering 70-70-60.

Research results in these two plots showed, that the best cotton irrigation regime was in 4th option, where pre-irrigation moisture was 70-80-60% against FFC, while in collective farm "Kommunizm" moisture was 80-80-60% against FFC and higher and more profitable production results were obtained (table 1.2.2.1a):

Table 1.2.2.1

Assessment of irrigation water expenses within the growing period per agricultural production unit (cotton)

Pilot's index	Soil-climatic zone	Water-allowance district	Salinity degree	Type of information	Field efficiency	Irrigation depth, m^3/ha	Irrigation norm, m^3/ha		Achieved productivity of irrigation water	Yield, c/ha	Yield increment, c/ha (%)	Water expenses per production unit	
							net	gross	expenses m^3/ha, (%)			net, m^3/c	gross, m^3/c
1.06. Uz.	Ц-1-А	III	strongly saline	ОВРО 70x80x60 К	0,82 0,76	700-1100 1080-1100	4235 4900	5200 6447	725 (17,3)	42-44,1 32,2-36	9,1 (21)	96,5 143,7	117,8 189,0
1.01.Tad	Ю-II-Б	III	non-saline	ОВРО 80x80x60 К	0,80 0,85	770-1230 790-1280	8499 8190	10653 9543	+1110 (+10,4)	42,7 33,4	9,3 (11)	199,0 245,2	250 285,7
1.04.Tad	Ю-II-А	II	non-saline	ОВРО	0,74	569	6260	8460	1790 (22,2)	32,7	1,6 (4,8)	191,4	258,7
				65x70x60 К	0,73	447	8050	11027		31,1		258,8	354,6
1.06.Tad	Ю-I-Г	III	non-saline	ОВРО 65x70x65	0,85	880-875	4423	5203	930 (17,8)	58,5	9,9 (16,9)	75,6	88,9

Pilot's index	Soil-climatic zone	Water-allo-wance district	Salinity degree	Type of informa-tion	Field effici-ency	Irriga-tion depth, m^3/ha	Irrigation norm, m^3/ha		Achieved pro-ducti-vity of irrigati-on water	Yield, c/ha	Yield incre-ment, c/ha (%)	Water ex-penses per production unit	
							net	gross	expen-ses m^3/ha, (%)			net, m^3/c	gross, m^3/c
				K	0,75	942-1159	4600	6132		48,4		95,0	126,7
Experi-mental base of KKNIIZ	Ц-А-1	IV	weakly saline	Experi-ment 70x80x60	-	900-1100	2361	-	-	36,4	-	650	-
Experi-mental base of KKNIIZ	Ц-А-1	IV	weakly saline	Experi-ment 70x80x60	-	900-1000	2657	-	-	32,0	-	83,0	-
Experi-mental base of KKNIIZ	Ц-А-1	IV	medium saline	Experi-ment 70x80x60	-	900-1200	1924	-	-	29,4	-	65,4	-

- the lowest irrigation norms of 4200-4250 m^3/ha, 4 waterings with depth of 700-1100 m^3/ha (irrigation interval - 18-23 days), are fixed under hydromorphous conditions;
- irrigation norm for automorphous conditions is 7691 m^3/ha: 11 waterings with depth of 770-1230 m^3/ha;
- high cotton productivity - 44,3-44,8 c/ha with the following specific water expenditures per yield unit: 96 m^3/c (net) and 117 m^3/c (gross) in "Khalkabad"; 191,4 m^3/c (net) and 258 m^3/c (gross) (table 1.2.2.1a);
- the least water losses for release and infiltration were about 21% in collective farm "Kommunizm" against 24-25% in control plots.

As a whole, 15-20% of irrigation water is saved under optimal irrigation regimes as compared with control options. At the same time, according to research results it was determined that the larger pre-irrigation moisture the smaller irrigation interval and more waterings. For instance, under optimal pre-irrigation moisture irrigation interval varies within 14-18 days while it is 25-28 days with moisture 60-60-60. The same situation is with number of irrigations. Under optimal pre-irrigation moisture there are 10-12 waterings in automorphous soils and 4-5 waterings in hydromorphous ones during growing period. The main advantage of frequent irrigation with small depth of 700-1100 m^3/ha for hydromorphous soils and with 770-1230 m^3/ha for automorphous ones is that supplied irrigation water is used mostly for moisture formation in the rooting zone. Under optimal irrigation regime soil moisture in the rooting zone (0-1m) riches 93-97% against FFC after irrigation, while in other options it exceeds FFC on 3-5% and more. In other words, in automorphous and hydromorphous soils frequent irrigation with small depth, even under ordinary furrow irrigation without stream regulation, creates favorable condition for controlling water flows with even moistening of irrigated area. In this case furrow irrigation technology meets moisture formation conditions in the rooting zone under surge and high frequency irrigation.

It should be noted that in both plots in options with pre-irrigation moisture different from an optimal one (the former is both higher and lower) lower cotton yields were gathered. The difference is 3-7 c/ha. Under very high pre-irrigation moisture cotton grows rapidly with more vegetation mass that affects yield increase due to such called obesity.

While organizing pilot studies on norm and depth of irrigation optimization the one of the important issues is selection of soil moistening depth with regard for growth and development of biomass and root system. In this respect results achieved in the pilot plot located in SPA "Zemledelie", Hissar district, Republic of Tadjikistan, is of big concern.

In this plot cotton irrigation regime was studied under pre-irrigation moisture 65-70-65% against FFC with ±2% deviation. Depth of moistening to establish date of irrigation was the following: 70-100-70 cm - control; 70-90-70 cm and 50-50-50 cm. Depth of moistening to establish depth of irrigation was 70-100-130 cm. Study on establishing dates of irrigation lasted 7 years. There were 5-7 waterings in control, 7 waterings under scheme of watering 70-70-70 cm and 5-7 waterings in other options. Irrigation norm in control option (70-100-70/100) ranged from 4708 m^3/ha (1963) to 6952 m^3/ha (1966), while depth of irrigation ranged from 942 m^3/ha to 1160 m^3/ha. In other options depth of irrigation was 700-900 m^3/ha, while irrigation norms were 5700-6700 m^3/ha (maximum) and 3500-4000 m^3/ha (minimum) (table 1.2.2.2).

The table shows, that the deeper moistening depth the more depth and norm of irrigation. Thus, in option with moistening depth of 50cm and 70cm depth and norm of irrigation vary

within 3500-5700 m^3/ha, while under depth of 100cm and 130 cm they account for 942-1344 m^3/ha and 4700-678 m^3/ha, respectively. According to amount of supplied irrigation water and depending on moistening depth certain results on irrigation regime effectiveness were achieved and are shown in table 1.2.2.3.

Table 1.2.2.2

Norm and depth of irrigation, surface and deep releases

Options	Year	Norm of irrigation, m^3/ha	Scheme of watering	Depth of irrigation, m^3/ha	Surface release, %	Deep release, %
Control 70-100-70 100	 1963(min) 1969(max)	 4708 6952	 1-4-0 1-4-1	 942 1159		
70cm 70	1963(min) 1965(max)	3516 5706	1-4-0 1-4-1	703 951		
50cm 70	1963(min) 1965(max)	3552 5716	1-4-0 1-4-1	710 953		
70cm 70	1966(min) 1965(max)	5161 5245	1-5-0 1-4-1	860 814	5-19 0-10	2,3 5,9
70-100-70 130	1965(min) 1966(max)	6529 6718	1-3-1 1-4-0	1306 1344	4-11 9-23	6,4 7,7

Table 1.2.2.3 shows, that the best results were achieved with moistening depth of 70-70-70cm/70cm and moisture was determined both by V.Kabayev and by weight method.

Another important issue is establishing an optimal nutrition regime for the highest crop productivity. This was studied in Lenin collective farm, Khodjekent district. The following pre-irrigation moistures were kept: 55-60-60% against FFC; 65-70-60% against FFC; and 75-80-60% against FFC. Nutrition regime was as follow: N150 P100-200, N250-350 P100-200. While analyzing data on norms and depth of irrigation and crop productivity formation it was found, that under conditions of the Northern Tadjikistan with thin stony gray-brown soils the optimal irrigation regime for middle-fiber cotton meets pre-irrigation moisture 65-70-60% of FFC and the following nutrition regime: N250-300; P100-200; K100-150 (table 1.2.2.4 and 1.2.2.5).

Table 1.2.2.3

Changes of yield, cotton water consumption depending on depth of calculated layer of soil moistening

Options	Time period (1960-1966)	Yield, c/ha	Irrigation norm	Total water consumption, m^3/ha	Release, %		Specific water expenses, m^3/c
					surface	deep	
Control	1963(min) 1966(max)	41,5 60,2	4708 6952	- 8350	34,5 17,5	6,9 6,7	113 115

Options	Time period (1960-1966)	Yield, c/ha	Irrigation norm	Total water consumption, m^3/ha	Release, %		Specific water expenses, m^3/c
					surface	deep	
$\frac{70x100x70}{100(см)}$ Weight method of moisture definition	average 1961-1966	48,7	5634	7349	26,8	7	121
$\frac{70(см)}{70(см)}$ Method of Karabayev	1963(min) 1966 average 1960-1966	43,5 57,3 49,3	3516 4976 4655	- 6790 6441	25,5 10,5 20,5	1,7 3,6 8,5	81 83 118
$\frac{50(см)}{70(см)}$ Method of Karabayev	1961 1966 average 1961-1966	42,2 59,5 49,9	3552 4967 4641	- 1203 6526	31,5 13 13,2	1,9 3,2 6,7	84 83 93
$\frac{70}{70}$ Weight method	1965 1966 average 1965-1966	58,4 58,70 58,55	5245 5161 5203	6199 6964 6584	0-10 12 11	5,9 2,3 4,1	90 88 89
$\frac{70x100x70}{130}$ Weight method	1965 1966 average 1965-1966	57,6 58,4 58,0	6529 6718 6624	7807 8240 8024	7,5 16,0 11,7	6,4 7,7 7,05	113 115 114

Table 1.2.2.4.

Water supply to the site, irrigation depth, number of waterings and irrigation norm

Irrigation regime	Fertilization background	Number of waterings	Irrigation scheme	Average irrigation depth, m^3/ha	Irrigation norm, m^3/ha	Total water consumption, m^3/ha
55-60-60	№ O^pO №150^p100-200 №250-350^p100-200	8 9 10	3-5-0 3-6-0 3-6-1	566 570 550	4525 5125 5507	5147 5747 6129
65-70-60	№O^pO №150^p100-200 №150^p-350^p100-200	10 11 11	4-6-0 4-7-0 4-7-0	537 543 569	5372 5975 6263	5930 6533 6821
75-80-60	№O^pO №150^p100-200 №150^p-350^p100-	14 17 18	6-8-0 6-11-0 6-12-0	460 463 447	6425 7867 8049	6932 8374 8556

	200					

Table 1.2.2.5.

Combination of irrigation regime and fertilizers application norm influence on row cotton yield on stony soils (after H.Domullojanov, V.Solodenko

# #	Fertilization norm, kg/ha		65-70-60 %		75-80-60 %	
	N	P_2O_5	average yield, c/ha	yield increment due to fertilization	average yield, c/ha	yield increment due to fertilization
1.	0	0	10,8	-	11,3	-
2.	150	0	26,8	16,0	26,6	15,3
3.	150	100	23,5	12,7	26,6	15,3
4.	150	150	24,8	14,0	26,5	15,2
5.	150	200	26,5	15,7	24,8	13,5
6.	250	0	29,3	18,5	30,8	19,5
7.	250	100	29,1	18,3	35,0	23,7
8.	250	150	27,1	16,3	33,7	22,4
9.	250	200	30,5	19,7	32,7	21,4
10.	350	0	30,0	19,2	31,0	18,7
11.	350	100	28,3	17,5	29,5	18,2
12.	350	150	30,1	19,3	32,5	21,2
13.	350	200	33,3	22,5	31,1	19,8

1.2.3 Cotton water consumption

Crop water consumption comprises water used to form biomass (productive losses) and water lost for evaporation from soil surface and depends on many factors, such as productivity level, fertilizers portion, groundwater level, etc. Correlation of transpiration and total water consumption varies with crop development phases: evaporation from soil much exceeds transpiration during the phase "germination-flowering" and opposite situation occurs from flowering till fruit formation and ripening.

There were various cotton water consumption rates depending on irrigation and nutrition regimes as well as on genetic type of soils.

Considering information on changes in water consumption rates formed during growing period it should be said that the largest value is achieved in plots located within automophous soils. Actual water consumption in NISTO is 8080 m^3/ha under furrow irrigation and 8070 m^3/ha under sprinkler irrigation. Out of these water consumption values portion of water supply is 90% (7275 m^3/ha) under surface irrigation and 49% (3990 m^3/ha) under sprinkler irrigation. The rest is covered by water storage formed both by recharge irrigation and by precipitation. According to water consumption 26 c/ha of cotton was gathered under furrow irrigation and 31 c/ha under sprinkler irrigation. There were 4 waterings with depth of 1653-2250 m^3/ha under surface irrigation and 7 waterings with depth of 430-630 m^3/ha under sprinkler irrigation. For pure transpiration, i.e. for biomass formation, 60% of water was used under furrow irrigation and 64% under sprinkler irrigation. The rest of water was used to cover unproductive losses (table 1.2.2.6).

Maximum cotton yields with minimum water consumption are gathered while moistening 70 cm layer. Minimum cotton yields with maximum water consumption are gathered while moistening 100 cm and 50 cm layer.

In other plots of automorphous range, located in Hissar valley and Khodjekent district, maximum cotton yields (from 35,5 c/ha in thin stony soil to 58,5 c/ha in dark gray soil) are gathered under water consumption varied within 6584 (1.06.Tad)-10800 (1.01.Tad) m^3/ha. In other options of irrigation regime, where cotton yield does not exceed 32-33,4 c/ha (excluding pilot plot 1.06.Tad with yield of 48,7 c/ha), water consumption is 7349-9791 m^3/ha. It should be said, that under condition of automorphous range crop water consumption is covered mainly through water supply. Water supply portion in water consumption accounts for 92-98%, the rest portion is precipitation. Out of total water consumption 70-76% is used for transpiration and 24-30% is lost with evaporation from soil surface (table 1.2.2.6).

Under conditions of semi-automorphous and hydromorphous soils cotton water consumption decreases. Under conditions of semi-automorphous soil in state farm N24 of Karshi steppe water consumption during initial period of development accounted for 8050 m^3/ha and 10350 m^3/ha, of which only 73-77% were used efficiently. Low yields are accounted by repeated soil salinization.

Table 1.2.2.6

Actual cotton water consumption and its distribution on the elements

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Code	Location and soil type	Water consumption under min and max yield, m^3/ha		Water consumption distribution on the elements in percentage of total volume			
		max	min	water stock max / min	water supply max / min	ground water max / min	transpiration share
1.01.Uz.	NISTO. Tashkent province, automorphous, furrow, sprinklers		8080(26ц/га) – 8070(31ц/га) –	10 / 51	90(7275) / 49(3990)	- / -	60 / 64
1.02. Uz.	state farm G.Gulyam, half-automorphous (2-3 m)	8170(32ц/га) –	7830(24ц/га –	28	60	12	67
1.06. Uz.	state farm Khalkabad, hydromorphous	5370(44,3ц/га) 70x80x70	5618(35,5ц/га) 60x70x80	13 / 14,5	76,0 / 76,1	11,0 / 10,6	- / -
1.08. Uz.	state farm # 24 (Karshi steppe), half-automorphous	8050(28ц/га) –	10350(11ц/га) –	- / -	100 / 100	- / -	73-77
1.01.Tad.	collective farm «Kommunizm», automorphous	10653(42,7ц/га) 70x70x60	9791(33,4ц/га) 60x60x60	1,4 / 4,8	98,6 / 95,2	- / -	73,5 / 70,2
1.04.Tad.	collective farm «Lenin», automorphous	6821(35,2ц/га) 65x70x60	8556(32,3ц/га) 75x80x60	8,2 / 6,0	91,8 / 94	- / -	76 / 72
1.06.Tad.	SPA «Zemledelie», automorphous	6584(58,5ц/га) 65x70x65 (x)	7349(48,7ц/га 65x70x65 (x)	- / -	- / -	- / -	- / -

Note: All tests were conducted under the same regime of pre-irrigation soil moisture with change of calculated layer.

The same situation is observed when having 8770 m^3/ha and 7830 m^3/ha of actual water consumption there is effect of groundwater. Groundwater portion in water consumption is 14-15%. The highest cotton yields (38-44 c/ha) were gathered under hydromorphous soils in collective farm “Khalkabad”, Khorezm province. In the plot actual water consumption varied within 5350-5500 m^3/ha (average is 5370 m^3/ha) under maximum yield and was more than 5600 m^3/ha with yields below 40 c/ha. In total water consumption water supply portion is 70-78%, while groundwater portion is 10,6-11%. The rest is covered through water storage formed during leachings ranging from 3500 m^3/ha to 7000 m^3/ha (average is 5000 m^3/ha).

Leaching irrigation regime and leachings before vegetation provide negative field water-salt balance with 15-23 t/ha of removed salts and optimal soil water-salt regime.

At the same time, water storage and groundwater use portion in positive part of the balance are increasing. Due to this fact yield in the balance decreases and accounts for 70-75%. In negative part of the balance drainage modulus (effluent) is of the big importance and ranges from 15% to 30-35%.