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# Investigating the advantages of sub-surface irrigation method in winter wheat productivity

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**Abstract**. Studies have found that the sub-surface method of winter wheat irrigation halves the number of irrigations and reduces the crop water consumption by 970-1015 m3, inter-row treatment procedures, and the consumption of fuels and lubricants. The productivity of winter wheat grain in comparison with the control (without sub-surface irrigation) is increased by 0.9 t/ha, environmental pollution from agrochemicals is prevented. The sub-surface irrigation method in conditions of meadow soils with a groundwater level of 1-3 m and mineralization of 1-3 g/l experimented in this paper and the influence of this method on the development dynamics of winter wheat (Polovchanka) on obtaining high yields was also tested. The number of irrigations increased to 6-7 times instead of 3-4. Therefore, on such lands, we recommend while designing the drainage system, the designers should plan the depth of the drains no more than 1.5 meters. Sub-surface irrigation is a temporary closure of closed drainage during the growing season of winter wheat, leading to an increase in groundwater level (80-130 cm), thereby leading to an increase in the moisture reserve in the soil.

## 1. Introduction

In today's contemporary society, the area of agricultural land undergoing soil degradation is increasingly growing in the world. In particular, 56% of the global arable land is under the risk of water erosion, following by 28% from wind erosion, 12% suffering soil nutrient content reduction and, soil salinization and contamination, and lastly, 4% under swamping and shrinkage. Each year, as a result of soil threats, roughly 7 million hectares of arable land become agriculturally unusable, and, in 80 countries of the world, there is a shortage of fresh water [10-13].

In several prestigious research centers and higher education institutions of the world such as the United States Department of Agriculture (USDA), the Food and Agriculture Organization (FAO), Colorado State University, Institute of Cotton Research (ICR, CAAS), Shehezi University (China), Stockholm Technology University (Sweden), International Water Management Institute (IWMI), Australian Cotton Research Institute, Indian Agricultural Research Institute (India), the Tashkent Institute of Irrigation and Agricultural Mechanization Engineers (Uzbekistan) has been undertaking scientific research on the development of a sub-irrigation method in agriculture following soil, climate, reclamation, hydrogeological and economic conditions [14 -18].

In irrigated agriculture, the ameliorative condition of land mainly depends on the level of groundwater, salinization of the soil, and air temperature. According to the results of recent studies, there are different contradictory opinions of scientists at what level groundwater must be held during the growing season. They found that to prevent the vulnerability of secondary salinization on saline and slightly saline areas, keeping the groundwater level below the critical level by building deep drains. [1, 2, 3, 4, 5]. Also, depending on soil conditions, keeping the groundwater level of 1.0-1.5 m is highly recommended to save watering rates [6, 7].

In recent years, under lysimetric conditions, high yields of raw cotton and alfalfa have been harvested by maintaining the groundwater level at a depth of 1 m. Maintaining the groundwater level deeper than 1 m (1.5, 2.0, and 2.6 m) may lead to a decrease in crop yields [8, 9, 12]. One of the most important factors adversely affecting Uzbekistan's agricultural sector and environmental protection is soil salinization. In Uzbekistan, over 2.0 million hectares or about 50% of agricultural land are vulnerable to soil salinization in various levels. Soil salinization is the reason behind a number of the following factors: the cataclycmic context of the Aral Sea; the unsustainable management of land and water resources; global climate change and other natural and human-induced factors. Another main cause of soil salinization is the filtration of a large number of water resources of conventional irrigation systems. The overuse of irrigation water in the crop yards leading to the increase in groundwater levels causes constant evaporation of groundwater over time.

About 50% of the average annual water resources (4.2 – 4.6 billion m3) used in the irrigated areas of Bukhara province, 1.9 – 2.2 billion m3 is wasted due to the run-off from irrigated areas using collector-drainage systems. This run-off mainly occurs in regards to the traditional irrigation systems (i.e. collector and drainage), filtrating irrigation water during the growing and leaching seasons. The collector-drainage water is to some extent mineralized and when reused in agriculture during the water shortage period, this leads to soil salinization processes. Consequently, using highly mineralized collector-drainage water negatively affects crop development and reduces crop productivity by 30-80%. The used water resources in Bukhara province are almost completely delivered through the Amu Darya River by two, three, and in some areas, four pump station elevations which is economically inappropriate. Therefore, this research is dedicated to contribute to unraveling the land degradation issues by promoting careful and efficient water use [15].

Moisturizing the soil enables the crop nutrient uptake, while microorganicms accelerate the mineralization of organic substances and increases solubility as well as improving the use of fertilizers. Thus, soil fertility is increased [16].

Scientists and agricultural experts continuously aim to search for new and up-to-the-date methods of irrigation, appropriate agricultural techniques, and technologies for crops, tackling soil salinization issues and promoting waterlogging in irrigated lands [14, 15].

In the agricultural land of Uzbekistan, i.e. in the Ferghana Valley, during the growing season of agricultural crops, there is not sufficient water for irrigation. To reduce the amount of irrigation water and the number of irrigation, temporary blocking the open and closed drainages is essential during the growing season [17, 18].

The goal of our study is to investigate the implementation of sub-surface irrigation (blocking the drainages) to raise the level of low-mineralized groundwater and thereby reducing the number of irrigation and naturally increasing the yield of crops

## 2. Materials and methods

The sub-surface irrigation method in conditions of meadow soils with a groundwater level of 1-3 m and mineralization of 1-3 g/l was experimented in this paper and the influence of this method on the development dynamics of winter wheat (Polovchanka) on obtaining high yields was also tested.

Moreover, to validate our results, field experiments were carried out following the methods of “Methods of State sort testing of agricultural crops”, “Methods of agrochemical, agrophysical and microbiological studies in irrigated cotton areas”, “Methods of field experiments in the cotton yard. Statistical analysis of experimental data was carried out by following the method of B. D. Doshekhova in Microsoft Excel.

## 3. Results and discussion

With a groundwater depth of 1.0 m on soils consisting of physical clay, the growing speed of crop seed can exceed 0.1 cm/hour, if deeper than 25 cm- 0.10-0.12 cm per hour; at a depth of 50 cm-0.05

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cm per hour; upon reaching 100 cm – 0.012 cm per hour. On clayey soils at the beginning, 8-12 cm per hour; at 25 cm – 1. 7 cm per hour; at a depth of 50 cm – 0.88 cm per hour and 100 cm – 0.33 cm per hour; on sandy soils, the ascent rate is very high and almost reaches 90 cm.

During sub-surface irrigation, irrigation water, fuel, and lubricants for inter-row treatment are reduced by 50% compared to surface furrow irrigation, and the ecological balance of the environment is ensured.

On arable land with groundwater salinity of 1-3 grams per liter, the existing collector-drainage network is damped from the beginning of the sowing period until the first half of August. Simultaneously, the groundwater level reaches the optimum value (1.0-1.3 m). After closing the collector-drainage network, the depth of the groundwater can be measured (capillarity may be different depending on the composition of the soil-soil), additional water must be delivered to the drain to align the growth and development of cotton. Although similar studies were undertaken earlier, however, on particular lands located on the same array, on the same collector-drainage network system with several farms in the conditions of the Ferghana region, the studies claimed that the results of the studies can be envisaged to extend to various crops.

Vertical movement of excessive soil moisture with a height of 1.0 m, it will take 15 hours for soils consisting completely of physical clay and about 3 hours for loamy soils and for horizontal movement of soil moisture over a distance 50-75 m from the drainage system reaches to 9-10 hours respectively.

In terms of soil and climate zoning, the Ferghana experimental station, where we conducted the experiment, is located in the hydro-geologically dispersed zone and soil flow directed from south to north.

The soil of the study area is a meadow, slightly saline with spots of medium salinity in agricultural fields and highly saline on the fallow. The agrochemical characteristics of the soil were given in Table 1.

**Table 1.** Agrochemical characteristics of the *soils of the experimental area*

| Depth (cm) | Gross soil solution contents (%) | | | | Additives mg per kilo of soil. | | |
|---|---|---|---|---|---|---|---|
| | Humus | N | P | K | N-$NO_3$ | $P_2O_5$ | $K_2O$ |
| **M-8/2 (control)** | | | | | | | |
| 0-30 | 2.07 | 0.216 | 0.210 | 1.425 | 1.8 | 32.4 | 290 |
| 30-50 | 1.51 | 0.161 | 0.162 | 1.261 | 1.3 | 10.1 | 276 |
| **M-8/3 (experimental)** | | | | | | | |
| 0-30 | 2.03 | 0.215 | 0.215 | 1.461 | 1.8 | 36.2 | 276 |
| 30-50 | 1.53 | 0.165 | 0.160 | 1.291 | 1.2 | 9.8 | 258 |

From the data illustrated in Table 1, the soils, rich of humus, are sufficient to seed the agricultural cropland accounts for 2.03 – 2.07% out of the total soil contents. The gross content of soil solution consisted of 0.216 – 0.215% nitrogen; 0.162 – 0.215% phosphorus; 1.261 – 1.461% potassium. Regarding the soil additives, the nitrate content is classified as low-income, the average for phosphorus, and the average for potassium. Higher wheat yields require high rates of nitrogen fertilizer.

According to the mechanical composition of the soil, clay, and heavy loam, the content of the physical clay fraction (0.01 mm) ranges from 44.8 to 78.1% (Table 2).

**Table 2.** The mechanical composition of the soil, % by the weight of soil

| Layer, cm | Fractions, mm | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1-0.25 | 0.25-0.1 | 0.1-0.05 | 0.05-0.01 | 0.01-0.005 | 0.005-0.001 | 0.001 | Physical clay |
| 0-30 | 1.2 | 2.9 | 2.5 | 29.0 | 12.5 | 24.3 | 27.6 | 64.4 |
| 30-42 | 0.5 | 1.7 | 0.2 | 20.7 | 12.8 | 27.2 | 28.9 | 68.9 |
| 42-60 | 0.5 | 1.3 | 0.9 | 19.2 | 31.0 | 19.0 | 33.1 | 78.1 |
| 60-77 | 2.3 | 6.1 | 5.6 | 30.5 | 12.4 | 22.9 | 20.2 | 55.0 |
| 80-90 | 5.2 | 10.1 | 5.4 | 34.6 | 11.9 | 15.3 | 17.6 | 44.8 |
| 120-130 | 0.4 | 1.2 | 2.2 | 21.1 | 9.8 | 29.9 | 35.4 | 75.1 |

The volumetric mass of the soil layer varies between the range of 1.24-1.32 g/cm in the layer, 0–30–1.31 g/cm, following 0–50 cm – 1.35 g/cm, and 0–100–1.37 g/cm, i.e. optimal for wheat growth and development.

The minimum soil moisture capacity, 26.0-27.0% by weight of the soil, was determined during the study (Table 3).

**Table 3.** Bulk mass and minimum soil water capacity of the experimental area

| In the soil layer, cm | Bulk weight, g/cm3 | Soil moisture capacity, % |
|---|---|---|
| 0-10 | 1.24 | 26.9 |
| 10-20 | 1.32 | 26.9 |
| 20-30 | 1.38 | 26.4 |
| 30-40 | 1.42 | 26.1 |
| 40-50 | 1.40 | 26.5 |
| 50-60 | 1.36 | 27.0 |
| 60-70 | 1.33 | 26.7 |
| 70-80 | 1.38 | 25.8 |
| 80-90 | 1.42 | 25.5 |
| 90-100 | 1.43 | 25.4 |
| 0-30 | 1.31 | |
| 0-50 | 1.35 | |
| 0-100 | 1.37 | |
| x) 0-30 | | 26.7 |
| 0-50 | | 26.5 |
| 0-70 | | 26.5 |

Groundwater level of the experimental area: The groundwater level for the massives M-8/2 (control), M-8/3 (experimental), and M-8/4 (experimental) fluctuated throughout the given period.

The groundwater level changed every month, especially after irrigation, the groundwater level rose sharply. The average annual groundwater level at M-8/2 (control) is -150 cm, at M-8/3 (experimental) -160 cm, and M-8/4 (experimental) -152 cm.

Mineralization of groundwater and drainage water: Mineralization of groundwater in the experimental field was given in Table 4.

**Table 4.** Mineralization of ground and drainage water, in liters

| Arrays | $HCO_3$ | Cl | Dissolved solids |
|---|---|---|---|
| M-8/2 (control) | 0.316 | 0.108 | 3.452 |
| M-8/3 (experimental) | 0.357 | 0.127 | 3.058 |
| M-8/4 (experimental) | 0.413 | 0.155 | 3.752 |

From the above-illustrated data, the salinity of groundwater over massives ranged from 3.058 to 3.752 grams per liter. The massives were less mineralized on M-8/3 (experimental), and more on M-8/4.

The level of mineralization of drainage water: on M-8/2 (control), in the spring 4.70 grams per liter, annual average 5.06 grams per liter, on M-8/3 (experimental) in the spring 4.63 grams per liter, an average of 4.51 grams per liter over the year. The dissolved solids for the year ranged from 3.08 to 7.43 grams per liter on M – 8/2 (control) and from 3.09 to 6.46 grams per liter on M-8/3 (experimental). In the non-growing season, the level of mineralization is always greater, but during the growing season is contrarily less (3.08-3.09 grams per liter)

Comparing the mineralization of groundwater in the territory of the Ferghana branch to ours, we assume that groundwater from strong mineralization turned into low-mineralized.

Salt regime of the soil: The content of soil water-soluble salts of the experimental area was given in Table 5 below.

**Table 5.** The content of water-soluble salts in the soil, %

| Furrow length,m | Depth, cm | In the beginning of the vegetation | | | In the end of vegetation | | |
|---|---|---|---|---|---|---|---|
| | | $HCO_3$ | CL | Solid residue | $HCO_3$ | Cl | Solid residue |
| **M-8/2 (control)** | | | | | | | |
| 50 | 0-30 | 0.024 | 0.005 | 0.236 | 0.021 | 0.003 | 0.244 |
| | 30-50 | 0.021 | 0.005 | 0.362 | 0.021 | 0.003 | 0.552 |
| | 50-70 | 0.016 | 0.004 | 0.848 | 0.020 | 0.005 | 0.642 |
| | 70-100 | 0.014 | 0.005 | 1.348 | 0.019 | 0.005 | 0.914 |
| | 100-150 | 0.013 | 0.005 | 1.538 | 0.014 | 0.003 | 1.066 |
| 100 | 0-30 | 0.022 | 0.006 | 0.418 | 0.025 | 0.003 | 0.316 |
| | 30-50 | 0.018 | 0.003 | 0.492 | 0.021 | 0.003 | 0.420 |
| | 50-70 | 0.014 | 0.004 | 1.308 | 0.022 | 0.003 | 0.906 |
| | 70-100 | 0.012 | 0.004 | 1.486 | 0.024 | 0.005 | 1.140 |
| | 100-150 | 0.012 | 0.005 | 1.688 | 0.019 | 0.005 | 1.590 |
| 150 | 0-30 | 0.028 | 0.004 | 0.300 | 0.020 | 0.005 | 0.398 |
| | 30-50 | 0.022 | 0.004 | 0.402 | 0.019 | 0.005 | 0.442 |
| | 50-70 | 0.018 | 0.003 | 0.654 | 0.018 | 0.004 | 0.711 |
| | 70-100 | 0.011 | 0.003 | 1.384 | 0.015 | 0.005 | 1.032 |
| | 100-150 | 0.011 | 0.003 | 1.460 | 0.012 | 0.005 | 1.290 |
| **M-8/3 (experimental)** | | | | | | | |
| 50 | 0-30 | 0.025 | 0.007 | 0.200 | 0.020 | 0.005 | 0.216 |
| | 30-50 | 0.022 | 0.005 | 0.210 | 0.019 | 0.005 | 0.286 |
| | 50-70 | 0.021 | 0.003 | 0.230 | 0.018 | 0.004 | 0.332 |
| | 70-100 | 0.020 | 0.003 | 0.400 | 0.018 | 0.004 | 0.415 |
| | 100-150 | 0.014 | 0.004 | 1.310 | 0.015 | 0.004 | 1.144 |
| 100 | 0-30 | 0.081 | 0.003 | 0.206 | 0.019 | 0.003 | 0.266 |
| | 30-50 | 0.020 | 0.004 | 0.486 | 0.020 | 0.004 | 0.560 |
| | 50-70 | 6.014 | 0.003 | 1.976 | 0.019 | 0.004 | 0.850 |
| | 70-100 | 0.013 | 0.003 | 1.172 | 0.016 | 0.003 | 0.988 |
| | 100-150 | 0.009 | 0.003 | 1.404 | 0.011 | 0.004 | 1.290 |
| **Medium M-8/2 (control)** | | | | | | | |
| | 0-30 | 0.024 | 0.005 | 0.342 | 0.022 | 0.004 | 0.319 |
| | 30-50 | 0.020 | 0.004 | 0.425 | 0.020 | 0.004 | 0.471 |
| | 50-70 | 0.016 | 0.004 | 0.937 | 0.020 | 0.004 | 0.753 |
| | 70-100 | 0.012 | 0.004 | 1.404 | 0.019 | 0.005 | 1.287 |
| | 100-150 | 0.012 | 0.004 | 1.562 | 0.015 | 0.004 | 1.315 |
| **Medium M-8/3 (experimental)** | | | | | | | |
| | 0-30 | 0.023 | 0.005 | 0.203 | 0.020 | 0.004 | 0.231 |
| | 30-50 | 0.021 | 0.004 | 0.348 | 0.019 | 0.005 | 0.420 |
| | 50-70 | 0.017 | 0.004 | 0.603 | 0.019 | 0.004 | 0.542 |
| | 70-100 | 0.017 | 0.003 | 0.786 | 0.017 | 0.104 | 0.715 |
| | 100-150 | 0.012 | 0.003 | 1.375 | 0.013 | 0.004 | 1.217 |

The soils of the experimental area were slightly saline and the type of soil salinity was sulfate-chloride. Thus, as a result of land reclamation for a long period in solonchak soil type and highly saline soils, they turned into not and slightly saline areas.

The effect of overlapping drainage on the level and mineralization of groundwater: The groundwater level in the observation wells located in the experimental area were shown in Table 6. As a result of overlapping drains, the groundwater level has risen and this rise can be observed especially in May at a distance of 25 m and 50 m from the drainage system.

**Table 6.** Groundwater level in the observation wells of the experimental area, in centimeters

| Date of observation | From cross-over places, m | M-8/2 (control) | | | M-8/3 (experimental) | | |
|---|---|---|---|---|---|---|---|
| | | 50 m | 100 m | 150 m | 25 m | 50 m | 100 m |
| 15.04 | 50 | - | - | - | - | - | - |
| | 100 | - | - | - | - | - | - |
| | 150 | watering | | | - | 170 | 175 |
| | Average | - | - | - | - | 170 | 175 |
| 30.04 | 50 | - | - | - | - | - | - |
| | 100 | - | - | - | - | - | - |
| | 150 | 117 | 131 | 168 | - | 138 | 164 |
| | Average | 117 | 131 | 168 | - | 138 | 164 |
| 15.05 | 50 | 165 | 182 | 193 | 74 | 105 | 148 |
| | 100 | 162 | 175 | 180 | 68 | 105 | 150 |
| | 150 | 171 | 175 | 186 | 84 | 110 | 156 |
| | Average | 166 | 177 | 186 | 75 | 107 | 151 |
| 31.05 | 50 | 163 | 156 | 172 | 132 | 148 | 158 |
| | 100 | 156 | 169 | 182 | 138 | 152 | 162 |
| | 150 | 158 | 171 | 178 | 128 | 142 | 160 |
| | Average | 159 | 164 | 177 | 133 | 147 | 160 |

Groundwater mineralization was shown in Table 7.

The mineralization level of groundwater on May 1 was at the control site of 5.49 grams per liter, and on June 1 it was recorded as 4.59 grams per liter. the content of water-soluble salts increased by 1 gram per liter.

In the experimental area, the groundwater mineralization ranged from 5.77 to 4.95 grams per liter.

Consequently, the rise in groundwater had almost no effect on its mineralization.

Note: The design of the holes in the pipe: 3-2.3; 8-1, 8-2, 8-3, 9-3, 9-4, 9-5, 6-8 mm were staggered; the pipe has 6 holes; located at the bottom, and 4 holes located at the top.

The effect of drainage overlap on changes in soil moisture: The dynamics of soil moisture were given in Table 8 below. The overlapping of drainages strongly affected the soil moisture, especially at distances of 25 and 50 m from the drainage system.

**Table 7.** Groundwater mineralization in observation wells, in grams per liter

| Furrow length, m | In the beginning of the vegetation | | | In the end of the vegetation | | |
|---|---|---|---|---|---|---|
| | $HCO_3$ | Cl | Dissolved solids | $HCO_3$ | Cl | Dissolved solids |
| | | | **M-8/2 (control)** | | | |
| 50 | 0.365 | 0.081 | 4.83 | 0.182 | 0.061 | 4.59 |
| 100 | 0.347 | 0.098 | 5.45 | 0.283 | 0.067 | 4.16 |
| 150 | 0.265 | 0.104 | 6.20 | 0.265 | 0.064 | 5.02 |
| **Average** | **0.326** | **0.094** | **5.49** | **0.243** | **0.064** | **4.59** |
| | | | **M-8/3 (control)** | | | |
| 25 | - | - | - | 0.194 | 0.077 | 5.50 |
| 50 | 0.324 | 0.111 | 5.62 | 0.200 | 0.077 | 4.39 |
| 100 | 0.277 | 0.067 | 5.93 | 0.182 | 0.077 | 4.97 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Average** | **0.300** | **0.089** | **5.77** | | **0.192** | **0.077** | **4.95** |

**Table 8.** Dynamics of soil moisture, %

| Furrow length, m | In the soil layer, cm 0-10 | 10-20 | 20-30 | 30-50 | 50-70 | 70-100 |
|---|---|---|---|---|---|---|
| **M-8/2 (control) 10.04** | | | | | | |
| 50 | 17.2 | 18.4 | 19.4 | 22.0 | 25.7 | 26.4 |
| 100 | 18.4 | 19.2 | 19.8 | 21.8 | 24.6 | 26.8 |
| 150 | 17.0 | 18.4 | 19.2 | 21.7 | 25.2 | 27.2 |
| **M-8/3 (experimental) 14.04** | | | | | | |
| 50 | 17.3 | 18.8 | 20.2 | 21.4 | 23.8 | 26.6 |
| 100 | 17.4 | 18.2 | 21.2 | 22.0 | 22.6 | 25.8 |
| **M-8/2 (control) 01.05** | | | | | | |
| 50 | 15.6 | 17.2 | 18.4 | 20.2 | 24.4 | 26.3 |
| 100 | 16.2 | 17.8 | 18.6 | 21.0 | 25.2 | 26.8 |
| 150 | 15.8 | 18.2 | 18.8 | 22.6 | 25.0 | 25.9 |
| **M-8/3 (experimental) 08.05** | | | | | | |
| 25 | 17.6 | 18.4 | 21.2 | 23.5 | 24.6 | 26.8 |
| 50 | 17.2 | 17.9 | 20.4 | 24.6 | 24.8 | 26.6 |
| 100 | 16.2 | 18.0 | 20.2 | 25.4 | 25.8 | 27.2 |
| **M-8/2 (control) 15.05** | | | | | | |
| 50 | 14.9 | 15.2 | 15.5 | 16.6 | 18.5 | 19.3 |
| 100 | 14.2 | 14.6 | 15.0 | 15.4 | 17.6 | 18.4 |
| 150 | 12.3 | 16.8 | 16.9 | 17.8 | 18.9 | 20.6 |
| **M-8/3 (experimental) 31.05** | | | | | | |
| 25 | 12.6 | 15.1 | 16.1 | 17.1 | 18.7 | 23.6 |
| 50 | 11.9 | 13.5 | 14.4 | 16.4 | 18.3 | 22.4 |
| 100 | 10.7 | 11.4 | 13.8 | 15.1 | 17.7 | 19.2 |

On May 30, in the checkpoint where from the drainage of 25 m, the soil moisture in the 0-10 cm layer was 12.6%, and at a drainage distance of 100 m, 10.7%, following the layers of 10-20 cm; 20-30; 30-50; 50-70 and 70-100 cm, 15.1%, and 11.4%; 16.1 and 13.8%; 17.1% and 15.1%; 18.7 and 17.7%; 23.6% and 19.2% of the mass of soil respectively.

Comparing all periods of observation of the soil moisture, soil moisture was higher in the sub-surface irrigation method than the surface furrow irrigation.

The effects of drainage overlap on the irrigation norms, timing, and iteration of wheat irrigation: The water delivered to the experiments was calculated using ‘Chippoletti’ spillways with a threshold width of 50 cm, and discharges with a threshold width of 25 cm.

Wheatgrass was irrigated at 70-70-70% of Ultimate Field Moisture Capacity (UFMC) to ensure the average soil moisture in the experimental areas should be 18.6% of the soil mass.

During the growing season, the control area was irrigated 4 times, and the experimental area 3 times (Table 9).

The irrigation rate in the control area was 4153.2 m3 per hectare and in the pilot area 2871.8 m3 per hectare.

As a result of sub-surface irrigation, the number of irrigations decreased by one time, and 1281.4 m3 per hectare of water saved.

**Table 9.** The number and norms of wheat irrigation in the experimental area, $m^3$/ha

| Array | Number of irrigations 1 | 2 | 3 | 4 | Irrigation rate |
|---|---|---|---|---|---|
| M – 8/2 | 918.2 | 960.4 | 1206.2 | 1068.4 | 4153.2 |
| M – 8/3 | 830.4 | 940.6 | 1100.8 | - | 2871.8 |
| | | | | | Total water saved: **1281.4 $m^3$/ha** |

When applying the sub-surface irrigation method for winter wheat irrigation for 3 years, an average of 3365 m3 per hectare was used, or 998 m3 per hectare less water used in comparison with the control area, and 970-1015 m3 per hectare less water in the Ferghana area (Fig. 1).

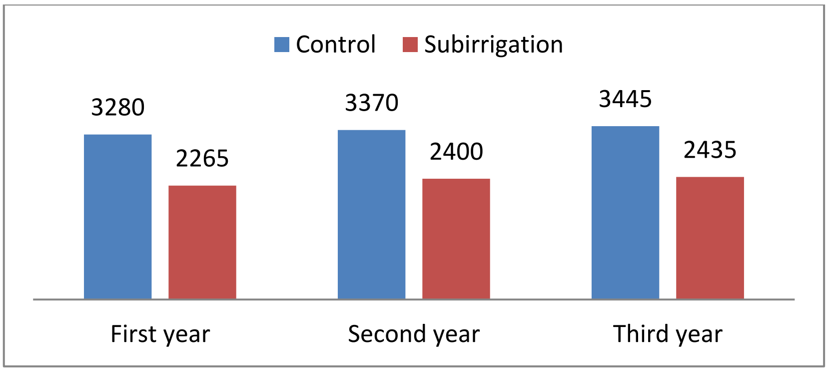


**Figure. 1.** Water consumption during the growing season of winter wheat, $m^3$/ha

The effects of drainage overlap on the growth, development, and productivity of wheat: The performance indicators of the experiment were shown in Table 10. In the surface method of irrigation, all indicators of yield were much less than in the sub-surface irrigation. In the surface method of irrigation, there was no regularity of yield indicators. The number of stems per one m2 ranged from 397 to 451 pieces. The height of the stems was 90.0-95.3 cm and the number of grains in one plant ranged from 36.7 to 40 pieces. The weight of 1000 Seeds also ranged from 36.8 to 37.4 gram, while grain yield from 63.7 to 65 kg per ha and straw from 87.3 to 99.2 kg per ha. The data obtained were mathematically reliable.

**Table 10.** Experiment productivity indicators

| Options | Weight of stems, grams. | Number of stems, 1 $m^2$/pcs. | Height of the stems, cm | Number of grain | Weight of 1000 seeds | Grain weight, 1$m^2$/g | Grain harvest, kg per ha | Harvest straw, kg/ha |
|---|---|---|---|---|---|---|---|---|
| **M-8/2 (control)** | | | | | | | | |
| 50 | 1550.0 | 397.0 | 90.0 | 39.0 | 37.4 | 637.0 | 63.7 | 91.3 |
| 100 | 1523.0 | 395.3 | 95.3 | 40.0 | 37.4 | 650.0 | 65.0 | 87.3 |
| 150 | 1633.0 | 451.0 | 94.7 | 36.7 | 36.8 | 641.0 | 64.1 | 99.2 |
| **Average** | **1568.9** | **414.4** | **93.3** | **38.6** | **37.2** | **642.7** | **64.3** | **92.6** |
| **M-8/3 (experimental)** | | | | | | | | |
| 25 | 2200.0 | 671.0 | 101.7 | 38.7 | 38.6 | 803.0 | 80.3 | 139.7 |
| 50 | 2100.0 | 664.0 | 98.3 | 36.7 | 37.6 | 733.0 | 73.3 | 136.7 |
| 100 | 1833.3 | 619.7 | 99.0 | 34.7 | 37.4 | 673.0 | 67.3 | 116.0 |
| **Average** | **2044.4** | **651.6** | **99.7** | **36.7** | **37.9** | **736.7** | **73.6** | **130.8** |

In the layers where sub-surface irrigation was carried out, depending on the drainage distance, the yield indicators were different and regular. The highest productivity was at a distance of 25 m from the drainage system.

At 25 m from the drainage, the weight of the stems with spikes was 1 m2-2200 gr. The number of stalks was 671 pieces. The height of the stalks was 101.7 cm whereas the number of grains in one spike was 38.7. Also, the weight of 1000 seeds was 38,6 grams and the grain weight was 803 grams. The yield was reached to 8 tons per ha and straw yield was approximately 14 tons per ha.

The number of grains in one branch closer to the drainage was 39 pieces and further (100m) was 35 pieces. The weight of 1000 seeds was 38.6 and 37.4 grams, respectively. The yield of straw was 139.7 and 116, tons per ha.

The average yield of wheat grain, according to the experimental area, in M-8/2 (control) was 6.4 tons per ha, and in the experiment of sub-surface irrigation 7.6 tons per ha which was 9.3 kg per ha more. (See in Fig. 2)

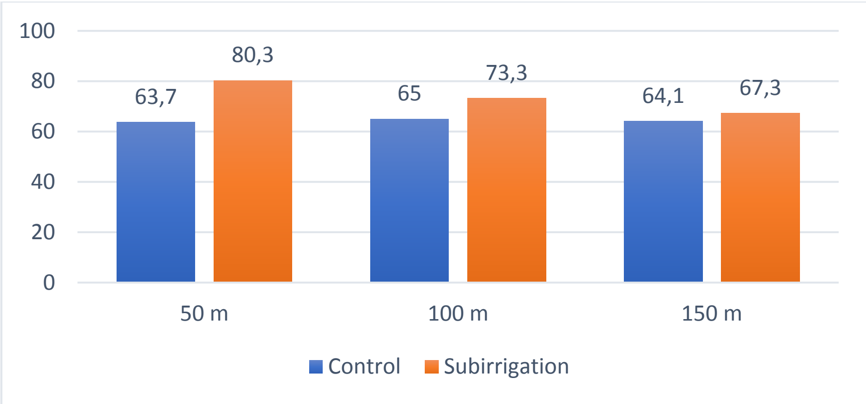


**Figure 2.** Productivity winter wheat grain, centner/ha

Normal and constant moistening of the soil (i.e. raising the groundwater level by sub-surface irrigation 120-130 cm from the soil surface) contributed to an increase in wheat yield indicators, specifically an increase in grain yield.

Based on the foregoing, to determine the reclamation, irrigation, environmental and economic efficiency of sub-surface irrigation, long-term studies were carried out on the territory of the Sardor collective farm located in Shahrikhan district of Andijan province, the Navbahor collective farm of the Tashlak district, the Kuvinsky collective farm of Uzbekistan. The Navoi collective farm of Yazyavan district, the Yangi Kurgan collective farm of Buvaida district, the Dustlik collective farm of Besharyk district of Fergana province, the Tozhi-Islam farm in Shavat district in Khorezm province, the Sh. Rashidov farm in Kasbi district of the Kashkadarya province. In these areas, numerous scientific experiments were also carried out within several years, which were identified that the number of irrigations decreased1.0-1.5 times and more, the flow of irrigation water decreased, the cotton productivity in comparison with the control (without sub-surface irrigation) increased by 0.15-0.25 ton per ha and the wheat crop increased by 0.4-0.5 ton per ha.

As a result of erosion processes, drainages deepened to 2.5-3.5 m or more. The number of irrigations was increased to 6-7 instead of 3-4. Therefore, on such lands, we recommend while designing the drainage system, the designers should plan the depth of the drains no more than 1.5 meters.

During sub-surface irrigation, making sure that nutrients are not washed out to the groundwater level is essential. This, firstly, helps us stabilize soil fertility, and secondly, the annual cleaning of collectors and drainages is not performed. When irrigating with river water in violation of irrigation technology, the active nutrients contained in the soil and agrochemicals used in the processing of plants are likely to be leached with water and may stay in the drainages and collectors. As a result, weeds and algae grow rapidly and all living species (fish, frogs, and others) may prematurely die.

After sub-surface irrigation, the number of weeds decreases, therefore, that their seeds enter the crop fields with irrigation water. The installation of dams on drainages is carried out taking into account the soil water-physical properties. On soils with a light mechanical composition (sandy loam), dams are made at a depression of 150 m, with medium loamy soils the distance between dams is 100 m, and on clay soils after 75 m.

After the dam is installed, when drainage water rises to 2/3 of the profile of the drain on the dam, a hole or a ditch is made to drain excessive water.

As a consequence of the implementation of sub-surface irrigation during the irrigation of crops at the end of the growing season, the salt content in the soil may probably increase. Therefore, flushing the soil with a norm of 1.5 – 2.5 thousand $m^3$ per ha in late autumn, winter or early spring is important.

## 4. Conclusions

Hinged on the one-year data obtained, we can draw the following preliminary conclusions:

1. Sub-surface irrigation is a temporary closure of closed drainage during the growing season of winter wheat, leading to an increase in groundwater level (80-130 cm), thereby leading to an increase in the moisture reserve in the soil.
2. Raising the groundwater level and increasing the moisture ratio in soils as a result of sub-surface irrigation had a positive effect mainly at a distance of 25-50 m from blocked drainage.
3. Temporary overlapping of drains made it possible to reduce the number of irrigations by one time and save irrigation water.
4. Temporary overlapping of drains under the indicated conditions hardly affected the accumulation of water-soluble salts in the soil and the salinity of groundwater.

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