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Application of drip irrigation for cotton farming in Central Asia: The case of Turkmenistan

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Abstract: The main purpose of this study is to determine the optimum water consumption for achieving water savings and obtaining good yields in cotton production, which has been expanding in Central Asia and Turkmenistan since the 1960s. In the last few decades, water resources in the region have been difficult to access, due to the expansion of agricultural activity and population growth. The oscillation of the amount of water released from dams of the Amudarya River to obtain energy for the upper countries in the winter season has been causing crises in countries of Central Asia.

An experiment was carried out in an agricultural field at a cotton research centre in the Yolöten district of Turkmenistan. The experiment led to the observation that it is possible to achieve higher efficiency and lower water consumption in cotton production. At the same time, the water savings that can be achieved as a result of using the drip irrigation method in cotton production throughout the country have been calculated. The calculations have provided the basis for recommending irrigation as a solution to the problems in question.

Keywords: Central Asia, cotton, drip irrigation, traditional irrigation, water resources

INTRODUCTION

Although industrialisation in Turkmenistan accelerated after the collapse of the Soviet Union, agriculture still contributes around 8–9% of the country's GDP [Turkmen Stat 2020]. Therefore, soil and water resources are the most important natural resources in the country, while the key objective of agricultural development is to meet the domestic demand for food. It is vital to use these resources rationally to improve the socio-economic development of the society of Turkmenistan.

The shortage of water resources caused by population growth, development of irrigated agriculture and industry, and oscillation of the amount of water released from dams are the main factors contributing to the regional water crisis in Central Asia [Kulmedov, Shcherbakov 2014]. The primary causes of problems in the watering of irrigated lands in Central Asia are related to decreasing soil fertility, salinisation, shortage of irrigation water, and pollution of water resources with drainage waters. It is crucial to use irrigation water more effectively and rationally and find new agricultural production methods to solve these problems.

At present, the area of irrigated land in the Amu Darya River basin exceeds 6 mln ha, and about 90% of irrigation is carried out by furrows. More than 50% of this cultivation area is devoted to cotton production, where about 4000 $m^3 \cdot ha^{-1}$ of water is consumed in furrow irrigation [Narbayev *et al.* 2014].

There are two main reasons why Turkmenistan must reduce water consumption in agriculture. The first reason is the constant threat of drought in the region [Zhupankhan *et al.* 2017]. The second reason is the increase in water consumption by industry and households, caused by population growth [Liu *et al.* 2020]. In addition to that, the growing population creates the need for irrigating the agricultural fields more effectively than before. The implementation of new irrigation systems and rehabilitation of present irrigation infrastructures in Turkmenistan and other countries of the Amudarya river basin will help improve the practical usage of water resources and help solve the problem of salinisation of the lands. Therefore, in order to maintain the ecological balance and stabilise agricultural development, in Amudarya river basin countries, need to start using the irrigated lands and water resources more rationally.

Turkmenistan owns a significant amount of land resources. The total area of Turkmenistan is 49,120.9 thous. ha [KULMEDOV, SHCHERBAKOV 2014]. Around 81% of this territory, which amounts to 39927 thous. ha, are agricultural lands. Pastures occupy 38196.2 thous. ha, or 95.7% of agricultural lands, irrigated lands and long-term plantings involve 1695.5 thous. ha or 3.5% of agricultural lands [STANCHIN, LERMAN 2017]. Irrigation lands are the primary basis of the rural population's existence, which plays a crucial role in meeting the population's demand for food and raw materials for industrial production (textile, light industry, etc.). Therefore, the economic development of Turkmenistan is directly related to the quantity of the irrigated areas, their quality, and practical usage.

With 25 km^3 of total renewable water resources [ZHUPANKHAN *et al.* 2017], Turkmenistan is one of the driest countries in Central Asia. Approximately 90% of these water resources are used for agricultural purposes [SHCHERBAKOV, KULMEDOV 2017]. The Amudarya river water, which has an average water flow of 79.6 km^3, was divided in half between the two neighbouring countries, Turkmenistan, and Uzbekistan, as a consequence of an agreement signed in 1996 [ZHUPANKHAN *et al.* 2017]. As a result of the loss of water during runoff in canals and rivers, and the increase in the amount of water drawn from the Amudarya River, hardly any water reaches the Aral Sea. Ultimately, we are faced with the Aral problem, which has been experienced more acutely in this century.

Wheat and cotton are the major crops in Turkmenistan, followed by potato, vegetables, and fruits. Figure 1 shows that the cotton seeding area, which demands more water than others, occupies 40% of the total irrigated area [Turkmen Stat 2020]. Therefore, in this article, we analysed the introduction of drip irrigation in cotton farming.

In the last decade, approximately 600 thous. ha was dedicated to cotton farming in Turkmenistan every year. The exact figure differed slightly from year to year. For instance, according to the national newspaper of Turkmenistan, "Neytral'nyy Turkmenistan", in 2020, cotton was sown on 620 thous. ha, and 1250 thous. Mg of cotton were produced; it gives the average of 2.01 Mg·ha^{-1} [ALIMOVA 2021].

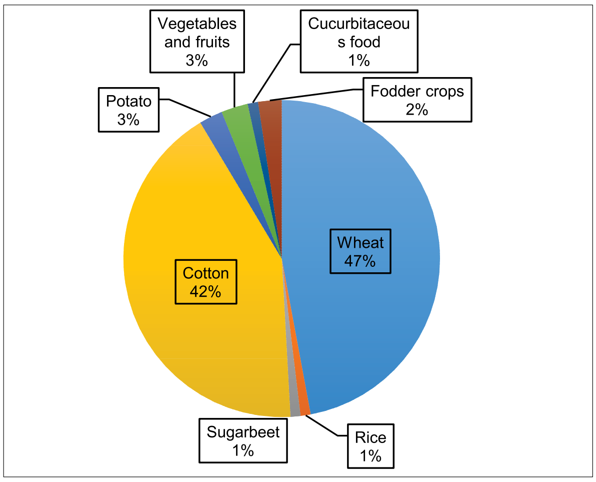

Fig. 1. The percentage of sown areas in Turkmenistan (2019); source: Turkmen Stat [2020]

Water use efficiency (*WUE*, kg·m^{-3}) in cotton production may be calculated as units of dry yield per unit of land area (*Y*, kg·m^{-2}) divided by units of water consumed by the crop per unit land area (*ET*, m^3·m^{-2}, usually reported as mm) to produce that yield, or [IBRAGIMOV *et al.* 2007]:

$$WUE = \frac{Y}{ET} \tag{1}$$

where: *Y* = dry yield per unit land area (kg·m^{-2}), *ET* = crop evapotranspiration (depth of water, mm).

Another key parameter for estimating cropping system productivity is the irrigation water use efficiency (*IWUE*, kg·m^{-3}):

$$IWUE = \frac{Y - Y_D}{I} \tag{2}$$

where: *Y* = dry yield (kg·m^{-2}) under the irrigated condition, Y_D = the dry yield (kg·m^{-2}) under dryland (no-irrigation) conditions, *I* = the irrigation water applied (m).

According to research by IBRAGIMOV *et al.* [2007] in Uzbekistan, water savings of 18–42% were achieved with the optimum drip irrigation method (70–70–60% of field capacity – *FC*) compared to the furrow irrigation method applied in the same conditions. The efficiency of irrigation water use increased by 35–103% compared to the classic irrigation method, and the cotton yields increased by 10–19% compared to traditionally irrigated cotton [IBRAGIMOV *et al.* 2007].

The studies of REDDY *et al.* [2012] in Uzbekistan and Tajikistan revealed that only 78% of cotton irrigation water was used efficiently, and the remaining 22% was lost from the lands.

Prior to this study, experiments conducted in the Dashoguz and Ahal regions of Turkmenistan by BERDIMYRADOV *et al.* [2014], showed that it is possible to reduce water consumption and increase cotton productivity in the case of drip irrigation. The advantages of the drip irrigation method in agricultural and economic terms have been investigated [BERDIMYRADOV 2014; KURTOVEZOV *et al.* 2019].

One of the objectives of our study is to obtain the same or higher cotton yield than is obtained with the application of the traditional method, and to reduce water consumption by means of using the drip irrigation method. It also aims to calculate the water savings and the amount of water that would be obtained if this method was applied in all cotton fields in the country. The country-wide water savings resulting from the mitigation of water supply problems in the region, such as the Aral Sea problem, will be analysed.

MATERIALS AND METHODS

The field experiment was conducted over three consecutive years at the research territory of the Yolöten cotton research and seed production centre in Mary province of Turkmenistan (37°18'05.6" N 62°25'08.3" E, elevation 257 m a.m.s.l.). The experimental area with sandy soil feature covers 4 ha in total, and 2 ha were used for drip irrigation, while the remaining area was used for furrow irrigation, as shown in Figure 2. The cotton sowing took place in the middle of April, which is the time when the temperature is most appropriate. The cotton-picking continued until the end of November (when the cotton bolls froze). Furrows were dug by a tractor at 90 cm intervals, and dripper pipes were arranged neatly in each line (Fig. 5).

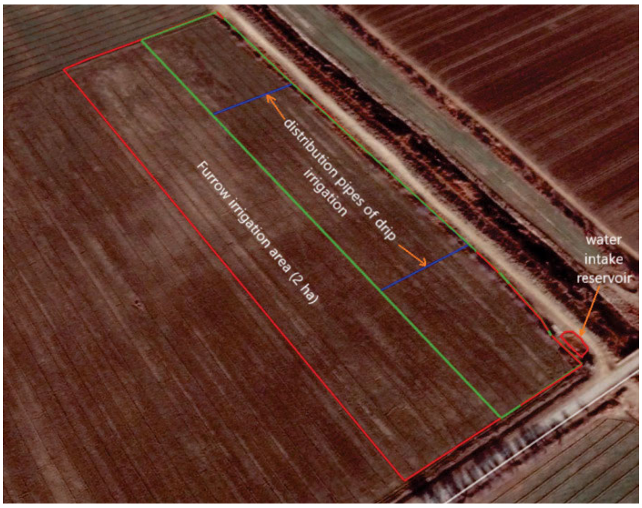

Fig. 2. Experiment field; source: own elaboration based on Google maps

The amount of water consumed through drip irrigation was measured by an in-line propeller-type flow meter. The amount of water for the furrow irrigation was calculated with the use of trapezoidal weirs in the supply trench (Photo 1). At the end of the furrows, the waters gathered in the same area.

Photo 1. Water supply trench next to experiment area (phot. *B. Kulmedov*)

The installation for supplying water to drip irrigation consisted of a pumping unit, a hydrocyclone, two-stage pressure filters with a quartz loading, a solution tank for introducing a solution in the form of nitrogen or phosphorus fertilisers (Photo 2).

Since the water from the source contains mineral and organic contaminants, a pressure hydrocyclone is included in the installation scheme to remove large impurities. Small particles are captured on pressure filters. That ensures the system's reliability, and prevents the clogging of nozzles, the diameter of which is 0.2–0.5 mm.

The 16-mm diameter drip irrigation pipe had emitters spaced at 60 cm; the emitter discharge rate was 2 $dm^3 \cdot h^{-1}$ at the 1000–1500 hPa operating pressure.

Photo 2. Installation for a drip irrigation system (phot. *B. Kulmedov*)

Photo 3. Layout of main and distribution pipes (phot. *B. Kulmedov*)

RESULTS AND DISCUSSION

RESULTS

Cotton (*Gossypium hirsutum* L., cv. Yoloten-14) was planted and thinned to achieve a population density of 8–9 $plants \cdot m^{-2}$. The fertilisers applied during the season included: 320 kg $(NH_2)_2CO \cdot ha^{-1}$, 200 kg $P \cdot ha^{-1}$, 150 kg $K \cdot ha^{-1}$ and 50 kg amofos $fertiliser \cdot ha^{-1}$. No herbicides were used and weeds were removed manually.

By furrow irrigation method, 5000 $m^3 \cdot ha^{-1}$ of water, which is accepted as an average for the country (it is watered 4 or 5 times, depending on demand), was consumed. As a result, an average yield of 4.75 Mg of cotton was collected. In the drip irrigation method, 3000 $m^3 \cdot ha^{-1}$ of water was used during the first year; the water consumption in the subsequent years amounted to 3500 and 4000 $m^3 \cdot ha^{-1}$, respectively. As a result, the amount of harvested cotton was 5, 5.79, and 5.81 $Mg \cdot ha^{-1}$, respectively.

Table 1 shows the amount of consumed water, the amount of cotton collected, and the amount of water consumed per kg of cotton, depending on the applied irrigation method.

Table 1. Results according to methods

Variation	Water consumption ($m^3 \cdot ha^{-1}$)	Cotton yield ($Mg \cdot ha^{-1}$)	Water consumption for the 1 kg of cotton production ($m^3 \cdot kg^{-1}$)
Furrow irrigation	5000	4.75	1.052
1st year – drip irrigation	3000	5.00	0.600
2nd year – drip irrigation	3500	5.79	0.604
3rd year – drip irrigation	4000	5.81	0.688

Source: own study.

As we can see from the table in the first version, we applied furrow irrigation, which is the traditional method, and three options of using drip irrigation (drip irrigation 1, 2, 3). As a result of this analysis, it can be concluded that drip irrigation can reduce water consumption by up to 1000–2000 $m^3 \cdot ha^{-1}$ (that is 20–40%) in comparison to the traditional irrigation method, while still allowing for good harvest.

Even according to the research conducted by IBRAGIMOV *et al.* [2007] in the neighbouring country of Uzbekistan, 10–19% larger cotton yield was obtained by saving approximately the same amount (18–42%) of water. We can attribute this similarity to similar climatic conditions and soil structure.

THEORETICAL WATER REQUIREMENT FOR TRADITIONAL IRRIGATION

Let us assume that total cotton area of 600 thous. ha under normal conditions in Turkmenistan consumes 5,000 m^3 of water per hectare of cotton field. We can then calculate the amount of water required for irrigation by applying the Equation (3):

$$Q = Sq \tag{3}$$

where: Q = the total water flow, S = area, q = water consumption per unit.

$Q = Sq$ = 600000 ha · 5000 $m^3 \cdot ha^{-1}$ = $3 \cdot 10^9$ m^3 or 3 km^3

The amount of total water consumption for the country's cotton production, disregarding the loss, accounts for 12% of the total renewable water resources of Turkmenistan [ZONN, KOSTIANOY 2013]. However, World Bank research results show that the loss of irrigation water in Central Asia reaches 79% (mainly due to the filtering of unlined earth canals), while the total indicator for the region's developing countries is around 60% [UNDP, WHO 2009].

THEORETICAL WATER REQUIREMENT FOR DRIP IRRIGATION

Similarly, we accepted 3500 $m^3 \cdot ha^{-1}$ as an optimum variant and defined the total consumption of water by Equation (3):

$Q = Sq$ = 600000 ha · 3500 $m^3 \cdot ha^{-1}$ = $2.1 \cdot 10^9$ m^3 or 2.1 km^3

This amount corresponds to 8.4% of the country's total renewable water resources; in other words, 3.6% (0.9 km^3) of the water resources of Turkmenistan will be preserved.

CONCLUSIONS

Under drip irrigation, the total consumption of water for cotton production in the country corresponds to 8.4% water resources of Turkmenistan (disregarding losses). The difference between the two irrigation methods is noticeable, both in terms of water consumption and productivity.

From the calculation above, it can be concluded that using drip irrigation reduces water consumption by 30% in comparison to traditional irrigation and reduces water losses to a minimum. In addition, in the drip irrigation method, every plant will receive an equal amount of water from the system, so the unevenness of the land will not cause any problems. Since only plant stems get water, there will be fewer weeds and interline cultivation via tiller will also be reduced.

Although the initial investment cost is high, the application of a drip irrigation system has a positive impact on the yield of the agricultural products.

The application of drip irrigation has a significant impact on the land, which generally depends on the irrigation systems used, properties of water used for irrigation, and soil conditions.

Rehabilitation of irrigation channel infrastructures and the use of drip irrigation systems will reduce pressure on water resources in Turkmenistan and other countries of Central Asia and it will help to reduce water-related environmental problems in the Aral Sea basin.

The Aral Sea will take a lot of time to be restored to its former state (as it was before the 1960s), or it will not be restored to it at all. However, as a proverb says, "it's better late than never"; therefore, it is necessary to start taking action as soon as possible for the sake of nature and the people living in that region.

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