

DEVELOPMENT OF A DRUM-HOSE IRRIGATION MACHINE DESIGN ADAPTED FOR FURROW IRRIGATION OF AGRICULTURAL CROPS

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Abstract

Efficient and rational use of water resources in agriculture is one of the most pressing issues today. Traditional sprinkler irrigation machines result in significant water losses due to evaporation and wind influence. This article proposes a new design based on drum-hose sprinkler machines, adapted specifically for furrow irrigation. The proposed device delivers water directly to the plant root zone without spraying it into the air, thereby preventing losses caused by evaporation and wind. The design, operating principle, and efficiency of the furrow irrigation machine are analyzed and compared with traditional sprinkler machines. Based on calculations and tabular analysis, it has been shown that water savings of 20% or more can be achieved with furrow irrigation.

Keywords: Furrow irrigation, sprinkler machines, water resources, evaporation, efficiency, root zone, drum-hose machine, pipe, wind influence.

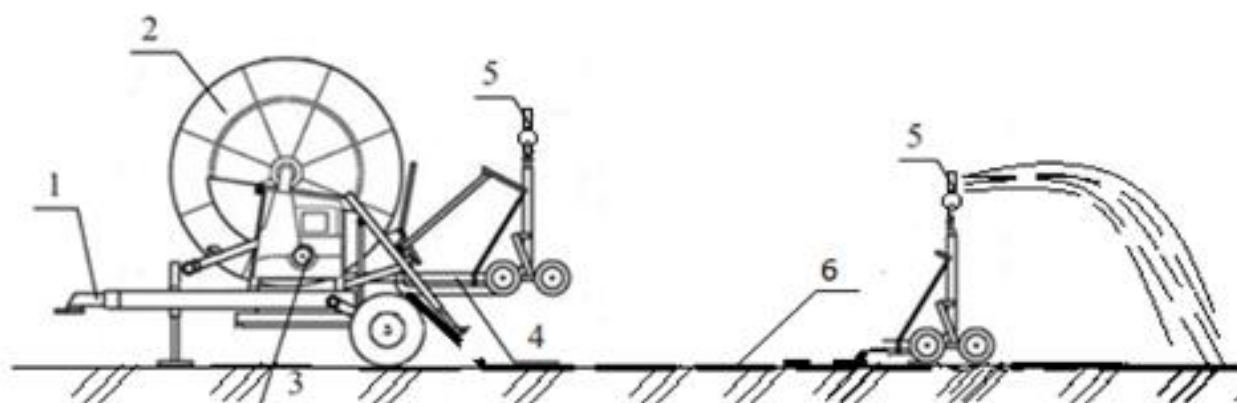
Introduction

Efficient and rational use of water resources in agriculture is one of the urgent issues. In traditional sprinkler irrigation systems, water losses occur due to evaporation and the effects of wind during the irrigation process. When sprinkler machines are used, 7–10% of water droplets are blown away by the wind, and evaporation accounts for 13.7% to 20.7%, with total water losses reaching up to 30% [1, 2]. Taking this into account, this article proposes a new design for furrow irrigation, based on drum-hose sprinkler machines.

Materials and Methods

The existing drum-type sprinkler irrigation machines, i.e., pipe-drum sprinkler machines, are intended for irrigating all types of crops [3]. The pipe-drum sprinkler irrigation machine consists of a movable console and a drum-mounted chassis (Figure 1) that winds the hose. A winding mechanism (3) is mounted on the chassis (1), on which the drum (2) is installed. The sprinkler console (5) has a travel cart (4). A flexible hose (6) is wound on the drum, one end of which is connected to the sprinkler console (5) located on the cart (4). Before starting irrigation, the machine is connected to a water pump from a water source, the flexible hose (6) is unwound from the drum, and the sprinkler console (5) is positioned at a working distance from the chassis (1). When water is supplied to the flexible hose (6) via pumps, the drum (2) slowly rotates, winding the hose (6), causing the sprinkler console (5) to move. The nozzle device installed on the console then begins to irrigate the field by spraying water.





1 – Chassis of the pipe-drum sprinkler machine; 2 – Drum; 3 – Hose winding mechanism; 4 – Traveling cart; 5 – Sprinkler console (rain-generating device); 6 – Flexible hose

Figure 1. Structural-layout diagram of the pipe-drum sprinkler irrigation machine

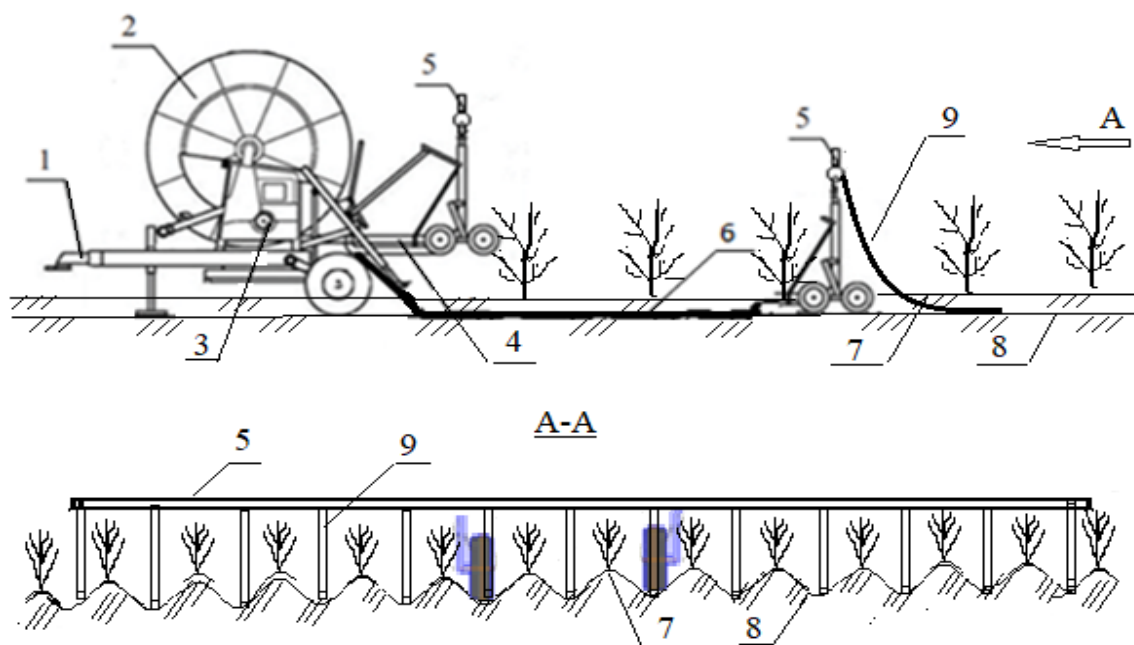
When the sprinkler console (5) approaches the drum (2), the water shut-off system is activated, the water supply is stopped, and the console (5) stops next to the machine. Then the machine is moved a distance equal to its coverage width, and the technological process is repeated. As previously mentioned, the main drawback of these machines is water loss due to evaporation and wind drift of water droplets during the irrigation process.

Sprinkler irrigation machines are based on the technological process of creating artificial rain. During the aerial movement of the generated droplets, they are exposed to environmental factors, which requires the improvement of their design for effective irrigation, especially in arid and hot regions.

The proposed **furrow irrigation device** replaces the rain-generating nozzle mounted on the sprinkler console. This device delivers water directly to the soil and the plant root zone through flexible hoses, without spraying it into the air. As a result, water loss is prevented.

The furrow irrigation machine is developed on the basis of a pipe-drum sprinkler irrigation machine. It differs from the sprinkler machine in that the **rain-generating device (5)** on the sprinkler console (see Figure 1) is replaced with a **furrow irrigation device (9)** (see Figure 2).

The **pipe-drum furrow irrigation machine** consists of a movable sprinkler console (5) and a chassis (1) with a drum (2) that winds the hose (6). A winding mechanism (3) is mounted on the chassis (1), and the drum (2) is installed on it. The sprinkler console (5) is equipped with a traveling cart (4). A flexible hose (6) is wound around the drum (2), and one end is connected to the sprinkler console (5) on the traveling cart (4). The **furrow irrigation device (9)** is mounted on the sprinkler console (5) in accordance with the spacing between crop furrows.



1 – Chassis of the pipe-drum furrow irrigation machine; 2 – Drum; 3 – Hose winding mechanism; 4 – Traveling cart; 5 – Sprinkler console; 6 – Flexible hose; 7 – Plants sown between furrows; 8 – Furrow spacing; 9 – Furrow irrigation device

Figure 2. Furrow irrigation machine

Before starting irrigation, the furrow irrigation machine is connected to a water pump fed by a water source. The flexible hoses (6) are unwound from the drum (2) and the sprinkler console (5) is positioned at a certain distance from the chassis (1) in working condition. When water is supplied through the flexible hoses (6) via pumps, the drum (2) slowly begins to rotate due to the hydrodynamic forces of the water flow, winding the hose (6) and causing the sprinkler console (5) to move.

At this time, water is delivered through the sprinkler console (5) to the furrow irrigation device (9). The water supplied to the furrow irrigation device is conveyed through its flexible outlet pipes directly into the furrow spaces (8) between the rows of plants (7). When the sprinkler console (5) approaches the drum (2), the automatic shut-off system is triggered, stopping the water supply and bringing the console to a halt near the chassis (1) of the furrow irrigation machine.

Then the furrow irrigation machine is moved a distance equal to its coverage width, and the technological process is repeated.

Results and Discussion

If we assume that water loss due to evaporation on the field surface during furrow irrigation is no more than 3%, then compared to traditional sprinkler irrigation, total water losses are reduced by 18–19% (Figure 3).

Currently in Uzbekistan, 1000–1100 m³/ha of water is used for growing agricultural crops depending on the crop type. By applying the furrow irrigation machine, it is possible to save 180–200 m³ of water per hectare compared to conventional sprinkler irrigation.

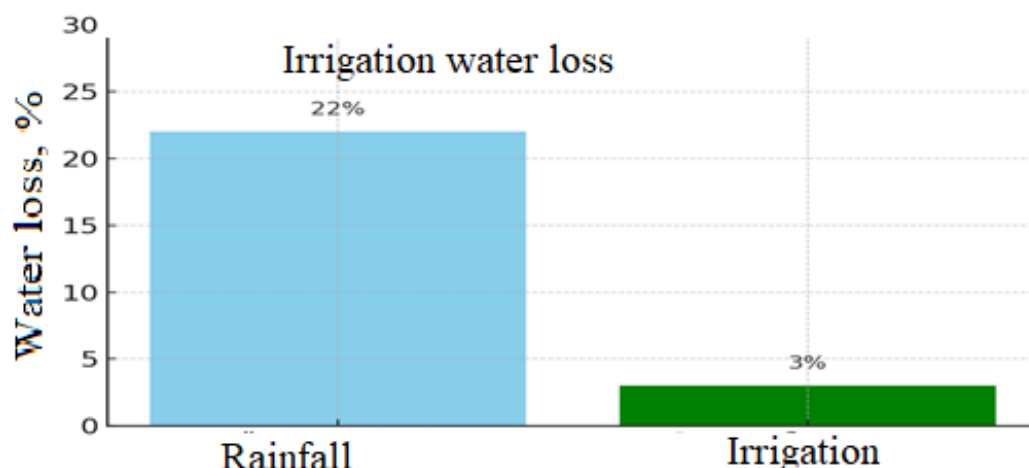


Figure 3. Water losses in sprinkler and furrow irrigation machines

The main disadvantages of sprinkler irrigation machines are water loss due to evaporation, drift caused by wind, and damage to the soil structure. In contrast, the proposed furrow irrigation device experiences virtually no water loss, as the water is delivered directly to the plant root zone.

A comparison of the two machines is provided in Table 1. In furrow irrigation, water is supplied to the field surface under atmospheric pressure and at a low flow velocity, which does not damage the soil structure [4].

Table 1. Comparison between sprinkler and furrow irrigation machines

№	Indicator	Sprinkler Irrigation	Furrow Irrigation
1	Water loss	20–24%	0–3%
2	Evaporation impact	High	Almost none
3	Impact on soil	Damages	Preserved

The efficiency of water usage for the furrow irrigation device can be evaluated using the following formula:

$$\eta = \frac{V_{plante}}{V_{pump}}, \quad (1)$$

η – efficiency coefficient; V_{plante} – volume of water reaching the plant, m^3
 V_{pump} – volume of water pumped from the source, m^3

In furrow irrigation, η can reach up to 95–99%, which provides more than 20% water savings compared to traditional sprinkler irrigation.

Conclusion

The analysis and proposals presented in this article show that water losses in traditional sprinkler machines (20–24%) can be reduced to as little as 0–3% with the proposed furrow irrigation device. This not only conserves water resources but also preserves the structure of the soil. Since the proposed furrow irrigation device is adapted based on hose-reel sprinkler machines, it allows for the use of existing agricultural machinery infrastructure.



Achieving an efficiency coefficient of up to 95–99% makes this device highly suitable for widespread implementation in agriculture. Therefore, this technology holds great significance in arid and water-scarce regions.

References

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