A new innovative irrigation method for wood, shrub crops and grapes

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Abstract. The article analyzes the main disadvantages of traditional methods of watering woody, shrubby fruit, ornamental crops and grapes and suggests a new innovative way of watering them. According to the principle of implementation, it belongs to the group of subsurface irrigation and is a new version of them. There is a wide list of positive qualities of the new irrigation method that allow for much more rational use of irrigation water but create more favorable conditions for the growth and development of watered plants. A description of its design features and methods of implementation is given. The proposed new jet-pit irrigation method is not inferior in its technical capabilities to the most modern irrigation method – drip, but it is much cheaper and more reliable than the latter.

1. Introduction

Currently, more than 300 million hectares of agricultural crops are irrigated in the world, this is 18% of their total volume but only 66 million hectares are equipped with full-fledged drainage [1]. Consequently, it is natural that problematic processes of salinization and waterlogging appear on the bulk of the irrigated areas, which significantly reduces the productivity of these fields. The situation is aggravated by that due to a complex of unfavorable factors in the world, the problem of freshwater resources is becoming more and more acute [2]. Therefore, the techniques and methods that allow more efficient use of irrigated land and water for irrigation are very relevant. The South Ural State Agrarian University has developed and patented a new innovative string-pit irrigation method. It has a wide range of advantages when watering fruit, tree ornamental crops, and grapes in comparison with other currently used irrigation methods.

The main methods of watering. At present, sprinkling is the most widespread irrigation method [3, 4], but it is rarely used for this group of crops due to five serious problems associated with this method.

The first is that the large habitus of plants of this group does not allow the use of conventional wide-grip sprinklers with high productivity for irrigation [5].

Second is that these crops are positioned in one place for a long time, which greatly increases the infectious background and therefore the irrigation water supply through a raindrop greatly aggravates this problem, catastrophically increasing the degree of disease damage to plants on an irrigated plantation.

Third - great water losses for evaporation with this method of irrigation.

Fourth - the danger of water erosion of soil during sprinkling [6, 7, 8].
Fifth, the destruction of surface soil aggregates by irrigation drops leads to the formation of a crust on the soil surface after it dries. Three of the currently existing options for the underground irrigation method [9] are also rarely used for irrigating this group of crops since they have low reliability (in subsoil irrigation pipes due to water outlets' overgrowing with roots) or location restrictions (only on drained areas and where groundwaters are not salinated) or (low productivity and high cost) for machine methods.

Currently on industrial fruit, berry, and grape plantations, the main method is the surface irrigation method [10]. But this most ancient method of watering also has many very serious disadvantages [11].

The first one is a very strong irregularity of area watering (much more water is supplied to the beginning of the irrigated row than to its end).

The second disadvantage is associated with the first one and is in a large amount of water, which seeps into the lower horizons under the influence of gravity, worsens soil aeration and causes a rise in the groundwater level, which can provoke waterlogging and secondary salinization of the area [2].

The third drawback of the surface irrigation method also naturally follows from the technical implementation of irrigation, in which only very large irrigation rates are possible, while more than half of the irrigation water is not used rationally, bringing the irrigated area more harm than good [1].

Fourth - surface irrigation is always accompanied by strong water erosion of the soil, even more intense than during sprinkling [12].

Fifth - the method is always accompanied by strong silting of soil horizons, which significantly impairs their aeration and water transmissivity.

The sixth drawback of the method lies in its great labor intensity (it is impossible without a whole army of irrigators).

It is such a large list of serious shortcomings of the surface irrigation method in rich countries with developed agriculture that makes farmers replace it with drip irrigation on these crops.

At the moment, drip irrigation is considered the most perfect irrigation method for this group of crops [13, 14, 15, 16, 17]. Undoubtedly, it has a lot of advantages over the surface irrigation method (high uniformity of area irrigation, the ability to establish any irrigation rate, fertilization introduction along with irrigation, almost complete automation of the process). But despite this, it is not yet widespread in economically underdeveloped countries due to its main shortcomings (this is very high cost of equipment and tooling for implementing this irrigation method and operational fragility - especially of field tooling) [18].

2. Materials and methods
A thorough multidimensional analysis of the advantages and disadvantages of existing irrigation methods allowed to simulate a scheme for a new irrigation option of this group's crops, which is not inferior to drip irrigation in its technical capabilities; but at the same time, it is much cheaper than the latter in equipment and maintenance and is incomparably more durable.

3. Results and discussion
The new jet-pit irrigation method consists in supplying water or a nutrient irrigation solution to pit holes located at a certain distance in the soil, and therefore we believe that it should be attributed to the group of subsurface irrigation.

But at the present time, only three options for the implementation of the subsurface irrigation method are registered in this group in the Russian Federation:

1). technical methods of subsurface irrigation - along artificial pipes laid at a certain depth from the soil surface;
2). subsoil irrigation by raising and regulating the level of fresh groundwater on drained lands;
3). machine methods of subsurface irrigation.
The jet-pit irrigation method can obviously be considered the fourth option of the subsurface irrigation method since it differs from the already known options of this group in terms of the implementation concept and technical solution.

Let us describe the features of the new irrigation method in more detail. Two versions of the new irrigation method have been developed: 1 - stationary pressure irrigation and 2 - mobile gravity.

**In a stationary pressure version,** water from the pumping station after cleaning on mechanical filters enters the main pipelines (if necessary, the water passes through the solution unit to obtain a nutrient solution prior to it). Then water or nutrient solution enters the distribution pipelines of various levels and gets into the end distribution hoses (1) (Figure 1) laid on both sides of the row of irrigated plants. Irrigation water is supplied by a stream through the water outlets (2) to the pit holes with drainage material (3).

![Figure 1. Scheme of string-pit irrigation.](image)

The size of the water outlets on the end distribution hoses is gradually increased to ensure an even flow of irrigation water over the entire length of the row.

Water-receiving pit holes are located on the irrigated area to the right and left at a distance of 0.7-1.0 m from the row of irrigated plants, depending on the row spacing width or the design of the trellises. The distance between the pit holes along the row depends on the soil texture in the irrigated area and can vary from 1.5 meters on sandy loam soils to 3 meters on clay soils. The depth of the pit holes also depends on the soil texture and ranges from 40 to 80 centimeters. For sufficient water intake capacity on different soils, the diameter of the pit holes can be from 15 to 30 centimeters. The holes are filled with drainage materials to protect them from collapse and erosion. Crushed rocks of medium or large fraction are placed in the lower part, sawdust (chaff, straw) is poured above it with a thickness of 20 centimeters. These materials allow moisture to pass through well, but do not allow the cold to penetrate the deep layers of the soil in winter and damage the root system of the watered plants. To reduce the cost of building the system, it is possible to completely fill the pit holes with local organic material (straw, chaff, sawdust, etc.); only in the future, it will need to be periodically added in a timely manner since these materials will shrink annually.
From the pit holes, irrigation water enters all soil horizons under the action of meniscus forces with minimal evaporation losses (Figure 1). Since a significant part of the water seeps into deeper soil horizons, this naturally contributes to the formation of a deeper and more powerful root system in the plants watered in a new way.

Irrigation cyclicity even with drip irrigation has a positive effect on the aeration of soil horizons [19]. The presence of pit holes in the new method provides an even more intense pulsation of water and gas media in a wide range of soil horizons, which improves soil aeration and favorably affects the passage of all processes in the soil biocenosis.

Even with a surface irrigation method, the use of pits in irrigation furrows allows to reduce the loss of spring and storm water [20]. Naturally, significantly higher water-absorption capacity of the new irrigation method allows to completely solve these problems due to the pits. This allows to effectively use natural precipitation and save significant amounts of irrigation water. In addition, water erosion in the irrigated area is almost completely eliminated, which is a serious problem both with surface irrigation methods and with sprinkling.

Like drip irrigation, the new method allows to provide any irrigation rate with a high uniformity of water distribution over the irrigated area.

As noted above, the method provides the possibility of introducing mineral or organic fertilizers and other components with irrigation water required by the technology.

The absence of irrigation water drops on the crown leaves of irrigated plants and on the main soil surface makes it possible to effectively restrain the development of diseases and weeds in the irrigated area.

In the stationary version, the jet-pit method is fully automated same as drip irrigation.

The relatively large diameter of new irrigation method's outlets significantly reduces the cost of cleaning irrigation water from mechanical impurities. Calibrated water outlets in an irrigation system of string-pit irrigation are incomparably more reliable, more durable and cheaper than droppers. In addition, they need several times less per unit of irrigated area than droppers.

The complex of positive design features of the new irrigation system's elements in comparison with the drip method makes it cheaper, more reliable, durable and easy to maintain and operate.

Since so far in many countries the surface method of irrigation remains the main one, a mobile gravity version was also developed for the new irrigation method. It allows to use the new jet-pit irrigation method using the channel network available on irrigated areas for surface irrigation without its reconstruction and additional pumping equipment. This is done by means of a long intake device laid in the supply channel. From it, water is fed through the fire hoses to the end distribution hoses laid down along the relief elements to ensure the gravity flow of water in the system equipment for a certain number of rows. After irrigation with the desired irrigation rate on the site, the system equipment is reeled up on special trolleys and moved to a new position. There it is quickly unwound and the watering cycle repeats. Due to special containers, the mobile version also has the ability to work with the nutrient solution, if necessary.

Undoubtedly, the mobile gravity version is more time-consuming than the stationary one, but it is incomparably cheaper per unit of irrigated area. Most likely, it will be in demand primarily by small farms in a modern market economy, for which a stationary version of an even cheaper new irrigation method together with the drip irrigation method will most likely be financially unavailable.

By purchasing one mobile unit for several farms, they will be able to provide irrigation on an area of 30 to 60 hectares on their own depending on the irrigation rates of grown crops. The use of the new irrigation method will ensure the creation of significantly better conditions for the growth and development of plants on the irrigated plantation and an increase in their productivity, despite a multiple decrease in the consumption of irrigation water. If necessary, the created reserve of irrigation water can be used in the coming years for a significant expansion of the irrigated areas of agricultural crops in the area.
4. Conclusions
The above thorough analysis of the main advantages of the new jet-pit irrigation method allows to conclude that it can significantly help in improving the irrigation efficiency for a wide group of crops, saving and more rational use of water resources and weakening several environmental problems on a global scale.

For the developed new method of irrigation, a patent was received under No. 2747703 dated April 7, 2020.

A new method is also very promising for watering greenery plantings of ornamental crops in settlements, especially in countries with hot climates.

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