УДК 631.674.11(575) DOI 10.22314/2073-7599-2021-15-2-4-8

Equipment and Technology for Subsurface Irrigation of Intensive Gardens in the Bukhara Region of the Republic of Uzbekistan

Fazliddin U. Zhuraev,
Dr.Sc.(Eng.), associate professor,
e-mail: fjuraev66@mail.ru;

Galib Kh. Karimov,
doctoral student, e-mail: karimov.golib1988@mail.ru

Bukhara branch of the Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Bukhara, Republic of Uzbekistan

Abstract. Experience shows that for the irrigation of intensive gardens, various types of equipment and technologies are used, such as continuous irrigation (invasive), drip irrigation, subsurface irrigation and other methods. All irrigation options have some shortcomings, such as water evaporation, high water consumption, high consumption of mineral fertilizers and energy. (*Research purpose*) To develop an automated system for subsurface irrigation of intensive gardens with groundwater using electric pumps and solar panels, and to create a mathematical model of soil moisture distribution. (*Materials and methods*) Special devices shaped as pegs were designed to supply water with dissolved mineral fertilizers directly into the root system of intensive gardens. The authors investigated the pegs' geometric parameters and the criteria for their placement in the soil, taking into account the consumption of water and nutrients. The authors examined soil mechanical composition and salinity as well as its physical and mechanical, technological properties. (*Results and discussion*) It was found out that the installation of the peg facilitates soil moisturizing through the central pipeline within the radius of 1.55-1.75 meters at the depth of 0.7-0.9 meters. Three-four pegs, being equidistant from each other and inclined in relation to the vertical axis by 20-30 degrees, were placed around a tree. Water consumption was determined for various irrigation methods: for furrow irrigation (control) – 1125.7 cubic meters per hectare, for continuous irrigation (invasive) – 1812.3 cubic meters per hectare, for drip irrigation – 618.6 and subsurface irrigation – 506.4 cubic meters per hectare. (*Conclusions*) Based on the results of the experimental study carried out in farms with intensive gardens using various irrigation methods, continuous irrigation (invasive), drip irrigation and subsurface irrigation were compared in terms of water consumption. The results show that drip irrigation and subsurface irrigation ensure less water consumption than flood irrigation, by 46 per cent and 57 per cent respectively. It was found out that subsurface irrigation ensures 57 per cent water and 25-35 per cent mineral fertilizer economy, in comparison with the other methods of providing trees with water and nutrients.
Keywords: intensive gardening, garden irrigation, water filters, pipelines, water flow, nutrient solution.

For citation: Zhuraev F.U., Karimov G.K. Oborudovanie i tekhnologiya dlya vnutripochvennogo orosheniya intensivnykh sadov v Bukharskoy oblasti Respubliki Uzbekistan [Equipment and technology for subsurface irrigation of intensive gardens in the Bukhara Region of the Republic of Uzbekistan] *Sel'skokhozyaystvennye mashiny i tekhnologii*. 2021. Vol. 15. N2. 4-8 (In English). DOI 10.22314/2073-7599-2021-15-2-4-8.

Оборудование и технология для внутрипочвенного орошения интенсивных садов в Бухарской области Республики Узбекистан

Фазлиддин Уринович Жураев,
доктор технических наук, доцент,
e-mail: fjuraev66@mail.ru;

Галиб Хаджикурбанович Каримов,
докторант, e-mail: karimov.golib1988@mail.ru

Бухарский филиал Ташкентского института инженеров ирригации и механизации сельского хозяйства, г. Бухара, Республика Узбекистан

Реферат. Показали, что для обеспечения интенсивных садов водой применяют различные технологии: бороздковый полив, капельное или внутрипочвенное орошение. Отметили среди недостатков во всех вариантах большой расход воды, минеральных удобрений и энергии. (*Цель исследования*) Разработать автоматизированную систему внутрипочвенного орошения интенсивных садов грунтовыми водами с помощью электронасосов и с использованием солнечных батарей, а также создать математическую модель распределения почвенной влаги. (*Материалы и методы*) Создали специальные устройства в виде колышков для подачи воды с растворенными в ней минеральными удобрениями прямо в корневую систему интенсивных садов. Исследовали их геометрические параметры и критерии размещения в почве с учетом расхода воды и питательных веществ. Изучили физико-механические, технологические свойства, механический состав и засоленость почвы. (*Результаты и обсуждение*) Показали, что при установке разработанного колышка обеспечивается увлажнение почвы через центральный трубопровод в радиусе 1,55-1,75 метра на глубине 0,7-0,9 метра. Разместили вокруг дерева 3-4 колышка, равноудаленных друг от друга, с наклоном по отношению к вертикальной оси на 20-30 градусов. Определили расход воды при различных способах орошения: при бороздковом поливе (контроль) – 1125,7 кубометра на гектар, при капельном орошении – 618,6 и внутрипочвенном – 506,4 кубометра на гектар. (*Выводы*) Определили, что внутрипочвенное орошение, по сравнению с другими способами обеспечения деревьев водой и питательными веществами, способствует экономии воды на 57 процентов, минеральных удобрений на 25-35 процентов.

Ключевые слова: интенсивное садоводство, орошение садов, фильтры воды, трубопроводы, расход воды, питательный раствор.

Для цирования: Жураев Ф.У., Каримов Г.Х. Оборудование и технология для внутрипочвенного орошения интенсивных садов в Бухарской области Республики Узбекистан // *Сельскохозяйственные машины и технологии*. 2021. Т. 15. N2. С. 4-8. DOI 10.22314/2073-7599-2021-15-2-4-8.

In the Republic of Uzbekistan, the need for water is increasing, and agriculture is experiencing a particular shortage of this resource: 85% of the water used in the industry comes from the neighbouring countries. In such conditions, it is important to minimize water consumption in agro-industrial production, including irrigation [1-4].

In foreign countries, positive results have been revealed when using subsoil irrigation of intensive gardens. They are confirmed by experimental and theoretical studies, as well as by mathematical modelling of moisture transfer. Experimental plants have been created that have successfully passed field tests [5, 6].

The research purpose is to develop new equipment and technologies for intensive gardens irrigation in the soil and climatic conditions of the Bukhara region in Uzbekistan, as well as to create a mathematical model of the soil moisture distribution.

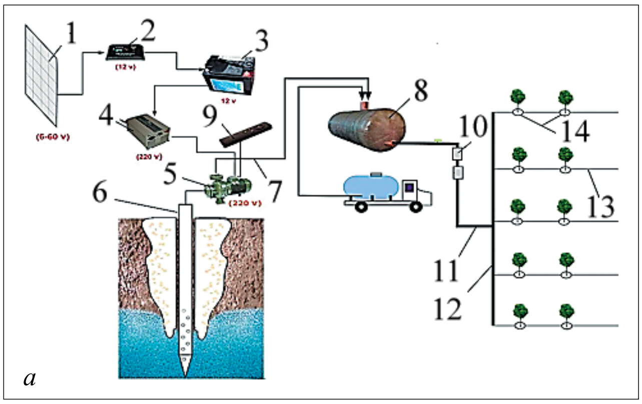
Materials and methods. In the region, meadow-alluvial soils are widespread, which texture is represented by light, medium and heavy sands. The groundwater level is at the depth of 1.5-2.0 m, the salinity is 1.0-1.2 g/l. Field experiments were carried out in 2016 at the Zodabek farm in the Kagan district of the Bukhara region. Six hectares are covered by an intensive orchard, represented by medium-sized Golden Delicious apple trees.

In accordance with the structure of the soil, the irrigation pegs were made from a polyethylene pipe with the diameter of 16-25 mm and the length of 30-80 mm.

We used systematic analysis, mathematical planning of experiments, modern methods for determining the water and energy consumption and conducting field experiments at the Research Institute of Agricultural Technology of Cotton Seed Production.

Results and discussions. The proposed irrigation technology provides for the use of groundwater in areas with water scarcity.

The automated groundwater irrigation system employs solar-powered electric pumps (*Fig. 1*). From a solar panel sized 4 × 5 = 20 m^2, a voltage of 6-60 V is supplied to the controller generating 12 V, charges the storage battery powered through an inverter (a device for converting direct current into alternating current with a voltage value



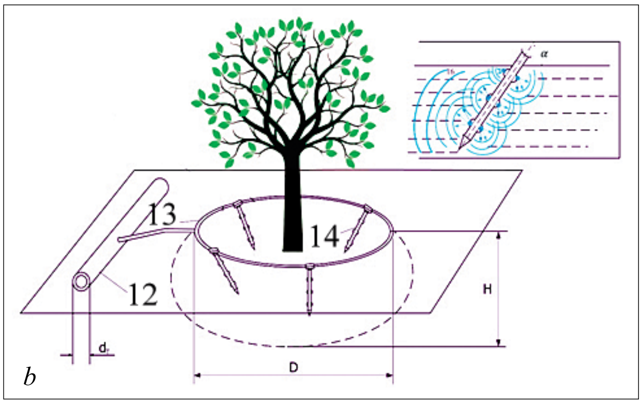


Fig. 1. The overall structure of the subsurface irrigation system (a) and a scheme of the peg installation in the seedling root system (b): 1 – solar panel; 2 – controller; 3 – storage battery; 4 – inverter; 5 – borehole pump; 6 – suction pipe; 7 – transport pipeline; 8 – water tank; 9 – automatic control panel; 10 – filters; 11 – main irrigation pipes; 12 – distribution pipes; 13 – thin tube; 14 – pegs; D is the diameter of the peg on the thin tube; H is the depth of soil moisture distribution from the peg; d_T is the diameter of the distribution pipes; h is the distance between the holes in the peg; β – peg installation angle (60-70 degrees to the horizontal axis)

change) under a voltage of 220 V. A pump, capable of pumping 0.5-0.7 m^3 of water per hour from the ground, takes water from a single 10-15 m depth well at the flow rate of 84.6 m^3/day and fills a 100-ton cistern, from where the water is sent through a transport pipeline.

If the level of groundwater mineralization exceeds 0.085% in terms of chlorine ion, it is diluted with river water in appropriate proportions. Through a system of automatic control valves installed in the outlet of the tank, the water is treated with a water purifier. The main irrigation flow is directed to the pegs along the main pipes, distribution pipes and a thin pipe to provide the required amount of water (*Fig. 1a*) [7-12].

Three-four pegs intended for subsurface irrigation are placed in the soil equidistantly around the tree. They are inclined by 60-70° in relation to the horizon (*Fig. 1b*).

In the upper part, the pegs are connected by means of tees with pipes for supplying and discharging water. With the help of an additional segment, it is possible to increase the depth of the device. The lower part of the peg ends with a pointed cylinder.

During the operation, the water flows from top to bottom. A rubber diaphragm is installed in the peg cavity, which regulates the water flow uniformity. It expands and contracts depending on the pressure of the fluid (*Fig. 2*).

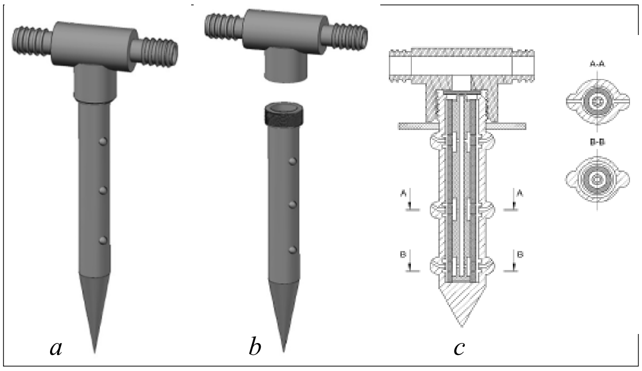


Fig. 2. The design of a peg for subsurface irrigation: a – general; b – fragmented; c – in section

On average, 1.8-2.5 liters of water flows through each hole in an hour, and the seedling's entire root system is irrigated by the moderate moistening of the soil with a mixture of mineral fertilizers. As a result, water savings amount to 55% compared to the local flood irrigation.

In addition to the flow compression, it tends to reveal inversion, that is, a change in the shape of the lateral motion along its length. For example, a square shape can take the shape of a cross or another shape. The liquid outflow through the irrigation peg hole was determined parametrically (*Fig. 3*).

Theoretically, the water flow can be calculated from the pipeline to the pipe distribution network.

The number of tree subsurface watering time periods for the entire growing season and for each month is determined by the following formula:

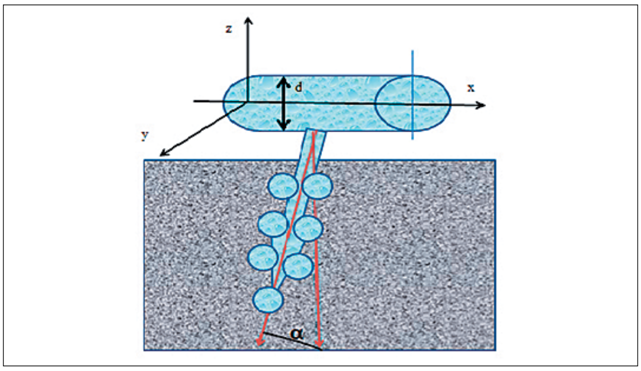


Fig. 3. The movement of water along the irrigation peg: d – the diameter of the thin tube; α – the angle of the peg in relation to the vertical axis (20-30 degrees)

$$k = V/m, \quad (1)$$

where k is the number of watering time periods;

V – irrigation rate for the entire period, m^3/ha;

m – one-time irrigation rate, m^3/ha.

The seasonal irrigation periods were determined by the generally accepted graphic-analytical method for monthly and ten-day water balance deficit based on tabular analysis.

The average duration of the between-irrigation period is:

$$N_1 = m/h, \quad (2)$$

where N_1 is the average interval between the watering time periods, days;

h – water balance deficit within a certain growing season, m^3/day,

$$h = V/N, \quad (3)$$

where N is the duration of the growth period, days.

The time required to supply the amount of water corresponding to the irrigation rate was determined experimentally depending on the structure of the irrigation network, the irrigation rate and the soil properties [13].

For the subsurface irrigation, the watering time is determined by the formula:

$$t = \frac{m \cdot 1000}{q \cdot n_1 \cdot n_2}, \quad (4)$$

where t is the watering time, h;

q – water consumption by one peg, l/h;

n_1 – the number of pegs around one tree, pcs;

n_2 – the number of trees per hectare, pcs;

When moistening the rows of trees arranged in a line, the time required to supply the amount of water corresponding to the irrigation rate is:

$$t = \frac{m \cdot b \cdot \Delta l}{10 \cdot q}, \quad (5)$$

where b is the distance between the rows of irrigated crops, m;

Δl is the distance between the drops of the peg irrigation system, m.

During the intra-soil watering of fruit trees, only a part – 0.1-0.2 of the area is moistened, not the whole garden. This indicator usually depends on the plant type and variety, its age, size, planting density, soil and climatic conditions. In this case, the following expression is used to calculate the irrigation rate:

$$V=(R-Q)\frac{W_k \cdot r}{\sqrt{0,3\cdot(1-W_k+W_k^2)}}, \quad (6)$$

where R is evaporation from the surface of open water during the growing season, m^3/ha;

Q is the amount of precipitation during the growing season, m^3/ha;

r – coefficient of proportionality between evaporation from the surface of open water and water consumed by plants through the moisture circuit;

W_k is the moisture contour coefficient representing the wetted part of the plant nutrition zone.

For the surface irrigation of agricultural crops, the seasonal rate can be determined taking into account the bioclimatic coefficients of crops [14, 15]:

$$V=\frac{(W\sum d-Q)\,W_k}{\sqrt{0,3\cdot(1-W_k+W_k^2)}}, \quad (7)$$

where W is the bioclimatic coefficient for different climatic zones and crops;

$\sum d$ is the average daily moisture deficit during the growth of agricultural crops, mm.

For the subsurface irrigation, a one-time irrigation rate is calculated using the expression [15, 16]:

$$m=\frac{100\cdot h\cdot g\cdot W_k(\varphi_y-\varphi_q)}{\sqrt{0,3\cdot(1-W_k+W_k^2)}}, \quad (8)$$

$$H=\frac{m\cdot\sqrt{0,3\cdot(1-W_k+W_k^2)}}{100\cdot h\cdot g\cdot W_k(\varphi_y-\varphi_q)}, \quad (9)$$

where H is the depth of the moistened soil layer, m;

g – the volumetric weight of the reference soil layer, t/m^3;

y – the upper limit of the average soil layer moisture content,%.;

q – the lower limit of the average soil layer moisture content,%.

To calculate the one-time and seasonal irrigation rates, the R, Q indicators can be found in the databases of hydrometeorological observations for the region [3, 5, 7].

Experimental studies were carried out in 2017-2019. An intensive garden of dwarf varieties covering the area of 6 hectares was divided into three 2-hectare plots.

The first plot is a reference one for the continuous irrigation, the second plot is for the drip irrigation, and the third one is for the subsurface irrigation.

The interval between the watering periods is 9-17 days.

Water consumption during the continuous irrigation was determined during the irrigation using a Chipoletti water meter, and in the other two options – during the drip and subsurface irrigation – this indicator was calculated based on the pump performance per unit time [12-14].

The boundaries of the water distribution were studied in the laboratory when organizing pile irrigation for various texture soils (*Fig. 4*).

In the laboratory experiment, at the end of the first hour the water absorption rate was 0.079 m/h in the medium sandy soils, at the end of the fourth hour it was 0.05 m/h, and the filtration coefficients were 0.018 and 0.013 m/h, respectively.

Fig. 4. The pile method for studying the water distribution boundaries: a – determining the peg angle when installed at an angle; b – initial soil moisture; c – complete soil moistening

Table

Water consumption depending on the irrigation method

Irrigation methods	2017 year		2018 year		2019 year		Water consumption on average for 3 years, m^3/ha
	Number of waterings	Irrigation rate, m^3/ha	Number of waterings	Irrigation rate, m^3/ha	Number of waterings	Irrigation rate, m^3/ha	
Furrow irrigation (control)	11	1080	12	1111.9	11	1185,2	1125,7
Drip	15	594	19	610.7	18	651,1	618,6
Subsurface	13	486	14	500.2	15	533	506,4

The experiments were carried out according to the following system: the first option (the reference one) – furrow irrigation, the second option – drip irrigation, the third option – subsurface irrigation (*table*).

Compared to the reference plot, water consumption during the drip irrigation was 507.1 m^3/ha (45%), during the subsurface irrigation – 619.3 m^3/ha (55%). As you can see, the subsurface irrigation is more efficient in terms of water saving. Compared to the reference option, the water consumption during the drip irrigation was reduced by 45% (507.1 m^3/ha), and during the subsurface irrigation – by 55% (619.3 m^3/ha).

Conclusions. For the irrigation of intensive gardens with a moisture deficit, ground waters can be used supplemented with river water. The equipment and technology for the subsurface irrigation have been developed. Water consumption was as follows: for the furrow irrigation – 1125.7 m^3/ha, for the drip irrigation – 618.6 and for the subsoil irrigation – 506.4 m^3/ha. The subsurface irrigation, in comparison with other methods of providing trees with water and nutrients, increases water saving by 57%, mineral fertilizer saving by 25-35%. Excessive post-irrigation drainage and filtration losses were avoided while the topsoil was retained soft. Seasonal irrigation rates depend on rainfalls.

REFERENCES

1. Gulamov S.B. Features of application of fertilizers in dry irrigation. *International Journal of Engineering, Science and Mathematics*. 2018. Vol. 7. N7. 26-30 (In Uzbek).

2. Baraev F.A., Serikbaev B.S., Gulomov S.B. Nadezhnost' sistem kapel'nogo orosheniya [Reliability of drip irrigation systems]. *Irrigation and Melioration*. 2017. N4(10). 10-12 (In Uzbek).

3. Khamidov M., Muratov A. Effectiveness of rainwater irrigation in agricultural crops in the context of water resources. *IOP Conference Series: Materials Science and Engineering*. 2021. N1030(1). 012130 (In English).

4. Khamidov M.Kh., Isabaev K.T., Urazbaev I.K., Islomov U.P., Inamov A.N. Hydromodule of irrigated land of the southern districts of the republic of karakalpakstan using the geographical information system creation of regional maps. *European Journal of Molecular and Clinical Medicine*. 2020. N7(2). 1649-1657 (In English).

5. Khamidov M., Isabaev K., Urazbaev I., Inamov A., Mamatkulov Z. Application of geoinformation technologies for sustainable use of water resources. *European Journal of Molecular and Clinical Medicine*. 2020. N7(2). 1639-1648 (In English).

6. Khamidov M., Khamraev K. Water-saving irrigation technologies for cotton in the conditions of global climate change and lack of water resources. IOP Conference Series: Materials Science and Engineering. 2020. N883(1). 012077 (In English).

7. Zhuraev F.U., Musulmanov F.Sh. Primenenie tekhniki i tekhnologii dlya sil'nozasolennykh pochv [Equipment and technology application for washing highly saline soils]. *Sel'skohozyajstvennye mashiny i tekhnologii*. 2020. Vol. 14. N2. 29-33 (In Russian).

8. Juraev F., Karimov G. Water saving technique and technology of subsurface irrigation. IOP Conference Series: Materials Science and Engineering. 2020. N883(1). 012095 (In English).

9. Alimdzhanov A.A., Karimov A.Kh., Nasibov B.R. Nedostatki planirovaniya vodopol'zovaniya na urovne vodopotrebiteley i assotsiatsiy vodopotrebiteley [Inadequacy of current water use planning at the level of water users and WUAs]. *Irrigation and Melioration*. 2020. N4(22). 12-18 (In Uzbek).

10. Gaybullaev B.Sh. Tyagovoe soprotivlenie korpusa pluga k ovoshchevodcheskomu traktoru [Tractive resistance of the body of the plow to vegerable-growing tractor]. *Irrigation and Melioration*. 2017. N2(8). 52-54 (In Rissian).

11. Sadiev F.F., Yuldashev M.Z., Shirokova Yu.I., Paluashova G.K., Yakubov M.A. O metodakh vosstanovleniya gipsonosnykh i sil'nozasolennykh pochv Syrdar'inskoy oblasti v sovremennykh usloviyakh [About methods for restoring hypson-based and high salinity of soils of the Sirdarya region under modern conditions]. *Irrigation and Melioration*. 2019. N4(18). 7-13 (In Uzbek).

12. Khort D.O., Maistrenko N.A., Tereshin A.N., Vershinin R.V. Issledovanie usloviy sema yagod zemlyaniki sadovoy robotizirovannymi mashinami [Studying the methods of harvesting garden strawberry with robotic machines]. *Sel'skohozyaystvennye mashiny i tekhnologii*. 2020. Vol. 14. N1. 27-33 (In Russian).

13. Liskin I.V., Mironova A.V. Obosnovanie iskusstvennoy pochvennoy sredy dlya laboratornykh issledovaniy iznosa i tyagovykh kharakteristik pochvorezhushchikh rabochikh organov [Artificial Soil Environment Justification for Laboratory Studies of Wear and Traction Characteristics of Soil-Cutting Working Bodies]. *Sel'skohozyaystvennye mashiny i tekhnologii*. 2020. Vol. 14. N3. 53-58 (In Russian).

14. Kurbanov R.K, Zakharova N.I. Application of vegetation indices to assess the state of crops. *Sel'skokhozyaystvennye mashiny i tekhnologii*. 2020. Vol. 14. N2. 4-11 (In English).

15. Melikhova E.V. Sozdaniye sistemy podderzhki prinyatiya resheniy pri vybore rezhima orosheniya selskokhozyaystvennykh kultur [The development of a decision support system when choosing a crop irrigation regime]. *Melioratsiya*. 2019. N1(87). 28-22 (In Russian).

16. Abramovich G.N., Girshovich T.A., Krasheninnikov S.Y. et al. Teoriya turbulentnykh struy [The theory of turbulent jets]. Moscow: Nauka. 1984. 716 (In Russian).

Конфликт интересов. Авторы заявляют об отсутствии конфликта интересов.

Conflict of interest. The authors declare no conflict of interest.

Статья поступила в редакцию 05.04.2021
The paper was submitted to the Editorial Office on 05.04.2021

Статья принята к публикации 25.05.2021
The paper was accepted for publication on 25.05.2021