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Elaboration of Subsurface Irrigation Technique of Onions.

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ABSTRACT

At the present time, the increasingly growing deficiency of water resources requires application of new water-saving irrigation techniques allowing the most productive use of irrigation water and achieving maximum yield while using the minimum amount of irrigation water. Therefore, the development of subsurface irrigation of vegetable crops is main objective of the current research. Subsurface irrigation is one of the promising water-saving irrigation technologies of agricultural crops that previously has not been used in the Republic of Kazakhstan. Elaboration of subsurface irrigation technology of onion was carried out in comparison with the onion cultivation technology at drip irrigation and furrow irrigation. To save water at optimal watering and nutrition regimes, the subsoil irrigation of plants was carried out through porous water-conducting hoses produced by "Kazkauchuk" LLP (Kyzylorda). The article presents the research results on subsurface irrigation of bulb onions. The growth and development phases of "Manas" variety onions were determined at subsurface, drip, and furrow irrigations. Besides, the authors have further developed subsurface irrigation regime with regard to bulb onions cultivation, determining the actual yield and the water-use ratio of cultivated crops. The analysis of the water use supplied in various test options showed that the lowest irrigation rate was observed when carrying out subsurface irrigation.

Keywords: irrigation techniques, subsurface irrigation, watering, water use, porous water-conducting hoses, water-use ratio.

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INTRODUCTION

Worldwide, irrigated agriculture is one of the main factors ensuring the sustainability of agricultural production and food security. The irrigation development helps to ensure the guaranteed volumes of production, reduce economic risk associated with crop losses due to the instability of weather conditions, create jobs for the rural population, and improve populated localities as well as contribute to number of other factors providing the growth in the living standard.

Analysis of the applied technologies and technical means of irrigation in the world (1, 2, 3, 4, 5, 6, 7) leads to the conclusion that drip, subsurface, and sprinkler irrigations are the most acceptable techniques in terms of water and energy saving. At that, drip irrigation and subsurface irrigation, as compared with sprinkler irrigation, have a distinct advantage because of the lower overall water use and energy consumption per unit of produced agricultural product, and can be recommended for countries with lack of irrigation water (Asia, Africa), where surface irrigation is the main watering technique.

One of the promising resource-saving irrigation techniques is subsurface irrigation, which consists in supplying water directly to the zone of plant root system through special subsurface moisturizers, making it possible to maintain constant humidity level in the active layer of the soil and prevent it from significant fluctuations. This technique provides soil aeration and does not prevent from carrying out mechanized works (8, 9, 10).

TECHNIQUE

The main parameters and elements of subsurface irrigation technique include the following: depth of humidifiers (0.05-0.6 m); the pressure head in the humidifiers (0.2-0.5 m); specific flow rate of liquid in humidifiers (0.02-0.33 l/s per 100 m of length); the total length of the humidifiers (50-250 m); the distance between the humidifiers or wetting zones (0.3-3.5 m for systems without a natural confining layer); and the duration of irrigation. In Russia, subsurface irrigation is carried out employing capillary irrigation method, in which vessels, situated below the soil surface and connected with surface lines, deliver water to the plants' root system from the bottom holes arranged with a capillary clearance above the bowl-shaped vessel. This technical solution allows excluding the penetration of sucklings into the holes and grooves of vessels and increases the efficiency of subsurface irrigation (11, 12, 13).

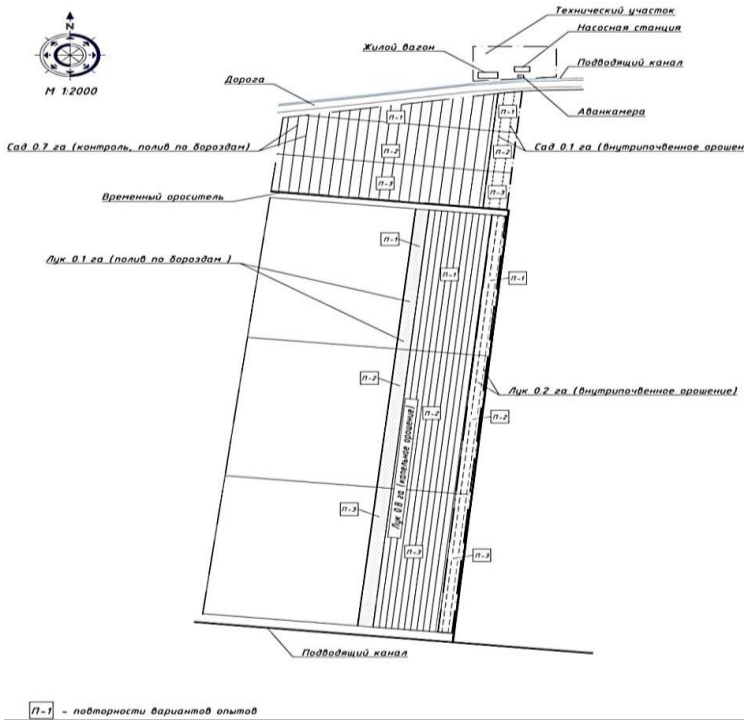

Figure 1. Pilot production site of Kazakh Scientific Research Institute of Water Economy

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Technical site	Bedding, 0.1 ha (subsurface irrigation)
Irrigation pumping plant	Field ditch
Portable cabin	Onions, 0.1 ha (furrow irrigation)
Feeder channel	Onions, 0.2 ha (subsurface irrigation)
Road	Onions, 0.8 ha (drip irrigation)
Intake chamber	Supply canal
Bedding, 0.7 ha (control and furrow irrigation)	R-1 Test replications

In 2015, the tests to study and elaboration of subsurface irrigation technique at onions cultivation under the climatic conditions of the southern region of Kazakhstan were initiated at the pilot production site (PPS) of 0.2 ha (Fig 1).

In terms of mechanical composition, meadow-gray soils of pilot plot are medium-textured loams with a density of 1.22 ton/m^3 and the lowest moisture equivalent of 21-22% by weight of the dry soil, and ground water level GWL=1.9-2.4 m. In terms of water permeability, the soils of pilot plot are regarded to those with an average permeability (Fig. 2).

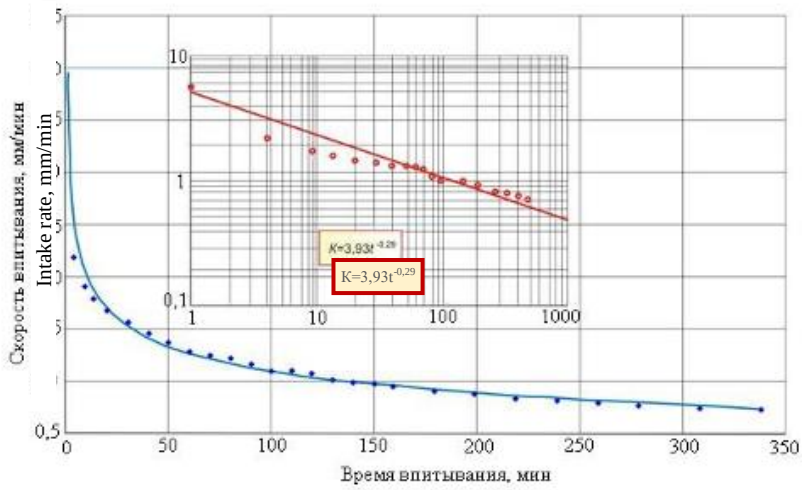

Figure 2. Water permeabilities.

Absorption rate during the first hour was 1.288 mm/min or 7.73 cm/h, while the attenuation factor was 0.28.

The following was determined during the preparation and implementation of field experiments on water saving technique at onions cultivation with subsurface irrigation at the PPS: the water-physical and agrochemical properties of the soil, rooting depth, groundwater salinity and a number of other indicators according to existing established survey technique.

Phenological and biometrical observations were carried out according to the established practice, while experimental results were processed using statistical methods (14, 15). Agrochemical properties of the soil were determined through the laboratory studies according to standard techniques (16, 17, 18, 19, 20).

RESULTS

The subsurface irrigation system includes water source, irrigation pumping plant, supply, distribution and irrigation lines and the devices for subsurface irrigation of plants.

Water-conducting porous hoses produced by "Kazkauchuk" LLP (Kyzylorda) according to German technology are applicable for use in subsurface irrigation systems.

The hose has a dense structure and micropores along its full length, through which water penetrates directly to the plant roots allowing it to be used both on the earth's surface and at landing into the soil in almost any area providing an increased efficiency of agricultural crops development.

At a slight pressure in the network (<0.06 MPa), water-filled hoses ooze, and thanks to the suction properties of the roots and capillarity of the soil, the water flows directly to the roots, that is, water is almost completely used for the purpose intended. The additional advantage of this system is the ability to provide plants of agricultural crops with fertilizers and minor nutrient elements as well as ambient oxygen.

In the tests, drip irrigation and traditional furrow irrigation were used as control options.

The following test options were studied:

Option 1 – subsurface irrigation; irrigation was carried out through oozing hoses produced by "Kazkauchuk" LLC, laid in the ground at a depth of 5-7 cm.

Option 2 – drip irrigation; irrigation was carried out through drip irrigation system of the "NaanDanJain" company;

Option 3 – control; furrow irrigation was carried out.

The plots area at subsurface irrigation was 0.2 ha, drip irrigation - 1.0 ha, and control (furrow) irrigation - 0.1 ha.

The onions cultivation technology at subsurface irrigation consists of the following main stages:

1. Soil preparation;
2. Sowing;
3. The calculation of subsurface irrigation system and its installation in the field;
4. Nutrition and irrigation regimes;
5. Control of weeds, pests and diseases;
6. Onions harvesting.

In the spring (March 19), after harvesting of crop residues at the onions cultivation site, we conducted moldboard plowing of test plot to a depth of 23 cm plowing up by 3 furrow share plow and harrowing by light harrows 3BP-0.6 to a depth of 5-7 cm (Fig. 3). The cultivation of the treated soil, leveling and compaction of the topsoil, as well as layout of the PPS surface were carried out during the timeframe from 6 to 13 April.

Figure 3. Harrowing by light harrows 3BP-0.6 to a depth of 5-7 cm.

The treatment with solid mineral fertilizers was carried out on April 18 using a mechanical spreader in all test options (150 kg/ha of "Suprafos", 100 kg/ha of ammophos, and 500 kg/ha of potassium sulfate).

The use of quality hybrid seeds for growing onions is the prerequisite and the groundwork of the future harvest. The seeds of the "Manas" variety, having a high tolerance to pink rot and fusarium, were selected for planting in all test options.

The use of contemporary heterotic hybrids and varieties is economically justified only in the case of availability of precision seed drills. Therefore, sowing the seeds of "Manas" variety onions was conducted on April 22 employing precision seed drill with seeding rate of 9 kg/ha and simultaneous laying of lines for subsurface and drip irrigation. For these options, 10-row planting scheme of onions through 1.4 m (Fig. 4) was chosen. With this planting scheme, one irrigation line evenly moistens five sowing lines.

Figure 4. Onions planting with simultaneous laying of lines for subsurface and drip irrigation

Supply and distribution networks, irrigation lines with the necessary shut-off and control valves, irrigation facilities, means of irrigation control and other necessary equipment was installed at the pilot production site. After this, pre-emergent irrigations were carried out in all test options. Further, watering through the subsurface and drip irrigation systems were carried out every 2-4 days depending on the need of the crops.

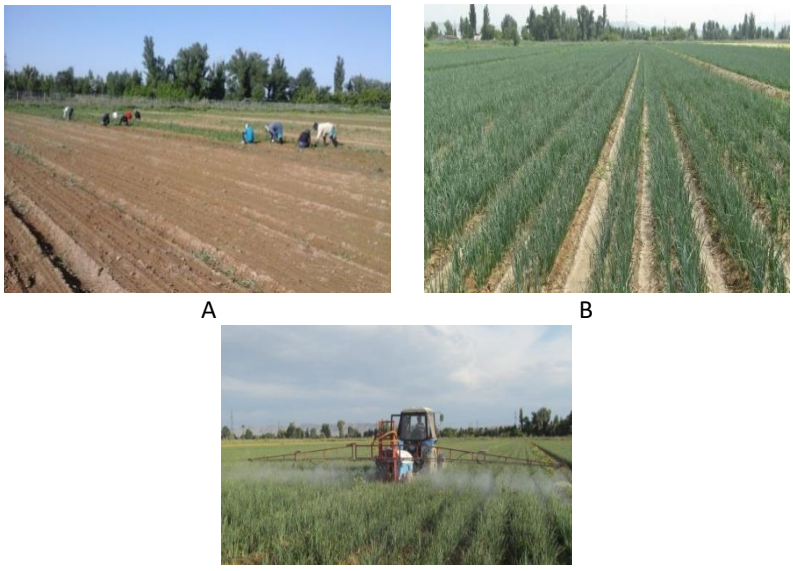

Figure 5. Carrying out works on pilot production site:

a) weeding of onion; b) onions growth and development monitoring area;
c) onions processing with insecticides and pesticides against diseases and pests.

Onions is one of the most demanding crops in terms of water use, especially during the first 3-4 weeks after germination, when the first true leaves appear. Therefore, immediately after sowing of onions and installation of subsurface drip irrigation systems, watering was carried out until complete soaking of the humidification contour in the area of seeds occurrence.

The soil moisture in the roots concentration area was maintained during the growing season at minimal water capacity (MWC) of 70-80%. Maintaining soil moisture in the zone of the root system occurrence at optimum level is a basic principle of subsurface and drip irrigation. Irrigation depth and, consequently, the irrigation regime were determined based on the quantity of moisture evaporated and used by the plants.

Observations of the plants growth and development, sampling of soil for determination of its moisture content, monitoring ground water levels, weeding, onions processing against diseases and pests, etc. were carried out in all test options (Fig. 5).

The results of observations of the “Manas” variety onions growth and development phases are shown in Table 1.

Table 1. The growth and development phases of "Manas" variety onions in various test options.

Growth and development phases of the elements of agrotechnics	Dates		
	Subsurface irrigation	Drip irrigation	Control
Sowing	22.04.	22.04.	22.04.
Seeds germination	10.05.	11.05.	01.05.
Crookneck	17.05.	19.05.	09.05.
Flag	26.05.	27.05.	17.05.
The 1st leaf phase	17.06.	17.06.	10.06.
The 2nd leaf phase	01.07.	01.07.	30.06.
The 3rd leaf phase	07.07.	07.07.	07.07.
The 4th leaf phase (seedling phase)	15.07.	15.07.	18.07.
The 5th leaf phase	22.07	22.07	25.07.
The 6th leaf phase	25.07.	25.07.	28.07.
The 7th leaf phase	29.07.	29.07.	03.08.
The beginning of bulb formation	05.08.	05.08.	11.08.
Formed bulb	17.08.	17.08.	26.08.
Matured bulb	12.09.	12.09.	20.09.
Onions harvesting	02.10.	02.10.	10.10.

Farming cultivation of onions in the tests was carried out in accordance with the flow process chart of bulb onion cultivation. Care of crops during the growing season consisted in a timely and high-quality inter-cultivation, weed, as well as pests and diseases control. Additionally, foliar applications were carried out for complete supply of onions with essential minor nutrient elements at growth and development stages (Table 2). The types and amounts of mineral fertilizers were selected on the basis of soil and climatic conditions as well as flow process charts of onions cultivation at subsurface and drip irrigation.

Table 2. Flow process chart of onions cultivation at subsurface and drip irrigation

Type of works and resources	Area, ha	Execution period	Types and amounts of fertilizers and plant protection agents	Purpose of the formulations	Type of agricultural equipment
1	2	3	4	5	6
Cleaning of plant residues from the field preceding crop	1.3	17.03.			MT3-82+draught with harrow and manually

Plowing to a depth of 23cm	1.3	19.03.			MT3-82+draught with PON-3-30 share plow
Cultivation	1.3	06.04.			MT3-82+draught with KPS-4 cultivator
Leveling and compaction of the topsoil	1.3	10.04.			MV-6 land leveler
Layout	1.3	13.04.			Autograder
Harrowing to a depth of 5-7 cm	1.3	13.04.			MT3-82+draught with 3BM-0.6 harrow
Presowing application of mineral fertilizers	1.3	18.04.	Suprafos[1]: 150 kg/ha; Ammophos: 100 kg/ha; Potassium sulfate: 500 kg/ha		T-25+RUM5-0.35
Presowing cultivation	1.3	21.04.			MT3-82+draught with KPS-4 cultivator
Planting of Manas variety onions at a seeding rate of 9 kg/ha with simultaneous cutting of ridges and laying tape for subsurface and drip irrigation	1.3	22.04.			Precision seed drill
After seeding tillage	1.3	24.04.	Stomp: 10 packs; BI-58: 1 l packs; Gaucho (imidacloprid): 17 l	Against dicotyledonous weeds; pest control	MTZ-82+ OP 2000
Hilling of field ditches for irrigation	1.3	25.04.			K-701+KOR-500
Hilling of field ditches for the furrow irrigation	0.1	01.05.			MTZ-82.1+KOR
Laying of lines and hoses for subsurface irrigation	0.2	05.05.			Manually
Installation of drip irrigation to laflete	1.0	06.05.-07.05.			Manually
Preparing of pumping equipment for watering	1.2	10.05.			Manually
The application of insecticide in test option #3	0.1	13.05.	BI-58 (dimethoate): 1.0 l/ha	Pest control	MTZ-82+ OP 2000
Foliar application of onion in test option #3	0.1	13.05.	Ammonium Phosphate: 3 kg/ha	Adjustment of plant nutrition	Manually
Fertilizer application in test option #3	0.1	15.05.	Ammonium sulphate: 60 kg/ha	Top-dressing	MTZ-82+ KRN 4.2 cultivator
Fertilizer applications in test options #1 and #2	1.2	17.05.-19.05.	Ammonium Sulphate: 60 kg/ha BI-58 (dimethoate): : 1.0 l/ha	Plant-root fertilization; Pest control	Subsurface and drip irrigation system
Spraying of crops	1.3	21.05.	Aktara[6]: 375 g/ha	Pest control	MTZ-82+ OP 2000
Post-emergence weeding	1.3	28.05-6.06.			Manually
Spraying of crops	1.3	02.06-03.06.	Aktara: 375 g/ha	Pest control	MTZ-82.1+ OP 2000
Top-dressing with mineral fertilizers in test options #1 and #2	1.2	0.6.06.	UAN: 3 l/ha	Plant-root ertilization for balanced plant nutrition	Subsurface and drip irrigation system

The application of fertilizer in test option #3	0.1	08.09.	Ammonium saltpeter: 100 kg/ha	Top-dressing with nitrogen	Manually
Application of fertilizers in test options #1 and #2	1.2	08.06.-10.06.	Ammonium saltpeter: 75 kg; Novalon 19-19-19: 6 kg	Top-dressing by nitrogen; NPK complex fertilizer	Subsurface and drip irrigation system
The application of fertilizer and insecticide in test options #3	0.1	10.06.	UAN: 7 l; Gaucho (imidacloprid): 4 l	Plant-root fertilization against wide range of pests	With water along the furrows
Spraying the onion by minor nutrient elements in test options #1and #2	1.2	12.06.	Grogreen: 500 gr/ha; Gum: 100 gr/ha	Growth stimulator; elimination of micronutrient deficiencies	Subsurface and drip irrigation system
Weeding of onions in test option #3	0.1	14.06.-16.06.			Manually
Weeding of onions in test options #1 and #2	1.2	17.06.			Manually
Application of fertilizers in test options #1 and #2	1.2	18.06.	Ammonium saltpeter: 50 kg/ha; «Polytrin» – 0.5 l/ha	Top-dressing with nitrogen against the larvae of lepidopteran pests and other leaf-eating insects	Subsurface and drip irrigation system
Application of fertilizer in test options #1 and #2	1.2	20.06.	Suprafos: 50 kg/ha		Subsurface and drip irrigation system
Soraying of field ditches by herbicides	1.3	21.06.	Zellek-Super “Hurricane”	Destruction of all kinds of grass weeds in dicotyledonous crops	Manually
Application of fertilizers with water in test options #1 and #2	1.2	22.06.	UAN: 26 l “Baikal”[3]: 1 l	Plant-root fertilization; growth promoting factor	Subsurface and drip irrigation system
Application of fertilizers in test option #3	0.1	25.06-26.06.	Ammonium saltpeter: 250 kg/ha	Top-dressing with nitrogen	With water along the furrows
Spraying of onion in test option #3	0.1	27.06.	“Bravo”[4]: 5 l; Nurel: 2 l	Disease control	Manually
Application of fertilizers in test options #1 and #2	1.2	28.06.-29.06	Ammonium saltpeter: 150 kg; UAN - 17 l	Plant-root fertilization Side dressing by nitrogen	Subsurface and drip irrigation system
Spraying onion with a mixture in test options #1 and #2	1.2	30.06.	Grogreen N13-P40: K13: 3 kg; LukRost: 100 gr; Calcium: 2 kg	Growth promoting factor; Plant-root fertilization	MTZ-82+ OP 2000 (per 400 l of water)
Spraying onion with a mixture in test option #3	0.1	30.06.	Ascot: 2 l; LukRost: 200 gr; “Baikal”:- 2 l; Calcium: 4 kg; Novalon 19-19-19: 5 kg	Growth promoting factor; NPK complex fertilizer	MTZ-82+ OP 2000 (per 800 l of water)
Application of fertilizers in	1.2	30.06.	Calcium - 5 kg/ha	Vitamins preventing	Subsurface and drip

test options #1 and #2				the lodging	irrigation system
Spraying onion with a mixture in test options #1 and #2	1.2	03.07.	Novalon 19-19-19: 3 kg; "Baikal": 2 l; Calcium: 1 kg; Gum: 1 l	NPK complex Fertilizer; Growth promoting factor; Prevention and elimination of micronutrient deficiencies	MTZ-82+ OP 2000 (per 400 l of water)
Spraying onion with a mixture in test option #3	0.1	03.07.	Novalon 19-19-19: 4 kg; "Baikal": 1l; Calcium: 2 kg; Gum: 1 l; Boron: 0.5 kg	NPK complex fertilizer; Growth promoting factor; prevention and elimination of micronutrient deficiencies	MTZ-82+ OP 2000 (per 800 l of water)
Spraying onion with a mixture in test options #1, #2 and #3	1.3	07.07.	"Bravo": 9 l; "Borey": 300 gr; "Polytrin": 2 l; "Stroby": 3 l.	Disease control against the larvae of Lepidoptera pests and other leaf-eating insects	MTZ-82+ OP 2000 (per 1200 l of water)
Application of fertilizers in test options #1 and #2	1.2	08.07.-10.07.	Carbamide: 200 kg; Ammonium saltpeter: 400 kg; «Baikal» 0.5 l	Side dressing with nitrogen and minor nutrient elements	Subsurface and drip irrigation system
Application of fertilizers in test option #3	0.1	08.07.	Carbamide: 350 kg	Top-dressing with nitrogen	With irrigation water along the furrows
Weeding of onions in all test options	1.3	09.07.-14.07.			Manually
Spraying onions with an insecticide	1.3	21.07.	"Karate"[2]: 0.2 l/ha	Pest control	MTZ-82+ OP 2000
Spraying onions with an insecticide	1.3	22.07.	"Akrobat": 2 kg/ha	The destruction of weeds, insects, their larvae and eggs	MTZ-82+ OP 2000
Spraying onions with a mixture in test option #3	0.1	27.07.	"Tien Shan": 2.kg/ha; "Polytrin": 0.7 l/ha; "Diamant": 0.7 l/ha	Chemical fertilizers against dicotyledonous weeds	MTZ-82+ OP 2000
Spraying onions with a mixture in test options #1 and #2	1.2	28.07.	Morbidol: 2 l; Calcium: 2 l; "Polytrin": 2 l; "Diamant": 2 l/ha	Pests control against the larvae of Lepidoptera pests and other leaf-eating insects	MTZ-82+ OP 2000
Top-dressing onions in test option #3	0.1	28.07.-29.07.	Ammonium saltpeter-600 kg	Top-dressing with nitrogen	Manually and through subsurface and drip irrigation system
Top-dressing onions by fertilizers in test options #1 and #3	0.3	30.07.	Novalon 19-19-19: 2 kg; UAN: 4 l; "Baikal": 1l	NPK complex fertilizer; Nitrogen fertilizer	Manually and through the subsurface irrigation system
Top-dressing onions by fertilizers in test option #2	1.0	31.07.	Novalon 19-19-19: 1 kg; UAN: 2 l; "Baikal": 1 l	NPK complex fertilizer; Plant-root fertilization; Growth promoting factor	Manually and through the drip irrigation system
Spraying onions with a	1.3	03.08	Carbamide: 75 kg;	Top-dressing of	MTZ-82+ OP 2000

mixture in all test options			Magnesium sulfate: 16 kg; Novalon 19 -19-19: 7.5 kg; Boron: 3 kg; "Karate": 2 l; "Polytrin": 1 l; "Enjio"[10]: 0.5 l	onions, pest and diseases control	
Top-dressing onions in test options #1 and #2	1.2	03.08.	"Dense calcium ": 2 kg; Beres-4 (calhumite): 0.2 l; "Baikal"; 1 l	Plant-root fertilization N: 15.5%, CaO: 26.5%. Top-dressing with minor nutrient elements	Subsurface and drip irrigation system
Spraying onions with a herbicide in test option #3	0.1	04.08.	Morbidol, 1 l/ha	Pests control	MTZ-82+ OP 2000
Spraying onions with a biological fertilizer in all test options	1.3	05.08.	"Izabion"[9]: 2 l/ha	Plants Growth promoting factor	MTZ-82+ OP 2000
Top-dressing onions in test options #1 and #2	1.2	07.08, 09.08.	Ammonium saltpeter 50 + 25 kg	Top-dressing with nitrogen	Subsurface and drip irrigation system
Top-dressing onions in test option #3	0.1	09.08. 10.08.	Ammonium saltpeter 350 kg+500 kg	Top-dressing with nitrogen	Manually with irrigation water
Spraying onions with a mixture in all test options	1.3	10.08.	Acetamiprid: 300 gr/ha; "Karate": 300 gr/ha	Coleoptera and Lepidoptera pests and mites control	MTZ-82+ OP 2000
Top-dressing onions in test options #1 and #2	1.2	11.08.	Ammonium saltpeter: - 25 kg	Top-dressing with nitrogen	Subsurface and drip irrigation system
Top-dressing onions in test option #3	0.1	12.08.	Ammonium saltpeter- 100 kg	Top-dressing with nitrogen	Manually with irrigation water
Spraying onions with herbicides in test options #2 and #3	1.1	14.08.	Morbidol: 0.5 l/ha; "Baikal": 2 l/ha; Grogreen – 5 kg/ha	Growth stimulation weeds control	MTZ-82+ OP 2000
Spraying onions with herbicides in test options #2 and #3	0.1	27.08.	"Goal" – 0.5 l; Acetamiprid: 6 packs	Pest and dicotyledonous weeds control	MTZ-82+ OP 2000
Application of agent in test option #2	1.0	29.08.	Lime saltpeter: 6 kg/ha	Top-dressing with nitrogen	Drip irrigation system
Spraying onions with a mixture in test options #1 and #2	1.2	02.09.	"Baikal": 1 l; "Izabion": 1 l; Calcium: 7 kg; Potashium – 10 kg; Gum Potashium 2 l	Bio-stimulation of plants growth, application of mineral fertilizers	MTZ-82+ OP 2000
Spraying onions with a mixture in test option #3	0.1	02.09.	"Baikal": 4 l; MWC 101: 10 packs; Calcium: 7 kg; Potassium: 5 kg Potassium Gum: 1 l	Stimulation of plants growth, application of mineral fertilizers	MTZ-82+ OP 2000
Top-dressing onions in test option #3	0.1	03.09.	Ammonium saltpeter: 100 kg	Top-dressing with nitrogen	Manually with irrigation water
Top-dressing onions with mineral fertilizers in test options #1 and #2	1.2	12.09.	Gum: 1 l; Potashium: 1 l	Application of mineral fertilizers	Subsurface and drip irrigation system
Harvesting onions	1.3	02.10	02.10	12.10.	Manually

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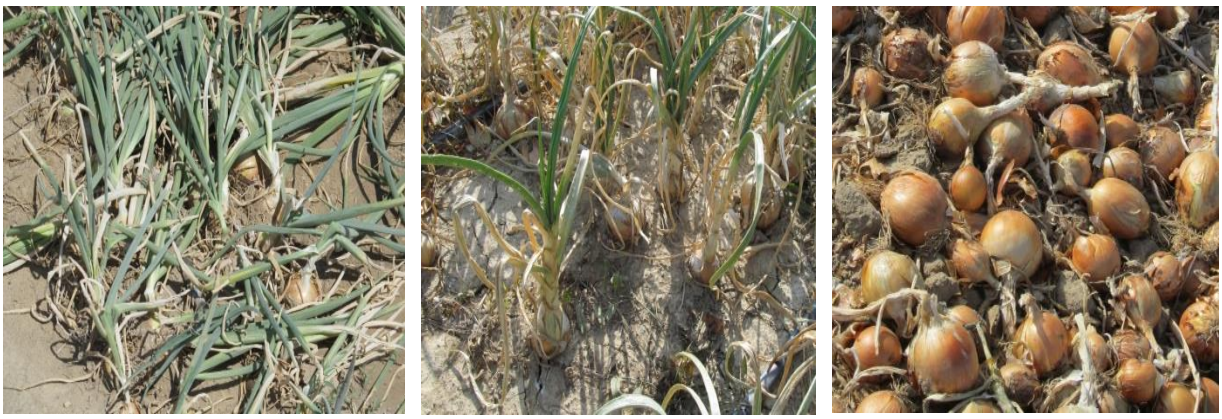
[1] "Suprafos" – N: 12% , P: 24% , Ca: 14%, S: 25%, and Mg: 0.5%;
[2] "Karate" – lambda cyhalothrin;
[3] "Baikal" – microbial fertilizer containing a large number of anabiotic effective microorganisms;
[4] "Bravo" – fungicide;
[5] "Polytrin" – broad-spectrum insecticide;
[6] "Aktara" – insecticide of intestinal-contact action for protection of cultivated plants against sucking and leaf-eating pests;
[7] "Zellek Super" – specialized herbicide to fully kill perennial and annual grass weeds in crops of dicotyledonous crops;
[8] "Stroby" – highly effective broad-spectrum fungicide;
[9] "Izabion" – amino acids and peptides;
[10] "Enjio" – neonicotinoids and pyrethroids.

The onion reaches the stage of physiological maturity and is ready to harvest when the neck of the bulb loses its elasticity, leading to lodging that indicates the readiness of bulb onion for long-term storage. Before harvesting the onions should be allowed to dry and ripen (Fig. 6c). Watering of the onions should be stopped at the lodging stage to allow the bulbs to dry out during the field ripening. The optimal level of onions bunch lodging to start harvesting is 50-75% (Fig. 6a and 6b).



a) –Bunch lodging b) – Bunch drying and ripening c) – Matured bulb onions

Figure 6. Stages of physiological maturity of "Manas" variety onion.

It was revealed that implementation of pre-irrigation soil moistening differentiated according to cropper development phases is the most effective. Table 3 shows the levels of antecedent soil water and the depth of hydration depending on the onions development phase as well as the average values of irrigation rates for the medium loamy soil at PPS.

Table 3. Onions subsurface and drip irrigation options at the PPS

Bulb onion plant development phase	Antecedent soil water, MWC%	Depth of hydration, cm	Irrigation rate, m^3/ha
Medium loamy soil			
Seedling – early formation of bulbs	85	30-35	65-75
Formation – the beginning of bulbs maturation	70	35-40	140-155
Bulbs maturation	75	35-40	130-150

At the furrow irrigation, the irrigation depth was ranged from 600 to 800 m^3/ha depending on the onions development phase and water use.

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According to the results on amount of water applied to various test options as well as taking into consideration onions development phases, climatic conditions, soil moisture, and frequency of irrigation, we have revealed that among all irrigation techniques under study the lowest irrigation rate was observed at subsurface irrigation (5400 m^3/ha). At drip irrigation it amounted to 5600 m^3/ha, while at furrow irrigation it was 7200 m^3/ha. Increase of irrigation rates at drip irrigation by 3.9% was due to additional water losses on evaporation from the soil surface.

Irrigation regimes of onions for various test options as well as biological and actual yield and the croppers water-use ratios are shown in Table 4.

Table 4. Irrigation schedule of onions for different test options

Title	Subsurface irrigation			Drip irrigation			Furrow irrigation		
	Seedling – early formation of bulbs	Formation – the beginning of bulbs maturation	Bulbs maturation	Seedling – early formation of bulbs	Formation – the beginning of bulbs maturation	Bulbs maturation	Seedling – early formation of bulbs	Formation – the beginning of bulbs maturation	Bulbs maturation
Antecedent soil water, MWC %	85	70	75	85	70	75	85	70	75
Depth of hydration, cm	30-35	35-40	35-40	30-35	35-40	35-40	30-35	35-40	35-40
Irrigation depth, m^3/ha	65-75	140-151	130-150	65-75	140-155	130-150	200	140-155	130-150
Amount of irrigation	35			35			15		
Irrigation water requirement, m^3/ha	5400			5600			7200		
Biological yield of onion, ton/ha	90.1			90.1			73.0		
Actual yield of onion, ton/ha (with regard to sowing dates)	80.4			75.6			50.1		
Water-use ratio, m^3/ton	67.2			74.1			143.7		

CONCLUSION

The highest yield of onions was noted at subsurface irrigation as compared to drip and furrow irrigations. At that, in terms of water use, subsurface irrigation is more efficient. Water-use ratio here amounts to 67.2 m^3/ton while at drip irrigation it reaches to 74.1 m^3/ton.

The research on subsurface irrigation technology leads to the following conclusion. Under the conditions of Zhambyl Region the use of subsurface irrigation regimes, differentiated by plants growth and

development phases, provided optimal soil moisture content that along with the use of fertilizers allowed obtaining the biological yield of "Manas" variety bulb onions up to 90 ton/ha. At that, soil moisture content in the layer of 0.3-0.4 m was 70-85% (MWC) during the first half of the growing season (from germination to the beginning of the bulb formation), and 70-75% (MWC) during the second half of the growing season (from the bulb formation to industrial ripeness). This technique ensured the reduction in water use per unit of product by 10.3% in comparison with drip irrigation and by 113.8% compared to furrow irrigation.

With increasing water scarcity, subsurface irrigation will undoubtedly find a wide application. Therefore, it is necessary to continue practicing in the near future the subsurface irrigation technique for other promising agricultural crops.

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