Drop Irrigation of Potatoes and Vegetable Cultures in the Southeast of Kazakhstan

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Abstract: There are stated the results of researches on studying of influence of a drop irrigation on economy of extremely scarce irrigating water taking into account the establishment of optimum modes and norms of watering for foothill dark-chestnut soils of the southeast of Kazakhstan. Application of drop technology promoted decrease in consumption of irrigating water for 35.8% on potatoes and 39.0% - on a tomato. Among vegetable cultures the best indicator is noted in experiences with a cucumber – 47.4%. On a white cabbage the economy of irrigation water was minimum (30.3%) percentagewise, but the water volume (1720 m³/ha) rather high. The cabbage is hygrophilous vegetable culture, it consumes a lot of water, it explains big consumption of irrigation water and smaller percent of economy. On bulb onion which is also exacting to an irrigation mode, 33.6% of water resources are saved. At the accounting of irrigation water consumption there were also considered the expenditure of water on formation of an additional crop of cultures. It is established that when using drop technology efficiency of potatoes and vegetable cultures considerably increases. Intensive development and formation of a powerful biomass of plants is noted. On a drop irrigation there is got: 36.6% of a rise of a crop of potatoes, 30.2% - cabbage, 34.4% - red beets, 36.2% - a tomato, 36.6% - bulb onion, 43.3% - a cucumber.

Abbreviations: t – ton, kg – kilogram, g – gram, mg – miligram, t/ha – ton on a hectare, m³ – cubic meter, m³/ha – square meter, m³/ha – cubic meter on a hectare, l – liter, ha – hectare, % – percent

Key words: Potatoes • Vegetable cultures • Drop irrigation • Technology of watering • Norm of watering • Economy of irrigating water • Productivity • Quality of potatoes and Vegetables

INTRODUCTION

The sustainable development of vegetable-growing branch of Kazakhstan with high profitability of production of vegetable production is possible only on high-fertile irrigated lands. The hot and droughty climate, limitation of water resources compels vegetable growers of the republic to pass to water preserving technologies. In many countries of the world, including enough provided with water sources and a humid climate ones, progressive water preserving technologies are widely introduced. Thus the most perspective and demanded is the drop irrigation [1].

The main advantage of a drop irrigation is considered the economy of irrigation water - from 30-50% to 2-3 times [2]. However it should be noted such important advantage of this way of watering, as prevention of an irrigational erosion. Only for it, it is possible to introduce widely drop technology in irrigated vegetable growing [3, 4]. In favor of a drop irrigation specify such positive moments as improvement of a phytosanitary condition of fields and decrease in pesticidal loading, increase of efficiency of fertilizers, increase in productivity and improvement of biochemical structure of vegetables [5, 6, 7]. The drop irrigation allows to conduct irrigated vegetable growing as well in areas with a rough relief and an acute shortage of irrigation water [8].

For Kazakhstan the drop irrigation is rather new technology. In 2005 in the country only 160 hectares were irrigated in the drop way. In 2009 of the area under a drop irrigation reached 4206 hectares, in 2010 - 10788 hectares, in 2011 - 18311 hectares. In 2013 water preserving technologies are planned to be introduced for the area more than 30 thousand hectares. That is, the increase makes about 200 times. However, if to consider that
irrigated lands in the republic make about 2 million hectares from which now in irrigation agriculture less than 1 million hectares is used, these indicators are low [9].

For expansion of cultivated areas of the vegetable cultures irrigated in the drop way, it is necessary to study comprehensively this technology and to develop the scientific and reasonable recommendations providing high agroeconomic and ecological efficiency [10, 11, 12].

Vegetable cultures, melon and gourd and potatoes are generally cultivated on irrigation. In the Republic of Kazakhstan potatoes annually occupy 170-180 thousand hectares, vegetables – 120-130 thousand hectares, a melon field – 45-50 thousand hectares. In the southeast of the country the area of potatoes makes 30-33 thousand hectares, vegetable cultures – 22-25 thousand hectares. Thus, there is a high potential for introduction and application of the system of drop irrigation in this region [13, 14]. For 2012 in Kazakhstan water preserving technologies are introduced on the area of 25 thousand hectares, including in the southeast (Almaty area) only on 7 thousand hectares, including potatoes, vegetables, fruit and grapes. Thus this technology is introduced by limited quantity of rather large-scale enterprises with allotments of 50-100 hectares and more. It should be noted that the drop irrigation is used only on several types of vegetable cultures – generally tomato and bulb onion.

The analysis of efficiency of various drop technologies shows that their adaptation taking into account local soil climatic conditions, biological and high-quality features of cultivated vegetable cultures is necessary. It is necessary to establish optimum terms of crops of seeds and disembarkation of seedling of vegetable cultures, potatoes landings, optimum schemes of their placement, to develop economically and ecologically effective systems of application of organo-mineral fertilizers and pesticides taking into account specific structure and a threshold of injuriousness of harmful organisms in system of a drop irrigation. Adaptation and development of technologies of a drop irrigation by other valuable types of vegetable cultures (cabbage, carrots, beet table, etc.) has importance.

Considering the abovementioned, scientists of Kazakhstan since 2009 carry out research works on adaptation and an assessment of efficiency of water preserving technologies (a drop, sprinkler and subsoil irrigation) of Israel, China, South Korea, Germany. There is given in this article the data of researches on a drop irrigation of vegetable cultures and potatoes, carried out in 2009-2011gg. which are important for potato growing and vegetable growing development in the southeast of Kazakhstan.

MATERIALS AND METHODS

**Fields Details:** Researches are conducted on a skilled permanent establishment of the Kazakh research institute of potato growing and the vegetable growing (KazRIPGVG), located in the Karasay region of Almaty area of the Republic of Kazakhstan, in 2009-2011. The region – the southeast of Kazakhstan, a foothill zone, 1000-1050 m above sea level, a bias of skilled fields – from 2 to 9°C. Climate is sharply continental. The warm period – 240-275 days, frost free days – 140-170 days. The sum of active temperatures – 3100-3400°C. Hydrothermal coefficient – 0.7-1.0. The annual amount of precipitation – 350-600 mm, for the vegetative period drops out 250-320 mm. The soil – dark-chestnut, middle sandy loam, the maintenance of a humus – 3%, the general nitrogen – 0.18-0.20%, gross phosphorus – 0.19-0.20%, gross potassium – 2.4-2.7%, P<sub>2</sub>O<sub>5</sub> – 33-35 mg/kg, K<sub>2</sub>O – 340-360 mg/kg, pH 7.3-7.4, volume weight – 1.1-1.2 g/cm³. Experience options with an irrigation: ridge-and-furrow irrigation (control), drop irrigation, mist irrigation system (“Naan Dan Jain”, Israel). The length of irrigation furrows on skilled sites on the average made 100 m (from 96 to 105 m), width of row-spacing – 0.7 m. All cultures landed with a row-spacing of 70 cm and between plants the distance equaled 30 cm on potatoes and tomato, 20 cm – a cucumber, 55 cm – cabbage and red beet is seeded according to the scheme of 70:2õ10 cm, bulb onions – three line on crests. These schemes as a whole provide optimum acceptable, rational density of standing of plants (thousand units/hectare): potatoes and tomato – 47.6; cucumber – 71.4; red beet – 285.7; cabbage – 26.0; onions – 857.4.

At a drop irrigation of studied cultures pressure in the main pipes equaled 0.75-1.0, working pressure in drop tapes – 0.3-0.5 atmospheres. On 1 hectare of the area 47 620 pieces of droppers took place on the average.

Crop rotation: 1-grain with lucerne crops, 2-3 lucerne, 4 – potatoes, 5 – cabbage, 6 – cucumber, 7 – tomato, 8 - root crops. Agrotechnology of potatoes and vegetable cultures – standard for this zone, developed by KazRIPGVG.

**Sample Preparation and Analytical Methods:** Researches are conducted by the standard techniques [15-18]. In field experiments and laboratory researches are used:
technique of agrochemical researches (Yudin, 1980); technique of a field experiment (Dospehov, 1985); technique of skilled business in vegetable growing and melon growing (Byelik, 1992). Biochemical analyses: solid - a weight method, starch - according to Evers’s method, the general sugar - according to Bertran’s method, vitamin C - according to Murri’s method, nitrates – potentiometric.

Norms of vegetative waterings - on I.A.Kostyakov’s formula: \[ M = 100 \cdot L \cdot h \cdot (MWC - AM) \cdot CF, \] where: \( M \) - irrigation norm, m³/hectare; \( L \) - volume mass of the soil, g/cm³; \( h \) - depth of wetting, m; \( MWC \) – the minimum water capacity, %; \( AM \) - actual moisture before irrigation, %; \( CF \) - correction factor for the accounting of water on evaporation and (\( CF = 1 \)). Granulometric structure - a pipette method with preliminary processing by a sodium pyrophosphate (Grabarov’s modification); micromodular structure and volume weight – according to Kachinsky’s method; specific weight – picnometer method; porosity - a settlement method on specific and volume masses. Water durability of units - Savvinov’s method, humidity and a moisture capacity - a weight method, water penetration – Nesterov’s device.

**RESULTS AND DISCUSSION**

Important research problem was establishment of a crop of vegetable cultures. Firms-suppliers of system of drop irrigation recommend 3-4 hours as a time of watering. Our researches showed that for watering of vegetable cultures with use of drop tapes in the conditions of a foothill zone of the southeast of Kazakhstan with rather fertile dark-chestnut soils and total quantity of an atmospheric precipitation for the vegetative period at the level of 300-400 mm and more, 2-2,5 hours is enough. So, in the conditions of 2011 full watering of tomato and potatoes was reached in 2,5 hour, of cucumber – 2 hours, of red beets – 2 hours 15 minutes, of late white cabbage – 2 hours 45 minutes, of bulb onions– 2 hours. That is, on those cultures which root system generally takes place in the top layer of earth, the time of water supply can be reduced till 2 hours.

As a whole, on all cultures watering time considerably can be reduced that is important as allows to save irrigation water and the electric power.

In 1 hour of drop watering the soil surface (a radical zone) is humidified in the diameter at 18,8-22,5 cm and in 2 hours – on 24,8-29,3 cm and infiltration (wetting) of irrigation water deep into soils in 2 hours of a drop irrigation made 18,0-20,4 cm. It is quite enough for many types of vegetable cultures. It should be noted that in early phenological phases of development of vegetable cultures time of watering can be reduced (till 1,5-2 hours) and during later periods, on the contrary, is increased (till 2,5-3,5 hours). Thus the period of watering depends on a type of cultivated culture.

Water giving on 1 hectare for one watering significantly differs by types of cultures (m³): cucumber and bulb onions -138,1; red beet – 155,4; potatoes and tomato –172,6; white cabbage -189,9.

Repeated measurements for the accounting of the irrigation water given by 1 dropper, showed that in 1 hour of time 1,4-1,5 l of water are spent. The measured cylinder with a capacity of 500 ml is filled in 20 minutes (+30 seconds). Some fluctuation is explained by pressure in drop tapes.

The consumption of water on 1 plant for one watering also fluctuates in big limits (from 0,161 l to 7,312 l) that depends on density of standing of plants which, in turn, is defined by the scheme of cultivation and biological features of the studied cultures.

For the vegetative period the different number of waterings by types of cultures was carried out: potatoes – 12, tomato-16, cucumber – 18, red beet – 11, late cabbage- 22, onions – 17. It is connected with duration of the vegetative period, need for irrigating water and size of a crop of vegetable cultures.

In Table 1 comparative data of expenses of irrigation water are given at an irrigation of potatoes and vegetable cultures in the southeast of Kazakhstan.

Potatoes consumed irrigation water ridge-and-furrow irrigation way from calculation of 500-600 m³ on 1 hectare. For the vegetative period 5 waterings with various irrigation norms depending on phenological phase of cultural development are carried out. During the season the irrigating norm made 2780 m³/hectare. Potatoes on a drop way of an irrigation consumed less water. So, in the sum for the vegetative period, since a phase of a full butonization (the II decade of June) until the end of a phase of intensive formation of tubers (the III decade of August) 1785 m³/hectare of irrigating water were spent for drop watering of plants of potatoes. Thus, in comparison with traditional ridge-and-furrow irrigation way of watering, the drop technology allowed to save 995 thousand m³/hectare of irrigation water that makes 35,8%.

On a tomato when watering on furrows of expense of water 550 m³/hectare equaled. For vegetation of tomato were made 9 waterings with norms from 350-450 m³/hectare (at disembarkation of seedling and in initial phases of vegetation of culture) to 550-650 m³/hectare. Totally the consumption of irrigation water on growth,
Table 1: Consumption of irrigation water depending on ways of irrigation of potatoes and vegetable cultures, one thousand cubic meter/hectare (2009-2011)

<table>
<thead>
<tr>
<th>Ways of irrigation of cultures</th>
<th>Irrigated cultures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Watered with a blousing on furrows with row-spacings of 45 and 70 cm (traditional)</td>
<td></td>
</tr>
<tr>
<td>2. Watering on a drop technology with use of tapes (experimental)</td>
<td></td>
</tr>
<tr>
<td>Economy of irrigation water at drop system of irrigation during the season</td>
<td>( \frac{\text{м}^3}{\text{га}} )</td>
</tr>
<tr>
<td>Potato</td>
<td>3670</td>
</tr>
<tr>
<td>Tomato</td>
<td>3900</td>
</tr>
<tr>
<td>Cucumber</td>
<td>2670</td>
</tr>
<tr>
<td>Red beet</td>
<td>5670</td>
</tr>
<tr>
<td>White cabbage</td>
<td>3330</td>
</tr>
<tr>
<td>Bulb onion</td>
<td>2210</td>
</tr>
</tbody>
</table>

* the note - without taking into account water losses on a filtration and evaporation

The difference between two technologies of irrigation made 1720 m³/hectare. The economy of irrigation water was minimum (30.3%) in percentage terms, but on the water volume (1720 m³/hectare) rather high. The cabbage is hygrophilous vegetable culture, consumes a lot of water, that explains the big consumption of irrigation water and smaller percent of economy. Here it should be noted large volume of the saved water on formation of a crop of heads of cabbage.

On bulb onions which are also exacting to a mode of irrigation and moisture security of the soil, similar data are obtained. During vegetation of onions it was carried out on a traditional way 8 waterings with average irrigation norm by years from 400 to 450 m³/hectare, the irrigating norm averaged 3330 m³/hectare for 3 years. On a drop irrigation the consumption of water on the average for 2009-2011 made 2210 m³/hectare. Decrease in expenses of water resources on development of a biomass of bulbous plants and formation of a crop of bulbs made 1120 m³/hectare (33.6%).

It should be especially noted that we didn't consider losses of irrigation water on filtration and evaporation which make 35-40% and in sharp dry years- 45-50%. Therefore, at ridge-and-furrow irrigation way of watering which demands simultaneous start-up of large volume of irrigating water, its unthrifty losses very big - on the average 40-45%. At a drop irrigation which doesn't demand a big water stream, unproductive losses of irrigation water make about 10-15% that is very important. And it needs to be noted and considered. Possibility of irrigation of bigger number of the area at the minimum volume of arriving water is one of powerful advantages of system of a drop irrigation. So, if within a day single watering of 10 hectares of the area of potatoes and vegetables requires 4000-5000 m³ of water and taking into account losses – 5600-7000 m³, on drop technology for these purposes are enough to have 670 m³/hectare and taking into account losses – about 1000 m³, that is is 5-7 times less.

development and formation of a crop of tomato made 3670 m³/hectare. When watering on drop technology the consumption of water was much less – 2240 m³/hectare. The economy of irrigation water made 1430 m³/hectare (39.0%).

In experiences with a cucumber at ridge-and-furrow irrigation way consumption of irrigation water was the greatest, despite rather short vegetative period – 400 m³/hectare. It was totally carried out (the I decade of June – the I decade of September) 14 waterings with norms from 30-350 to 400-450 m³/hectare depending on a phenological phase of development, moisture content of the soil and weather conditions. The irrigating norm when using system of drop irrigation under a cucumber was much less and equaled 2050 m³/hectare, i.e. as a whole for the irrigated period the consumption of water decreased twice. The economy of water on drop technology made 1430 m³/hectare that 47.4% to ridge-and-furrow irrigation way of watering are equal. It is the best indicator among all studied cultures.

At red beet water consumption was the smallest in comparison with other cultures. It is capable to grow and create rather powerful biomass and full-fledged crops at smaller number of waterings, using soil moisture and an atmospheric precipitation. 5 waterings with norm of 500-550 m³/hectare are carried out. For the vegetative period 2670 m³/hectare of water are spent. At drop technology of an irrigation of beet the consumption of irrigation water was cut to 1560 m³/hectare, i.e. decreased by 1110 m³/hectare or for 41.6%. Decrease in expenses of water almost twice can be estimated as good effect of a studied way of irrigation on this vegetable culture.

The white cabbage differed by the greatest water consumption. It is connected with a bigger biomass, a bigger surface of leaves and evaporation of bigger amount of moisture, respectively carrying out bigger number of waterings. During the season plants of late cabbage consumed 5650 m³/hectare on a traditional way of watering and 3950 m³/hectare - on a studied way.
Table 2: Productivity of potatoes and vegetable cultures depending on technology of irrigation, ton/hectare (2009-2011)

<table>
<thead>
<tr>
<th>Ways of watering</th>
<th>Potato</th>
<th>Tomato</th>
<th>Cucumber</th>
<th>Red beet</th>
<th>Cabbage</th>
<th>Onion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Furrow irrigation</td>
<td>22,4</td>
<td>42,3</td>
<td>18,7</td>
<td>37,8</td>
<td>35,8</td>
<td>37,4</td>
</tr>
<tr>
<td>2. Drop irrigation</td>
<td>30,6</td>
<td>57,6</td>
<td>26,8</td>
<td>50,8</td>
<td>46,6</td>
<td>51,1</td>
</tr>
<tr>
<td>Difference on corp t/ha</td>
<td>8,2</td>
<td>15,3</td>
<td>8,1</td>
<td>13,0</td>
<td>10,8</td>
<td>13,7</td>
</tr>
<tr>
<td>%</td>
<td>36,6</td>
<td>36,2</td>
<td>43,3</td>
<td>34,4</td>
<td>30,2</td>
<td>36,6</td>
</tr>
</tbody>
</table>

Table 3: Quality indicators of potatoes and vegetables depending on ways of an irrigation (2009-2011)

<table>
<thead>
<tr>
<th>Culture</th>
<th>Solid, %</th>
<th>General sugar, %</th>
<th>Vitamin C, mg %</th>
<th>Starch, %</th>
<th>Acidity, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1*</td>
<td>2*</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Potato</td>
<td>25,77</td>
<td>27,33</td>
<td>2,02</td>
<td>1,95</td>
<td>12,46</td>
</tr>
<tr>
<td>Tomato</td>
<td>5,62</td>
<td>6,11</td>
<td>3,28</td>
<td>3,05</td>
<td>19,43</td>
</tr>
<tr>
<td>Cucumber</td>
<td>5,15</td>
<td>5,19</td>
<td>2,43</td>
<td>2,44</td>
<td>6,86</td>
</tr>
<tr>
<td>Cabbage</td>
<td>9,33</td>
<td>10,59</td>
<td>4,93</td>
<td>5,42</td>
<td>37,00</td>
</tr>
<tr>
<td>Onion</td>
<td>11,17</td>
<td>11,65</td>
<td>9,46</td>
<td>9,08</td>
<td>6,43</td>
</tr>
<tr>
<td>Red beet</td>
<td>17,91</td>
<td>19,99</td>
<td>12,77</td>
<td>13,60</td>
<td>25,96</td>
</tr>
</tbody>
</table>

*The note: 1 - ridge-and-furrow irrigation way; 2 – drop technology of watering.

At the accounting of a consumption of irrigation water it is necessary to consider also the costs of water for formation of an additional crop of production. According to our data, when using drop technology of watering productivity of potatoes and vegetable cultures increases for 32,6-51,5%.

The main indicator is productivity of crops. According to it we can estimate efficiency of developed introduced agroreceptions. Researches showed that the drop irrigation promotes formation of a powerful biomass of plants, increase in productivity of potatoes at 36,6%, vegetable cultures - on 30,2-43,3% (Table 2).

In experiences with potatoes productivity of standard tubers made on "watering on furrows" option 22,4 t/hectare and on "drop watering" option - 30,6 t/hectare. Excess of a crop made 8,2 t/hectare (36,6%).

Productivity of a tomato on a traditional way of watering was created at the level of 42,3 t/hectare, the examinee of a water preserving way – at the level of 57,6 t/hectare. The additional crop of a tomato was equal 15,3 t/hectare (36,2%).

On a cucumber it is in addition received 8,1 t/hectare or 43,3% of a crop. In experience with dining room beet when using a traditional way of watering – a blousing on furrows it is created 37,8 t/hectare standard root crops, when watering plants on drop technology – 50,8 t/hectare. That is, the studied water preserving way at the expense of portion and uniform water supply and creation of an optimum water-air mode in the soil provided 13,0 t/hectare of an increase of a crop of root crops that makes 34,3%.

Similar data are obtained and on a white cabbage and onions. Application of drop technology increased productivity of heads of cabbage on 10,8 t/hectare (30,2%), onions - a turnip on 13,7 t/hectare (36,6%) that is an essential increase of a crop of these cultures.

Influence of ways of an irrigation on biochemical structure of potato and vegetable production is investigated. The types of vegetable cultures studied in field experiments are the main, the most demanded by the population. These vegetables are used in food all the year round, almost daily. Thus, they are consumed fresh or after superficial processing. Therefore, very much importance has quality indicators of consumed production. Vegetable production has to be good quality, high-vitamin, environmentally friendly. Considering it, we defined quality of potatoes and vegetables depending on technologies of an irrigation. Data are provided in Table 3.

It is established that use of system of drop irrigation on landings of potatoes and crops of vegetable cultures has positive impact on separate quality indicators, doesn't worsen quality of production in comparison with ridge-and-furrow irrigation way. At drop irrigation depending on a type of grown-up production, the increase in solids, sugars and vitamins is noted.

**CONCLUSIONS**

By results of 3 years' researches (2009-2011) it is established that in comparison with traditional way of watering (a blousing on furrows) the drop technology provides economy of irrigation water for 35,8% on culture...
of potatoes, 39.0% - on tomato, 47.4% - on cucumber, 41.6% - on red beet, 30.3% - on white cabbage and 33.6% - on onions. At determination of size of expenses of irrigating water it is necessary to consider 3 main indicators: factor cost of irrigation water on irrigation; costs of evaporation and filtration; expenses of water on formation of additional production.

When using drop technology of irrigation at the expense of intensive development of plants, increase of efficiency of potatoes and vegetable cultures in comparison with ridge-and-furrow irrigation way was observed. Productivity of potatoes increased for 36.6% (from 22.4 to 30.6 t/hectare), tomato – for 36.2% (from 42.3 to 57.6 t/hectare), cucumber – 43.3% (from 18.7 to 26.8 t/hectare), red beets – 34.4% (from 37.8 to 50.8 t/hectare), white cabbage – 30.2% (from 35.8 to 46.6 t/hectare), bulb onions – 35.2% (from 37.4 to 51.1 t/hectare).

Positive influence of technology of drop watering on quality indicators of grown-up production is established. Increase of the content of solids, starch (tubers), the general sugar and ascorbic acid (vitamin C) in potatoes tubers, tomato and cucumber fruits, heads of cabbage, onions turnip and root crops of red beet is noted.

REFERENCES