Features of impulse sprinkling technology
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ABSTRACT
The principle of non-stop water supply to plants and soil in accordance with their water intake is progressive. Drip irrigation and impulse sprinkling correspond to this principle. Drip irrigation provides optimal water and nutrient regimes directly to the root system of plants. However, this irrigation is not effective enough under conditions of high temperature (over 25–35 °C) as growth processes are known to slow down and photosynthesis to cease, consequently affecting the yielding capacity. Impulse sprinkling provides optimal moisture level in the given layer, improved microclimate in the plant environment and water regime of plants within the whole vegetation period and is most effective within daytime. Through improvement of microclimate and plants’ water regime within periods of high temperature and low air humidity under the conditions of South Kazakhstan, the technology of impulse sprinkling enabled increasing productivity of a clonal rootstock mother plantation for the 3 years of research on average by 19.4% compared to regular sprinkling. The applied technology provided optimization of layers’ growth and development conditions upon decrease of the moistening of the soil layer of mother plantation bushes for derogation of their water regime after hilling the grown root layers.

Key words | features, impulse sprinkling, research, results

IRRIGATION TECHNIQUES IN AGRICULTURE
Irrigated agriculture is one of the main factors providing stability of agricultural production and food safety.

Increasing production of agricultural crops in the desert regions of the world is connected with both expansion of the irrigated areas and increasing yielding capacity of the cultivated plants. Increased productivity of water utilization is an actual direction of crop cultivation for increasing production of foods.

The thousand-year practice of crop cultivation has worked out specific irrigation techniques, surface irrigation, sprinkling and drip irrigation being the main ones.

Technologies of surface irrigation and standard sprinkling based on the periodic accumulation of water in the soil ensure intermittent high-amplitude introduction and distribution of moisture. In these conditions the nature of moisture distribution with the said techniques causes overmoistening of topsoil after irrigation, and water deficiency is observed at the end of the irrigation interval. This water supply regime leads to stress situations in plants’ development, consequently reducing their yielding capacity.

The introduction of new equipment and increasing requirements for the environmental safety of irrigation techniques under irrigation water deficiency conditions predetermine the necessity of the use of water-saving technologies in the process of the cultivation of crops, ensuring all the required conditions for their growth and development. These technologies include technologies of irrigation with a pulse water supply to plants by small rates with a certain cycle (Shengguo & Xiuqiao 2011; Kalashnikov et al. 2014; Angold & Zharkov 2015).

Drip irrigation and impulse sprinkling are progressive irrigation techniques. These technologies are targeted at a non-stop water supply to plants in accordance with their water consumption (Angold & Zharkov 2014).

Drip irrigation is a type of local irrigation, when the required amount of water with diluted nutrients is supplied directly to the root system of each plant. Direct metered water supply throughout the vegetation period creates an optimal soil moisture regime in the root system. However, the problem of microclimate is not solved by drip irrigation although
increase of the crop yielding capacity depends on it and it is one of the main problems (Report of the General Secretary of the Conference 1962; Badanova 1968; Ovchinnikov et al. 2015).

In fact, the required water regime of plants cannot be achieved at low relative air humidity, even under conditions of optimal soil moisture. As a result, growth slows down and the yielding capacity of the crops falls. Premature fading may occur at low values of air humidity (Pavlova 1984).

Growth processes and productivity of photosynthesis of some crops slow down at air temperatures exceeding 25 °C as well.

Although all irrigation techniques and periodic sprinkling in particular improve the microclimate of areas where it is applied, the level of these changes is not always sufficient to provide high yielding capacity of plants.

Impulse sprinkling technology is targeted at the improvement of microclimatic indexes in the adjacent air environment and water regime of crops at the optimal values of soil moisture in the given layer.

**IMPULSE SPRINKLING TECHNOLOGY**

The technology of impulse sprinkling is based on the intermittent supply of daily irrigation depth to plants under impulse mode providing frequent watering with small irrigation depths at specific hours with optimal soil moisture. The characteristic feature of this sprinkling is the maintenance of the long-term effect of artificial rain over the plants’ growth and development conditions and environment. The moisture of the active layer is maintained at the optimal level without acute fluctuations, which would be peculiar for the usual intermittent watering.

During the hot period of the day, sprinkling enables reduction of the temperature of the surface air and creation of more favorable conditions for the plants’ growth and development. Increasing yielding capacity of crops upon sprinkling is based on the intensification of several physiological processes, photosynthesis in particular.

**Technical facilities for technology implementation**

Impulse sprinkling technology is carried out by the irrigation system with 1 hectare coverage (Figure 1). The principal units of the set comprise: pump (1) with remote control (2); valves (3, 5); pressure pulse generator (4); network of distribution (6) and irrigation (7) pipelines; pulse sprinklers (9) and control pulse sprinkler (10) with feedback (8).

The mode of impulse water supply to the irrigated area is carried out with impulse sprinklers (Figure 2). An impulse sprinkler has an accumulation tank in the form of a
hydro-accumulator (1) with limiting sphere (2) and membrane (3), valve (4) and sprinkler (5).

The valve provides a water shut off to the sprinkler while the hydro-accumulator is filling upon pressure increase and an opening of water access to it upon pressure reduction in the supply pipeline. Formation of pressure increase and reduction impulses is carried out by the impulse generator. Impulse sprinklers operate under alternating pressure intermittently discharging water from the sprinkler. Water discharge alternates with pauses of accumulation in the hydro-accumulator providing increase of rain-effect duration over the plant and its environment.

The impulse sprinkling system operates in the following way. When watering is required, the pumping station is activated on a soil moisture signal or in accordance with the program. Water is supplied to the pipeline network and accumulated in the cavities of the hydro-accumulators of the impulse sprinklers. On a signal from the filling sensor or on a signal from the time relay a command is sent from the remote control to the impulse generator forming a definite-duration signal of pressure reduction for the pipeline network. Impulse sprinkler valves are activated and accumulated water volume is discharged under the effect of compressed air through sprinklers to the adjacent area. Valve closing is carried out on a pressure increase signal in the pipeline. The frequency of working cycles depends on the hydro-accumulators filing time and is controlled by the impulse generator. The average intensity of impulse sprinklers does not exceed 0.02 mm/min (Shtepa et al. 1990). The technical facilities of impulse sprinkling technology enable daily watering during the day and at night.

Medium-range sprinklers are used as sprinkling nozzles on the impulse sprinkling systems.

Use of impulse sprinkling technology is preferable for foothill conditions where use of other techniques is impossible. This irrigation system enables the introduction of soluble mineral fertilizers and protection agents for plant protection during irrigation.

Research on impulse sprinkling technology, results

Impulse sprinkling technology research was carried out on the basis of comparison with the technology of standard intermittent sprinkling. Experiments were conducted on a plot of mother plantation of clonal rootstock within the experimental grounds of Kazakh Scientific and Research Institute of Water Economy (Taraz City, the Republic of Kazakhstan) in 2009–2011. Climatic characteristics of the researched area are provided in Table 1 in accordance with data from Dzhambul meteorological stations.

During the plants’ vegetation period in the summer time, high temperatures (up to 43 °C) are recorded during the day with relative air moisture reaching 30.7–49%. These conditions result in the reduction of plants’ yielding capacity, consequently microclimate improvement is one of the main problems (Badanova 1968; Alexandrov et al. 1975).

The area is covered by a mother plantation of plantation year 2007 (stock MM-106). The landing pattern is 1.8 × 0.2 m.

The following technological patterns (variants) of mother plantation watering have been studied: Variant 1 – impulse sprinkling while maintaining 75–85% HB soil moisture in the 0–50 sm layer throughout all the mother plantation vegetation; Variant 2 – impulse sprinkling while maintaining 75–85% HB soil moisture in the 0–50 sm layer prior to hilling mother plantation root layers and in the 0–20 sm layer after hilling of the root layer; Variant 4 – standard intermittent sprinkling – control. Control for humidity of the estimated soil layer depending on the phases of the cultures’ development has special value and provides the quality of the received production (Olgarenko et al. 2015).

To determine peculiarities of microclimatic changes in the plants’ development environment and assess its effect on growth, development and yield of clonal rootstock mother plantation, all watering of irrigation variants was carried out during the day time.

The impulse sprinkling water supply mode provided the principle of non-stop water supply in accordance with the daily water intake deficiency and approved level of moisture in the given soil layers.

Variant 4 was the control to be compared with the studied variants of mother plantation impulse sprinkling.

In the process of standard sprinkling, the irrigation rate was introduced periodically with account of the values of the plants’ water intake deficiency between watering. This mode provided water supply to the crops throughout the approved period and had a short-term effect on the
microclimate in the adjacent plant environment. Soil moisture change occurred intermittently, reaching its optimum approximately in the middle of the irrigation interval. The water supply mode was adjusted depending on mother plantation root layer moisture.

The irrigation rate for the variants varied from 3,485 to 3,676 m³/ha for Variant 1, from 3,395 to 3,547 m³/ha for Variant 2, and from 3,375 to 3,468 m³/ha for Variant 3. As for control Variant 4 it was 3,480 – 3,710 m³/ha. With account of water expenditure on microclimate formation and transfer outside the ground, irrigation rate increased by 16.2 – 20.2% depending on the technological pattern of irrigation used and prevailing conditions during the plants’ vegetation period.

Differences in water expenditure within vegetation periods for the mother plantation are connected with different meteorological conditions by research years, approved level of soil layer moisture, technological delays in irrigation behavior and water consumption on microclimate formation and transfer outside the area.

Monitoring the temperature and relative moisture of the surface air during the day identified that the majority of changes upon both impulse and ordinary sprinkling was recorded from 1 to 5 p.m. (Figure 3).

Air temperature differences between variants of impulse sprinkling and the control reached 2.7 °C, and the difference between values of relative air moisture was 11–21%. The greatest difference of these indexes occurred prior to standard sprinkling (19 June). During irrigation on the control (20 June) the air temperature went down, reaching the values of the impulse sprinkling section for the next 1–2 days, and exceeding them thereafter. Relative air moisture during the irrigation period on the control was higher during irrigation and for the next 2 days afterwards as compared to the impulse sprinkling. It was further recorded with lower values.

No dramatic differences in temperature differences and relative humidity were recorded because of the similarity of their operation mode. Only after hilling of mother plantation root layers with decreasing volumes of water supply to mother bushes in connection with changing the layer of mother plantation moistening from 0.5 to 0.35 m (Variant 2) and from 0.5 to 0.2 m (Variant 3), microclimatic indexes on Variant 1 had improved values.

<table>
<thead>
<tr>
<th>Months</th>
<th>Research year</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>October</th>
<th>For the period April–October</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Air temperature, °C</td>
<td>10.03</td>
<td>16.59</td>
<td>21.92</td>
<td>25.26</td>
<td>23.36</td>
<td>17.88</td>
<td>11.31</td>
<td>18.05</td>
</tr>
<tr>
<td>2009</td>
<td>Relative air moisture, %</td>
<td>76.30</td>
<td>63.74</td>
<td>42.48</td>
<td>34.32</td>
<td>39.65</td>
<td>53.50</td>
<td>56.87</td>
<td>52.41</td>
</tr>
<tr>
<td>2010</td>
<td>Precipitation, mm</td>
<td>49.7</td>
<td>37.3</td>
<td>23</td>
<td>20.7</td>
<td>9.5</td>
<td>19</td>
<td>1.5</td>
<td>160.7</td>
</tr>
<tr>
<td>2011</td>
<td>Average</td>
<td>67.14</td>
<td>58.50</td>
<td>47.09</td>
<td>37.44</td>
<td>38.40</td>
<td>47.37</td>
<td>61.07</td>
<td>51.00</td>
</tr>
<tr>
<td>2009</td>
<td>12.3</td>
<td>17.51</td>
<td>22.69</td>
<td>25.05</td>
<td>24.11</td>
<td>18.06</td>
<td>11.82</td>
<td>18.79</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>66.43</td>
<td>54.81</td>
<td>48.03</td>
<td>40.03</td>
<td>40.23</td>
<td>46.47</td>
<td>66.19</td>
<td>51.74</td>
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<tr>
<td>2011</td>
<td>58.70</td>
<td>56.94</td>
<td>50.77</td>
<td>37.97</td>
<td>35.32</td>
<td>42.13</td>
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<tr>
<td>Average</td>
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<td>58.50</td>
<td>47.09</td>
<td>37.44</td>
<td>38.40</td>
<td>47.37</td>
<td>61.07</td>
<td>51.00</td>
<td></td>
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</table>
Impulse sprinkling positively affected the water regime, growth and development of plants. Monitoring of water content in the mother plantation leaves demonstrated that water content in the leaves of mother plantation layers within the impulse sprinkling coverage exceeded that of the ordinary sprinkling area (Table 2).

It should be noted that during ordinary sprinkling (20 June) within the control ground, water content in the leaves of the mother plantation layers was recorded both during irrigation and for 1–2 days after it, when their values reached those of the impulse sprinkling and then declined.

As a result of monitoring leaves’ water-absorbing capacity it was discovered that, under conditions of impulse sprinkling, lower water absorption was recorded (Figure 4). Thus, during impulse sprinkling of all variants, water-absorbing capacity changed from 0.20 to 0.35 g/g of the dry weight, and within the control area increased by 0.4–0.43 g/g of the dry weight. Reduction of water absorption by the leaves of mother plantation layers was registered on the date of ordinary sprinkling. Reduction of water absorption by mother plantation leaves was observed after irrigation (20 June) and within the following 1–3 days.

Depending on growing conditions in the mother plantation, the intensity of leaves’ water return differs. Leaves of layers taken from the impulse sprinkling variants have the highest water return intensity (up to 38–58%). Leaves of the plants from the control ground have lower indexes of water return (21–42%). On the irrigation days within the control ground and for the next 1–3 days, water return on leaves may exceed water return of the leaves of layers from the impulse sprinkling variants by up to 36%. The difference in water return values is not high among the variants by reason of the similar water supply mode (Figure 5).

The highest values of transpiration from mother plantation leaves occur upon impulse sprinkling (up to 82 g/m² per hour). The value of leaves’ transpiration for the area with ordinary sprinkling is lower than the values obtained from impulse sprinkling areas and does not exceed 63 g/m² per hour (Figure 6).

Table 2 | Water content in the leaves of mother plantation layers at 1 p.m. (first research year), % of weight

<table>
<thead>
<tr>
<th>Date of monitoring</th>
<th>Variant 1</th>
<th>Variant 2</th>
<th>Variant 3</th>
<th>Variant 4*</th>
</tr>
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<tbody>
<tr>
<td>19.06</td>
<td>65.4</td>
<td>63.8</td>
<td>64.9</td>
<td>58.1</td>
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<tr>
<td>20.06</td>
<td>63.7</td>
<td>62.7</td>
<td>63.2</td>
<td>58.1</td>
</tr>
<tr>
<td>21.06</td>
<td>66.7</td>
<td>64.1</td>
<td>64.7</td>
<td>67.8</td>
</tr>
<tr>
<td>22.06</td>
<td>69.1</td>
<td>64.9</td>
<td>65.6</td>
<td>68.4</td>
</tr>
<tr>
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<td>68.3</td>
<td>66.5</td>
<td>66.2</td>
<td>66.0</td>
</tr>
<tr>
<td>24.06</td>
<td>67.8</td>
<td>65.7</td>
<td>66.9</td>
<td>65.2</td>
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<tr>
<td>25.06</td>
<td>66.9</td>
<td>65.9</td>
<td>64.8</td>
<td>65.2</td>
</tr>
<tr>
<td>26.06</td>
<td>66.1</td>
<td>62.8</td>
<td>63.9</td>
<td>61.7</td>
</tr>
<tr>
<td>27.06</td>
<td>63.3</td>
<td>62.6</td>
<td>62.9</td>
<td>60.3</td>
</tr>
<tr>
<td>28.06</td>
<td>62.9</td>
<td>61.3</td>
<td>61.8</td>
<td>59.1</td>
</tr>
</tbody>
</table>

*Sprinkling (control) – 20 June.
During irrigation on the control with ordinary sprinkling, transpiration here increased to 87 g/m² per hour. It then declined within 1–2 days and was lower until the next irrigation.

Deficiency of relative turgescence of leaves on the impulse sprinkling variants did not exceed 17.5% during hot hours. As for ordinary sprinkling it made 20% and more. Relative turgescence of the leaves of mother plantation layers increased during ordinary sprinkling on the control area through abundant water supply and its deficiency was reduced by 14% (Figure 7). In 2–3 days after irrigation, water deficiency occurred in the leaves until the next watering. In this way the amount of water in impulse sprinkling required for complete saturation of leaves is less than that in ordinary sprinkling.

From the experimental data it can be concluded that indexes of water regimes of plants under conditions of impulse sprinkling with small irrigation rates in the day time are better than those of plants irrigated with ordinary sprinkling.

It has been determined than the most intensive growth of mother plantation layers was observed in the first variant. For the years of monitoring, the values of the layers’ growth varied from 78 to 81.2 sm by the end of vegetation. The layers’ growth was lower in the second variant and changed from 68 to 79 sm by the end of vegetation. Layers of the third variant had growth varying from 66 to 74 sm.

Peculiarities of the root layers’ collar development variants show that instead of faster growth of layers in the first variant, the diameter of the conditional root collar varied from 4.7 to 8.2 mm, whereas on the second and the third variants it was from 6.5 to 9.0 mm on the second and from 6.5 to 11.0 mm on the third.

During ordinary sprinkling, the growth of layers varied from 40 to 72 sm at 4.6–8.2 mm rook collar diameter.

It should be mentioned that in the variants of impulse sprinkling, the majority of roots were of secondary structure with 10–15 sm root length. As for standard sprinkling, 50% of roots had primary structure and length of roots was up to 10 sm. The rooting area of layers under impulse sprinkling reached 7–10 sm, whereas it was 3–8 sm in the control.
Monitoring of the biological indexes of root layers in the mother plantation upon their growing in pulse sprinkling variants compared with the control (standard regular sprinkling) showed that there are the following differences in the root formation area. The size of the rooting zone of the root layers from the impulse sprinkling variants reached 11–12 sm. It did not exceed 8–9 sm under standard sprinkling. By the end of vegetation, a multilayer root system develops on the sufficiently large part of the shoot. Layers under impulse sprinkling can be distinguished by a larger number of rooting points. The root system of layers in the ordinary sprinkling variant is weaker and mainly consists of primary roots. The results of standard layers’ yield for the last 3 years on average are given in Figure 8.

CONCLUSIONS

The technology of impulse sprinkling provides optimal soil moisture in accordance with the approved horizon of root zone moistening, improves microclimate in plants’ development environment during the day time as well as their water regime and increases the yielding capacity of crops. Use of impulse sprinkling technology enables the yield of the mother plantation of clonal rootstock to be increased by 19.4% on average in comparison with the control variant of standard sprinkling. This technology provides optimization of growth conditions and output of standard layers by 120,400 pieces per hectare upon reduction of the soil layer of mother plantation bushes moisturizing up to 20 sm for restriction of their water regime after hilling of grown layers.

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