Special features of drip-sprinkler irrigation technology

Ye. V. Angold and V. A. Zharkov

ABSTRACT

Irrigation techniques and technology based on principle of regular accumulation of moisture in active layer (surface irrigation, regular sprinkler irrigation) are most common in science and in practice. More progressive is principle of non-stop water supply of plants and soil in conformity to their water consumption. Drip irrigation and impulse sprinkling are based on this principle. The main advantage of drip irrigation is establishment of optimal water and nutritive regime directly in the plant root system. However, such irrigation is not effective enough under conditions of high air temperatures (over 25–35 °C), as growing process of several agricultural plants is known to slow down at 30–35 °C and photosynthesis, consequently, stops, which, in turn, affects plants yielding capacity. Sprinkling irrigation provides improvement of both microclimate in plant's environment and their water regime. Combination of drip and sprinkling irrigation permits the positive characteristics of each individual technology to be united, and to remove a series of disadvantages of their separate use as well as to use drip-sprinkler irrigation technology to create optimal conditions for plant development. Drip-sprinkler irrigation technology facilitates saving of irrigation water through drip irrigation in the main vegetation period and through improvement of microclimate and water regime of agricultural plants with additional sprinkling irrigation within the period of high temperatures and low air humidity that affects the growing process and increases yielding capacity of grown cultures.

Key words | drip-sprinkler irrigation, special features, technology

DEVELOPMENT OF DRIP-SPRINKLER IRRIGATION TECHNOLOGY

Increasing water deficiency affects the world agricultural sector. Increase of water utilization productivity is an actual trend for increase of food production (Annual Report 2011-12 ICID 2012).

In irrigation agriculture irrigation technology shall secure optimal supply of agricultural plants with water based on biological peculiarities of each culture. With this purpose peculiarities of existing irrigation techniques and technologies affecting plant’s environment shall be considered.

Surface irrigation technology is based on the principle of regular accumulation of moisture in active layer. Technology of standard regular sprinkling also provides regular accumulation of moisture in soil and also increases air humidity and lowers its temperature during sprinkling which is a positive factor.

Progressive irrigation techniques are drip irrigation, thin dispersed irrigation and impulse sprinkling. These technologies are directed to non-stop supply of plants with water in accordance with their water consumption. Effectiveness of these technologies has been proved by results of their application throughout the world (Annual Report 2011-12 ICID 2012).

Comparative efficiency of various irrigative regimes of sprinkling and drip irrigation of sunflowers in Mediterranean region of Turkey certifies that both drip watering and sprinkling irrigation provide acceptable increase in yielding capacity and quality of sunflowers under water deficiency conditions. Here, the increase and decrease of sunflower seeds productivity is observed both at drip and at sprinkling irrigation depending on the accepted irrigation regime. It correspondingly influences indexes of oil content in seeds (Sezen et al.)
Priority of drip irrigation in Australia compared to aged power-consuming sprinkling irrigation systems has been proved by effectiveness of water resources use and energy consumption on lettuce production systems (Maraseni et al. 2012). In Iran parametric approach to irrigation technique assessment with account of soil peculiarities, salinization level and landscape slopes for the purpose of water resources saving is recommended on 23,790 hectares out of 60,000 hectares, whereas drip irrigation is recommended on 33,261 hectares (Albaji et al. 2010). Micro-sprinkling for irrigation of trees and vineyards has been highly assessed in the USA (Boman et al. 2012). In contrast with drip irrigation this technology secures also plant protection against frosts.

In research works of Russian scientists of the irrigation regimes of strawberry plants at sprinkling irrigation and drip watering on production expenses economic expediency of drip irrigation in comparison with sprinkling irrigation has been established (Shuravilin & Khrabrov 2011). At the same time research provided sprinkling irrigation during the hot period of plant vegetation every 3–5 days, instead of daily and full assessment of sprinkling irrigation efficiency effect over culture which is not sufficient. On daily watering basis technology of sprinkling irrigation provides improved microclimatic indexes in the plant’s environment, improves process of photosynthesis and on the whole leads to increase of crop productivity. Efficiency of such sprinkling irrigation is especially for the periods of plant vegetation with high air temperatures and its low humidity.

Assessment of economic feasibility of drip watering, circular sprinkling machines and stationary sprinkling systems in Portugal with account of comparability of water saving and economic results demonstrates necessity of their selection based on high effectiveness of irrigation machinery and increase of yielding capacity of agricultural crops rather than water saving exclusively (Rodrigues et al. 2013).

Drip irrigation is a type of local micro-irrigation, when required amount of water and nutrients dissolved in this water are supplied directly to root area of each plant. Dosed and directed water supply within the vegetation period creates optimal regime of soil moisture in the root system.

The main advantage of drip irrigation is establishment of optimal water nutritive regime directly in the root system of plants and thus reduction of water and fertilizers consumption by 40–50%.

In comparison with other irrigation systems drip irrigation has disadvantages that must be taken into account when using this technology. They include: possibility of trickle blockage, mechanic damage and short life of drip tapes, possibility of uneven watering. Typical systems require usage of safety valves, pressure gauges and flow meters for control; they also have restrictions to application (Shtepa et al. 1990). To remove trickle blockage water filters are required. Microclimate problem cannot be solved during drip irrigation, increase of agricultural productivity depends on this problem, being one of the major issues (Irrigation & use of water resources 1962; Badanova 1968).

Such irrigation is not effective enough at high temperatures of air (over 25–35 °C) and its low humidity. Growing process of several agricultural plants is known to slow down at 30–35 °C and photosynthesis, consequently, stops, which, in turn, affects plants yield. Photosynthesis in plants is simultaneous with breathing process. At this time accumulated carbohydrates oxidize and produce energy, resulting in synthesizing of protein and other compounds. At increased temperature balance of carbohydrates synthesis is broken and their order is disturbed. For example, photosynthesis depression in potato plants begins at over 18 °C, and at over 25 °C photosynthesis stops. Breathing energy rises which causes dramatic reduction of plants yielding capacity for this period. Photosynthesis productivity for wheat falls at 20 °C, of cabbage at 21 °C, of maize 24–25 °C, and of cotton over 28 °C (Alexandrov et al. 1975).

Air humidity conditions intensity of plant transpiration and evaporation from soil, and affects biochemical processes in plants. At low values of air humidity premature fading of plants may occur (Pavlova 1984).

Optimal conditions for development of agricultural plants in the dry regions are established by measures directed to maintenance of optimal water regime of plants. This regime can be established only upon sufficient soil moisture and air humidity. These conditions can be created by sprinkling. Increase of agricultural crops yielding capacity upon sprinkling is caused by intensification of series of physiological processes, photosynthesis in particular.

Optimal conditions for growth and development of agricultural plants are provided by daily impulse sprinkling. Process of impulse sprinkling means filling of necessary volume of water into hydraulic accumulators upon pressure
increase and water discharge in the form of rain under effect of compressed air or elastic materials upon pressure reduction (Shtepa et al. 1990). In connection herewith possibility of any siltation in hydraulic accumulators is prevented due to change of pressure in pipeline network by means of pulse generator.

Application of pulse water supply technology to plants at drip irrigation upon change of water pressure from maximum to minimum also will allow removal of blockage of outlets of irrigation devices and, thereby, to lower requirements to irrigative water.

This direction has been confirmed by inventions of scientists from Chinese Peoples’ Republic who developed pulse type system of drip irrigation where irrigation intensity and elimination of water purification filters is carried out through wide range change of impulses frequency change (Shengguo & Xiuqiao 2011).

This development removes blockage of outlets and lowers requirements to irrigative water, however, the microclimate problem on which increase of crop productivity depends remains unsolved.

Analysis of advantages and disadvantages of technologies being viewed permits the conclusion that for smooth regulation of plant growing under conditions of high temperatures and low air humidity combination of drip and sprinkler irrigation with applied technology of pulse operation principle is required.

Combination of drip irrigation and sprinkling enables advantages of each technology to be united, and to avoid series of disadvantages of these technologies when used separately. Drip-sprinkler irrigation technology provides optimal conditions for plant development.

**Technology principle**

Drip-sprinkler irrigation technology is directed to improvement of microclimatic indexes in plant environment and water regime of agricultural plants.

Drip-sprinkler irrigation is achieved by issue of daily irrigation rate by plants under pulse mode to provide frequent sprinkling with low watering rates at specific hours (Kalashnikov et al. 2011). At 25 °C 100% of irrigation rate is consumed for local moisturizing of soil (by drip irrigation) and at over 25 °C up to 10% of irrigation rate is consumed for local moisturizing and up to 90% for sprinkler moisturizing of surface air and leaf area of plants.

During summer period sprinkling in addition to drip irrigation enables lowering of the temperature of surface air and topsoil, an increase in air moisture and creating more favorable conditions for plant growth and development.

This technology enables saving of water within vegetation period of plant development under conditions of water deficiency, and sprinkling irrigation at air temperature over 25 °C (in high temperature areas in particular) permits improvement of parameters of micro and plant climate.

**TECHNICAL FACILITIES FOR TECHNOLOGY IMPLEMENTATION**

Drip-sprinkler irrigation technology is carried out by irrigation system (Zharkov et al. 2010, 2012) consisting of water intake facility, command pulse generator, distribution...
pipeline, emitters with water outlets and auxiliary pumping device with air-temperature sensor (Figure 1(a)).

Water discharge system has outlet for drip irrigation and a sprinkler nozzle active with connected auxiliary pumping device. To secure fixed volume of water supply to the plant's water outlet is equipped with waterproof flexible ball, upon compression of which water accumulation in its body is performed (Figure 1(b)).

Irrigation system (Figure 1(a)) operates the following way. Water is supplied from water intake facility 1 by pumping device 2 through command pulse generator 5. As a result water fills pipeline 6, emitters 7 and water outlets 8. Filling of body 13 (Figure 1(b)) is carried out through inlet of cover 10 after displacement of unilateral collar 11 towards adapter 12. Water flowing along edges of collar 11 enters hydraulic accumulator 13, compressing waterproof elastic ball 15. Hydraulic accumulator 13 is filled to preset value upon blocking water outlet through adapter 12. Adapter 12 has spring sprinkler nozzle 17 and trickle 16, which can be connected to emitter with a row of auxiliary trickles.

After filling of hydraulic accumulator 13 pressure reduction pulse is sent to pipe system by command pulse generator 5. Because of pressure difference in hydraulic accumulator 13 and emitters network collar 11 moves towards the cover 10. Water from 13 enters adapter 12 and through trickle to the atmosphere. Drip irrigation is performed.

At air temperature of 25 °C and higher air temperature sensor 4 (Figure 1(a)) is connected to auxiliary pumping device 3 of irrigation system. Water under pressure of pumping units 2 and 3 is delivered to emitters network and water outlets. High pressure is formed in hydraulic accumulator 13. After water outlet body is filled (Figure 1(b)) reduced pressure pulse is sent to pipe system. Water from hydraulic accumulator 13 is supplied to adapter upon collar 11 initial position and then upon release of spring sprinkler nozzle 17 is emitted to atmosphere. Sprinkling is performed. With further reduction of pressure sprinkler nozzle returns to initial position and the rest of water is delivered to plants through trickle 16. Further irrigation process is the same.

Implementation of drip-sprinkler irrigation technology of the viewed irrigation system enables automation of irrigation process under drip irrigation and sprinkling regimes.

Table 1: Climatic characteristics of region in the data by weather station Dzhambul

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Months</th>
<th>Year</th>
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<tbody>
<tr>
<td>Temperature, °C</td>
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<td>II</td>
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<td>21</td>
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<td>52</td>
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<td>Relative humidity, %</td>
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<td>67</td>
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<tr>
<td>Average &gt;80%, days</td>
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<tr>
<td>Average &lt;30%, days</td>
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<td>Air relative humidity, %</td>
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<td>67</td>
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to secure strictly fixed volume of water supply to plants independently of relief. At high temperatures in summer period of plant vegetation air temperature is declined and air humidity is increased through sprinkling, thus making favorable conditions for plant growth and development and facilitating increase of their yielding capacity.

Research of technology: results

Research of drip-sprinkler irrigation technology was carried out in comparison with drip irrigation technology. Experiments were performed in apple-tree garden on stunted apple trees Golden Delicious within experimental ground of Kazakh Scientific Research Institute of Water Economy (Taraz city, Kazakhstan) in 2009–2011. Climatic characteristics of research region (long-time annual average) by weather station Dzhambul are provided in Table 1.

From the data of climatic characteristics of studied region high air temperatures (up to 43 °C) at 50.7–49% average relative humidity of air are observed for the whole vegetation period of plant development. Such conditions lead to reduction of plant yields (Alexandrov et al. 1975) and issue of microclimate improvement is the most acute in the region (Badanova 1968).

Drip-sprinkler irrigation technology is secured by pulsed technical facilities (water outlets). Drip watering was performed at air temperature up to 25 °C, sprinkling irrigation was provided within high temperature period (over 25 °C). Sprinkling irrigation was performed particularly within day time, from 12:00 to 18:00. Duration of water outlets working cycle including accumulation of estimated water volume in hydraulic accumulators and time of its discharge was measured within 10 to 120 seconds. Plants irrigation at drip irrigation sector (control) was

Figure 2 | Daily fluctuations of air temperature and moisture in June.
carried out by drip heads for the whole vegetation period of these plants.

Based on accepted irrigation technologies principle factors affecting growth and development of apple-trees were studied. Air temperature and moisture indexes, water content, water yield, water absorption and intensity of transpiration by apple-tree leaves were specified.

Monitoring air temperature and moisture was performed within grounds where soil was moisturized by technical irrigation facilities. Daily fluctuations of temperature and relative air moisture in the year 2011 are demonstrated by month in Figures 2–4.

Monitoring determined changes of main factors affecting conditions of growth and development of plants within the period of air temperatures higher than 25 °C and air humidity lower than 30–40%. Upon drip-sprinkler irrigation compared to drip irrigation difference in air temperature reached 2.7 °C in bottom layer (0.66 feet). Difference of air humidity values reached 23%.

Additional sprinkling irrigation within intensive apple-tree vegetation period performed at drip-sprinkler irrigation section positively affected water regime, growth and development of plants.

Water content in apple-tree leaves upon drip-sprinkler irrigation surpassed water content in leaves from drip-irrigation section by 5.8–15% (Table 2).

Apple-tree leaves transpiration intensity at 13:00 on drip-sprinkler irrigation increased by 6–12%. Water absorbing
Figure 4 | Daily fluctuations of air temperature and moisture in August.

Table 2 | Water content in apple-tree leaves at 13:00, % of weight

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<th>14.07</th>
<th>15.07</th>
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<td>Drip-sprinkler irrigation</td>
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<td>68.3</td>
<td>71.2</td>
<td>68.9</td>
<td>70.0</td>
<td>66.1</td>
<td>75.9</td>
<td>72.1</td>
<td>71.1</td>
<td>69.1</td>
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<tr>
<td>Drip irrigation</td>
<td>63.3</td>
<td>62.1</td>
<td>63.7</td>
<td>62.2</td>
<td>63.1</td>
<td>60.3</td>
<td>60.9</td>
<td>60.3</td>
<td>62.3</td>
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<table>
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<th>14.08</th>
<th>15.08</th>
<th>16.08</th>
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<td>Drip-sprinkler irrigation</td>
<td>71.0</td>
<td>73.0</td>
<td>69.0</td>
<td>70.0</td>
<td>77.0</td>
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<tr>
<td>Drip irrigation</td>
<td>65.0</td>
<td>66.0</td>
<td>60.0</td>
<td>61.0</td>
<td>67.0</td>
</tr>
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</table>
capacity of apple-tree leaves at 13:00 under conditions of additional sprinkling reduced by 0.05–0.13 g/g of dry weight (Figure 5). Leaves relative turgescence deficiency declined by 2.0–3.3%.

Water regime of plants naturally varies during the day depending on weather conditions and reaches maximum at 13:00–14:00.

Improved microclimatic and water regime indexes provided additional increase of summer sprouts by 9.0–12.8%, of apple-trees girth by 9.6–10.8% and tree heights by 6.8–9.8%.

Drip-sprinkler irrigation technology through additional sprinkling in hot hours facilitated growing processes in apple-trees based on improved microclimatic indexes in plant growing environment and water regime and resulted in increase of yielding capacity by 5.6–9.9%.

Based on the obtained results this technology can be referred to water resource saving irrigation technology in agricultural production (Zharkov et al. 2013).

**CONCLUSIONS**

Combination of drip watering and sprinkling irrigation unify positive characteristics of each technology.

Drip-sprinkler irrigation technology enables saving of irrigation water through drip watering of plants within main vegetation period and stimulates growing process of cultivated culture by improvement of microclimate and water regime of crops upon additional irrigation within high temperature and low air moisture period.
Drip-sprinkler irrigation technology applied to apple-tree garden within period of air temperatures over 25 °C enabled reduction of air temperature in plant environment by 1.5–2.7 °C and an increase in its relative moisture by 5–23%.

When drip-sprinkler irrigation is applied leaves water content rises by 5.8–15%, water absorption falls by 0.05–0.13 g/g of dry weight, relative turgescence deficiency of leaves decreases by 2.0–3.3%, and intensity of transpiration by leaves increases by 6–12%.

This technology enables growth of one-year whips by 9–12.8%, trunk circle by 9.6–10.8% and tree height by 6.8–9.8%. Total yield of apple-trees increases by 5.6–9.9% due to improved microclimatic indexes in the apple trees’ environment and their water regime.

REFERENCES


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