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Moisture consumption by plum seedlings under drip irrigation in the Central Nonchernozem zone of Russia

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Abstract. The aim of the study was to establish influence of different soil moisture content and climatic factors on water consumption of plum seedlings grown in a fruit nursery in the Nonchernozem zone. According to the results of studies conducted on plum seedlings under drip irrigation in the Moscow region for two years, evapotranspiration with different precipitation availability and temperature was determined. Variability of total water consumption depending on meteorological factors and irrigation regime was considered. Studies have confirmed the increase in the value of evapotranspiration with increasing pre-irrigation threshold of humidity with low-volume drip irrigation. The maximum values of water consumption by year of research, as expected, were recorded in the most wetted variant of the experiment, where moisture content of soil root zone did not fall below 80 % of the field moisture capacity. The statistical analysis carried out did not confirm the effect of varietal characteristics on evapotranspiration, which may be associated with the use of related rootstocks and the use of seedlings with the comparable force of growth in laying the experience. Structure of evapotranspiration of plum seedlings was determined according to experimental data of two research years. Precipitation and irrigation were the most part of total water consumption.

Keywords: drip irrigation, drainage, water consumption, evapotranspiration

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Introduction

The main rational of human nutrition is fresh and processed fruits, which are the most important source of minerals, vitamins and antioxidants. In developed countries, more than 100 kg of fruits and berries is consumed by one person per year. Domestic horticulture has low efficiency and does not meet the requirements of world production, and the highest and first type of product can be attributed to no more than 30 % of the fruits grown. Among the factors explaining the low efficiency of horticulture, it should be noted: destabilization of the water-temperature regime of the soil during the most important periods of plant development, illiterate placement of plantings without considering the topography and level of occurrence of groundwater, deficiency of high-quality planting material and its unsatisfactory phytosanitary condition, imperfection of existing growing technologies seedlings in nurseries [1, 2].

The moisture supply of fruit plants during the growing season is one of the most important factors ensuring their normal development and high productivity. Despite excessive moisture, the nonchernozem zone is characterized by an extremely uneven distribution of precipitation during the growing season, which negatively affects the quality of planting material [3]. All this indicates the need for a competent selection of irrigation methods and regimes developed and adapted on the basis of the results of scientific research conducted with seedlings of various types of fruit crops in this particular natural and climatic zone. At the same time, within the framework of the concept of sustainable development, scientific and technological achievements should be introduced into practice, the technologies that meet the principles of resource saving should be mastered, and production should be modernized as a whole.

In accordance with the Federal Target Program “Development of Land Reclamation of Agricultural Land of Russia for 2014—2020”, one of the ways to intensify agricultural production is to increase the efficiency of the use of irrigation water, land, energy and other resources [4, 5]. The solution of this problem can be facilitated by the expansion of the currently small areas under drip irrigation, in particular in nurseries, since this highly efficient and technologically advanced method is very promising and is widely implemented throughout the world.

One of the ways to increase the productivity of agricultural production in horticulture and plant growing is to increase the efficiency of nature management through the use of resource-saving technologies [6, 7]. As one of such technologies, drip irrigation can be noted, which allows improving the quality and productivity of crops [8—11]. Currently, there are no scientifically based resource-saving technologies for growing seedlings in nurseries of the nonchernozem region of Russia, so the research aim is to identify the features of the growth and development of plum seedlings in non-black soil under different drip irrigation regimes.

Materials and methods

To obtain high-quality planting material, it is necessary to create optimal conditions conducive for the growth and development of seedlings in nurseries. Often, natural fertility and water-physical regime of soils do not correspond to the optimum for most crops;

therefore, the need for comprehensive reclamation measures for efficient management in any natural and climatic zone should be recognized [12]. Drip irrigation is a powerful agricultural technique that allows regulating the development of crops, which has a direct and indirect effect on all other soil regimes (air, microbiological, nutritious, thermal, etc.). With such a complex effect on the conditions of plant development, clarification of this effect becomes very difficult. Therefore, it is necessary to study the effect of irrigation in this climate zone in relation to each species and plant variety.

Field research was carried out on the territory of the training and experimental fruit growing laboratory of the Russian State Agrarian University — Moscow Timiryazev Agricultural Academy — "Michurinsky Garden". By geographic location, climatic and soil conditions, the "Michurinsky Garden" refers to the center of the non-chernozem zone of Russia. But since it is located within the boundaries of the city of Moscow, the climate is close to the conditions of the Ryazan and Tambov regions. In Spring 2016, there was laid a two-factor experiment to study the affect of different moistening ranges on formation of plum seedlings of two varieties grafted on seed plum of plum spread. The scheme of the experiment included four variants (factor A) for the regime of soil moistening: control (without irrigation), maintaining humidity 60…80 %, 70…90 %, and 80…100 % of the field moisture capacity.

The proposed irrigation regimes in which the soil moisture content is maintained in a narrow range allow not only to increase the efficiency of irrigation water use and to reduce the water consumption of products, but also to maintain a more optimal water and air regime. In addition to this, the design features of drip irrigation allow for maintaining soil moisture in small ranges through increase in frequency of irrigation with small amounts of water in accordance with the biological needs of the crop.

The second factor (factor B) was plum varieties — "Mashenka" and "Utro". The "Mashenka" variety was obtained at the Suzdal state section of the Vladimir Region as a result of free pollination of the "Evrasia-21" variety. The author of the variety is V.P. Jagunov. "Utro" plum variety was obtained at the All-Russian Horticultural Institute for Breeding, Agrotechnology and Nursery from crossing varieties "Skorospelka krasnaya" and "Greenhouse Ullensa". Authors of the variety are H.K. Enikeev, S.N. Satarova, V.S. Simonov. "Utro" plum variety was introduced into the State Register in the Central Region in 2001.

Planting of seedlings was carried out according to the scheme of 0.9 × 0.33 m. The distance between the rows of one variant was 90 cm, and the distance between the plants in the row was 33 cm, while the distance between adjacent rows of different variants was 1 m. This scheme provides the density of planting 33.5 thousand seedlings per ha.

All variants of the experiment were laid in 3-fold repetition with a systematic arrangement of the plots. The plot area is 40 m^2, in each replication 30 seedlings of each variety were planted. The total area of the pilot site was 930 m^2. The total number of plum trees planted was 1080 pcs. For the purpose of carrying out biometric measurements and phenological observations, 24 countable plants and 6 protective plants, 1 plant at the beginning and end of the row, were isolated on each plot.

The experimental site is located on sod-podzolic, cultivated, soil-gley, deep-till, medium loamy soil on moraine loam lined at the depth of 150…170 cm by submerged sands.

For irrigation, a long-term drip line equipped with built-in droppers was used. During the experiment, a constant flow rate of water was maintained, which was 3.8 l/h. The moisture content in the root layer of the soil was monitored using tensiometers calibrated according to the thermostat-weight method.

Results and discussion

The organization of irrigation and the design of the irrigation system largely depends on the total water consumption (evapotranspiration) of the cultivated crops. This indicator determines not only the irrigation intensity, but also allows you to determine the required amount of water for irrigation activities in specific climatic conditions.

During the growing season, evapotranspiration depends mainly on meteorological conditions and the phase of development of plum seedlings. The highest values of the total water consumption by experiment variants in annual and biennial plum seedlings were obtained in the third decade of July. This period with the highest total water consumption is characterized by high meteorological intensity (higher temperatures, the highest inflow of total solar radiation, low relative humidity, etc.) and the most intensive development of plum seedlings.

The statistical analysis carried out did not confirm the effect of varietal characteristics on evapotranspiration. This circumstance may be associated with the use of related rootstocks and using seedlings with comparable growth force for laying experience.

By the end of the growing season, after the cessation of irrigation, water consumption in all variants of the experiment is equalized and reaches minimum values. The greatest water consumption at all stages of growth and the formation of seedlings was noted in the experiment with maintaining soil moisture in the root layer in the range of 80…100 % of the field moisture capacity. Table 1 shows the equations of the decadal total water consumption of plum seedlings with different types of drip irrigation.

Table 1

Equations of the decadal total water consumption of plum seedlings under different types of drip irrigation

Year	Variants	Equation	Coefficient of determination R^2
2016	Control	$y = -0.3197x^2 + 4.6292x + 5.4752$	0.3462
	60…80 %	$y = -0.4026x^2 + 5.8592x + 6.8967$	0.4149
	70…90 %	$y = -0.457x^2 + 6.6262x + 7.9387$	0.4216
	80…100 %	$y = -0.4863x^2 + 7.0343x + 9.5611$	0.5065
2017	Control	$y = -0.3423x^2 + 4.9926x + 4.5805$	0.3683
	60…80 %	$y = -0.4158x^2 + 6.0768x + 5.6524$	0.3764
	70…90 %	$y = -0.4564x^2 + 6.7x + 6.2895$	0.3990
	80…100 %	$y = -0.4920x^2 + 7.1039x + 8.3396$	0.7421

y — evapotranspiration, mm; *x* — the ordinal number of the decade (1 — the first decade of May, 15 — the last decade of September).

Fig. 1, 2 show the integral evapotranspiration curves for the experiment variants for 2016—2017. It is clearly seen from them that the period of the highest intensity of evapotranspiration coincides with the phase of active growth and development of plum seedlings, where the maximum value relates to the most wetted variant with maintaining soil moisture in the root zone of the soil in the range of 80…100 % of the field moisture capacity.

In 2016, by the last decade of September, the total evapotranspiration in the variant of experiment 80…100 % of field capacity was 385 mm, in the variant 70…90 % — 348 mm, in the variant 60…80 % — 307 mm and in the control 241 mm. Thus, the total water consumption in the most humid version is 1.6 fold more compared to the control.

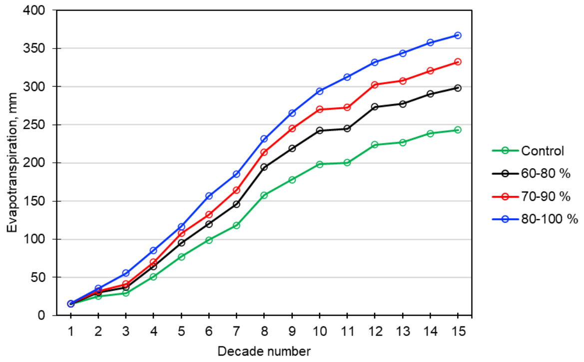

Fig. 1. Integral curves of evapotranspiration of plum seedlings in 2016 according to experiment variants: 1 — the first decade of May; 15 — the last decade of September

In 2017, by the last decade of September, the total evapotranspiration in the variant of experiment 80…100 % of the field capacity was 367 mm, in the variant 70…90 % — 332 mm, in the variant 60…80 % — 298 mm and 243 mm without irrigation. Thus, in 2017, the total water consumption of plum seedlings in the most humidified version is 1.5 fold more compared to the control without irrigation.

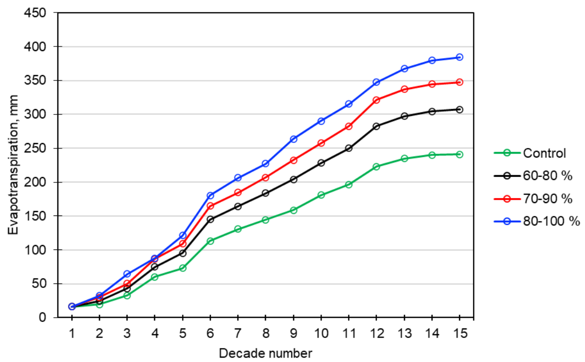

Fig. 2. Integral curves of evapotranspiration of plum seedlings in 2017 according to experiment variants: 1 — the first decade of May; 15 — the last decade of September

According to the results of experimental data, the structure of evapotranspiration of pear seedlings was determined according to the experiment of two years of research. The structure of the total water consumption of plum seedlings for 2016 and 2017 is presented in Fig. 3, 4. The main share of the total water consumption of irrigated variants in 2016 was precipitation (from 19.5 to 21.2 %) and irrigation rate (from 66.7 to 69.2 %). In 2017, the share of irrigation in the structure of total water consumption changed in the direction of increasing the share of moisture coming from precipitation to 21.2…26.5 % and reducing the share of irrigation norm to 57.6…65.3 %. Changes in the structure of water consumption in 2017 compared to 2016 are due to the fact that 2016 was more arid compared to 2017.

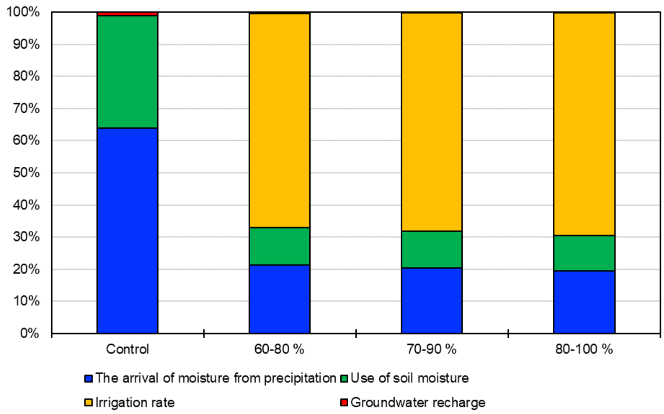

Fig. 3. The structure of the total water consumption of plum seedlings in 2016 by experiment variants

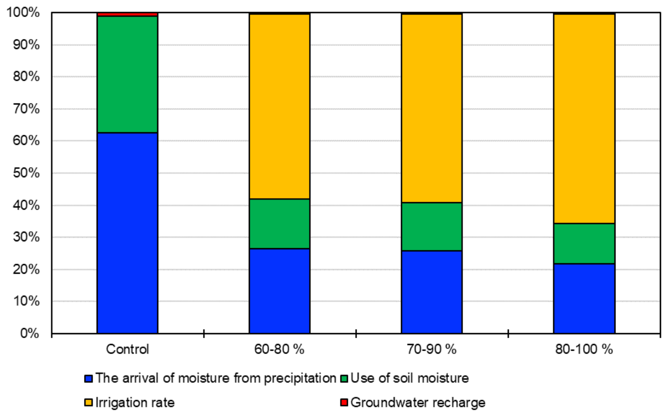

Fig. 4. The structure of the total water consumption of plum seedlings in 2017 by variants

Negative values of vertical water exchange took, mainly, starting from the third decade of August, after the termination of irrigation and continued in September, due to heavy precipitation. In addition, during this period there was an infiltration of precipitation into the underlying horizons. The arrival of moisture as a result of groundwater recharge was insignificant due to their deep occurrence and light particle size distribution of subsurface horizons.

In the course of research for two years of varying degrees of supply and plum seedlings of different ages, a linear dependence of water consumption on such meteorological factors as the inflow of total solar radiation and the sum of average daily temperatures was established. The resulting regression equations and their reliability are shown in Table 2.

Table 2

Equations of decadal moisture consumption from total solar radiation and the sum of average daily temperatures

Year	Variants	Equation	Coefficient of determination R^2
2016	60…80 % MC	$y = 8.272-1.028x+1.731z+4.749x^2-3.878z^2$	0.895
	70…90 % MC	$y = 8.124-1.535x+9.253z+3.275x^2-2.758z^2$	0.876
	80…100 % MC	$y = 2.573+1.037x+6.369z+1.801x^2-2.251z^2$	0.887
2017	60…80 % MC	$y = -1.352+1.743x+1.169z - 1.871x^2-2.563z^2$	0.901
	70…90 % MC	$y = -4.143+1.852x+2.831z - 8.439x^2-5.642z^2$	0.898
	80…100 % MC	$y = -9.743+2.451x+8.238z - 1.545x^2-1.895z^2$	0.875

In the equations under consideration, y — the total water consumption per decade, mm; x — the sum of average daily temperatures in a decade, °C; z — the influx of total solar radiation per decade, MJ/m^2. It should be noted that these relationships are valid only for the irrigated period, water consumption at the end of the growing season is difficult to describe with these equations, since average daily temperatures are significantly reduced, the total solar radiation influx and a large amount of precipitation falls.

Conclusions

1. The statistical analysis carried out did not confirm the effect of varietal characteristics on evapotranspiration, which may be associated with the use of related rootstocks and the use of seedlings with comparable force of growth in laying the experience.
2. Studies have confirmed an increase in the value of evapotranspiration with an increase in the pre-irrigation threshold of humidity with low-volume drip irrigation. The maximum values of water consumption by year of study, as expected, were recorded in the most wetted variant of the experiment, where the moisture content of the root zone of the soil did not fall below 80 % of the field moisture capacity.
3. According to the results of experimental data, the structure of evapotranspiration of pear seedlings was determined according to the experiment of two years of research. The main share of total water consumption was precipitation and irrigation rate.
4. In the course of research for two years of varying degrees of supply and plum seedlings of different ages, a linear dependence of water consumption on such meteorological factors as the inflow of total solar radiation and the sum of average daily temperatures was established.

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Особенности влагопотребления саженцев сливы при капельном орошении в условиях Центрального Нечерноземья

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Аннотация. Целью исследования является установление влияния различной влагообеспеченности почвы, климатических факторов на величину водопотребления саженцев сливы, выращиваемых в плодовом питомнике в условиях Нечерноземной зоны. По результатам исследований, проведенных в течение двух лет, на саженцах сливы сортов «Машенька» и «Утро», выращиваемых при капельном орошении в условиях Московской области, определены значения эвапотранспирации для разных значений обеспеченности осадками и температурой. Кроме того, в результате проведенных полевых исследований была рассмотрена изменчивость суммарного водопотребления в зависимости от двух факторов: метеорологические условия и режим орошения. Проведенные исследования позволили сделать вывод, что происходит увеличение значения эвапотранспирации при повышении предполивного порога влажности почвы при применении малообъемного капельного орошения. Наибольшие значения водопотребления саженцев по годам проведения опыта зафиксированы в наиболее увлажняемом варианте опыта, где влажность в корнеобитаемом слое почвы не достигала меньше 80 % наименьшей влагоемкости. По результатам полевых данных определена структура эвапотранспирации саженцев сливы по вариантам опыта двух лет исследования. Основную долю суммарного водопотребления составляли атмосферные осадки и оросительная норма.

Ключевые слова: капельное орошение, слива, водопотребление, эвапотранспирация

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