Drip irrigation of the apple orchard in the conditions of Tashkent region in Uzbekistan

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Abstract. This article presents the results of long-term theoretical experimental field studies on drip irrigation of Apple orchard of the cultivar "Golden" in the conditions of Tashkent region. Based on the analysis of climate, soil, hydrogeological, hydrological and economic conditions of the experimental plot and biological features of the garden is determined by the values of total water use, scarcity of water, irrigation, irrigation norms and number of irrigations bioclimatic method.

1 Introduction

Uzbekistan is a powerful state in Central Asia by the presence of irrigated lands, irrigation and drainage systems. Currently in the Republic the area of irrigation is 4280 hectares and rich in natural and economic conditions, availability of labor resources has enabled steady economic growth and development of the national economy [1]. In the last two years through the use of innovative equipment, irrigation technologies, irrigation and drainage systems achieved high yields in many farms of cotton, vegetables, orchards and vineyards, fodder, legumes etc [2-15]. Advances received two or more crops on the irrigated lands during the calendar year [1, 7, 11, 15]. In 2017, the area of drip irrigation in the region amounted to 890 ha, of which 554 hectares of gardens, vineyards and vegetables.
Irrigated garden areas in districts of Tashkent region are shown in Table 1.

Table 1. Irrigated area of garden farms in the Tashkent region in 2017

Areas	Garden area, ha
Akkurgan	13.900
Bekabad	14.700
Buka	14.475
Kuyi Chirchik	13.200
Yukori Chirchik	4.300
Piskent	8.900
Orta Chirchik	9.850
Chinaz	7.117
In the region:	86.442

Source: Based on Chirchik-Ahangaran Basin Management of Irrigation System (CABMIS)

The climatic conditions of the Tashkent oasis are somewhat more favorable than the desert regions of Uzbekistan, due to the proximity of a powerful mountain system. However, the climate of the region is characterized by sharp continental and aridity [1, 3, 4].
The average annual rainfall at Tashkent weather stations is 388.2 mm. Moreover, in July and August there is practically no rainfall. The daily maximum precipitation maxima at weather stations are (mm): Tashkent - 50. Charvak - 86, Aktash - 77, Pskent - 70. Heavy rains occur in the warm season and contribute to mudflow formation.
Average annual temperatures decrease with increasing terrain and are equal to Tashkent + 13.3 °C, Charvak + 11.6 °C, Chimgan + 7.6 ° C according to the weather station. The warmest month is July, the coldest month is January. The maximum air temperature at the Tashkent weather station is + 44 °C, Charvak + 40 °C, the minimum temperature at the Tashkent weather station is -30 ° C-29 °C [3, 4, 6].
The sum of temperatures for a period with an average temperature above + 5 °C in Tashkent is 4749 °C, in Charvak - 4210 °C; the sum of temperatures above + 10 °C in Tashkent is 4391 °C, in Charvak - 3864 °C. The last frost in the valley occurs at the end of March, and the first frost at the end of October. The frost-free period lasts about 210 days. The average number of hours of sunshine in Tashkent is 2870 per year.
In the valley, winds of east and north-east directions prevail. The average annual wind speeds usually do not exceed 3-4 m / s.
The climate of the region is sharply continental and arid with an abundance of heat and light over the years of research. The coldest month is January. Its average monthly temperature at the Tuytyepa weather station is 1.70 °C; the absolute

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minimum temperature is 270 °C; in the remaining months of the year, air temperature is usually positive. Summer is hot and dry. The hottest month is July, its average monthly temperature is + 240 °C, and the absolute maximum is + 42.40 °C. The daily temperature amplitude in summer is 16 - 200 °C. The sum of positive temperatures in a year is 44800C. The average annual temperature is + 14.70 °C. Annual precipitation averages 380 mm. Their intra-annual distribution is extremely uneven. Most rainfall occurs in the winter and spring months. Their maximum often occurs in March (78 mm), at least at the end of summer (0.5 mm). The rainfall prevails. Monthly precipitation dynamics is shown in Fig. 1.

2 Methods

Experimental plots are located in the fields of irrigation Chirchik-Akhangaran Basin Management of Irrigation System (CABMIS) of administrative division belongs to the middle-Chirchik district of Tashkent region.
1) Educational and Scientific Center of the Tashkent Institute of Irrigation and Agricultural   Mechanization Engineers.
2) Training and Research Center of the Ministry of Higher and Secondary Special Education of the Republic of Uzbekistan.
The subject of the research is to develop recommendations regime apple tree garden irrigation. The site is a rectangle of 34 × 300 m in size, limited by the PT-3 irrigation pipeline, C-1.3 discharge and field roads.
The rainfall prevails. Monthly precipitation dynamics is shown in Fig. 1.
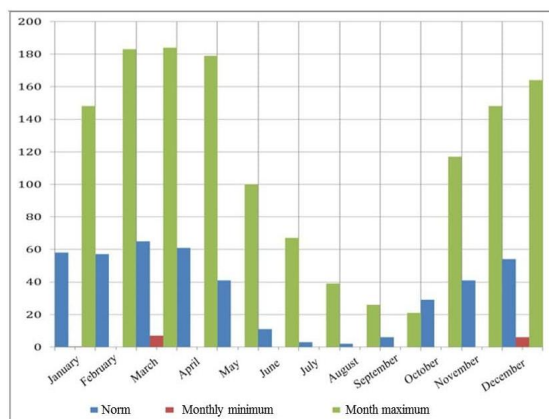

Fig.1. Dynamics of monthly precipitation

The snow cover is unstable. The number of days with snow cover on average during the winter is 30 - 34; snow cover on average 2 -12 cm. Freezing depth of soils 20 -30 cm.
Relative humidity in a wide range of air throughout the year, and in March it begins an intensive decrease. Minimum account for the month of July. Absolute humidity is changed from 4.4 Mb to 17.3 in January mb in July. Lack of saturation reaches the highest values in the warm season (April to October), and the highest value in June - July (18.4 mb).
High temperatures and humidity deficit causes a large evaporation. Average evaporation per year reaches 800 - 900 mm. The maximum monthly average evaporation reaches 225 - 265 mm (July - August). Amount of evaporation in July 8 - 10 times more than in January. On the processes of soil formation and the direction of their development is influenced by the following factors: climatic, lithological and geomorphological, hydro and irrigation and household.
According to the climatic conditions of the territory in question belongs to the central cotton zone. The vertical zoning it is confined to a belt typical grey soil passing into the upper east side of the belt wearing, and the bottom at Sirdarya - light gray soils.
On the processes of soil formation and the direction of their development is influenced by the following factors: climatic, lithological and geomorphological, hydro and irrigation and household.
The methodological provisions are based on the results of theoretical and field research (R&D) of a broad generalization of the practical experience of drip irrigation in the garden. Scientific works TIIIMSH, NIIIVP, VNIIGIM them. A.N. Kostyakova. Field studies were carried out using standard and specially developed methods, the reliability of the results was evaluated by verifying the results of the studies. In the experiments, the following observations, counts and definitions were carried out:
 - morphological descriptions of soils. To do this, before laying the experiments, a soil section was laid up to the level of groundwater and a description of the soil profile by genetic horizons was made;
- the granulometric composition of the soil was determined by pipetting using sodium hexametophosphate in samples taken from soil sections;
- volumetric mass of soil was determined using steel cylinders 10 cm high. Dates of determination - at the beginning of the growing season of each year of the experiment, to a depth of one meter in layers of 10 cm;

- the smallest moisture capacity of the soil was determined at the beginning of the research by the method of flooded sites (Rozov method) of 2 x 2 m2;
- water permeability of the soil was determined at the beginning and end of research using cylindrical circles by the Nesterov method;
- soil moisture was determined by thermostatic - weighted method and using a portable neutron hygrometer VNP-1. In each variant of all repetitions, soil samples were taken from one point to a depth of 0-100 cm every 10 cm. To draw up the water balance of the site, soil samples were taken to the level of groundwater at the beginning and end of the growing season;
- the dynamics of the GW level was studied on all variants of the second repetition of experiments, where observation wells were installed;
- the content of humus in the soil was determined before laying experiments according to the method of N.V. Tyurin;
- accounting of irrigation water in the on-farm dispenser at each irrigation was carried out using the weirs of Chipoletti and Thomson;

The area of innovative methods of drip irrigation and irrigation using flexible pipelines and polyethylene films in 2018 and 2019 amounted to 1880 and 2350 ha, respectively, using flexible pipelines poured 2500 ha and 4000 ha, watering with polyethylene films in 2018 –800 ha and 2019 year –1000 ha.

Experiment options for establishing the regime of garden irrigation are shown in Table 2.

Table 2. Variant for the establishment of an apple orchard irrigation regime

Options for field trials	irrigation method	watering dates
The control	furrow irrigation	By deficiency of moisture in the active layer of soil
Hose length irrigation emitter 200 m	drip	By deficiency of moisture in the active layer of soil
The length of the drip irrigation hose-250m	drip	By deficiency of moisture in the active layer of soil
Hose length irrigation emitter 300 m	drip	By deficiency of moisture in the active layer of soil

The experiments maintained the same humidity conditions, irrigation regimes, fertilizer application and all other operations.

Determining the uniformity of soil moisture along the length of irrigation furrows was carried out using strain gauge indicators.

The degree of siltation of the dropper tubes was checked on time and after each watering by flushing the tubes and weighing the remaining sludge along the length of the tubes.

The strength of the material of the dropper tubes was tested for the influence of external conditions. For this, the magnitude of the breaking forces of the tubes before and after each irrigation is investigated.

The regime of garden irrigation during drip irrigation is determined by ensuring the shortage of water consumption during the growing season. The main parameters of the irrigation regime are:

- irrigation and basic irrigation norms, terms and duration of irrigation, number of irrigations.

The irrigation norm of the garden was established on the control option when watering the garden on furrows on the recommendation of A.N. Kostyakova by the method of water balance.

$$M = E_v - (W_H + O + G) + W_k \tag{1}$$

Where: M - Garden irrigation rate, m3/ha;

E_v -Garden total water consumption, m3/ha;

W_H - supply of water in the soil in the planting day m3/ha;

O - the amount of precipitation during the growing season m3 ha;

G - the number of incoming groundwater calculated layer m3/ha;

W_k -supply of water in the soil on the day of harvest, m3/ha.

And the irrigation rate is determined by the following formula:

$$M_0 = \sum m^o \tag{2}$$

Where m^o - irrigation rate under drip irrigation, m3/ha.

Garden irrigation regime established bioclimatic techniques, garden irrigation rate is much lower compared with surface irrigation.

The total water consumption (mm) was found from the relationship:

$$ET = k_b k_0 ET_0 \tag{3}$$

Where k_b - biological factor characterizing the role of plants;

k_0 - microclimatic coefficient;

ET_0 - evaporation (potential evaporation) mm.

3

Of the foreign methods for determining evaporation (potential evapotranspiration), the most widespread are the computational models of H.L. Penman, L. Turk, and H.F. Blaini and V.D. Creed.

Of the calculation methods for determining evaporation and water consumption, the method of A.M. and S.M. Alpatyev, based on the use of a simplified formula of N. N. Ivanov, which has the form:

$$ET_0 = k_{pr} \sum d\varphi \tag{4}$$

Where ET_0 - evaporation, mm;

k_{pr} - the proportionality factor between evaporation and lack of humidity equal to 0.61;

$\sum d\varphi$ - the sum of deficits of humidity during the billing period, mm.

Scientists and specialists around the world developed a huge number of methods for calculating ET_0 (Potential evapotranspiration) in different climatic parameters. These methods often have only local significance and can not be used in other parts of the world. The test of any method in other conditions is laborious, lengthy affair, and in ET data is needed quickly.

FAO (Food argonization agriculture) assessed four computational methods: radiation, Penman method, a method with an evaporator, the refined method of Penman. According to the results of this evaluation, conducted under the guidance of the Committee on Irrigation and water consumption of the American Society of Civil Engineers, the FAO recommended method for calculating evapotranspiration Penman-montain as the only standard method.

Penman unified theory of the energy balance of the method and the mass transfer equation derived for calculating evaporation from open water surface for standard climatic conditions: the solar lighting, temperature, humidity, and wind velocity. This so-called combinational method was further developed by many researchers, and distributed on the inoculated surface by introducing resistance factors.

$$ET_0 = \frac{0{,}408 \cdot \Delta (R_n - G) + \gamma \cdot T + 273 \cdot u_2 \cdot (e_s - e_a)}{\Delta + \gamma \cdot (1 + 0{,}34 \cdot u_2)} \tag{5}$$

Where; ET_0 – potential evapotranspiration (mm day^{-1});
Net R_n-radiation on the surface of the culture [MJm^{-2} day^{-1}]
G-density of soil heat flow [MJm^{-2} day^{-1}]
T - average daily temperature at a height of m^2 [°C]
u_2-wind speed at a height of 2m [〚ms^{-1}]
Δ is the slope of the saturated vapor pressure curve [kPa °С$^{-1}$]
γ-psychometric constant [kPa °С$^{-1}$]
e_- actual vapor pressure [kPa]
e_s- saturated vapor pressure [kPa]
e_s-e_a-deficiency saturated vapor pressure [kPa].

The total potential evaporation for the Golden apple tree was determined by N. N. Ivanov's formula, taking into account temperature and air humidity:

$$E = 0.0061(25 + t)^2 (1 - 0.01a) \tag{6}$$

here; evaporation, mm/ha;
- average temperature, ° C;
-relative humidity for the estimated period, %.

The calculation of the elementary irrigation norm m_1 during drip irrigation was determined according to the formula of A.N. Kostyakov, taking into account the area of humidification:

$$m_1 = 100 S h_p p 9 \, (W_{HB} - \beta W_{HB}) \tag{7}$$

Where; S-wetted area of a fraction of a unit;
h_p-calculated soil layer, m;
P - average bulk soil mass, t/m^3;
W_{HB} - the lowest moisture capacity, % of the mass of dry soil;
β-coefficient of pre-irrigation moisture, corresponding to the lower boundary of optimal soil moisture, fraction of a unit.

$$S = n\omega / S_{total} \tag{8}$$

Where; Stotal area of the plot, m^2
n is the number of droppers in the area
ω is the area moistened by one dropper, m^2

The flow of moisture into the aeration zone from groundwater (mm) was also taken into account, since in the experimental section their level varies from 1.6 - 2.8 m during the growing season.

The supply of groundwater to the soil, the soil of the calculated layer, we determined by the formula of S.F. Averyanov.

$$G = \sum E \, (1 - h_{op}/h_r), \, \text{m}^3/\text{ga} \tag{9}$$

Where; $\sum E$ - total water consumption of the garden during the growing season, m^3/ga

h_{op}- groundwater depth, m

h_r-is the depth of groundwater, where there are no groundwater inflows into the soil of the calculated layer G=0 with $h_r \geq 3.0$ m.

$$\sum E = E \cdot \kappa_6 \cdot \kappa_\kappa, \ m^3/ga \qquad (10)$$

Where; k_b is the biological coefficient of the garden (0.74: 0.88)

k_k - microclimatic coefficient (0.72: 0.83)

The bioclimatic method allows you to quickly adjust the timing, norms, terms and numbers of irrigation of crops in connection with changes in climatic and economic conditions.

With this method, the irrigation rate is determined by the following dependence.

$$E_\gamma = M = \sum E - (W_R + P + G) + W_K, \ m^3/ga \qquad (11)$$

$$I + T = E = And \cdot k_b \cdot k_k \dots m^3/ga$$

Monthly volatility is determined by the formula of N.N. Ivanov:

$$I_M = (A_a \cdot (25 + t)^2) / 55.5, \ m^3/ga \qquad (12)$$

Where; $\Delta a = I00 - a$;

a-relative humidity of the surface air layer;

t-average monthly temperature of the surface air layer, ^oC,

P-atmospheric precipitation, mm;

G-amount of incoming groundwater into the calculated layer, m^3/ga.

W_k-Water reserve calculated layer at the end of the growing season m^3/ga.

$W_R \geq W_{min}$ - water supply in the calculated layer on the day of irrigation, m^3/ga

The elementary irrigation norm of a garden with drip irrigation is the required amount of water to create a calculated moisture zone within a unit of strip length or a calculated center of moisture.

Irrigation rate for focal hydration of the garden is determined by the formula N.N Dubenok .:

$$m_a = N\mu_0 \qquad (13)$$

Where: - elementary irrigation net rate for focal moistening, m^3/ga;

N - the number of trees in one hectare, pcs.

μ_0 - the norm of moistening the root zone of one tree, m^3/ga

To determine the values of garden eotranspiration, the value of the "standard" eotranspiration should be established.

With drip irrigation of a garden with a strip, each tree is wetted, hence the formula for moistening each watering will have the following logical form for gardens according to the formula N.N Dubenok.:Where: m_a - elementary irrigation rate net in focal moisture, m^3/ga;

N - the number of trees in one hectare, pcs.

μ_0 - humidification rate root zone of the tree, m^3/ga

To determine the Garden evotranspiration should set the value of "etallon" evotranspiration (ET_0).

With drip irrigation garden bandpass moistened with each tree, hence the formula moistening each watering will have the following logical form for gardens formula N.N.Dubenok:

$$m = 100d\left(H\,\frac{BV}{a\varepsilon}\,\omega \right) \cdot \left(\beta_{HB} - \beta_{\min} \right) \qquad (14)$$

Where;B - field width, m;

V - field length, m;

a - distance between apple trees by field width m;

d- volumetric mass calculated soil layer, t/m^3;

β_{HB} - soil moisture calculated layer of an apple orchard in the percentage of d

$\beta_{\min}$ - soil moisture estimated garden bed before watering,% of d

ω -ploschad bandpass humidification m^2;

3 Results

Analysis water-physical properties of soils studied showed that the topsoil characterized doughy addition, the density of solid particles (bulk weight) varies widely and the redistribution layer is 1.36-1.45 cm 0-100 t / m3 (Table 3).

The density of the solid phase (bulk mass) in the plowed horizon was 2.61-2.70 m / m3, which increases with increasing depth of the layer ameliorated. Significant changes in soil solid phase density due to a low content of humus and features of mineralogical composition.

Table 3. Basic water-physical properties of soils experimental field

sampling depth, cm	Density t/ m3	The density of the solid phase, t / m3	Soil depravity, %	Maximum hygroscopicity % by weight of soil	HB to the mass of dry soil%	Margin available moisture, m3 / ha
0-20	1.32	2.58	51.8	5.1	21.3	292
20-40	1.41	2.70	50.9	5.3	18.3	304
40-60	1.54	2.69	50.1	5.4	15.9	312
60-80	1.62	2.68	48.8	5.2	13.1	318
80-100	1.66	2.66	48.5	5.4	12.0	305
0-60	1.42	2.63	50.9	5.3	18.5	908
0-80	1.47	2.66	50.4	5.3	17.0	1226
0-100	1.51	2.67	49.8	5.4	16.1	1531

Soil depravity is inversely related to the value of bulk density. The total soil depravity along the vertical profile varies in wide aisles, and its maximum value is noted in the arable horizon of 50.9-51.8%, and at a depth of 80-100 cm it decreases to 48.5%.

Table 4. Results of mechanical analysis of soil of experimental field

The layer of soil, cm	Dimensions functions (mm) and their content%						physical clay < 001%
	1,0-0,25	0.25-0.05	0.05-0.01	0.01-0.005	0.005-0.001	< 0.001%	
0-20	0.77	36.75	25.32	8.02	12.42	16.72	37.16
20-40	0.83	33.14	29.26	6.18	15.14	15,45	36.77
40-60	0.95	27.54	35.58	7.56	15.78	12.59	35.93
60-80	0.39	26.92	34.32	7.54	15.44	15.39	38.37
80-100	0.31	29.17	32.90	8.96	13.72	14.94	37.62
100-160	0.30	30.89	27,50	10.22	14.88	16.21	41.31

The smallest moisture capacity is directly dependent on the mechanical composition of the soil and varies in the range of 16-21%. So, in the calculated layer 0-60 cm 21.0% in the meter layer 16.1%. An important indicator on which productivity depends is the productive supply of moisture, calculated by the difference between the lowest moisture capacity and humidity of the institution (Table 4).

The reaction of the soil is alkaline, the pH ranges from 8.0 to 8.5.

The humus content in the upper arable layer (0-30 cm) ranges from 1.28 - 1.72%. Deeper than this horizon (40-60 cm), the humus content sharply decreases to 0.524% (Table 5). Mobile forms of potassium - 21.0 - 26.4 mg per 100 g of soil. The content of CO_2 carbonates along the profile of these soils ranges from 5.31 - 6.47%.

Table 5. The chemical composition of the soil experimental area

The depth of the sample	pH	Humus,%	Gross nitrogen (N)	total phosphorus	Movable, mg / 100g			CO_2%
					nitrogen (NO_3)	phosphorus (P_2O_5)	potassium (K_2O)	
0-20	8.24	1.72	0.092	0.120	3.74	3.32	26.4	5.31
20-40	8.45	1.28	0.078	0.110	3.40	77	24.7	5.72
40-60	8.37	0.308	0.071	0.080	2.86	0.43	25.6	6.47
60-80	8.21	0.524	0.051	0.060	2.92	0.48	25.0	6.52
80-100	8.00	0.476	0.040	0.067	2.29	0.14	21.0	6.59

During field of experimental research in experimental plot climatic conditions differ from the long-term values: the average temperature during the growing season amounted to 18.6°C, humidity - 44%, the amount of precipitation - 50 mm, evaporation of year to 1208 mm, including during the growing period - 992 mm. In 2015 - 2017 years, these values were as follows: air temperature, respectively, 1.03; 12,63 and 11,85 ° C; humidity 59.91, 58.5 and 54.83% total precipitation -121.2; 145.2; 78.4 mm. Marked deviations affected the irrigation timing and amount of irrigation norms. During the research volatility during the vegetation period was as follows: in 2015 -1183mm, in 2016 -1056 mm, in 2017 -1072 mm.

4 Conclusions and Recommendations

a) The rich natural and economic conditions of the territory of the Tashkent region favor the widespread introduction of a low-pressure drip irrigation system in the garden.

b) In the control variant, when irrigation along furrows, the irrigation norm is m = 900-994 m³/ha, the number of irrigations is 4.

c) On options, the favorable irrigation rate of the Golden variety garden is m = 3900 m^3/ha. established by the bioclimatic method. The values of elementary irrigation norms amounted to 179-210 m^3/ha, irrigation norm m = 2060 ÷ 2170 m^3/ha, the number of irrigation - 11.

d) The saving of irrigation water during drip irrigation of the garden compared to furrow irrigation was 45% less. The yield of the Golden variety apple in the control variant was 12.3 t / ha, in the drip irrigation variants it was 19.8 t / ha. Yield growth amounted to 7.5 t / ha.

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