Water productivity and the effect of watering on apples grown under conditions of optimal irrigation and water deficit

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Summary: *In order to determine the productivity and the effect of irrigation on apples grown under soil and meteorological conditions in the area of the village of Chelopechene - Sofia, research was conducted on drip irrigation of a plantation of the "Florina" variety, and different regimes were tested - from complete satisfaction of the daily needs of water to irrigate the culture with irrigation rates reduced by 20% and 40%. A non-irrigation variant has also been tested.*

The productivity of the irrigation rate at optimal irrigation varies by years from 16.3 to 28.0 kg.ha^{-1}.mm^{-1}, and at 40% reduction of the irrigation rate from 19.3 to 26.0 kg.ha^{-1}. mm^{-1}

The highest values of productivity of the irrigation rate are reached at irrigation with a 40% reduction of the irrigation rate, in the dry 2004 high values were obtained and at the variant irrigated with 100% irrigation rate 28,0 kg.ha^{-1}.mm^{-1}

The optimization of moisture in the active soil layer contributes to a significant increase and stabilization of yields, which for the test conditions are from 1266 to 2087 kg / dka. Additional yields ranged from 542 to 821 kg / dka, averaging over the study period.

KEYWORDS*: APPLES, YIELDS, DRIP IRRIGATION, IRRIGATION RATE, PRECIPITATION, WATER DEFICIT, ECONOMIC EFFICIENCY, IRRIGATION OPTIONS*

Introduction

Good irrigation effect and the most productive use of irrigation water is only possible when applying the optimum irrigation regime that is in accordance with the requirements of the cultivated crops [5,6].

There are a number of studies conducted on the limiting factor - water, in Bulgaria. Their main purpose is to determine the effectiveness of the application of different irrigation regimes for optimal and insufficient water supply. The effect of irrigation is in most cases determined on the basis of the additional yield obtained from irrigation and the productivity of irrigation water [2,3,4,9].

The economic effectiveness of apple production under our climatic conditions is largely determined by the application of rational irrigation regimes and appropriate irrigation techniques. From the conducted researches it is established that from the applied techniques and technologies for irrigation of apples the drip irrigation is most suitable for their biological requirements [1].

The purpose of this development is to determine the productivity of water and the effect of irrigation of apples grown under conditions of optimal irrigation and water deficit for the Sofia region.

Material and method

To determine the productivity and the effect of irrigation of apples grown under soil and meteorological conditions in the area of the village of Chelopechene - Sofia, studies were conducted on drip irrigation of a plantation of "Florina" variety. Different regimes have been tested - from fully satisfying the daily needs of the water culture to irrigation with reduced irrigation rates of 20% and 40%. A non-irrigation variant has also been tested.

The following irrigation options were tested at pre irrigation moisture at 85-90% of WHC / water holding capacity/ maximum field moisture capacity /:

1.Option without irrigation;
2. Irrigation with Water application rate 100% M;
2. Irrigation with Water application rate 80% M;
3. Irrigation with Water application rate 60% M.

For soil moisture dynamics, soil samples were taken at variant 2 (100% bp) at a depth of 0–60 cm every 10 cm, which were processed by the weight-thermostatic method. The soil is leached cinnamon forest, slightly sandy - clay in the plow layer, formed on the base of an old deluvial cone of sedimentary materials. It is poorly stocked with nitrogen, medium in phosphorus and well in potassium. The average for the layer 0 - 60 cm the soil has the following water-physical properties: WHC = 22.1%, moisture content - 12.3% by weight of absolutely dry soil, volume weight at WHC - 1.47 g / cm3. For the soil layer 0-100 cm the same indicators have values: WHC - 21.8%, wilt moisture - 12.3% and volume weight - 1.50 cm3. In general, the soil is suitable for growing apples.

The irrigation was carried out by drip, with dropformers KP - 4.6, perforated tube through 0.60 m. With Drip irrigation we do not apply the entire irrigation rate as with other irrigation methods. A reduction is needed at the expense of the unsaturated zone. For this purpose, the equation of [8] was used, taking into account the planting scheme. After calculating the irrigation rate for Option 2, the size of the other variants is reduced relative to its size. For each specific site, the design parameters of the irrigation system and performance are specified.

Results and discussions

The productivity of each crop depends on a complex of factors, the main ones being: the type of crop, its varietal characteristics, the agricultural technology applied, the number of irrigation plants sold, the way they were submitted.

Table 1: *Rainfall during apples vegetation period (2001– 2005 г.)*

Periods	Total rainfall, mm				
Years	2001	2002	2003	2004	2005
м. IV – IX	358	418	329	258	765
Average multi-annual	365	365	365	365	365
м. VII – VIII	75	158	104	73	400
Average multi-annual	110	110	110	110	110

The amount of rainfall in the 50-year series characterizes the growing season of the culture development (April-September) during the experimental years, as follows: medium humid - 2001, 2002, and 2003; wet -2005 and 2004 very dry. The lowest rainfall occurred in 2004 (258 mm) and the highest in 2005 (765 mm). During the remaining three years, the rainfall is from 329 to 418 mm, Table 1, and Figures 1 and 2. The fallen rainfall during the growing season of the crop is unevenly distributed, which led to the realization of irritations.

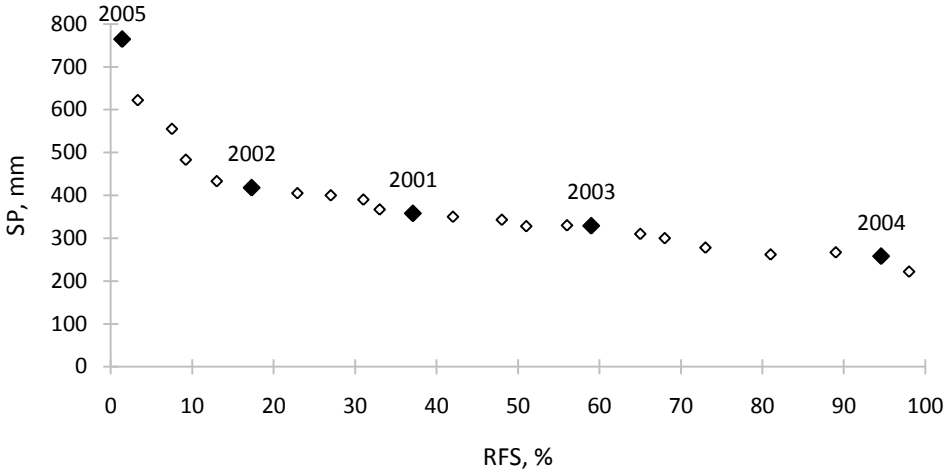

Fig. 1. *Sums of precipitations (SP, mm) for the April-September period of 1956-2005 and the relative frequency security (RFS, %) of the amount of rainfall in the Sofia field*

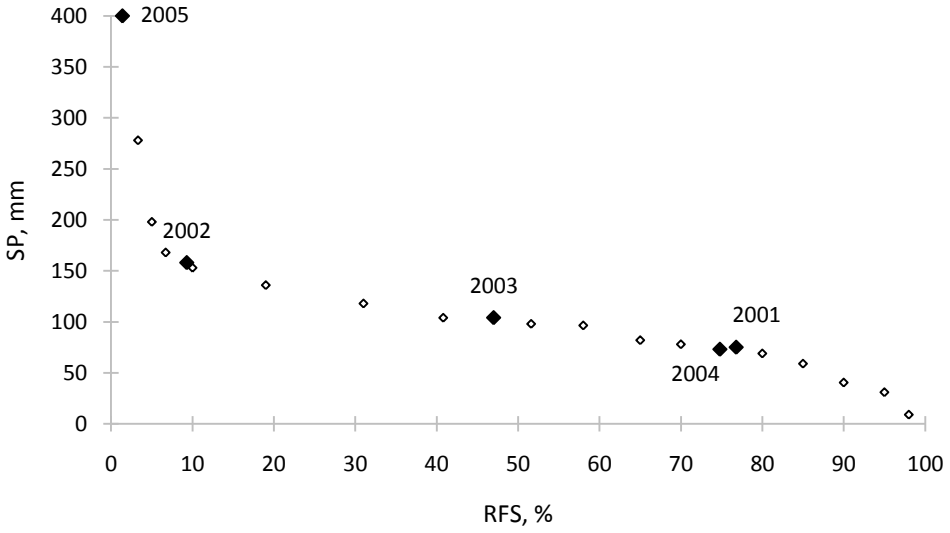

Fig. 2. *Sum of precipitations (SP, mm) for the July-August period for 1956-2005 and the relative frequency security (RFS, %) of the amount of rainfall in the Sofia field*

When determining the effect of irrigation on apples by the change in the yield obtained from the non-irrigated variant, it was found that for the variant with 100% irrigation rate the increase in apple yield reaches 821 kg / dka, and for the variants irrigated with irrigation rate respectively by 542 up to 686 kg / dka, according to the non-irrigation variant, Table 2.

The optimization of moisture in the active soil layer contributes to a significant increase and stabilization of yields, which for the test conditions are from 1266 to 2087 kg / dka. Additional yields ranged from 542 to 821 kg / dka, averaging over the study period.

Table 2: *Efficiency and productivity of water for apples on average for the period (2001-2005) apples*

Variant	Irrigation rate m^3/ha	Ttotal yield (Y) kg/dka	Added yeild (+Y) kg/dka	Compared to v 1, %	Compared to 2, %	Productivity of m^3 water
Non irrigated	-	1266	-	100	40	-
100% M	316	2087	821	164	100	6,6
80%M	261	1952	686	154	7	7,7
60%M	204	1808	542	142	14	8,9

The effect of irrigation is measured by the additional yield as well as the productivity of the irrigation water supplied. The data by years are presented in Table 3. It has been shown that in conditions of regulated water deficit, the yield does not change in proportion to the change in the size of the irrigation rate. Therefore, water productivity is often higher at a lower irrigation rate. For the test conditions, the values range from 16.3 to 28.0 $kg.ha^{-1}.mm^{-1}$. In the first and second test years, the highest water

productivity values reach a 40% reduction in the irrigation rate from 19.3 kg.ha^{-1}.mm^{-1} to 26.0 kg.ha^{-1}.mm^{-1} a -low values at 100% M from 16.3 kg. ha^{-1}. mm^{-1} to 21.3 kg.ha^{-1}.mm^{-1}. During the dry year, the highest values were obtained with the variant irrigated with 100% irrigation rate : 28.0 kg.ha^{-1}.mm^{-1}

Table 3: *Productivity of irrigation rate for medium moist and dry year - apples*

variant	2001			2003			2004			average		
	+Y	M	PR	+Y	M	PR	+Y	M	PR	+Y	M	PR
100%M	5550	340	16,3	8100	380	21,3	10110	360	28,0	7920	360	22
80%M	4850	272	17,8	6930	304	22,7	8260	300	27,5	6680	292	23
60%M	4370	221	19,3	5770	244	23,7	5960	220	26,0	5366	228	24

Where : +Y is the additional yield , kg/ha; M – irrigation norm , mm; PR – productivity of the irrigation rate kg.ha^{-1}.mm^{-1} .

The productivity of the irrigation rate at optimum irrigation varies by years from 16.3 to 28.0 kg.ha^{-1}.mm^{-1} and at a 40% reduction in the irrigation rate from 19.3 to 26.0 kg.ha^{-1}. mm^{-1}

The results obtained for apple production during the different humid years indicate the effect of drip irrigation on its size. The largest increase in yield was obtained in 2004 (dry), which is 55% more than the non-irrigation option (Table 4). The smallest increase of 667 kg / ha (25%) was obtained in the wet 2005.

Reduced irrigation rates during the growing season of apples result in losses of yields that are adequate to the percentage reduction in unprovided water. At 20% correction of the irrigation rate the yield decreased by 4% compared to the optimal variant, and at 40% reduction of the irrigation norm - up to 14%, Table 4.

Table 4: *Total and relative yield of apples in the Sofia area*

Years	2001		2002		2003		2004		2005		average 2001-2005	
Watering norm (share,%)	Y	R	Y	R	Y	R	Y	R	Y	R	Y	R
Noirriga-tion	1567	100	704	100	1135	100	855	100	2070	100	1266	100
100%M	2122	135	1769	251	1945	156	1866	218	2737	132	2087	164
80%M	2053	131	1603	228	1828	143	1681	196	2592	125	1952	154
60%M	2004	128	1421	202	1712	135	1459	170	2444	118	1808	142

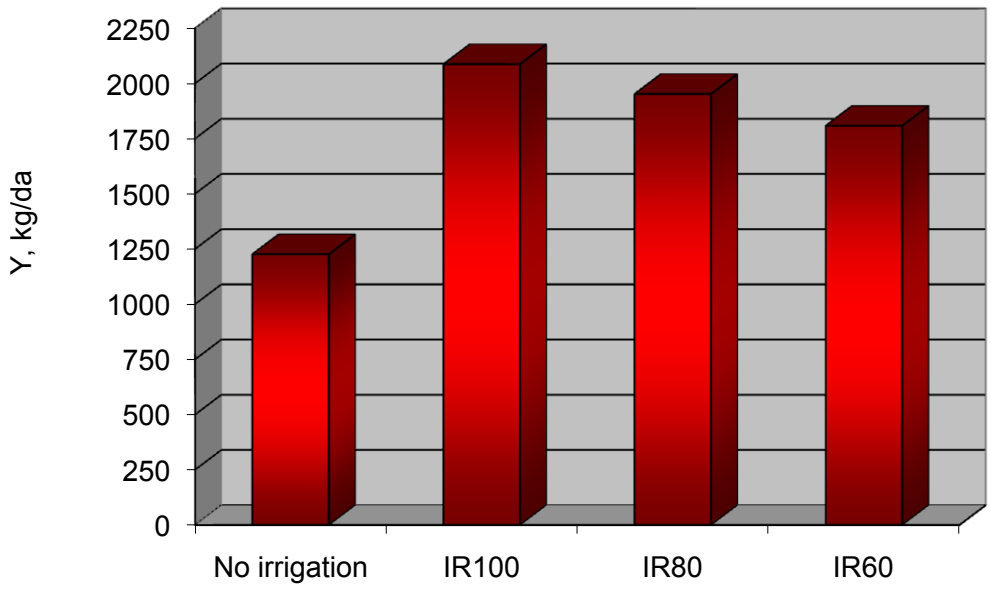

Fig. 3. *Dependence of* ***total apple yield*** *(Y, kg/da) on the irrigation rate (IR, % of IR_{100}) in Chelopechene, Sofia, for the period of 2001-2005*

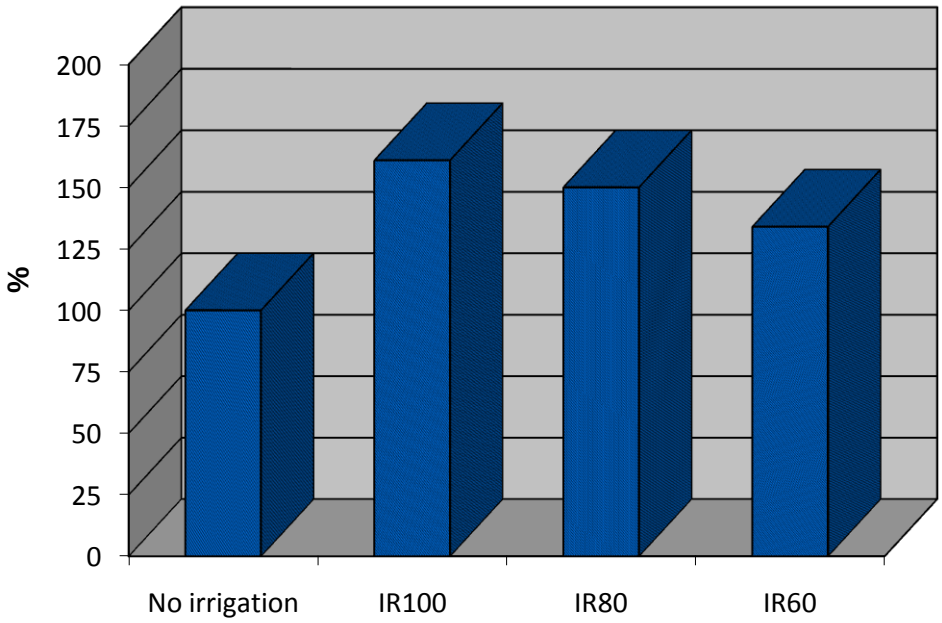

Fig. 4. *elative-to-control (no irrigation) total yield of apples (%) obtained for different regimes of drip irrigation in Chelopechene, Sofia*

The total cost of growing apples under drip irrigation is almost the same for different areas and ranges from 827 to 986 lv / dka. Yields double as a result of which higher net income is generated, even in areas of 1 dka.

The results show that, with drip irrigation of apples, the additional net irrigation income ranges from 392 to 533 lv / dka. For areas up to 5 dka, the additional net income increases with the increase of the area, above an area of 5 dka it does not depend on the size of the irrigated area. This is due to the large initial investment for command-line equipment for drip irrigation, which is almost the same for areas up to 20 dka. After 20 dka there is also an increase in investment, which is due to the equipment of the system with more powerful pump units with higher value, Table. 5.

Table 5: *Basic production costs for growing apples and total net income for drip irrigation*

№	Culture	1 dka	5 dka	10 dka	20 dka
I.	Apples with drip irrigation				
1.1	Total cost of cultivation of irrigation culture, lv / dka	967	891	827	887
1.2.	yield with Irrigation, kg / dka	2087	2087	2087	2087
1.3.	Production purchase price, lv / kg закупна цена на продукцията, lv/kg	0.8	0.8	0.8	0.8
1.4.	Total net income with irrigation, in lv / dka	702	779	843	783
I I.	Apples without irrigation				
1.5	Total net income lv/dka	310	310	310	310
	additional net income, lv/dka	392	469	533	473

The main factor in determining the profit or additional net income from irrigation is the purchase price of the production, which is proportional to the income. With a lower purchase price in smaller areas, the irrigation effect is minimal. Another major factor is the cost of irrigation water. When using water supplied by an irrigation canal, the cost of water is high and, although irrigation systems are low in cost, often additional net income is minimal.

The cost of irrigation water is directly dependent on the water source. For surface or groundwater abstraction, the cost is 0.001 lv / m^3, and for irrigation from the irrigation canal, the value of 1 m^3 of water is 0.23 lv / m^3 for gravity water supply and 0.43 lv / m^3 for pumping.

Conclusions

Moisture optimization in the active soil layer contributes to a significant increase and stabilization of yields, which for the experimental conditions range from 1266 to 2087 kg / dka, with additional yields ranging from 542 to 821, averaging over the study period.

Reduced irrigation rates during the growing season of apples result in a decrease in yields that is proportional to the percentage reduction in untreated water. At 20% correction of the

irrigation rate the yield decreases by 4% compared to the optimal variant, and at 40% reduction of the irrigation rate - up to 14%

Water productivity at optimum irrigation varies by years from 16.3 to 28.0 kg.ha^{-1}.mm-1, and at 40% reduction of the irrigation rate from 19.3 to 26.0 kg.ha^{-1}.mm $^{-1}$

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