РЕПРОДУКТИВНИ ПРОЯВИ И ЕНЕРГИЙНА ПРОДУКТИВНОСТ НА ДЕТЕРМИНАНТНИ ДОМАТИ В УСЛОВИЯ НА ВОДЕН ДЕФИЦИТ
REPRODUCTIVE CHARACTERISTICS AND ENERGY PRODUCTIVITY OF DETERMINATE TOMATO PLANTS UNDER WATER DEFICIT

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Резюме

Проучено е влиянието на редуцираното напояване върху репродуктивните прояви и енергийната продуктивност на два сорта детерминантни домати - "Марти" и "Яна". Приложено е засушаване от фаза начало на цъфтежа до начало на узряване на доматените плодове. Установено е ускоряване на узряването до 14,31% и увеличаване на сухото вещество на плодовете до 9,61%, както и намаляване на средните добиви с до 18,70% и средната маса на плода – с до 20,07%. Общите енергийни разходи при вариантите с воден дефицит са по-ниски с 3,82% при сорта "Марти" и с 4,82% при сорта "Яна", но това води и до по-малки енергийни приходи с добива и не се формира енергийна печалба. При сорта "Марти" енергийната продуктивност е 0,43 kg/MJ, а при сорта "Яна" – 0,46 kg/MJ. По-толерантен към воден дефицит е сортът "Яна".

Abstract

The aim of the research was to study the effect of reduced irrigation on the reproduction and the energy productivity of two tomato cultivars – *Marti* and *Yana*. In the research no irrigation was used during the period from the start of the flowering stage to early tomato fruit-ripening stage. The results indicated that the ripening process was accelerated by up to 14.31%, the dry matter in the fruits increased by up to 9.61%, the average tomato yield and the average fruit weight were reduced by up to 18.70% and 20.07% respectively. The total energy inputs in the variants under water deficit were lower by 3.82% in cv. *Marti* and by 4.82% in cv. *Yana*, and that resulted in lower overall energy outputs and therefore no energy profit. The energy productivity of *Marti* and *Yana* was 0.43 kg/MJ and 0.46 kg/MJ respectively. The results proved *Yana* to be more tolerant to water deficit than *Marti*.

Ключови думи: стопанска ранозрелост, добив, маса на плода, енергия.
Key words: earliness, yield, fruit weight, energy assessment.

INTRODUCTION

The climate conditions in Bulgaria vary and the plants are put under more prolonged water deficit combined with high temperatures. The average annual rainfall in Bulgaria is enough but the quantity of rainfall varies by season and vegetation periods and is irregular (Cholakov, 2002). The most effective means of drought and high temperature control is the development of tolerant tomato varieties that have normal fruitage without worsening of the produce quality in short-term water deficit of soil humidity (Danailov et al., 1990; Yordanov et al., 2000). The period from phenophase "blossoming start" to "fruit ripening" is the most critical period for tomato plant growing and development. The changes observed in the plants in stress depend on the power and the continuance of the unfavourable influence as well as of the adaptability and quick restore of the variety (Trethowan and Pfeiffer, 1999).

The investigations on the irrigation regime in the conditions of water deficit are performed for establishing of the relationship water-yield as varieties are studied and physiological tests are developed with purpose for rapid diagnostics (Zlatev et al., 2003, 2010; Vassillev et al., 2010; Stoeva, 2010).

The most frequently the assessment of the plant produce is made by agronomical and economical criteria that are restricting and give incomplete information. More frequently the energy analysis is accepted as an indicator for sustainable agriculture (Tonev, 1997).

The purpose of the study is some morphological and economic indexes to be established and the energy productivity of determinate tomato to be determined in reduced irrigation.

MATERIAL AND METHODS

The study was carried out in the period 2009-2011 at the Maritsa Vegetable Crops Research Institute, Plovdiv on strongly leached meadew-cinnamonic soil with two tomato varieties – Marti and Yana by the method of mid-early production of determinate tomato by pricked out seedlings. The sowing was performed during the second half of March in unheated greenhouse. The plants are transplanted on the field manually in the period 9-12 May. Technological basis is seed-bed and furrow surface with high flat bed by the scheme 120+40/30 cm. The experiment was set by the method of long plots in 4 replications and with 20 recorded plant per each replication. The agricultural practices were performed according to the technology card and in time. The irrigation was carried out by drip system.

Two variants were studied:

- *Variant 1 (V_1) – Control* – 10 irrigations (with total irrigation rate 300 m^3 water) and
- *Variant 2 (V_2)* – 5 irrigations (with total irrigation rate 150 m^3 water)

Plants in the variant V2 were set in normal irrigation conditions after phase "start of tomato fruit ripening".

The economic earliness was determined by the yield obtained up to August the 5th. The total yield includes the standard fruits from all harvests. The average fruit weight (g) and dry matter content (refractometrically, %) were determined by using 20 fruits, picked individually from random sample in a stage of technological ripening.

The parameters of the energy analysis were determined by established formula (Ivanov, 1999). The energy equivalents used in the research are shown in Table 1. The energy equivalents of the tomato seedlings (kg) and of the obtained produce (kg) were calculated by Mihov (2010). The energy equivalents of the remaining costs were used by the researchers Helsel (1992), Yaldiz et al.

Таблица 1. Енергийни еквиваленти
Table 1. Energy equivalents

№	Параметър / Parameter	Единица / Unit	Еквивалент / Equivalent, (MJ/unit)	Източник / References
	А. Разходи / Inputs			
1	ПРЗ* (а.в.)** / Pesticides (a.i.)**			
	хербициди / herbicides	kg	238.00	Helsel, 1992
	фунгициди / fungicides	kg	92.00	Helsel, 1992
	инсектициди / insecticides	kg	238.00	Helsel, 1992
2	Минерални торове (а.в.) / Chemical fertilizers (a.i.)			
	азот (N)	kg	64.40	Singh et al., 2002
	фосфор (P_2O_5)	kg	11.96	Singh et al., 2002
	калий (K_2O)	kg	6.70	Singh et al., 2002
	магнезий ($MgSO_4$)	kg	6.70	Singh et al., 2002
3	ГСМ / Diesel	L	56.30	Singh et al., 2002
4	Амортизации и ремонт / Machinery	h	62.70	Singh et al., 2002
5	Човешки труд / Human power			
	механизатори / mechanics	h	2.30	Yaldiz et al., 1993
	работници / workers	h	1.96	Yaldiz et al., 1993
6	Разсад / Seedlings	kg	1.91	Mihov, 2010
7	Вода за напояване и пръскане / Water for irrigation and sprinkling	m3	0.63	Yaldiz et al., 1993
	В. Приходи / Outputs			
	Домати / Tomato	kg	0.92	Mihov, 2010

** Продукти за растителна защита*
*** Активно вещество / Active ingredient*

(1993) and Singh et al. (2002) for estimation of the energy inputs in production of agricultural produce.

The natural indexes of diesel, machinery and human power including those of the technicians, and farm-workers were determined on the basis of developed modal technological cards.

The obtained results were processed statistically by variation analysis (Lakin, 1990) and dispersion analysis (Duncan, 1955).

RESULTS AND DISCUSSION

The reduced irrigation in variant V2 in June and July corresponds to the blossoming period and to the set formation in tomatoes leading to faster fruit ripening.. The early yield is higher in both studied varieties (Table 2). Statistically proven differences between the variants were observed in variety Marti. The average standard deviation and the variation coefficients are lower in variant V2 that determine a lighter effect of the meteorological conditions over the years on the ripeness. The increase of the economic ripeness by reduced irrigation could prolong the period of raw material entering in the processing enterprises.

In optimal and reduced irrigation variety Yana gave higher total yield compared to that of variety Marti 615,3 kg/da and 338,7 kg/da, respectively. The recorded differences in total yield between the two variants are greater in variety Marti and they are statistically significant. The average standard deviation and the variation coefficients in variety Yana are higher compared to that of variety Marti showing that this variety reacts stronger to the changes in climate conditions over the years than to the factor water deficit only.

The average fruit weight is an important yield component. The studied varieties are suitable for fresh consumption and industrial processing as they are used mainly in the canning industry. The results from morphological analysis show that reduced irrigation effects are stronger on this characteristic in variety Yana that gives larger fruits. The average fruit weight in variety Marti decreases but there are no significant statistical differences between the two variants. The size of the tomato fruits is not too important in processing as juices and concentrates.

A significant increase of dry matter was observed in the variants with water deficit in the two varieties. This characteristic is one of the fundamental criteria for tomato intended for canning industry. Higher dry matter content in tomato fruits compensates a part of the obtained lower yield in second variant.

The structure of the energy inputs is presented in table 3. A constant quantity of 2,10 kg in active ingredient (a.i.) pesticides, 53,73 kg in a.i. chemical fertilizers (N, P_2O_5, K_2O, $MgSO_4$), 7,8 kg polyethylene wrapping and 74,16 kg seedlings per 0,1 hectare was used in the research.

Under normal properly applied irrigation (variant V1), 340 m^3 of water (irrigation, watering at planting and replanting of seedlings) were invested. The manual operations involved required 164,38-180,53 h of human power (according to variety), for the mechanized operations involved 44,31-46,27 h of machinery and 48,28-50,73 L of diesel. Under reduced irrigation (variant V2) 190 m3 of water, 144,67-154,88 h of human power, 41,93-43,17 h of machinery and 45,29-46,84 L of diesel were invested respectively.

The costs detailed above generate total energy inputs in the range from 9334,84 to 9627,66 MJ/da and from 8978,25 to 9163,48 MJ/da for the both varieties in variant V1.

The total energy inputs in the variants under water deficit (V2) are 3,82% lower for variety Marti and 4,82% lower for variety Yana. The reasons for the decrease in the energy inputs are the lower energy inputs of human power

Таблица 2. Структура на добива и качество на продукцията
Table 2. Structure of the yield and quality of the tomato production

Сорт, варианти / Variety, variants		Параметри средно за периода / Parameters average for the period (2009-2011)							
		Средна маса на плода / Average fruit weight, g		Сухо вещество / Dry mater, %		Стопанска ранозрелост/ Earliness, kg/da		Общ добив / Standard production, kg/da	
		$\bar{x} \pm sd$	CV, %	$\bar{x} \pm sd$	CV, %	$\bar{x} \pm sd$	CV, %	$\bar{x} \pm sd$	CV, %
Марти / Marti	V1	107,3±5,7 b	5.3	5,4±0,15 b	2.8	1301,7±85,5 b	6.6	4611,0±617,0 ab	13.4
	V2	92,0±6,0 b	6.5	5,6±0,06 a	1.0	1488,0±37,0 a	2.5	3860,3±378,4 c	9.8
Яна / Yana	V1	143,0±19,2 a	13.4	5,2±0,12 b	2.2	1466,0±115,9 a	7.9	5226,3±671,4 a	13.4
	V2	114,0±21,5 b	18.8	5,7±0,06 a	1.0	1583,3±65,3 a	4.1	4249,0±543,9 ab	12.8

a,b,c – Duncan's Multiply Range Test, P<0.05

Таблица 3. Структура на енергийните разходи и приходи
Table 3. Structure of energy inputs and outputs

Приходи и разходи / Inputs and outputs	Сорт Марти / Cv. Marti				Сорт Яна / Cv. Yana			
	V1		V2		V1		V2	
	Quantity, unit/da	Total energy equivalent, MJ/da	Quantity, unit/da	Total energy equivalent, MJ/da	Quantity, unit/da	Total energy equivalent, MJ/da	Quantity, unit/da	Total energy equivalent, MJ/da
ПРЗ (а.в.) / Pesticides (a.i.), kg	2.10	339.20	2.10	339.20	2.10	339.20	2.10	339.20
хербициди / herbicides	0.70	166.60	0.70	166.60	0.70	166.60	0.70	166.60
фунгициди / fungicides	1.10	101.20	1.10	101.20	1.10	101.20	1.10	101.20
инсектициди / insecticides	0.30	71.40	0.30	71.40	0.30	71.40	0.30	71.40
Мин.торове (а.в.) / Fertilizers (a.i.), kg	53.73	1623.43	53.73	1623.43	53.73	1623.43	53.73	1623.43
фосфор (P_2O_5)	23.00	275.08	23.00	275.08	23.00	275.08	23.00	275.08
калий (K_2O)	6.25	41.88	6.25	41.88	6.25	41.88	6.25	41.88
магнезий ($MgSO_4$)	4.68	31.36	4.68	31.36	4.68	31.36	4.68	31.36
азот (N)	19.80	1275.12	19.80	1275.12	19.80	1275.12	19.80	1275.12
Гориво / Diesel, L	48.28	2718.16	45.29	2549.83	50.73	2856.10	46.84	2637.09
Амортизации и ремонт / Machinery, h	44.31	2778.24	41.93	2629.01	46.27	2901.13	43.17	2706.76
Човешки труд / Human power, h	164.38	330.17	144.67	291.14	180.53	362.16	154.88	311.36
механизатори / technicians	23.50	54.05	22.31	51.31	24.48	56.30	22.93	52.74
полски работници / farm-workers	140.88	276.12	122.36	239.83	156.05	305.86	131.95	258.62
Вода за напояване / Water for irrigation, m3	340.00	214.20	190.00	119.70	340.00	214.20	190.00	119.70
Пластмасов амбалаж и консумативи / Polyethylene wrapping, kg	7.80	1404.00	7.80	1404.00	7.80	1404.00	7.80	1404.00
Разсад / Seedlings, kg	74.16	141.64	74.16	141.64	74.16	141.64	74.16	141.64
Общи разходи / Total inputs, MJ		9 334.84		8 978.25		9 627.66		9 163.48
Добив от домати / Yield, kg	4611.00	4242.12	3860.30	3551.48	5226.30	4808.20	4229.00	3890.68

Таблица 4. Параметри на енергийния анализ
Table 4. Parameters of the energy analysis

№	Параметър / Parameters	Единица / Unit	Сорт Марти / Cv. Marti		Сорт Яна / Cv. Yana	
			V1	V2	V1	V2
1	Енергиен разход / Energy inputs	MJ/ha	9334.84	8978.25	9627.66	9163.48
2	Енергиен приход / Energy outputs	MJ/ha	4242.12	3551.48	4808.20	3890.68
3	Енергийна продуктивност / Energy productivity	kg/MJ	0.49	0.43	0.54	0.46
4	Коеф. на енергийна ефективност / Energy use efficiency	-	0.45	0.40	0.50	0.42
5	Енергийна интензивност / Energy intensity	MJ/kg	2.02	2.33	1.84	2.17

for harvesting (the yield is lower) and to a lesser extent the lower energy equivalent of the water for irrigation. The smaller quantity of the tomato yield require lower energy costs for diesel and machinery for the transportation of produce.

The parameters of the energy analysis are presented in Table 4. Data in this table demonstrate that the reduced energy inputs for production of determinate tomato under water deficit also result in lower energy outputs with the yield and no energy profit is achieved. Better energy balance results are observed in the production of variety Yana. The energy outputs are 9,55% higher in comparison to those observed for variety Marti when grown under water deficit conditions (variant V2). More favourable are the values of the inputs-outputs ratio (0,42 units) and the energy intensity (2,17 MJ/kg).

In terms of energy productivity in the tomato production, better results were observed in the control variant V1. For variety Marti it decreased by 12,96% to a value of 0,43 kg/MJ, while in variety Yana it decreased by 14,98% to a value of 0,46 kg/MJ.

CONCLUSIONS

If no irrigation was used during the period from the start of the flowering stage to early tomato fruit ripening stage the ripening process is of up to 14,31% faster, the dry matter in the fruits has increased by up to 9,61%, the average tomato yield and the average fruit weight have reduced by up to 18,70% and 20,07% respectively.

The total energy inputs of growing under water deficit are lower with 3,82% in variety Marti and with 4,82% in variety Yana, however this results in lower overall energy outputs and therefore no energy profit. The energy productivity of the varieties Marti and Yana is 0,43 kg/MJ and 0,46 kg/MJ respectively.

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