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Investigation the relationship "Yield – Evapotranspiration" by stages of rooted celery, variety "IBIS" in the region of Plovdiv

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Abstract

The purpose of this study was to be established the parameters of the "Yield – ET" by stages of turnip rooted celery (celeriac), variety "IBIS", using drip irrigation in the conditions of Plovdiv. The experiment was conducted on the experimental field of Department of Melioration and Land Surveying, Agricultural University – Plovdiv during 2010-2012. The parameters of the relationship have been established based on existing formulas as follows: first and second degree of exponent formulas of Davidov D. and linear formula of FAO. The used data are the yield and ET by stages of celery with the following variants: 1) irrigation with 130% of the irrigation rate **m**; 2) irrigation with 100% of the estimated irrigation rate **m** - 1 control; 3) irrigation with 70% of irrigation rate **m**; 4) irrigation with 50% of irrigation rate **m**; 5) irrigation with 30% of irrigation rate **m**; and 6) without irrigation - control 2. For the purpose of the investigation the growing season of celeriac is divided into three sub-stages (from transplant of seedlings to the beginning of celery root formation, start of root growth; intensive root growth). The investigated relationship for the conditions of the experiment is best represented by a second degree formula of Davidov D. at R = 0.939. The exponent for the entire growing period is N = 1.4. The values of the exponents for the different sub-stages of growing period are as follows: M_1 = 0.13; M_2 = 1.03 and M_3 = 1.06. This means that the celery root production is very susceptible during the second and third sub-stage of growth.

Keywords: rooted celery, drip irrigation, evapotranspiration.

Introduction

Irrigation of agricultural crops has influenced the yield and the intensity of crop evapotranspiration ET. It could be established the most favorable irrigation regime and the quantity of water consumed by the plant. From the investigations of a number of authors, it appears that rooted celery (celeriac) has been very strongly influenced by the supplied amount of water (Janik G., 2007; De Pascale et al., 2003; Jablonska - Ceglarek, R. et al, 2004; Dyduch J., 1997, 2005; and Breschini SJ et al., 2002). The scientists recommend the amount of irrigation rate to be varied from 85 to 414% of the reference evapotranspiration (ET_0) during the vegetation. Hartz T.K. (1997, 2000) suggested very often irrigation by drip installation with the size of irrigation rate (m) between 7-15 mm for conditions of California, so that the water does not drain into the lower layers.

In terms of rooted celery, publications related to the relationship "Yield - ET" are very few and concern only the tendency "Yield - total ET", which gives direction to present investigation, namely to establish the parameters of the "Yield - ET by stages" of rooted celery, variety "IBIS" in the region of Plovdiv. In the presence of experimental data is determined concrete relationship "Yield - ET by stages" with the linear formula of FAO (Doorenbos, J. & A.Kassam, 1979) and by the first and second degree exponent formulas of Davidov D. (1994). The established parameters in the formulas give the models, describing the demand dependence.

Method and Materials

To establish the relationship "Yield – Evapotranspiration'' of rooted celery, variety "IBIS" has been carried out 3 years experiment at the experimental field of the Department of "Melioration and Geodesy" in Agricultural University – Plovdiv during 2010-2012. The soil type is alluvial - meadow, a former waterlogged and it is characterized by the following parameters for the layer 0 - 0.40m: bulk density - 1.33 t/m^3;

field capacity - 30.9%.; maximum water capacity - 164.4mm; porosity - 47%.

Table1. Meteorological factors for the period June-October in the region of Plovdiv

Year/Month		VI	VII	VIII	IX	X	Average
2010	ΣN(mm)	59	120	24	13	119	334.7
	P%	47	8.9	52	72	4.4	13.30%
2011	ΣN(mm)	15	42	68	3.2	70.4	198.1
	P%	94	48	17	93	16.7	60
2012	ΣN(mm)	42	2.4	19	15	39.4	100.3
	P%	69	96	64	69	43.3	90

Table2. Yield of celery root (t/ha) and evapotranspiration for variants (mm) in the years, defined the relationship '"Yield – ET by stages"

Year	Irrigation	Yield		ET by sub-stages					
				I		II		III	
		t/ha	relative	mm	relative	mm	relative	mm	relative
1	2	3	4	5	6	7	8	9	10
2010	130%	24.5	1	84	1	151	1	182	1
	100%	20.4	0.833	84	1	137	0.912	169	0.929
	70%	16.9	0.691	71.6	0.852	114	0.757	142	0.777
	50%	13.4	0.549	68	0.809	106	0.7	125	0.685
	30%	9.25	0.378	65.1	0.775	102	0.675	121	0.664
	0%	4.77	0.195	51.2	0.604	79.6	0.529	94.7	0.52
2011	130%	22.8	1	95.6	1	249	1	303	1
	100%	19.7	0.862	95.3	0.997	239	0.959	254	0.839
	70%	17.9	0.784	69.2	0.724	195	0.783	212	0.7
	50%	13.8	0.602	63.5	0.664	119	0.48	149	0.49
	30%	7.55	0.33	52.2	0.546	102	0.48	121	0.399
	0%	2.66	0.116	49.1	0.514	82.2	0.33	63.8	0.21
2012	130%	19	1	285	1	116	1	119	1
	100%	16.8	0.885	279	0.975	121	1.043	118	0.992
	70%	15.7	0.824	191	0.668	104	0.892	94.9	0.799
	50%	11.2	0.589	155	0.541	70.6	0.608	77.2	0.65
	30%	3.28	0.173	119	0.417	47.7	0.41	48.4	0.408
	0%	0.59	0.031	71.5	0.25	10	0.086	6.6	0.056
Average	130%	22.1	1	155	1	172	1	201	1
	100%	19	0.86	153	0.986	166	0.964	180	0.896
	70%	16.2	0.734	111	0.713	138	0.8	150	0.743
	50%	12.8	0.579	95.3	0.615	98.5	0.573	117	0.581
	30%	6.69	0.303	78.7	0.508	83.6	0.486	98	0.487
	0%	2.67	0.121	60.3	0.389	46.1	0.268	35.2	0.175
Sub-stages		I	from the beginning of celery root formation to start of root growth						
		II	growth of root						
		III	intensive root growth						

The experience is designed by the method of long plots in four replications with size of experimental plots - 8.0 m^2, and the harvest plots - 4 m^2. The planting scheme of seedlings was 70 + 30 + 30 + 30 x 20 cm (5 plants of 1 meter). Studied variants regarding irrigation scheduling are following:

1. Irrigation with 130% of irrigation rate **m**;
2. Irrigation with 100% of the estimated irrigation rate **m** – control 1;
3.Irrigation with 70% of irrigation rate **m**;
4.Irrigation with 50% of irrigation rate **m**; 5. Irrigation with 30% of irrigation rate **m**;
6. Without irrigation - control 2.

The magnitude of the irrigation rate is determined by all variants according to the value of variant 2, which is control 1 – the irrigation with 100% of **m.** The size of the irrigation rate **(m**) is estimated for wetting of the layer 0 - 40cm, while maintained soil moisture became higher than 80% of field capacity. Soil moisture was determined by weighing samples every 5 - 7 days. By all variants (3, 4 and 5) irrigation rates were reduced with 30, 50 and 70% relative to calculated irrigation rate of a variant 2. The variant 1 has an increased irrigation rate with 30%. The irrigation is done with a drip system - two laterals at a distance of 60 cm with discharge rate for drippers of 4 l/hr, which are of 20 cm.

The yield data for all variants and the four replications were processed by the dispersion analysis. It was established the probability of differences. The evapotranspiration was calculated at every 20 cm using the balance method for all variants in the experiment to a depth of 1 m.

In relation to establishing the parameters of the relationship "Yield – ET by stages", the vegetation period of celeriac is divided into the following four stages (sub-periods, phases):

- Zero stage - from transplanting of seedlings to the beginning of celery root formation;
- First stage - from the beginning of celery root formation to start of root growth;
- Second stage - growth of root;
- Third stage - intensive root growth.

Experimental data were processed by the method of the least squares, as it is applied the program "Yield" of Davidov D. (1994), using the following formulas:

- The formula of Davidov D. (1994) – the first degree exponent formula for the relationship between yield and evapotranspiration by stages:

$$\frac{Y}{Y_0} = \prod_1^S \left[1 - \left(1 - \frac{ET_i}{ET_{0i}} \right)^{Ni} \right] \quad (1)$$

Where: s is number of stages (phases);

N_i – exponent by stages;

ET_i – evapotranspiration of a stage (i) – available;

ET_{oi} – evapotranspiration of a stage (i) – maximum.

- The formula of Davidov D. (1994) – the second degree exponent formula for the relationship between yield and evapotranspiration by stages:

$$\frac{Y}{Y_0} = \prod_1^S \left[1 - \left(1 - \frac{ET_i}{ET_{0i}} \right)^{N} \right]^{Mi} \quad (2)$$

Where: s is number of stages (phases);

M_i – exponent by stages;

N – exponent for vegetation period;

ET_i – evapotranspiration of a stage (i) – available;

ET_{oi} – evapotranspiration of a stage (i) – maximum.

- Linear formula by sub-stages/ FAO/ (1979):

$$\frac{Y}{Y_0} = \prod_1^S \left[1 - A_i \left(1 - \frac{ET_i}{ET_{0i}} \right) \right] \quad (3)$$

Where: s is number of stages (phases);

A_i – coefficient, determining susceptibility of the sub-stage of growth;

ET_i – evapotranspiration of a stage (i) – available;

ET_{oi} – evapotranspiration of a stage (i) – maximum.

Results

The climatic conditions of the region are closely related to irrigation during the growing period, especially in the variants with reduced irrigation requirements. It was done statistical evaluation of the experimental years in terms of rainfall, temperature and relative humidity during the growing period – from June till October. It was used statistical data from previous years (from 1912 till 2012). In Table 1 are included data for probability of exceedance (P %) of the rainfall.

The differences of climatic conditions in the experimental years reflected in the number and size of the applied irrigation rates. In 2010 were realized 7 irrigations because it turns humid. In 2011 and 2012.number of irrigations were 14, but all were differently distributed. The results after the processing of the data of table 2 by the formulas and the special program "Yield" of D.Davidov (1994) are as follows:

1) Formula (1) of D.Davidov (the first degree exponent) with a correlation coefficient R=0.921 has the following values of the exponent N_i, as follows:

In stage I (from seedlings to capture early formation of root) $N_1 = 0.05$

- In stage II (start of root growth) $N_2 = 1.04$
- In stage III (intensive growth of root) $N_3 = 1.2$

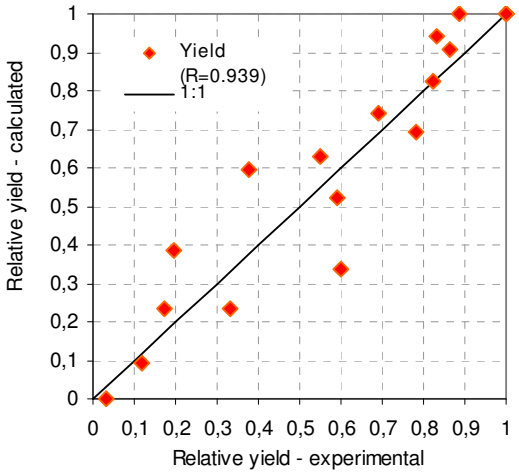

Figure1. Relationship between experimental and calculated yields by the first degree exponent formula of D.Davidov (1)

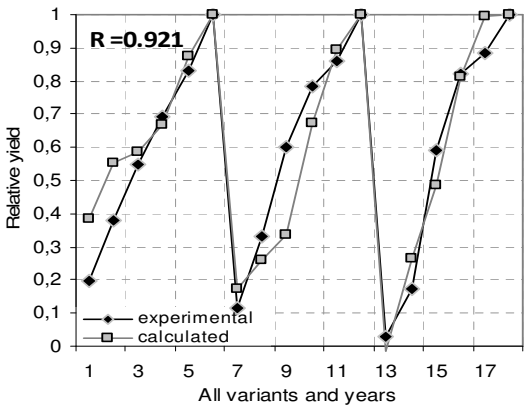

Figure2. Relative yields – experimental and calculated by formula (1)

In figure 1 are plotted points, which coordinates are the relative values of yields - experimental and calculated by the formula (1). In figure 2 are the calculated and experimental relative yields of the variants. These two figures illustrate the degree of approximation of the relationship with this formula.

In figure 3 is plotted the relationship between yield and evapotranspiration of celery for each stage (phase). It is seen that the second and third stage of rooted celery development are the most susceptible. This is clearly evident for the values of parameter Ni.

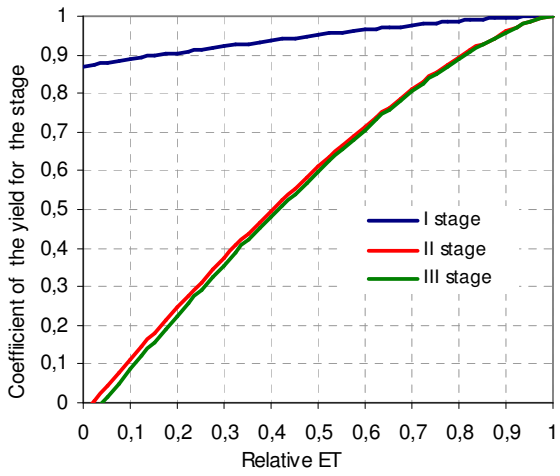

Figure 3. The relationship between yield and evapotranspiration ET by stages, calculated by the first degree exponent formula of D.Davidov (1)

2) The formula (2) of D.Davidov (the second degree exponent formula). It has been established the correlation coefficient R = 0.939, the exponent for the entire growing season N = 1.4 and exponent M_i by stages, respectively:

- $M_1 = 0.13$ for stage I (from the beginning of celery root formation to start of root growth);
- $M_2 = 1.03$ for stage II (growth of root)
- $M_3 = 1.06$ for stage III (intensive root growth)

In figure 4 are plotted the experimental and calculated data by formula (2) and in figure 5 - relative yields for variants (experimental and calculated).

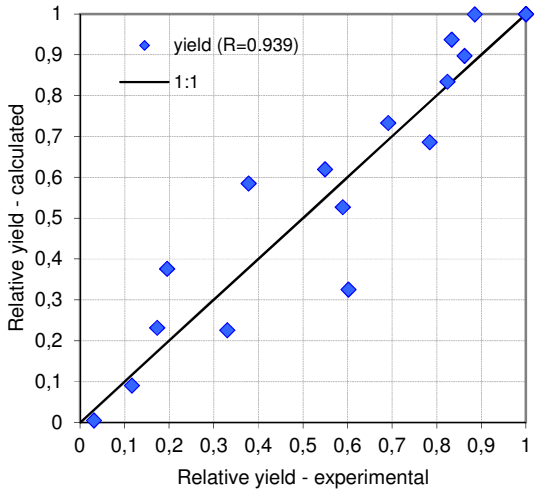

Figure 4. The relationship between experimental and calculated yields by the second degree exponent formula (2) of D.Davidov

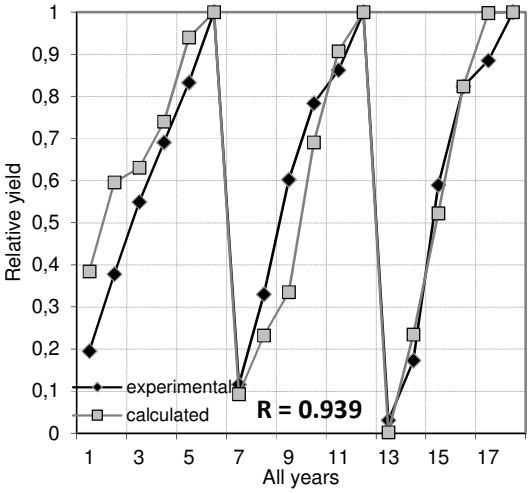

Figure 5. The relative yields – experimental and calculated by formula (2)

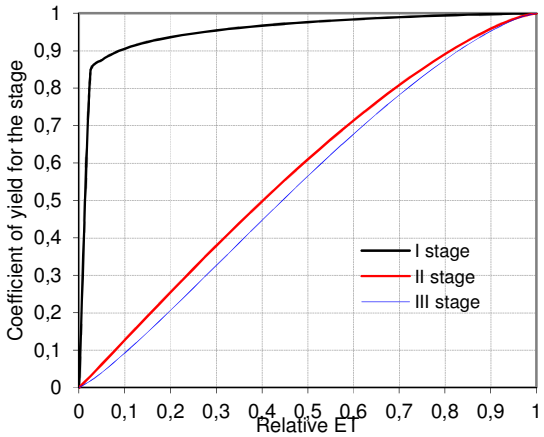

Figure 6. Relationship between yield and evapotranspiration ET by stages with formula (2)

Figure 6 depicts the relationship between yield and ET for each of the three stages of celery development. In the first stage of celery development relationship is curvilinear, expressed by convex top line. In the second and third stages dependence is represented by less convex parabolas. This is because of the exponent, similar to the unit in the two stages. The conclusion is that in the first stage of celery development its evapotranspiration at least influence on root yield, unlike the second and third stage, in which the susceptibility is high and approximately equal.

3) Linear formula of FAO (3) in figure 7, 8, and 9 are plotted the correlation with coefficient is R = 0.944 and a coefficient Ai determining the susceptibility of the stages is as follows:

- A_1 = 0.05 for stage I (from the beginning of celery root formation to start of root growth);
- A_2 = 1.12 for stage II (growth of root);
- A_3 = 0.38 for stage III (intensive root growth).

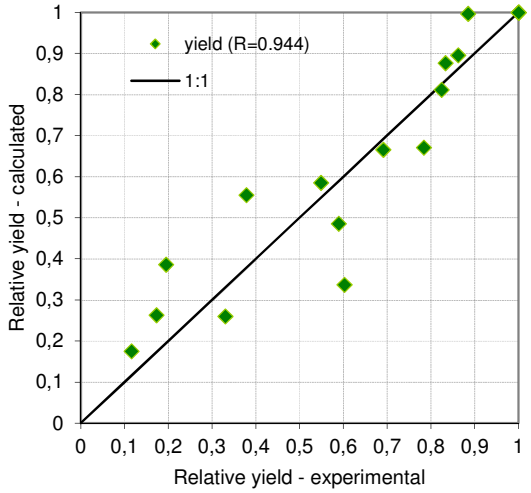

Figure7. Relationship between experimental and calculated yields by FAO

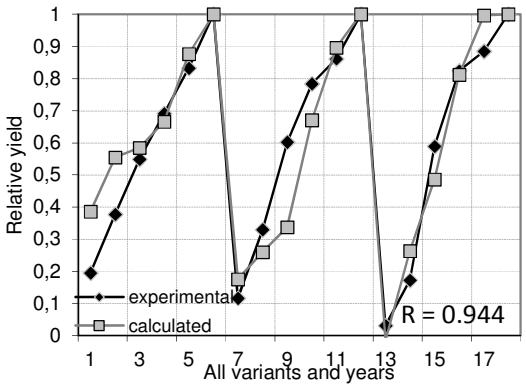

Figure 8. Relative yields, experimental and calculated by FAO (3)

The figures by the three formulas show the influence of evapotranspiration on the yield and susceptibility of the stages. The second and third stages have appeared very susceptible for the celery growth, while in the first one the effect of evapotranspiration is negligible.

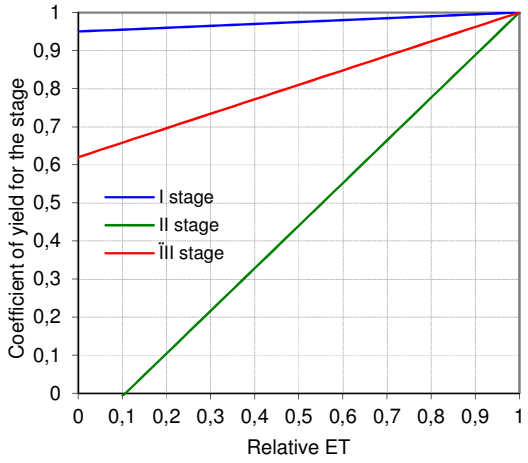

Figure 9. Relationship between yield and evapotranspiration by stages, calculated by FAO

Large differences between the experimental and calculated yields are only available in variants without irrigation and irrigation with a small irrigation rate that would not have practical application in the actual production of celery.

Conclusions

The formulas, used in this paper express accurately the relationship between yield and evapotranspiration of celery by stages with coefficient of correlation $R \geq 0.939$. The most susceptible to ET is the third stage (intensive root growth) and the second stage (growth of root), while during the first stage (from the beginning of celery root formation to start of root growth) the influence is negligible.

For the conditions of the experiment the second degree exponent formula (2) of D.Davidov (1994) reflects the relationship between yield and evapotranspiration by stages of rooted celery with the following parameters: $N = 1.4$; $M_1 = 0.13$; $M_2 = 1.03$ and $M_3 = 1.06$ at $R = 0.939$. Besides being a product of the influence of different stages of rooted celery, the relationship reflects with highest accuracy the changes of relative yields and relative evapotranspiration in each of the three sub-stages of the vegetation. The differences are the smallest between experimental and calculated yield of rooted celery by this formula (2).

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