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CLIMATIC CRITERIA FOR THE APPLICATION OF WATER THROUGH THE DRIP SYSTEM

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ABSTRACT. Irrigation conditions in this country are characterized using, as a climatic criterion, potential evapotranspiration /ETp/ and climatic water deficiency /WNK/ as a difference between ETp and precipitation /P/. Such criterion is compared with the results of a simplified water balance of soil, proving good conformity of both above indices. Put forward in this paper are the proposals concerning determination of the water requirements in the drip irrigation system under local conditions.

INTRODUCTION

Water deficiencies of crops, calculated as a result of the water balance of soil, constitute a criterion of the demand and range of irrigations. There are climatic /evapotranspiration, precipitations/, soil /its moisture level/ and biological /plant/ criteria. For practical purposes and for getting a general orientation, climatic criteria are applied, e.g. in hot and dry countries – potential evapotranspiration /ETp/, while in countries with a moderate climate – the difference between ETp and precipitation /ETp – P/. The critical indices of such types are named differently, e.g. deficit hydrique, water index, etc. In the present paper, that index will be defined as a „climatic water deficiency" /WNK/.

In this an attempt is made to characterize by means of the value of WNK = /Etp – P/ and by potential evapotranspiration, the conditions under which irrigations are applied in this country.

This characteristic is supplemented by the values of water deficiencies as being a result of the water balance in the soil. Also, proposals concerning the determination of the particular factors of this balance, in the case of its setting up in order to determine the water requirements of crops with drip irrigation, are presented in this paper.

Taking into consideration evapotranspiration and „climatic water deficiency" exclusively does not at all mean an underestimation of factors, such as solar radiation, air humidity, temperature, and wind velocity, etc. However, they will not be discussed here, because their joint effect is expressed, at least to a certain degree, by ETp and WNK = /ETp – P/.

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Table 1. Precipitations /P/, potential evapotranspiration /ETp/ and climatic water deficiencies /WNK/, means for the period 1966-1975

Month	Elements	Values in mm – in stations															
		Koszalin	Lębork	Suwałki	Szczecin	Chojnice	Ostrołęka	Białystok	Bydgoszcz	Gorzów Wlkp.	Poznań	Terespol	Leszno	Łódź	Włodawa	Opole	Rzeszów
May	P	65	65	58	58	62	62	57	68	52	54	60	51	66	64	68	76
	ETp	102.9	95.7	104.4	99.0	97.1	93.6	96.6	109.0	101.9	105.4	107.3	103.8	108.0	105.1	98.6	98.3
	WNK	38	31	46	41	35	32	40	41	50	51	47	53	42	41	31	22
June	P	58	56	76	55	79	79	79	77	69	66	73	64	75	77	93	106
	ETp	126.6	122.8	122.8	116.4	119.2	112.5	113.6	129.9	121.5	121.4	127.8	119.5	127.8	123.8	109.8	112.2
	WNK	69	67	47	61	40	34	35	53	53	55	55	56	53	47	17	6
July	P	96	83	85	62	95	75	91	71	58	69	76	75	93	97	103	90
	ETp	119.0	116.9	124.1	117.0	115.5	111.2	116.0	130.9	123.3	125.0	128.4	120.9	126.4	123.5	113.0	113.5
	WNK	23	34	39	55	21	36	25	60	65	56	52	46	33	27	10	24

The application of potential evapotranspiration and „climatic water deficiency" as criterial values arouses no reservations, when these values may serve for the estimation of demand and the range of irrigations in general, including also drip irrigations.

The drip irrigation system differs from other irrigation systems by technology consisting of the continous water feeding of plants, ensuring constant and uniform soil moisture / Slowik, 1978, Slowik and Kielak, 1978/. The processes occurring in the soil during the use of drip irrigation have not been satisfactorily recognized hitherto, and no reliable models have been developed for them. Therefore there are no other ways of characterizing them than by those characteristics applied for other irrigation systems.

ETp AND WNK = /ETp – P/ VALUES

On the basis of the concerned material / Sarnacka, Brzeska and Swierczynska,1978/, in the decade of /1966-1975/ the mean values of monthly sums /May, June and July/ of

- potential evapotranspiration /ETp/,
- precipitations /P/,
- „climatic water deficiency" – WNK = /ETp – P/,

have been determined and put together in Table 1 for 16 stations distributed all over the country's territory.

The potential evapotranspiration was calculated by means of the Brochet-Gerbier formula, which is a modification of the Penman formula. Both formulae, as has been proven / Doorenbos and Pruitt, 1975; Sarnacka, Brzeska and Swierczynska 1978; Sarnacka, 1979/, give very approximate, practically identical results and take into consideration the effect of almost all climatic and meteorological factors on the ETp value.

The chosen decade represents the climatic conditions of this country, rather correctly, as far as atmospheric precipitations are concerned, as follows from Table 2, where they are compared with the means for the period of 1951-1970 after Chomicz /1977/. In the months considered, no great differences in mean precipitation values occurred; in the decade of 1966-1975 they were insignificantly higher.

From Table 1 it can be seen that the spatial differentiations of mean monthly ETp sums were small. They lay within the following intervals: in May – from 95.7 to 109 mm, in June – from 109 to 129,9 mm and July – from 111.2 to 130.9 mm. Precipitation sums were more variable, lying within 51-76 mm in May; 55-106 mm in June and 62-103 mm in July. The ratio of maximum and minimum precipitation sums reached two and that of the climatic deficiencies, ten.

The WNK = /ETp – P/ value ranges in May amounted to 22-53 mm, in June – to 6-61 mm and in July – to 24-65 mm.

The distribution of WNK values over the decade is of interest and is summarized by the data put together in Table 3 on the basis of Sarnacka et al. /1978/. It is evident that the years without any water deficiencies and those with deficiencies reaching 100 mm or more, are few. As has already been mentioned, the indices applied give only a certain orientation concerning the climatic conditions which are of

Table 2. Comparison of mean monthly precipitation sums for the periods 1966-1975 and 1951-1970

Month	Periods	Mean mothly precipitation sums in mm particular stations														
		Koszalin	Lębork	Suwałki	Szczecin	Chojnice	Ostrołęka	Białystok	Bydgoszcz	Gorzów Wlkp.	Poznań	Terespol	Łódź	Włodawa	Opole	Rzeszów
May	1966-1975	65	65	58	58	62	62	57	68	52	54	60	66	64	68	76
	1951-1970	58	54	52	56	53	50	56	50	51	56	54	60	63	70	71
June	1966-1975	58	56	76	55	79	79	79	77	69	60	73	75	77	93	106
	1951-1975	57	67	66	56	67	57	67	54	63	59	71	74	64	73	80
July	1966-1975	96	83	85	62	95	75	91	71	58	69	76	93	97	103	90
	1951-1970	90	89	69	74	93	71	63	94	75	75	79	94	84	95	83

Table 3. Number of years with different values of climatic water deficiencies in May, June and July in the decade 1966-1975

Month	Denotations	Values for stations															
		Koszalin*	Lębork	Suwałki	Szczecin	Chojnice	Ostrołęka	Białystok	Bydgoszcz	Gorzów Wlkp.	Poznań	Terespol	Leszno	Łódź	Włodawa	Opole	Rzeszów
May	Without deficiencies	1	1	0	0	1	0	0	1	0	0	1	0	0	0	1	2
	Deficiencies below 50 mm	5	6	6	6	6	8	7	5	6	4	2	3	6	5	7	6
	Deficiencies 50-100 mm	2	3	4	4	3	2	3	4	4	6	7	7	4	5	2	2
	Deficiencies over 100 mm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	Wihout deficiencies	1	0	1	0	1	3	2	2	2	2	1	1	1	1	2	4
	Deficiencies below 50 mm	0	2	4	4	5	2	3	3	2	2	3	2	4	3	7	3
	Deficiencies 50-100 mm	5	6	4	5	4	5	5	3	4	5	6	6	5	6	1	3
	Deficiencies over 100 mm	2	2	1	1	0	0	0	2	2	1	0	1	0	0	0	0
July	Without deficiencies	2	1	3	1	1	3	3	1	0	2	1	1	4	4	5	2
	Deficiencies below 50 mm	2	5	3	4	8	2	3	3	5	3	5	6	1	4	2	5
	Deficiencies 50-100 mm	3	3	1	3	1	4	3	4	2	3	2	1	4	1	3	3
	Deficiencies over 100 mm	1	1	3	2	0	1	1	2	3	2	2	2	1	1	0	0

* Remark: for Koszalin – values are from 8 and not from 10 years

importance for irrigations, it is regarded that more reliable are the results of the water balance of the soil taking into consideration, the actual evapotranspiration /ETa/. A tentative balance of this kind is presented in next chapter.

AN ATTEMPT OF SETTING UP THE WATER BALANCE OF SOIL TAKING INTO CONSIDERATION THE ACTUAL EVAPOTRANSPIRATION

In order for us to get the values of water deficiencies, the water balance of soil should comprise of: actual evapotranspiration /ETa/, effective precipitation /P_E/, water reserves in soil /R/, outflow into deeper parental formation layers and lateral out and inflows. At an omittance of out and inflows, the balance will comprise of the first three factors: ETa, P_E and R, which will be discussed further in the text of this chapter.

The first factor: ETa, is determined very differently in particular countries and by different authors. In hot and dry countries the definition of ETa is not used at all, one simply speaks of water requirements, which when using drip irrigations when there is little or no precipitation is not baseless. Most methods hitherto applied in these countries make use of the value of evaporation from a free water surface; for regions of moderate climate there is, as far as we know, a lack of such a widespread index.

According to Black, the water requirement values /in precipitationless periods equal to ETa/ are determined in the drip irrigation practice:

a/ on the basis of evaporation measured by the USA evaporimeter of the A class /more rarely by the Piche evaporimeter or another one/ and on the basis of reducing coefficients / Kenworthy, 1972/, established in empirical investigations,

b/ on the basis of evaporation, as under a/, but it is used for the determination of the potential evapotranspiration /ETp/ and then, through the application of biological coefficients – the actual evapotranspiration /ETa/ is found. In calculations using this method, also additional coefficients, are applied which take into consideration the water losses in strongly permeable soils and the exhaustion degree of soil moisture / Hoare et al. 1974/. The ETa value obtained in such a way is submitted to further reduction in view of the specificity of drip irrigation,

c/ on the basis of potential evapotranspiration, calculated usually according to Penman, much less often according to Blaney-Criddle or Thornthwaite, as well as on the basis of biological coefficients resulting from the application of drip irrigation.

In general, all the aforesaid can be reduced to the statement that, while estimating the water requirements for drip irrigations, the methods could be applied as in other irrigation systems /with a distinct prevalance of evaporimetric methods/ and the obtained results, multiplied by the reducing coefficient which takes into consideration the technological features of this new kind of irrigation / Black, Hoare, 1974, Kenworthy, 1972/. The latter coefficient varies within a wide range: from 0.5-0.6-0.8 in hot and dry climates with high ETa values and with wide spacings of plant rows, to 0.9-1.0 in moderate climates with low ETa values and densely growing plants /trees, shrubs, etc./.

In Poland we do not dispose of the numerous measurement results from large evaporimeters, and therefore, we will be compelled /at least in the near future/ to take the calculated ETa values as a basis.

It is necessary to stress that the evaporation-reducing coefficients, measured by the A class evaporimeters and lying within an interval of 0.5-0.8 / Black, Hoare et al. 1974, Kenworthy, 1972/, do not differ significantly from the values of the coefficients /0.5-0.75/ which are applied for the conversion of the evaporation, from the same measuring devices, into the potential evapotranspiration / Doorenbos and Pruitt, 1975/. It confirms, at least to a certain degree, the correctness of taking potential and actual evapotranspiration as a basis for determining the water requirements of crops. The ETp values in the balance presented in this paper /Table 4/; which are the same as those quoted in Table 1 and necessary for the ETa determination, have been assumed from the work of Samacka et al. /1978/.

The ETa values for apple trees were calculated as products of ETp and the biological coefficients Kc in May amounted to 0.75 in June – to 1.0 and in July – to 1.1 / Samacka, 1978/.

The ETa = Kc · ETp values calculated in such a way are presented in Table 4.

The second element of the balance, atmospheric precipitations, is not fully utilized by plants in view of the losses caused by interception, surface and underground water run off.

The diminished atmospheric precipitation values is called effective precipitation and depends on actual evapotranspiration, precipitation amount and the water reserve of the soil. There is still a lack of unified, generally applied methods for the determination of effective precipitation: it is estimated either as a part of the measured value /70-80 %/, or by disregarding low precipitations – below 2, 5, 8 and sometimes 12 mm, or of high precipitations – over 30-50 mm a day. Respective investigations were started in this country to unify the views concerning this whole problem.

In the situation as presented above, it is doubtful whether the introduction of the effective precipitation value into the balance would be met with comprehension and therefore, in Table 4 /balance/ the values of the precipitations measured by means of the standard Hellmann's pluviometer, placed at the level of 1 m above the soil surface, are quoted.

The third and last element of the water balance of soil is the water retention of soil. This element is of less importance in the case of the drip irrigation system since the basic principle of this irrigation technology is to maintain soil moisture at a level approximating the field water capacity. This principle results from the necessity of ensuring high crop yields, which should justify the drip irrigation application.

It follows, from the above review of the water balance elements, that the result of the balance–a water deficiency is the difference between the ETa and P values multiplied by the reducing coefficients alternatively assumed in drip irrigation as 0.6 and 0.8 , respectively. Such calculated deficiencies are put together in Table 4; they are values to be considered in the drip irrigation system.

Table 4. Balance table. Precipitations /P/, actual evapotranspiration /ETa/ and climatic water deficiencies /WNK/ – specification for trickle irrigation, mean for the period 1966-1975

Month	Water balance elements in mm	Koszalin	Lębork	Suwałki	Szczecin	Chojnice	Ostrołęka	Białystok	Bydgoszcz	Gorzów Wlkp.	Poznań	Terespol	Leszno	Łódź	Włodawa	Opole	Rzeszów
		Values in mm in stations															
May	P	65	65	58	58	62	62	57	68	52	54	60	51	66	64	68	76
	ETa	77.2	71.2	78.3	74.0	72.8	70.2	72.4	81.7	76.4	75.0	80.5	77.8	81.0	78.8	73.9	73.7
	WNK · 0.6	7.3	3.7	12.2	9.7	6.5	4.9	9.2	8.2	14.6	12.6	12.3	16.1	9.0	8.9	3.6	-1.4
	WNK · 0.8	9.8	5.0	16.2	12.8	8.6	6.6	12.3	11.0	19.5	16.8	16.4	21.5	12.0	11.9	4.8	-1.8
June	P	58	56	76	55	79	79	79	77	69	66	73	64	75	77	93	106
	ETa	126.6	122.8	122.8	116.4	119.2	112.5	113.6	129.9	121.5	121.4	127.8	119.5	127.8	123.8	109.8	112.2
	WNK · 0.6	41.2	40.1	28.1	36.8	24.1	20.1	20.8	31.7	31.5	33.2	32.9	33.3	31.7	28.1	10.1	3.7
	WNK · 0.8	54.9	53.4	37.4	49.1	32.2	26.8	27.7	42.3	42.0	44.3	43.8	44.4	42.2	37.4	13.4	5.0
July	P	96	83	85	62	95	75	91	71	58	69	76	75	93	97	103	90
	ETa	130.9	128.6	136.5	128.7	127.0	122.3	127.6	144.0	135.6	137.5	141.2	133.0	139.0	135.8	124.3	124.8
	WNK · 0.6	20.9	27.4	30.9	40.0	19.2	28.4	22.0	43.8	46.6	41.1	39.1	34.8	27.6	23.3	12.8	20.9
	WNK · 0.8	27.9	36.5	41.2	53.4	25.6	37.8	29.3	58.4	62.1	54.8	52.2	46.4	36.8	31.0	17.0	27.8

EFFICIENCY OF INSTALLATION

The values presented concern mean monthly values and ensure an orientation as to the amount of water for irrigation in only particular months or in the whole three-month period. However, they do not determine the maximum possible water requirements which occur in precipitationless periods, when actual evapotranspiration will at the same time represent the deficiency value. The periods of drought or of scarce precipitations which probably do not increase the moisture content in soil, are long and frequent in cetrain parts of this country. For example, at the station Koszalin, precipitationless periods longer than 5 days, with a single precipitation amount below 3 mm or with several day precipitations below 3 mm, occurred at short intervals during most of the growing seasons during the period 1961-1972.

As follows from Table 4, the maximum ETa values, multiplied alternatively by 0.6 and 0.8 constitute, in drought periods the water requirements, which with drip irrigation, calculated e.g. for July /130-144/, 0.6 or 0.8, amounted to 78-104 or 87-113 mm, respectively. It follows from the above that the drip irrigation installations should be dimensioned for at least 113/30 equaling about 4 mm a day. This number constitutes only a certain orientation and is related to mean and not maximum ETa values; more reliable information could be obtained, while disposing of the longer period of investigations and the greater number of stations, establishing on this basis the ETa values with a definite occurrence probability and assuming one of them as sufficiently safe.

CONCLUSIONS

1. Results of the analyses carried out in the work, proved that the climatic water deficiency, calculated on the basis of actual evapotranspiration and precipitations, constitutes an appropriate climatic criterion for the estimation of the demands and the range of irrigation, including also the drip irrigation system.
2. The applied method for the determination of the plants water requirement for drip irrigation needs, based on the results of measurements with the USA evaporimeters of the A class cannot be used in our conditions because of a very low number of such evaporimeters installed in this country.
3. In the present situation, until the time when more rational methods are developed it can be proposed that to determine the water amounts needed for drip irrigation the difference between the two water balance elements should be taken: a/ actual evapotranspiration /ETa/, calculated as a product of potential evapotranspiration /ETp/ and biological coefficients /Kc/ as well as reducing coefficients taking into consideration the specificity of the drip irrigation system. On the basis of the results of the studies / Sarnacka et al. 1978, Sarnacka , 1979/ the potential evapotranspiration determined by the Penman method or, by what is synonymous to the very simple Brochet-Gerbier method can be recommended; b/ precipitation, in accordance with standard measurements.
4. In view of a frequent drought occurrence in this country, the total efficiency of the drip irrigation installation should be determined as equal to the maximum actual evapotranspiration in the way quoted under 3, but without reduction by the precipitation value.

5. The analyses mentioned in the paper were based on relatively scarce materials /10-year investigation period, 16 stations/. To get more comprehensive information on the water requirements of plants, both for water management analyses and for determining the efficiency of the installations, such a widening in time and space of the works /about 25 years of investigation and about 60-70 stations/ would be necessary, so as to ensure appropriate conditions for the statistical elaboration of the results obtained.

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