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EFFECT OF CLIMATIC FACTORS - AIR TEMPERATURE AND HUMIDITY - ON BIOLOGICAL CHARACTERS OF SUNFLOWER

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Summary

Research objective was to determine the extent of changes in biological characters of sunflowers as affected by air temperature and humidity, as well as to establish whether certain developmental phases require the same temperature sums or the sums change from year to year.

We studied effects of air temperature and humidity on biological characters of sunflower grown in four ecological regions situated between 35th and 40th degree geographic latitude. The research, which lasted for five years (1970-1974), included the following nine cultivars: VNIIMK 8931, Mayack, Peredovic, No. 317, No. 61, Chernyanka 66, Armavirsky 3497, VNIIMK 6540 and Armavirec. The size of basic plot was 25.2 m.sq. There were five replications. Leaf area size was measured at 20 plants by the formula of Montgomery. Plant height was measured at 100 plants. Oil content was calculated by the method of Soxlet.

There are favorable and limiting factors in each region. In the first tested region, the limiting factor was a low humic content (1%), in the second, third, and fourth region unfavorable air temperatures and humidity. In spite of a low soil fertility in the first region, the highest average seed yield of the nine cultivars (32.0 mtc/ha) was obtained there. The average seed yields in the second, third, and fourth region were 30.9 mtc/ha, 31.5 mtc/ha, and 28 mtc/ha, respectively.

Oil content in absolutely dry seed was 49% in the first region (five-year average of the nine cultivars), 44.1% in the second, 44.6% in the third, and 45.0% in the fourth. These results show that the oil content in the first region was higher by 4-4.9% than the contents in the other three regions. It was also found that individual cultivars had highest oil contents in the first region. What does bring differences in oil contents? During the phase of oil synthesis, the mean daily temperatures in the first region were 26°C in July and 23.3°C in August (five-year average), in the second region 27°C in both months, in the third region 24°C in July and 26°C in August, and in the fourth region 25°C in July and 26°C in August. These figures indicate that high mean daily temperatures alone, without other adverse climatic factors, do not reduce oil contents. In those ecological conditions, however, in which high maximum temperatures (36-40°C) are accompanied by a high relative humidity (90-100%) during the phase of seed filling, oil content is reduced by 4-5%. It may also be noticed that sunflower plants endure easily such adverse climatic conditions if they occur before flowering. Our results show that sunflower plants, during the last 10-14 days of seed filling, are incapable of enduring such climatic

conditions. The vegetation practically ceases if the temperatures exceed +40°C and the air humidity is above 90%.

Our results showed that sunflower plants were shortest and had smallest leaf area in the first region (with lowest air humidity). On the five-year average for the nine cultivars, leaf area was 3187 cm.sq. in the first region, 5268 cm.sq. in the second region, 5473 cm.sq. in the third region, and 4594 in the fourth region. The leaf area was smaller by 44-71% in the first region than in the other three regions.

The results of another three-year research show that the plant development in different developmental phases requires the same sum of effective temperatures regardless of the year of growing and date of planting.

In Novi Sad, the sum of effective temperatures for the phase from sprouting to budding of the cultivar VNIIMK 8931 is 529.7°C, for the phase from budding to flowering 348.7°C (average of 17 planting dates and three test years). If the developmental phases are to be determined in days, the number of days changes as follows: if planting is performed on March 5, the stage of budding begins after 61 days; if planting is performed on June 23, the stage of budding begins after 38 days (average of three years). On the basis of these results, we decided that the vegetation length should not be counted in days but by the sum of effective temperatures. In the latter case, it is possible to realistically compare all biological characters of cultivars and hybrids grown at a similar geographic latitude.

Materials and Methods

Effects of air temperature and relative humidity on biological characters of some sunflower cultivars were studied in four ecological regions which differed in the above climatic factors. The regions are located between 35 and 40 degrees latitude. Experiments lasted for five years (1970-1974) and included nine cultivars: VNIIMK 8931, Mayak, Peredovic, No. 317, No. 61, Chernyanka 66, Armavirsky 3497, VNIIMK 6540, and Armavirec. Calculated basic plot size was 25.2 m.sq. Experiments were conducted in five replications. Leaf area size was determined by Montgomery's formula, using 20 plants. Plant height measurements included 100 plants. Soxlet's method was employed for oil content determinations.

Experiments were conducted at the experimental field of the Institute of Field and Vegetable Crops in Novi Sad to establish eventual relationships between air temperature and certain developmental phases in sunflower plants. Each test year (1967, 1968 and 1969) we planted the seed of the tested cultivars at 17 dates, the first planting date being March 5, the last June 23, i.e., each seven days. In this way we provided conditions for different temperatures to affect different developmental phases in natural conditions. These experiments included the cultivar VNIIMK 8931. Effective temperatures were calculated as follows: 5°C were subtracted from the mean daily temperature; the remaining daily temperatures were summed up for the phases sprouting-budding; budding-flowering, and flowering-physiological maturity.

Results and Discussion

Seed yield is the result of a number of factors including the ecological ones -- climate and soil. There are favorable and limiting factors in each region. In the first ecological region, humic content was low and the soil was clayey; in the second, third and fourth regions, humic contents ranged from 3 to 4.5%. In the first region, humic content was a limiting factor; in second, third and fourth regions, air temperature and humidity were limiting factors.

In spite of a low fertility of soil in the first region, the highest average seed yield of the nine cultivars (32.0 mtc/ha) was obtained there. The average seed yields in the second, third and fourth regions were 30.9 mtc/ha, 31.5 mtc/ha, and 28.1 mtc/ha, respectively.

Oil content in absolutely dry and pure seed was 49.0% in the first region (five-year average for the nine cultivars), 44.1% in the second, 44.6% in the third, and 45.0% in the fourth. These results show that the oil content in the first region was higher by 4-4.9% than the contents in the other three regions. This difference is highly significant.

Analysing oil contents in individual cultivars, it was found that all cultivars had highest oil contents in the first region.

Table 3 shows that the mean daily temperature in the first region was 26.1°C in July and 23.3°C in August (phase of oil synthesis), in the second region 27°C in both months, in the third region 24°C in July and 26°C in August, in the fourth 25°C in July and 26°C in August (five-year average). These figures indicated that there were no large differences among the mean daily temperatures for the tested regions. However, differences in oil contents for the tested cultivars were highly significant in favor of the first region. These results lead us to conclude that high temperature does not decrease oil content. However, in the regions with high temperatures (36-40°C) and high air humidity (90-100%) during the phase of oil synthesis, oil content decreases by 4-5%. It should be mentioned at this point that sunflower plants endure high maximum temperatures and high relative air humidity during the phase of leaf development.

In our studies we also analysed effects of ecological factors on leaf area size and plant height. Our results show that the plants in the first region were shortest and had smallest leaf area. On the five-year average for the nine cultivars, leaf area per plant was 3187 cm.sq. in the first region, 5268 cm.sq. in the second, 5473 cm.sq. in the third, and 4594 cm.sq. in the fourth, i.e., the average leaf area in the first region was smaller by 44 to 71% in respect to the leaf areas in the other three regions.

Plant heights ranged from 152 cm in the first region to 206 cm in the third region. Our opinion is that leaf area size and plant height are mostly affected by soil fertility.

It is our observation that vegetation practically ceases, i.e., oil synthesis is ended, when air temperature reaches +40°C and the air humidity is above 90%. At early developmental stages (leaf formation, intenstive growth, seed set) sunflower plants are capable of enduring much harsher climatic conditions. During the last 10-14 days of vegetation, however, vital functions in plants are slower and plants cannot endure either abrupt temperature changes (shocks) or the combination of high temperatures (+40°C) and high relative air humidity (higher than 90%).

Shepetina (the USSR) found in his studies that a high air humidity at the phase of seed filling negatively affects yield and quality of sunflower seed. This author stated that academician Pustavoit had reached the same conclusion. Shepetina explains that different conditions of growing change characters of physiological processes which results in changed yields and quality of seed. Cupina found that the respiration of injured plants is intensified which forces these plants to spend more energy. In view of the above results and the results of our experiments, we concluded that sunflower plants respire more intensively, spending at the same time more energy, in an unfavorable microclimate. Plants can endure such conditions during earlier phases of development but it is not so at the end of vegetation and thus the plants are forced into earlier maturation. This was probably the basic reason for decreases in oil contents in the second, third, and fourth ecological regions.

Table 7 shows the sums of effective temperatures (ET°C) according to the developmental phases of sunflowers. In case of the cultivar VNIIMK 8931, budding started after the sum of effective temperatures reached 629°C (average for 17 planting dates and three test years). The above results indicate that the phases of leaf formation and budding will not be ended until the sum of effective temperatures does not reach the required level. After the planting on March 5, budding started after 627°C of effective temperatures; after the planting on June 23, after 645°C (three-year average). Table 8 shows the developmental phases according to the number of days. On the three-year average, the plants planted on March 5 budded 61 days after the planting, while the plants planted on June 23 budded after 38 days.

In case of the cultivar VNIIMK 8931, the sum of effective temperatures necessary for the phase of intensive growth (budding-flowering) is 348°C (the average of 17 planting dates and three test years). The above results indicate that flowering will not start until the sum of effective temperatures does not reach the required level, regardless of the number of days. Table 8 shows that the period from budding to flowering was 28 days for the plants planted on March 10 and 23 days for the plants planted on June 16.

The plants planted on March 5 were physiologically mature by May 5. The sum of effective temperatures for the period planting - physiological maturity ranged from 720 to 806°C, depending on the planting date. The sum of effective temperatures decreased rapidly to reach 455°C for the planting date of June 23. Of course, the plants were forced into earlier maturation in this case.

Our results enabled us to conclude that the developmental phases of sunflower plants should be related to the sum of effective temperatures rather than to the vegetation length in days because the former way of calculation facilitates a more precise forecast.

Smirnova calculated the effective temperature by subtracting +10°C from the mean daily temperature. Her calculation was valid for the northern border of sunflower-growing region (50-55° latitude). Semihnenko had different criteria for individual developmental phases (germination-sprouting: +5°C; sprouting-budding: 11-12°C; budding-flowering: 15-16°C; flowering-physiological maturity: 10-14°C). Biologists and ecologists should match the calculation of effective temperatures with the latitude. As our experiments were conducted at 45° latitude, we calculated the effective temperature by subtracting +5°C from the mean daily temperature.

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TABLE 1. Effect of abiotic factors, temperature and air humidity, on seed and oil yields and oil contents in four different ecological regions - Five Year average (1970-1974).

Cultivar	Ecological Region											
	I			II			III			IV		
	Seed Yield mtc/ha	Oil % in abs. dry seed	Oil Yield kg/ha	Seed Yield mtc/ha	Oil % in abs dry seed	Oil yield kg/ha	Seed yield mtc/ha	Oil % in abs dry seed	Oil yield kg/ha	Seed yield mtc/ha	Oil% in abs dry seed	Oil yield kg/ha
VNIIMK 8931	33.7	49.3	1494	33.2	44.1	1282	31.4	43.2	1236	26.6	44.4	1054
Mayak	32.2	50.1	1439	30.1	46.4	1292	31.6	45.4	1253	29.4	45.9	1150
Peredovic	32.9	50.3	1518	33.8	45.1	1335	30.0	45.4	1196	28.7	44.8	1150
No. 317	34.8	49.8	1532	35.3	44.6	1376	28.2	44.5	1141	26.9	45.3	1065
No. 61	33.3	50.4	1493	33.1	44.7	1273	29.3	45.9	1188	26.9	45.8	1074
Chernyanka 66	27.1	46.9	1138	27.8	43.2	1057	30.2	44.0	1261	28.1	44.3	1080
Armavirsky 3497	32.9	48.1	1378	29.7	43.6	1135	34.6	44.3	1347	28.3	45.1	1092
VNIIMK 6540	35.5	50.0	1532	32.2	44.7	1261	34.6	45.5	1378	28.8	46.6	1179
Armavirec	26.0	46.9	1051	23.4	41.0	841	33.6	43.4	1271	29.3	43.4	1112
Average	32.0	49.0	1397	30.9	44.1	1205	31.5	44.6	1252	28.1	45.0	1106
LSD 5%	478		184	326		161	339		146	499		182
LSD 1%	635		244	432		219	450		198	672		256

Seed yield per ec. region LSD 5% 251
1% 348

Oil yield per ed. region LSD 5% 176
1% 249

TABLE 2. Leaf area size and plant height of nine cultivars tested in four ecological regions - Five-year average (1970-1974).

Cultivar	Ecological Region							
	I		II		III		IV	
	Leaf area/ plant cm sg	Plant height in cm	Leaf area/ plant cm sg	Plant height in cm	Leaf area/ plant cm sg	Plant height in cm	Leaf area/ plant cm sg	Plant height in cm
VNIIMK 8931	3995	171	6136	196	6118	228	4905	177
Mayak	3415	170	5476	178	6363	229	3918	184
Peredovic	3293	167	5290	178	7760	234	4624	173
No. 317	3333	161	6155	173	6614	231	4961	163
No. 61	3275	158	5636	170	6733	212	5108	175
Chernyanka 66	2586	81	4488	94	5670	128	4188	98
Armavirs, 3497	3275	164	5794	172	5878	213	4850	180
VNIIMK 6540	3289	169	4686	172	6251	213	4619	173
Armavirec	2229	127	3753	115	5862	167	4176	139
Average	3187	152	4268	160	5473	206	4594	162

TABLE 3. Temperature and air humidity during growing season in the period 1970-1974 - Ecological locality I

Month	Year	Temp in ^{o}C			Rel. Air Humidity (%) at	
		Abs. Min.	Abs. Max.	Mean Daily	3 A.M.	9 A.M.
May	1970	10.2	31.0	19.5	86	74
	1971	3.0	27.5	16.7	80	53
	1972	1.5	35.0	18.4	57	29
	1973	5.5	32.8	17.5	76	40
	1974	4.8	31.3	17.8	72	38
Average		5.0	31.5	17.9	74	32
June	1970	8.0	36.0	21.4	57	39
	1971	8.5	36.5	22.0	71	50
	1972	7.0	41.5	24.0	57	24
	1973	10.0	40.0	24.1	64	41
	1974	10.9	35.0	22.0	63	42
Average		8.8	37.8	22.7	62	39
July	1970	12.5	38.5	26.0	47	29
	1971	12.0	38.5	25.0	60	36
	1972	11.5	42.5	26.3	58	31
	1973	13.8	39.8	27.6	42	18
	1974	12.6	39.3	25.6	51	28
Average		12.4	39.7	26.1	51	28
August	1970	7.5	37.0	23.7	81	66
	1971	12.5	37.5	24.3	58	33
	1972	8.5	37.0	22.9	63	25
	1973	12.5	41.0	21.5	51	24
	1974	9.4	38.2	24.2	49	21
Average		10.0	38.1	23.3	60	34

TABLE 4. Temperature and air humidity during growing season in the period 1970 - 1974 - Ecological locality II

Month	Year	Temp in °C Abs. Min.	Abs. Max.	Mean Daily	Rel. Air Humidity (%) at 3 A.M.	9 A.M.
May	1970	10.4	43.0	23.2	70	44
	1971	13.0	35.0	22.3	73	51
	1972	10.0	39.0	19.6	76	57
	1973	11.0	41.0	21.7	76	48
	1974	9.0	37.0	22.0	74	58
Average		10.6	39.0	21.7	74	52
June	1970	14.6	32.6	24.0	76	50
	1971	14.4	38.0	24.5	70	43
	1972	16.3	38.0	26.7	73	49
	1973	15.8	37.0	23.9	77	54
	1974	15.3	37.0	25.7	70	48
Average		15.2	36.5	24.9	73	49
July	1970	20.0	37.6	27.4	71	46
	1971	19.1	38.0	28.7	67	42
	1972	20.2	37.0	29.2	71	44
	1973	19.4	39.4	27.0	72	52
	1974	19.2	40.2	25.8	78	61
Average		19.5	38.4	27.6	72	49
August	1970	20.4	35.6	27.1	81	59
	1971	21.0	37.0	27.4	71	47
	1972	18.1	40.0	27.5	66	42
	1973	19.4	37.0	28.3	78	52
	1974	18.2	37.0	26.4	74	52
Average		19.4	37.3	27.3	74	50

TABLE 5. Temperature and air humidity during growing season in the period 1970-1974 - Ecological locality III

Month	Year	Temp in °C Abs. Min.	Temp in °C Abs. Max.	Temp in °C Mean Daily	Rel. Air Humidity (%) at 3 A.M.	Rel. Air Humidity (%) at 9 A.M.
May	1970	6.5	36.2	20.7	81	53
	1971	10.5	33.5	20.8	92	62
	1972	9.0	34.5	18.9	88	74
	1973	8.4	35.3	19.6	87	68
	1974	5.5	33.5	19.8	87	66
Average		7.9	34.6	19.9	87	64
June	1970	11.5	32.5	20.7	81	53
	1971	12.0	34.5	20.8	92	62
	1972	15.2	35.5	18.7	88	74
	1973	12.4	33.5	19.8	87	68
	1974	13.1	33.5	19.6	88	66
Average		12.8	33.9	19.9	87	65
July	1970	17.0	35.5	26.0	77	60
	1971	16.5	36.0	21.9	76	57
	1972	19.5	35.5	28.3	83	61
	1973	16.0	38.0	20.5	85	69
	1974	17.2	37.1	23.1	86	68
Average		17.2	36.4	23.9	81	63
August	1970	19.5	34.0	26.3	92	69
	1971	18.0	34.1	26.5	80	59
	1972	15.0	37.5	25.5	86	62
	1973	20.0	33.5	26.9	89	77
	1974	17.0	33.2	25.4	87	72
Average		17.9	34.4	26.1	87	68

TABLE 6. Temperature and air humidity during growing season in the period 1970-1974 - Ecological locality IV

Month	Year	Temp in °C Abs. Min.	Abs. Max.	Mean Daily	Rel. Air Humidity (%) at 3 A.M.	9 A.M.
	1970	5.4	32.5	18.3	74	42
	1971	6.0	30.0	16.5	84	61
May	1972	4.5	33.0	17.4	82	55
	1973	3.0	30.0	17.0	82	73
	1974	4.7	31.4	19.0	83	67
Average		4.7	31.3	17.6	81	59
	1970	6.0	35.6	20.3	66	48
	1971	7.0	37.0	20.9	78	53
June	1972	9.5	35.5	22.6	75	49
	1973	8.5	38.5	22.6	75	49
	1974	7.6	34.5	20.6	73	48
Average		7.7	36.2	21.1	74	50
	1970	7.0	39.0	23.6	63	53
	1971	11.5	41.2	25.1	64	44
July	1972	10.5	37.0	24.1	79	39
	1973	9.6	36.5	26.6	81	43
	1974	10.2	36.5	24.2	74	56
Average		9.7	38.0	24.7	72	47
	1970	14.0	40.5	27.0	67	55
	1971	12.0	39.5	26.5	70	59
August	1972	6.5	36.5	22.9	86	45
	1973	10.5	35.5	24.5	73	48
	1974	11.2	36.4	28.0	74	50
Average		10.8	37.6	25.7	74	51

TABLE 7. Sums of effective temperatures for developmental phases of the cultivar VNIIMK 8931 - Three-year average (1957-1959)

Planting Date	Average				
	Plant Sprouting	Sprout Budding	Budding Flowering	Flower. Ph.mat.	Sprouting Ph. mat.
March 5	63.7	627.9	326.3	788.4	1742
March 10	75.3	619.4	355.9	775.6	1750
March 17	87.9	614.2	326.1	806.9	1747
March 24	94.2	616.1	338.1	799.2	1753
March 31	90.1	613.1	32.14	788.3	1722
April 7	82.5	631.2	309.9	759.8	1700
April 14	87.0	618.4	365.8	762.8	1747
April 21	129.9	645.5	354.9	738.6	1739
April 28	121.3	630.8	358.0	720.2	1709
May	105.6	629.0	348.4	757.6	1735
May 12	133.4	594.0	335.3	714.8	1644
May 19	95.6	614.3	399.5	671.2	1685
May 26	115.2	635.3	352.4	659.1	1646
June 2	74.8	656.9	371.2	597.4	1625
June 9	79.4	663.6	378.6	537.2	1579
June 16	91.7	649.8	360.3	531.7	1541
June 23	94.5	645.7	326.3	455.2	1327

TABLE 8. Length of developmental phases, sprouting-budding and budding-flowering, in days for the cultivar VNIIMK 8931.

Planting Date	Sprouting-Budding			Budding-Flowering		
	Year			Year		
	1967	1968	1969	1967	1968	1969
March 5	74	59	51	28	24	30
March 10	67	56	49	27	25	33
March 17	64	57	51	25	22	33
March 24	62	58	51	26	22	33
March 31	60	54	50	29	21	33
April 4	64	57	44	26	21	33
April 14	57	49	44	24	22	27
April 21	58	50	44	26	19	31
April 28	56	43	44	23	23	26
May 5	52	43	43	24	20	32
May 12	48	40	42	24	24	31
May 19	47	39	40	24	23	27
May 26	48	38	41	23	26	28
June 2	46	38	41	26	28	24
June 9	46	37	42	20	30	24
June 16	39	40	39	22	24	25
June 23	38	39	37	25	25	25