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Observations on the development of plants IV.

The development of annual hibernating plants

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The influence of exterior conditions (chiefly of light and temperature) on the development of plants appears — with the accumulation of more experimental data — both more complicated and varied than it was so far believed (Bünning 1953, Junges 1958).

Our observations carried on since 1957 on various species of perennial and annual plants, whether hibernating or beginning their vegetation in spring (Listowski and Jeśmianowicz 1960a, 1960b, 1961) also indicate a varying relation between development and exterior conditions as well as different interaction of light and temperature in their inhibiting or stimulating influence on vegetative and generative development. It also results from our observations that the development of many perennial, biannual and hibernating plants is not inhibited but only retarded, if these plants grow continually in elevated temperature conditions, while the influence of daylength extends to all plants, though its intensity may vary.

Further observations are in progress and are being extended to other species both perennial and hibernating.

According to Tymrakiewicz (Weed Atlas, 1959), of the 149 species of our segetal flora 34 are perennials, and above 65 — spring species, germinating, however, mostly in late summer and hibernating in the form of a rosette.

Of this group of hibernating plants the following have been examined (Listowski and Jeśmianowicz 1960a, 1960b): *Centaurea cyanus, Agrostemma githago* and *Delphinium consolida.* In all of these a strong inhibiting effect of short day treatment of various intensity was established in dependence on the data of sowing, but practically no stimulating effect of lower temperature was observed.

It seemed of interest to extend observations to further species belonging to this group of plants (Table 1).

Experiments were, also undertaken on three species not included in the above table:

Table 1

Species	Date of sowing	*L*			*S*			Difference *S* — *L*
		Number of days to:		No. of flowering plants in %	Number of days to:		No. of flowering plants in %	
		begin of flower.	full bloom		begin of flower.	full bloom		
Veronica arvensis	1.VI	42	50	100	44	54	100	4
	6.VII	42	50	100	46	57	100	7
	25.VIII	77	95	100	95	117	100	22
Lithospermum arvense	1.VI	—	36	100	—	37	100	1
	1.VII	—	46	100	—	48	100	2
	31.VIII	—	103	100	—	144	100	41
	16.II	42	47	100	63	70	100	23
Viola tricolor	6.VII	—	43	100	—	45	100	2
	7.VIII	168	235	100	240	256	50	21
	31.VIII	158	198	75	198	222	40	24
Arenaria serpyllifolia	1.VI	42	46	100	48	60	100	14
	6.VII	44	56	100	81	100	80	44
	25.VIII	57	77	100	109	136	50	59
Cerastium viscosum	1.VI	56	61	100	79	92	100	31
	6.VII	66	78	100	77	97	80	19
	7.VIII	74	95	100	222	262	100	167
	31.VIII	74	89	100	198	237	80	146
Cerastium vulgatum	31.VIII	80	89	100	203	224	60	135
	16.II	69	74	100	99	—	—	—
Galium aparine	1.VII	59	68	100	—	161	100	23
	25.VII	—	65	100	—	136	100	71
Papaver Rhoeas	23.VII	217	241	100	—	332	100	91
	25.IX	217	227	100	217	—	spor.	—
Capsella bursa pastoris	6.VII	39	50	100	—	78	100	28
	7.VIII	59	76	100	88	111	100	35
	31.VIII	65	72	100	112	125	100	53
Geranium pusillum	9.VII	96	111	100	—	325	100	214

1. *Spergula arvensis* (winter or spring species) exclusively under natural daylight of varying length. Very slow growth in autumn and in the first half of winter. In February extension of shoots. The plants flowered early and died towards the end of April. *Draba verna* (winter species) — complete inhibition of growth under winter and autumn short day of low intensity. From mid January new leaves appear — the plants came into flower early and died after 7 weeks.

2. *Oxalis acetosella.* Sown on August 25. Flowered under continuous daylight after 263 days. Under short day conditions complete inhibition of growth and gradual wilting. Sown on February 16: came into flower under continual daylight conditions after 101 days; under short day conditions but of higher intensity than in autumn flowered after 134 days.

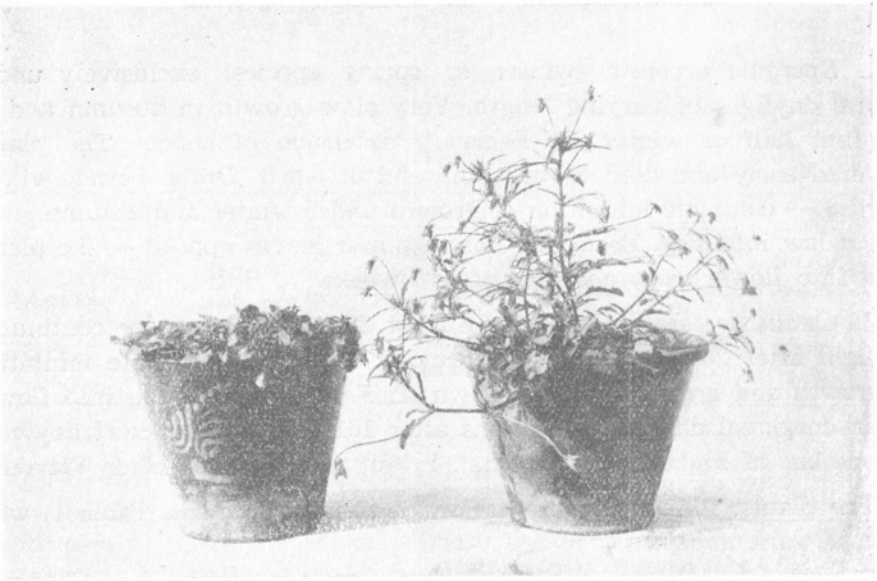
The plants, for which observations are summarized in Table 1, were sown at various dates.

The plants sown in June and July were kept during the whole vegetation period in the vegetation house. Long day (*L*) means here natural long days gradually becoming shorter. Short day (*S*) — daylight reduced to ± 8 hours by shading the plants from 3 P.M. The plants sown in the period from August to the first days of September were transferred to the glass-house, placing the combination "*L*" under continuous illumination and the combination "*S*" under an 8 hours daylight regime. The intensity of natural light was raised by the use of a fluorescent lamp in combinations "*S*" and "*L*" and daylength was prolonged in combination "*L*".

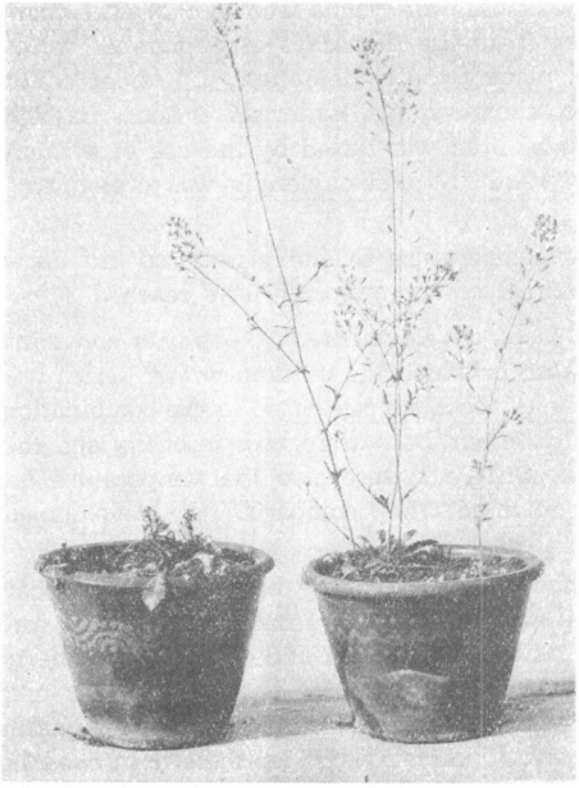
The minimal temperature in the glasshouse did not descend below 12° and the maximal on sunny spring days reached 30°.

The conditions of development of the plants sown in early summer differed from those in which the autumn-winter series were sown in the hothouse. In spite of the same daylength in the combination "*S*", the light conditions were different, both as regards intensity and the spectral composition of light. Different were also the temperature amplitudes. This should be kept in mind when comparing the development of plants in series sown at different dates.

Generative development. As may be seen from the data in Table 1, all the plants flowered without vernalization though earlier on a long day regime and at a delayed term under short day. The inhibitive influence of short day on the generative phase — weaker in plants sown in summer — increases greatly, if the plants grow in autumn and winter under less intensive illumination. Under these light conditions the flowering in combination "*L*" is also delayed. In *Cerastium* and *Arenaria* — in combination "*L*" — the retardation of development in series sown later

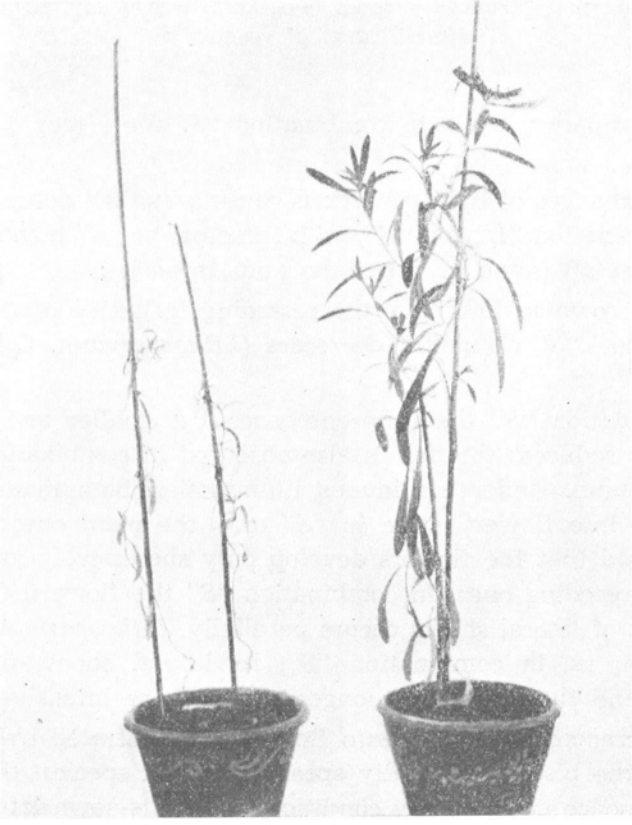


Phot. 1. *Viola arvensis* — sown 6.VII. Left — short day, right — long day, after 100 days of vegetation

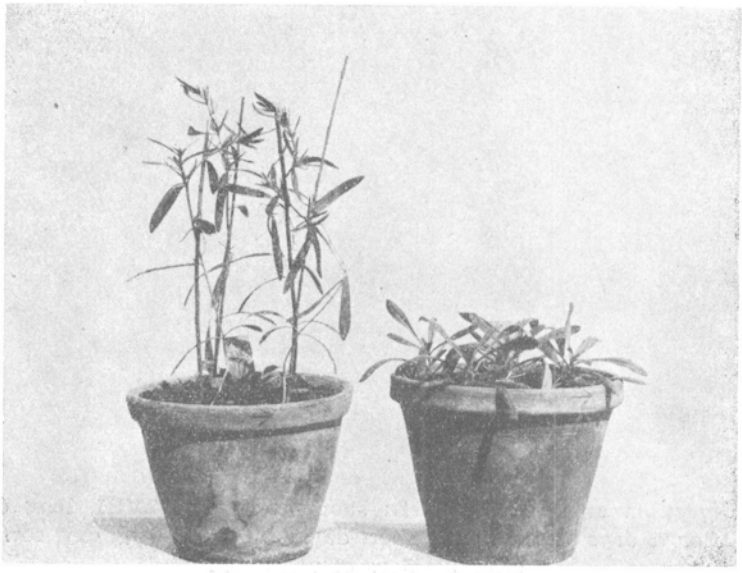


Phot. 2. *Capsella bursa pastoris* — sown 6.VII. Left — short day, right — long day, after 100 days of vegetation

Phot. 3. *Cerastium arvense*. From left: short day, sown 7.VIII, long day, sown 7.VIII — after 75 days of vegetation; short day, sown 6.VII, long day, sown 6.VII — after 100 days of vegetation



Phot. 4. *Lithospermum arvense* — sown 31.VII. Left — long day, right — short day, after 190 days of vegetation



Phot. 5. *Lithospermum arvense* — sown 16 II. Left — long day, right — short day, after 53 days of vegetation

is relatively smaller, while in combination "*S*" the effect is very pronounced.

In *Viola* changes of light conditions cause a marked delay in flowering both in combination "*L*" and "*S*", with some of the "*S*" plants not coming into flower at all (same as *Cerastium* and *Arenaria*).

In plants sown in February the retarding influence of the conditions of combination "*S*" distinctly decreases (*Lithospermum, Cerastium vulgatum*).

In combination "*S*" the inflorenscences are smaller and the number of flowers is reduced; this fall is also observed in combination "*L*" when sown in autumn. Under continuous illumination both main and lateral shoots come into flower, while in "*S*" only the main ones do and it is often observed that the flowers develop only successively after the wilting of the preceding ones. In combination "*S*" the flowering and further development of lateral shoots occurs parallelly, *Lithospermum* only being an exception, as, in combination "*S*", its lateral shoots develop more intensively and flowering lasts longer and is more intensive.

The differences in coming into flower are illustrated by photographs of some of the plants. Generally speaking, in all species, the strong inhibitive influence of short day conditions in plants sown late is due both to the reduced daylength and to the decreased light intensity. It is prob-

Table 2

Development stage of plants	No. of days from sowing	Height of main stem in cm.		No. of leaves on main shoot		No. of lateral shoots		Length of lateral shoots in cm.		Aerial parts of one plant (g) fresh weight		Aerial parts of one plant (g) dry weight		Root weight of one plant (g) dry weight	
		L	*S*	*L*	*S*	*L*	*S*	*L*	*S*	*L*	*S*	*L*	*S*	*L*	*S*
Cerastium viscosum — sown 7.VIII															
Flowering of series *L*	95	30.90	5.1	24	21	7	9	15.1	2.4	2.58	—	0.27	—	—	—
Flowering of series *S*	270	—	26.3	—	34	—	19	—	21.2	—	15.50	—	2.14	—	—
Cerastium viscosum — sown 31.VIII															
Flowering of series *L*	90	37.6	4.0	22	17	7	3	—	—	2.48	—	0.39	—	—	—
Flowering of series *S*	240	—	16.2	—	36	—	16	—	—	—	16.67	—	2.05	—	—
Cerastium vulgatum — sown 31.VIII															
Flowering of series *L*	90	58.3	8.0	25.0	22	7	4	—	—	7.03	—	0.79	—	—	—
Flowering of series *S*	230	—	32.4	—	32	—	18	—	—	—	19.30	—	2.46	—	—
Capsella bursa-pastoris — sown 7.VIII															
Flowering of series *L*	80	30.0	1.4	19	30	—	—	—	—	1.83	—	0.18	—	0.07	—
Flowering of series *S*	120	—	12.3	—	32	—	—	—	—	—	2.13	—	0.20	—	0.16
Capsella bursa-pastoris — sown 31.VIII															
Flowering of series *L*	75	191	roz.	13	26	—	—	—	—	2.33	—	0.25	—	0.07	—
Flowering of series *S*	125	—	6.4	—	29	—	—	—	—	—	2.53	—	0.23	—	0.140
Lithospermum arvense — sown 16.II															
Flowering of series *L*	50	8.0	1.6	8	6	—	—	—	—	0.45	0.22	0.06	0.02	0.03	0.01
Flowering of series *S*	70	—	35.6	—	24	—	—	—	—	—	4.62	—	0.54	—	0.06
Veronica arvensis — sown 25.VIII															
Flowering of series *L*	100	25.6	18.2	20	19	12	10	15.2	9.8	1.71	—	0.40	—	1.18	—
Flowering of series *S*	120	—	27.0	—	25	—	10	—	14.7	—	0.67	—	0.11	—	0.54

able also that the change in the spectral composition of light plays here a certain role (W a s i n k and S t o l w i j k 1956).

Under long day or continuous illumination conditions the individual plants come into flower, end flowering and their seeds ripen almost simultaneously. In combination "*S*" — on the contrary — the differences in the individual development of the plants are much wider. The life of the entire plant as well as of the particular leaves is significantly prolonged. These differences between "*L*" and "*S*" are particularly marked when the plants are sown in autumn. The long day plants sown in July, when transferred to the autumn-winter short day conditions begin to grow and flower again.

Vegetative development. In plants sown earlier (in summer) the differences in vegetative development between series "*S*" and "*L*" are relatively small and increase with later dates of sowing.

The reaction in the particular species (with some exceptions) is similar, therefore we have restricted the data given in table 2 to only several species.

The plants of series "*S*" as compared to "*L*" exhibit:

1. A reduced rate of growth of the main stem and lateral shoots. In many plants this inhibition is particularly marked in the period from October to January, decreasing later. Growth, particularly in series "*S*", is visibly accelerated. The stems in this combination are mostly thicker.

2. The rate of formation of lateral shoots varies: it is lower e.g. in *Viola* and *Cerastium* and higher and more intensive in *Lithospermum.*

3. The internodes are distinctly shorter giving the plants, together with the horizontal position of the leaves, a compact habitus, so that the plants often adhere to the ground.

4. The leaves are mostly smaller, rarely of the same size *(Viola)* or larger (*Lithospermum*). Their colour is generally darker, seldom lighter (*Papaver*).

5. The petioles are shorter, the blades smaller (*Veronica, Cerastium, Capsella*) less frequently larger (*Lithospermum*) or about the same size (*Viola*).

6. The rate of growth of the leaves is slower (e.g. *Cerastium, Viola, Lithospermum*), the same (*Veronica, Arenaria*) or quicker (*Capsella*).

SUMMARY

Observations on some dozen species of monocyclic plants hibernating in our conditions in rosette form, proved a strong dependence of growth and generative development on daylength and light intensity.

Long daylight, notwithstanding the intensity of light, accelerates both vegetative and generative development.

Short daylight retards flowering. Its effect is particularly strong when combined with low light intensity. It results in greatly delayed flowering and its reduced intensity, so that some of the plants do not come into flower at all or develop only single flowers.

Simultaneously a marked retardation of growth processes is observed up to almost complete inhibition of differentiation of leaves but with simultaneous considerable prolongation of the life of the plants as well as of their particular leaves.

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