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Observations on plant development (X)

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Among the 26 species of biennial and perennial plants the development of which was investigated (A. Listowski and Jackowska 1964), five developed only vegetatively without vernalization (A) and five flowered sporadically after several years notwithstanding the daylength (B) to which they were exposed.

Plant species	Type	Flowers under natural conditions	Seeding time	Length of observations years
A.				
Betonica officinalis	♄	June - September	February 1962	2 1/2
Cichorium intybus	♄	July - September	September 1957	6
Heracleum sphondylium	♄ or ☉	June - September	August 1959	4 1/2
Potentilla reptans	♄	June - August	September 1960	3 1/2
Valeriana officinalis	♄	June - August	October 1959	3
B.				
Centaure Jacea	♄	July - August	October 1959 February 1960	4
Tragopogon pratensis	♄	June - July	September 1957 (further series with various seeding dates)	6 1-2
Salvia sclarea	♄	June - July	September 1957	6
Verbascum thapsiforme	☉	July - September	1958-1960 various seeding dates	3
Aretium minus	☉	August - September	August 1959	4 1/2

The differences in leaf size and in rosette structure (under L_{24} larger, lighter leaves with long petioles) were distinct in *Cichorium intybus* and *Valeriana officinalis* as well as in *Heracleum sphondylium* in the first year of life. In *Betonica* the differences were but slight, whereas in *Potentilla reptans* the differences were reversed, i.e. leaves larger under S_8 — the tendrils of this species are long and numerous under long and considerably shorter under short day.

The seasonal variation in differentiation and development of leaves was distinct in *Cichorium* and *Valeriana* and small in *Betonica* and *Potentilla reptans.*

In *Heracleum* the period of differentiation of new leaves began in February and lasted till June under continuous daylight and throughout

summer under short daylight. In autumn, growth ceased and "summer leaves" dried under short daylight, whereas under L_{24} all the leaves dried and the plants underwent full dormancy for about 2 months. All the long-day plants of *Cichorium intybus* died within the autumn period 4 years after sprouting and some of the short-day individuals died the next year owing to the deperishment of the root neck.

The observations on *Arctium minus* will be discussed separately.

Salvia sclarea came into flower profusely and uniformly after 4 weeks of vernalization (without vernalization rosettes). In the second year of life under continuous and natural daylight, in the course of summer short shoots densely foliated, with shortened internodes developed and formed secondary rosettes on the top apexes. These short shoots as well as a part of the rosette leaves died in autumn, when growth "stagnated": In the second half of winter new leaves differentiated and the short shoots began to elongate.

In the 6th year of life a part of the plants (mainly under L_{24}) died, and simultaneously, two individuals came into flower.

Centaurea Jacea exhibited a pronounced vegetative reaction to daylength. Under L_{24} when sown in autumn, the rosette consisted of 6—8 leaves. The leaves were very large, soft, thin, with very long petioles and elongated oval blades. Juvenile leaves were not lobed (reaction to low light intensity).

In autumn and the first half of winter the growth stagnated and a part of the leaves died. The active phase started in February—March. The new leaves were large, but having the typical shape for *Centaurea*.

When the plants were sown in February, the developing leaves had at once the typical shape.

Under short day the rosettes were compact, with dark-gray-green, short petioled leaves having smaller blades and a typical shape. The differentiation of leaves was very slow and the seasonal variation small.

Under continuous daylight three of nine plants came into flower between the 372 and 405th day after sprouting (October—November). In series II (seeded in February) three of ten plants came into flower after 16 months (June). These plants as well as two others (about 40%) flowered again in the next year. The flower stems were of normal height, the period of flowering was very long, whereas the florescence — less profuse than under natural conditions.

Under short day in series I two of eight plants came into flower 460 days after sprouting and in the next season the same two and one more plant flowered. In series II also several plants flowered 1 1/2—2 years after sprouting (about 25%). The flower stem was short and densely foliated. The intensiveness of flowering was low. The vernalized plants flowered uniformly and profusely, notwithstanding the daylength before vernalization.

Tragopogon pratensis flowers in June to August under natural conditions. The plants were sown on September 15, 1957 and grew in the greenhouse without vernalization under L_{24}, and S_8. The differences in habitus were pronounced — under L_{24}, the leaves were erect longer, wider and lighter.

In both combinations the following seasonal oscillations of activity were observed:

L_{24} — second half of winter to full summer: phase of differentiation and intensive growth of leaves. In full summer — older leaves die while new ones develop very poorly. Early autumn: second phase of leaf differentiation. October—December: more and more intensive dying of leaves, while differentiation and growth stagnate.

Under short day: except late autumn and the first half of winter the differentiation and growth of leaves is more or less uniform.

To the end of the third year of life, at the period of autumn "stagnation" three of seven plants died owing to the decay of root necks. Three others died in the same season in the fourth year, while one plant flowered intensively. Under short day, after four years five plants died, one flowered and three still continue to develop only vegetatively.

Two experiments were made in order to elucidate the influence of vernalization in interaction with seeding time.

Experiment 1 (Table 1) — 6 dates of seeding, the plants from the first four seedings were transferred to the hothouse on October 10, December 23 and February 10, respectively whereas those from the two last seedings — on December 23 and February 10. The plants from the control combination remained only vegetative.

Vernalized: in mid April the first plants from the first and second date of seeding began to form stems. After mid August no further plants came into flower. The percentage of flowering plants is summarized in Table 1.

Table 1

Date of		Age of plants on Oct.18	Percentage of flowering plants		
seeding	sprouting		Oct. 18	Dec. 23	Febr. 10
July 7	July 15	95	0	30	77
July 27	August 3	76	0	25	25
August 24	August 31	48	1 plant of 16	0	0
September 7	September 13	35	0	0	0
September 21	October 3		-	0	0
October 5	October 27		-	0	0

The following slight differences in the habitus were observed in dependence on the date of transfer to the hothouse:

1) Largest and widest leaves occurred on plants transferred on October 18 and December 23.

2) Differentiation of leaves was most rapid in plants transferred on February 10, the more rapid the earlier the seeding date.

3) The plants from early dates of seeding, notwithstanding the date of transfer, exhibited a more horizontal rosette structure. The differences in the habitus were obliterated in the course of summer.

Experiment 2 — seeding on June 2, July 12, August 3. The plants grew in the greenhouse, but a part was placed out of doors for a certain period (natural vernalization):

Combination A: natural vernalization from December 25 to January 25 (31 days),

Combination B: natural vernalization from February 4 to February 19 (15 days),

Combination C: the plants were transferred on March 4 to a vegetation house (out-door temperature conditions).

Age of plants at the moment of transfer for vernalization:

Seeding date	A	B	C
June 2	206	247	274
July 12	166	207	234
August 3	144	185	212

The mean number of leaves per 1 plant, from the successive dates of seeding, at the period of the autumn passing into "dormancy" were: 1 date — 17.3, 2 date — 17.4, 3 date — 11.5.

Table 2

Date of seeding	Time of vernalization	Date of observations and age of plants					
		June 30	July 17	Aug. 2	Aug. 21	Sept. 28	Total %
June 2	A	1	1	2	2	7	20
	B	5	6	6	7	8	80
	C	8	9	10			100
July 12	A	1	3	3	3	3	30
	B	8	9	9	9	9	90
	C	5	9	9	9	10	100
August 3	A	0	0	0	1	2	20
	B	7	7	8	8	9	90
	C	9	9	10	-	-	100

The results are summarized in Table 2.

The following conclusion may be advanced on the basis of the

observations of non-vernalized plants and of the results of both experiments:

1. Similarly as it was observed in many plants (Higazy 1962; Doorenbos and Wellensieck 1954; Napp-Zinn 1960) the ability of reaction to vernalization changes with the plant's age. Below a certain age (juvenile phase) the plant does not respond to the influence of lower temperatures, while above a certain age the reactivity is highest (> 150 days) and the differences between plants from various seeding dates become obliterate. The duration of the inactive juvenile phase is subject to wide individual variation, which is probably also the expression of population segregation. It is probable that the passing from the inactive juvenile phase to the phase of "maximum activity" does not occur abruptly, but there exists a post-juvenile phase in the course of which the perception of the temperature stimulus and thus the effectiveness of vernalization gradually increases and also the duration of vernalization exerts a positive effect.

2. The effect of vernalization shows, however, no direct dependence on its duration. The rapidity and frequency of passing to the generative phase, in the light of the results of Experiment 2, point to the rather complex character of the dependence between the plant's age, time and duration of vernalization, "physiological condition" of the plant and light conditions before, during and after vernalization.

The vernalization between December 25 and January 25 (A) though of longer standing (31 days) gave poor results, more or less equal in plants from all three seeding dates. It may be supposed that these plants were in their postjuvenile phase, growing before, however, in the period of weaning daylight they gradually passed to the phase of "minimum physiological activity", i.e. the phase of growth stagnation. The vernalization started at this period. The low accumulation level of "development activators" and low vernalization effectiveness would be due to this. Also devernalization of the plants could occur after transferring them to higher temperatures. This hypothesis was discussed in detail in the author's earlier paper (on the development of *Potentilla supina* — Listowski 1964).

In the second (B) and particularly in the third (C) period of vernalization the plants exposed to lower temperatures were not only a little older but already in the phase of increasing physiological activity owing to the rising light conditions. Consequently, the effectiveness of vernalization was higher in period "B" and still higher in period "C" manifested by the rapidity and uniformity of coming into flower.

3. Sporadic flowering was observed after several years in the non-vernalized series. It occurred at the time when most plants reached their "age limit" and died owing to the decay of the root neck. Analo-

gous phenomena occurred in many other plants. Assuming them to be "non-accidental" the authors postpone their discussion to the final general remarks.

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Obserwacje nad rozwojem roślin (X)

Streszczenie

Spośród badanych 26 gatunków dwu- i wieloletnich roślin u 5 nie obserwowano w ciągu okresu badań (2 do 6 lat) zakwitania, zaś u 6 gatunków rośliny bez jaryzacji zakwitały jedynie sporadycznie. Szczegółowo opisano rozwój *Tragopogon pratensis* — analizując zwłaszcza wpływ jaryzacji stosowanej w różnych terminach, przez różną ilość dni na rośliny w różnym wieku.

Stwierdzono występowanie inaktywnej fazy juvenilnej i przypuszczalnie fazy post-juvenilnej charakteryzującej się stopniowym nasilaniem się reaktywności rośliny.

Efekt jaryzacji nie koreluje się bezpośrednio z długością chłodzenia, ale wykazuje interakcję z wiekiem rośliny, jej stanem fizjologicznym i warunkami świetlnymi.