ACTA SOCIETATIS
BOTANICORUM POLONIAE
vol. XXXV — nr 3
1966

Further observations on the development of hibernating annual plants

(Observations on plant development. XIII.)

A. LISTOWSKI

In several earlier papers the authors reported a number of observations on a dozen facultative winter annuals, i.e. plants which, under natural conditions, germinate either in spring or in autumn and in the latter case hibernate in the form of rosettes. This group of plants is very common in our conditions. The 15 species earlier investigated may be regarded as facultative long day plants or as photoperiodically neutral with a more or less intensive retarding influence of short day, particularly in interaction with decreasing light conditions. The joint influence of short day and low light intensity causes that a number of these plants develop only a rosette in autumn, while other species having a lower critical limit of light quantity come into bloom oving to the fact that the growth and generative development may occur at a relatively wide temperature amplitude.

The following plants of this group were under observations:

Sisymbrium officinale (flowering from May to October in natural conditions), seeded in September and kept under continuous daylight developed rosettes with short-petiole leaves, smaller than those under short day; at the end of December (100 days) the plants developed stems and flowered profusely in April. Under short day budding and flowering started at more or less the same period. Thus the plant exhibited a very weak photoperiodical reaction.

Two species of genus *Melandrium* growing in Poland, i.e. *M. album* and *M. rubrum* exhibited different reactions.

Melandrium rubrum (flowering from May to September in natural conditions) seeded on August 29 — came into flower under long and continuous daylight and with some delay also under short day (see Table 1).

The next combination was sown at the end of January. The plants flowered after 65 days under L_{24} and after 197 days under S_8.

Melandrium album—comes into flower very rapidly under long and continuous daylight; when it was sown at the optimal date (May 26), the decrease of light intensity (by shading with cheesecloth. A. Listowski and J. Jackowska (1962) after noon accelerated flowering and increased the intensity of florescence. The development was rather intensively inhibited under short day. On the other hand when the plants were sown at the period of weaning daylight (autumn) the inhibition under short daylight was so strong that shoots with very short internodes and

many leaves developed as late as after 22 months. In late summer 1962 (more than 2 years after sprouting) 2 of 8 plants came into flower. In the course of the third year 2 further plants flowered, of the other plants 2 died and 2 remained at the stage of rosettes.

Table 1

The generative development of *Melandrium rubrum*

Combination	Budding		Full florescence	Number of leaves	Height	Other remarks
	beginning	general		in the phase of florescence		
L_{24}	67	77	92	23	38.9	Leaves visibly larger, lighter. Rapid growth of stem.
S_8	150	165	172	23	26.2	Leaves smaller, dark green, short petioles. Stems thicker. Height when coming into flower L_{24}—4.5 cm.

Mathon (1961) noticed that *Melandrium album* flowered without vernalization only in continuous day but after vernalization also sporadically in short day conditions (strain from environ of Poitiers, France).

Trifolium arvense. An interesting course of development was observed in *T. arvense.*

The plants in Experiment I were sown on August 25 (sprouted on September 22) and died in December after developing small rosettes.

The plants in the next experiment were sown on February 16 (sprouted on February 22).

L_{24} (continuous light) leaves erect, larger and lighter.

The stem extends between the 100—140th day after sprouting (June and July). The plants came into flower in July and simultaneously the rosette leaves withered.

To the beginning of September (190 days after sprouting) about 30 percent plants flowered
To the beginning of October (220 days after sprouting) about 40 percent plants flowered
To the beginning of November (252 days after sprouting) about 75 percent plants flowered
To the beginning of December (285) days after sprouting) about 90 percent plants flowered

Subsequently the plants withered and died.

S_8 (short eight-hours day) — small rosette with small leaves. Very slow growth of shoots of some plants — they did not flower till autumn and then the plants gradually died.

The next experiment was carried out on February 15 in order to establish the influence of vernalization perticularly in interaction with short day. A part of the plants underwent natural vernalization for 15 days beginning from March 4.

Experimental combinations:

nonvernalized: L_{24} (continuous light — natural day light+exposure to 6000—8000 Lux), S_8 (short day — 8 hrs — natural light), N — natural varying daylight.

Table 2

The development of *Trifolium arvense*

Date	Days after sprouting	N			L_{24}			$L_{24}(V)L_{24}$			$N(V)L_{24}$			$S(V)L_{24}$			S_8			$L_{24}(V)S$			N(V)S			S(V)S		
		a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
Apr. 25	62	0			35			30			14			60														
May 4	75	0			50	10	25	85	30	14	30			60														
May 12	79	20			50	40	50	100	70	60	100	15	15	100	100	60												
May 26	93	20			100	50	50	100	90	90	100	60	60	100	100	100												
June 5	104	45	10	20	mean number of shoots per plant (May 27)												10			10			0			25		
					1,1			4,1			3,3			3,6														
June 13	122	50	20	40													10			10			60			90		
June 19	128	50	40	40													10			60			80			90	10	
July 1	199	mean number of shoots June 5, 3,5															40			60			80			90	10	
July 9	147																50			75			90			90	10	
July 20	158																50			90			90			90	10	
August 6	175																80	0	50	100	0	80	100	0	50	100	10	60

a = percentage of plants with schoots
b = ,, ,, main apex transforming into stem
c = ,, ,, flowering plants

	mean number of shoots per plant			
June 9	4,1	7,0	5,4	8,8
August 6	4,0	7,4	6,6	9,4

vernalized: before vernalization L_{24}, S_8, N after vernalization L_{24} or S_8. The results are summarized in Table 2.

Similarly as in white clover (Thomas 1962; Ryńska 1962) the occurrence of axillary buds is the morphological index of generative induction.

The increase of growth rate of axillary shoots (longer internodes, more rapid growth), the increase in number of stems and capitula, their earlier blooming, more rapid dying of rosette leaves and finally the transformation of the main apex into a flowering stem are indices of the trend towards external conditions favorable to the generative processes. Under conditions, optimal as regards the intensiveness of generative processes, the rate of transformation of the main apex into the stalk was accelerated, whereas the growth of the main stem is more rapid than that of the lateral shoots. Under these conditions the rosette leaves died more rapidly. Also entire plants die frequently.

The daylength as well as the light intensity and vernalization were external factors accelerating and intensifying the generative development.

Taking into account the above-mentioned morphological indices as well as the uniformity of the plants development within a combination it becomes visible that the most considerable acceleration (i.e. $\pm$ optimal system) occurs under continuous daylight in interaction with vernalization then under the influence of continuous day without vernalization. When the inhibitory influence of the short day, however, is taken into account, then the highest acceleration as well as the highest effectiveness of vernalization occurred in the combination S_8 (vern) L_{24}.

Under short day the rosette stage is longer and the development of stems is retarded and their growth becomes slower. The uniformity of coming into flower and intensiveness of flowering were low. Also the period from budding to flowering was prolonged. The most pronounced inhibition occurred in control plants and it was weakest in the combination S_8 (vern) S_8.

In vernalized combinations the mean number of axillary shoots increased. On the other hand, the number of axillary shoots was higher under short day (S_8 and N at the beginning when the daylength is still relatively short). These stems are shorter, with shorter internodes, and a profusion of leaves, and grow slowly. Also Ryńska (1963) observed in *T. repens* a more intensive appearance of axillary shoots under short day, while their growth was inhibited.

Observations performed by other authors on various clover (*T. repens*, *T. pratensis*, *T. hybridum*, *T. subterraneum*) demonstrated similar interactions. All these species exhibit a positive reaction to long daylight and an inhibition of various intensiveness under short day. According to Haggar (1961) in wild white clover the most pronounced acceleration and highest intensiveness of florescence occurred under continuous daylight. A positive correlation occurs between the growth of stems and intensiveness of florescence (Stoddart 1953; Ryńska 1962; Aitken 1955; Evans 1955). In *T. repens*, Thomas (1962) observed coming into flower under S and L in interaction with vernalization whereas without vernalization flowering was weak under L and normal under varying daylength (initially S then L). Under S the plants did not come into flower. The intensifying influence of verna-

lization was observed in wild white clover (Haggar 1961) and in *Trifolium incarnatum* (Luciani, Gaillochet, Tomaselli, Mathon 1962).

The present observations allow to assume *T. arvense* as a "neutral" photoperodical plant with a pronouncedly intensifying influence of long and continuous day on the generative processes. Vernalization acts as a factor accelerating and intensifying the generative process, notwithstanding the daylength. Varying daylength is not the optimal condition. There occurs an outstanding correlation with the amount and, therefore, intensity of light. Under short day of low intensity the plants do not develop and die.

This influence of light intensity becomes particularly pronounced, when the behaviour of plants in experiment II and III sown at more or less the same time, is compared. The winter and spring period of 1963 had an exceptional number of cloudless days (also as compared with 1962), i.e. a larger amount of light. Owing to this wide differences occur between the plants development in both experiment, notwithstanding the daylength.

Differences in the rate of development of the plants under various combinations of external conditions analogously as in *T. pratense* (Stoddart 1963) may be explained by different levels of the synthesis of endogenous gibberellins.This synthesis exhibits a pronounced interaction with daylength, light intensity and vernalization.

The development of plants under natural conditions may be presented as follows: initial phases under weaning light conditions then winter „dormancy" and vernalization, and the further development in spring under rising daylight and increasing light intensity, thus its course is similar to the optimum, initially for the vegetative development and then for the generative development.

Institute of Soil Science
and Plant Cultivation
Puławy (Poland)

REFERENCES

Aitken Y., 1955, Austral. J. of Agric. Res. 16.
Evans I., 1950, Austral. J. of Agric. Res.10.
Haggar R. J., 1961, Nature 191, 4793.
Listowski A. i Jackowska I., 1961, Acta Soc. Bot. Pol. 30(3—4):269.
Listowski A. i Jackowska I., 1962, Acta Soc. Bot. Pol. 31(1):103.
Luciani F., Gaillochet J., Tomaselli R., Mathon C. C., 1962, Archiv. Botanico e Biogeografico Italiano 38.
Mathon C. C., 1961, Bull d. Mus. Nat. d'Hist. Naturelle 2 sèrie 33, 3.
Ryńska A., 1962, Genetica Polonica 1.
Stoddart I., 1959, Nature 184, 4685
Stoddart I., 1963, Nature 199, 4990.
Thomas R. G., 1962, Annals of Bot. NS. 26, 103.

XIII. Obserwacje nad rozwojem roślin zimujących

Streszczenie

W nawiązaniu do poprzednich obserwacji nad rozwojem różnych zimujących gatunków opisana jest reakcja dalszych roślin należących do tego samego typu ekologicznego — *Sisymbrium officinale*, *Melandrium album* i *M. rubrum* oraz *Trifolium arvense*. Ten ostatni gatunek daje się scharakteryzować jako fotoperiodycznie, neutralny, o ile chodzi o zakładanie się zawiązków pędów (indukcja generatywna), ale fakultatywnie długodniowy w odniesieniu do szybkości wzrostu pędów oraz formowania się i rozwijania organów generatywnych, mimo że na dniu krótkim ilość założonych związków pędów kwiatowych jest większa.

Jaryzacja jest czynnikiem przyspieszającym i intyfikującym kwitnienie zarówno na dniu ciągłym i długim, jak i krótkim.