

SEASONAL FLUCTUATIONS OF ORGANIC FOOD RESERVES IN UNDERGROUND PARTS OF *CIRSIIUM ARVENSE* (L.) SCOP. AND *TUSSILAGO FARFARA* L.

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SUMMARY

Seasonal fluctuations of dry matter, water soluble carbohydrates and total nitrogen content were traced in underground storage organs of *Cirsium arvense* and *Tussilago farfara*. Samples from experimentally planted monocultures of the two species were analysed.

Both species showed identical fluctuations in dry matter and carbohydrate contents. A gradual decrease in autumn and winter, succeeded by a rapid decline in spring, after a distinct minimum in April-May was followed by a steep rise towards a maximum in late summer. Fluctuations seem to be affected by weather conditions during the growing season.

The nitrogen content decreased gradually from early spring until the middle of the summer and then increased similarly until the start of the cycle.

1. INTRODUCTION

In the newly reclaimed Zuiderzee polders *Cirsium arvense* and still more *Tussilago farfara* are the most troublesome perennial weeds. Within the scope of control experiments underground storage organs from undisturbed monocultures were sampled and analysed throughout the year, which offered the opportunity to use the data obtained for a study of seasonal fluctuations of the analysed substances.

Cirsium arvense is a root geophyte. Growth and life-cycle of this species has been extensively described by DETMERS (1927), BAKKER (1960), and SAGAR & RAWSON (1965). Thickened roots, growing horizontally in different soil levels, serve both vegetative reproduction and storage of food reserves. From these roots leaf rosettes emerge in spring, predominantly in March. Towards the end of April most of these rosettes develop leafy stems on which inflorescence buds appear in May. The first buds open at the onset of June. During bloom the entire old lateral root system or part of it dies back and new thickened horizontal roots are formed. In the autumn all aerial parts die and only the roots survive winter.

ROGERS (1925), investigating dry matter, ash and carbohydrate contents in the roots of *Cirsium arvense* in Iowa, found that the total carbohydrate content is lowest during the latter part of June, at the onset of flowering. WELTON *et al.* (1929) investigated fluctuations in dry matter, carbohydrates, and total nitrogen in the roots of *Cirsium arvense* in Ohio. They found a gradual decrease of all three during the early part of the growing season, a dry matter and carbohydrate

minimum in June, and a nitrogen minimum in July, at full bloom. Then the reserves gradually increased until the end of the season. Similar results were obtained by ARNY (1932) in Minnesota, except for the carbohydrates at full bloom occurring in the first part of July.

Growth and life-cycle of the rhizome geophyte *Tussilago farfara* have been described extensively by BAKKER (1951, 1960). Horizontally growing rhizomes have the same function as lateral roots of *Cirsium arvense*. From their rhizomes leaf rosettes emerge in March and April. In August inflorescence buds are formed in the leaf axils. These buds give rise to solitary flower heads in February-March. As a rule all aerial parts die in the winter. BAKKER (1951), investigating fluctuations in water soluble carbohydrate content of the rhizomes, established a decrease from October to May and an increase from May to October.

Fluctuations in organic reserves, described in papers cited above, refer to spontaneously occurring stands of the weeds. This may have resulted in relatively large sampling errors and a variation that is difficult to interpret. As an alternative the opportunity arose to trace variations in organic food reserves of subterranean parts, sampled from experimental fields of *Cirsium arvense* and *Tussilago farfara*. Some of the results have already been published by BAKKER (1960). The most striking features of the presented carbohydrate cycles are the very early minima, occurring in late April, and the striking similarity between the two investigated species. These findings might indicate that climatic conditions are largely responsible for the fluctuations in subterranean carbohydrate content of geophytes. Lower latitudes and more pronounced continental climates of the investigated North American habitats of *Cirsium arvense* are regarded as determining the typical carbohydrate cycle of these populations. In this connection ARNY (1932) reported that in Minnesota *Cirsium arvense* emerges in April/May, whereas in the Netherlands the plant appears in March.

Investigations of other species also demonstrate the importance of climatic effects. STAESCHE (1966, 1967), investigating seasonal fluctuations in root carbohydrate contents of *Symphytum officinale* in South-West Germany, found fluctuations very similar to those in *Cirsium arvense* reported by BAKKER (1960). There was a distinct minimum towards late April and a pronounced influence of day-length.

MOONEY & BILLINGS (1965), who studied carbohydrate reserves of mountain plants, found a number of these to exhibit more rapid depletions of stored carbohydrates when transplanted to lower altitudes where temperatures were higher. On the other hand, populations of the same species growing naturally at lower altitudes showed higher carbohydrate contents at the same stage of development. They concluded that the pattern of depletion and storage of carbohydrates forms part of the ecotypic or ecocline adaptation. HADLEY & BLISS (1964) recorded energy reserves as well as rates of photosynthesis and respiration of different alpine tundra plants and found that most of the species had their light compensation and saturation points, their respiratory and photo-

synthetic rates, and their optimal temperatures for net photosynthesis well adapted to the severe climate.

As may be deduced from the above, carbohydrate metabolism plays an important part in the adaptation of perennial plants to climatic conditions. As demonstrated by MOONEY & BILLINGS (1965), genetic adaptation may be of importance. Still, plants must also possess a certain plasticity as expressed by their response to vagaries of the weather. Data obtained in this five-years study of two perennial species present a solid basis to prove this assumption.

2. MATERIAL AND PREPARATION OF SAMPLES

Both species were established in trial fields on different soils dredged from the future polder "Oostelijk Flevoland" in 1954. Specimens of *Cirsium arvense* with lateral roots were planted on a clay loam in the springs of 1957, 1958, 1959, and 1960. In order to avoid seed dispersal only plants of male clones were used. Rhizomes of *Tussilago farfara* were planted on sandy soil in the spring of 1957.

At regular intervals approximately 200 grams of roots or rhizomes were sampled, each time in previously undisturbed plots. Fresh samples were washed and surface dried with hot air on sheets of blotting paper. Directly afterwards the samples were cut into inch length pieces and dried in a ventilator oven for seven hours at 70°C, followed by one hour at 105°C. Dry matter contents were calculated from weights taken before and after oven drying. Final grinding to < 0.5 mm took place in a hammer mill.

3. ANALYTICAL METHODS

Following BOSMAN (1953), simple sugars were Soxhlet extracted with 90% ethyl alcohol. After the removal of alcohol by vacuum distillation and clearing with neutral lead acetate (DE MAN & DE HEUS 1949), part of the extract was used for the determination of reducing sugars. In another part non-reducing sugars were hydrolyzed by boiling with 0.05 n sulfuric acid (DE MAN & DE HEUS 1949).

Polysaccharids were determined in a simple hot water extract of the residue, as previously filtered, cleared and boiled with 0,05 n sulfuric acid.

Total water soluble carbohydrates were determined in a straight hot water extract, filtered, cleared and hydrolyzed.

All sugar analyses were performed by means of a copper reduction method (according to VAN DER PLANK 1936). Glucose solutions served as a standard and all values were expressed as glucose-equivalents in percentages of fresh material.

No attempts were made to estimate water-insoluble carbohydrates. Qualitative tests proved the absence of starch. These findings agree with those of COLIN (1925) and HEGNAUER (1964) who, with reference to *Compositae*, reported fructosans to be of regular and starch of exceptional occurrence as storage forms.

Total nitrogen analyses were carried out with a modified Kjeldahl technique

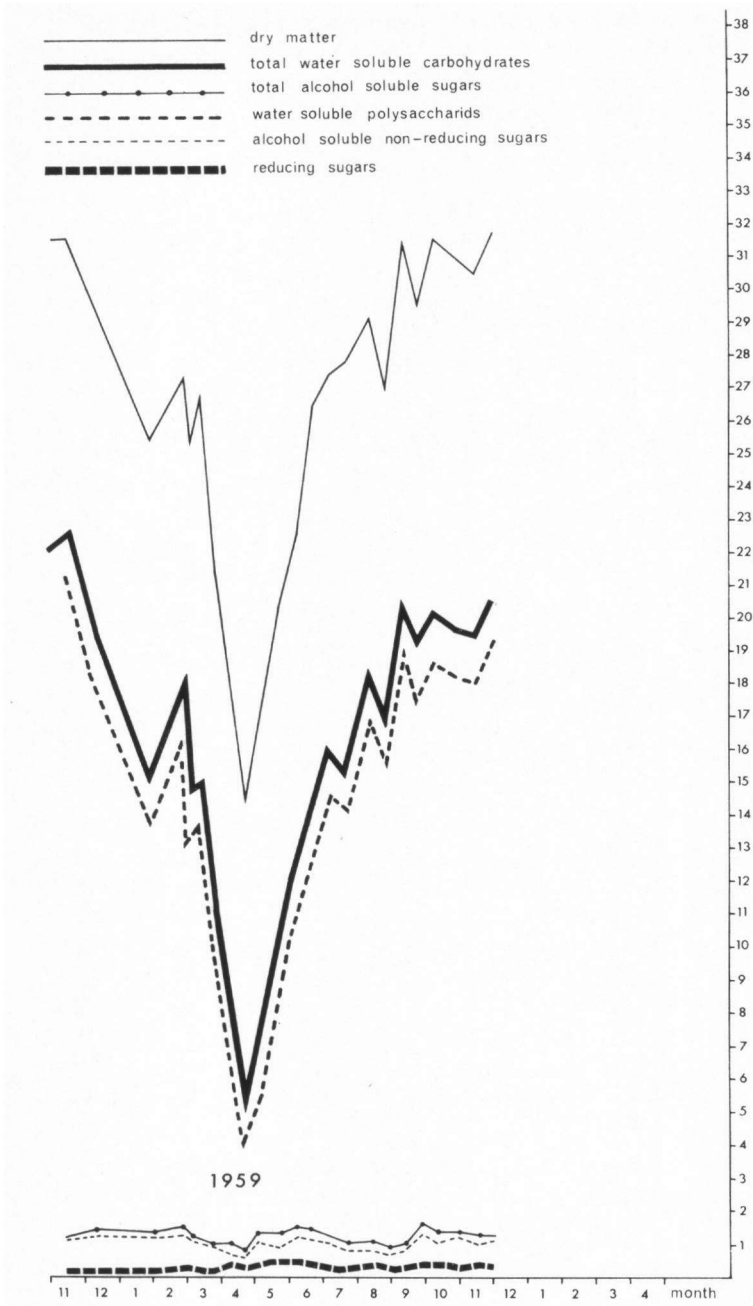


Fig. 1. Dry matter and water soluble carbohydrate contents in underground storage organs of 1957 planted *Cirsium arvense*, percentages of fresh weight.

(WIENINGER 1936). N-percentages were multiplied by the conventional factor 6.25, for conversion to "crude-protein". The conversion was made to permit simultaneous graphic representation with dry matter and carbohydrate contents. It does not imply an opinion on the physiological value of "crude-protein".

4. RESULTS

Time fluctuations of dry matter, total water soluble carbohydrates, and crude-protein contents in underground storage organs of *Cirsium arvense* and *Tussilago farfara* are summarized in fig. 2. For *Cirsium arvense* they represent mean values related to thistle stands planted in different years. As no significant differences could be observed between values related to stands of different ages, it would appear superfluous to present all individual data.

Most thistle samples were analysed for alcohol soluble reducing and non-reducing sugars and also for water soluble polysaccharids. As this grouping of sugars yielded little more information, separate presentation is given only for one growing-season in fig. 1.

Dry matter and soluble carbohydrate contents show a gradual decrease in autumn and winter, followed by a rapid increase in spring. After a distinct minimum in April-May values increased rapidly until late summer; they were not significantly interrupted by the generative maturity phase of *Cirsium arvense*. Only in the case of the exceptionally warm and dry summer and autumn of 1959 the rapid rise stopped in July and was followed by a gradual increase until October; dry soil in summer and favourable conditions for growth and photosynthesis in autumn may have caused this aberration.

Carbohydrate minima in the roots of *Cirsium arvense* appeared on dates between April 21 and May 24. Dates for the opening of the first inflorescence buds of this species varied between June 6 and June 27. Fluctuations in stored carbohydrates appear to be more influenced by weather than the time of flowering.

Table 1. Temperature deviations from long term means for March, April, May and June, recorded by the Royal Meteorological Institute, De Bilt, and carbohydrate minima at the onset of flowering.

Year	Deviation in °C from long term means, all recorded at De Bilt				Date of carbohydrate minimum in the roots of <i>Cirsium arvense</i>	Appearance date of first flowers	Days between carbohydrate minimum and onset of flowering
	March	April	May	June			
1958	-2.0	-2.0	-0.4	-0.9	May 18	June 18	31
1959	+2.0	+1.5	+0.6	+0.7	April 21	June 6	45
1960	+0.7	+0.6	+0.3	+0.8	April 24	June 12	49
1961	+2.2	+1.9	-1.7	-0.3	May 1	June 15	45
1962	-3.3	-0.4	-2.4	-2.2	May 24	June 27	34

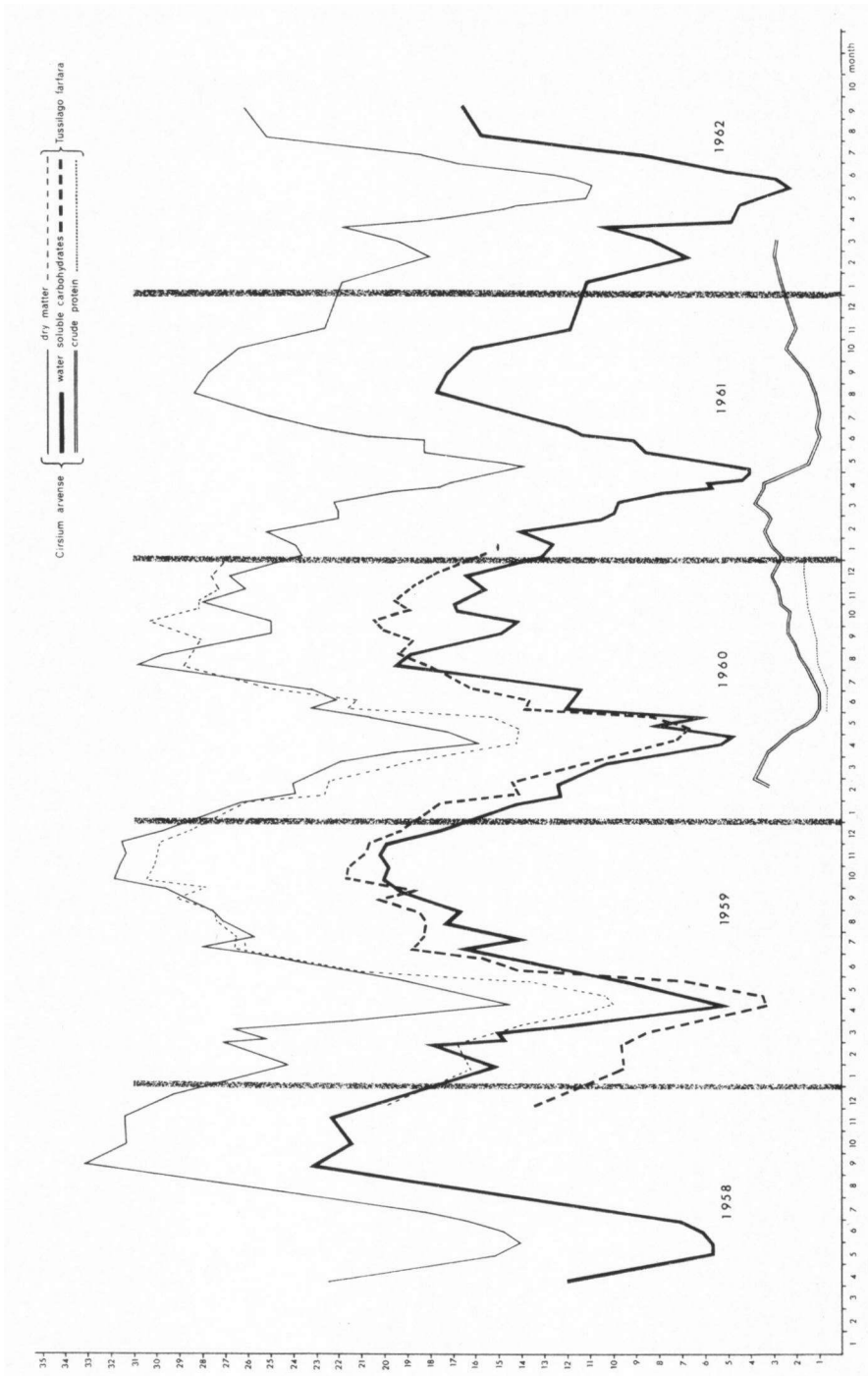


Fig. 2. Dry matter, water soluble carbohydrates, and crude protein contents in underground storage organs of *Cirsium arvense* and *Tussilago farfara*, percentages of fresh weight.

For *Cirsium arvense* the time interval between carbohydrate minimum and first flowering appears shortened by a cold spring. Considering this the different time intervals reported by other authors can with reasonable probability be ascribed to deviating climatic conditions.

The striking similarity and synchronism between carbohydrate cycli of the two investigated species, as already reported by BAKKER (1960), seem to be generally valid. For two years the cycli appeared as duplicates of each other. This similarity between species differing in their generative cycli gives further support to the thesis that atmospheric conditions are of prime importance in shaping the carbohydrate fluctuations.

Though only estimated in part of the samples, the crude protein content shows similar changes, but with a remarkable phase-shift. Nitrogen is accumulated during the entire period from flowering in June to early spring, whereas carbohydrates begin to decrease already following die-off in autumn. In both species decrease after early spring maxima leads to ill defined minima round July. The absence of distinct minima might be explained by shortage of available nitrogen as a growth limiting factor. Doubt may be cast on the significance of increase in crude protein content based on fresh weight during the winter. This might be simulated by a decrease in dry matter caused by metabolic loss of carbohydrates. In order to test this hypothesis nitrogen contents expressed as percentages of fresh weight were compared with percentages computed on the basis of dry matter minus TWSC (total water soluble carbohydrates). For *Cirsium arvense* planted in 1957 correlation coefficients computed for the period 5/9/60–29/3/61 are given in table 2.

Table 2. Correlation coefficients (r).

	r
between N in % of fresh weight and time	0.878
between N in % of dry matter minus TWSC and time	0.826
between dry matter in % of fresh weight and N in % of fresh weight	-0.495

The data suggest that increase in nitrogen content based on fresh weight may be explained only partially by simultaneous decrease of dry matter.

Fig. 1 and 2 show that time-consuming carbohydrate analyses give little more information on organic food reserves than can be obtained from simple estimations of dry matter content. Consequently only the latter is required, if desired with supplementary and occasional sugar analysis, if and when expense or time are limiting factors in research.

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