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A COMPARISON OF THE PRODUCTION OF THE GROUND FLORA AND OF THE RATE OF ORGANIC FALL IN TWO AREAS OF THE ASSOCIATION *CIRCAEO-ALNETUM* OBERD., 1953, IN THE BIAŁOWIEŻA NATIONAL PARK*

ABSTRACT: In the Białowieża National Park a study has been carried out to determine the annual net production of the ground flora in two different areas of the association *Circaeo-Alnetum* Oberd.,1953, and the amount of organic fall accumulated during a three-year period. The value of the annual production of the ground flora in the area typical of the association was estimated at 1075 kg/ha, and the average amount of fall – at 4386 kg/ha. In the typical area of the association the ratio between the value of the fall and the production of the ground flora was 4.1, and in the degraded-association area – 1.9. The fall of seeds and woody parts was found to vary considerably from year to year, whereas the variation of the remaining fractions of the organic fall was much smaller. During a year in the association studied the total amount of matter, from the ground flora and the organic fall, returned to the soil is almost 5000 kg/ha.

Contents

*The study was carried out at the Institute of Forest and Wood Protection, Warsaw Agricultural University, and at the Mammals Research Institute, Polish Academy of Sciences, Białowieża, in continuation of the research work under the International Biological Programme.

1. INTRODUCTION

The International Biological Programme has contributed to the intensification of studies on the productivity of various ecosystems and among them also forest ecosystems. As regards forest communities, the object of analyses was, apart from the basic product, i.e., wood, also the production of other elements. Wood production has for a long time been studied by foresters using methods which they developed themselves, whereas the remaining elements, being less important economically, are usually studied by biologists who are concerned primarily with the analysis of the production of the ground flora and the organic fall, and to a lesser extent of the production of the root systems. In general, the production of the thallophytes has not so far been the object of a detailed study. Both the root systems and the thallophytes require more difficult methods, and are less important economically than the above-ground parts of higher plants.

Some of the above-ground production is directly utilised by man, the remainder providing food for the herbivores, or being returned to the soil through the reducer level.

Ground flora production has already been studied in many forest associations, and so has the organic fall. The following papers concerned with forests in Poland contain detailed analyses of the primary production of the ground flora, and of the organic fall: Rajchel (1965), Kaźmierczakowa (1967, 1971), H. Traczyk and T. Traczyk (1967), T. Traczyk (1967a), Aulak (1970), Dzięciołowski (1970), Moszyńska (1970), Plewczyńska (1970) and Wójcik (1970). The above-named papers contain data obtained by using various methods in studies carried out in different areas of Poland, in various communities, and in different years. The results are not, therefore, comparable, and besides, they contain errors of the methods used. Thus what can be found in them is in essence the range of production values for various forest ecosystems.

In spite of this the data contained in the above-mentioned studies makes it possible to find considerable differences in the primary production of the ground flora between individual associations and also, in several cases, in the production of different areas within the same association. And as a rule the richer the habitat, the higher the productivity.

The present study is based on the materials collected from two areas of the association *Circaeo-Alnetum* Oberd., 1953, in the Białowieża National Park. In one of the areas concerned a typically-formed association was found, whereas in the other area certain deformities could be seen such as a lower density and younger age of the tree stand, and a higher water content in the soil.

2. STUDY AREA AND METHODS

Simultaneously with the investigations aggregations of small terrestrial mammals, mainly *Rodentia* and *Insectivora*, were analysed over an area of about 6 ha. The study area was set up in Compartment No. 398 of the Białowieża National Park. As the association under study is a stream-side community and it is difficult to find such large homogeneous area, it was necessary to include in the study area a typical part ($C\text{–}A_t$) and

Tab. I. Floristic description of the areas of the association under study

Designation of the area		Typical $C\text{–}A_t$			Degraded $C\text{–}A_d$		
Phase		Optimum			Regenerative		
No. of phytocenological record		1	2	3	4	5	6
Cover in per cent	a	80	80	80	60	60	60
	a_1	70	80	60	60	60	60
	a_2	30	40	50	10	10	10
	b	40	40	30	10	10	+
	c	100	100	100	100	100	100
	d	50	+	50	60	80	70
Record surface area in m^2		200	200	200	200	200	200
Number of species		49	44	37	36	40	42
Alnus glutinosa	a	3.3	3.4	3.3	2.2	2.2	4.4
	b	.	.	1.2	1.1	1.1	1.1
	c	.	.	+	.	.	.
Fraxinus excelsior	a	3.3	2.2	2.1	.	.	.
	b	1.1	+	1.1	+	+	.
	c	+	+	+	+	+	+
Picea excelsa	a	2.2	3.3	3.4	1.1	1.1	1.1
	b	1.1	.	+	1.2	1.1	+
	c	+	.	.	+	.	.
Tilia cordata	a	1.1	.	3.2	.	.	.
	b	+2	.	2.2	.	.	.
Ulmus laevis	a	1.1	.	.	.	.	.
Ulmus scabra	b	1.1	.	.	.	.	.
Sorbus aucuparia	b	+	(+)	1.1	.	.	.
	c	+	.	+	.	.	.
Acer platanoides	a		+		.	.	.
	b		+		.	.	.
Padus avium	b	.	1.2	.	.	.	.
	c	.	+	.	.	.	.
Quercus robur	c	.	+	.	.	+	.
Pinus silvestris	a	.	.	.	1.1	.	.
Salix caprea	a	.	.	.	.	1.1	.
Betula pubescens	a	.	.	.	3.4	4.4	2.2
	b	.	.	.	+	+	+
Characteristic species of the association *Circaeo-Alnetum* and of the *Alno-Padion* alliance							
Chaerophyllum hirsutum		2.2	1.2	2.2	1.1	2.2	+2
Chrysosplenium alternifolium		3.4	2.2	1.2	3.4	2.4	2.4
Poa remota		+2	+2	+2	+2	+2	+2
Festuca gigantea		1.2	+2	1.2	.	+2	.
Circaea lutetiana		(+)	.	1.2	.	+	.
Carex remota		+2	.	+	.	+2	.
Mnium undulatum		1.3	.	3.4	.	+2	.
Equisetum silvaticum		+2	.	+	.	.	.
Circaea alpina		+2	.	+2	.	.	.

Tab. I (contd)

No. of phytocenological record		1	2	3	4	5	6
Characteristic species of the order *Fagetalia* and of class *Querco-Fagetea*							
Ribes schlechtendalii		1.2	+2	1.1	+2	.	.
Stellaria nemorum		2.2	2.2	3.4	.	.	2.3
Dryopteris filix-mas		.	+2	.	.	.	+2
Corylus avellana	b	3.3	3.3	2.2	.	.	.
	c	+2	.	.	.	.	.
Millium effusum		+2	+2	1.2	.	.	.
Viburnum opulus	b	+	1.2	.	.	.	.
	c	+2	+2	.	.	.	.
Evonymus europaea	b	+	.	.	.	.	.
	c	+2	+2	.	.	.	.
Aegopodium podagraria		1.2	1.2	.	.	.	.
Brachypodium silvaticum		+2	+2	.	.	.	.
Ranunculus lanuginosus		+	+	.	.	.	.
Paris quadrifolia		+	+	.	.	.	.
Aruncus silvester		1.1	(+)	.	.	.	.
Asperula odorata		+2	2.2	.	.	.	.
Mercurialis perennis		+2	.	.	.	.	.
Lathyrus vernus		+	.	.	.	.	.
Galeobdolon luteum		.	3.4	2.3	.	.	.
Asarum europaeum		.	2.3	.	.	.	.
Platanthera bifolia		.	.	+	.	.	.
Polygonatum multiflorum		.	.	.	.	+	.
Impatiens noli-tangere		.	.	.	.	.	+
Differential species							
Dryopteris thelypteris		.	.	.	+2	+2	+2
Dryopteris austriaca		.	.	.	+2	+2	+2
Climatium dendroides		.	.	.	+2	+3	+2
Phragmites communis		.	.	.	3.3	+2	1.2
Carex acutiformis		.	.	.	1.2	1.2	2.3
Carex paniculata		.	.	.	+2	+2	+2
Lythrum salicaria		.	.	.	+	+	+
Lychnis flos-cuculi		.	.	.	+	+	+
Lycopus europaeus		.	.	.	+2	.	+2
Scirpus silvaticus		.	.	.	.	+2	+2
Accompanying species							
Urtica dioica		3.4	3.4	3.4	3.4	4.4	3.4
Cardamine amara		1.2	+2	1.2	1.3	1.2	1.2
Cirsium oleraceum		+	1.1	1.1	2.2	2.2	2.2
Dryopteris spinulosa		+2	+2	+2	+2	+2	+2
Athyrium filix-femina		+2	+2	1.2	+2	1.2	1.2
Geranium robertianum		+2	+2	+2	1.3	+2	1.3
Lysimachia vulgaris		+	(+)	+	+	+	+
Eurhynchium swartzii		3.4	+2	+2	.	2.3	2.3
Filipendula ulmaria		.	(+)	+	1.2	1.1	+
Poa trivialis		+2	.	+2	+2	+2	+3

Tab. I. (contd)

No. of phytocenological record	1	2	3	4	5	6
Deschampsia caespitosa	+2	.	.	+2	+2	+2
Solanum dulcamara	.	.	+	+	+	1.2
Myosotis palustris	.	.	+	+	+	+
Galium palustre ssp. *elongatum*	.	.	+	1.3	+2	1.3
Scutellaria galericulata	.	.	+	+	+2	+
Ranunculus repens	.	.	+2	+2	.	+2
Ribes nigrum	1.1	1.2	.	.	+	+2
Brachythecium sp.	.	+2	+2	+2	.	.
Rubus idaeus	+2	.	+2	.	.	.
Mnium sp.	+3	.	.	.	1.2	.
Moehringia trinervia	+2	.	.	.	.	+
Calamagrostis canescens	.	.	+2	.	.	+
Polygonum mite	.	.	+	.	.	+
Geum rivale	1.2	+	1.2	.	.	.
Oxalis acetosella	2.3	+2	1.3	.	.	.

Sporadic species

No. 1: *Luzula pilosa* +, *Sambucus racemosa* b +, *Taraxacum officinale* juv. +; No. 2: *Galeopsis tetrahit* +; No. 4: *Peucedanum palustre* +, *Sphagnum palustre* +; No. 6: *Galium aparine* 3.4, *Equisetum palustre* +.

a part which appeared to be somewhat deformed ($C\text{–}A_d$). The analysis of the ground flora production and of the organic fall was carried out in each of the two areas separately, but using the same method in both cases.

A floristic description of the two areas considered has been given in Table I.

The value of production was only assessed in 1967, using Traczyk's (1967b) *DG* method in which the density (*D*) and the average individual production (*G*) are analysed separately for the population of each species. The value of the production of a population is $P = D \times G$.

In both facies of the association the density was determined from 100 samples, each of 0.1 m^2. In addition to these, for the ferns and rare species 15 samples, each of 25 m^2, had been set up. A detailed description can be found in the paper by Aulak (1970), where also a detailed analysis of the ground flora production is given for a typical area of this association. For this reason in the present paper only the differences between the two areas are pointed out in the analysis of the ground flora production, without an analysis of density, or any other concomitant parameters.

The organic fall was studied over a period of three years, from August 1, 1967, until July 31, 1970. Over the entire area 50 organic fall catchers, each of 0.1 m^2 in surface area, were put up at random (along transect lines). Each of the catchers had a fairly deep collecting-bag to prevent the blowing-out of the fall by wind. The catching surface was placed about 1 m above ground. According to Andrzejewski, Borowski and Olszewski (1968), the surface of a catcher is in essence sufficient for the determination of the amount of organic fall. Of the 50 catchers 30 were placed in the typical area ($C\text{–}A_t$), and 20 in the deformed area ($C\text{–}A_d$).

For the first two years fall was removed every 10 days, and in the third year the material was removed at irregular intervals.

The material collected at one time from all the catchers in a given area was regarded to be one aggregate sample. The material was divided into the following fractions: seeds (according to species), coniferous litter, leaf-litter, other parts of plant (inflorescences, bud scales, etc.), and woody parts (twigs, bark, etc.).

Subsequently, the material was dried until the constant-weight state was reached (in an electric oven), and then weight was determined with an accuracy to the nearest 1 mg – for seeds, and to the nearest 10 mg – for the remaining fractions.

There were basically two reasons for continuing the study of the organic fall for three years. The first reason was a considerable variability of production, over several-year cycles, of some of the elements of the fall (seeds), the second – a prolonged production of some of the seeds, coniferous litter, etc. It is for this reason that an average for three years was adopted as the annual amount of fall.

As the characteristic values of the association, both in respect of the ground flora production and the amount of organic fall, the data for the typical part ($C–A_t$) were adopted. Values obtained for the defermed area of the association were considered to be one of the possible variants within the range of variation of on the association *Circaeo-Alnetum.*

3. GROUND FLORA PRODUCTION

The method used analyses the production of the population of each species separately. The time of collecting samples for the unit weight (average individual production) was

Tab. II. Ground flora production in two areas of the association

Species	$C–A_t$		$C–A_d$	
	mg/m^2	%	mg/m^2	%
Urtica dioica	45,325.6	42.18	132,108.0	75.03
Impatiens noli-tangere	16,577.4	15.43	940.3	0.53
Chaerophyllum hirsutum	12,351.0	11.49	2,074.0	0.61
Cirsium oleraceum	4,294.8	4.00	9,816.0	5.57
Stellaria nemorum	3,973.4	3.70	–	–
Circaea lutetiana	3,668.2	3.41	–	–
Chrysosplenium alternifolium	3,265.4	3.04	2,256.2	1.28
Aegopodium podagraria	3,075.0	2.86	–	–
Geum urbanum	1,926.6	1.79	4,001.4	2.27
Crepis palludosa	1,492.1	1.39	555.2	0.32
Geranium robertianum	1,358.0	1.26	1,829.1	1.04
Ranunculus lanuginosus	1,331.0	1.24	–	–
Caltha palustris	1,271.4	1.18	172.4	0.10
Circaea alpina	1,198.1	1.11	284.0	0.16
Lysimachia vulgaris	202.2	0.19	3,033.8	1.72
Myosotis palustris	9.0	0.01	1,723.3	0.98
Dryopteris thelypteris			2,016.7	1.14
Graminae	299.8	0.28	6,824.0	3.88
Cyperaceae	–	–	7,302.0	4.15
Other species	5,838.2	5.44	2,139.3	1.22
Total	107,457.2	100.00	176,075.7	100.00

different for each species, in accordance with the assumptions of the method that the highest average individual weight is found in the period between mass-flowering and fructification.

The results of the analysis of the production of the ground flora are contained in Table II. The species are arranged in order of descending contribution to the production of the typical area; *Graminae* and *Cyperceae* have not been split up into species.

The production of the ground flora in the deformed part ($C–A_d$) exceeds that in the typical part ($C–A_t$) by about 64%. This is no doubt due to a higher supply of solar energy to the forest floor, and a higher soil moisture. Different too is the species structure of production, in both absolute values and percentages.

In both areas the absolute dominant species was *Urtica dioica*[1], with its absolute production in the deformed part being almost three times that in the typical part. In $C–A_d$ *Urtica dioica* represents over 75% of the total production of the ground flora, that is, more than the same species together with two subdominant species in $C–A_t$ (Tab. II). In this case the percentage of *Urtica dioica* in the deformed part does not confirm the known regularity relating to the number and contribution of species in various ecosystems depending on the fertility of the habitat. While one would rather expect that with such a high productivity of a ground flora, indicating a high fertility of the habitat, there should not be a superdominant species, and there should thus be more species with a similar contribution to the production, the relations in the deformed area resemble a percentage-distribution of a poor community with one superdominant species and a low percentage of other species.

In the area under study there existed particularly favourable conditions for *Urtica dioica*. Its production was higher than the total production of all species in the typical area.

The production of the remaining species in the two areas studied appeared to be higher in $C–A_t$ (about 1.4). Thus the higher total production of the deformed part is the result of the dominance of *Urtica dioica*.

The analysis of the production of the remainder of species revealed certain regularities, namely in $C–A_d$ the lack is noted of those species whose ecological range extends rather towards the *Tilio-Carpinetum* association (*Stellaria nemorum*, *Aegopodium podagraria*, *Renunculus lanuginosus*). These species occur there sporadically, but they had not been represented in the 100 samples analysed.

A much higher production was recorded for species with a higher preference of moist habitats (*Cirsium oleraceum*, *Geum urbanum*, *Lysimachia vulgaris*, *Myosotis palustris*, *Dryopteris thelypteris*). A high percentage was also recorded for *Cyperaceae* and *Graminae* whose joint production was higher than that of *Chaerophyllum hirsutum* in $C–A_t$, that is, the third species in respect of production value in the typical area. The high proportion of *Cyperaceae* is accounted for by the presence in the deformed part of temporary bodies of ponded-back water.

The production of the ground flora in these two areas ($C–A_t$ = 1075 kg/ha and $C–A_d$ = 1761 kg/ha) is fairly high, and it considerably exceeds the production of the ecosystems in coniferous-forest and mixed-forest habitats.

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[1] The plant species names are given after Szafer, Kulczyński, and Pawłowski (1953).

4. THE RATE OF ORGANIC FALL

Table III shows the average rate of organic fall for a three-year period, according to fractions. The rate of organic fall in the two areas considered appears to differ clearly both in respect of the absolute values and percentages.

Tab. III. Average annual amount of the organic fall in two areas of the association

Fraction		$C–A_t$		$C–A_d$		$C–A_t/C–A_d$
		mg/m²	%	mg/m²	%	
Total		438,572.5	100.00	343,148.1	100.00	1.28
Coniferous litter		85,890.0	19.58	42,180.0	12.29	2.03
Leaf-litter		211,960.0	48.33	213,153.3	62.11	0.99
Other plant parts		63,902.2	14.57	51,800.0	15.10	1.23
Woody parts		67,703.3	15.44	32,071.7	9.35	2.12
Seeds		9,117.0	2.08	3,943.1	1.15	1.64
including seeds of:	*Betula*	169.9		428.3		0.40
	Alnus	1,823.6		2,097.7		0.87
	Fraxinus	7,041.0		1,153.0		6.11
	Carpinus	47.7		227.3		0.21
	Tilia	2.9		–		–
	Ulmus	10.1		–		–
	Acer	–		36.8		–
	Picea	21.8		–		–

Apart from the coniferous litter, the fall of which is slightly larger in the deformed part than in the typical part, all other fractions show a clear quantitative predominance in the typical marsh forest.

In both facies leaf-litter prevails in the fall. This is understandable, because the tree stand of a marsh forest association is made up mainly of broad-leaved species.

The lowest percentage in the organic fall is recorded for the seeds. The heavy-seed species of such genera as *Quercus* or *Fagus* are absent. The considerably larger proportion of this fraction in the typical part is accounted for by the fall of *Fraxinus* seeds. In either facies seeds of *Fraxinus*, *Alnus* and *Betula* represent above 90% of the total fall of seeds.

In the structure of the organic fall a clearly larger proportion of coniferous litter can be seen in $C–A_t$ than in $C–A_d$. This is due to the larger proportion of *Picea* in the stand of the typical part of the association. In absolute values the fall of *Picea* needles there is more than twice greater than in the deformed part.

The two parts of the association do not differ considerably in respect of the percentage of the other parts of plants, although in absolute values the fall rate appears to be greater in the typical part.

The much lower contribution of woody parts in $C–A_d$, both in percentages and in absolute values, is due to a lower contribution of old trees some of which die and lose branches and boughs. In the typical part the catchers were found to contain not only fine twigs, but also remnants of wood and bark from the trees that were falling out of the stand.

The rate of the organic fall per 1 ha was in $C\text{–}A_t$ about 4386 kg and in $C\text{–}A_d$ – about 3431 kg.

The analysis of the fall over a three-year cycle (Fig. 1) shows clearly that it is wrong to assess organic fall on the basis of data for one year. Over the three-year period the fall appeared to vary from year to year, being the highest in the first year of study and the lowest in the third year. Both areas of the association showed a similar variation in the rate of organic fall.

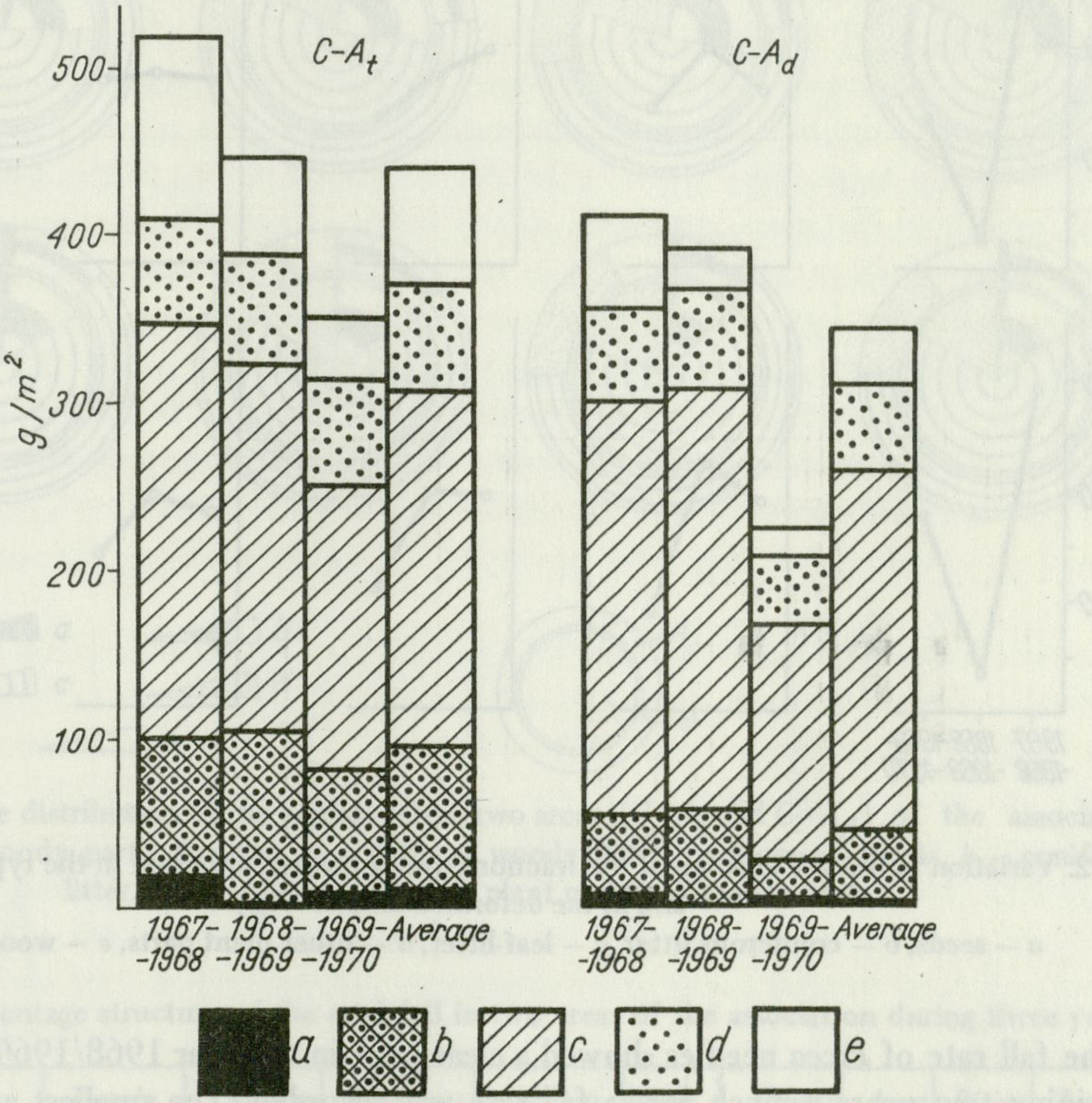

Fig. 1. The rate or organic fall over a three-year cycle in the typical area ($C\text{–}A_t$) and in the deformed area ($C\text{–}A_d$)
a – seeds, *b* – coniferous litter, *c* – leaf-litter, *d* – other parts of plants, *e* – woody parts

An analysis was carried out of the variation of the fall rate of individual fractions over the three-year period (Fig. 2) in both the areas considered. The course of the curves for individual fractions is in essence similar in the two areas. The only exception is the leaf-litter of 1968/1969 which showed a slight increase in the deformed part, relative to the typical part in which a decrease was recorded, as compared with the year 1967/1968.

In the year 1968/1969 the seed crop appeared to be poor, and as a result a strong decrease occurred in both areas.

The other fractions (inflorescences, bud scales, etc.) showed a slight variation from year to year, the maximum value having been recorded for the second year of study, whereas the remaining fractions were found to differ significantly.

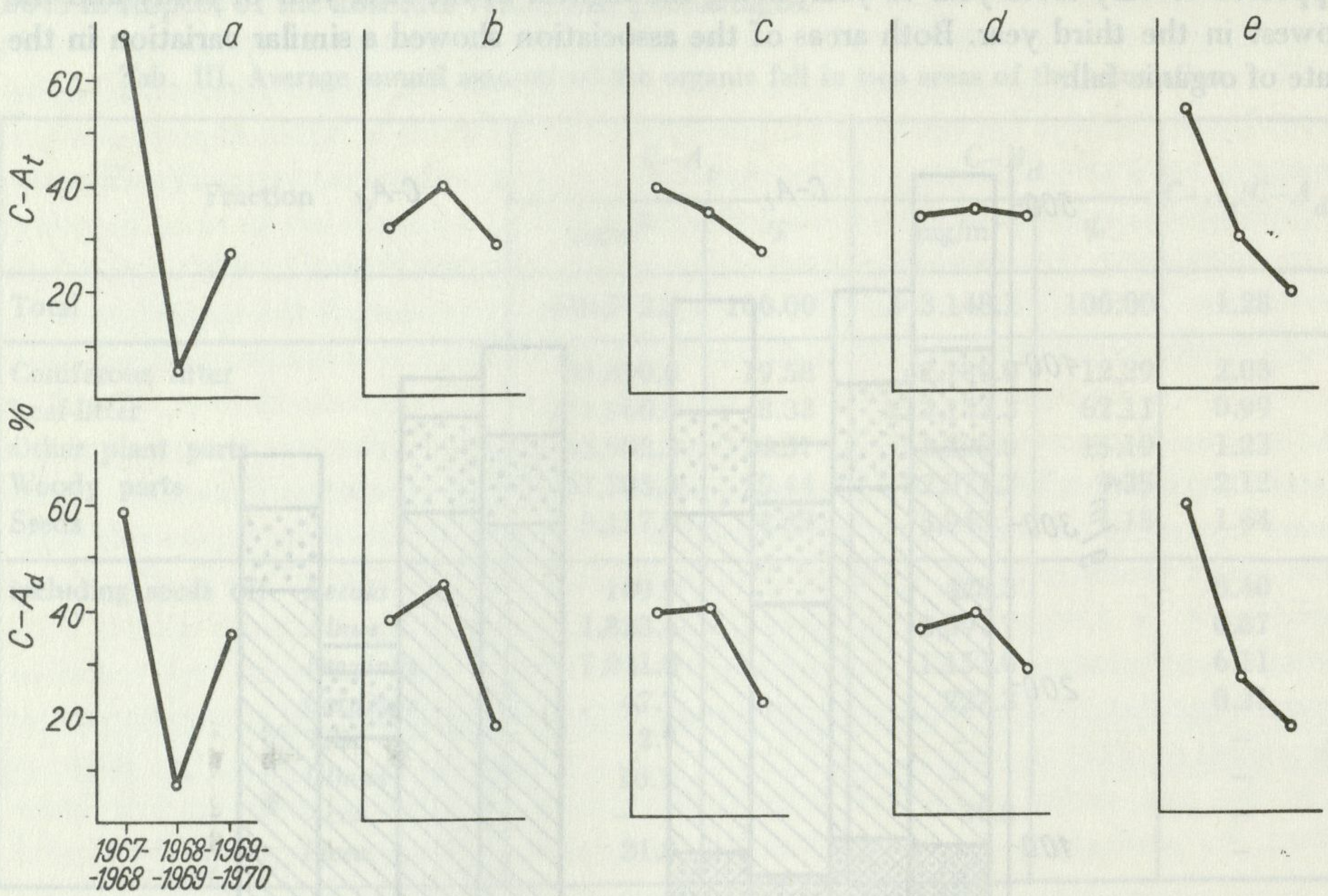

Fig. 2. Variation in the fall of some of the fractions over a three-year period in the typical area ($C-A_t$) and in the deformed area ($C-A_d$)
a – seeds, *b* – coniferous litter, *c* – leaf-litter, *d* – other plant parts, *e* – woody parts

The fall rate of *Picea* needles showed a clear peak in the year 1968/1969, while for the remaining two years a much lower fall rate was recorded. The smallest amount of leaf--litter was found in the third year of study, the fall rate for the year 1968/1969 being lower, as compared with the preceding year, in the typical part, and slightly higher in the deformed part.

It is difficult to discuss the variations in the fall rate of the woody parts, which showed a steady decrease from the first to the third year of study, because the value of fall of this fraction depends to a largae extent on chance factors (strong winds, large tufts of snow on the branches, etc.). This part of the fall is not shed by the trees in a controlled manner.

The variable rate of fall of individual fractions over the three-year cycle is reflected in the percentage distribution of the fall (Fig. 3). There are two versions of the distribution in the graph: (1) without woody parts and (2) with the fraction of woody parts. Although wood remnants are one of the elements of the organic fall, the variation in their

fall rate is not related to the biology of the woody species. Therefore the actual fall rate of this fraction in a given year may affect the structure of the controlled fall (seeds, litter, inflorescences, etc.). The seed fraction shows the highest variation of its percentage in the fall from year to year.

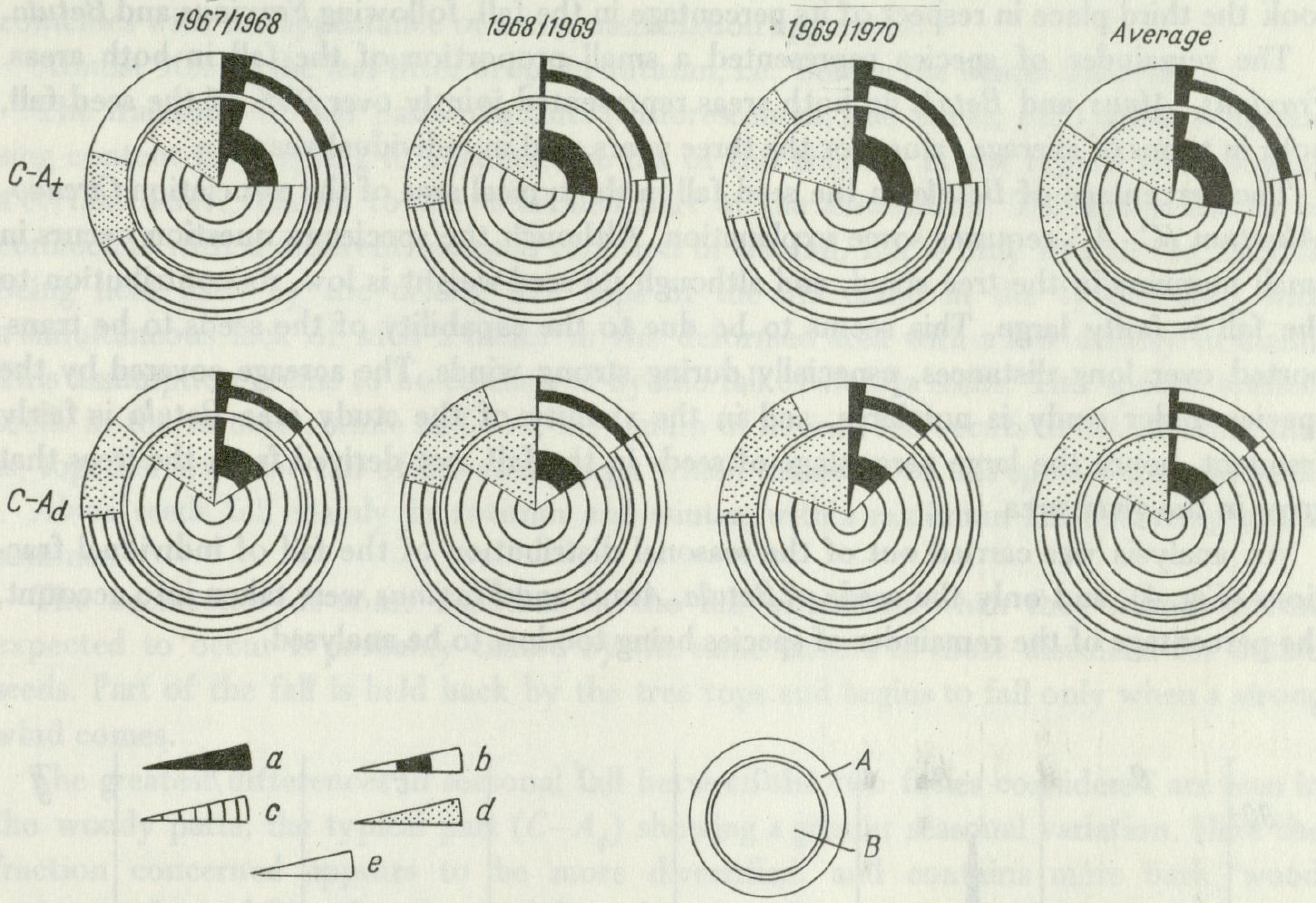

Fig. 3. Percentage distribution of the organic fall in two areas ($C\text{–}A_t$ and $C\text{–}A_d$) of the association *A* – including woody parts' fraction, *B* – without woody parts' fraction, *a* – seeds, *b* – coniferous litter, *c* – leaf-litter, *d* – other plant parts, *e* – woody parts

Tab. IV. Percentage structure of the seed fall in two areas of the association during three years

Area	Year	*Betula*	*Alnus*	*Fraxinus*	*Carpinus*	*Tilia*	*Ulmus*	*Acer*	*Picea*	Total
$C\text{–}A_t$	1967/68	0.53	15.93	82.55	0.76	0.03	0.16	–	0.04	100.00
	1968/69	4.03	12.85	78.73	–	0.18	–	–	4.21	100.00
	1969/70	4.86	31.58	63.52	–	–	–	–	0.04	100.00
$C\text{–}A_d$	1967/68	2.22	58.88	29.39	9.51	–	–	–	–	100.00
	1968/69	25.10	22.68	48.80	3.42	–	–	–	–	100.00
	1969/70	22.60	49.26	25.50	–	–	–	2.64	–	100.00
$C\text{–}A_t$	average	1.86	20.00	77.24	0.52	0.03	0.11	–	0.24	100.00
$C\text{–}A_d$	average	10.86	53.21	29.24	5.76	–	–	0.93	–	100.00

The percentage of seeds of individual species varies from year to year (Tab. IV). In $C\text{–}A_t$ *Fraxinus* dominated every year, where during the three-year period it accounted on

the average for almost 80% of the seed fall. The second place in each year, and with regard to the average for the three years, was held by *Alnus*.

In $C\text{–}A_d$ the dominant species in respect of the average values for the three years was *Alnus, Fraxinus* holding the second place; in the year 1968/1969 the dominant species took the third place in respect of its percentage in the fall, following *Fraxinus* and *Betula*.

The remainder of species represented a small proportion of the fall in both areas. *Fraxinus, Alnus* and *Betula* in both areas represented jointly over 90% of the seed fall, both in terms of average values for the three years, and in individual years.

The percentage of *Betula* in the seed fall in the typical area of the association *Circaeo-Alnetum* ($C\text{–}A_t$) requires some explanation. Although the species in question occurs in small numbers in the tree stand, and although its seed-weight is low, its contribution to the fall is fairly large. This seems to be due to the capability of the seeds to be transported over long distances, especially during strong winds. The acreage covered by the species under study is not large, and in the vicinity of the study area *Betula* is fairly frequent, hence the large percentage of seeds in the fall, not derived from the trees that grow in the given area.

An analysis was carried out of the seasonal distribution of the fall of individual fractions (Fig. 4), and only the seeds of *Betula, Alnus* and *Fraxinus* were taken into account, the percentage of the remainder of species being too low to be analysed.

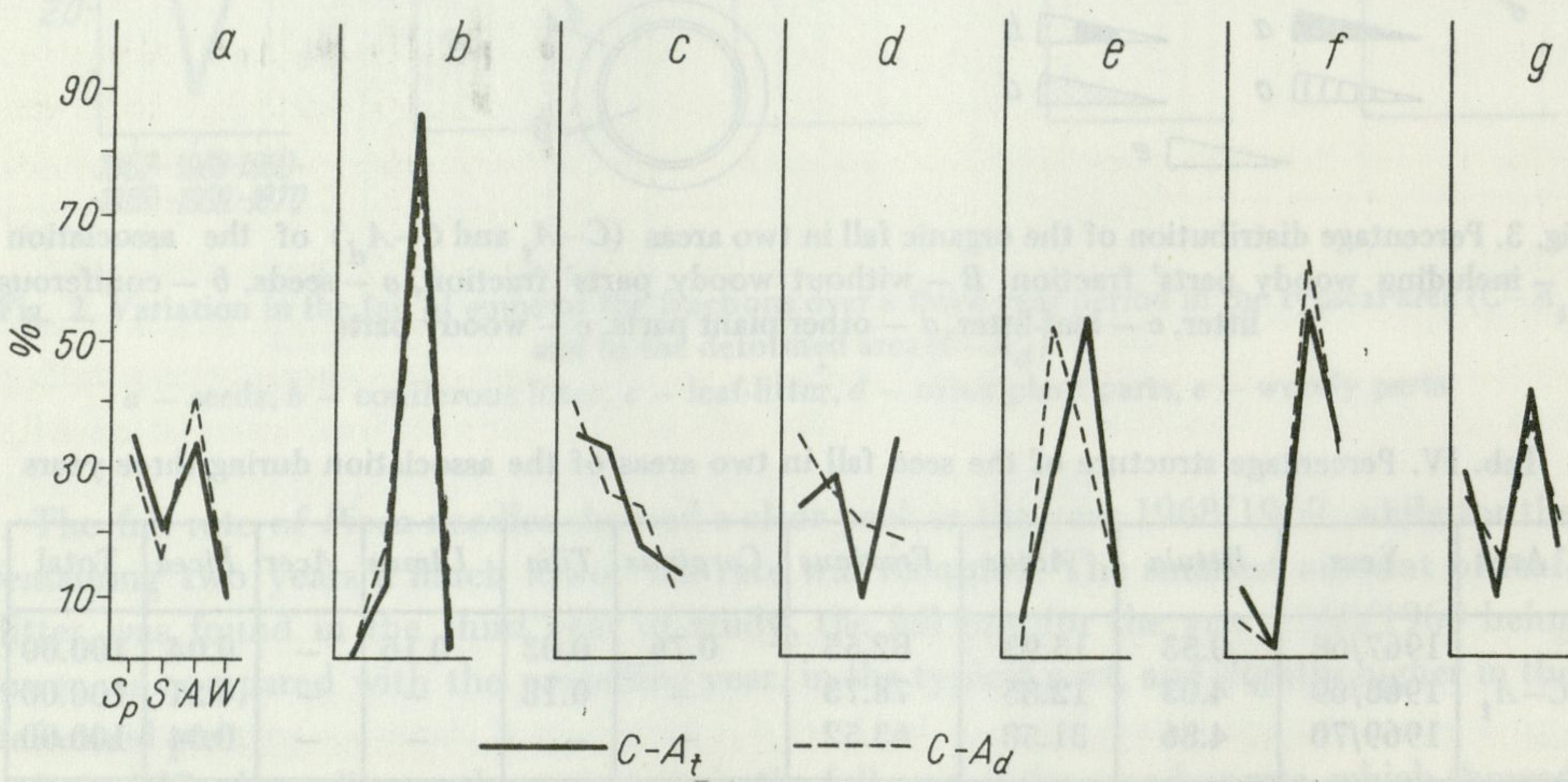

Fig. 4. Seasonal variation of the organic fall according to summarised data for two years (1967/1968 and 1968/1969) in two areas ($C\text{–}A_t$ and $C\text{–}A_d$) of the association
a – coniferous litter, *b* – leaf-litter, *c* – other plant parts, *d* – woody parts, *e* – *Betula* seeds, *f* – *Alnus* seeds, *g* – *Fraxinus* seeds, *Sp*– spring, *S* – summer, *A* – autumn, *W* – winter

The adopted division into seasons, which was fairly artificial, is as follows: spring – March to May, summer – June to August, autumn – September to November, winter – December to February. The material collected during the first two years (in the third year material was collected at irregular intervals) was sorted according to the seasons distinguished.

Many of the fractions show a similar variation of fall rate in both areas.

For the coniferous litter two clear peaks were recorded, a spring, and an autumn peak. In the area considered the only source of needles was the spruce. The autumn peak is due to the shedding of the assimilation apparatus to reduce transpiration. The second peak coincides with the appearance of a new assimilation apparatus.

Almost 90% of the leaf-litter drops in autumn, i.e., before the winter interval.

The fraction of other parts of plants (inflorescences, bud scales, etc.) shows a decreasing content from spring to autumn, the fall of this fraction in the typical area showing a certain delay, relative to the deformed part of the association. This seems not to be connected with a different seasonal variation in the fall, but is only due to the fraction being held back by the denser tree tops of the old stand in the typical area, with a simultaneous lack of such a factor in the deformed area with a low density of stand. This assumption seems to be confirmed by the fall of *Betula* seeds. This species scatters seeds in the summer, while in $C–A_t$ maximum of its seed fall occurs in the autumn, that is, together with the fall of leaves amongst which the seeds of this species are held back.

Alnus seeds fall mainly in autumn and winter, with a minimum fall occurring in the summer.

The occurrence of some fractions in the fall in seasons when they should not be expected to occur is probably caused by the same factors as those discussed for *Betula* seeds. Part of the fall is held back by the tree tops and begins to fall only when a strong wind comes.

The greatest differences in seasonal fall between the two facies considered are seen in the woody parts, the typical part ($C–A_t$) showing a greater seasonal variation. Here the fraction concerned appears to be more diversified, and contains more bark, wood remnants from falling boughs, and branches, etc. Two peaks are seen in the typical part – one in summer, and the other in winter. In the former case this coincides with the period of fairly strong winds which, with the full-foliaged tree tops rubbing against one another, cause the dead parts of a tree top to break off. The second peak occurs during the time of fairly high snowfall when snow tufts often occur on tree branches causing some of them to break.

5. DISCUSSION

The present study is concerned with two fairly significant elements of the primary production of the association *Circaeo-Alnetum* Oberd., 1953. Outside the scope of the analysis remains the production of wood, of the root systems of all plants, and the production (small in the association considered) of mosses and lower plants. The woody parts, collected in the catchers in amounts of about 677 kg/ha for $C–A_t$, and about 321 kg/ha for $C–A_d$, bear no relation to the production of wood.

The organic fall in a marsh forest, as in other forest types, exceeds the production of the ground flora, that is, that part of the producer species which brings about an increase in the strongly shaded bottom-part of the community.

In comparison with other forest communities in Poland (Tab. V), it can be seen that as the production of the ground flora in this association is many times higher, and the rate

Tab. V. Ground flora production and the annual amount of organic fall in different forest associations in Poland

Association	Ground flora (kg/ha)	Fall (kg/ha)	Fall/ /ground flora	Author
A. Dry and medium-moist associations				
Cladonio-Pinetum Kobendza, 1930	177	4660	26.3	Wójcik 1970
Leucobryo-Pinetum typicum Mat., 1962	431	?	?	Dzięciołowski 1970
Vaccinio myrtilli-Pinetum Kobendza, 1930	131	3246	24.8	T. Traczyk 1967a
Vaccinio myrtilli-Pinetum Kobendza, 1930	244	?	?	H. Traczyk and T. Traczyk 1967
Pino-Quercetum Kozł., 1925	166	3729	22.5	T. Traczyk 1967a
Pino-Quercetum Kozł., 1925	496	6638	13.5	Plewczyńska 1970
Pino-Quercetum Kozł., 1925	270	?	?	H. Traczyk and T. Traczyk 1967
Pino-Quercetum Kozł., 1925	803	?	?	Rajchel 1965
Fago-Quercetum trientaletosum Tx., 1955	402	?	?	Dzięciołowski 1970
Potentillo albae-Quercetum Libb., 1933	2264	2396	1.1	Kaźmierczakowa 1971
Stellario-Carpinetum calamagrostietosum Oberd., 1957	399	?	?	Dzięciołowski 1970
Tilio-Carpinetum Tracz., 1962	167	3731	22.3	T. Traczyk 1967a
Tilio-Carpinetum Tracz., 1962	281	?	?	H. Traczyk and T. Traczyk 1967
Tilio-Carpinetum Tracz., 1962	?	2512	?	Myczkowski 1967
Fagetum carpaticum Klika, 1927	46[a]	3991[b]	85.8	[a]Kaźmierczakowa 1967 [b]Myczkowski 1967
Fagetum carpaticum Klika, 1927	250	?	?	Rajchel 1965
B. Moist and water-logged associations				
Vaccinio uliginosi-Pinetum Kleist, 1929	1038	?	?	Moszyńska 1970
Calamagrosti villosae-Pinetum Staszk., 1958	2293	?	?	Dzięciołowski 1970
Tilio-Carpinetum stachyetosum silvaticae Tracz., 1962	1696	2682	1.6	Kaźmierczakowa 1971
Carici elongatae-Alnetum Koch., 1926	557	4091	7.3	T. Traczyk 1967a
Carici elorgatae-Alnetum Koch., 1926	1050	?	?	H. Traczyk and T. Traczyk 1967
Circaeo-Alnetum Oberd., 1953 ($C{-}A_t$)	1075[c]	4386[d]	4.1	[c]Aulak 1970
Circaeo-Alnetum Oberd., 1953 ($C{-}A_d$)	1761[d]	3431[d]	1.9	[d]Aulak – present data

of the organic fall is fairly high, the values of the ratios between the fall rate and ground flora production are small, namely 4.1 in $C–A_t$, and 1.9 in $C–A_d$. This very low ratio is due to the soil being very rich and of excellent moisture conditions, which results in a very high production of the ground flora. In this association the water does not stagnate, but it temporarily fertilizes the soil, and indirectly contributes to a faster decomposition of the organic matter, which enables the matter derived from the production in the past periods to be included in the cycle. Marsh forest habitats are, like the alder forest habitats, very fertile (Tab. V). For both these communities with a high production of the ground flora the values of the ratio between the fall rate and ground flora production are much smaller than those for the remaining types of forest, let alone the beech forest where the production of the ground flora is very low.

The much lower value of the ratio for the $C–A_d$ area, relative to $C–A_t$, is caused by a higher production of the ground flora in the deformed part, and a much lower rate of organic fall from the younger and less dense stand.

Leaving out the wood fallen during a year, which decomposes fairly slowly, the marsh forest community receives each year on the average almost 5000 kg/ha of organic matter that can be fairly quickly included in a new cycle (Tab. VI).

Tab. VI. Annual amount of organic matter of the ground flora and fall in two areas of the association, undergoing a fast decomposition on the forest floor

Fraction	$C–A_t$	$C–A_d$
Coniferous litter	85,890.0	42,180.0
Leaf-litter	211,960.0	213,153.3
Other plant parts	63,902.2	51,800.0
Seeds	9,117.0	3,943.1
Ground flora	107,457.2	176,075.7
Total (mg/m^2)	478,326.4	487,152.1

At the same time some of the matter (mainly the ground flora and seeds) is returned to the soil through tle level of consumers, while the remainder returns to the soil by being decomposed by the reducers.

So large amounts of matter cycling in this ecosystem indicate that its productivity is high, as compared with the coniferous forest, and mixed forest ecosystems.

I wish to express my cordial thanks to Docent Dr. T. Traczyk for making me familiar with the use of the DG method for the assessment of ground flora production. Cordial thanks are extended also to Professor Dr. Z. Pucek for providing technical assistants and equipment for studying the organic fall, and to Docent Dr. J. B. Faliński for disinterestedly preparing for me the phytosociological documentation of the areas studied.

6. SUMMARY

In the Białowieża National Park the production of the ground flora, and the rate of organic fall were studied in two areas of the association *Circaeo-Alnetum* Oberd., 1953. One of the areas was a typical area of the association ($C–A_t$), and the other one was to some extent deformed ($C–A_d$) in that the tree stand in it was younger and less dense, while the soil appeared to be more water-logged.

The production of the ground flora was determined in 1967 by using the *DG* method published by T. T r a c z y k (1967b). The fall rate was analysed over a three-year period, from August 1, 1967, to July 31, 1970. To collect organic fall special catchers were used, each of 0.1 m^2 in surface area. In the typical part of the association 30 catchers were put up, and only 20 in the deformed part. The following fractions were distinguished in the fall: seeds, coniferous litter, leaf-litter, other parts of plants (inflorescences, bud scales, etc.), as well as woody parts (twigs, bark, wood remnants, etc.).

The production of the ground flora in the typical part was about 1075 kg/ha, and in the deformed part – about 1761 kg/ha (Tab. II). The much larger production of the deformed part was due mainly to *Urtica dioica*, the superdominant species.

The average amount of organic fall for the three-year period was about 4386 kg/ha in the typical part, and about 3431 kg/ha in the deformed part (Tab. III). The absolute value of the fall (Fig. 1), and the percentage distribution of the fractions (Fig. 3) varied clearly from year to year. The greatest variation over the three-year period was recorded for the seeds and woody parts (Fig. 2).

Seeds of *Fraxinus, Alnus* and *Betula* were found to represent over 90% of the total amount of seed fall, the remaining species accounting for only a small proportion of the seed fall.

The value of the ratio between the annual fall and the ground flora production was 4.1 for the typical part, and 1.9 for the deformed part of the association. Similarly low ratios are recorded also for other moist, and water-logged forest communities in Poland (Tab. V), the ratios being much lower than those for coniferous forests, and mixed forest ecosystems. In the association *Circaeo-Alnetum* the value of ground flora production exceeds 1000 kg/ha, in both the typical and the deformed parts, this corresponding to the value of production in similar habitats in other parts of Poland.

The total annual amounts of organic matter (without woody parts) returned to the soil from the fall and ground flora production are as follows: in the typical part – about 4783 kg/ha, and in the deformed part – about 4872 kg/ha.

7. POLISH SUMMARY (STRESZCZENIE)

W Białowieskim Parku Narodowym, w zespole *Circaeo-Alnetum* Oberd.,1953, zbadano produkcję runa oraz wielkość opadu organicznego w dwóch płatach. Pierwszy z nich był płatem typowym zespołu ($C–A_t$), drugi natomiast był w pewnym stopniu zniekształcony ($C–A_d$), co wyrażało się młodszym i mniej zwartym drzewostanem oraz silniejszym podtopieniem gleby.

Produkcję runa określono w roku 1967 metodą *DG* T. T r a c z y k a (1967b). Opad analizowano w cyklu trzyletnim, od 1 sierpnia 1967 r. do 31 lipca 1970 r. Do zbioru zastosowano chwytacze o powierzchni chwytnej 0,1 m^2 każdy. W części typowej zainstalowano 30 chwytaczy, natomiast w części zniekształconej 20. W opadzie wyróżniono następujące frakcje: nasiona, ściółka iglasta, ściółka liściasta, inne części roślinne (kwiatostany, łuski pączków itp.) oraz części zdrewniałe (gałązki, kora, szczątki drewna itp.).

Produkcja runa w części typowej wyniosła około 1075 kg/ha, w części zniekształconej około 1761 kg/ha (tab. II). Na znacznie większą produkcję płatu zniekształconego wpłynął głównie superdominant *Urtica dioica*.

Przeciętna wielkość opadu z okresu trzech lat wyniosła w części typowej około 4386 kg/ha a w części zniekształconej około 3431 kg/ha (tab. III). Między poszczególnymi latami zaznaczyła się wyraźna różnica w wielkości absolutnej opadu (fig. 1) jak i w spektrum procentowym poszczególnych frakcji (fig. 3). Największe wahania w cyklu trzyletnim zaznaczyły się w frakcji nasion i części zdrewniałych (fig. 2).

Ponad 90% opadu nasion stanowią nasiona *Fraxinus*, *Alnus* i *Betula*. Pozostałe gatunki przynoszą niewielki opad nasion.

Stosunek rocznej wielkości opadu do produkcji runa wyniósł w części typowej 4,1 a w części zniekształconej 1,9. Podobnie niskie wskaźniki występują też w innych wilgotnych i podtopionych zbiorowiskach leśnych Polski (tab. V). Są one znacznie niższe niż w borach i lasoborach. Produkcja runa w *Circaeo-Alnetum* przekracza 1000 kg/ha tak w części typowej jak i w zniekształconej, co odpowiada produkcji na podobnych siedliskach w innych częściach Polski.

Łacznie z opadu i produkcji runa powracają do gleby w ciągu roku następujące ilości materii organicznej (bez części zdrewniałych): w części typowej około 4783 kg/ha, a w części zniekształconej około 4872 kg/ha.

8. REFERENCES

1. Andrzejewski R., Borowski S., Olszewski L. 1968 – Ustalenie powierzchni chwytnika opadu organicznego w lesie liściastym – Sylwan, 112: 55–58.
2. Aulak W. 1970 – Studies on herb layer production in the *Circaeo-Alnetum* Oberd. 1953 association – Ekol. pol. A, 18: 411–427.
3. Dzięciołowski R. 1970 – Produkcja pierwotna netto roślin runa w czterech zespołach leśnych – Folia Forest. Pol. A, 16: 91–108.
4. Kaźmierczakowa R. 1967 – Runo lasu bukowego *Fagetum carpaticum*, jego fenologia i ekologia produkcji pierwotnej – Studia Nat. A, 1: 95–114.
5. Kaźmierczakowa R. 1971 – Ekologia i produkcja runa świetlistej dąbrowy i grądu w rezerwatach Kwiatówka i Lipiny Dół na Wyżynie Małopolskiej – Studia Nat. A, 5: 1–104.
6. Moszyńska B. 1970 – Estimation of the green top production of the herb layer in a bog pinewood *Vaccinio uliginosi-Pinetum* – Ekol. pol. A, 18: 779–803.
7. Myczkowski S. 1967 – Skład florystyczny, struktura i produktywność roślinności drzewiastej płatu *Fagetum carpaticum* – Studia Nat. A, 1: 61–93.
8. Plewczyńska U. 1970 – Herb layer production and plant fall in the association *Pino-Quercetum* Kozłowska 1925 in the Pisz Forest – Ekol. pol. A, 18: 757–778.
9. Rajchel R. 1965 – Produktywność pierwotna netto runa w dwóch zespołach leśnych Ojcowskiego Parku Narodowego – Fragm. flor. geobot. 11: 121–150.
10. Szafer W., Kulczyński S., Pawłowski B. 1953 – Rośliny polskie – PWN, Warszawa, 1020 pp.
11. Traczyk H., Traczyk T. 1967 – Tentative estimation of the production of herb layer – Ekol, pol. A, 15: 823–835.
12. Traczyk T. 1967a – Studies on herb layer production estimate and the size of plant fall – Ekol. pol. A, 15: 837–867.
13. Traczyk T. 1967b – Propozycja nowego sposobu oceny produkcji runa – Ekol. pol. B, 13: 241–247.
14. Wójcik Z. 1970 – Primary production of the herb layer and plant fall in a dry pine forest (*Cladonio-Pinetum* Kobendza 1930) in the Kampinos National Park – Ekol. pol. A, 18: 393–409.

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