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GROWTH OF WETLAND PLANTS EXPOSED TO VARIOUS BIOTIC AND ABIOTIC FACTORS IN LABORATORY EXPERIMENTS

ABSTRACT: Accumulation of plant remains caused a successive increase of the studied shore part in the eutrophic Mikołajskie lake. Five zones have been distinguished which differred by the period of formation and the soil conditions. Studies were done on the effect of these conditions on the growth of marsh plants. Culture experiments were conducted in a greenhouse. Significant differences were found between the numbers of seedlings and species of germinating plants on soils from various zones. Soil age and water level had an essential effect on the plant growth.

KEY WORDS: lake littoral, marsh plants, water level, soil age.

1. INTRODUCTION

Long term observations of Mikołajskie Lake shores revealed a high variety of the shore habitats (P i e c z y ń s k a 1972). One of the more floristically interesting parts of the lake shore is called Pisna Kępa. The species diversity in its marshy part suggest the influence of specific environmental conditions determining plant occurrence. An attempt was made to analyse the mechanisms causing the variation in the plant colonization of the marshy part of Pisna Kępa. The youngest parts of studied areas which formed a year, or two before the collection of soil samples for experiments, have not been, almost entirely, colonized by plants. This raised a question, if it had not been caused by the absence of seeds in these zones. This however seemed unlikely because of a small distance of these areas from others. It appears, that environmental conditions were responsible for the inhibition of seeds germination, while further growth of seedlings was thwarted by allelopatic substances exuding from partly decomposed plant remains.

The aim of the present studies was an experimental analyses of the factors affecting plant colonisation of the marshy shore part at Pisna Kępa, Mikołajskie Lake. Analyses were done of the effect of chosen biotic and abiotic factors on the growth of plants. This included : composition and density of seedlings on soil from various zones of the marshy area of Pisna Kępa, the effect of soil age on the growth of chosen plant species and the effect of water level on the growth of plants.

2. STUDY AREA AND METHODS

2.1. STUDY AREA

Floristically rich, shore part of the eutrophic Mikołajskie Lake (surface area 460 ha; max. depth 27.5 m) called Pisna Kępa has been the object of studies (Figs. 1A, 1B). It has been successively formed during many years. In 1982, five zones which had farmed at different times were distniguished. Two oldest zones developed during several years, while three younger ones were formed following the consecutive autumn-winter season.

Each zone had formed from broken plant debris of land origin (such as leaves of trees), from fragments of littoral and marsh plants, and from littoral sand brought in by autumn storms. The degree of decomposition of plant remnants in each zone was dependent on the time of the zone formation. Plant colonization were observed on newly formed zones of the marshy part, however, it occurred with one or two years delay. The youngest zone developed in the last autumn–winter period was only partly covered with vegetation.

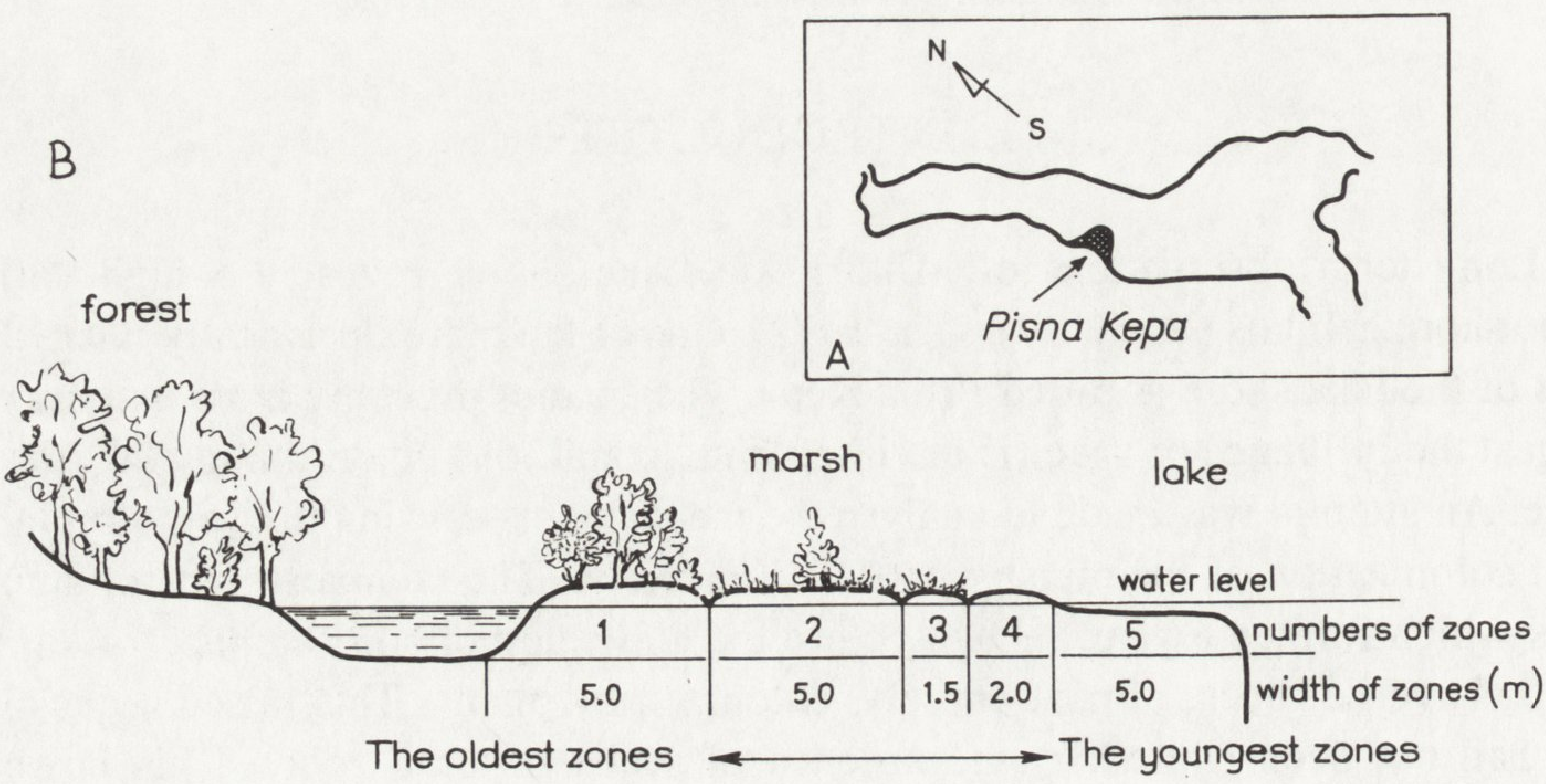

Fig. 1. Mikołajskie Lake with the studied shore fragment of Pisna Kępa (A)
Horizontal profile of the marsh part of Pisna Kępa (B)

Figure 1 B shows a horizontal profile of the marsh area with the distinguished zones, where soil samples were taken for experiments. Considering the age of trees, such as *Alnus glutinosa* (L.) Gaertn. and *Salix cinerea* L., growing in zone 1, its period of existance has been identified for about 20 yrs. The age of zone 2 has been identified for about 10 yrs. It was covered with herb plants and single shrubs of *Alnus glutinosa* up to 1 m high. Of the herb plants in this zone the following species were identified which were present in rather high numbers: *Bidens cernuus* L., *Lycopus europaeus* L., *Rorippa amphibia* (L.) Bess., *Typha latifolia* L. and *Carex pseudocyperus* L. Other species occurred in lower numbers: *Epilobium hirsutum* L., *Urtica dioica* L., *Heleocharis acicularis* (L.) R. et Sch., *Stellaria uliginosa* Murr., *Scutellaria galericulata* L., *Rumex hydrolapathum* Huds., *Senecio fluviatilis* Wallr., Gramineae, *Polygonum* sp. and *Solanum dulcamara* L. A total of 16 plant species occurred in zone 2 in 1982 (the author's unpublished data). Next three zones: 3, 4, and 5 developed consecutively during the last three years (1981–1983). Zone 3 began to be colonised in 1982 by many species (21) but rather small numbers of individuals. In 1983 the species numbers declined to 15, but the quantity of individuals considerably increased. Plant species in the zone 3 in 1982 were the same as in the zone 2 and following new species appeard: *Phragmites australis* (Cav.) Trin ex Steud., *Mentha* sp., *Ranunculus sceleratus* L., *Iris pseudoacorus* L., *Hydrocharis morsus-ranae* L., *Sagittaria sagittifolia* L., *Alisma plantago-aquatica* L. and one species of the family Juncaceae. Zone 4 had formed in 1982 during autumnal storms. Its substrate consisted of detritus particles coarser than in the other zones. This was related to a comparatively shorter decomposition period of the plants forming this zone. Almost no plants were observed there in 1982, while in 1983 already 20 species were recorded. During the vegetative period, the average plant biomass in this zone (331 g dry wt m^{-2}) was lower than in zone 3 (464 g dry wt m^{-2}: the author's unpublished data). In 1982 zone 5 was still submerged, however, a small heaps had already formed from the accumulated leaves. In spring 1983 this zone substrate consisted of dead, but still unbroken tree leaves, debris of reed, and still green fragments of plants, mainly *Ceratophyllum submersum* L. No growing plants were observed there in 1983.

2.2. METHODS

2.2.1. Experiment 1

Determinations were made of the composition of species which had germinated on soils of the 5 zones of Pisna Kępa; plant numbers were also counted. Quantitities of dead plants were also considered to ascertain which soils in a given zone were unfavourable for a given species.

In autumn 1982 five soil samples were collected from each of the five zones. The samples of every zone were well mixed, and placed in two plastic cuvettes having the total surface area of 0.5 m^2. The total soil surface from 5 zones covered 2.5 m^2. The amount of soil in every cuvette was the same. The cultures were carried out in a greenhouse with the plants having the same light and temperature conditions. In winter the greenhouse was heated. Soil was continuously saturated with water. The experiment lasted five months (11 Nov. 1982–12 Apr. 1983). In winter seedlings were registered every two weeks; in spring every week. Newly germinated seedling was marked with a plastic rod. Whenever possible seedlings were identified to species. Seedling numbers of a given species, and all the seedlings were counted. At the end of the experiment the plants were cut, dried at 105 °C during 24 h and weighed.

2.2.2. Experiment 2

In a greenhouse culture, the growth of three chosen species (*Epilobium palustre, Typha latifolia*, and *Phragmites australis*) was followed on soils from all zones of Pisna Kępa. Observations were made of which of the species develop best on a given soil, and thus will have the best chance of winning competition with other species.

Soils where the first experiment was conducted, were cleaned of growing plants and rhizomes. Soils from each zone were seperately well mixed and placed in 9 plastic cuvettes of 0.06 m^2 each. 45 cuvettes were used for the culture of three species on soils from five zones. Three replicates were made of each culture treatment. Several seeds of every species were placed in each of 6 chosen places in a cuvette. Sowing points were marked with rods. Following seed germination, only one seedling was left in a given place, thus a total of six plants in one cuvette. Seeds were sown on 18 Apr. 1983; after five months (20 Sept. 1983) the experiment ended. *Epilobium palustre* germinated in four days in all places of sowing and soils from all zones. On the other hand, both *Typha latifolia* and *Phragmites australis* had to be sown again twice, since they did not germinate on soils developed one year earlier (zone 5) and two years earlier (zone 4) (Fig. 1B). Only after third sowing, 1.5 months following the first attempt, both species seedlings had appeared on soils from all zones. All seedlings were removed before each new sowing of both these species. In greenhouse cultures during several years, these species usually germinated in spring during 5–6 days (author's own data, unpublished). The culture of *Epilobium palustre* lasted from 18 Apr. to 1 Aug. 1983. *Typha latifolia* and *Phragmites australis* were cultured from 30 May to 20 Sep. 1983. Subsequently, the plants were cut, dried at 105 °C in 24 h and weighed. Average height and weight of 18 individuals were calculated. Student t-test was used to statistically determine differences in the plant height.

2.2.3. Experiment 3

The effect of different water levels on the growth of plants was studied; special interest was taken in *Epilobium palustre*. Soil for the experiment

(5 samples) was obtained from the oldest zone 1 (Fig. 1B) in December of 1982, and was transferred into the greenhouse. The plants growing were removed, the soil well mixed, and placed in 4 plastic cuvettes 0.11 m^2 each. Vertically placed tubes controlled the water level. Five centimeters of a thick gravel layer at the cuvette bottom was covered with 5 cm soil layer. Water levels in the experimental treatments varied: it stayed at 5 and 1 cm below soil level in cuvettes 1 and 2, at the soil surface (3) and 2.5 cm above soil surface (4). No repetitions were done. The cultures lasted from the middle of December 1982 to the middle of April 1983. Plants were not sown at the start of the experiment, but they germinated from the sampled soil. The numbers of species and individuals, as well as dry weight of plants of particular species were determined at the end of the experiment. Average maximal height was calculated as the mean of 5 highest individuals. As in the other experiments, the plants were dried. The test was conducted in a greenhouse, using the same temperature and light for all the treatments, however, they were changing with weather and hours of the day.

3. RESULTS

3.1. COMPOSITION AND DENSITY OF SEEDLINGS ON SOILS FROM DIFFERENT ZONES OF THE MARSHY PART OF PISNA KĘPA (EXPERIMENT 1)

In general 26 species germinated on soils from all the zones of Pisna Kępa. Some of them, such as *Poa annua* and *Typha angustifolia* occurred only in zone 1 (Table 1). *Scutellaria galericulata* and *Rorippa amphibia* were found on soils from zones 1 and 2, with the latter species being rather numerous in zone 2 (14 individuals per 0.5 m^2) and rare in zone 1. *Typha latifolia* and *Alisma plantago-aquatica* were found on soils from zones 1 and 3. Species, such as *Ranunculus sceleratus, Lycopus europaeus* and *Rumex paluster* were recorded on soils from zones 1, 2, and 3. *Bidens cernuus* occurred on soils from zones 1, 2, 3, 4, while *Epilobium palustre* on soil from all zones, however, with very different number of seedlings in particular zones. Thus, 70 seedlings per 0.5 m^2 occurred on soil of zone 1; a half of the number on soil from zone 2. Only 2 seedlings were found on each of the soil from zones 3, 4, and 5. *Hydrocharis morsus-ranae* occurred only on soil from zone 3, while *Alnus glutinosa* from zone 5.

Numbers of species and seedlings differed considerably on soils from particular zones (Table 1). Most species occurred on soil from zone 1 (19); less from zones 2 and 3 (18); 5 and 8 species on soils from zones 4 and 5, respectively. The highest number of seedlings (134 per 0.5 m^2) was also found on soil from zone 1; then from zones 2 (103), 3 (35), 4 (11), and 5 (15). On soil from zone 5 more species and seedlings occurred than on soil from zone 4, however, 53% of seedlings of the former zone had disappered. A smaller percentage of dead seedlings was noted on soils from other zones (Table 1).

Table 1. Species composition and numbers of seedlings growing on soils from particular zones (1–5), (see Fig. 1B). Period of culture: 151 d (11 Nov. 1982 to 12 Apr. 1983)

	Species	Zone				
		1	2	3	4	5
		number of seedlings per 0.5 m^2				
1	*Poa annua* L.	3				
2	*Typha angustifolia* L.	1				
3	*Rorippa amphibia* (L.) Bees.	1	14			
4	*Scutellaria galericulata* L.	2	3			
5	*Thpha latifolia* L.	2		1		
6	*Alisma plantago-aquatica* L.	1		3		
7	*Ranunculus sceleratus* L.	10	3	1		
8	*Lycopus europaeus* L.	6	10	1		
9	*Rumex paluster* Sm.	3	5	1		
10	*Bidens cernuus* L.	4	2	4	2	
11	*Epilobium palustre* L.	70	35	2	2	2
12	*Monocotyledones* spp.	2	4	2	3	3
13	*Carex pseudocyperus* L.	5	8	2		2
14	*Heleocharis palustris* (L.) R. et Sch.	1	1	1		1
15	*Urtica dioica* L.	5		2		1
16	*Bidens tripartitus* L.		2			
17	*Rumex hydrolapathum* Huds.		2	1	2	
18	*Hydrocharis morsus-ranae* L.			4		
19	*Heleocharis acicularis* (L.) R. et Sch.			1		1
20	*Alnus glutinosa* (L.) Gaertn.					1
	Indeterminate species (6)	18	14	9	2	4
	Total no. of species	19	18	18	5	8
	Seedling numbers of all species per 0.5 m^2	134	103	35	11	15
	Number of dead seedlings	10	12	4	1	8
	Percentage (%) of dead seedlings	7.5	11.7	11.4	9.1	53.3
	Percent species contribution in a given zone (Σ species = 100%)	73.1	69.2	69.2	19.2	30.8
	Percent contribution of seedlings in a given zone (Σ species = 100%)	45.0	34.6	11.7	3.7	5.0

3.2. GROWTH OF THREE PLANT SPECIES ON SOILS FROM PARTICULAR ZONES OF THE MARSHY PART OF PISNA KĘPA (EXPERIMENT 2)

In the beginning period of *Epilobium palustre* culture, the heights of plants of this species on soils from zones 1 to 5 did not differ substantially (Fig. 2). Height variation occurred only at the end of June. Examination with t-Student test of the

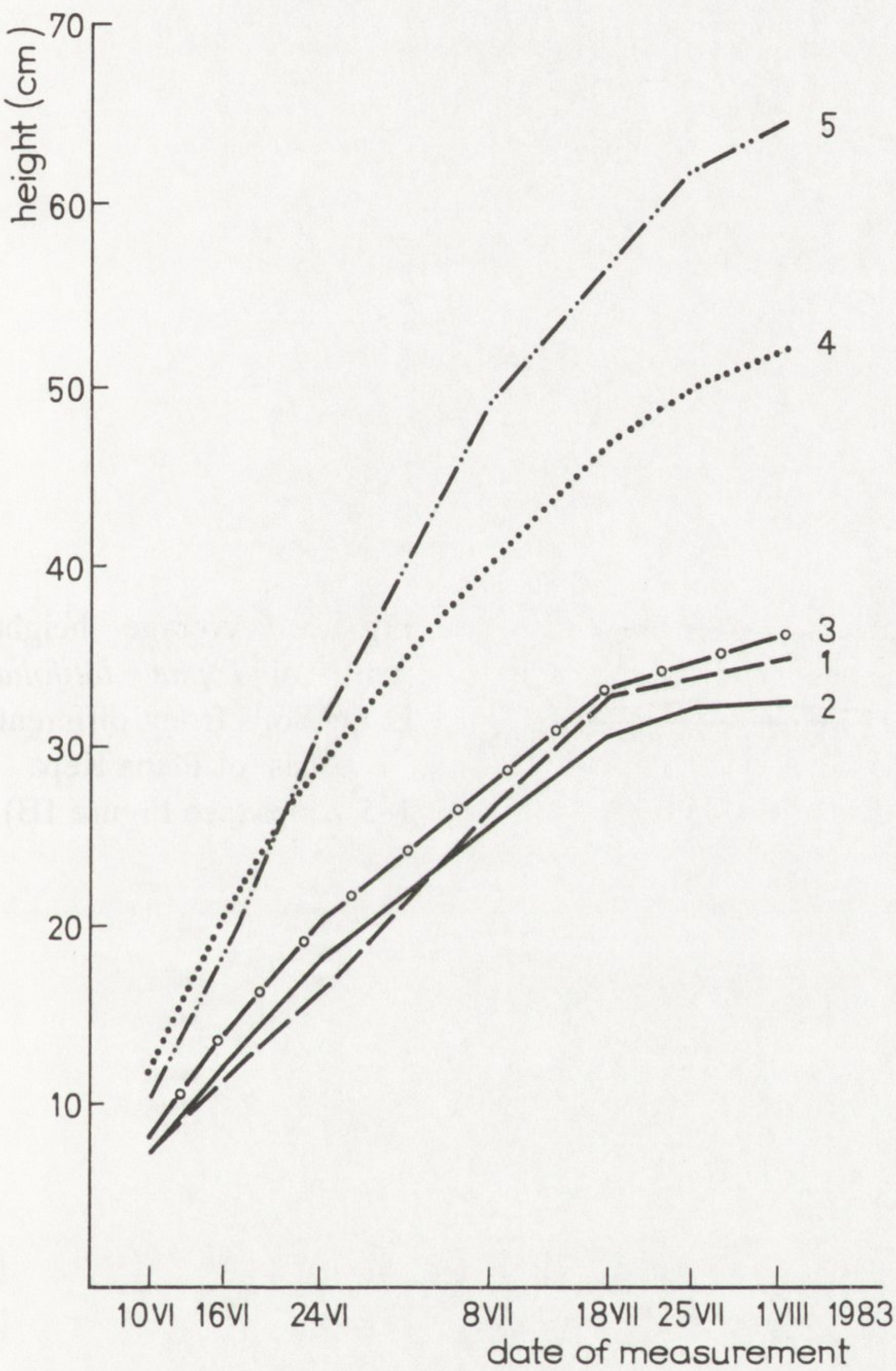

Fig. 2. Average height (cm) of *Epilobium palustre* L. on soils from different zones of Pisna Kępa 1–5 zones (see Figure 1B)

samples from 24 June have shown, that the heights of *E. palustre* growing on soils from zones 1, 2, and 3, differ significantly from those on soil of zones 4 and 5 (α = 0.05). No statistically significant differences were observed for the plant heights on soils from zones 1, 2 and 3, and between zones 4 and 5. Height measurements from 8 July showed significant differences in the heights of this species growing on soil from zone 3 and 4, and 4 and 5. Height differences of this species on soils from zones 1, 2 and 3 were insignificant during the entire period of culture. In the later period of culture, the maximum height of *E. palustre* was observed on soil of zone 5. This suggested the best soil conditions for this species at that time in this zone. Somewhat lower height of *E. palustre* was noted on soil from zone 4. Soils of zones 4 and 5 were the most recently formed: 2 years before soil collection in zone 4, and one year before sampling in zone 5.

In the begining period of culture (8 July), the height of *Typha latifolia* was smaller on soil from zone 5 than on other soils (Fig. 3). Differences in height in zones 1, 2, and 4 did not differ statistically. Significant statistical differences (α = 0.05) were noted for the height of plants growing on soils from zones 3 and 4, as well as 2 and 5. Measurements of 16 August showed, that the heights of *T. latifo-*

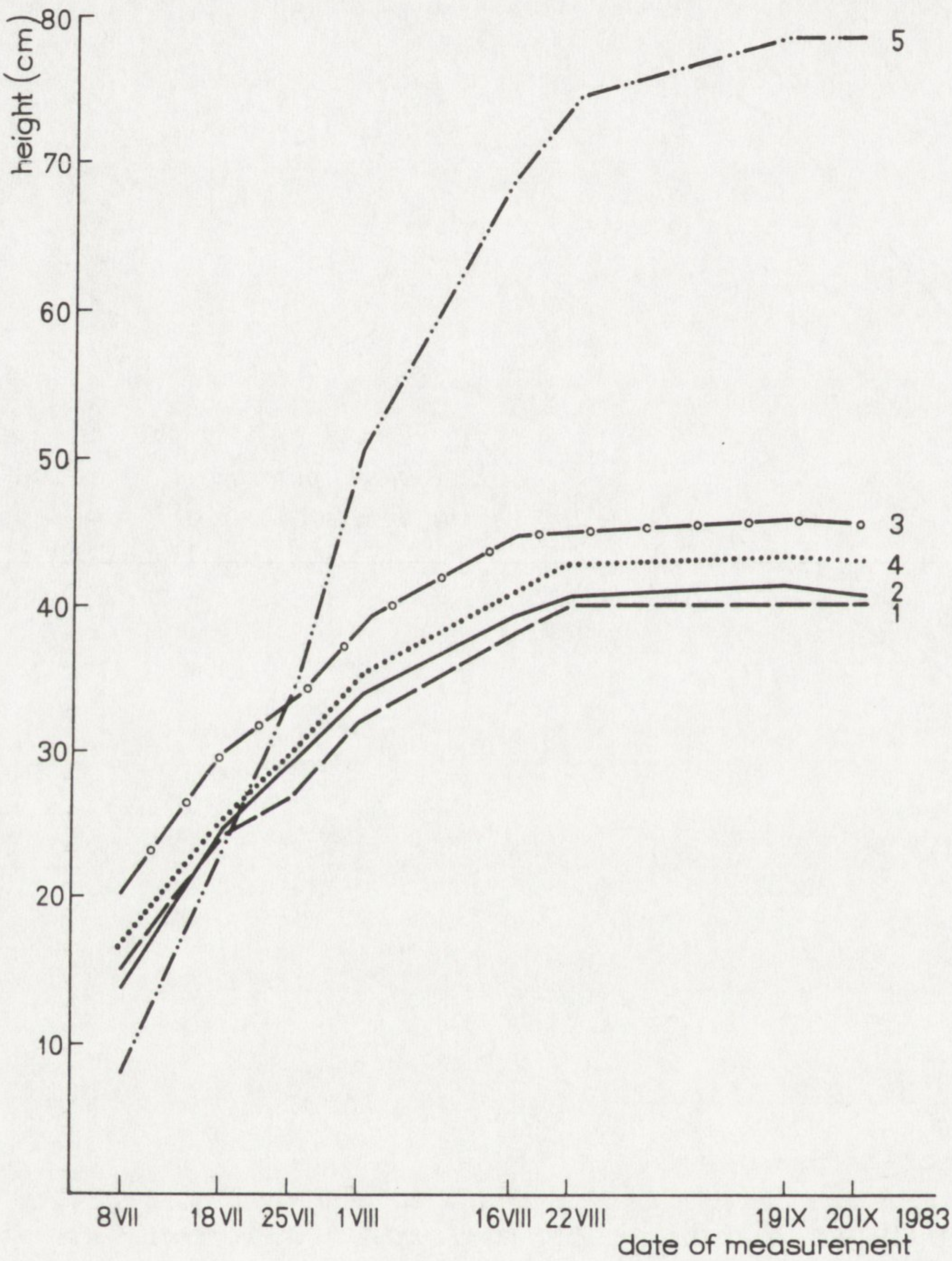

Fig. 3. Average height (cm) of *Typha latifolia* L. on soils from different zones of Pisna Kępa 1–5 zones (see Figure 1B)

lia on soils from zones 1 and 4, as well as 3 and 5 had statistically differed. On the other hand, no significant differences for the plant heights were found in zones 1 and 2, as well as 3 and 4. Measurements done on 13 September revealed no significant differences for the height of the species on soils from zones 1 and 2, 2 and 4 as well as 3 and 4. However, on the soils of zones 2 and 3 and 1, 2, 3, 4 and 5 significant differences in the species height were recorded ($\alpha = 0.05$). Height measurements of *T. latifolia* on soil from zone 5 led to the conclusion, that unfavourable growing conditions at the start of the culture had favourably changed at the begining of August, with the best growth conditions having occurred in the middle of September.

With the exception of zone 5, *Phragmites australis* reached nearly the same height on soils from all other zones (Fig. 4). Considerable inhibition of its growth was observed on soil from zone 5 during the entire culture period. Differences between the reed height in zone 5 and other zones were statistically significant. Best development of the species occurred on soil from the oldest zone no. 1 of Pisna Kępa.

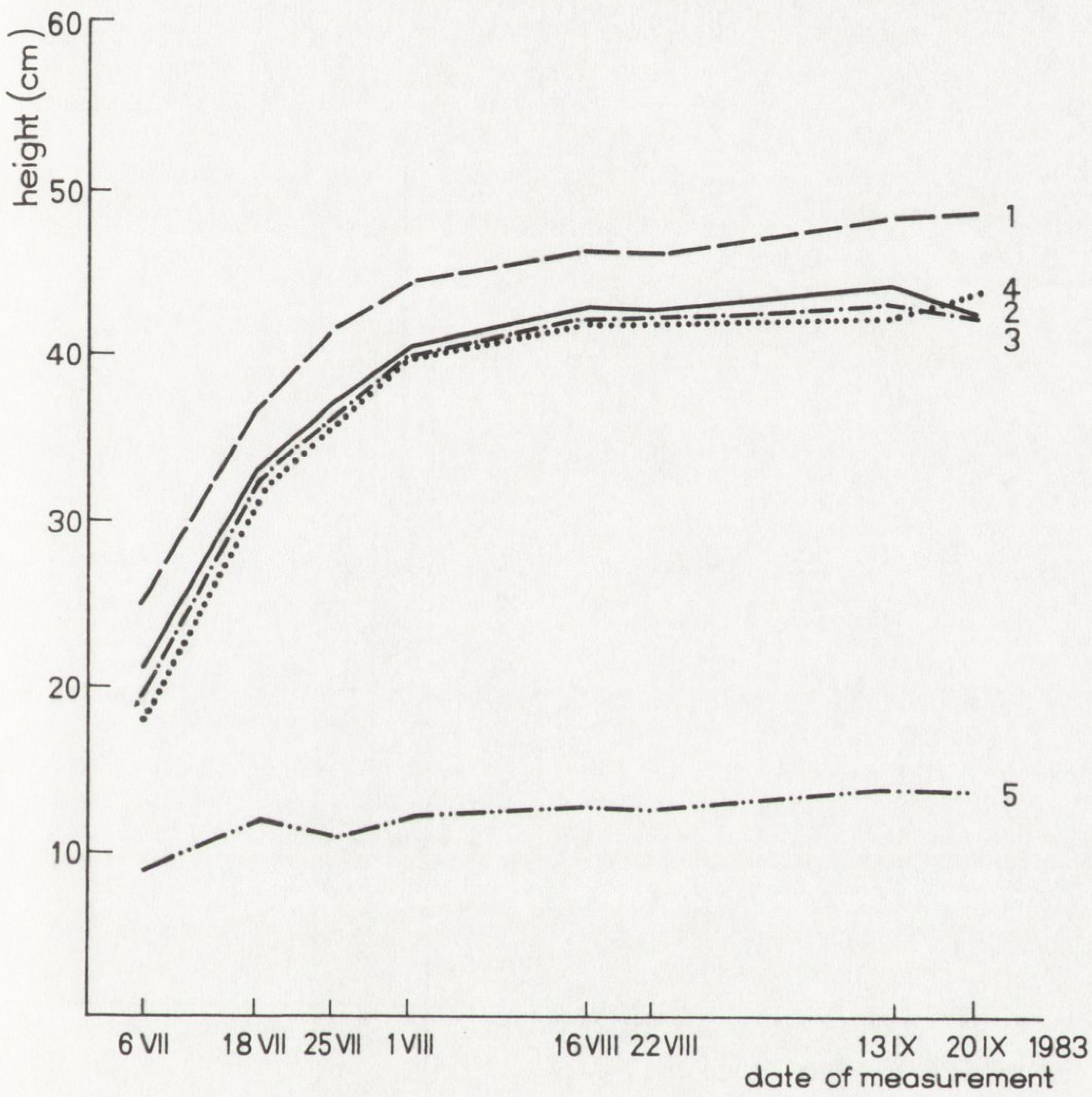

Fig. 4. Average height (cm) of *Phragmites australis* on soils from different zones of Pisna Kępa
1–5 zones(see Figure 1B)

The weights of plants were similar for all three species on soils from zones 1 to 3 (Fig. 5). *Epilobium palustre* developed best on soil from the youngest zones 4 and 5. Also *T. latifolia* grew well on soil from zone 5. In contrast, a distinct growth inhibition on the same soil was noted for *P. australis*. Reeds developed best on soil collected from zone 1.

3.3. EFFECT OF WATER LEVEL ON THE GROWTH OF SWAMP PLANTS (EXPERIMENT 3)

It was found that even small differences in the water level (between –5 cm and +2.5 cm) had affected the numbers of both, species and seedlings, as well as their biomass. The highest number of seedlings (98 per 0.11 m^2) occurred in the driest conditions of treatment 1, where the water level stayed 5 cm below soil surface. The numbers decreased to 48 seedlings in treatment 2, with the water level 1 cm below soil surface. In treatments 3 and 4 with the water levels 0 and 2.5 cm, above the soil surface, respectively, the numbers of seedlings were similar (46 and 47, Table 2). Also the species numbers were the highest in treatment 1 (13); nearly a half fewer (7) in treatment 2; accounting 10 in treatments 3 and 4 (Table 2). The highest biomass of all plants was found in treatment 2. The lowest biomass was recorded in the submersed conditions (treatment 4). Only in the most dry conditions there occurred *Rumex hudrolapathum*, *Polygonum* sp., *Rumex*

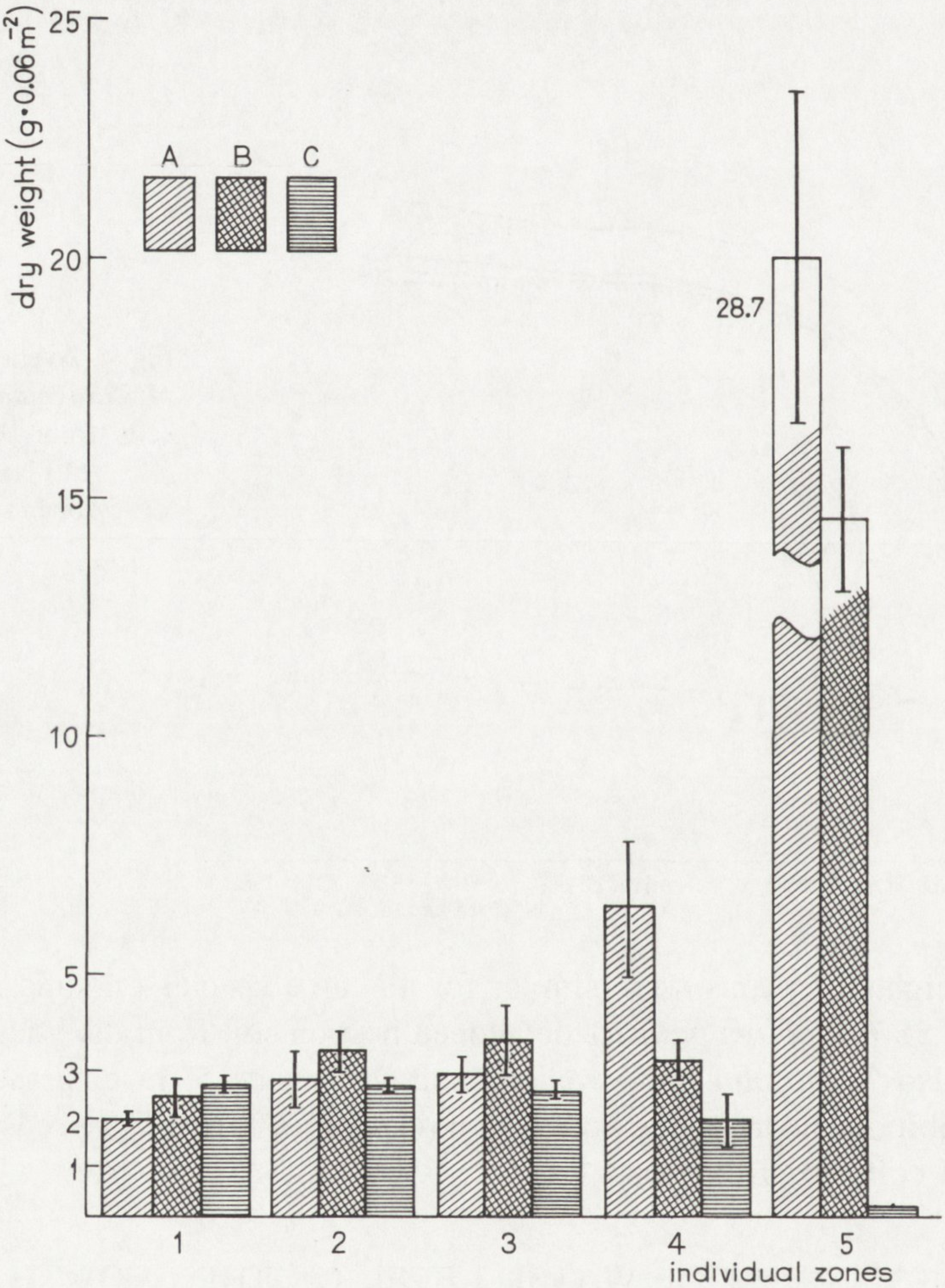

Fig. 5. Average plant weight (g): A – *Epilobium palustre*, B – *Typha latifolia*, C – *Phragmites australis* growing on soils from different zones of Pisna Kępa (averages of 3 replicas ± SD) Data for *T. latifolia* and *P. australis*, are from 20 Sept. 1983, for *Epilobium palustre* from 1 Aug. 1983. 1–5 zones (see Figure 1B)

paluster and *Malachium aquaticum*. In two or three treatments (Table 2) the following species were found: *Urtica dioica, Bidens cernuus, Ranunculus sceleratus, Rorippa amphibia, Lycopus europeus* and *Alnus glutinosa*. *Carex* sp., *Bidens tripartitus* and *Iris pseudoacorus* only occurred in the submersed conditions. High numbers of *Epilobium palustre* seedlings were found in all treatments with the maximum in treatment 1; however, the largest biomass of this species was noted in treatment 2 (Fig. 6). In the consecutive treatments, the percent contribution of *Epilobium palustre* biomass in the total biomass of all plants accounted for 97, 92, 94 and 92%. Respectively, the seedlings of this species comprised 46, 86, 65, and 55% of the total quantity of all seedlings. Thus, the biomass of *Epilobium palustre,* percent contribution of its seedlings to the total quantities, and the height of plants, reached the largest values in treatment 2, (Fig. 6), at the water level staying 1 cm below the soil surface.

Table 2. Species composition and numbers of plants on soils with varying water level. Period of experiment from 15 Dec. 1982 to 15 Apr. 1983

	Treatment	1	2	3	4
	Water level in relation to soil surface (cm)	–5	–1	0	+2.5
	Species number of individuals per 0.11 m^2				
1	*Epilobium palustre*	45	41	30	26
2	*Rumex hydrolapathum*	4			
3	*Polygonum* sp.	1			
4	*Rumex paluster*	1			
5	*Malachium aquaticum*	1			
6	*Urtica dioica*	9	1	1	
7	*Bidens cernuus*	3	1		1
8	*Ranunculus sceleratus*	2		1	
9	*Rorippa amphibia*	1		1	
10	*Lycopus europaeus*	3		1	4
11	*Typha latifolia*		1		3
12	*Scutellaria galericulata*		1	1	
13	*Alnus glutinosa*			1	3
14	*Carex* sp.				1
15	*Iris pseudoacorus*				1
16	*Bidens tripartitus*				1
17	Indeterminate sp. sp.	28	3	10	7
	Number of species	13	7	10	10
	Seedling numbers of all species per 0.11 m^2	9	48	46	47
	Dry weight of all species (g 0.11 m^{-2})	6.7	8.1	6.0	4.6

4. DISCUSSION

Complex environmental conditions, the kinds of substrate, and water level affect in a variety of ways the growth of plants. The abundance and species seed variation in soil are some of the major factors influencing the species composition of plants in a given environment. Species record of plants developed in the same environmental conditions does not provide a full information about the potential abundance of seeds in soil, the reason being, that many species have different requirements for germination. Van der Valk and Davis (1978) kept soil

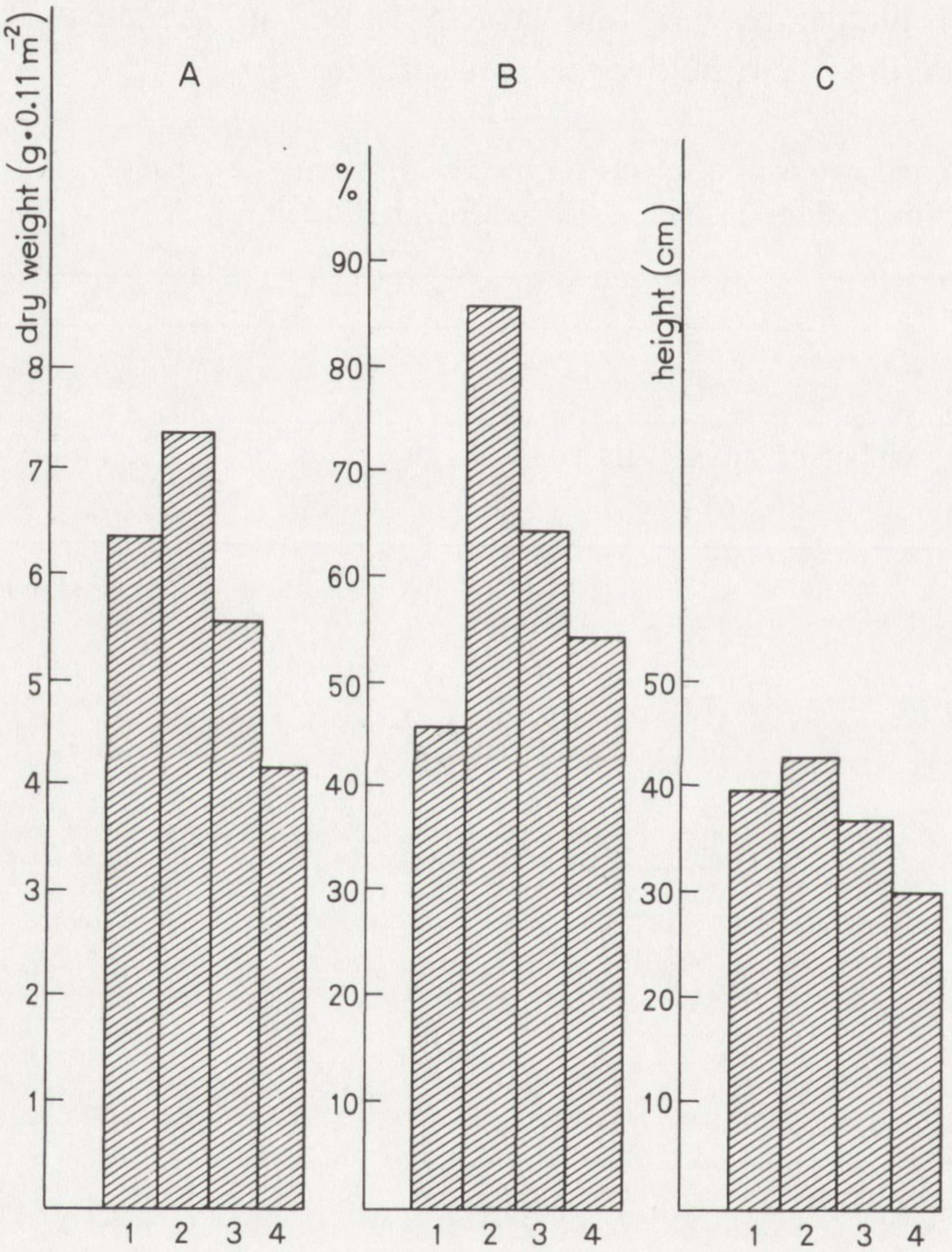

Fig. 6. Effect of water level on the growth of *Epilobium palustre* L.
A – biomass of *E. palustre* (g dry wt per 0.11 m^2), B – contribution (%) of *E. palustre* seedlings in relation to all plant seedlings, C – height of *E. palustre* (average from 5 heighest plants, cm). Water level: 1 – 5 cm below soil surface, 2 – 1 cm below soil surface, 3 – at the soil surface, 4 – 2.5 cm above soil surface

samples in two different environmental conditions and received considerably more species on exposed mud, than in submersed treatment. Poloni and Jonson (1989) investigated the effect of the period of submergence on the species composition of seedlings and found, that longer lasting submergence had decreased seed density in the open water zone. Thus, not only the numbers and quality of seeds in soil afffect the quantitative and qualitative composition of plants in a given environment, but it is also influenced by the conditions of germination and further growth. For example, not all the plant species which had germinated on soils from the marshy zones of Pisna Kępa had found suitable growth conditions in the natural marshy areas. To these belong such species, as *Urtica dioica* which occurred on soils from zones 3 and 5 in experiment 1, and *Alnus glutinosa*, the seeds of which had reached lake water from neighbouring trees, and were carried by waves to the youngest zone 5. Other own unpublished field observations confirm, that many seedlings of this species had disappeared without finding suitable conditions for development.

Soil type and inhibiting action of chemical substances – the phenomenon of allelopathy are the other environmental factors which may influence the seed germination and their further development (Rice 1974). Mc Naughton (1968) found that leaf extract of *Typha latifolia* was toxic for the seedlings of this species. Wołek (1979) observed, that media from the culture of *Wolffia arrhiza* (L.) Wimm. not only strongly inhibited the growth rate of *Spirodella polyrryza* (L.) Schleiden, but had also induced the production of turions of this species. This author suggested, that the appearence of pioneer species might be of value for the success of plant colonization not only with regard to the environmental resources, but also through the creation of a biological barrier. It has been found (Szczepańska 1987), that in unstable plant communities, at the early stages of succession, allelopathy steers the development of the system and determines its structure. Phytotoxic effects of plant remnants are dependent on the advancement of their decomposition (Kimber 1973). The strongest growth inhibition of wheat seedlings was observed by this author during the first 21 d of decomposition of Germineae and Leguminaceae. A similar phenomenon was noted by the present author. The highest growth inhibition of *Typha latifolia* and *Phragmites australis* occurred during the first weeks of the plant remnants decomposition (Szczepańska 1977). In the second experiment of the present study, where three marsh species were sown, the inhibition of germination and plant growth were observed on soils from the youngest zones, thus where the processes of the plant decomposition were just in the early stage, and were intensive enough. Small number of species and seedlings on soils from the youngest zones in experiment 1 (Table 1), and the necessity of three sowing replicates of *Phragmites australis* and *Typha latifolia* in experiment 2, may indicate the presence of toxic substances, the inhibitors of germination in these soils. In expriment 2 not all the species reacted in a similar way to the soil conditions of a given zone. No inhibition of germination was observed for *Epilobium palustre* on soil from zones 4 and 5 where the plants developed well. Conversely, inhibition of germination and of further growth was noted for *Phragmites australis* and *Typha latifolia* on soil from zone 5. A similar, as in experiment 2, process of growth inhibition for *P. australis* and *T. latifolia* at the early period of culture, was observed for both species growing on lake profundal mud with addition of plant debris (Szczepańska 1977). Very large quantitities of plant remains added (80 and 256 g per 4 l of mud) had even caused a disappearance of some seedlings. For *Typha latifolia*, the 20 days period of growth inhibition followed by growth acceleration the higher, the greater was the previous inhibition. *Phragmites australis* growing on plant remains of its own species, and those of *Typha latifolia*, did not later show any increase of growth rate (Szczepańska 1977). A similar phenomenon was observed in the present studies, in experiment 2. The results suggest, that only *Epilobium palustre* and *Typha latifolia*, may grow well on soils recently developed from plant remnants, while no appropriate growth conditions are found there for *Phragmites australis*.

Rabotnov (1981) shows different kinds of adaptations through detoxication, which enable the survival of plants in the presence of excretions by other plant species. In some cases detoxication is related to absorption of toxic substances by soil colloides. Bonner and Galston (1944) stated, that toxic substances are not durable and their concentration decreases with time.

Nowiński (1961) observed, that substances produced in the first stage of plant fragments decomposition, may have an inhibiting effect on the growth of neighbouring plants, and only following a longer period of their decomposition in soil, they form suitable substrate for plant growth. Experiment 2 of the present study corroborates this observation. Only in the late stage of culture, *Epilobium palustre* had developed well on soils from zones 4 and 5 (Figs. 2, 3). At the begining of culture this soil consisted of rather large, undecomposed plant fragments. This early period was one of fermentation and decomposition of plant matter in soil. While at the later stage of culture, *Epilobium palustre* and *Typha latifolia* developed very well on soil from zones 4 and 5, a growth inhibition of *Phragmites australis* on soil from zone 5 was observed throughout the culture period (Figs. 4, 5). This provides an evidence of various adaptation of plant species to environmental conditions. Variety of plant adaptations, or their different possibilities of soil detoxication, which provide suitable environment for a given species, may act as important factors controlling plant succession. The present experiments (mainly 2) suggest, that the youngest zone of the marshy part of Pisna Kępa should be at first colonized by *Epilobium palustre*, then by *Typha latifolia*, while *Phragmites australis* will develop on older soils.

Water level also regulates the occurrence of aquatic and marsh plant species. Hejny (1971) stated, that changes in water level determine plant distribution in the littoral zone. The role of water level in plant succession and formation of communities has been also emphasized by Van der Valk and Bliss (1971), Hejny and Husak (1978), Podbielkowski and Tomaszewicz (1979). In experiment 3, even very small changes in water level (from –5 cm to +2.5 cm) have induced differences in germination of individual species, in their numbers and biomass (Fig. 6, Table 2). For instance, the conditions in treatment 2, where water level remained just below soil surface, seems to be optimal for the growth of *Epilobium palustre*. These conditions affected the highest percent contribution of the seedlings, biomass and height of this species (Fig. 6). Most plant species and seedlings of all the plants have occurred in the driest environment. Dry weight of plants was lowest in the submersed habitat.

The present experiments showed, that there is a high range of factors influencing plant development from seeds contained in soil of a given environment. This is the reason, why in natural conditions one observes differences in the colonization by plants of shore zones in various stages of development and of varying age.

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5. SUMMARY

Three greenhouse experiments were conducted in 1983 for the purpose of recognition and understanding of some mechanisms of plant colonization and development on soils from the marshy part of Pisna Kępa, Mikołajskie Lake. This marshy part of Pisna Kępa had increased successively as a result of plant debris accumulation during autumn storms. In 1982, five zones which had formed at different times, were distinguished (Figs. 1A, 1B). The first zone was the oldest , and 5-th one the youngest, which had developed one year preceding the experiments. Soils from these zones were collected in autumn of 1982, and transferred to a greenhouse for the purpose of being used as a culture substrate. The studies included: composition and density of seedlings on soils from different zones of Pisna Kępa, the effect of soil age on the growth of chosen plant species and the effect of water level on the growth of these plants. First experiment showed, that *Epilobium palustre* occurred most numerously, and was followed by *Rorippa amphibia, Ranunculus sceleratus* and *Lycopus europaeus*. *Epilobium palustre* was most abundant on soil from the oldest zone 1 (70 seedlings per 0.5 m^2); less numerous on soil from zone 2 (35 seedlings); and only 2 individuals were present on soil from zones 3, 4 and 5 (Table 1). Soils from the older zones 1, 2, and 3 contained nearly the same numbers of species: 19 and 18. Their counts in younger zones were fewer; zone 4 (5), and zone 5 (8). The highest density of seedlings was found on soil from the oldest zone 1. Fewer numbers were observed in zone 2, and still less in soil of zone 3. The soil of zone 4 contained the least number of both species and seedlings. Although the soil of the youngest zone (5) had somewhat more species and seedlings than zone 4, however, it was accompanied by considerable dying of the young seedlings (53%) (Table 1).

Second experiment pertained to the development of three swamp species, *Epilobium palustre, Typha latifolia* and *Phragmites australis* on soils from different zones. The first species was found to grow best (from the middle of culture period) on soil from the youngest zone 5 (Fig. 2). *Typha latifolia,* in the first period of culture was much smaller on soil from zone 5 than from other zones. However, in the middle of the culture period it had reached there the largest height (Fig. 3). Growth of *Phragmites australis* on the soil of zone 5 was totally inhibited during the entire culture period. This species showed the best development on soil from the oldest zone (Figs. 4, 5).

The effect of water level on the growth of marsh species was investigated in experiment 3. It has been found, that even very small variations in the water level (from –5 cm to + 2.5 cm) affected both, the numbers of species and seedlings (Table 2). *Epilobium palustre* grew best where the water level stayed below soil surface (Fig. 6, Table 2).

6. POLISH SUMMARY

W 1983 r. przeprowadzono 3 eksperymenty szklarniowe mające na celu zapoznanie się z niektórymi mechanizmami osiedlania się i rozwoju roślin na glebach z bagnistej części Pisnej Kępy Jez. Mikołajskiego. Ta bagnista część Pisnej Kępy powiększała się sukcesywnie w wyniku akumulacji szczątków roślinnych podczas jesiennych sztormów. Wyróżniono tu w 1982 r. 5 stref w zależności od czasu powstania (rys. 1 A i 1 B). Pierwsza strefa była najstarsza, piąta najmłodsza, powstała rok przed eksperymentami. Gleby z tych stref pobrane w jesieni 1982 r.

przeniesiono do szklarni i na nich przeprowadzono hodowle. Badano: skład i zagęszczenie siewek na glebach w różnych strefach bagnistej części Pisnej Kępy, wpływ wieku gleby oraz poziomu wody na rozwój wybranych gatunków roślin bagiennych. W wyniku eksperymentu pierwszego stwierdzono, że najliczniej występującym gatunkiem było *Epilobium palustre,* następnie *Rorippa amphibia, Ranunculus sceleratus* i *Lycopus europaeus. Epilobium palustre* wystąpiło najliczniej na glebie ze strefy 1 najstarszej w liczbie 70 siewek na 0,5 m^2, w mniejszej liczbie osobników na glebie ze strefy 2 (35 siewek), a tylko 2 osobniki na glebie ze stref 3, 4 i 5 (tab. 1). Liczba gatunków na glebach ze starszych stref 1, 2 i 3 była prawie jednakowa, t.j. 19, 18 i 18, na glebach z młodszych stref 4 i 5 znacznie mniejsza (5 i 8). Liczba siewek była największa na glebie ze strefy 2, jeszcze mniejsza ze strefy 3. Na glebie ze strefy 4 było najmniej gatunków oraz siewek. Na glebie z najmłodszej strefy wystąpiło nieco więcej gatunków i siewek niż w strefie 4, jednocześnie jednak zaobserwowano duży procent usychania młodych siewek – 53% (tab. 1).

W eksperymencie drugim – dotyczącym rozwoju trzech bagiennych gatunków: *Eplilobium palustre, Typha latifolia* i *Phragmites australis* na glebach z poszczególnych stref stwierdzono, że *Epilobium palustre* było najdorodniejsze na glebie z najmłodszej strefy – 5 już od 8 lipca (rys. 2). *Typha latifolia* w początkowym okresie hodowli była znacznie mniejsza na glebie ze strefy 5 niż na glebach z innych stref, ale już w połowie okresu hodowlanego gatunek ten osiągał na tej właśnie glebie największe wysokości i biomasę (rys. 3, 5). Rozwój *Phragmites australis* na glebie ze strefy najmłodszej – 5 był całkowicie zahamowany przez cały okres hodowli. Natomiast najlepiej rozwijał się ten gatunek na glebie ze strefy 1 – najstarszej (rys. 4, 5).

Na podstawie eksperymentu trzeciego – dotyczącego wpływu poziomu wody na rozwój roślin bagiennych – stwierdzono, że nawet tak niewielkie różnice poziomu wody (od –5 do +2,5 cm) miały wpływ na liczbę gatunków oraz siewek (tab. 2). *Epilobium palustre* rozwijał się najlepiej tam, gdzie poziom wody był pod powierzchnią gleby (rys. 6).

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