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THE INFLUENCE OF ORGANIC FERTILIZATION ON THE TRANSPIRATION RATE IN HELOPHYTES*

ABSTRACT: Experiments were carried out to follow the effect of organic fertilization on the transpiration of six helophyte species: *Phragmites australis* (Cav.) Trin. ex Steud., *Glyceria aquatica* (L.) Wahlb., *Typha latifolia* L., *T. angustifolia* L., *Acorus calamus* L. and *Schoenoplectus lacustris* (L.) Palla. Liquid manure was found to have a strong inhibitory effect on the transpiration of helophytes, and when used as a 100% solution it caused plants to wilt within a short time. As a result of treatment with 25% liquid manure, the helophytes utilized less water to produce their biomass. Following the treatment, the water content in the plants varied much less than did the transpiration rate.

KEY WORDS: Helophytes, fertilization, transpiration rate, water content, laboratory investigations.

Contents

1. INTRODUCTION

In connection with the intensification of agriculture, in the Masurian Lakeland area the amounts of commercial (mineral) and organic fertilizers used in cropfields continue to increase. Nutrients are transported by precipitation waters into stagnant and ground waters, and become

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a menace to the natural environment. Liquid manure, one of the organic fertilizers used, is more dangerous to the waters than is the municipal sewage water, because it carries larger amounts of pollutants (Maćkowiak 1974) and contains large quantities of mineral substances, which cause a eutrophication of waters. The fertilizers flowing into bodies of water are in the first place in contact with the helophytes, the plants of the littoral zone. As treatment with fertilizers was known to affect some of the physiological processes of plants, including their water regime (Górski and Hoff 1953, Mamber-Rylska 1961), experiments were carried out to determine the effect of liquid manure on the transpiration process in the dominant helophyte species of the lake littoral.

2. MATERIAL AND METHODS

The investigations were carried out at the Wetland Research Laboratory, Institute of Ecology, Polish Academy of Sciences at Mikołajki, during the growing season of 1972. They covered six helophyte species: *Phragmites australis* (Cav.) Trin. ex Steud., *Glyceria aquatica* (L.) Wahlb., *Typha latifolia* L., *T. angustifolia* L., *Acorus calamus* L., and *Schoenoplectus lacustris* (L.) Palla. The study material consisted of plants produced from the rhizomes of the helophytes. Rhizomes with young shoots were collected from the littoral zones of three eutrophic lakes: Bełdany (*Glyceria aquatica*), Tałty (*Typha latifolia*, *Phragmites australis*, *Acorus calamus* and *Schoenoplectus lacustris*), and Inulec (*Typha angustifolia*). The rhizomes were subsequently planted in sandy garden soil in plastic pots, each 5 l in capacity. The planting was done in the first days of June. The soil in the pots was watered so that there was always a layer of water (about 10 mm) above the surface. After new shoots had appeared, the old ones, i.e., those that had been above the substrate surface at the time of planting the rhizomes, were cut off. For each of the species under observation 40 pots with seedlings were prepared. The soil in the pots containing the helophytes was treated with liquid manure, in which the following amounts of the essential components were contained: 3.69 g/l org. $N + N{-}NH_4$, 0.025 g/l total P, and 5.2 g/l total K (M. Planter – unpublished data). The liquid manure was used in the following concentrations: 100%, 50% and 25%, unchlorinated tap water being used to obtain the dilution required. During the growing season the fertilizer was applied 9 times at the following dates: (1) 21 June, (2) 1 July, (3) 11 July, (4) 21 July, (5) 31 July, (6) 10 August, (7) 20 August, (8) 30 August, and (9) 9 September, that is, every 10 days the plants received a new amount of the fertilizer.

Prior to each treatment with the fertilizer (1 l of the liquid manure per pot) the transpiration rate and the content of water in the leaves, or shoots (*Schoenoplectus lacustris)* of the plants were measured. Apart from this, the leaf biomass produced by the treated and the control plants was also determined. For the measurements 3 samples were taken for each species, taking into account all the manure concentrations used. Each sample consisted of 3 the youngest, fully developed leaves, and in the case of *Schoenoplectus lacustris* - 3 shoots, randomly selected. The samples were taken simultaneously for the treated and the control plants; the same analysis manner was applied.

The transpiration rate of the helophytes was determined by the quick-weighing method (Ivanov, Silina and Celniker 1950), using a torsion balance (type WT, accuracy to 1 mg), specially adjusted to the weighing of leaves, and used for this purpose in previous investigations of transpiration (Królikowska 1972, Durska 1974). During the measurements of transpiration the temperature and relative air humidity were recorded. The water content in the plant material was determined from the difference between the fresh and dry weights, found after drying the material to a constant weight at 105°C.

3. RESULTS

During the measurement of the transpiration of the helophytes the air temperature varied between 20.6 and 33.6°C, while the relative air humidity ranged from 88 to 52%. The higher the air temperature was, and the lower the relative air humidity, the higher was the transpiration rate in both the control and treated plants (Fig. 1).

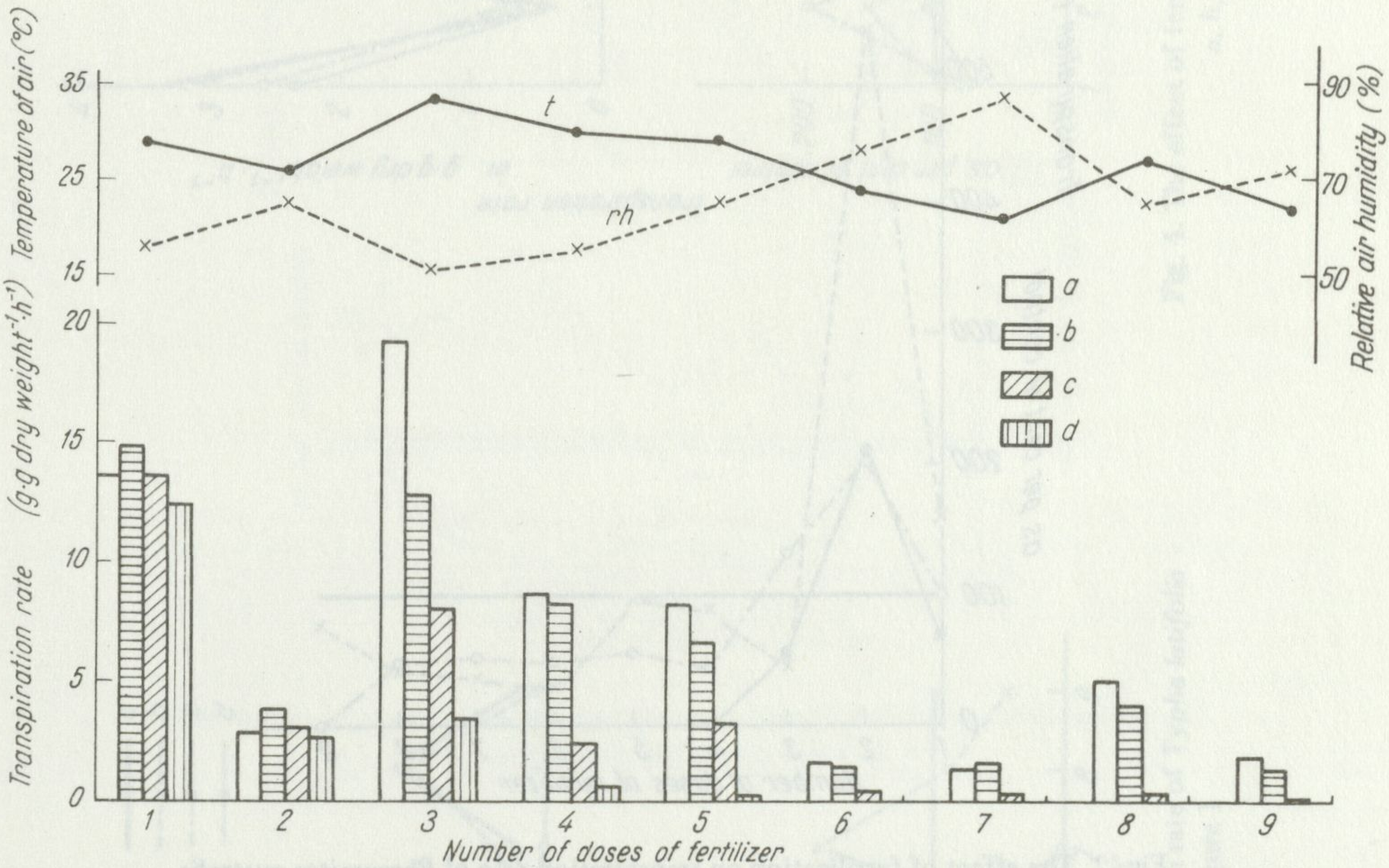

Fig. 1. The effect of fertilization on total transpiration rate of helophytes
a – control, *b* – 25% fertilizer, *c* – 50% fertilizer, *d* – 100% fertilizer

Due to the fertilization, the transpiration rate varied, depending on the concentration of the fertilizer, the number of treatments, and on the plant species. Ten days after the first treatment with the fertilizer an increase in the transpiration rate, relative to the control plants, was seen in *Phragmites australis*, *Typha latifolia*, and in *Acorus calamus*, *Phragmites australis* plants treated with 100% liquid manure being an exception (Fig. 2). The strongest stimulation of the process of transpiration occurred in *Typha latifolia* as a result of treatment with 100 and 50% liquid manure, the transpiration rate being about 100% higher than in the controls (Fig. 3). For *Typha angustifolia*, *Schoenoplectus lacustris* and *Glyceria aquatica* (the latter except 25% liquid manure) a lowered transpiration rate was recorded after the first treatment with the fertilizer (Figs. 4–6).

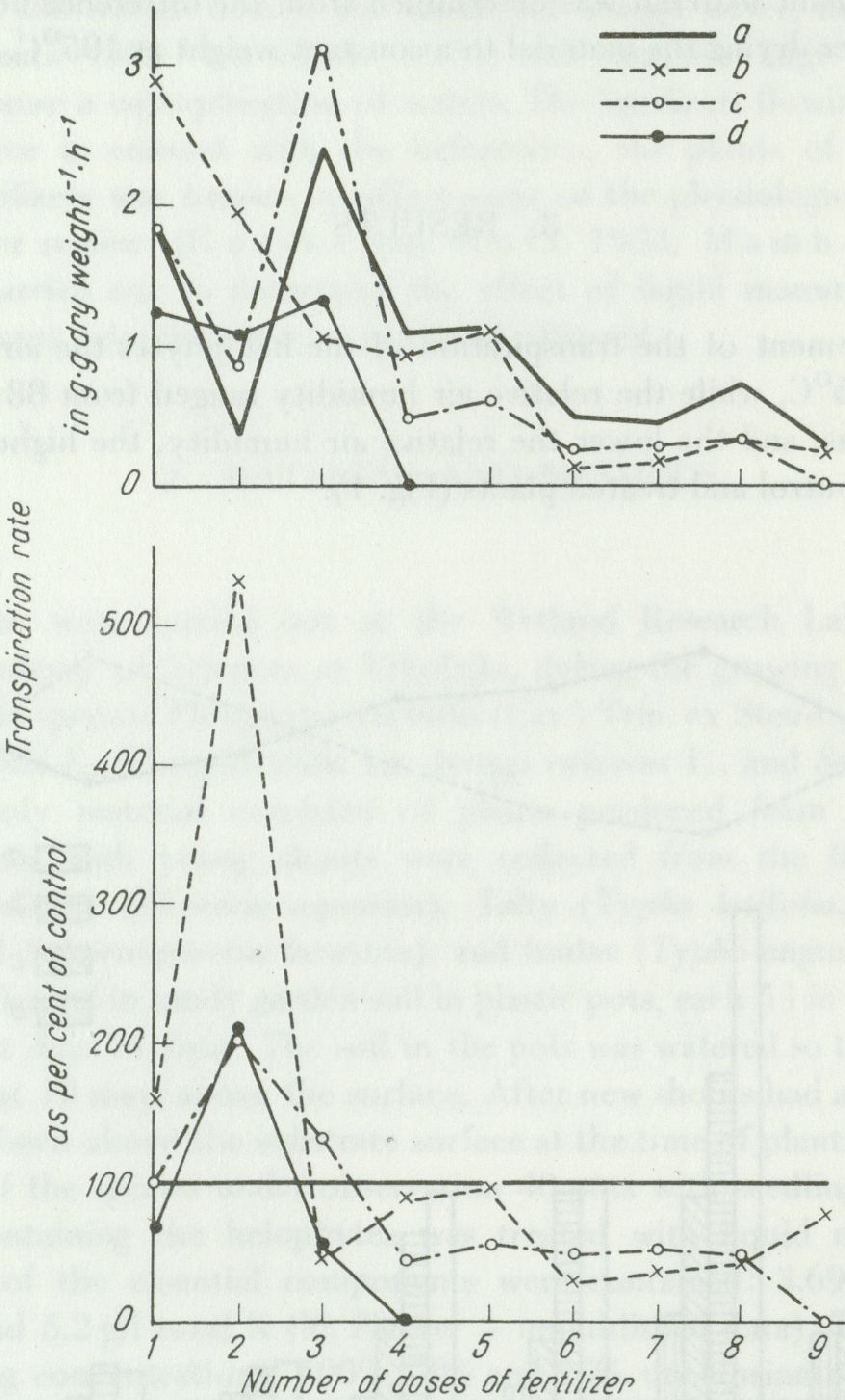

Fig. 2. The effect of fertilization on transpiration rate of *Phragmites australis*
a, b, c, d – denotation as in Figure 1

The second treatment with the fertilizer (in the second 10-days' period of July) was followed by an increase in the transpiration rate in *Phragmites australis*, *Typha angustifolia* and *Schoenoplectus lacustris*, treated with the liquid manure in all the concentrations used, while *Glyceria aquatica* transpired much less water than did the control plants. After the second treatment, the greatest changes in the transpiration rate were found in *Phragmites australis* treated with 25% liquid manure. The transpiration rate was found to be 400% higher than in the controls (Fig. 2).

In the third 10-days' period of July, the untreated helophytes attained the maximum values of transpiration for the study period. Among the treated plants (3rd treatment) it was only *Phragmites australis*, treated with 50% liquid manure, and *Schoenoplectus lacustris* – 25% liquid manure, that showed a slightly higher, than in the controls, transpiration rate, whereas in the remaining helophyte species a strong inhibition of transpiration was seen.

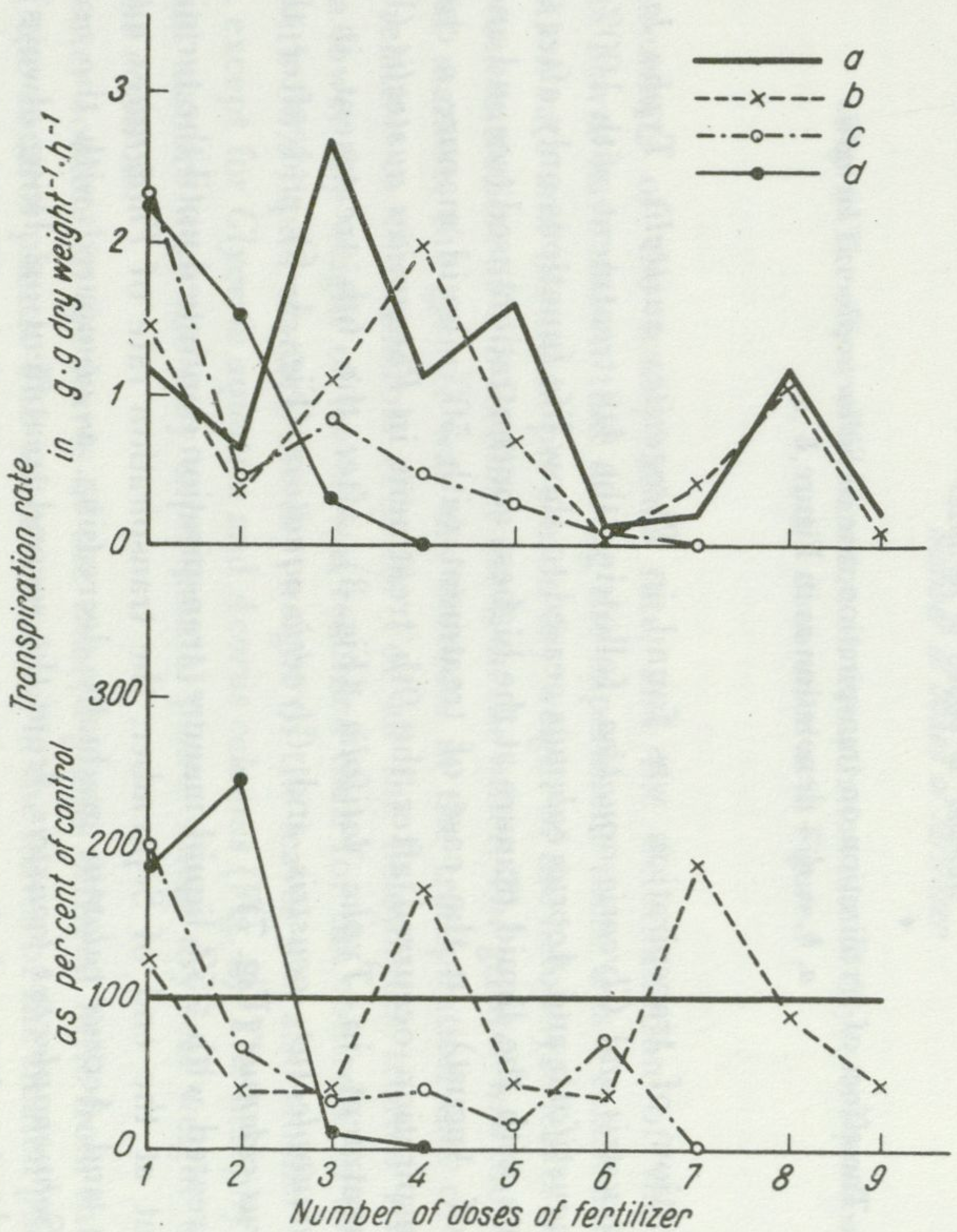

Fig. 3. The effect of fertilization on transpiration rate of *Typha latifolia*
a, b, c, d **— denotation as in Figure 1**

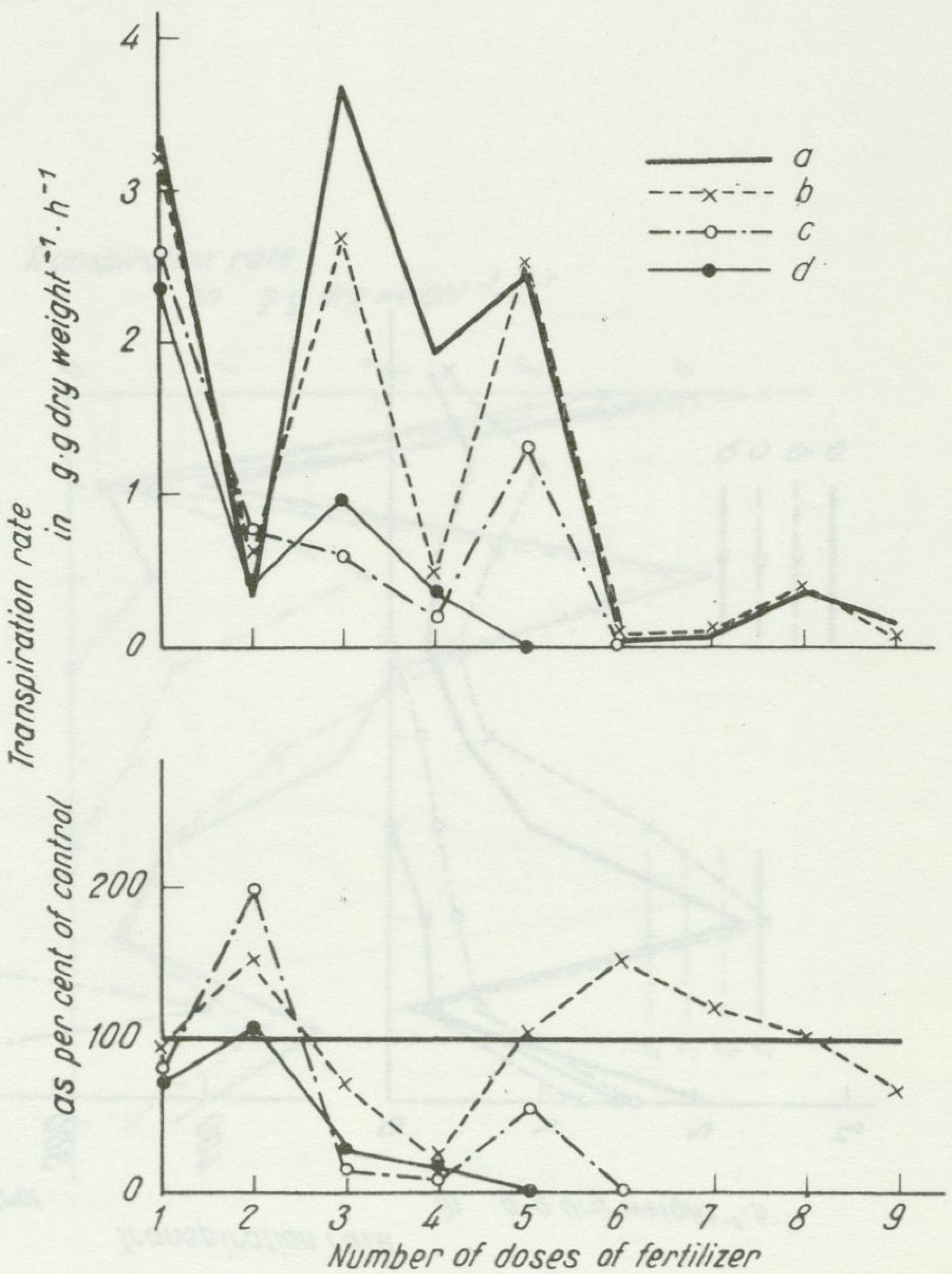

Fig. 4. The effect of fertilization on transpiration rate of *Typha angustifolia*
a, b, c, d **— denotation as in Figure 1**

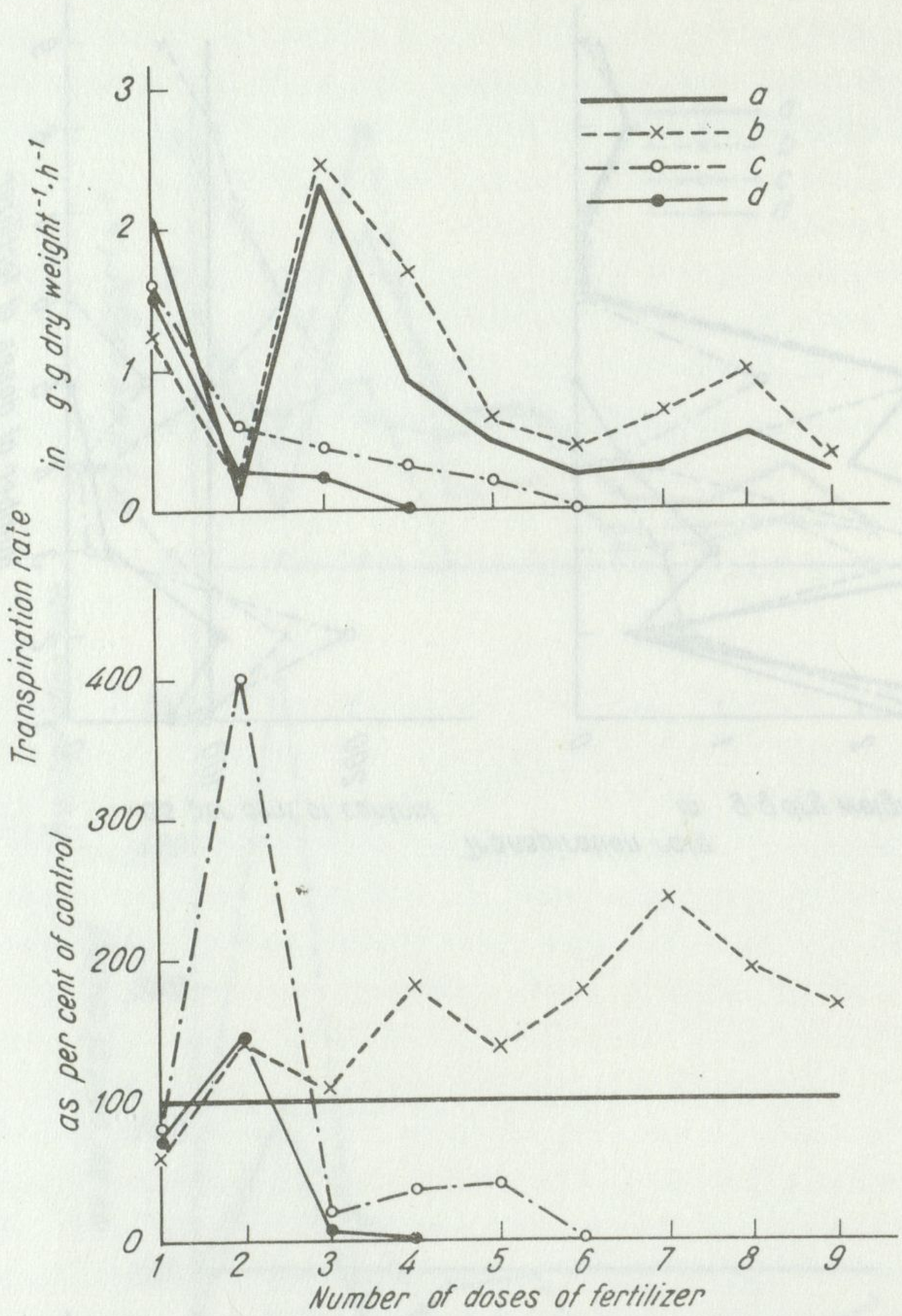

Fig. 5. The effect of fertilization on transpiration rate of *Schoenoplectus lacustris*
a, *b*, *c*, *d* – denotation as in Figure 1

A complete inhibition of transpiration was found in *Phragmites australis*, *Typha latifolia*, *Schoenoplectus lacustris* and *Glyceria aquatica*, following the 4th treatment with 100% liquid manure. *Typha angustifolia* and *Acorus calamus* ceased to show life functions only after the 5th and 6th treatments with the liquid manure at the highest concentration used (second and third 10-days' period of August). In the case of treatment with 50% liquid manure a complete inhibition of transpiration occurred after the 9th treatment in *Phragmites australis* (Fig. 2), after the 7th treatment in *Typha latifolia* (Fig. 3), after the 6th treatment in *Typha angustifolia*, *Schoenoplectus lacustris* and *Glyceria aquatica* (Figs. 4–6), and after the 8th treatment in *Acorus calamus* (Fig. 7).

In the plants treated with 25% liquid manure, transpiration continued until the termination of the experiment at the end of September, the transpiration rate of *Phragmites australis*, *Glyceria aquatica* and *Acorus calamus* gradually decreasing, as compared with the controls, whereas that of *Schoenoplectus lacustris*, from the second treatment on, being always higher than in the controls.

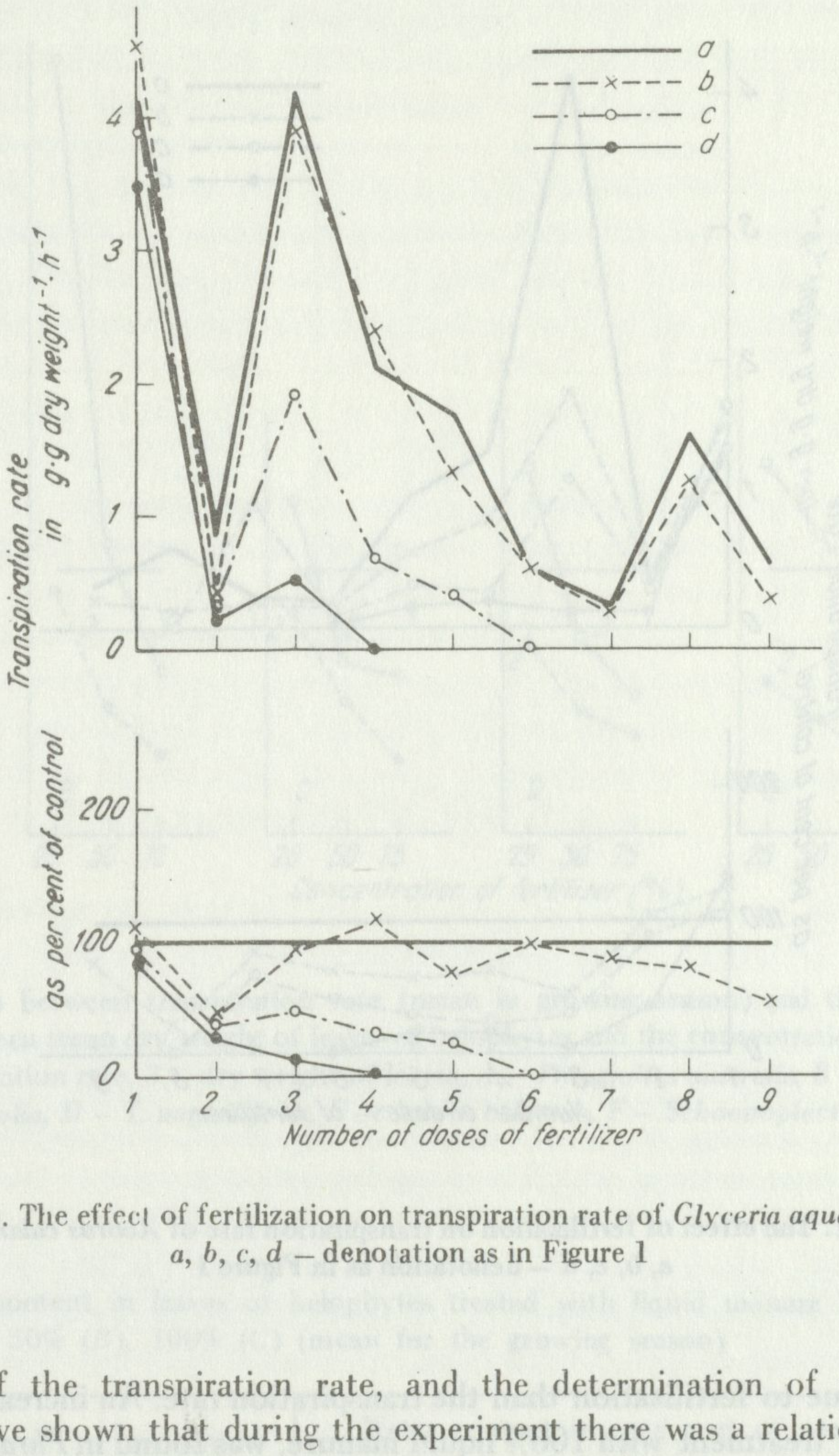

Fig. 6. The effect of fertilization on transpiration rate of *Glyceria aquatica*
a, *b*, *c*, *d* – denotation as in Figure 1

Measurements of the transpiration rate, and the determination of the dry weight of helophyte leaves have shown that during the experiment there was a relationship between the transpiration rate and the mean per season dry weight of the helophyte leaves on the one hand, and the concentration of the fertilizer used, on the other. The greater was the concentration of the liquid manure, the greater was the decrease in the transpiration rate of the helophytes treated, relative to the controls (Fig. 8). For all the helophytes treated with 100% liquid manure a lower dry weight of leaves was recorded than for the controls. In the case of plants treated with 50% liquid manure the dry weight of the leaves was also smaller than that of the controls, except for *Glyceria aquatica* and *Acorus calamus* (Fig. 8). The helophytes treated with 25% liquid manure were the only experimental plants whose dry leaf weight was greater than that of the controls.

The water content in the leaves of the treated plants differed little from that found for the leaves of the control plants. The water contained in the leaves of the treated plants represented from 91.2 up to 101.5% of the water content in the control plants, thus being subject to less

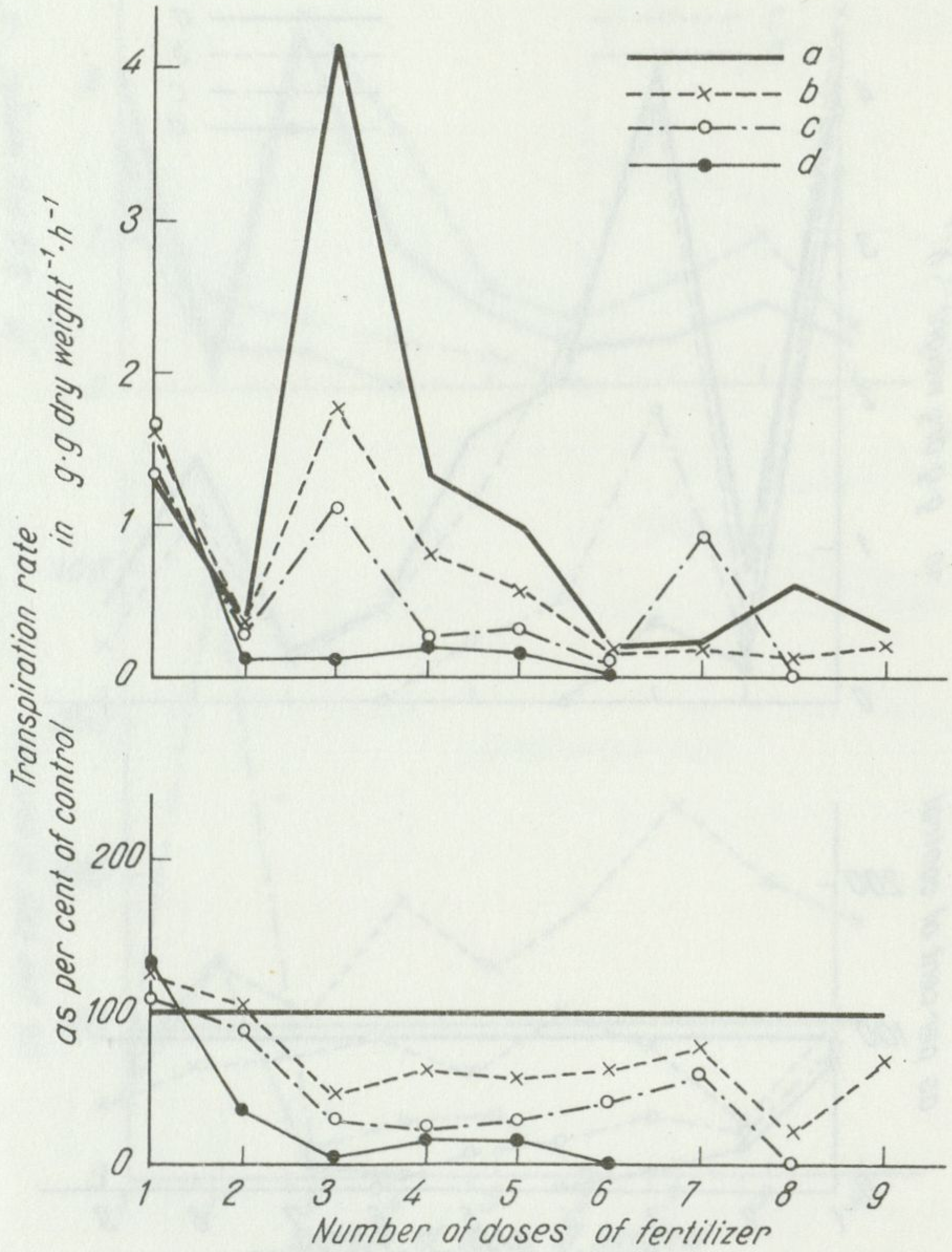

Fig. 7. The effect of fertilization on transpiration rate of *Acorus calamus*
a, b, c, d **— denotation as in Figure 1**

marked variations due to fertilization than the transpiration rate. An increase in the content of water, as a result of treatment with 100% liquid manure, was found in *Phragmites australis* and *Glyceria aquatica*, as also in the shoots of *Schoenoplectus lacustris* (Table I).

From the values of the water content in the leaves after each successive treatment with the fertilizer, used in three different concentrations, the changes in the water content in the leaves of the helophytes studied were calculated. Due to the treatment with 25% liquid manure, a little higher water content in the leaves of the helophytes was found during the period from the 20th to the 60th day following the first treatment, whereas towards the end of the experiment the water content in the leaves was lower than in the control plants. The greatest lowering of the water content, relative to the controls, was found in the leaves of plants treated with 100% liquid manure, but again it did not exceed 10% (Table II).

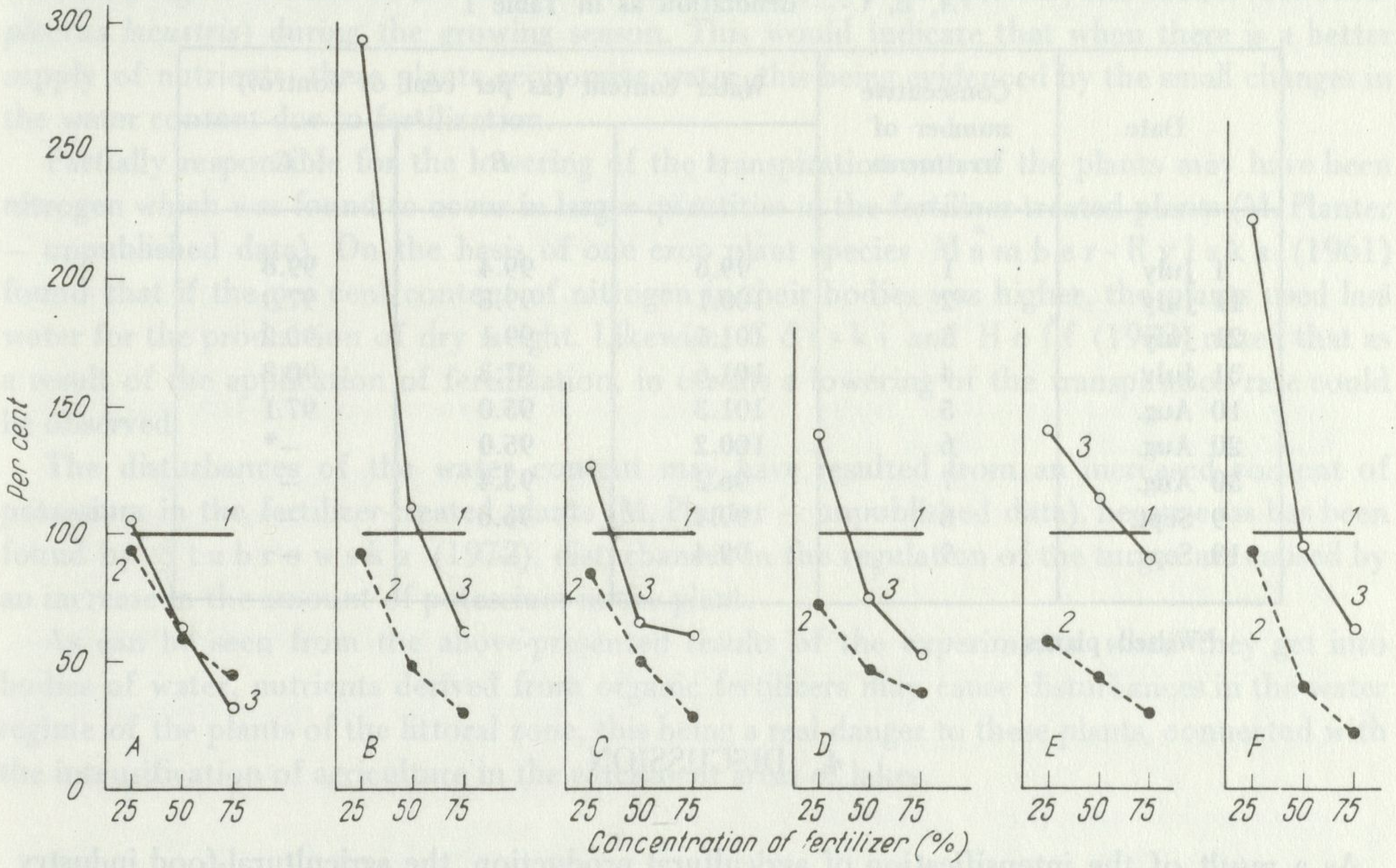

Fig. 8. The relationship between transpiration rate (mean in growing season) and the concentration of fertilizer and between mean dry weight of leaves of helophytes and the concentration of fertilizer
1 – control, 2 – transpiration rate, 3 – dry weight of leaves, A – *Phragmites australis*, B – *Glyceria aquatica*, C – *Typha latifolia*, D – *T. angustifolia*, E – *Acorus calamus*, F – *Schoenoplectus lacustris*

Table I. Water content in leaves of helophytes treated with liquid manure 25% (*A*), 50% (*B*), 100% (*C*) (mean for the growing season)

Plant	Water content (as per cent of control)		
	A	*B*	*C*
Phragmites australis	101.5	97.2	98.5
Glyceria aquatica	100.8	97.2	98.0
Typha latifolia	97.6	95.3	94.3
T. angustifolia	99.5	98.3	96.7
Acorus calamus	98.6	97.6	91.2
*Schoenoplectus lacustris**	101.5	100.5	95.2

*Shoots.

Table II. Changes of water content in leaves of helophytes (mean for species investigated caused by fertilization) during the growing season
A, *B*, *C* – denotation as in Table I

Date	Consecutive number of treatments	Water content (as per cent of control)		
		A	*B*	*C*
1 July	1	99.6	99.4	99.8
11 July	2	100.1	99.8	97.9
21 July	3	101.5	99.1	90.2
31 July	4	101.6	97.3	90.8
10 Aug.	5	101.3	95.0	97.1
20 Aug.	6	100.2	95.0	–*
30 Aug.	7	96.2	93.4	–
9 Sept.	8	99.4	96.6	–
19 Sept.	9	99.4	–	–

*Wilted plants.

4. DISCUSSION

As a result of the intensification of agricultural production, the agricultural-food industry uses large amounts of water, at the same time producing equally large amounts of effluents which are dangerous to aquatic ecosystems.

The experiments in which helophytes were treated with liquid manure have shown that when applied in the form of a 100% solution, this fertilizer caused disturbances in the life processes of plants, leading on to the death of the latter. The experiments have shown disturbances in the transpiration, which is a very important process in the life of a plant. The immediate cause of this was the dying of the underground parts of the helophytes due to the decaying of the roots, which made it difficult for the plants to take up water. Dzieżyc (1974) found that high concentrations of soil solutions impeded the uptake of water by plants and created unfavourable oxygen conditions in the substratum, which finally caused the plants to wilt.

Similar processes were observed by Bassalik (1955) in the case of treatment with manure. He found that fertilization had a negative effect on the metabolism of the roots, reducing their functional capacity, and that as a result of oxygen deficiency the plants produced substances which inhibited their growth and life functions. Because of its high utilization of oxygen, the liquid manure is a real danger to aquatic organisms when it flows into aquatic ecosystems in large amounts, the BOD of liquid manure being 20,000 mg/l O_2 (Maćkowiak 1974).

As has been reported by many authors, the runoff of nutrients from intensely fertilized fields is the result of a wrong use of fertilizers, where the objective of fertilization is to treat the soil, and not to supply the plants with the nutrients they need (Jaag 1972, Jung 1972, Olson 1972, Wróbel 1974). Brought into bodies of water, the substances derived from organic and commercial (mineral) fertilizers at first get into the zone colonized by the helophytes.

As has been proved experimentally, diluted liquid manure caused a fall in the transpiration rate of the helophytes, relative to the control plants. At the same time fertilizer-treated plants showed a higher increase in the biomass of their leaves (*Glyceria aquatica*) and shoots (*Schoenoplectus lacustris*) during the growing season. This would indicate that when there is a better supply of nutrients, these plants economize water, this being evidenced by the small changes in the water content due to fertilization.

Partially responsible for the lowering of the transpiration rate of the plants may have been nitrogen which was found to occur in larger quantities in the fertilizer-treated plants (M. Planter – unpublished data). On the basis of one crop plant species Mamber-Rylska (1961) found that if the per cent content of nitrogen in their bodies was higher, the plants used less water for the production of dry weight. Likewise, Górski and Hoff (1953) noted that as a result of the application of fertilization, in cereals a lowering of the transpiration rate could be observed.

The disturbances of the water content may have resulted from an increased content of potassium in the fertilizer-treated plants (M. Planter – unpublished data), because, as has been found by Stabrowska (1972), disturbances in the regulation of the turgor are caused by an increase in the amount of potassium in the plant.

As can be seen from the above-presented results of the experiments, when they get into bodies of water, nutrients derived from organic fertilizers may cause disturbances in the water regime of the plants of the littoral zone, this being a real danger to these plants, connected with the intensification of agriculture in the catchment areas of lakes.

5. SUMMARY

In the growing season of 1972 experimental studies were carried out to determine the effect of an organic fertilizer – liquid manure – on the transpiration of six helophyte species: *Phragmites australis, Glyceria aquatica, Typha latifolia, T. angustifolia, Acorus calamus* and *Schoenoplectus lacustris*. Treatment with the fertilizer was repeated every 10 days, from June to September. Prior to each treatment the transpiration rate was measured. The following liquid fertilizer concentrations were used: 100, 50 and 25%; plants watered with unchlorinated tap water were used as controls.

During the transpiration rate measurements the temperature and relative air humidity were recorded, and samples were collected for the determination of the water content and the biomass of the plant material.

The results of the experiments indicate that when used in high concentrations, the liquid manure causes considerable disturbances in the transpiration process (Figs. 2–7), leading on to the death of the plants. In some of the helophytes a diluted solution of the fertilizer caused a more economic utilization of water by the plants, that is to say, the plants used smaller amounts of water to produce dry weight than did the untreated plants (Fig. 8), changes in the water content of their leaves being insignificant (Tables I, II).

6. POLISH SUMMARY

W sezonie wegetacyjnym 1972 r. przeprowadzono badania eksperymentalne nad wpływem nawozu organicznego – gnojowicy – na transpirację sześciu gatunków helofitów: *Phragmites australis, Glyceria aquatica, Typha latifolia, T. angustifolia, Acorus calamus* i *Schoenoplectus lacustris*. Nawożenie przeprowadzano co 10 dni, w okresie od czerwca do września, prowadząc pomiary intensywności transpiracji przed każdym kolejnym nawożeniem. Stosowano 100, 50 i 25% gnojowicę; kontrolę stanowiły rośliny podlewane wodą wodociągową niechlorowaną.

W czasie wykonywania pomiarów transpiracji rejestrowano temperaturę i wilgotność względną powietrza oraz pobierano materiał do określenia zawartości wody i biomasy roślin.

W wyniku przeprowadzonych doświadczeń stwierdzono, że gnojowica stosowana w roztworach o dużych stężeniach powoduje silne zaburzenia w procesie transpiracji (rys. 2–7), w końcowym efekcie powodując obumieranie roślin. Rozcieńczony nawóz w przypadku niektórych helofitów powodował bardziej oszczędne gospodarowanie wodą przez rośliny, tzn. na wyprodukowanie suchej masy zużywały one mniej wody niż rośliny nie nawożone (rys. 8), przy czym stwierdzono niewielkie zmiany w zawartości wody w liściach roślin (tab. I, II).

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