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THE INFLUENCE OF NITROGEN AND POTASSIUM FERTILIZATION ON THE PRODUCTION AND WATER RELATIONS OF *TYPHA LATIFOLIA* L.*

ABSTRACT: Experiments have been carried out which have shown that when used separately, nitrogen and potassium have a slightly different effect on a plant than when used simultaneously. As a result of a high-rate nitrogen-potassium treatment *Typha latifolia* utilized water more economically than when treated with nitrogen or potassium, at the same time showing a high biomass production.

KEY WORDS: Greenhouse experiments, *Typha latifolia*, fertilization, water relation, biomass.

Contents

1. INTRODUCTION

For a high biomass increase a plant needs more water and nutrients. The intake of water and mineral salts by a plant is to a large extent genetically determined. For this reason, the nutrient and water requirements of individual plant species, and even varieties, are different (Tarkowski 1978). The water required by a plant is needed mainly to replace

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the water lost due to transpiration. The climatic and food conditions of a habitat control the water balance of a plant (Mamber-Rylska 1961, Christersson 1973, 1976, Samuilov 1974 and others). In the case of plants of the littoral, well supplied with water, the factor controlling their production and water regime is the supply of nutrients. These plants play an important role in aquatic ecosystems by exerting an influence on their food and water relations (Wolny 1956, Eisenlohr 1966, Beideman and Pautova 1969, Bernatowicz, Leszczyński and Tyczyńska 1976, Królikowska 1978b, Szczepański 1978). The development and intensification of agriculture, fertilization of fields with ever-growing amounts of mineral fertilizers cause a marked rise in the concentration of nutrient salts in waters. Cropfield surface runoff gets at first into the lake littoral inhabited by helophytes. To study the effect of mineral fertilizers on the production and water regime of the helophytes, experiments were carried out on *Typha latifolia*.

2. MATERIAL AND METHODS

The experiments were carried out under greenhouse conditions in the years 1977 and 1978, from mid-June to end of July in either year. During the experiments, the air temperature in the greenhouse ranged from 14°C at night to 35°C at daytime and the air humidity from 95 to 40%, respectively.

The material consisted of *Typha latifolia* seedlings grown in germination boxes on lake mud and then, after they had attained the height of about 20 mm, transplanted to small (150 ml capacity) culture vessels. Subsequently, young plants, about 200 mm tall, were transplanted to proper experimental pots (5 l capaeity), three plants in each pot. The pots were filled with lake mud which contained: N – 1.52%, P – 0.13% and K – 0.08%.

The mud used for the experiments was enriched with mineral fertilizers: ammonium nitrate (36.6% total N) and potassium salt (61.2% K_2O). The basic experimental amounts used were: 1 N – 1.374 g of ammonium nitrate und 1 K – 1.377 g of potassium salt. The aim of using these basic amounts was to maintain the same N to K ratio in the fertilizer-enriched substrate as that found in the lake mud used.

To determine the effect of nitrogen, the following doses were used: 0, 1, 2 and 3 N with constant 1 K. The effect of potassium on the production and water regime of *Typha latifolia* was determited using doses of 0, 1, 2 and 3 K with constant 1 N. The experiment also consisted in a simultaneous fertilization with nitrogen and potassium, using doses of: 0, 1, 2 and 3 NK.

To replace the water lost due to evapotranspiration, throughout the experiment measured amounts of water were added to the pots. Once a week the height was measured of all shoots. i.e., those planted (parent) and the new ones that appeared. After 6 weeks the following measurements were made: dry weight of the aboveground parts of each shoot, dry weight of underground parts in each pot, length of all shoots (shoot height from root neck to the tip of the longest leaf), and the young shoots were counted in each pot. To determine the coefficient of transpiration, that is, the amount of water used for the production of 1 g of dry plant weight, the amounts of water added to a pot during the experiment were totalled and the result was compared with the total amount of water added to the control vessel containing only lake mud covered by a water layer. By measuring the height of the shoots at constant time intervals the growth rate was determined of the planted plants and of young shoots. The difference between the wet and dry weights of the above-ground parts of the plants was used for determining the ratio of water content to dry weight content in a *Typha latifolia* shoot. The results presented are the mean values from 3 replications, whereas in the tables standard deviations are given in addition to the average values. A basic statistical analysis of the data in the drawings has also been carried out.

3. RESULTS

3.1. NITROGEN FERTILIZATION

Typha latifolia growing on a substrate enriched with different nitrogen doses, but in the presence of 1 K, was always of an intensely dark-green colour. Treatment with 3 N resulted in an exuberant growth of the plants and on young leaves transversal folds could be seen (Fig. 1). Within a short time the plants began to turn down (Fig. 2). The growth rate of nitrogen-treated *Typha latifolia* changed with the time. Non-treated plants and those treated with 1 N attained a maximum growth rate in the 2nd week (27.3 and 29.9 mm · · 24 h^{-1}). In the next weeks their growth rate values decreased. However, until the end of the experiment the growth rate of plants treated with 1 N was higher than that of plants growing on a substrate without nitrogen (Fig. 3). *Typha latifolia* plants treated with 2 N and 3 N attained the highest growth rate in the 3rd week, the rate amounting to 32.8 and 29.3 mm · 24 h^{-1}, whereafter it dropped gradually (Fig. 3).

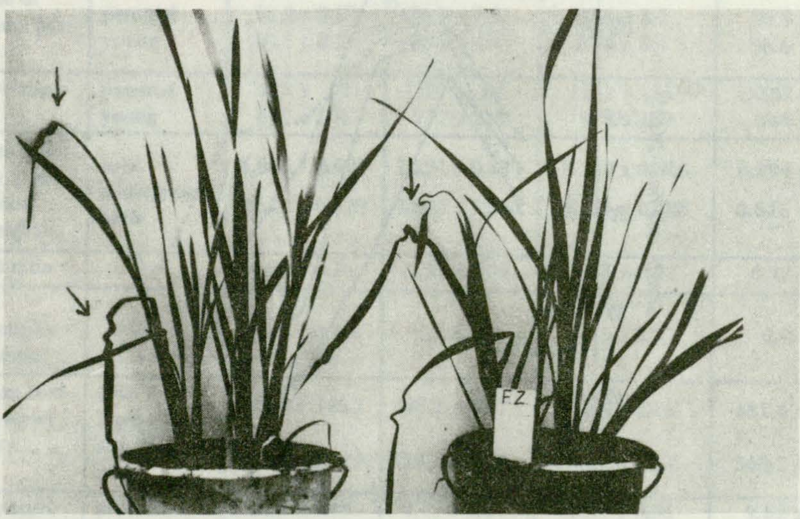

Fig. 1. Changes in normal growth of young leaves of nitrogen fertilized *Typha latifolia* (photo J. Królikowska)

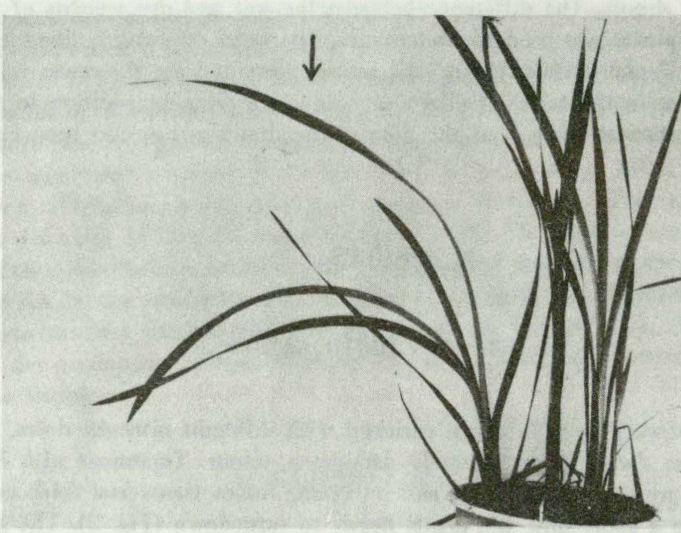

Fig. 2. Changes in normal growth of a shoot of nitrogen fertilized *Typha latifolia* (photo J. Królikowska)

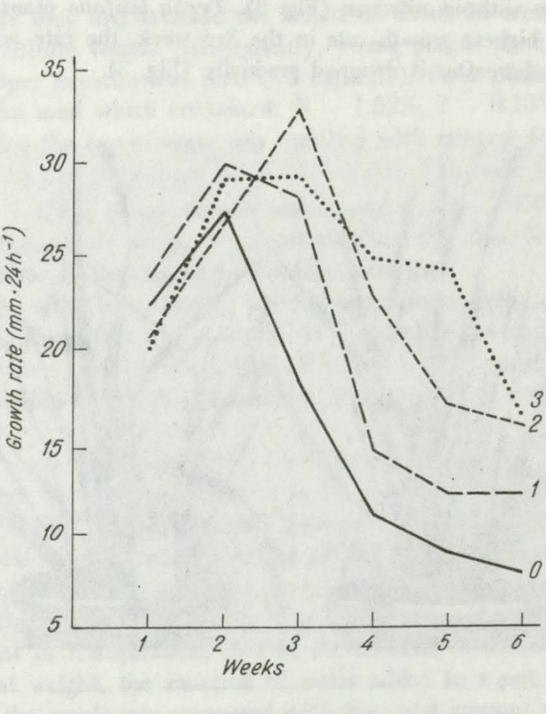

Fig. 3. The effect of nitrogen fertilization on the growth rate of *Typha latifolia* (in the presence of 1 dose of potassium)

0, 1, 2, 3 – numbers of fertilizer doses

In the 1st and 2nd weeks the growth rate differences among the plants treated with different nitrogen doses were not significant (at the level of 95%). In the 3rd week the growth rate of treated plants already differed significantly from the controls, but in the 4th week significant differences were found between the controls and plants treated with 2 N and 3 N, and also between those treated with 1 N and 2 and 3 N. Next week the growth rate of plants treated with the highest dose of nitrogen was significantly different from that of both the control and plants treated with lower nitrogen doses. It was also found that the fertilization with 2 N already caused a significant diversification of the growth rate relative to the control. In the last experimental week the growth rate of the controls significantly differed from that of plants treated with 2 N and 3 N.

Parent plants and the young ones that came up during the experiment showed a growth rate dependent on the nitrogen level in the substrate, the higher the nitrogen level, the higher the growth rate. Obviously, young shoots always showed a higher growth in height against time than that of the parent plants (Table I). The height attained by parent plants at the end of the 6th week was greatest in the case of treatment with 3 N (1307 mm – Table I), while young shoots attained a variable average final height, depending on their numbers and time of appearance above the surface of the substrate. The largest numbers of young shoots were produced by parent plants growing on a substrate enriched with 2 N, where there were 1.3 young shoots per each parent plant (Table I).

Table I. The effect of nitrogen fertilization on the production and water relations of *Typha latifolia* (with 1 dose of potassium present)

Index	Subindex	Number of N doses: 0	1	2	3
Growth rate of shoots (mm per 24 h)	parental young	16.0 ± 2 5* 18.1 ± 2.2	20.2 ± 1.9 24.0 ± 4.4	22.6 ± 3.2 27.4 ± 3.4	23.9 ± 2.5 26.6 ± 9.4
Final shoot length (mm)	parental young	913 ± 91 627 ± 109	1127 ± 84 777 ± 215	1232 ± 145 978 ± 139	1307 ± 100 666 ± 386
The biomass produced by 1 parental shoot (g dry weight)	total aboveground parts	4.815 ± 0.906 2.612 ± 0.672	7.221 ± 0.333 4.685 ± 1.503	9.310 ± 0.315 6.724 ± 0.283	8.394 ± 1.903 6.615 ± 1.468
Root/shoot ratio		0.88 ± 0.16	0.55 ± 0.09	0.38 ± 0.02	0.27 ± 0.08
Number of shoots from 1 parental shoot		1.0 ± 0.7	1.2 ± 0.2	1.3 ± 0.3	0.9 ± 0.7
Transpiration coefficient (g water per 1 g dry weight)	total biomass aboveground parts	592.0 ± 106.3 1118.8 ± 299.9	488.7 ± 43.7 753.7 ± 53.4	422.5 ± 45.3 585.6 ± 70.0	431.4 ± 37.8 549.7 ± 76.8
Water/dry weight ratio in shoots	parental young	8.52 ± 0.78 7.86 ± 0.94	8.49 ± 0.57 8.41 ± 0.51	8.51 ± 0.55 8.08 ± 0.82	9.52 ± 1.82 7.50 ± 2.91
Evapotranspiration/evaporation		2.70 ± 0.09	3.43 ± 0.45	3.80 ± 0.30	3.49 ± 0.80

*Standard deviation.

The highest dry plant weight values (aboveground parts + underground parts) were found in the case of fertilization with 2 N, the lowered total biomass in the case of 3 N being caused mainly by the low biomass of the underground parts due to the intense fertilization with nitrogen. The biomass of the aboveground parts of plants not treated with nitrogen was less than half that of those treated with 2 N and 3 N (Table I). The root/shoot ratio decreased as the nitrogen dose increased, from 0.88 with no N, to 0.27 with a dose of 3 N. Subject to a similar change was the transpiration coefficient: from 1118.8 without nitrogen treatment to 549.7 g of water for the production of 1 g of dry weight of aboveground parts after treatment with 3 N (Table I). However, no clear changes were found in the ratio of water content to dry weight content in Typha latifolia shoots depending on the fertilizer dose, or a significant difference in this respect between the parent and the young plants (Table I).

3.2. POTASSIUM FERTILIZATION

Plants growing on potassium-fertilized substrate enriched with 1 N did not show such growth rate differences dependent on the dose level as in the case of nitrogen fertilization. In none of the experimental weeks were significant growth rate differences found depending on the potassium dose level (Fig. 4), and the highest growth rate values were recorded

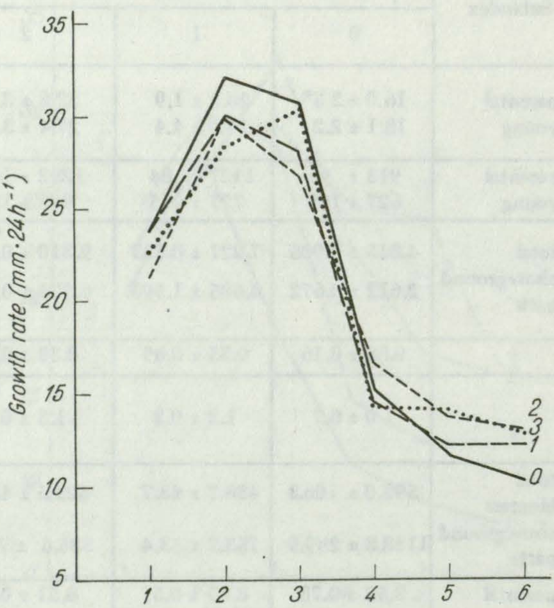

Fig. 4. The effect of potassium fertilization on the growth rate of *Typha latifolia* (in the presence of 1 dose of nitrogen)

0, 1, 2, 3 – numbers of fertilizer doses

in the 2nd week except plants treated with 3 K, for which maximum growth rate values were recorded in the 3rd week. For all the plants the lowest growth rate was found in the last week of the experiment (Fig. 4). Obviously, the average growth rate of young plants during the 6 weeks, regardless of the dose of K, was higher than that of parent plants (Table II).

Table II. The effect of potassium fertilization on the production and water relations of *Typha latifolia* (with 1 dose of nitrogen present)

Index	Subindex	Number of K doses			
		0	1	2	3
Growth rate of shoots (mm per 24 h)	parental young	20.6 ± 2.4* 25.0 ± 2.5	20.2 ± 1.9 24.0 ± 4.4	20.1 ± 1.6 23.7 ± 3.6	20.4 ± 2.2 24.6 ± 1.4
Final shoot length (mm)	parental young	1142 ± 76 802 ± 171	1127 ± 84 777 ± 215	1127 ± 84 861 ± 146	1116 ± 109 905 ± 123
The biomass produced by 1 parental shoot (g dry weight)	total aboveground parts	7.240 ± 0.909 4.900 ± 0.600	7.221 ± 0.333 4.685 ± 1.503	7.315 ± 1.637 4.783 ± 1.080	7.491 ± 0.691 4.800 ± 0.725
Root/shoot ratio		0.50 ± 0.03	0.55 ± 0.09	0.53 ± 0.04	0.57 ± 0.15
Number of shoots from 1 parental shoot		1.1 ± 0.20	1.22 ± 0.19	0.89 ± 0.19	1.11 ± 0.19
Transpiration coefficient (g water per 1 g dry weight)	total biomass aboveground parts	437.9 ± 43.6 1643.7 ± 67.1	488.7 ± 43.7 753.7 ± 53.4	456.4 ± 20.7 697.8 ± 23.8	426.9 ± 64.7 669.9 ± 103.5
Water/dry weight ratio	parental young	8.02 ± 1.01 7.87 ± 1.28	8.49 ± 0.57 8.41 ± 0.51	8.45 ± 0.74 8.36 ± 0.79	8.32 ± 0.34 8.45 ± 0.54
Evapotranspiration/evaporation		3.03 ± 0.14	3.43 ± 0.45	3.21 ± 0.61	3.07 ± 0.22

*Standard deviation.

The highest aboveground biomass was produced by plants growing on the substrate without fertilization, whereas the highest total biomass (aboveground + underground parts) was found in the case of 3 K fertilization (Table II). However, differences in biomass production between non-fertilized plants and those treated with various potassium doses were very small. A higher root/shoot ratio was found for treated than for non-treated plants; a similar situation was found as regards the transpiration coefficient (Table II). Neither the ratio of evapotranspiration to evaporation, nor the water content to dry weight content ratio changed significantly depending on the potassium dose level.

3.3. NITROGEN-POTASSIUM FERTILIZATION

When treated with nitrogen and potassium simultaneously, *Typha latifolia* showed a fairly diversified growth rate, depending on the fertilizer dose level: the higher the dose, the higher the growth rate of both young and parent plants (Fig. 5). In the 1st week the growth rate differences between non-treated plants and those treated with different NK doses were not significant (at the level of 95%). A similar situation was found in the 2nd week except the growth rate of plants treated with 2 NK. In the other experimental weeks the growth rate differences increased considerably: in the 3rd week significant growth rate differences were found between control plants and plants treated with different NK doses, whereas in the 4th week significant growth rate differences were found between non-treated and treated plants, as well as among those treated with different NK doses. In the last two weeks significant growth rate differences were found between control plants and those treated with the highest dose – 3 NK.

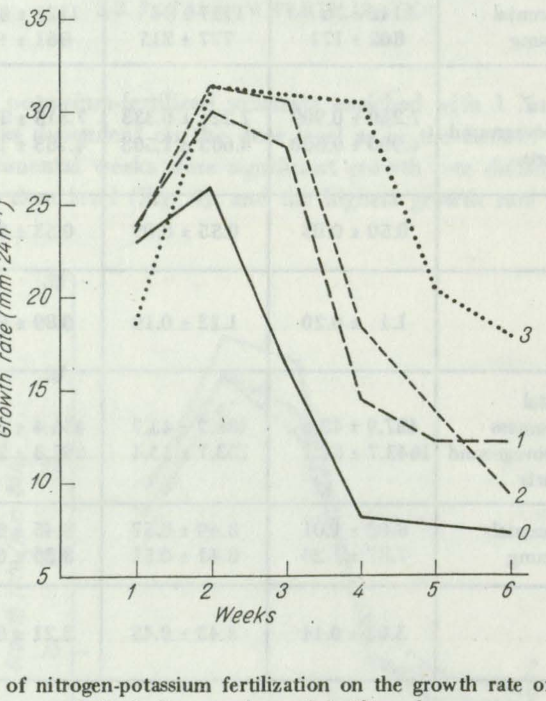

Fig. 5. The effect of nitrogen-potassium fertilization on the growth rate of *Typha latifolia*
0, 1, 2, 3 – numbers of fertilizer doses

In average values for the experimental period, the growth rate of parent plants as well as that of young shoots depended on the dose level, the higher the NK dose, the higher the growth rate. The fate of the maximum plant height value was similar (Table III). The dry weight produced, too, grew with the rising NK dose level, while the root/shoot ratio and the transpiration coefficient decreased as the NK dose increased (Table III). No noticeable differences were found in the content of water in plants, depending on the NK dose level; only between control and treated plants could some difference be seen in the ratio of water content to dry weight content – treated plants contained slightly more water

(Table III). With increasing NK doses the value of the evapotranspiration to evaporation ratio rose, too. For non-treated plants the smallest number of young shoots produced by one parent shoot was found, the largest was recorded in the case of 2 NK fertilization (Table III).

Table III. The effect of nitrogen-potassium fertilization on the production and water relations of *Typha latifolia*

Index	Subindex	Number of NK doses			
		0	1	2	3
Growth rate of shoots (mm per 24 h)	parental young	14.7 ± 1.8* 22.0 ± 3.4	20.2 ± 1.9 24.0 ± 4.4	21.2 ± 2.4 24.7 ± 5.3	24.9 ± 2.2 28.3 ± 11.1
Final shoot length (mm)	parental young	853 ± 49 697 ± 146	1127 ± 84 777 ± 215	1147 ± 100 808 ± 343	1349 ± 69 834 ± 426
The biomass produced by 1 parental shoot (g dry weight)	total aboveground parts	3.899 ± 0.466 2.479 ± 0.492	7.221 ± 0.333 4.685 ± 1.503	9.928 ± 0.529 7.130 ± 0.634	10.662 ± 1.321 8.262 ± 0.964
Root/shoot ratio		0.59 ± 0.12	0.55 ± 0.09	0.36 ± 0.09	0.29 ± 0.04
Number of shoots from 1 parental shoot		0.3 ± 0.3	1.2 ± 0.2	1.8 ± 0.2	1.3 ± 0.0
Transpiration coefficient (g water per 1 g dry weight)	total biomass aboveground parts	660.0 ± 47.1 1052.3 ± 152.4	488.7 ± 43.7 753.7 ± 53.4	414.2 ± 79.0 580.0 ± 128.5	390.0 ± 46.1 504.0 ± 70.1
Water/dry weight ratio	parental young	5.18 ± 0.47 5.91 ± 1.04	8.49 ± 0.57 8.41 ± 0.51	7.52 ± 0.57 7.29 ± 1.18	8.10 ± 1.07 7.55 ± 0.29
Evapotranspiration/evaporation		2.48 ± 0.13	3.43 ± 0.45	3.96 ± 0.64	4.06 ± 0.97

*Standard deviation.

4. DISCUSSION

When treated with nitrogen and potassium separately and jointly with nitrogen and potassium, *Typha latifolia* shows differences in production and water regime. An addition of nitrogen to the substrate caused a greater increase in biomass production and a faster growth in height than did a treatment with potassium. However, it has been found that a high rate fertilization with nitrogen caused an exuberant growth and turning down of the shoots. Considerable differences were also found in the rate of growth in length between younger and older leaves, leading to morphological changes of the leaves. There probably occurred some disturbance in the intake of other nutrients by plants, as a result of the high-rate fertilization with nitrogen. Potassium fertilization did not cause any significant changes in the growth rate of the plants. Plants treated with nitrogen, even though the content of potassium was low, showed a high production and growth rate, because the potassium had a favourable influence on the nitrogen uptake from the substrate. As it has been known, elements present in the soil interact with each other, water supply in the substratum being in this case of paramount importance (Tarkowski 1978). On substrates fertilized with nitrogen and with nitrogen and potassium jointly *Typha latifolia* showed a higher production of aboveground parts than on substrates fertilized with potassium. For this reason, the highest root/shoot ratio was found when the maximum potassium dose was used. This type of effect of nitrogen and potassium fertilization has been known in agriculture, where the influence of potassium, e.g., on the yield of grain is poor, but on the yield of root crops – strong. It must be remembered, however, that the nutrient requirements of plants are also determined genetically (Tarkowski 1978).

The quantities of water used by *Typha latifolia* for biomass production depended on the type and level of the fertilizer dose used. Where the supply of nitrogen was good, the plants utilized water much more economically. The larger were the nitrogen and nitrogen--potassium doses, the lower was the transpiration coefficient. Plants treated with large potassium doses used the largest amounts of water for biomass production, in spite of the presence of one N dose. The interaction of ions and their influence on the production and water balance of the plants could best be seen when different nitrogen-potassium doses were used simultaneously. Against this background the differences became visible in the action of fertilizers applied separately and jointly, which confirms the data reported by Daubenmire (1973).

The present experiment did not make it possible to precisely determine the direction of the action of potassium on the water regime of plants. According to Stabrowska (1972), potassium exerts an influence on the water regime of plants by raising the osmotic pressure of the cell sap, maintaining the cells in the state of turgor, thus facilitating the passage of water into them. In *Typha latifolia* treated with potassium the water content was not found to be noticeably higher than that found in plants treated with nitrogen, or with nitrogen and potassium jointly. This may have been due to the phosphorus present in the substrate, because phosphorus makes it difficult for plants to take up potassium (Tarkowski 1978). Rogalev (1958) has found that potassium lowers the rate of transpiration, but in the present experiment no significant changes could be observed in the process of evapotranspiration. Besides, data found in the literature concerning the role of potassium in the water regime are not unequivocal, e.g.: Biebl (1958) and Van Steveninck (1965) report that potassium causes an increased hydration of the cell colloids; Evenari (1962) thinks that the role of potassium consists in causing an increase in the cuticular transpiration rate, influencing the movements of the stomatal cells, and stimulating the absorption of water. Biebl (1958) finds that the action of potassium on different plant species varies, and that its effect on the hydration depends on the age of the plants. He, therefore, maintains that potassium may intensify or decrease the transpiration rate. Brag (1972) has found that a high content of potassium means a low transpiration rate, while Keller (1967) has found the reverse of the above. Excessive fertilization with potassium causes a lowering of the yield of crop plants, as has been reported for maize by Seidler (1968). The large potassium doses may have had a similar effect in the case of *Ty-*

pha latifolia. The data reported by the above authors and the results of the present experiment on the effect of potassium fertilization on *Typha latifolia* permit the statement that the uptake of potassium by plants varies considerably.

A high content of nutrients in the substrate can only to a certain degree increase the production of plant biomass and make plants to use water economically. Fertilization with too high doses leads to the suppressing of the physiological processes in a plant, which was found in previous investigations (Królikowska 1978a).

The experiment presented in the paper permits the statement that when treated with nitrogen and potassium, *Typha latifolia*, a plant species of fertile waters, changes its production of dry weight, its growth rate and the amount of water used for the production of its biomass, but the direction of the changes depends on the quantity and composition of the doses used. An increased biomass production and number of young shoots, due to fertilization, may be of significance in natural habitats where this plant species forms assemblages and finds good nutritional conditions (e.g. in fish ponds), because it may lead to the overgrowing of water bodies.

5. SUMMARY

In the years 1977 and 1978, experimental studies were carried out on the effect of mineral fertilization on the growth rate, biomass production and water regime of *Typha latifolia*. It has been found that nitrogen and potassium cause changes in biomass production and evapotranspiration of plants, depending on whether the nutrient components, nitrogen and potassium, have been used separately or jointly, and on their amount in the substrate.

Nitrogen and nitrogen-potassium fertilization caused an acceleration of the growth in height of plants (Figs. 3, 5) and an increased production of the aboveground parts of plants (Tables I, III), whereas potassium fertilization – of the underground parts of *Typha latifolia* (Table II). Increased amounts of nitrogen and potassium used jointly caused a reduction of the coefficient of plant transpiration (Tables I, III), but large doses of potassium increased the amount of water used by plants for the production of biomass, the larger the dose, the more water was used (Table II).

Non-treated plants produced the fewest young shoots per a perent plant (Table III) and attained the smallest final height. They have also been found to contain the smallest amounts of water.

6. POLISH SUMMARY

W latach 1977 i 1978 prowadzono badania eksperymentalne nad wpływem nawożenia mineralnego na tempo wzrostu, produkcję biomasy i gospodarkę wodną *Typha latifolia*. Stwierdzono, że azot i potas powodują zmiany w produkcji biomasy i ewapotranspiracji roślin, w zależności od tego, czy składniki pokarmowe azot i potas stosowano indywidualnie i łącznie oraz od ilości tych składników w podłożu.

Nawożenie azotowe i azotowo-potasowe zwiększało przyrost wysokości roślin w czasie (rys. 3, 5), a także produkcję części nadziemnych roślin (tab. I, III), natomiast potasowe – części podziemnych *Typha latifolia* (tab. II). Zwiększanie ilości stosowanego nawożenia łącznego azotem i potasem powodowało zmniejszanie współczynnika transpiracji roślin (tab. I, III), natomiast im wyższa była dawka potasu, tym więcej wody zużywały rośliny na produkcję biomasy (tab. II).

Rośliny nie nawożone produkowały najmniejszą liczbę młodych pędów na 1 roślinę rodzicielską (tab. III), a także osiągnęły najmniejszą wysokość końcową. Stwierdzono również u tych roślin najmniejszą zawartość wody.

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