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Gas exchange and organic substance production of Scots pine (*Pinus silvestris L.*) seedlings grown in soil cultures with ammonium or nitrate form of nitrogen*

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Abstract

Scots pine seedlings were grown in soil cultures with a known content of N and C as well as organic substances. Water solutions of the following salts: $NaNO_3$, $(NH_4)_2SO_4$, NH_4Cl, NH_4NO_3, NH_4HCO_3 were used as a source of nitrogen in particular nutritional variants. Organic matter accumulation in particular organs as well as the chlorophyll a and b content were determined, photosynthetic and respiration rates were also measured. It was found that differences in gas exchange and organic matter accumulation of seedlings grown on ammonium or nitrate form of nitrogen are similar in plants from water cultures as well as in those from soil cultures.

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INTRODUCTION

The experiment with plants grown in water culture (Zajączkowska, 1973) with different sources of nitrogen showed that seedlings grown with ammonium chloride accumulated higher amounts of organic substances and had a larger number of needles as compared to those grown with sodium nitrate and ammonium nitrate. The photosynthesis rates of plants grown in ammonium variant were found to be slightly higher compared with those grown on nitrate but only in the earlier growth stages.

An attempt was made to explain whether the previously found reactions of plants grown in water cultures were similar to those of plants grown under-closer to natural conditions, that is in soil cultures.

MATERIAL AND METHODS

Experiments were carried out on Scots pine seedlings during their first growing season. In the experiment of 1970 seedlings were grown in soil, defined as loamy light silty sand, containing small amounts of organic substances. In the experiment of 1971 seedlings were grown in soil defined as loamy light sand containing greater amounts of organic substances. Soil used in each of the experiments was mixed with sand (1 : 1 by volume). A short characterization of the soils is given in Table 1.

Table 1

Characteristic of soils used in pot cultures

Vegetation season	Chemical characteristic				Mechanical composition			Mechanical group
	pH in H_2O	% C	% organic subst.	% N	Percentage contents of fractions ∅ in mm			
					1—0.1	0.1—0.02	<0.02	
1970	6.0	0.30	0.52	0.05	59	27	14	loamy light sand silty
1971	6.4	0.69	1.20	0.05	75	13	12	loamy light sand

Experiment 1, in 1970

Several days old seedlings were planted in pots on the 10th of June. There were twenty eight seedlings in each pot. Pots contained 12 kg of air dry soil each. The soil water content was maintained at 60% of capillary capacity using distilled water. Nitrogen was added to the soil, in the amount of 50 mg per 1 kg of air dry soil. Water solutions of the following salts: $NaNO_3$, NH_4Cl, $(NH_4)_2SO_4$, NH_4NO_3 were used as nitrogen sources for particular experimental variants. Control plants were grown in unfertilized soil.

Needle samples of two months old seedlings were taken between the 4th and 8th of August, for manometric measurements of gas exchange. The measurements were carried out in the Warburg apparatus. Photosynthesis and respiration were also measured twice using an infrared gas analyzer between the 17th and 20th of August, that is when seedlings were two and a half months old, and on the 28th of October — when they were about four and a half months old.

Experiment 2, 1971

Pots containing 6.9 kg of air dry soil were used in this experiment. Three days old seedlings were planted on the 24th of April — thirty seedlings in each pot. Nitrogen was added twice; on the 26th of May and on the 9th of June, each time 12.5 mg of nitrogen per 1 kg of air dry soil. There were two variants of nitrogen source — $NaNO_3$ in one variant and NH_4HCO_3 in the other one. Control plants were grown in unfertilized soil. The soil was watered to 60% of capillary capacity like in the first experiment.

Needle samples for gas exchange measurements in the Warburg apparatus were taken from the middle part of shoots. Needles were placed in special vessels (Łotocki and Żelawski, 1973) with carbonate buffer. Illumination at sample level was about 20 000 lux. Temperature of the water bath was maintained at 25°C. Respiration measurements were carried out in darkness immediately after photosynthesis determinations. Measurements of photosynthesis and respiration were carried out in 15 replications, 8 needles in each replication. One measurement lasted for about one and a half hour. Measurements with infrared gas analyzer (Infralyt II) were carried out in closed circuit under conditions of: temperature 25°C, light intensity — about 10 000 lux and CO_2 concentration in the range of 350 — 300 ppm. Illumination system consisted of fluorescent and incandescent lamps arranged from three directions. Seedlings were adapted, for one hour, to the experimental conditions. Then they were cut and for the time of measurements they were placed in a tube with water.

The measurements of seedlings planted in 1970 were carried out twice; the first time in two repeats, 10 plants in each, and the second time in three repeats, 5 plants in each. Stem length was measured and needle number on shoot was determined after the end of each measurement.

Photosynthesis and respiration measurements of shoot as well as respiration measurements of root in the experiment with seedlings planted in 1971 were also carried out twice; the first time in eight repeats, 5 plants in each and the second time in twelve repeats, 3 plants in each. Respiration of roots, carefully extracted and rinsed of soil, was measured within a few minutes. The number of lateral shoots and number of needles on the main and lateral shoots as well as their dry weights were determined.

Needle samples for determinations of chlorophyll a and b content were taken simultaneously with gas exchange measurements. Needles were taken from the middle part of shoots. Chlorophyll content of each nutritional variant was determined in 10 repeats of samples containing about 100 mg of fresh needles. Chlorophyll content was determined spectrophotometrically in 80% acetone extract (Mac Kinney, 1941; Bruinsma, 1963).

To estimate the variation of the investigated plant material error of arithmetic mean was determined at the confidence level $p = 0.90$.

RESULTS

Experiment 1

The experiment with plants grown in 1970 showed that the longest shoots were formed by seedlings supplied with ammonium chloride and ammonium sulphate (Table 2). There were no distinct differences

Table 2

Growth characteristics of seedlings

Experimental variant	Length of the shoot (mm)	Number of needles on single seedling	Dry weight of single needle (mg)
Date of harvest: 17.VIII—20.VIII.			
$NaNO_3$	23.5±0.8	47±2	1.08
NH_4NO_3	24.0±1.5	46±3	1.14
$(NH_4)_2SO_4$	27.0±1.3	45±3	1.25
NH_4Cl	28.0±1.2	41±3	1.12
Control	23.5±1.3	34±2	1.04
Date of harvest: 28.X.			
$NaNO_3$	27.7±1.5	55±5	1.58
NH_4NO_3	30.4±1.3	57±3	1.67
$(NH_4)_2SO_4$	33.9±1.5	61±4	1.84
NH_4Cl	31.1±1.6	49±6	1.69

found in needle number between plants of all the nutritional variants except for control plants (no nutrients added), which showed the smallest number of needles. Dry weight of a single needle of seedlings grown in soil fertilized with $(NH_4)_2SO_4$ was the largest and that of seedlings supplied with $NaNO_3$ was the smallest. Seedlings supplied with ammonium sulphate also showed considerably higher dry weigth of particular organs compared with those of other nutritional variants (Table 3). Seedlings supplied with sodium nitrate and those grown in soil fertilized with ammonium chloride showed the smallest dry weight. Plants grown in soil fertilized with sodium nitrate showed the lowest value of the shoot to root ratio.

Table 3

Dry weight of needles, stem and root (mg/plant) and ratio shoot/root

Experimental variant	Needles	Stem	Root	Whole plant	Ratio: shoot/root
Date of harvest: 17.VIII—20.VIII.					
$NaNO_3$	50.6	5.6	30.3	86.5	1.85
NH_4NO_3	52.6	6.4	25.4	84.4	2.32
$(NH_4)_2SO_4$	56.3	7.5	33.8	97.6	1.89
NH_4Cl	46.1	5.9	23.0	75.0	2.26
Control	35.3	4.2	18.3	57.8	2.16
Date of harvest: 28.X.					
				Shoot	
$NaNO_3$	86.7	15.6	—	102.3	—
NH_4NO_3	95.5	18.4	—	113.9	—
$(NH_4)_2SO_4$	112.0	23.0	—	135.0	—
NH_4Cl	82.9	19.9	—	102.8	—

Table 4

Percentage distribution of dry matter in particular organs.
Date of harvest: 17.VIII—20.VIII

Experimental variant	Needles	Stem	Root
$NaNO_3$	58.5	6.5	35.0
NH_4NO_3	62.3	7.7	30.0
$(NH_4)_2SO_4$	57.7	7.7	34.6
NH_4Cl	61.4	7.9	30.7
Control	61.0	7.3	31.7

Table 5

Percent of increase of dry weight in particular organs between the first and second sampling (17.VIII—28.X)

Experimental variant	Needles	Stem
$NaNO_3$	71.3	178.6
NH_4NO_3	81.5	187.5
$(NH_4)_2SO_4$	98.9	206.7
NH_4Cl	79.8	237.3

Percentage participation of organic substances in plant organs was compared and it was found that differences between experimental variants were not significant (Table 4). However, percentage participation of organic substances of root was highest in seedlings grown with $NaNO_3$, on the other hand, participation of organic substances of needles was highest in seedlings grown with NH_4NO_3.

Mean shoot weight increment of a plant, during the period between the two harvests, was:

71 mg in seedlings supplied with $(NH_4)_2SO_4$,
55 mg in those supplied with NH_4NO_3,
51 mg in seedlings supplied with NH_4Cl,
46 mg in those supplied with $NaNO_3$.

Highest dry weight increment of needles was found, during the same period of time in seedlings growing in soil with ammonium sulphate (Table 5). Highest stem increments were observed in plants of the same variant as well as in those supplied with ammonium chloride. Lowest increments of needles as well as stems were found in plants grown in soil with sodium nitrate.

Table 6

Chlorophyll content in mg/g of needles dry weight and the ratio chlorophyll a/b

Experimental variant	Chlorophyll a	Chlorophyll b	Chlorophyll a+b	Ratio a:b
$NaNO_3$	4.49±0.15	1.82±0.08	6.51±0.23	2.47
NH_4NO_3	4.56±0.18	1.84±0.07	6.68±0.21	2.48
$(NH_4)_2SO_4$	4.82±0.16	1.91±0.08	7.00±0.25	2.52
NH_4Cl	4.21±0.15	1.66±0.25	6.15±0.25	2.54
Control	2.82±0.21	1.13±0.08	4.12±0.31	2.49

The addition of nitrogen to soil, in each form of the applied salts, caused significant increase of chlorophyll content in needles (Table 6). The highest chlorophyll content was found in seedlings supplied with $(NH_4)_2SO_4$ and the lowest in those supplied with NH_4Cl. Chlorophyll a to b ratio was similar in all the experimental variants.

The highest photosynthetic rate, measured by the amount of evolved oxygen, was achieved by needles of seedlings supplied with $(NH_4)_2SO_4$ — while those supplied with $NaNO_3$ and NH_4Cl showed the lowest rate of photosynthesis (Table 7). On the other hand, the highest respiration rate of needles, determined by the amount of absorbed oxygen, was found in seedlings supplied with $NaNO_3$. Consequently, the ratio of photosynthesis to respiration was found to be the lowest in seedlings grown in soil with $NaNO_3$.

Table 7

Characteristics of needles, their photosynthesis and respiration in ml O_2/hour/g of dry weight of needles

Experimental variant	Dry weight of a single needle (mg)	Photosynthesis		Respiration		Ratio: photosynthesis / respiration
		ml $O_2 \cdot h^{-1} \cdot$ $\cdot$g of dry weight^{-1}	ml $O_2 \cdot$ $\cdot h^{-1} \cdot$1 needle^{-1}	ml $O_2 \cdot h^{-1} \cdot$ $\cdot$g of dry weight^{-1}	ml $O_2 \cdot$ $\cdot h^{-1} \cdot$1 needle^{-1}	
$NaNO_3$	1.7	13.1±1.3	20.3	0.76±0.07	1.3	17.2
NH_4NO_3	2.0	14.2±1.4	25.6	0.68±0.07	1.3	20.9
$(NH_4)_2SO_4$	2.1	15.3±1.2	28.7	0.68±0.07	1.4	22.5
NH_4Cl	1.9	12.0±1.1	19.4	0.64±0.08	1.2	18.7

In measurements of CO_2 absorption a considerably lower photosynthetic rate was found in plants supplied with NH_4Cl at the first time of measurements (Table 8). The photosynthetic rate was lower in seedlings of all the experimental variants at the second time of measurements, and the lowest value was found again in seedlings supplied with NH_4Cl. Differences in the rate of photosynthesis between

Table 8

Photosynthesis rate, photosynthetic activity per plant and per 1000 needles, assimilation number, respiration rate and the ratio: photosynthesis/respiration of the shoot

Experimental variant	Photosynthesis				Respiration		Ratio: photosynthesis / respiration of the shoot
	mg $CO_2 \cdot$ $\cdot h^{-1} \cdot$g of dry weight^{-1}	mg $CO_2 \cdot$ $\cdot h^{-1} \cdot$1 plant $^{-1}$	mg $CO_2 \cdot$ $\cdot h^{-1} \cdot$1000 needles^{-1}	mg $CO_2 \cdot$ $\cdot h^{-1} \cdot$mg of chlorophyll^{-1}	mg $CO_2 \cdot$ $\cdot h^{-1} \cdot$g of dry weight of the shoot^{-1}	mg $CO_2 \cdot$ $\cdot h^{-1} \cdot$ $\cdot$shoot^{-1}	
Date of harvest: 17.VIII—20.VIII.							
$NaNO_3$	15.6	0.79	16.90	2.4	1.6	0.08	9.9
NH_4NO_3	15.7	0.83	17.94	2.4	1.7	0.09	9.2
$(NH_4)_2SO_4$	14.2	0.80	17.81	2.0	1.6	0.09	8.9
NH_4Cl	10.1	0.47	11.34	1.6	1.6	0.08	5.9
Control	11.1	0.39	11.55	2.7	1.2	0.04	9.7
Date of harvest: 28.X.							
$NaNO_3$	11.0	0.95	17.36	—	1.5	0.13	7.3
NH_4NO_3	10.8	1.03	18.00	—	1.3	0.12	8.6
$(NH_4)_2SO_4$	10.9	1.22	20.13	—	1.2	0.13	9.4
NH_4Cl	9.3	0.77	15.80	—	1.5	0.13	5.9

seedlings supplied with $NaNO_3$, NH_4NO_3, $(NH_4)_2SO_4$ were slight. Plants supplied with NH_4Cl were also found to show the lowest assimilation number. The highest values of photosynthetic activity of whole plants as well as of 1 000 needles was found, at both times of measurements, in seedlings supplied with $(NH_4)_2SO_4$ and with NH_4NO_3.

Differences in respiration rate between seedlings of different nutritional variant were not found to be significant, though the four and a half months old plants supplied with $NaNO_3$ and with NH_4Cl showed slightly higher rate of this process. The photosynthesis to respiration ratio was found at both times of measurements, to be the lowest in seedlings supplied with NH_4Cl.

Experiment 2.

The experiment with seedlings grown in 1971 showed that seedlings supplied with nitrogen in the form NH_4HCO_3 exhibited a larger number of lateral shoots as well as of needles than those supplied with $NaNO_3$ (Table 9). No distinct differences between seedlings of ammonium and nitrate variants were found in dry weight of one needle, at the first harvest. However, dry weight of one needle of seedlings in the nitrate variant was found to be slightly higher, at the second harvest, as compared to that of seedlings in the ammonium variant.

Table 9

Growth characteristics of seedlings

Experimental variant	Number of lateral shoots	Number of needles of main shoots	Number of needles of lateral shoots	Number of needles of a single seedling	Dry weight of a single needle (mg)
Date of harvest: 16.VIII.					
$NaNO_3$	1.27	104.3	25.5	130± 9	1.4
NH_4HCO_3	1.70	112.6	33.3	146±10	1.4
Control	0.75	90.9	13.9	105± 5	1.5
Date of harvest: 4.X.					
$NaNO_3$	1.17	118.8	22.6	141±10	1.9
NH_4HCO_3	1.36	124.5	26.9	151± 9	1.7
Control	1.21	98.0	22.2	120±10	1.6

There were no distinct differences found in dry weight of whole plant between seedlings grown in soil fertilized with $NaNO_3$ and with NH_4HCO_3 at both harvest times (Table 10). It was found, however, that needles dry weight of seedlings grown in soil fertilized with

Table 10

Dry weight of needles, stem and root (mg/plant) and ratio shoot/root

Experimental variant	Needles	Stem	Root	Whole plant	Ratio: shoot/root
Date of harvest: 16.VIII.					
$NaNO_3$	188.6± 8.9	29.4±1.9	165.3	383.3	1.32
NH_4HCO_3	208.1± 9.7	31.4±2.7	141.5	381.0	1.69
Control	155.7± 7.9	21.3±1.7	138.0	315.0	1.28
Date of harvest: 4.X.					
$NaNO_3$	265.3±17.7	53.3±3.6	210.4	529.0	1.51
NH_4HCO_3	260.5±13.4	57.4±4.6	223.5	541.4	1.42
Control	190.7±14.1	35.8±2.8	158.7	385.2	1.43

Table 11

Per cent increase of dry weight in particular organs between the first and second sampling (16.VIII—4.X)

Experimental variant	Needles	Stem	Root	Whole plant
$NaNO_3$	40.7	81.3	27.3	38.0
NH_4HCO_3	25.2	82.8	57.9	42.1
Control	22.5	68.1	15.0	22.3

Table 12

Percentage distribution of dry matter in particular organs

Experimental variant	Needles	Stem	Root
Date of harvest: 16.VIII.			
$NaNO_3$	49.2	7.7	43.1
NH_4HCO_3	54.6	8.2	37.2
Control	49.4	6.8	43.8
Date of harvest :4.X.			
$NaNO_3$	50.1	10.1	39.8
NH_4HCO_3	48.1	10.6	41.3
Control	49.5	9.3	41.2

Table 13

Chlorophyll content in mg/g of needles dry weight and the ratio chlorophyll a/b

Experimental variant	Chlorophyll a	Chlorophyll b	Chlorophyll a+b	Ratio: a/b
$NaNO_3$	5.18±0.16	2.09±0.06	7.58±0.18	2.48
NH_4HCO_3	4.63±0.18	1.86±0.06	6.78±0.27	2.49
Control	4.59±0.12	1.85±0.07	6.73±0.22	2.48

Table 14

Photosynthesis rate, photosynthetic activity per plant and per 1000 needles, assimilation number and the ratio: photosynthesis/respiration of the whole plant

Experimental variant	mg $CO_2 \cdot h^{-1} \cdot g$ of dry weight^{-1}	mg $CO_2 \cdot h^{-1} \cdot$ $\cdot 1$ plant^{-1}	mg $CO_2 \cdot h^{-1} \cdot$ $\cdot 1000$ needles^{-1}	mg $CO_2 \cdot h^{-1} \cdot$ $\cdot$mg of chlorophyll^{-1}	Ratio: photosynthesis / respiration of the whole plant
Date of harvest: 16.VIII.					
$NaNO_3$	15.6±0.6	2.9	22.7	2.1	5.4
NH_4HCO_3	14.2±0.6	3.0	20.3	2.1	5.4
Control	16.3±0.5	2.5	24.2	2.4	6.3
Date of harvest: 4.X.					
$NaNO_3$	11.5±0.2	3.0	21.6	—	—
NH_4HCO_3	12.5±0.5	3.2	21.5	—	—
Control	12.2±0.6	2.3	19.4	—	—

NH_4HCO_3 exceeded, at the first harvest time, that of seedlings supplied with $NaNO_3$. Root weight of plants in nitrate variant was, however, higher than that of seedlings in ammonium variant. Needle and root weights did not differ distinctly between seedlings of the two variants at the second harvest time.

Mean dry weight increment of the whole plant during the period between the two harvests was 146 mg — in seedlings supplied with $NaNO_3$ and 160 mg — in those supplied with NH_4HCO_3. Seedlings supplied with $NaNO_3$ showed considerably higher dry weight increment of needles compared to those of the ammonium variant (Table 11). Dry weight increment of roots was, however, higher in seedlings supplied with nitrogen in ammonium form than those supplied with the nitrate form. Percentage participation of organic substances in needles of seedlings of ammonium variant was found at the first harvest time to be higher than that of seedlings in nitrate variant

Table 15

Respiration rate

Experimental variant	Shoot		Root		$mg\ CO_2 \cdot h^{-1} \cdot$ $\cdot 1\ plant^{-1}$
	$mg\ CO_2 \cdot h^{-1} \cdot g$ of dry $weight^{-1}$	$mg\ CO_2 \cdot h^{-1} \cdot$ $\cdot 1\ shoot^{-1}$	$mg\ CO_2 \cdot h^{-1} \cdot$ $\cdot g$ of dry $weight^{-1}$	$mg\ CO_2 \cdot h^{-1} \cdot$ $\cdot root^{-1}$	
Date of harvest: 16.VIII.					
$NaNO_3$	1.4±0.05	0.27	1.7	0.27	0.54
NH_4HCO_3	1.4±0.03	0.29	1.9	0.26	0.55
Control	1.2±0.05	0.18	1.6	0.22	0.40
Date of harvest: 4.X.					
$NaNO_3$	1.0±0.10	0.27			
NH_4HCO_3	0.9±0.05	0.23			
Control	1.0±0.05	0.20			

(Table 12). Seedlings of the nitrate variant showed, however, higher percentage participation of organic substances in the root than those of the ammonium variant. There were no distinct differences found between seedlings of the two variants at the second harvest time.

The highest chlorophyll a and b content was found in needles of seedlings supplied with $NaNO_3$ (Table 13). The chlorophyll a to b ratio was similar in both experimental variants.

The addition of nitrogen in both forms did not cause any increase of the rate of photosynthesis compared with that of control plants (Table 14). Fertilized plants showed only increased photosynthetic activity of the whole plant, which was connected with a greater amount of assimilatory organs. A considerable decrease of the photosynthetic rate in plants of all experimental variants was observed at the end of the growing season. A greater decrease of this rate was found in seedlings supplied with $NaNO_3$ compared with those grown in soil fertilized with NH_4HCO_3.

Respiration rates of seedlings in both nutritional variants were similar (Table 15).

DISCUSSION

The obtained results indicate that in pine seedlings the ammonium form of nitrogen, compared with the nitrate form, favours higher accumulation of organic substance. The results are in agreement with those of other authors working with other coniferous species (Leyton, 1952; McFee and Stone, 1968). Experiments have shown that ammonium chloride causes considerably lower accumulation of organic substances compared with ammonium sulphate and ammonium nitrate. Unfavourable action of this salt was probably caused by some toxic effects of chlorine. Overabundance of chlorine in assimilatory organs of plants could inhibit chlorophyll formation and consequently reduce the photosynthetic rate (Baslawskaja and Syrojeszkina, 1936; Buchner, 1952); this could indirectly decrease the production of dry weight of the investigated seedlings. On the other hand, Arnon (1959) reported that chlorine uptaken in moderate amounts could cause stimulation of photosynthesis. In previous experiments with water culture plants (Zajączkowska, 1973), where the concentration of chlorine was lower, the reaction of seedlings grown with NH_4Cl was, in fact, positive. High accumulation of organic substances in seedlings grown with ammonium sulphate could be connected with the presence of sulphur, in the form of SO_4^{-2}. According to Barrow (1958) nitrogen can be utilized by plant in the presence of sulphur better than in the case of its absence.

The experiments with seedlings fertilized with ammonium or nitrate form of nitrogen generally did not show distinct differences in the photosynthetic rate — except for slightly higher photosynthetic rate of the two months old seedlings supplied with $(NH_4)_2SO_4$ and distinct inhibition of photosynthesis in those supplied with ammonium chloride.

The results of experiments indicate that the stimulating effect of ammonium form of nitrogen on photosynthesis is transient and disappears within a relatively short time after applying nitrogen fertilization.

Respiration rates, generally, did not show distinct differences between seedlings supplied with various form of nitrogen. An increase of respiration rate could be observed in experiments of 1970 in seedlings grown in soil fertilized with sodium nitrate. A stimulating effect of nitrate form of nitrogen on respiration rate in other species was found by: Warburg and Negelein, 1920; Gilbert and Shive, 1945; Gumiński et al., 1957.

Greater accumulation of organic substances in plants supplied with nitrogen in the ammonium form compared with those supplied with the nitrate form could partly result from greater accumulation of photosynthetic products by larger needles and a greater number of needles per shoot. Fertilizing with nitrates favoured more intensive root weight increment, while supplying nitrogen in the ammonium form caused greater needle weight increment. The ammonium form of nitrogen favoured the increase of number of lateral shoots and needles per shoot.

A slightly different growth course was found in seedlings grown in soil with higher content of organic substances (experiment of 1971), compared with seedlings grown in soil with lower content of organic substance (experiment of 1970).

The obtained results indicate that the content of organic substances in the soil can modify the response of plants to the form of nitrogen nutrition.

CONCLUSIONS

1. Photosynthetic rates in early stages of vegetation of pine seedlings grown on ammonium are slightly higher than of those grown on nitrate as source of nitrogen.

2. Respiration rates of pine seedlings grown on nitrate are slightly higher than of those grown on ammonium as source of nitrogen.

3. Accumulation of organic substance in the whole plant and in the assimilatory organs as well as the number of needles per plant were found to be higher in seedlings supplied with ammonium salts.

4. The response of pine seedlings to the form of nitrogen depends, to some extent, upon the content of organic substances in the soil as well as upon the kind of the salt used as nitrogen source.

5. Differences in gas exchange and in organic substance accumulation in seedlings supplied with either ammonium or nitrate form are of similar character both in water and soil culture.

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Wymiana gazowa i produkcja masy organicznej siewek sosny zwyczajnej (Pinus silvestris. L) wyhodowanych w kulturach glebowych w obecności amonowej lub azotanowej formy azotu

Streszczenie

Siewki sosny zwyczajnej hodowano w kulturach wazonowych w glebie o znanej zawartości N, C i substancji organicznych. Źródłem azotu dla poszczególnych wariantów nawożeniowych były roztwory wodne następujących soli: $NaNO_3$, NH_4Cl, $(NH_4)_2SO_4$, NH_4NO_3, NH_4HCO_3. Określono wielkość akumulacji masy organicznej w poszczególnych organach i zawartość chlorofilu a i b oraz zmierzono intensywność fotosyntezy i oddychania. Stwierdzono we wczesnych stadiach wegetacji nieco wyższą intensywność fotosyntezy siewek nawożonych azotem amonowym niż siewek nawożonych azotem azotanowym. Ponadto siewki nawożone azotem amonowym posiadały większą masę, jak również większe organy asymilacyjne i większą ich liczbę. Tak więc różnice w wymianie gazowej i akumulacji masy organicznej siewek nawożonych azotem amonowym i azotanowym mają podobny charakter u roślin wyhodowanych w kulturach wodnych (Zajączkowska 1973) i wyhodowanych w kulturach glebowych.