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Influence of hydrogen fluoride on the rate of CO_2 exchange in Scots Pines of different susceptibility to this gas

INTRODUCTION

The influence of hydrogen fluoride on the photosynthetic process has not been explained satisfactorily yet. Smith (1961) in experiments on beans treated with HF of concentrations of 10 to 15 ppb for 5 days established no changes in the intensity of photosynthesis, though several necroses on the leaf blade appeared. Also Thompson (1967) working on citruses and Hill et. al. (1958) on tomatos observed no changes in photosynthetic intensity under low concentrations of HF.

Thomas and Hendricks (1956) in their investigations on several varieties of *Gladiolus* treated with low (1 to 10 ppb) concentrations of this gas for short expositions realized a substantial decrease of CO_2 assimilation whereas no necroses of leaves occured. The reduction of photosynthesis with extention of time of exposition was correlated to the development of visible leaf damages.

The inhibition of photosynthesis can be reversed as long as no necroses occur in the case when plants are submitted to an acute but not chronic action of hydrogen fluoride (Hill et al., 1958; Hill, 1969; Bennett and Hill, 1973). It could be supposed that the reduction of photosynthesis is caused by the inhibiting influence of HF on the Hill-reaction (Spikes et al., 1955; Ballantyne, 1972), by the decrease of synthesis of plant pigments (Mc Nulty and Newman, 1956, 1961; Krawiarz et al., 1979; Oleksyn et al., 1980), by the decomposition of chloroplast membranes (Mc Nulty and Newman, 1961) or as a result of Mg^{++} ions being bound by F^{-} (Thomas and Alther, 1966). Plants treated with hydrogen fluoride show increased respiration (Applegate and Adams, 1960; Applegate et al., 1960; Christiansen and Thimann, 1950; Pilet, 1963, 1964). This process is stimulated either when there is a complete lack of visible injuries on the plant (Weinstein,, 1961; Yu and Miller, 1967; Miller and Miller, 1974), or when those injuries appeared (Hill et al., 1959;

Weinstein, 1977). Yang and Miller (1963) tried to explain this induction of the respiration process by an increased activity of phosphoenolpyruvate carboxylase and accumulation of organic acids and aminoacides.

Respiration intensity can be also inhibited by the hydrogen fluoride (Mc Nulty, 1961; Applegate et al., 1960). This inhibition depends on the age of the plant (Bejaoui and Pilet, 1975) and on the duration of exposition and gas concentration (Applegate and Adams, 1960).

The influence of hydrogen fluoride on photosynthesis and respiration was investigated mainly on annual plants. Informations concerning the effect of this gas on the metabolism of perennial plants, particularly trees are however scarce (Ziegler, 1973). There is also a lack of informations about the influence of hydrogen fluoride on the intensity of photorespiration.

I the present study the carbon dioxide exchange rate in light and in the darkness by Scots pines treated with hydrogen fluoride in laboratory conditions was investigated. Seedling progenies of Scots pine trees differing in their susceptibility to HF were used for this study.

MATERIAL AND METHODS

Two year old sedlings of 6 open pollinated Scots Pine trees differing in susceptibility to HF were used for the experiments. Maternal trees were selected on the basis of the experiments described before (Karolewski and Białobok, 1978; Oleksyn et al., 1980) and were marked as K-10-03 III, K-01-82 I, K-01-22 I (tolerant) and K-07-04 III, K-07-16 III, K-01-16 I (susceptible to the gas).

CO_2 exchange measurements. From 5 to 7 seedlings of each progeny were taken for the experiments in summer 1979. They were treated with hydrogen fluoride for two days, six hours every day with the concentration of 0.025 ppm — accordingly to the method developed by Karolewski and Białobok (1978). Seedlings growing in an atmosphere without any HF were used as controls.

The exchange of CO_2 was measured 24 hours after the cessation of gas treatment. A gaseous infra-red analyzer Infralyt III, working in a closed system was used for the measurements. The net photosynthesis, photorespiration and dark respiration intensities were determined by means of the previously published formulas (Lorenc-Plucińska, 1978).

Results obtained were statistically verified with help of the variance analysis and the Students „t" — test (Oktaba, 1976).

Table 1

CO_2 exchange in light and darkness. Net photosynthesis (NPS), photorespiration (PR) and dark respiration (DR) of Scots Pine seedlings treated with 0.025 ppm concentration of HF over two days 6 hours a day

			$\mu g\ CO_2 \times min^{-1} \times g$ dry wt. needls^{-1}								
			NPS			PR			DR		
	Plant		C	HF	t^+	C	HF	t^+	C	HF	t^+
Tolerant (T)	K-10-03	$\bar{x}$	134	116		56	56	0.002	20	26	
	III	S	25	19	1.137	14	9		7	4	1.760
	K-01-82	$\bar{x}$	106	130		61	69		17	18	
	III++	S	26	22	1.411	12	11	0.981	7	9	0.131
	K-01-22	$\bar{x}$	152	142		69	60		17	16	
	I	S	10	48	0.446	11	24	0.660	6	6	0.217
Susceptible (S)	K-07-04	$\bar{x}$	111	104		59	94		12	26	
	III	S	23	8	0.422	12	18	2.253*	4	5	4.120**
	K-07-16	$\bar{x}$	143	113		63	98		20	40	
	III	S	25	20	1.784°	15	16	2.190*	3	7	2.902*
	K-01-16	$\bar{x}$	160	138		64	113		21	36	
	I	S	20	4	2.236*	18	17	2.916*	5	4	3.365**
	α_1					× ×			×		

t^+ – Students test,
** – results averaged from 5 measurements,
° – verified at $\alpha = 0.1$ level,
* – verified at $\alpha = 0.05$ level,
** – verified at $\alpha = 0.01$ level,
C – control (untreated),
HF – hydrogen fluoride (treated),
α_1 = minimal level of significance at which the null hypothesis about the absence of interaction between treatments and individuals is rejected.

RESULTS

According to Table 1, seedlings treated with hydrogen fluoride changed their CO_2 exchange intensity in light and the fact that darkness in spite of the fact that no visible injuries on the needles had appeared. Those changes depended on the susceptibility of the seedlings to the gas.

Concentration of hydrogen fluoride of 0.025 ppm applied in course of two days 6 hour a day to the progeny of the relatively tolerant specimens K-10-03 III, K-01-82 I and K-01-22 I caused only slight disturbances in the processes of photosynthesis, photorespiration and dark respiration (Tab. 1). The same treatment when applied to the progeny of more susceptible specimens K-07-04 III, K-07-16 III, K-01-16 I, caused however a substantial decrease of photosynthesis (except in the K-07-04 III progeny) and an increase of photorespiration and dark respiration (Tab. 1).

It should be mentioned however that differences in the intensity of CO_2 exchange between the untreated tolerant and susceptible progenies are non significant.

Twelve hours of treatment of two year old Scots Pine seedlings with a 0.025 ppm concentration of HF caused statistically significant changes in the gaseous exchange only in the progeny of susceptible trees (Tab. 1). Progenies of tolerant specimens treated identically showed only in significant increases or decreases in the CO_2 exchange processes.

In spite of those differences in the CO_2 exchange rate an analysis of variance for both (tolerant and susceptible) groups of progenies proved an non significant interaction between the treatments and progenies as related to the net photosynthesis but a significant one in the cause photo- and dark respiration (Tab. 1).

DISCUSSION

The decrease of net photosynthesis intensity caused by HF in the progeny of susceptible trees is probably the result of an inhibiting influence of the gas on Hill's reaction (Spikes, 1955; Ballantyne, 1972) and of the significant increase in photorespiration. The increase of CO_2 emission intensity in light under the HF treatment compared to the control amounted to 59%, 56% and 77% respectively for progenies of trees K-07-04 III, K-07-16 III and K-01-16 I (Tab. 1).

From the energy point of view this rather high increase in photorespiration is undesirable since the products of photosynthesis are oxidated rapidly, CO_2 disappears and ATP can not be synthetized immediately (Zelich, 1971). Energy obtained by photorespiration and not utilized for ATP synthesis could however be used for constructing carbon patterns of the TTC-cycle compounds or the glycolic pathway, but this way of managing energy is not economic for the plant. The increase of photorespiration due to HF causes additionaly a decrease in binding CO_2 i.e. a drop in the total productivity of the plant.

Exposition of progenies of susceptible trees to the influence of hydrogen fluoride caused also a significant increase in dark respiration. It increased in the progenies of trees K-07-04 III, K-07-16 III and K-01--16 I compared to the control was 117%, 54% and 74% respectively. Stimulation of CO_2 emission in those progenies is probably associated with their susceptibility to HF. Similar conclusions were reached by Ross et al. (1969) after investigation of differently resistant varieties of *Gladiolus*. According to the opinion of those authors an increased emission of CO_2 in the darkness is connected to the high C-6/C-1 ratio in susceptible varieties. One can conclude there fore that hexose is in this case converted into triose as a result of glycolysis. In the resistant varieties the C-6/C-1 ratio was low which indicates that the pentose-phosphate cycles predominated.

Stimulation of dark respiration in the susceptible trees under the influence of HF is probably due to the higher metabolic activity of those plants.

Investigations of the influence of HF on CO_2 exchange in light and darkness could help in recognizing the caused of differentiation in susceptibility of trees against this gas. One could conclude from this study, that seedlings in which the CO_2 exchange is most affected by HF treatment are progenies of trees selected as most susceptible to this gas (Karolewski et al., 1978). Thus the phenotypic selections were confirmed genotypically.

SUMMARY

Carbon dioxide exchange rate in susceptible and tolerant to HF Scots Pine progenies after the treatment with this gas of 0.025 ppm concentration during two days (six hours a day) was investigated. Net photosynthesis, photorespiration and dark respiration intensities were established by means of an infra-red CO_2 analyzer. Measurements of the CO_2 exchange were performed 24 hours after the seedlings were fumigated. It was found that hydrogen fluoride has changed substantially the CO_2 exchange intensity in susceptible plants only. HF treatment of the progenies of sensitive trees caused a drop in the photosynthesis and a stimulation of respiration both in the light and in the darkness.

The same treatment with HF on the progeny of tolerant trees caused only non significant changes in the CO_2 exchange.

It should be added that the changes described above both in the progeny of sensitive and tolerant trees occured in spite of the fact that no visible damages on the needles have been observed. Those results point to the genetical character of the differentiation in tolerance in the maternal trees.

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Wpływ fluorowodoru na wymianę CO_2 sosny o różnej wrażliwości na ten gaz

Streszczenie

Badano wpływ dwudniowego działania HF (po 6 godzin dziennie) w stężeniu 0,025 ppm na wymianę CO_2 dwuletnich siewek sosny, będących potomstwem osobników tolerancyjnych i wrażliwych na ten gaz. Natężenie fotosyntezy netto, fotooddychania i oddychania ciemniowego oznaczono za pomocą analizatora CO_2 w podczerwieni. Pomiary wymiany CO_2 wykonano po 24 godzinach od ukończenia fumigacji. Wykazano, że fluorowodór istotnie zmienia natężenie procesów wymiany CO_2 tylko u potomstwa osobników wrażliwych. Trakowanie HF potomstwa osobników wrażliwych powodowało obniżenie natężenia fotosyntezy i stymulację oddychania, zarówno na świetle jak i w ciemności. Takie samo działanie HF na potomstwo osobników tolerancyjnych na ten gaz wywołało nieistotne zmiany w wymianie CO_2.

Należy zaznaczyć, że powyższe zmiany w natężeniu wymiany CO_2, zarówno u potomstwa osobników tolerancyjnych jak i wrażliwych, na HF zachodziły pomimo braku wizualnych uszkodzeń igieł. Wyniki te wskazują na genetyczny charakter zróżnicowania odporności drzew matecznych.

ГАБРИЕЛЯ ЛОРЕНЦ-ПЛЮЦИНЬСКА

Влияние фтористого водорода на обмен CO_2 у сосны в разной степени чувствительной к действию этого газа

Резюме

Исследовали влияние двухдневного действия HF (по 6 часов в день) в концентрации 0,021 мг $м^{-3}$ на обмен CO_2 у двухлетних сеянцев сосны, являющихся потомством особей устойчивых и чувствительных к действию этого газа. С помощью инфракрасного газоанализатора CO_2 была обозначена интенсивность фотосинтеза нетто, фотодыхания и темнового дыхыния. Измерения обмена CO_2 проводились 24 часа после окончания газирования. Найдено, что фтористый водород существенным образом повлиял на изменения интенсивности процессов обмена CO_2 только у потомства чувствительных к его действию особей. Газирование HF потомства чувствительных особей вызвало падение интенсивности фотоситеза нетто и увеличение фотодыхания и темнового дыхания. Под влиянием идентичных концентраций HF на потомство устойчивых особей не найдено существенных изменений в интенсивности обмена CO_2.

Необходимо подчеркнуть, что вышеуказанные изменения в интенсивности обмена CO_2, как у устойчивых так и у чувствительных к действию HF особей, имели место при отсутствии видимых повреждений хвои. Полученные результаты свидетельствуют об генетической обусловленности дифференциации устойчивости маточных деревьев.