ZESZYTY PROBLEMOWE POSTĘPÓW NAUK ROLNICZYCH 1994, z. 413, 321-326

THE INFLUENCE OF SOIL ACIDIFICATION ON CHEMICAL COMPOSITION OF TOBACCO LEAVES

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A b s t r a c t. A response in yield and chemical composition of flue-cured tobacco leaves to soil acidification was investigated in field experiments carried out on two soils with granulometrical composition of slightly clayey sand, which differed in their chemical composition, particularly the degree of acidification and the share of exchangeable aluminium in exchangeable soil acidity. Complete organic and mineral NPK fertilization (variant a) was applied and nitrogenous top dressing on its background (variant b). Similar yields of leaves were achieved on both soils, which confirms weak sensitivity of tobacco to soil acidification. Applied top dressing only slightly influenced the amount of yield. The level of majority of mineral components depended on soil acidification. The content of calcium, potassium, magnesium and total nitrogen in leaves from both experiments was similar. On very acid soil the leaves contained much less iron, copper and phosphorus, which results from lower availability in this environment or reciprocal retardation. In the same conditions the leaves contained decidedly more manganese and aluminium which effects from a higher leaching of these elements in very acid soils, and to minor degree of sodium and zinc. In most cases, top dressing with nitrogen decreased the level of mineral components in tobacco leaves, which was particularly clear for iron, sodium and potassium in both experiments, for aluminium and calcium on acid soil, and for manganese and magnesium on very acid soil.

K e y w o r d s: soil acidification, tobacco, chemical composition of tobacco

INTRODUCTION

Acidification is a grave problem in Poland because of high percentage of acid and very acid soils [16]. As the result of many factors, including fertilization and industrial pollution, the area of acid soils extends. Active forms of aluminium appear in acidified soils and in very acid soils may be toxic to plants [2]. Plants sensitivity to harmful activity of aluminium is diversified and depends, among others on the species and cultivar variety, organic matter content and ions level in soil [2,3,5].

Flue-cured tobacco belongs among the plants cultivated on light weakly acid or acid soils, as under such conditions raw material of good quality is achieved. At the same time the plants are less susceptible to roots black rot [12].

The aim of this paper was to study the response in yield and chemical composition of tobacco leaves to soil acidification in conditions of various share of exchangeable aluminium in exchangeable soil acidity.

MATERIALS

Field experiments on flue-cured tobacco Virginia were conducted in 1991 in two places on very light soils with granulometrical composition of slightly clayey sand, widely differentiated in their chemical properties (Table 1). Soils samples were collected before the experiment outset and after drying all analyses were made with commonly used methods. The content of Cu, Zn, Mn and Fe was assayed with AAS method after extraction with 1 mol dcm^{-3} solution of HCl. Soil 1 belonged

Table 1. The properties of soils used in the experiments

Soil property		Soil 1	Soil 2
pH_{KCl}		5.10	4.01
reaction class		acid	very acid
Hh		2.30	3.64
H_{exch}	(cmol (+) kg^{-1})	0.16	1.21
S		10.02	3.12
T		12.32	6.76
V		81	46
Al_{exch} : H_{exch}		62	89
C-org	(%)	0.62	0.81
fraction < 0.02 mm		10	7
Al_{exch}		9.3	96.9
K_2O		238 vh	50 l
P_2O_5		176 h	115 m
Cu	(mg kg^{-1})	2.43 m	1.22 m
Zn		19.2 h	5.88 h
Mn		126 m	87 m
Fe		585 l	627 l

Content: l - low, m - middle, h - high, vh - veryhigh

to podzolic soils, soil 2 to brown soils.

Complete organic and mineral fertilization before planting were applied as combination 'a' (Table 2), and top dressing with nitrogen was used on this background - as combination 'b'. Top dressing dosed 10 kg N ha^{-1} in ammonium nitrate was given pointwise close to the plant. The experiments were set with randomised blocks method in four replications. Tobacco was planted spaced 0.6 m x 0.4 m. The area of harvest plot was 10.8 m^2. Tobacco leaves were harvested as they reached technical maturity and the yield of green mass was determined. They were then dried in flue-curing burn and the yield of aeriel dry mass was determined. Four yields were harvested on soil 1 and three on soil 2 because of slower ripening of leaves and late start of harvest.

The leaves were sorted according to

Table 2. Basic fertilization (combination 'a')

Fertilization	Soil 1	Soil 2
FYM (t ha^{-1})	20	30
Mineral fertilization (kg ha^{-1})		
N - nitro-chalk	20	20
P_2O_5 - granulated superphosphate	110	110
K_2O - potassium sulphate	160	200

quality classes of raw material and their share in total yield was determined. Samples were collected from among the sorted material and after grounding set aside for chemical analyses. Ca, K, Mg, Na, Cu, Zn, Fe, Mn, and Al content in plant material was assayed with AAS method, total N content with Kjeldahl method, P content with vanadium-molybdenum method and Mo content with rhodanate method.

RESULTS

The weather course during vegetation did not favour a steady growth of plants. Periods, propitious for growth (warm and sufficiently wet June and August) were preceded with periods of inhibited growth rate (cool and droughty May with late ground frosts and hot and dry July). In spite of favourable weather course in the begining of September, the harvest of leaves was finished in the middle of the month for fear of autumnal ground frost. Similar yields of leaves were obtained in the experiments on both soils (Table 3). A higher productivity of aerial dry mass was achieved from the yields of leaves from middle and upper stalk positions (3rd and 4th crop on soil 1 and 2nd and 3rd crop on soil 2), which is connected with better richness.

Top dressing with nitrogen slightly increased the yield of leaves on acid soil, whereas it had no significant influence on its amount on very acid soil. The productivity of aerial dry mass decreased in the majority of crops and in total yield on both soils. It may be a result of both more exuberant growth of whole plants and bigger sizes of leaves, especially those situated on the upper stalk positions which is seen through biometric measurements.

The content of mineral components in tabacco leaves was to a various degree determined by soil acidification (Table 4).

The level of calcium, potassium, magnesium and nitrogen in plants from both experiments was similar. The leaves of tobacco grown on very acid soil contained much less iron, copper, phosphorus and molybdenum than those

Table 3. Tobacco leaves yield

Combination		Crop I	II	III	IV	$\bar{x}$	Σ	Σ
		(kg from a plot)						(t ha^{-1})
Soil 1								
'a'	gm*	5.58	6.20	5.40	4.38	5.39	21.55	20.0
	adm	0.69	0.76	0.91	0.89	0.81	3.24	3.0
adm : gm	%	12.3	12.3	16.8	20.2	15.0	15.0	
'b'	gm	5.90	6.18	6.08	5.38	5.88	23.53	22.0
	adm	0.74	0.76	0.98	1.05	0.88	3.52	3.3
adm : gm	%	12.5	12.2	16.1	19.4	14.9	14.9	
$LSD_{0.05}$	adm						0.058	0.05
Soil 2								
'a'	gm	8.23	8.40	6.30		7.64	22.93	21.2
	adm	1.00	1.44	1.01		1.15	3.45	3.2
adm : gm	%	12.2	17.1	16.1		15.0	15.0	
'b'	gm	8.18	8.34	6.40		7.64	22.93	21.2
	adm	0.96	1.29	1.14		1.13	3.39	3.1
adm : gm	%	11.8	15.4	17.8		14.8	14.8	

*gm -green mass, adm - aerial dry mass.

Table 4. Chemical composition of tobacco leaves

Combination	Ca	K	Mg	Total N	P_2O_5	Na
	(%)					(mg kg^{-1})
Soil 1						
'a'	2.3	3.9	0.62	2.1	0.77	55
'b'	2.0	3.6	0.64	2.3	0.80	50
Soil 2						
'a'	2.2	3.6	0.61	2.3	0.59	122
'b'	2.5	3.3	0.58	2.3	0.58	80
	Mo	Cu	Zn	Fe	Mn	Al
	(mg kg^{-1})					
Soil 1						
'a'	0.47	7.1	98	1052	236	136
'b'	0.47	7.4	96	829	237	99
Soil 2						
'a'	0.32	4.5	124	370	1208	274
'b'	0.30	4.9	133	327	1056	270

from less acidified soil. At the same time those on very acid soil contained definitely more manganese and aluminium, and to a lesser degree sodium and zinc.

Top dressing with nitrogen caused a decrease in concentration of most mineral components in tobacco leaves, which was particularly noticeable in case of iron, sodium and potassium from both experiments, calcium and aluminium on acid soil, and manganese on very acid soil. It also slightly affected the level of magnesium and molybdenum on very acid soil.

DISCUSSION

Similar yields of leaves, more than average from this type of usable tobacco, were obtained in the experiments on both soils, in spite of the differences in their acidification. The results confirm weak sensibility of the tobacco plant to soil acidification [12]. It also points to tolerance of the aluminium launched in very acid soil. In this case share of Al in exchangeable soil acidity was 89 % and in these conditions Al may be toxic to plants [4]. It could be that an increased content of aluminium in very acid soil did not have any harmful influence on the yield of tobacco leaves because of organic matter content slightly higher than in acid soil, and fertilization with FYM. Soil organic matter may lower the level of aluminium harmfulness by chelating [2,5]. Application of organic fertilization, especially FYM, also lessens aluminium harmfulness through the influence on soil buffer abilities [5]. Top dressing with nitrogen slightly affected tobacco yield on both soils, which may result from an abundance in this component from the fertilizer given before planting.

Chemical composition of tobacco leaves grown on acid soil was characterized by a higher, though various for particular components, content of calcium, potassium, magnesium, phosphorus, molybdenum, copper and iron. As to the other components: total N, sodium, zinc, manganese and aluminium, their levels were higher in tobacco leaves from very acid soil. In spite of the interrelations mentioned above, the level of calcium, potassium, magnesium and nitrogen in tobacco leaves from both experiments were very similar. However, they were widely different in case of phosphorus, sodium and microelements. The leaves of tobacco cultivated on very acid soil were characterized by much lower concentrations of iron, copper, phosphorus and molybdenum than those on acid soil. It may be so because of lower availability of Mo from highly acidified soils [10], P reterdation by aluminium [5], or manifestation of Fe and Mn ions antagonism caused by excessive concentration of manganese in highly acidified soils [11]. Mn concentration was much higher on very acid soil, also Zn level in tobacco on both soils was high. Tobacco is a plant with high ability to accumulation mineral components, even in amounts much higher than needs, but Mn and Zn contents increase along with pH decrease [1]. In case of manganese and aluminium, and to a minor extent sodium and zinc, tobacco leaves from very acid soil were more abundant in these components as compared with plants grown on acid soil. The content of Mn and Al is strictly dependent on Al level in this soil, because with an increased concentration of this component manganese uptake increases visibly [9] while Al concentration in plant is proportional to its amount in soil in mobile form [4].

The content of Ca, K, P and Na is similar to the results obtained by the author in a pot experiment on Virginia tobacco on light acid soil [14]. In case of Mg, total N and particularly Mn, their levels in leaves were much lower, whilst for Cu and Zn the values were slightly higher than in field conditions [14,15]. It is connected with different circumstances of components uptake from soil. In pot experiments, there is a stronger penetration by roots of small clod of soil within their reach and changes in soil properties are much higher than in field conditions. In field conditions also nutritive components are utilized from lower levels of soil horizon.

Changes in chemical composition of plants resulting from N-fertilization have been the subject matter of numerous investigations, but the results are not compatible. In case flue-cured tobacco grown in field conditions nitrogen fertilization caused decrease of K and P contents, but concentrations of Ca, Mg, Na and N increase in the same time [13]. There is a small information about effect of nitrogen on microelements content in tobacco leaves. In the presented experimnets, top dressing with nitrogen mostly either did not change the concentration of mineral components in tobacco leaves or lowered their level to various extent for particular elements. The contents of following elements decreased most clearly: iron, sodium and potassium in both experiments, calcium and aluminium on acid soil, manganese on very acid soil. The concentration of magnesium and molybdenum also lowered, to same degree, on very acid soil. Fertilization with nitrogen caused a small increase in copper content in leaves from both soils, and raise in calcium and zinc on very acid soil. It has confirmed, as a whole, the results obtained in earlier studies [6,7,8]. In case of K, and for Fe and Zn fertilized with middle doses of nitrogen, results are also compatible to those from an earlier pot experiment on tobacco, where concentrations these elements decreased as a result of fertilization with increasing doses of nitrogen. For the remaining components, except phosphorus and copper, an increase in their contents was achieved in pot experiment along with the dose of N-fertilization [14,15].

CONCLUSIONS

1. Similar yields of flue-cured tobacco Virginia leaves were obtained on soils with various acidification degree and share of exchangeable Al in exchangeable acidity. The fact may testify a low sensitivity of this plant to an increased content of aluminium in soil.

2. Top dressing with nitrogen slightly affected tobacco yield on acid soil, whilst on very acid soil it had no influence on its amount.

3. Ca, K, Mg and total N content in tobacco leaves was similar on both soils; on very acid soil Fe, Cu and P concentrations were much lower, whilst Na, Zn and particularly Mn and Al levels on this soil were much higher.

4. Fertilization with nitrogen caused a marked decrease in Fe, Na and K content in tobacco leaves from both experiments, in Al and Ca content on acid soil, and Mn and Mg content on very acid soil.

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WPŁYW ZAKWASZENIA GLEBY NA SKŁAD CHEMICZNY LIŚCI TYTONIU

W doświadczeniach polowych na dwóch glebach o składzie granulometrycznym piasku słabo gliniastego, różniących się właściwościami chemicznymi, szczególnie stopniem zakwaszenia oraz udziałem glinu wymiennego w kwasowości wymiennej gleby badano reakcję w plonie i składzie chemicznym liści tytoniu papierosowego jasnego na zakwaszenie gleby. Zastosowano pełne nawożenie organiczne i mineralne NPK (wariant a) oraz na tym tle nawożenie pogłówne azotem (wariant b). Na obu glebach uzyskano zbliżony plon liści, co potwierdza małą wrażliwość tytoniu na zakwaszenie gleby. Zastosowane pogłówne nawożenie azotem w niewielkim stopniu wpłynęło na wysokość plonu. Poziom większości składników mineralnych zależał od zakwaszenia gleby. Zawartość wapnia, potasu, magnezu i azotu ogólnego w liściach z obu doświadczeń była zbliżona. Na glebie bardzo kwaśnej liście zawierały znacznie mniej żelaza, miedzi i fosforu, co wynika z mniejszej ich dostępności w tym środowisku lub wzajemnego uwsteczniania. W tych samych warunkach zawierały zdecydowanie więcej manganu i glinu, co wynika z większego ich uruchamiania w glebach bardzo kwaśnych, oraz w mniejszym stopniu sodu i cynku. Pogłówne nawożenie azotem w większości przypadków spowodowało obniżenie poziomu składników mineralnych w liściach tytoniu, szczególnie widoczne dla żelaza, sodu i potasu z obu doświadczeń, glinu i wapnia na glebie kwaśnej oraz manganu i magnezu na glebie bardzo kwaśnej.

S ł o w a k l u c z o w e: zakwaszenie gleb, tytoń, skład chemiczny tytoniu.