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EFFECT OF NITROGEN FERTILISATION AND SOIL MANAGEMENT ON SOIL MINERAL NITROGEN IN THE APPLE ORCHARD

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A B S T R A C T

In autumn 1993, 'Šampion' apple trees were planted 3 × 1 m apart in humus-rich, silty alluvial loam in Warsaw-Wilanów. Herbicide was applied in a 1 m wide strip between rows. Starting in the spring of 1994, nitrogen was applied as ammonium nitrate according to five different treatments: N-0 (no nitrogen); N-50 (50 kg N·ha^{-1} over the whole growing area in early spring); N-100 (100 kg N·ha^{-1} over the whole growing area in early spring); N-5+5 (split dose: 50 kg N·ha^{-1} over the whole growing area in early spring, repeated about five weeks later); and N-50-Herb (50 kg N·ha^{-1} only in herbicide strips). In 1996 and 1997, mineral nitrogen (NH_4 + $N0_3$) in the upper 20 cm of the soil column was measured on three dates: before fertilisation (beginning of April); four weeks later (May) and nine weeks later (June). Separate soil samples were taken from the herbicide strips and from the swards. Soil treated with higher doses of fertilizer contained more mineral nitrogen (N-min), though this effect was not significant in the swards. As a rule, N-min was higher in the herbicide strips than in the swards; this difference was more pronounced in plots which were fertilised than in plots which were not fertilised. Soil N-min increased over time, peaking in June. N-min in unfertilised soil was similar at different sampling dates in 1996; in 1997 it was higher in June than in April or May. In 1996, N-min in unfertilised soil did not depend on where the sample was taken; in 1997, it was slightly higher under the herbicide strips.

Key words: apple, nitrogen-fertilisation, soil-management, nitrate-nitrogen, ammonium-nitrogen, sampling-date

INTRODUCTION

In orchards, soil mineral nitrogen (N-min) depends more on soil management than on nitrogen fertilisation. N-min released from soil organic matter is an important source of nitrogen for fruit trees (Dalbro and Neilsen, 1958; Vang-Peterson et al., 1973; Greenham, 1976; Ystaas, 1981; Aasen, 1986; Dickler and Schäfermeyer, 1991). The most common soil management system now in use employs permanent sward in alleyways, with herbicide strips between rows.

N-min can be used to estimate nitrogen availability in the soil column. Samples for measurement should be taken from the rooting zone of the tree at different dates during the season (Scharpf and Wehrmann, 1979; Huguet, 1988).

The aim of this study was to assess the dynamics of the forms of available nitrogen in the apple orchard under different regimes of soil management and nitrogen fertilisation. Some of the results of this study have been already presented elsewhere (Wrona and Sadowski, 1999).

MATERIAL AND METHODS

The study was carried out at Warsaw Agricultural University's Experimental Station in Wilanów. The soil here is a silty alluvial loam containing 2.2% humus in the A_1 horizon. The top twenty meters of the field used in this experiment was slightly acid (pH_{KCl} = 6.0), with high available magnesium (16.6 mg%) and phosphorus (6.6 mg%), medium available potassium (19.6 mg%), and a low K/Mg ratio (1.2). Taking into account the low potassium ratio, as well as the fact that neighbouring orchards had occasionally showed signs of potassium deficiency, potassium (200 kg $K_2O \cdot ha^{-1}$) was applied in the summer of 1993, and again at the same dose in the spring of 1996, when leaf potassium approached the lower limit of the optimum range and the experimental trees started showing signs of slight deficiency. In the autumn of 1993, 'Šampion' apple trees, on M.9 and P 22 rootstock, were planted 3 × 1 m apart. Trees were trained as slender spindles. The experiment was set up as a split-plot design, with 6 replicates. Each plot contained eight trees, four on M.9 rootstocks, and four on P 22 rootstocks. Herbicide strips, 1 m wide, were maintained between tree rows. The 2 m wide swards were frequently mown.

Nitrogen was applied as ammonium nitrate according to five different schemes: N-0 (no nitrogen); N-50 (50 kg $N \cdot ha^{-1}$ over the whole growing area in early spring); N-100 (100 kg $N \cdot ha^{-1}$ over the whole growing area in early spring); N-5+5 (split dose – 50 kg $N \cdot ha^{-1}$ over the whole growing area in early spring, repeated about five weeks later); and N-50-Herb (50 kg $N \cdot ha^{-1}$ only in herbicide strips).

Starting in the spring of 1994, the basic dose of fertilizer was applied no later than mid-April, before the start of vegetative growth. In 1996 and 1997, N-min in the upper 20 cm of the soil column was measured on three different dates. The first sampling was done before fertilisation (April 11, 1996 and

April 9, 1997); the second, about five weeks later (May 7, 1996 and May 8, 1997); and the third, four weeks after that (June 18, 1996 and June 18, 1997). Separate samples were taken from each plot, from the herbicide strips and from the swards, with six replicates. Soil samples were air dried before analysis. N-NO_3 was measured in a 0.03 N acetic acid extract, using ion-selective electrodes (Orion). N-NH_4 was measured by the method of Bremner, as modified by Starck (Nowosielski, 1974; Starck, 1969).

Data were analysed using multivariate analysis of variance, in a split-split-block design. Mean separation was performed using the Newman-Keuls test.

RESULTS

Soil N-min varied with nitrogen fertilisation, both in 1996 and 1997 (Tab. 1). It was higher in plots fertilised at 100 kg N·ha^{-1}, than in plots fertilised at 50 kg N·ha^{-1}. The N-NO_3/N-NH_4 ratio also increased with fertiliser dose (Tab. 2). Soil N-min depended on where the sample was taken. N-min and the N-NO_3/N-NH_4 ratio were always higher in the herbicide strips than in the swards, and increased over time, peaking in June (Tabs. 3, 4, 5 and 6). In general, N-min was higher in 1996 than in 1997.

Table 1. Soil N-min [mg·100 g^{-1}] and nitrogen fertilisation: mean values for all soil management treatments and all three dates

Treatment	1996	1997
0	1.82 a*	2.50 a
50	4.19 ab	3.92 c
100	6.83 b	4.66 d
50+50	5.76 b	4.60 d
50_{herb}	5.36 b	3.32 b

*Means marked with the same letter (in columns) are not significantly difference at P = 0.05

Table 2. N-NO_3/N-NH_4 ratio and N fertilisation: mean values for all soil management treatments and all three dates

Treatment	1996	1997
0	1.01 a	0.37 a
50	2.66 ab	0.99 b
100	3.88 b	1.11 b
50+50	2.41 ab	0.94 b
50_{herb}	2.45 ab	0.88 b

T a b l e 3. Soil N-min [mg·100 g^{-1}] and soil management: mean values for all fertiliser treatments and all three dates

Soil management	1996	1997
Herbicide strips	6.74	5.41
Swards	2.84	2.19
Difference and significance	3.90**	3.22**

**Significant at P = 0.01

T a b l e 4. N-NO_3/N-NH_4 ratio and soil management: mean values for all fertiliser treatments and all three dates

Soil management	1996	1997
Herbicide strips	3.72 b	1.42 b
Swards	1.25 a	0.30 a

T a b l e 5. Soil N-min [mg·100g^{-1}] and sampling date: mean values for all fertiliser and soil management treatments

Sampling date	1996	1997
April	2.15 a	2.06 a
May	4.22 b	4.01 b
June	8.00 c	5.33 c

T a b l e 6. N-NO_3/N-NH_4 ratio and sampling date: mean values for all fertiliser and soil management treatments

Sampling date	1996	1997
April	0.96 a	0.33 a
May	1.60 a	1.04 b
June	4.89 b	1.21 c

In 1996, in plots which had not been fertilised (N-0 treatment), N-min was not affected by when and where the samples were collected. In 1997, N-min was highest in June, and slightly higher in the herbicide strips (Tabs. 7 and 8).

Nitrogen fertilisation significantly increased N-min in the herbicide strips, but not in the swards (Figs. 1, 2 and Tab. 9). In April of both years, before fertiliser was applied, N-min started out at about the same level regardless of which fertiliser treatment was used (Figs. 3 and 4). Fertilisation caused a significant increase in N-min in both May and June. N-min was lowest in plots which had not been fertilised, and highest in plots which had been fertilized at 100 kg N·ha^{-1}.

Table 7. Soil N-min [mg·100 g^{-1}] in the unfertilised treatment (N-0) and sampling date: mean values for both soil management treatments

Sampling date	1996	1997
April	1.80 a	1.94 a
May	1.87 a	2.26 a
June	1.83 a	3.30 b

Table 8. Soil N-min [mg·100 g^{-1}] in the unfertilised treatment (N-0) and soil management; mean values for all three sampling dates

Soil management	1996	1997
Herbicide strips	2.17	2.96
Swards	1.48	2.04
Difference and significance	0.69 n.s.	0.92^{o}

Explanations: n.s. – non-significant; ^{o} significant at P = 0.10

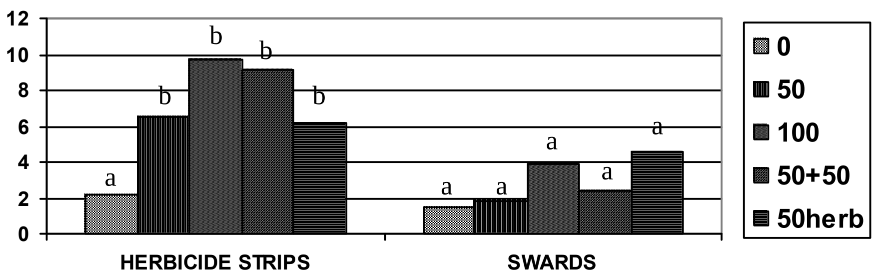

Figure 1. Effect of fertiliser treatments on soil N-min and soil management: mean values for all three sampling dates, 1996

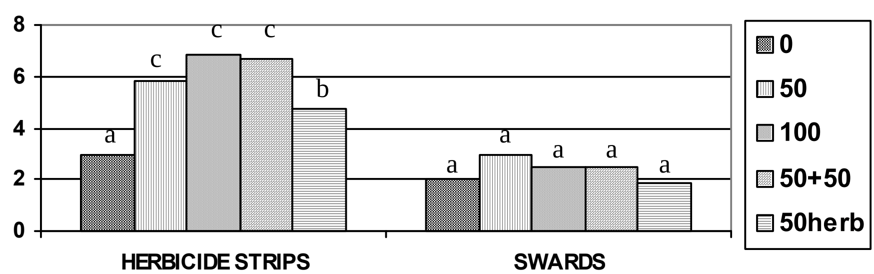

Figure 2. Effect of fertiliser treatments on soil N-min at different soil management: mean values for all three sampling dates, 1997

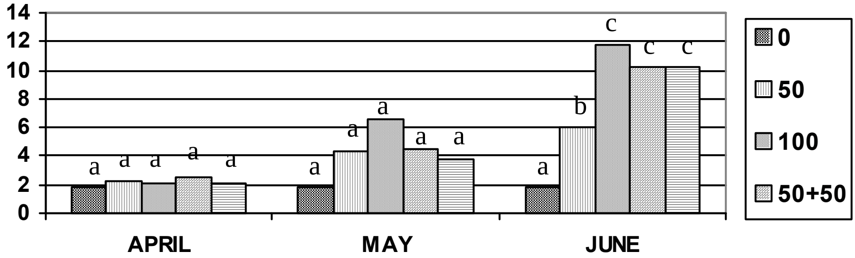

Figure 3. Effect of fertiliser treatments on soil N-min on different dates: mean values for both soil management treatments, 1996

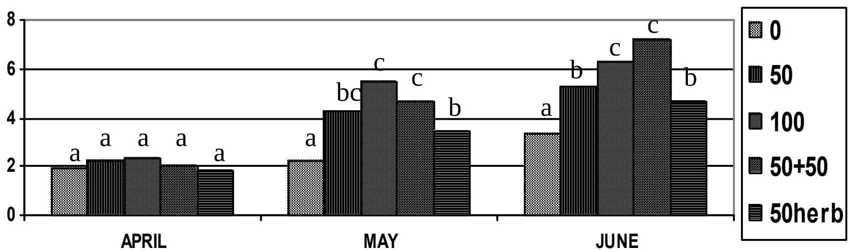

Figure 4. Effect of fertiliser treatments on soil N-min on different dates: mean values for both soil management treatments, 1997

T a b l e 9 . Soil N-min [mg·100 g^{-1}] and soil management and nitrogen fertilisation: mean values for all three dates

Treatment	Soil management				Difference and its significance	
	herbicide strips		swards			
	1996	1997	1996	1997	1996	1997
0	2.17	2.96	1.48	2.04	0.69 n.s.	0.92^{o}
50	6.54	5.86	1.83	1.97	4.71*	3.85**
100	9.71	6.80	3.94	2.52	5.77**	4.28**
50+50	9.15	6.69	2.37	2.51	6.78**	4.18**
50_{herb}	6.12	4.75	4.59	1.89	1.53 n.s.	2.86**

DISCUSSION

With current methods of orchard soil management, available nitrogen is higher in herbicide strips than in swards because of depletion by herbaceous plants (Scharpf and Wehrmann, 1979; Delver, 1980; Engel, 1985; Komosa, 1990; Kozanecka, 1995; Bielińska and Domżał, 1998). In our study as well, N-min was higher in herbicide strips than in swards. Mowing may also increase the differences in N-min between herbicide strips and swards. Considerable amounts of nitrogen are transferred in the organic matter ejected by the mower toward the tree rows (Jadczuk, 1990; Wrona and Sadowski, 1999). For diagnostic purposes, separate samples should be taken from herbicide strips and swards because the concentration of soil nutrients varies greatly across rows in the orchard.

In this study, soil N-min was generally high, even without fertilisation, and increased over time during the season. Similar results were obtained by Kozanecka (1995) who noted that N-min increased considerably during the season in soil which was not fertilised. The relatively high humus content of the soil used in this study played an important role in nitrogen availability. In fertile, humus-rich soils, nitrogen released during mineralisation of organic matter may fully satisfy the demand of fruit trees. White and Greenham (1967) calculated the annual amount of nitrogen mineralised in soil under clean cultivation, and found that, even after 30 years without fertilisation, this amount was roughly equal to the amount of nitrogen taken up by the trees.

In the herbicide strips, N-min increased depending on how much fertiliser was applied; in the swards, choice of fertilisation treatment did not have a large effect on N-min. This is in line with the findings of Rupp (1995), who found that nitrogen fertilisation increased nitrate levels in plots under clean cultivation, but not in swards. Weller (1977) also points out that nitrate was high in tilled soil, and low in swards.

The dynamics of available nitrogen in the soil indicates that nitrogen fertilisation is advisable only in early spring, when the N-min is at its minimum level. Later, sufficient amounts of nitrogen are released by natural processes in the soil. Nitrogen uptake by trees is most intensive from May to July (Faby and Naumann, 1986). Therefore, nitrogen fertiliser should be applied in early spring when mineralisation of organic matter is still very slow.

N-min and the $N\text{-}NO_3/N\text{-}NH_4$ ratio in the A_1 horizon were lower in 1997 than in 1996, particularly in June. This may have been because of more abundant rainfall in 1997, which apparently resulted in leaching of nitrates.

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WPŁYW NAWOŻENIA AZOTEM I SPOSOBU UTRZYMYWANIA GLEBY NA ZAWARTOŚĆ AZOTU MINERALNEGO W GLEBIE W SADZIE JABŁONIOWYM

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STRESZCZENIE

Drzewa odmiany ‘Szampion’ posadzono jesienią 1993 na polu doświadczalnym w Warszawie-Wilanowie na zasobnej w próchnicę madzie wykazującej skład pyłu ilastego w rozstawie 3 × 1 m. W międzyrzędziach utrzymywano murawę, a w rzędach drzew wąski ugór herbicydowy (1 m szer.). Zastosowano pięć kombinacji nawożenia: (1) N – 0 (bez azotu, kontrola); (2) N – 50 (50 kg N ha^{-1}, jednorazowo wiosną na całej powierzchni); (3) N – 100 (100 kg N ha^{-1}, jednorazowo wiosną na całej powierzchni); (4) N – 50 + 50 (50 kg N ha^{-1} wczesną wiosną + 50 kg N ha^{-1} około 5 tygodni później na całej powierzchni); (5) N – $50_{herb.}$ (50 kg N ha^{-1} wiosną tylko na pasach herbicydowych). Jako nawóz azotowy użyto saletry amonowej. W latach 1996 i 1997 próbki gleby na zawartość azotu mineralnego (NH_4+NO_3) pobierano z głębokości 0-20 cm trzykrotnie w ciągu sezonu wegetacyjnego: (początek kwietnia); cztery tygodnie później (maj) oraz dziewięć tygodni później (czerwiec). Oddzielnie pobierano próbki spod ugoru herbicydowego i oddzielnie spod murawy. Wraz z dawką nawożenia wzrastała zawartość azotu mineralnego (N-min) w glebie, ale tylko w ugorze herbicydowym; w murawie nie odnotowano istotnych różnic. Generalnie zawartość N-min była wyższa w ugorze herbicydowym w porównaniu do murawy; różnice te były wyraźniejsze na poletkach nawożonych niż nienawożonych azotem. Zawartość N-min wzrastała wraz z terminem pobierania próbek do analiz osiągając najwyższą wartość w czerwcu. W 1996 roku na poletkach nienawożonych azotem zawartość N-min była na podobnym poziomie przy wszystkich trzech terminach pobierania próbek; w 1997 była wyższa w czerwcu niż w kwietniu i maju. W 1996 roku zawartość N-min w glebie nienawożonej azotem nie zależała w sposób istotny od miejsca pobierania próbki; w 1997 roku zawartość ta była nieco wyższa w ugorze herbicydowym niż w murawie.

Słowa kluczowe: jabłoń, nawożenie azotem, utrzymywanie gleby, azot azotanowy, azot amonowy, termin pobierania próbek