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EFFECT OF AUTUMN FOLIAR UREA SPRAY ON NUTRIENTS STATUS OF 'ELISE' APPLE TREES

WPŁYW JESIENNEGO DOLISTNEGO NAWOŻENIA MOCZNIKIEM NA STAN ODŻYWIENIA MINERALNEGO JABŁONI ODMIANY 'ELISE'

Abstract: The present project was undertaken to study the influence of autumn foliar urea application on leaf and twigs macroelements content and yield of 5 year old 'Elise' apple. The study was carried out in years 2004–2007 in the experimental orchard at Garlica Murowana near Krakow. Trees were sprayed with 2 % and 4 % of urea at post-harvest in October. The yield of fruits and the contents of N, P, K, Mg and Ca were examined in plant samples collected.

The N status of apple trees was optimal or high independent on treatments. Autumn foliar urea sprays increased N content in twigs, but only in 2007 (after dry and warm 2006) affected fruit yield. There is some evidence that autumn application of urea would be most useful for trees with low nitrogen status. The results indicate that use of foliar urea at the high solution concentration (4 % m/v) is more efficient way to N supply than 2 %.

Keywords: 'Elise' apple, urea sprays, nutritional status

Foliar application of mineral nutrients by means of sprays offers a method of supplying nutrients to plants more rapidly than methods involving root application [1, 2]. Foliar nitrogen supply in orchard is gaining importance as a technique to integrate soil N applications or as an alternative to them [3, 4].

In fruit trees, spring growth, including flowering, depends on translocation of nitrogen stored in perennial organs [5]. Nitrogen is stored during the winter, predominantly as protein in the bark of twigs and trunk or roots, and translocated in the spring when the buds break [5, 6]. Translocation of N in spring provides nitrogen for leaf growth before rapid root uptake occurs and so is unaffected by the N supply to the soil [6–9]. Nitrogen utilized during bloom and the period of rapid shoot elongation

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following bloom is dependent upon the redistribution of stored nitrogen from previous year application [5].

Urea is considered the most suitable form of N to supply as a foliar spray because its non-polarity, and rapid absorption, low phytotoxicity and high solubility [1, 10]. Foliar supplied urea is absorbed by leaves and rapidly converted to amino acid [11]. It indicates that the metabolism of root-absorbed and leaf absorbed N do not differ [5]. Most studies were focused on plant N status and growth in response to urea sprays [2, 12–14]. Although urea may be used at any time during the growing season, autumn application may be most effective for deciduous trees because high urea concentration can be used with minimal concern about phytotoxicity [15]. The autumn foliar application of urea can increase N reserves and improve flowering, fruit set and growth in the following season. Nitrogen uptake through leaf surfaces may permit the reduction of soil N application in orchard, thus decreasing the potential nitrate leaching to the groundwater [16].

As a side effect of foliar application of urea, microflora populations on the leaf surface might be changed and spore germination and colony growth of pathogens thereby reduced [17].

The aim of the present research was to assess the effect of 2 % and 4 % urea solutions on the leaves and twigs macronutrients concentration, and yield of 'Elise' apples.

Materials and methods

The study was carried out in years 2004–2007 in the experimental orchard at Garlica Murowana near Krakow. Trees of 'Elise' cultivar, grafted on M.9 rootstock were planted in 2000 at 4 × 1.6 m spacing. The soil was kept in the herbicide strips in tree rows with grass between them.

Every year of the experiment in spring nitrogen soil fertilization was applied at the rate of 50 kg · ha^{-1} using ENTEC 26 (26 % N including 18.6 % NH_4-N with the addition of nitrification inhibitor). Nitrogen fertilizer was spread around each tree, in the area of herbicide strip.

The experiment was carried out in a complete randomized blocks in four replications (6 trees in one replication) and comprised:

1. Control (no foliar spraying, no soil N applied),
2. Control + soil N applied,
3. Trees sprayed with 2 % urea (one time),
4. Trees sprayed with 4 % urea (one time).

Solutions were used with an addition of the surfactant Aptolan 80EC (76 % of paraffin oil) in the amount of 1000 dm^3 · ha^{-1}. The sprayings were conducted after fruits harvest in the first decade of October.

Soil analysis

Soil samples were taken from the layers of 0–20 cm and 20–40 cm, each separately from herbicide stripes and grass strips, at the time of taking leaf assays. Nutrient contents in soil were estimated according to the Egner-Riehm (P and K) and Schachtschabel (Mg) methods as well as by universal methods (Ca) [18]. The pH value in water suspension (pH_{H_2O}) and in 1 mol · dm^{-3} KCl (pH_{KCl}) in 1 : 2 the soil : water (or soil : solution) ratio were measured. In soil samples granulometric composition by the aerometric method of Proszynski [19] and the organic carbon content by Tiurin's method were determined [18].

Leaf analysis

To estimate the nutritional status of the trees the leaves samples were collected every year at the end of July or the beginning of August. Samples of 10 mid-shoot leaves from current season's extension growth on shoots of representative vigor, in the periphery area around the each tree were collected. Plant material was dried at 70 °C and digested in the mixture of HNO_3, $HClO_4$ and H_2SO_4 (6 : 2 : 0.8 ratio). The contents of K, Mg and Ca were measured by atomic absorption spectrophotometer using the flame method; P was determined by spectrophotometric method with ammonium molybdate. Total nitrogen content in leaves was determined by Kjeldahl's methods [19].

Twigs analysis

At the beginning of December after leaves abscising 5 twigs (10 cm a length) of each tree were taken from the outer part of the tree, at the height of 1 m. The bark with a cambium layer and the wood of twigs were analyzed separately. Nitrogen, phosphorus, potassium, magnesium and calcium contents were determined after dried, milled and mineralization in acid mixture as previously described.

Every year in the first decade of September the yield of fruits was also estimated.

Statistical analysis

Data were subjected to two or tree-factor analysis of variance (ANOVA). Differences between means were assessed by Fisher's test. All statistical analyses were performed with Statistica 8.0 software.

Results and discussion

Soil analysis

The experimental orchard was established on heavy soil (> 35 % of fraction < 0.02 mm) of silt loam with a low pH_{KCl} 4.05–4.19. The phosphorus and magnesium content was high (> 4 mg P · 100 g^{-1} and 5–6 mg Mg · 100 g^{-1}, respectively) both in the herbicide and grass stripe samples of 0–20 cm and 20–40 cm layers. The potassium content was high and ranged between 16.3 (in 20–40 cm layer) to 22.4 mg K · 100 g^{-1} (in the humus layer). The potassium to magnesium ratio (K:Mg) in the soil was proper, lower than 3.5 (Table 1).

Table 1

Contents of P, K, Mg and Ca in the orchard soil

Factor		pH in KCl	P	K	Mg	Ca	K : Mg
			[mg 100 · g^{-1}]				
Place of sampling	Herbicide strip Grass strip	4.19 4.05	5.0 4.8	19.1 19.7	5.9 6.4	38.8 27.4	3.2 3.1
Soil layer [cm]	0–20 20–40	4.17 4.06	5.6 4.3	22.4 16.3	6.1 6.2	32.6 33.6	3.7 2.6

Leaves analyses

Environmental factors affected nutrient uptake by plant in years of research. Any year of the experiment magnesium and calcium content in the leaves ranged in the optimum values for the apple trees [20] (Table 2).

Table 2

Nutrient contents in leaves of apple 'Elise' cv.

Factor		N	K	Mg	Ca	P
		[% d.m.]				
Year	2005	2.53	1.72	0.25	1.32	0.17
	2006	2.36	1.21	0.26	1.34	0.08
	2007	2.44	1.21	0.24	1.52	0.14
Treatment	Control	2.46	1.33	0.26	1.41	0.13
	Control + N	2.39	1.42	0.25	1.37	0.13
	2 % urea	2.48	1.43	0.23	1.40	0.13
	4 % urea	2.45	1.34	0.26	1.40	0.13
$LSD_{0.05}$ for	Year Treatment	0.054 0.063	0.170 ns	ns 0.023	0.075 ns	0.015 ns

ns – not significant.

The phosphorus level reached the optimum range in 2005 and 2007, however, it was low in 2006. In 2006 the nitrogen level in leaves was in the optimum, while in 2005 and 2007 in the high range (more than 2.4 % N in d.m.). In 2005, high K content in the apple leaves was detected (> 1.5 % K in dm). In the present study spring soil N application (Control + N) resulted in a little lower than average leaf N. This result did not confirm conclusions of Khemira et al [21], who reported that spring-applied broadcast fertilizer in apple was found in aboveground tissues rather than roots, but that nitrogen from preharvest broadcast application was translocated preferentially to the roots.

Autumn foliar urea application did not affect P, K and Ca content in apple leaves. The lower content of Mg was measured in leaves treated 2 % urea solution than in the control trees and foliar applied of 4 % urea solution.

Twigs analyses

Oland [22] reported that foliar application of 4 % urea solution to apple trees in autumn increased the amount of nitrogen translocation from leaves during senescence, which resulted in a 31 % increase in N content of reproductive spurs by leaves fall and increased fruit yield in the subsequent year. In present studies foliar 4 % urea solution application significantly increased N content in bark of the one-year old apple twigs analyzed in the beginning of December in 2005 and 2006 (Table 3).

Table 3

Nitrogen content in the bark and wood of 'Elise' apple twigs

Treatment	Part of branch	N content [%]			
		2005	2006	2007	Mean
Control	Bark	1.41 a	1.43 ab	1.33 a	1.39 a
Control + N		1.48 a	1.35 a	1.29 a	1.37 a
2 % urea		1.48 a	1.50 bc	1.41 a	1.46 b
4 % urea		1.61 b	1.58 c	1.40 a	1.53 c
Control	Wood	0.84 a	0.69 ab	0.86 a	0.80 a
Control + N		0.84 a	0.58 a	1.04 b	0.82 ab
2 % urea		0.91 a	0.66 a	1.03 b	0.87 bc
4 % urea		1.06 b	0.80 b	0.90 a	0.92 c

In 2007 this trend was also observed, but was not statistically significant. In the wood samples only in 2005 application of 4 % urea statistical significantly augmented N content. The nitrogen content in bark was above 60 % higher than in wood tissues. An average (in 3 years of experiment) the amount of nitrogen in bark ranged between 1.37 % (control + N) to 1.53 % d.m. (4 % urea solution), while wood contained 0.80 % N (control) to 0.92 % d.m. (4 % urea solution). Khemira et al [23] reported that in mature spur and standard apple trees, very little N derived from autumn foliar applications was found in any tissues the following season. Authors showed that for trees with sufficient N at senescence, foliar applied urea may only replace leaves nitrogen that would normally be withdrawn, rather than augmenting it.

The phosphorus content in bark and wood of shoots was similar and independent on treatments in case of wood. Mean values of P in bark were 0.15–0.18 % d.m. (Table 4). The lowest P content was measured in bark of shoots collected from control treatment without N fertilization. In wood tissues the phosphorus content ranged from 0.16 % to 0.17 % d.m. The potassium content in bark as well as in wood did not affect by treatments. In wood measured above 40–46 % of K detected in bark (Table 4). The amount of Mg and Ca in wood tissues was much lower than in bark of apple twigs and amounted above 30 % and 23 % of bark content, respectively. The magnesium level in twigs wood tissues was not very differentiated following treatments, however statistical significant. The Mg content in bark and wood was higher in the control trees with soil applied N. These results are difficult to conclusive interpretation. The twigs collected from trees without N fertilization (control) or sprayed with 2 % urea solution had significantly higher calcium content.

Table 4

Nutrient content in the bark and wood of 'Elise' apple twigs (mean of 3 years)

Treatment	Part of branch	P	K	Mg	Ca
		[% d.m.]			
Control	Bark	0.15 a	0.61 a	0.15 a	1.92 ab
Control + N		0.18 b	0.76 a	0.17 b	1.74 a
2 % urea		0.17 b	0.67 a	0.15 a	2.01 b
4 % urea		0.17 b	0.62 a	0.15 a	1.73 a
Control	Wood	0.16 a	0.28 a	0.04 ab	0.45 a
Control + N		0.17 a	0.30 a	0.05 c	0.42 a
2 % urea		0.16 a	0.28 a	0.04 a	0.44 a
4 % urea		0.16 a	0.29 a	0.05 bc	0.42 a

Yield

In 2005 and 2006 yield of trees was similar and ranged between 12.3 to 13.1 kg per tree, while in 2007 over twice higher yield was obtained (Table 5).

Table 5

Yield [kg per tree] of 'Elise' apple in 2005–2007

Combination		Yield [kg per tree]			
		2005	2006	2007	Sum of 2005–2007
Control		14.3	11.3	29.5	55.1
Control + N		11.1	13.9	27.1	69.5
2 % urea		13.3	13.1	30.6	57.0
4 % urea		14.0	11.1	34.4	59.5
Mean for year		13.1	12.3	30.4	
$LSD_{0.05}$ for	Year		2.05		
	Treatment	ns	ns	ns	

Severe spring frost affected the fruit production for 2005 and 2006, whereas growing condition in 2007 was ideal with adequate rainfall during the summer and no significant frost/freeze conditions in the spring during bloom. Any year were not significant differences between treatments although, average yield from trees treated with 2 % and 4 % urea solutions was slightly higher (Fig. 1).

The growing season of 2006 was the warmest and driest. This year extremely dry month were recorded July and October. There were not favorable conditions to N uptake by roots and storing nitrogen in the woody tissues of the trees as proteins or

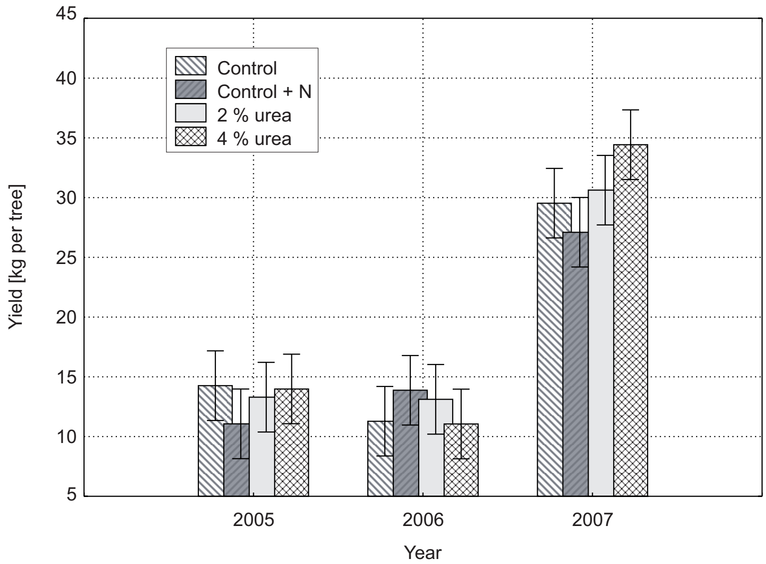

Fig. 1. Yield [kg per tree] of 'Elise' apple in 2005–2007

amino acids for the growth the following spring. Autumn urea-N applied could improve nitrogen sink for next year and affected yield in 2007. Fallahi et al [24] reported that a post-harvest urea application at the beginning of leaf senescence appears to be most efficient in providing N to the developing flower buds. Neilsen et al [9] showed that translocated nitrogen contributed 50 % of N in shoot leaves, 90 % of N in the spur leaves that subtend the fruit and 60 % of the nitrogen in the fruit.

Conclusion

Conditions which potentially limit the availability of nitrogen in the soil or their utilization (ie light textured soils, late fruit harvests, environmental conditions) represent situations in which foliar N application offers an important alternative means of supply for maintain nutrient N status. Post-harvest foliar N applications are typically made in summer/autumn to augment N reserves in the branches available to support the spring vegetative and reproductive growth occurring before the roots are capable of significant uptake of soil nitrogen. The results discussed here demonstrate the benefits of N post-harvest urea application in the average well-maintained apple orchard. In present study the nitrogen N status of apple trees was optimal or high N independent on treatments. Autumn foliar 4 % urea sprays slightly increased N content in twigs, but only in 2007 (after dry and warm 2006) affected fruit yield. There is some evidence that autumn application of urea would be most useful in trees with low nitrogen status. The results reported indicate that the use of foliar urea at the high concentration (4 % m/v) is more efficient way to supply N than 2 % solution.

References

[1] Marchner R.: Mineral Nutrition of Higher Plants. Press Academy, London 1995.
[2] Michajłoć Z. and Szewczuk C.: Acta Agrophys. 2003, **85**, 9–17.
[3] Klein I.: Acta Hort. 2002, **594**, 131–136.
[4] Mengel K.: Acta Hort. 2002, **594**, 33–38.
[5] Millard P.: Acta Hort. 1995, **383**, 3–10.
[6] Sanchez E. and Righetti T.: J. Amer. Soc. Hort. Sci. 1990, **115**, 934–937.
[7] Millard P.: J. Plant Nutr. Soil Sci. 1996, **159**, 1–10.
[8] Taglavini M., Quartieri M. and Millard P.: Plant Soil 1997, **159**, 437–442.
[9] Neilsen D., Millard P., Neilsen G. and Houge E.: J. Amer. Soc. Hort. Sci. 2001, **126**, 144–150.
[10] Swietlik D. and Faust M.: Hort. Rev. 1984, **6,** 287–355.
[11] Dong S., Cheng L., Scagel C. and Fuchigami L.H.: Tree Physiol. 2002, **22**, 1305–1310.
[12] Taglavini M., Millard P. and Quartieri M.: Tree Physiol. 1998, **18**, 203–207.
[13] Cheng L., Guak S., Dong S. and Fuchigami L.H.: Hort. Sci. 1999, **34**, 492–499.
[14] Tagliavini M. and Millard P.: Acta Sci. Pol. Hort. Cultus 2005, **4**, 21–30.
[15] Johnson R.S., Rosencrance R., Weinbaum S., Andris H. and Wang J.: J. Amer. Soc. Hort. Sci. 2001, **126,** 364–370.
[16] Neilsen G.H. and Neilsen D.: Apples: Botany, Production and Uses. CAB Publishing, Cambridge, USA 2003.
[17] Wood P.N. and Beresford R.M.: New Zealand Plant Protect. 2000, **53**, 382–386.
[18] Ostrowska A., Gawliński S. and Szczubiałka Z.: Metody analizy i oceny właściwości gleb i roślin. Wyd. IOŚ, Warszawa 1991.
[19] Sady W., Domagała I., Kowalska I., Lis-Krzyścin A. and Ostrowska J.: Przewodnik do ćwiczeń z uprawy roli i nawożenia roślin ogrodniczych. Wyd. AR, Kraków 1994.
[20] Sadowski A.: Nawożenie roślin sadowniczych. Sadownictwo. Wyd. Nauk. PWN, Warszawa 2000.
[21] Khemira H., Righetti T.L. and Azarenko A.N.: J. Hort. Sci. Biotechnol. 1998, **73**, 217–223.
[22] Oland K.: Nature 1960, **85**, 857.
[23] Khemira H., Righetti T.L. and Azarenko A.N.: Hort. Sci. 1999, **34**(6), 1079–1081.
[24] Fallahi E., Khemira H., Righetti L.T. and Azarenko A.N.: Acta Hort. 2002, **594**, 603–610.

WPŁYW JESIENNEGO DOLISTNEGO NAWOŻENIA MOCZNIKIEM NA STAN ODŻYWIENIA MINERALNEGO JABŁONI ODMIANY ‘ELISE’

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Abstrakt: Badano wpływ jesiennego dolistnego nawożenia mocznikiem na zawartość makroskładników w liściach i pędach 5-letnich jabłoni odmiany ‘Elise’. Doświadczenie prowadzono w latach 2004–2007 w Garlicy Murowanej koło Krakowa. Zabiegi dolistnego nawożenia 2 % i 4 % roztworem mocznikiem wykonywano po zbiorze owoców w pierwszej dekadzie października. Określano plon owoców oraz zawartość azotu, fosforu, potasu, magnezu i wapnia w liściach i pędach jabłoni.

Przeprowadzone analizy materiału roślinnego wykazały, że we wszystkich latach prowadzenia badań stan odżywienia jabłoni azotem był optymalny lub duży, niezależnie od zastosowanego nawożenia. Jesienne pozakorzeniowe stosowanie mocznika zwiększało zawartość N w pędach jabłoni, ale tylko w 2007 r. (po suchym i gorącym roku 2006) zwiększyło plony owoców. Lepsze wyniki uzyskano, stosując większe stężenia mocznika (roztwór 4 %).

Słowa kluczowe: jabłka odmiany ‘Elise’, dolistne nawożenie mocznikiem, odżywienie mineralne