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EFFECT OF NITROGEN FERTILIZATION ON GROWTH AND NITROGEN DISTRIBUTION IN 'RED FUJI' APPLE TREES

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ABSTRACT

The aim of this study was to examine the response of young 'Red Fuji' apple (*Malus domestica* Borkh.) trees grafted on *M. hupenensis* Rehd to different levels of nitrogen fertilization. A root dividing system was used. The level of nitrogen fertilization affected growth and physiological processes in 'Red Fuji' apple trees. As the volume of root system treated with nitrogen increased, the density of absorbing roots and hair roots decreased, as did the root/shoot ratio. In nitrogen deficiency, root biomass increased, but root nitrogen content decreased. As nitrogen level and the volume of root system treated with nitrogen increased, shoot growth went up, and root nitrogen also increased slightly.

Key words: nitrogen supply level, apple trees, growth, nitrogen distribution

INTRODUCTION

Nitrogen is an macronutrient essential for normal growth in higher plants (Marschner, 1995), and is a critical element in crop culture, particularly apple production (Shu, 1993). Nitrogen is usually insufficient in the apple orchard; fertilization is often needed to assure normal growth and development. Excessively high soil nitrogen promotes vegetative growth at the expense of

fruit yield and quality (Gu, 1986; Hou, 1999). Runoff from orchards which have been over-fertilized can pollute the environment (Lu, 1998). This study was carried out as out an experiment with a root dividing system with the aim of determining the optimal level of nitrogen fertilization in the apple orchard.

MATERIAL AND METHODS

Plant material and growth conditions

One-year-old apple trees (*Malus domestica* Borkh. 'Red Fuji'/*M. hupenensis* Rehd) were planted in plastic boxes (30 cm high x 40 cm in diameter), each containing 40 kg of sandy loam (for physical and chemical properties of the soil, see Table 1). Each box was divided into two parts, so that one part of the root system could be treated with nitrogen, and the other part remain untreated. In early March, the apple trees were planted in the boxes in the field 1 x 1 m apart.

T a b l e 1 . Physical and chemical properties of the soil

pH	Specific gravity [g cm^{-3}]	Total bases [mol kg^{-1}]	Organic matter [g kg^{-1}]	Total nitrogen [g kg^{-1}]	Available [mg kg^{-1}]		
					N	P	K
6.8	1.32	24.2	9.5	0.63	38.6	48.9	76.4

Nitrogen treatments and the design of the experiment

At the end of June, nitrogen fertilizer (^{15}N-urea) was applied to 10% (T-10%), 20% (T-20%), 50% (T-50%), and 100% (T-100%) of root volume at the rates of 1, 2, 5 and 10 g, respectively. Control trees were left untreated. Thirty trees were treated and evaluated on two dates (July 24 and September 26). There were three replicates for each treatment.

Measurements and observations

After one month (July 24) and three months (September 26), samples were collected and the following were measured: Dry weight of root and shoot (after drying to constant weight in a forced-draft oven at 75º C; and ^{15}N in root and shoot (after drying and grinding plant material with an agate mill). Nitrogen was determined using a mass spectrometer.

Statistical analysis

Differences in mean values for absorbing root and root hair were evaluated by Duncan's t-test at P = 0.05.

RESULTS AND DISCUSSION

Effect of nitrogen level on root system

After one month and three months of nitrogen treatment, the quantities of absorbing root and root hair per 100 cm^3 were measured. When nitrogen level was low, the quantity of absorbing root increased to compensate (Tab. 2). As the nitrogen level increased, the quantity of absorbing root decreased, while in the untreated part, the absorbing root increased by about the same factor as did root hair.

Table 2. Effect of nitrogen level on absorbing root and root hair in 'Red Fuji' apple trees, mean of both dates

Treatment	Absorbing root [100 cm^3]			Hair root [100 cm^3]		
	treated part (T)	untreated part (U)	ratio of T/U	treated part (T)	untreated part (U)	ratio of T/U
Control	13d*	13c	1.0	543d	543b	1.0
T-10%	99a	12c	8.3	1808a	133d	13.6
T-20%	44b	21b	2.1	833b	388c	2.1
T-50%	33c	31a	1.1	730c	547b	1.3
T-100%	30c	30a	1.0	679c	679a	1.0

*Means within the columns with the same letter are not significantly different at P = 0.05 according to Duncan's t-test

Effect of nitrogen level on shoot biomass

Upper plant biomass increases with increasing nitrogen level (Tab. 3). The proportion of shoot is highest with treatment T-20%, and lowest in the control. The proportion of leaf is highest with treatment T-100%.

Table 3. Effect of nitrogen level on biomass of different parts of 'Red Fuji' apple trees, mean of both dates

Treatment	Relative value [%]			
	shoot	leaf	stem	total
Control	13.6	16.6	69.8	100
T-10%	21.2	16.1	62.7	100
T-20%	26.3	16.9	56.8	100
T-50%	22.5	18.3	59.2	100
T-100%	19.0	28.9	52.1	100

Effect of nitrogen level on root/shoot ratio

Both the ratio of total root to total shoot and the ratio of new root to new shoot decreased with increasing nitrogen level on both dates, with the

exception of treatment T-100% in July (Tab. 4). When nitrogen level is low, root growth increases to expand the nutritional area of the root system in the soil. Nitrogen fertilization promotes shoot growth.

Table 4. Effects of nitrogen level on root/shoot ratio in 'Red Fuji' apple trees

Treatment	Root/shoot ratio			
	new root/new shoot		total root/total shoot	
	24 July	26 Sep.	24 July	26 Sep.
Control	0.597	0.821	0.629	1.060
T-10%	0.834	0.942	0.590	1.687
T-20%	0.795	0.880	0.522	1.555
T-50%	0.671	0.754	0.512	1.269
T-100%	0.843	0.655	0.704	0.727

Effect of nitrogen level on nitrogen distribution

Analysis of the distribution of nitrogen in different parts of treated plants showed that when nitrogen level is low, nitrogen is first transported to the leaf fraction. Root nitrogen increases with soil nitrogen up to a certain point, then starts to decrease again (Tab. 5). Over-fertilization decreases both leaf and root nitrogen.

Table 5. Effect of nitrogen level on nitrogen content in shoots and roots of 'Red Fuji' apple trees, September 26

Nitrogen content [mg kg^{-1}]	Control	T-10%	T-20%	T-50%	T-100%
Shoot	22.9	22.2	22.5	23.5	21.7
Root	7.7	13.7	10.9	10.3	9.6

CONCLUSIONS

The level of nitrogen fertilization affected growth and physiological processes in 'Red Fuji' apple trees. As the volume of root system treated with nitrogen increased, the density of absorbing roots and hair roots decreased, as did the root/shoot ratio. In nitrogen deficiency, root biomass increased, but root nitrogen content decreased. As nitrogen level and the volume of root system treated with nitrogen increased, shoot growth went up, and root nitrogen also increased slightly.

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WPŁYW AZOTU NA WZROST ORAZ ROZMIESZCZENIE TEGO SKŁADNIKA W JABŁONIACH ODMIANY ‘RED FUJI’

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STRESZCZENIE

Celem doświadczenia była ocena reakcji młodych drzew jabłoni odm. ‘Red Fuji’ (*Malus domestica* Borkh.) okulizowanych na podkładce *M. hupenensis* Rehd, na zróżnicowane dawki azotu. Drzewka posadzano do pojemników rozdzielając objętościowo w określonych relacjach ich korzenie i rozmieszczając je w zdywersyfikowanych objętościach gleby nawożonej wzrastającymi dawkami azotu. Przeprowadzone badania wykazały, iż wzrost roślin oraz ich funkcje fizjologiczne zmieniały się w zależności od zastosowanych dawek azotu oraz układu rozdzielenia korzeni. Gęstość korzeni tym bardziej malała, im większa ich objętość była traktowana azotem. Okazało się także, że stosunek masy korzeni do pędu zmniejszał się wraz ze wzrostem objętości korzeni traktowanych azotem. Przy niedoborze azotu biomasa korzeni zwiększała się, podczas gdy zawartość azotu w korzeniach malała. Wzrost zaś dawki azotu przy równocześnie narastającej objętości korzeni traktowanych azotem powodowało intensywniejszy przyrost pędu i niewielki wzrost zawartości azotu w korzeniach.

Słowa kluczowe: dawka azotu, jabłoń, wzrost, rozmieszczenie azotu