

CHARACTERIZATION OF RED BEET AND CARROT WITH SPECIAL EMPHASIS ON NITRATE ACCUMULATION

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Nitrate accumulation in plants is a natural phenomenon resulting from uptake of nitrate ion in excess of its reduction and subsequent assimilation. The water soluble nitrate content of various carrot and red beet varieties was measured as a function of irrigation and mineral supplement in three years. In the first year, the nitrate content increased in both roots (significant differences were found for three carrot and at three red beet cultivars) following the irrigation. The activity of nitrate-reductase in the leaves was also significantly higher after irrigation in three red beet varieties in 1998. The mineral supplement in most of the carrot varieties increased the nitrate content. In the third year, the impact of water supply showed various tendencies in nitrate accumulation in both vegetables. On the basis of results for three years, the conclusion was that the seasonal and varietal differences were also remarkable.

Keywords: carrot, red beet, irrigation, nitrate, nitrate-reductase

Vegetables and drinking water provide two of the main sources of human exposure to nitrate and nitrite, the other major source being the preservatives added to meat to prevent botulism and to enhance colour (FORMAN □ DOLL, 1985).

Nitrate may be converted to nitrite during storage of plant products as the result of bacterial action or plant nitrate-reductase activity. Nitrite may also be formed from nitrate after ingestion. In humans with healthy alimentary canals, nitrate is absorbed rapidly without reduction in the upper intestines, but gastrointestinal disturbances may delay absorption and increase chances for reduction. Reduction is more likely in infants than in adults, on one hand, because of the lesser acidity in the gastrointestinal tract which allows nitrate-reducing coliforms and clostridia to survive and, on the other hand, because of higher frequency of digestive disturbances which might bring the nitrate-reducing bacteria into the upper intestinal tract (GREENWOOD □ HUNT, 1986).

The Expert Committee of FAO/WHO determined the Acceptable Daily Intake (ADI) value as 5 mg sodium-nitrate, and 0.2 mg sodium-nitrite/body weight kg. The average nitrate intake in European countries is 100 mg daily, of which 70–80% derives from vegetables (PENTILLA, 1996).

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It is well known that red beet, leaf-greens, kohlrabi and radish are considered as high nitrate accumulation plants (BUCKENHÜSKES & GIERSCHE, 1986). Nitrate content was one of the indicators of the overall acceptability and value of spinach (POSPIŠIL et al., 1988). Nitrate content of carrot is much less than previously mentioned, and is an important raw material for baby foods.

The nitrate assimilation depends on the environment, agrotechnical elements such as fertiliser management, irrigation and type of soil. It is well documented that reductions in light intensity are often associated with increased nitrate concentrations in plants. The first step in nitrate assimilation is the reduction of nitrate to nitrite mediated by the enzyme nitrate-reductase (NR), a metallo-flavoprotein. It is considered a rate-limiting step because nitrate may accumulate, while other intermediates in the process normally do not, at least prior to the amino N-stage. Nitrate-reductase activity and its relationship to accumulation of nitrate in various plants has also been studied (GEBAUER et al., 1988).

The aim of this work was to study the effect of treatments including irrigation with water and magnesium-sulphate solution on nitrate accumulation in vegetables. Comparing the carrot and red beet varieties in view of nitrate accumulation is also very essential. The nitrate content was measured in various red beet and carrot varieties as a function of cultivation methods in three years (1998–2000). The relationship of the nitrate content in carrot and red beet roots and the activity of nitrate-reductase in leaves were also studied in the year of 1998.

1. Materials and methods

1.1. Materials

Red beet (*Beta vulgaris* ssp. *esculenta* var. *rubra*) and carrot (*Daucus carota* L.) were chosen for the experiments. Samples were obtained from the experimental plots (meadow silt soil) of the Research Institute for Irrigation in Szarvas. Altogether seven red beet (Favorit, Bordó, Rubin, Bonel, Nero, Detroit and Cylindra) and eight carrot (Nantes, Fertődi vörös, Vörös óriás, Danvers, Rekord, Flakker, Szupra, K-arany) cultivars were analysed during three-year period. The soil nutrient supply was the most appropriate for red beet (N: 80 kg ha⁻¹, P₂O₅: 80 kg ha⁻¹ and K₂O: 220 kg ha⁻¹) and carrot (N: 100 kg ha⁻¹, P₂O₅: 70 kg ha⁻¹ and K₂O: 200 kg ha⁻¹). Carrots and red beet seeds were sown in April and in June, respectively. The impact of irrigation on the nitrate content was investigated in two years (1998, 2000), because the weather was rainy in 1999. Irrigation – 30–40 mm – was applied (micro nuzzles) three times in case of carrots and twice for red beet during the vegetation period. Furthermore, 1% magnesium-sulphate solution as mineral supplement was sprayed twice on carrot leaves. The vegetables were harvested in October. Red beet and carrot varieties were harvested from 4–4 parallel experimental plots and the nitrate content of the samples was measured in 3×3 replicates.

The meteorological data during the growing period are summarized in Table 1.

Table 1. Meteorological data during the growing period on the experimental plots. Szarvas, 1998–2000

Years	Months						Total
	April	May	June	July	August	September	
Sun shine hours							
1998	155.7	231.4	277.7	189.9	307.3	175.7	1337.7
1999	212.0	252.8	239.9	309.2	283.9	201.1	1498.9
2000	208.1	323.1	356.1	250.7	330.1	189.3	1657.4
Rain fall/month (mm)							
1998	64.7	60.5	25.9	109.5	69.5	100.2	430.3
1999	67.6	68.7	160.0	96.2	53.0	50.2	495.7
2000	40.8	29.4	7.5	63.8	11.0	61.2	213.7
Average temperature (°C)							
1998	12.2	15.2	21.3	21.8	21.4	15.5	17.9
1999	18.6	21.9	20.3	22.7	20.8	18.2	20.45
2000	14.4	19.1	21.6	20.7	23.3	15.8	19.15

1.2. Nitrate assay

Carrots and red beets were hand peeled and cut into slices of 5 mm thickness.

To determine the water soluble nitrate content of plant extracts, a procedure using hydrazine sulphate as reducing agent and N-(1-naphtyl)-ethylene-diamine + sulphanil acid as colour producing reagents were applied (THAMM, 1987–1988).

The nitrate contents of the control and irrigated red beet and carrot roots were determined in two years (1998 and 2000). The effect of magnesium-sulphate treatment on the nitrate content of carrot roots was also investigated in 1999.

1.3. Nitrate-reductase assay

The activity of nitrate-reductase (E.: C. 1.6.6.1.) was determined in carrot and red beet leaves according to the method of HAGEMAN and HUCKLESBY (1971) in the year of 1998.

1.4. Statistical methods

For the evaluation of the results the mean values (n=12) and SD% were calculated. Student's *t*-test ($P \leq 0.05$) was applied for the evaluation of the results (MINITAB 13.0).

2. Results and discussion

2.1. Nitrate measurements in red beet

In case of red beet varieties, 195–261 mg nitrate/100 g fresh weight was measured in the roots of non-irrigated plants (control) in 1998. The nitrate content was significantly ($P \leq 0.05$) higher (291–384 mg/100 g) in the irrigated Nero and Rubin cultivars (Fig. 1).

In 1999, the climate was so rainy (total rain fall was 495.7 mm from April until September) that the effect of irrigation was not investigated. Among the varieties investigated (Bordó, Rubin, Favorit, Detroit and Cylindra), the lowest nitrate content was measured in Cylindra (216.2 mg/100 g) and the highest in Favorit (287.4 mg/100 g).

Comparing the five varieties in 2000 the results varied in a wide range (66–264 mg/100 g). In two varieties – Rubin and Bordó – the nitrate content was significantly ($P \leq 0.05$) higher in irrigated roots, the results of which are summarised in Fig. 2.

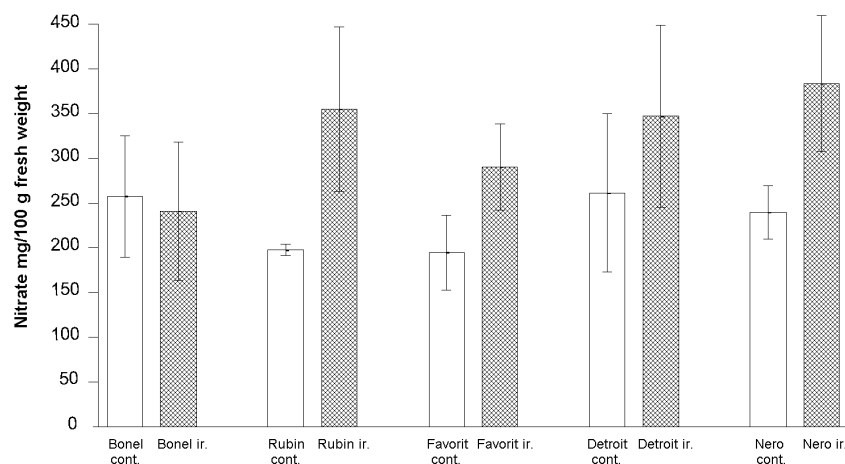


Fig. 1. Effect of irrigation on nitrate accumulation in red beet roots (1998)

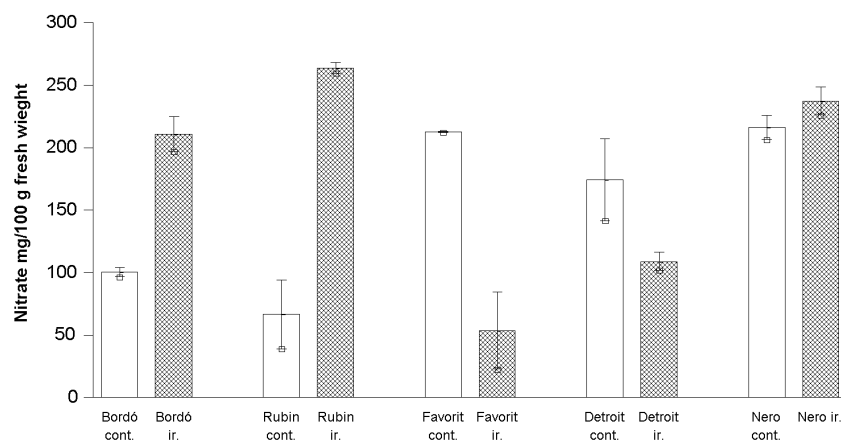


Fig. 2. Effect of irrigation on nitrate content in red beet roots (2000)

2.2. Nitrate measurements in carrot

The water soluble nitrate content varied in the range of 7–40 mg/100 g fresh weight in carrot samples grown under natural water supply (control) environments in 1998. In most of the irrigated varieties – Nantes, Danver 126 and Vörös óriás – the nitrate content increased significantly ($P \leq 0.05$). These results are shown in Fig. 3.

The effect of magnesium-sulphate solution was studied in 1999. The nitrate values were higher and more uniform following the mineral supplement (20–34 mg nitrate/100 g fresh weight) than in the control (3–26 mg nitrate/100 g fresh weight) samples. The roots accumulated significantly higher nitrate content in the cultivars K-arany, Flakker and Rekord, following the treatment with mineral solution. The data are summarised in Table 2.

Table 2. Effect of mineral supplement on nitrate content in carrot roots (1999)

Varieties	Nitrate mg/100 g fr. wt.	
	Control	Supplemented
K-arany	13.7 ^a ±5.1	32.9 ^b ±5.4
Rekord	11.9 ^a ±4.2	33.8 ^b ±4.1
Fertődi v.	26.1 ^a ±2.9	20.8 ^a ±2.8
Flakker	2.9 ^a ±0.6	31.2 ^b ±3.1
Szupra	17.4 ^a ±1.3	21.3 ^a ±4.2

Different letters mean significant difference ($P \leq 0.05$) within the row

In 2000, the five carrot varieties showed no unique tendency. In Flakker and Szupra the nitrate contents did not show differences between control and irrigated not samples. In Rekord, the nitrate content showed an increasing tendency after the irrigation (Fig. 4).

With regard to the impact of irrigation on the activity of nitrate-reductase in carrot and red beet leaves, there were no significant differences in carrot leaves. The nitrate-reductase activities of five varieties were very low in both irrigated and control carrot leaves (6.0–9.1 U g⁻¹ fresh weight).

On the other hand, the nitrate-reductase activity of irrigated red beet leaves were higher than that of the control, and significant difference ($P \leq 0.05$) occurred in cultivars Rubin, Favorit and Nero, as can be seen in Fig. 5.

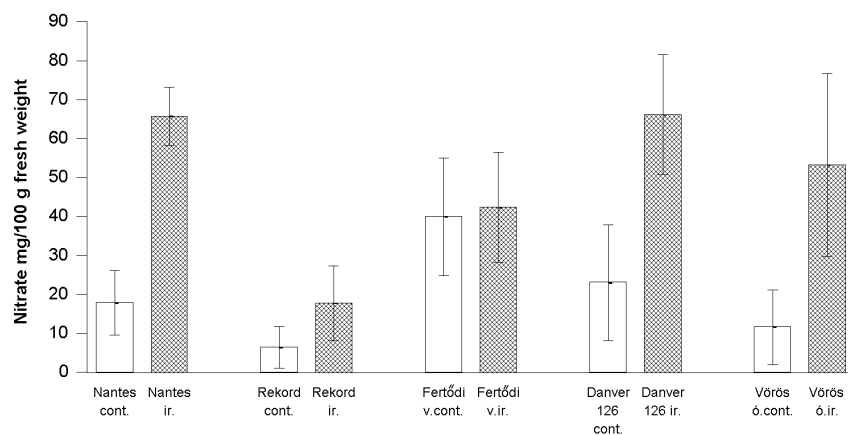


Fig. 3. Effect of irrigation on nitrate accumulation in carrot roots (1998)

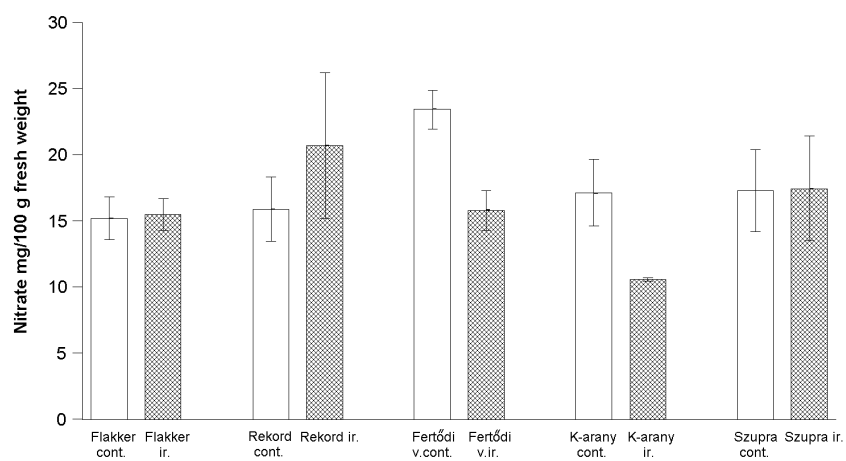


Fig. 4. Effect of irrigation on nitrate content in carrot roots (2000)

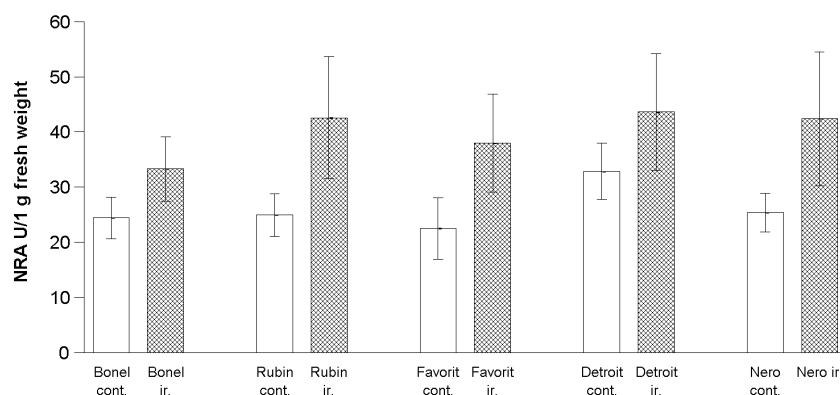


Fig. 5. Effect of irrigation on nitrate-reductase activity in red beet leaves (1998)

The change of the nitrate content and nitrate-reductase activity in five red beet cultivars following irrigation in 1998 is summarized in Table 3.

Table 3. Change of nitrate content in red beet roots and nitrate-reductase activity in red beet leaves as an effect of irrigation in 1998

	Change (%)				
	Bonel	Rubin	Favorit	Detroit	Nero
Nitrate content	-6.48	+79.79	+49.18	+32.91	+59.96
Nitrate-reductase activity	+36.59	+71.08	+68.44	+32.93	+66.93

Data proved that the increased nitrate content resulted in an increase in the activity of nitrate-reductase enzyme. According to BEEVERS and HAGEMAN (1969), nitrate-reductase activity can be induced by nitrate concentration.

Vegetables react in different ways to the treatments including water supply and mineral supplement with magnesium-sulphate. MATIČIĆ and co-workers (1992) stated that the potential impact of irrigation could be a higher nitrate accumulation in plants.

Summarizing the results, the nitrate values of carrot and red beet roots were in the same range as found in the literature (BUCKENHÜSKES & GIERSCHE, 1986). The nitrate content of red beet varieties were 5–10 times higher than in carrots without irrigation in three-year period.

On the basis of the results in 1998–2000, the nitrate contents of control red beet varieties fluctuated less compared to the irrigated roots.

3. Conclusions

In 1998, the total sun shine hours were the lowest during the three-year period, which is in harmony with average temperature values. The three meteorological parameters showed high fluctuations from 1998 till 2000. All these seasonal differences were presumably significant during the experiments, the impact of environmental circumstances (climate) and cultivars on the nitrate accumulation were both very remarkable.

In accordance with earlier studies, the results proved that nitrate-reductase activity was directly proportional to nitrate content.

Further experiments should be conducted to help growers select varieties with low nitrate accumulation feature.

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