ROCZNIKI GLEBOZNAWCZE T. XLII, NR 3/4, WARSZAWA 1991: 155-163

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RELATIONSHIP BETWEEN IRRIGATION, CONTENT OF MINERAL NITROGEN AND YIELD OF CABBAGE, RED BEET AND CELERY AT DIFFERENT FERTILIZATION

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INTRODUCTION

Between different possibilities of increase of the vegetable production, the irrigation and fertilization exert the quickest and most pronounced effect. The result of optimalization of soil-water and nutrient regime in the soil is maximal yield. Use of high amounts of nitrogen in mineral fertilizers leads to an increase of nitrates in plants, while a part of nitrates not absorbed by plants is washed away by rain and pollutes the ground water [4].

The qunatity of nitrates contained in vegetables depends on the relative speed of two physiological processes: absorption of nitrates by the roots and reduction of nitrates to effect of the synthesis of protein. If the speed of absorption of nitrates is greater than the rate of protein synthesis, nitrates would automatically accumulate in plants. If, on the other hand, nitrates were transformed into protein along with absorption, the nitrates would occur in small amounts only.

Disproportion between nitrogen absorption and protein synthesis may be caused by two factors which sometimes may be synergic: a) excessive quantities of nitrates in the soil, b) slowing down the protein synthesis.

From literature it is known that the nitrate level in plants depends on the type of soil, climatic conditions (water), soil cultivation, age of plants, type of vegetables and variety. The nitrate level is always higher in young plants.

Nitrate nitrogen excess in the soil results above all from nitrogen fertilizers applied particularly in the form of nitrates which are easily available to vegetables [1]. There are two causes of toxicity of nitrate-derived compounds: a) nitrates oxidize the ferrous ion of the hemoglobin into ferric, methemoglobin is formed and transport of oxygen is hampered (methaemoglobinaemia) and b) nitrosamines are carcinogenic [1].

The primary aim of our research was to study water-fertilizer production functions for cabbage, red beet and celery on the cambisol soil type. We were intending to establish the influence of different water and nitrogen application levels on yield and discovered ranges of water and fertilizer applications where the production function reaches the maximum. This means quantitative evaluation. Experiment with cabbage and red beet was repeated in three growing seasons of 1985-1987 and with celery in 1988. The secondary aim of our work was qualitative evaluation of crops and to observe the influence of different application levels of water and mineral nitrogen on the content of nitrates, nitrites and ammonium in cabbage, red beet and celery.

METHODOLOGY

Experiment with cabbage, red beet and celery was carried out of Agrohydrological Station of Biotechnical Faculty, Ljubljana in 1985-1988. Plants were growing in 72 lysimeters which are 530 mm in cross-section and 780 mm in depth. Lysimeters are so equipped that gravitation water can outflow into external barrel. Percolated water was regularly pumped. The lysimeters are filled with „cambisol" soil.

Plants were treated with six different water application levels (11, 12 ... 16) and four different nitrogen application levels (N_1, N_2... N_4). Both water and nitrogen levels were assumed for each lysimeter using random choice. Therefore in the experiment we got 24 different combination each repeated three times to give 72 independent yield values. Automatic movable canvas is stretched above the lysimeters, it covers them when first raindrops fall and uncovers them when the rain stops. Water application rates are thus absolutely controlled.

Early cabbage (variety Rapid-F1-hybrid Ditmar type) was growing in spring, red beet in summer and autumn. Celery was planted in June and harvested in November. The growth period of cabbage lasted 50-57 days. Plant density was 33.200 plants per hectare. Red beet variety of Detroit was used. Plant density was 424.500 plants per hectare after thinning. Plants were collected in November thus the growth period amounted to 112 days. Celery used was the „Prague" variety and its growth period was 155 days.

For cabbage all lysimeters were fertilized with 150 kg P_2O_5 per ha and 300 kg K_2O per ha. Cabbage was treated with four different nitrogen application levels: 0, 130, 260 and 390 kg of nitrogen per ha which were divided into two parts. Red beet was fertilized with the same rates of phosphorus (150 kg/ha) and potassium (300 kg/ha) as cabbage, before sowing. For nitrogen, four rates were applied: 0, 120, 240 and 360 kg N per ha. The rates were divided into two parts. The K_2O rate for celery was the same as for cabbage and the phosphorus rate was 100 kg P_2O_5 per ha. Nitrogen was applied at four different rates (0, 100, 200, 400 kg N per ha) and was divided into three parts. The nitrogen fertilizer used was KAN (calcium-ammonium-nitrate) with 27% of nitrogen.

Plants in the lysimeters were irrigated by the dripping system on to the lysimeter surfaces. Daily amount of water was determined by the water application level and the potential evapotranspiration calculated by Penman's method for the previous day.

Close after the harvest the samples of fresh plants were ground in mixer and analysis of nitrate (NO_3), nitrite (NO_2) and ammonium (NH_4) was done using Technicon autoanalyzer.

RESULTS AND DISCUSSION

Our study of water production functions is based on the assumption that the yield-irrigation-fertilization relationship can be expressed with the function of irrigation (I) and fertilization (N):

$Y(\mathrm{I}, \mathrm{N}) = \mathrm{f}(\mathrm{I})\mathrm{g}(\mathrm{N})$

where:

Y — yield,

I — irrigation,

N — fertilization with nitrogen.

We expressed the function as a polynomial approximation. Regression plane for yield (Y) was determined considering the average measured values of three plants for each replication. Measured yield values were approximated with square polynomial using least square method:

$Y = b_0 + b_1 I + b_2 N + b_3 I + b_4 N^2 + b_5 IN$

Approximated polynomial for the cabbage was:

$Y = -333.69929 + 13.55972 \times I + 0.4547 \times N - 0.02697 \times I^2 - 0.0021 \times N^2 + 0.00269 \times I \times N$

where:

Y — cabbage yield (g/lysimeter),

I — irrigation (mm of water/vegetation period),

N — fertilization with nitrogen (kg of N per ha).

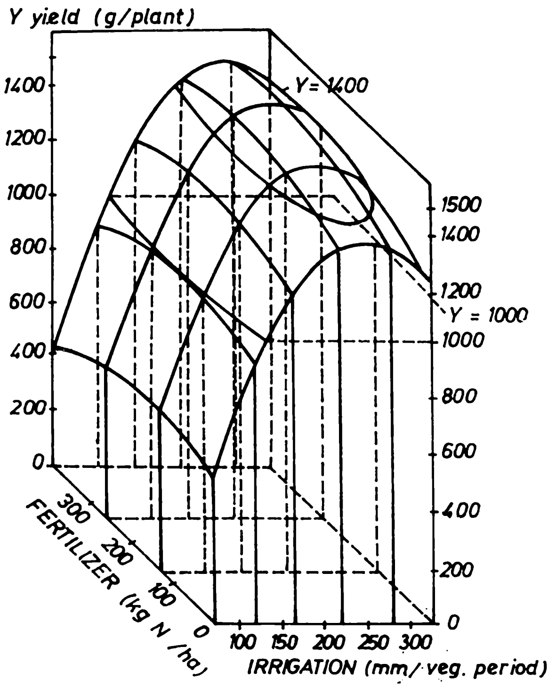

Fig. 1. Cabbage water production functions in relation to irrigation and nitrogen application

Maximum of the above polynomial represents the yield of 1524,5 g/lysimeter (50,6 t/ha) which is reached at I = 265 mm of water/growth period and N = 272 kg of N per ha, Figure 1. Coefficient of determination was 0,91 and indicates good fitting of measured and approximated values.

The influence of irrigation on the cabbage is significant and much higher than the influence of fertilization with nitrogen.

Late sowing and unfavorable climatic conditions in 1987 prevented normal growth and maturing of red beet so it could not reach marketable size and water-fertilizer-production function for red beet did not reach the maximum. Maximal estimated yield of leaves (32.18 t/ha) and bulbs (19.44 t/ha) of celery were reached at the highest level of applied water (1022 mm/vegetation) and the highest nitrogen rate (400 kg N per ha). Parts of bulbs was smaller in relation to leaves and roots.

In fresh samples the amount of nitrate is varying in cabbage from 695 to 1320 mg/kg, in red beet roots from 624 to 3437 mg/kg and in celery from 0 to 236 mg/kg in bulbs and from 1 to 1014 mg/kg in leaves. The lowest values of nitrates are in samples not treated with nitrogen, while the highest values are in samples treated with the highest nitrogen rates.

The increase of water application levels caused decreasing of NO_3 content in cabbage until the water application reached the fixed limit (in our experiment 280 mm of water per growth period), further increase of water application also increased the NO_3 content. Influence of irrigation on the content of NO_3 in cabbage is higher than that of fertilization with nitrogen (Fig. 2).

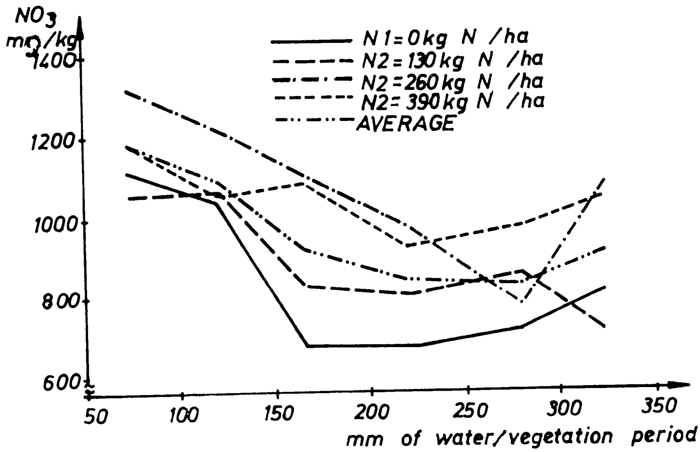

Fig. 2. Content of NO_3 in cabbage comparing with different irrigation and fertilization levels

Increasing water application levels (in our experiment up to 789 mm of water) decrease amount of NO_3 in celery. Further increase of the water application also increases the NO_3 content (Figs. 3 and 4). The extreme amounts of water: minimal, when plants are suffering from drought and maximal, when plant have to much water for normal growth, increase the value of NO_3 in celery. Increasing fertilization with nitrogen from 0 to 360 kg/ha caused, on the whole, an increase by more than twice of nitrates in red beet roots (Fig. 5).

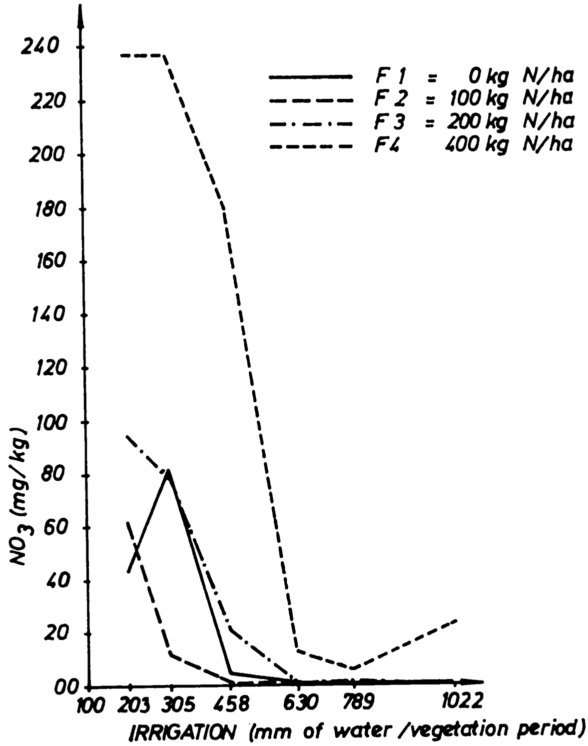

Fig. 3. The nitrate content in celery bulbs at different water and nitrogen application levels

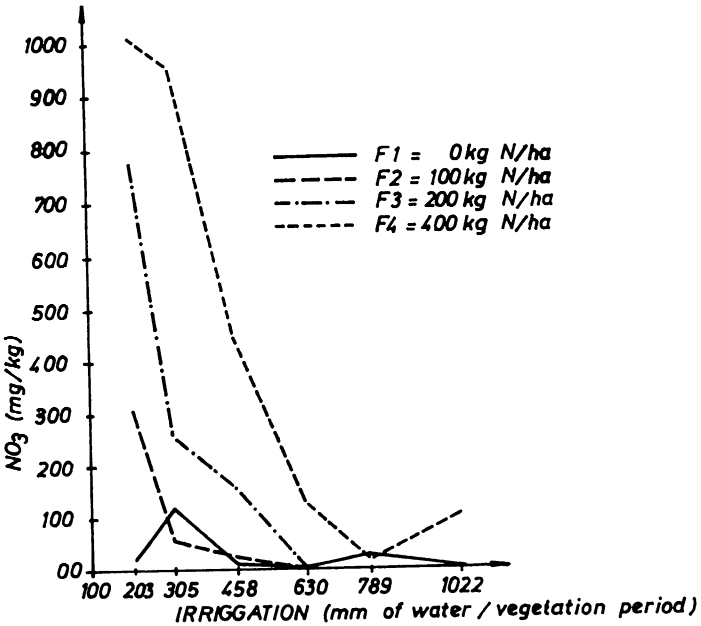

Fig. 4. The nitrate content in celery leaves at different water and nitrogen application levels

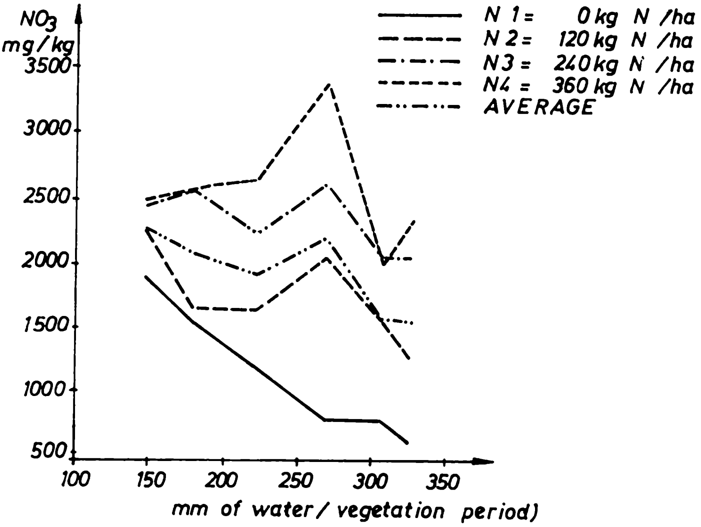

Fig. 5. Nitrate levels of red beet roots at different irrigation and fertilization levels

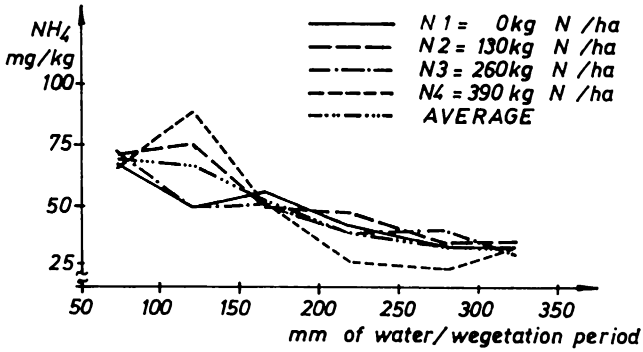

Fig. 6. Ammonium content in cabbage at different irrigation and nitrogen levels

The analysis of NO_2 content in experimental plants show high differences: in cabbage the nitrite content is varying from 0,02 to 0,32 mg/kg, in red beet from 4,47 to 11,99 mg/kg and in celery from 0,08 to 0,40 mg/kg in bulbs and from 0,04 to 1,56 mg/kg in leaves. The nitrite content in red beet is extremely high. On the average, the lowest NO_2 content in cabbage is in samples treated with the maximal water level — 0,03 mg/kg. For red beet the highest values of NO_2 is found in the samples not treated with nitrogen, while the lowest was found in those, which got 240 kg N per ha. The influence of irrigation on the NO_2 content in red beet leaves is as follows: increasing irrigation from 146 to 222 mm of water per growth period increases, on the average, the NO_2 content; additional increase of water application decreases the amount of nitrites.

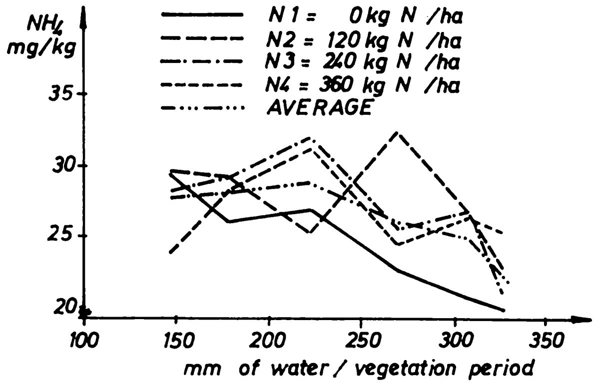

Fig. 7. Ammonium content in red beet roots at different irrigation and nitrogen levels

Different irrigation levels exerted no statistically significant influence on the NO_2 content in celery, although a decreasing tendency in the NO_2 content was observed.

The content of ammonium in cabbage was varying from 25.01 to 90.38 mg/kg of fresh sample. Our experiment has proved that increasing irrigation decreases ammonium content in fresh cabbage. The NH_4 content in cabbage samples which got maximal water rate is by 50% lower than in the sample which got the minimal water rate. The influence of fertilization with nitrogen on the NH_4 content in cabbage is not significant (Fig. 6). The amount of ammonium ion in fresh red beet is lower than in cabbage — the boundary levels are: 10.39-59.91 mg/kg of fresh sample. Increasing nitrogen application levels increased NH_4 content in red beet is very different; with increased water application levels from 146 to 269 mm of water per growth period the amount of ammonium in leaves increased, but further increase of water application levels to 327 mm per growth period decreased the ammonium content, while in roots the decrease began at 222 mm of water per growth period (Fig. 7). The content of ammonium in celery bulbs was varying from 23.66 to 70.12 mg/kg and in leaves from 20.22 to 51.13 mg/kg of fresh sample. Increasing irrigation rate decreased the ammonium content in bulbs. The influence of irrigation on the NH_4 content in leaves is not significant. We can regard the influence of different fertilization with nitrogen on the ammonium content in bulbs as statistically significant, but in leaves the influence of fertilization is not significant.

COCNLUSIONS

1. The influence of irrigation on the yield of cabbage, red beet and celery is significant and higher than the influence of fertilization with nitrogen.

2. Plants not treated with nitrogen and treated with optimal water supply have the minimal amount of nitrates.

3. The influence of different water and nitrogen application levels on the nitrite and ammonium content is very different.

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ЗАВИСИМОСТЬ МЕЖДУ ОРОШЕНИЕМ, СОДЕРЖАНИЕМ МИНЕРАЛЬНОГО АЗОТА И УРОЖАЕМ КАПУСТЫ, СТОЛОВОЙ СВЕКЛЫ И СЕЛЬДЕРЕЯ В УСЛОВИЯХ ДИФФЕРЕНЦИРОВАННОГО УДОБРЕНИЯ

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Резюме

В 1985-1988 гг. исследовали влияние орошения и азотного удобрения на содержание нитратов, нитритов и аммония в капусте сорта „Рапид фıи;, столовой свекле сорта „Детроит" и сельдерее сорта „Прага". Опыт проводился в 72 лизиметрах. Этот опыт охватывал 4 уровня азотного удобрения и 6 уровней орошения. Капусту выращивали весной и в начале лета, столовую свеклу летом и осенью, а сельдерей от июня до ноября. Влияние орошения на урожай было более существенным, чем действие азотного удобрения. Самый большой урожай ранней капусты 50,6 т/га был получен при орошении 265 мм воды во время вегетации и при удобрении 272 кг N/га. Установлено, что орошение и азотное удобрение оказывают значительное влияние на содержание нитратов в сыром веществе капусты, столовой свеклы и сельдеря. Не наблюдалась регулярная зависимость между орошением и содержанием нитритов и аммония в исследуемых овощах.

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ZALEŻNOŚĆ MIĘDZY NAWADNIANIEM, ZAWARTOŚCIĄ MINERALNEGO AZOTU A PLONEM KAPUSTY, BURAKÓW ĆWIKŁOWYCH I SELERÓW W WARUNKACH ZRÓŻNICOWANEGO NAWOŻENIA

Zakład Rolnictwa, Uniwersytet w Ljublianie

Streszczenie

W latach 1985-1988 badano wpływ nawadniania i nawożenia azotowego na plon oraz na zawartość azotanów, azotynów i N-amonowego w kapuście odmiany Rapid F1, buraku ćwikłowym odm. Detroit i selerze odm. Prague. Doświadczenie prowadzone w 72 lizymetrach obejmowało cztery poziomy nawożenia azotowego i sześć poziomów nawadniania, każdy obiekt w 3 powtórzeniach. Kapustę uprawiano wiosną, buraki ćwikłowe w lecie i jesieni, a selery od czerwca do listopada. Wpływ nawadniania na plon był istotny i większy niż działanie nawożenia azotowego. Największy plon wczesnej kapusty, wynoszący 50,6 t/ha, uzyskano przy nawadnianiu 265 mm wody w okresie wegetacyjnym i nawożeniu 272 kg N/ha. Stwierdzono, że zarówno nawadnianie, jak i nawożenia azotowe miały istotny wpływ na zawartość azota-

nów w świeżej masie wszystkich trzech roślin testowych. Natomiast ich działanie na zawartość azotynów i N-amonowego było nieregularne.

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Praca wpłynęła do redakcji w marcu 1991 r.