# The influence of organic and mineral fertilization on nutrient status, nitrate accumulation, and yield of head chicory

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**ABSTRACT**

The influence of different fertilizer forms and rates on nitrogen, phosphorus and potassium contents, nitrate accumulation and yield in red head chicory (*Cichorium intybus* var. *foliosum* L.) was investigated. Field fertilization trials were set up at two localities in Northwest Croatia in 1999 and 2000. Trials were laid out according to the Latin square scheme in five fertilization treatments: manure 5 kg/m$^2$, three rates of complex mineral fertilizer NPK (5:20:30) – 50, 100 and 150 g/m$^2$, and an unfertilized control variant. The results of investigations indicate that there were no significant differences between treatments in the plant nitrogen and phosphorus contents. Significant fluctuations of the chicory potassium content (3.27–4.75% K) depending on the fertilization variant were recorded only in 1999 while in 2000 all values (4.13–5.12% K) were uniform. Plant nitrate levels were influenced by weather conditions more significantly than by the form and rates of fertilizers. All the recorded values are within the limits tolerated for leafy vegetables. Comparing the trial years, yields were generally higher in 1999 (1.58–4.95 kg/m$^2$) than in 2000 (0.40–2.70 kg/m$^2$). No significant differences in yield were recorded between the application of stable manure and the lowest mineral fertilizer rate.

**Keywords:** organic and mineral fertilization; N, P, K; nitrate contents in plants; yield; head chicory

World agriculture is at its historical crossroads, faced with two different approaches. On the one hand, production of enough food for all, the trend of the poor and undeveloped, and on the other hand, production of little food of high nutritive quality, the trend of the rich countries of the world.

Such a challenge can be met only by ecologically acceptable and sustainable agriculture, which besides being concerned about agriculture and consumers, pays significant attention to the environment, and is based on high know-how rather than on high inputs. Since the application of organic fertilizers was rather neglected in the last 50 years, due to striving for higher yields (Chung et al. 2000), it is not surprising that inputs, including mineral fertilizers, have started to be reduced in sustainable agriculture again.

Vegetables production is more demanding than other agricultural production (Krug 1986) because of its high yields per unit area and several harvests a year, so the nutrition of vegetables requires an exceptionally serious approach (Maynard and Hochmuth 1997, Lešić et al. 2002).

A number of papers deals with the influence of fertilization, notably with nitrogen, on the yield and some parameters of the quality of vegetables (Splittstoesser et al. 1974, Míča and Vokál 1990, Rumpel and Kaniszerski 1994, Sorensen et al. 1995, Elia et al. 1998, Ćustić et al. 2000), but regretfully only few authors have compared the results achieved by the application of organic and mineral fertilizers (Müler and Hippe 1987, Hamouz 1991, Gontcharenko 1994).

For this reason, the goal of these investigations, carried out in the field, was to determine the influence of organic and mineral fertilization on yields as well as on the levels of nitrogen, phosphorus, potassium and nitrates in head chicory. This might suggest some new solutions, or clarify some unknown facts about the methods and rates of fertilizing chicory, but also vegetables in the broader sense.

## MATERIAL AND METHODS

Identical field fertilization trials with head chicory were carried out at two localities in North-western Croatia (Žumberak and Lika) in two years (1999 and 2000). The trial was set up according to the Latin square method with five fertilization treatments.

Trial treatments included: manure (5 kg/m$^2$), three rates of complex mineral fertilizer NPK – 5:20:30 (50, 100 and 150 g/m$^2$), and an unfertilized control.

The overall amounts supplied with mineral fertilizers were: 2.5, 5.0, 7.5 g N/m$^2$, 4.4, 8.7, 13.1 g P/m$^2$, and 12.4, 24.8, 37.2 g K/m$^2$, while ca. 2.0–3.0 g N, 0.74 g P, and 2.5 g K/m$^2$ was added with 5.0 kg/m$^2$ of stable manure.

The trial was set up on silt-loamy soil. Humus content ranged from 2.2 to 3.1%, soil reaction ($H_2O$) ranged from 5.9 to 7.0, available phosphorus was 3.0 mg P/100 g soil,

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and available potassium 9.1 mg K/100 g of soil (Egner et al. 1960). The climate is humid. Weather conditions in the chicory growing period varied widely per investigation years, and they are presented for each year (Figures 1 and 2) and for both localities. It can be concluded generally that the year 1999 was optimal for chicory culture whereas extreme drought with high temperatures prevailed in the post-planting period of 2000 (the third decade in July and the whole of August).

Chicory seed (Leonardo, Bejo Zaden) was sown into polystyrene containers, and the developed seedlings were planted onto the trial plots (40 × 40 cm) in July. Standard agricultural management practices were applied. Chicory was harvested when mature (in October). Each plot was 12 $m^2$ in size, and yield was calculated in kg/$m^2$. Four chicory heads were randomly taken from each plot for chemical analyses.

Total nitrogen was determined by Kjeldahl method while the xylenol method was applied for nitrates (AOAC 1975). Potassium and phosphorus were determined by the method of wet digestion in acid medium with concentrated $H_2SO_4$ and $HClO_4$. Potassium was determined with a flame-photometer and phosphorus with a spectrophotometer. Statistical data processing was performed by the two-way analysis of variance, using the SAS System Software (SAS 1989). The studied parameters were analyzed individually for each year and locality because of the different weather conditions during the trial period.

## RESULTS AND DISCUSSION

Research results show that there were no significant differences in chicory nitrogen levels between fertilization treatments, which is in accord with the reports for potatoes by Míča and Vokál (1990). Head chicory nitrogen values are fairly uniform (2.92–3.69% N), in agreement with some of our previous investigations (Ćustić 1996, Ćustić et al. 2002), and are slightly lower than those reported by other authors for similar crops such as lettuce (4.50–5.50% N) (Bergmann 1992) and cabbage (Krug 1986).

Besides the effects of different fertilizer forms and rates upon the plant total nitrogen, attention was also paid to nitrate accumulation, as a potential negative manifestation of fertilization and a significant cause of decreased vegetable quality (Ćustić 1996). Corre and Breimer (1979) reported as much as 90% of nitrates in human nutrition originating from vegetables while Reining and Bloom-Zandstra (1989) considered leafy vegetables to be the major source of nitrates. Comparison of the obtained nitrate values in chicory per fertilization treatments (Table 1) shows that significant differences in chicory nitrate levels were recorded in 1999 at both localities whereas there were no significant differences in 2000. In general, the higher nitrate values in 1999 are probably a consequence of weather conditions (water quantity and distribution in the growing period) that favoured their uptake

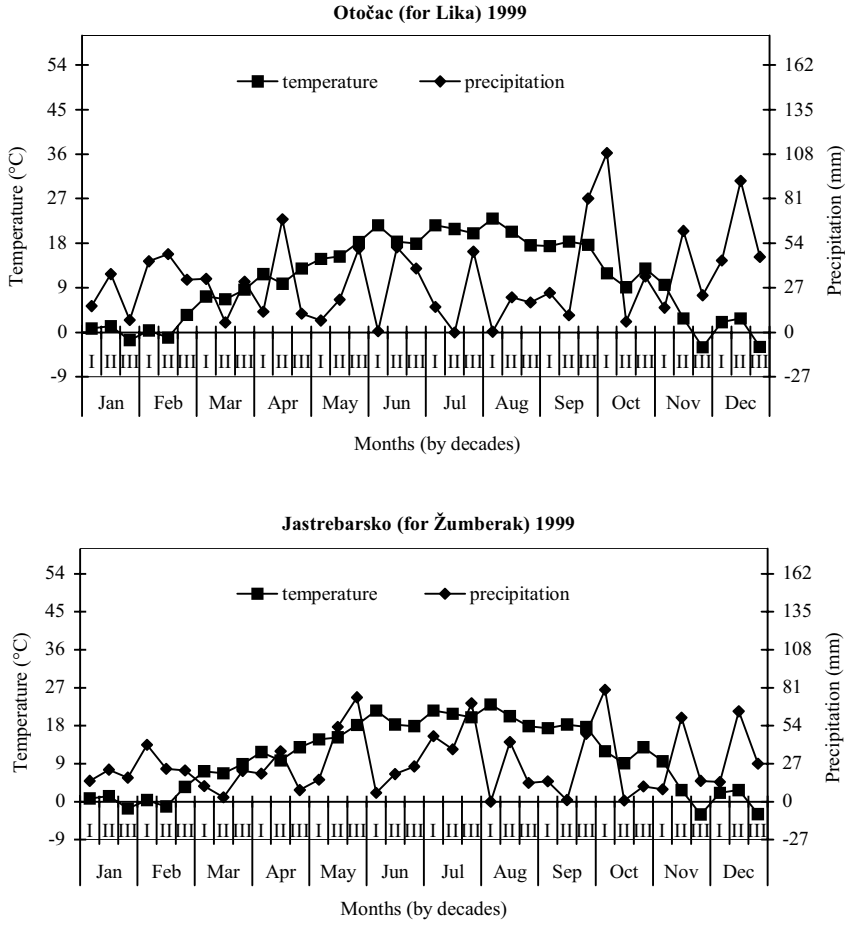


Figure 1. Climatic characteristics 1999 (Lika and Žumberak)

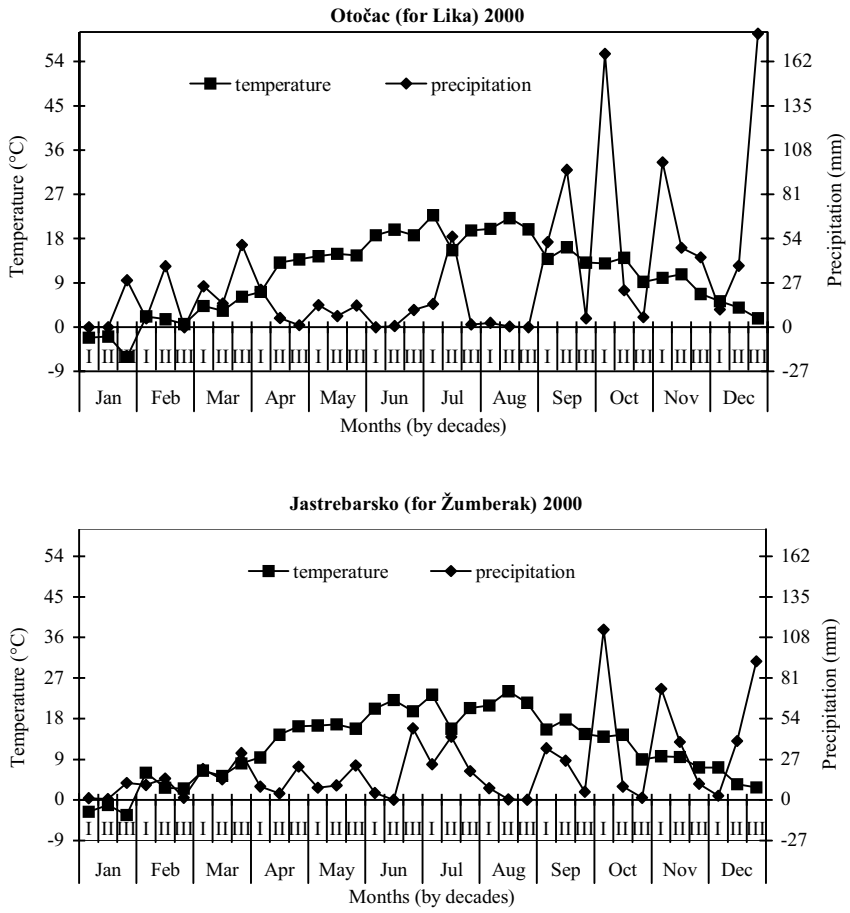


Figure 2. Climatic characteristics 2000 (Lika and Žumberak)

from the soil. This is due to the fact that nitrates are mostly transported toward plants by mass flow (Mengel and Kirkby 2001).

Somewhat higher chicory nitrate values in these investigations, compared to some values from our previous research (Ćustić 1996), were recorded in 1999 at Lika locality with the application of 100 and 150 g/m$^2$ NPK – 5:20:30 while at Žumberak locality higher nitrate values were determined with the application of 50 g/m$^2$ NPK – 5:20:30 and, very, interestingly, with the application of 5 kg/m$^2$ of manure. Hamouz et al. (1999) also reported the influence of locality on the nitrate content.

Although nitrate values are generally within the tolerated limits (Bergmann 1992), it is obvious that in warm and wet years like 1999 their increased accumulation in the plant is possible, regardless of whether they originate from organic or mineral sources.

Phosphorus levels in head chicory did not vary significantly per fertilization treatments. All phosphorus values ranged from 0.38 to 0.55% P, which is in accord with the reports by some other authors for similar crops like cabbage (*Brassica oleracea capitata*, 0.30–0.50% P, and slightly higher than for *Cichorium endivia*, 0.20–0.30% P), as reported by Bergmann (1992).

Significant differences in head chicory potassium levels between fertilization treatments were recorded in 1999, at both trial localities. In 2000, however, there were no significant differences between fertilization treatments though there was a discernible trend of potassium increase in chicory in fertilized treatments compared to the control. Potassium values ranged from 3.27 to 5.16% K (Table 2), which is generally in accord with some of our previous investigations (Ćustić 1996) and higher than those reported by Bergmann (1992) for some similar crops like *Cichorium endivia* (1.50–2.00% K) or *Brassica oleracea capitata* (3.00–4.00% K).

Regardless of the research years and fertilization treatments, yields of head chicory (*Cichorium intybus* L. var. *foliosum*) ranged from 0.40 to 4.90 kg/m$^2$ (Table 3). Besides fertilization, such wide variations are likely to result also from different climatic conditions (Figures 1 and 2). Thus, the year 1999 was exceptionally favourable for the production of head chicory, with sufficient precipitation and favourable temperatures, notably in Lika, where the highest yields were also achieved, regardless of fertilization (2.70–4.90 kg/m$^2$). These yields surpass some of those reported in literature (Jacot et al. 1987, Ćustić 1996). In contrast, 2000 was expressly unfavourable, with a long dry period and very high temperatures that had an adverse effect on yield, notably at Žumberak locality (0.40–0.70 kg/m$^2$).

Comparison of yields per fertilization treatments clearly shows that the control treatment always gave the lowest yields, both per research years and per localities (0.40–2.70 kg/m$^2$). Treatments involving the application of 100 and 150 g/m$^2$ of mineral fertilizer rendered the high-

Table 1. Nitrate content in red head chicory per treatments

| Year | Treatment* | $NO_3$ (g/kg F.W.) | |
|---|---|---|---|
| | | Žumberak | Lika |
| 1999 | 1 | 1.11 b | 1.67 b |
| | 2 | 1.34 ab | 1.50 b |
| | 3 | 1.68 a | 1.64 b |
| | 4 | 1.22 b | 2.01 a |
| | 5 | 0.96 b | 2.04 a |
| *LSD* ($P < 0.05$) | | 0.389 | 0.338 |
| 2000 | 1 | 0.67 | 0.80 |
| | 2 | 0.65 | 0.73 |
| | 3 | 0.66 | 0.85 |
| | 4 | 0.72 | 0.82 |
| | 5 | 0.76 | 0.96 |
| *LSD* ($P < 0.05$) | | ns | ns |

The values of particular components followed by different letters are significantly different at the 95% confidence level
* 1 = 0, 2 = 5 kg manure, 3 = 50 g NPK (5:20:30), 4 = 100 g NPK (5:20:30), 5 = 150 g NPK (5:20:30)

Table 2. Potassium content in red head chicory per treatments

| Year | Treatment* | Potassium (% K) | |
|---|---|---|---|
| | | Žumberak | Lika |
| 1999 | 1 | 3.27 d | 3.31 b |
| | 2 | 3.50 cd | 3.61 b |
| | 3 | 3.83 bc | 4.38 a |
| | 4 | 4.81 a | 4.32 a |
| | 5 | 4.26 b | 4.75 a |
| *LSD* ($P < 0.05$) | | 0.436 | 0.467 |
| 2000 | 1 | 4.13 | 5.11 |
| | 2 | 4.26 | 5.13 |
| | 3 | 4.63 | 5.16 |
| | 4 | 4.56 | 5.12 |
| | 5 | 4.23 | 5.01 |
| *LSD* ($P < 0.05$) | | ns | ns |

The values of particular components followed by different letters are significantly different at the 95% confidence level
* 1 = 0, 2 = 5 kg manure, 3 = 50 g NPK (5:20:30), 4 = 100 g NPK (5:20:30), 5 = 150 g NPK (5:20:30)

est yields, without any significant difference between them. An interesting finding of this research is that no statistically significant differences in yield were recorded between treatments with manure and those fertilized with the lowest mineral fertilizer rates (50 g/m$^2$). Hence, the application of 5.0–7.5 g N, 8.7 g P, and 24.7 g K per m$^2$ can be recommended for chicory. The research findings, with small corrections, can also be applied to other vegetables of similar requirements, produced in similar agro-ecological conditions.

Table 3. Yield of red head chicory per treatments

| Year | Treatment* | Yield (kg/m$^2$) | |
|---|---|---|---|
| | | Žumberak | Lika |
| 1999 | 1 | 1.58 d | 2.70 c |
| | 2 | 2.30 c | 3.30 bc |
| | 3 | 2.40 bc | 3.60 b |
| | 4 | 2.80 ab | 4.60 a |
| | 5 | 2.97 a | 4.95 a |
| *LSD* ($P < 0.05$) | | 0.467 | 0.717 |
| 2000 | 1 | 0.40 | 2.10 |
| | 2 | 0.50 | 2.40 |
| | 3 | 0.60 | 2.40 |
| | 4 | 0.70 | 2.70 |
| | 5 | 0.60 | 2.30 |
| *LSD* ($P < 0.05$) | | ns | ns |

The values of particular components followed by different letters are significantly different at the 95% confidence level
* 1 = 0, 2 = 5 kg manure, 3 = 50 g NPK (5:20:30), 4 = 100 g NPK (5:20:30), 5 = 150 g NPK (5:20:30)

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**ABSTRAKT**

**Vliv organického a minerálního hnojení na obsah živin, akumulaci nitrátů a na výnos červené hlavaté čekanky**

Byl sledován vliv různých forem a dávek hnojiva na obsah dusíku, fosforu a draslíku, akumulaci nitrátů v rostlině a na výnos červené hlavaté čekanky (*Cichorium intybus* var. *foliosum* L.). Ve dvou oblastech severozápadního Chorvatska byly v letech 1999 a 2000 založeny metodou latinského čtverce polní pokusy s pěti variantami hnojení: chlévský hnůj 5 kg/m$^2$, tři dávky kombinovaného hnojiva NPK (5:20:30) – 50, 100 a 150 g/m$^2$ a kontrolní varianta bez hnojení. Mezi variantami nebyly zjištěny průkazné rozdíly v obsahu dusíku a fosforu v rostlinách. Významné změny v obsahu draslíku v čekance (3.27–4.75 % K) v závislosti na variantách hnojení byly zaznamenány pouze v roce 1999, zatímco v roce 2000 byly hodnoty vyrovnané (4.13–5.12 % K). Na obsah nitrátů v rostlině měly významnější vliv povětrnostní podmínky než forma a dávky přidávaných hnojiv. Hodnoty obsahu nitrátů nepřekročily nejvyšší přípustné koncentrace udávané pro listovou zeleninu. Výnosy čekanky byly v průměru vyšší v roce 1999 (1.58–4.95 kg/m$^2$) než v roce 2000 (0.40–2.70 kg/m$^2$). Nebyly nalezeny průkazné rozdíly ve výnosu mezi variantou s chlévským hnojem a nejnižší dávkou minerálního hnojiva.

**Klíčová slova:** organické a minerální hnojení; N, P, K; obsah nitrátů v rostlině; výnos; hlavatá čekanka

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