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The Content of NPK Nutrients in Vegetative Organs of Cauliflower (*Brassica oleracea var. botrytis* L.) Grown in Soilless Culture Technique

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Abstract

The experiment was carried out in a greenhouse in the Mediterranean Agronomic Institute of Bari (IAMB.) located in the southeastern Italy. The aim of this research was to evaluate macronutrient (NPK) status of cauliflower grown in three inert substrates (perlite, gravel and pozzolana). Nutrient losses were very low due to a good management practice and control of fertiliser application. The highest NPK nutrients application efficiency was obtained in phosphorus, 97.2%. Among nutrients, potassium was lost in the highest percentage (11.6%). Obtained losses did not cause high pollution of the soil and ground water.

Key words: nutrients, substrate, potassium, cauliflower.

Introduction

Controlled environment agriculture has gained in horticultural importance not only in vegetable and ornamental crop production but also in the production of plant seedlings, either from seed or through tissue culture procedures. One of the most important factors for a successful production in soilless cultures (hydroponics or substrate cultures) is water quality and its availability. The choice of irrigation water must be based mainly on quality, storage capacity and price (Van Assche and Vangheel, 1989).

The use of inert substrates in greenhouse vegetable production requires precise control of fertigation as inert substrates do not contain nutrients. The measurement of pH, EC and nutrients concentration in the leached solution indicates whether fertilisers are being applied in excess or deficiency, and therefore allows the consecutive correction of the fertigation regime. It is recommended to collect the leached solution from containers and the solution that leaves drippers, and to compare both solutions on a daily basis (Scaife and Bar-Yosef, 1995). Since inert substrates were used in this experiment, leaching of accumulated salts with relatively small water quantity was allowed. This prevents precipitation of nutrients and changes in chemical reaction of inert substrates.

The elements particularly involved in the building up of salinity in the slabs include sodium and chloride. These ions are frequently present in the water supply, but are required by most plants in quite small quantities. In practice, most waters, the salinity of which does not exceed 2500 ppm, are suitable for the soilless growth of crops. Some waters do, however, contain small amounts of certain toxic elements, which would inhibit or have fatal effects on plant life. It is, therefore, always desirable to test the quality of water before using it (Douglas, 1990). Availability of micronutrients such as iron, manganese, zinc, copper, and boron can influence plant growth which can be reduced severely by high substrate and irrigation water pH. High pH water can cause salts to precipitate out of fertiliser stock tanks. Plant availability of essential nutrients (NPK) grown in hydroponics systems is the highest at the pH range 5.4 to 6.2 and it is recommended for most greenhouse crops (Bailey and Bilderback, 1998).

In hydroponics production of cauliflower, pH should range from 5.2 to 6.8 for irrigation water and 5.4 to 6.3 for substrate solution. Water pH levels above the desirable range hinder absorption of certain nutrients, which may cause toxicity (Jensen and Malter, 1995). Calcium and magnesium deficiencies can develop when pH is too low. There is a greater chance of ammonium toxicity problems in low pH conditions; and phosphorus leaching increases at a low pH. At the other end of the spectrum, pH above 6.2 can lead to problems such as chlorosis, an indication of iron deficiency. The level of pH and alkalinity (measured as carbonates and bicarbonates) of irrigation water affect pH levels within the growing media. These pH levels, in return, affect the absorption of certain nutrients by the roots and thus the health and vitality of a plant.

The fertiliser requirements of cauliflower are 200 $kg \cdot ha^{-1}$ N, 75 $kg \cdot ha^{-1}$ P and 225 $kg \cdot ha^{-1}$ K (Dellacecca, 1990). Starving the cauliflower plants from nitrogen can prevent curd initiation (Atherton et al., 1987). This is because the leaf area development is restricted and the plant cannot support generative growth. In plants growing in nitrogen deficient conditions physiological disorders like "buttons" can occur. Cauliflower requires high magnesium levels and shows deficiency symptoms readily when soils are too acid or the element is in short supply (Sanders, 1996). Potassium deficiency can also occur, causing shortening of internodes, thickening and curling of lamina, purple pigmentation along the leaf veins, inhibition of curd formation and floral bud necrosis (IFA, 1992).

Materials and methods

A cauliflower variety Fremont was grown. This variety has excellent weight, uniformity, density and colour. Self-wrapping leaves surround a deep domed white head. Cauliflower was grown in an open hydroponics system. The trial was carried out using three media: sand, pozzolana and perlite.

The total experimental area was about 93 m^2, with 31 m^2 for each individual substrate. Cauliflower seedlings were transplanted on 1 December 2004 with a distance of 50 cm on line and 40 cm between the lines giving a plantation density of 5 seedlings per m^2. The experiment layout is given in Fig. 1. Cauliflower harvest was done when it achieved full maturity (8 March 2005).

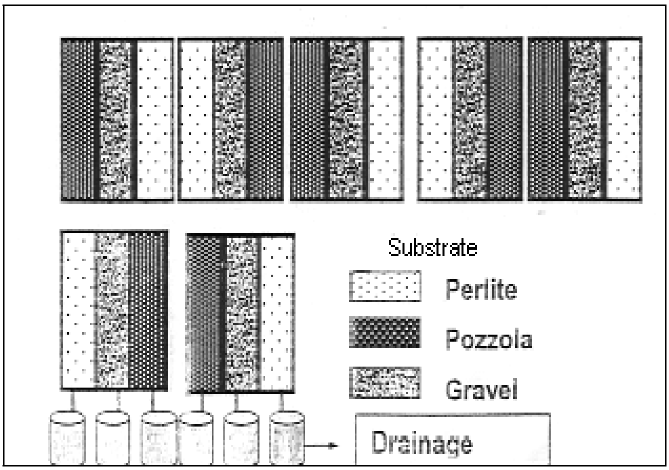

Fig. 1. Soilless culture experiment layout
Pregled eksperimenta hidroponskog uzgoja

A computerised Priva Nutriflex (version 1.0, 1995) was used to control, monitor and record information related to environmental conditions (total radiation), volume and irrigation frequency and finally pH and EC of the input nutrient solution. Thus, the computer was set to release the precise amount of stock nutrient solution input on weekly basis, adjusting the EC and pH values of nutrient solution to the pre-settled amounts.

The nutrient solution reaches plants throughout small polyethylene tubes, commonly named “spaghetti” tubes, connected on one end to the tube. On the other end, a plastic or lead weight anchors them to the base of each plant. These are self-compensating drippers giving 4 $l \cdot h^{-1}$ discharges. Crop water requirements were estimated on water balance basis. In our soilless culture system, two components were controlled: supplied amount of water and drainage volume.

To allow adequate leaching of the salts carried in the nutrient solution, a drainage volume between 20 to 30% of the irrigation volume was required. This was done by permanent control of substrate and drainage EC.

In this experiment, the same irrigation volume and water frequency were applied to three substrates. In the beginning, irrigation was applied three times a day. When plants start to grow more intensively, the number of irrigations was increased from 3 to 6 irrigations per day.

Table 1 shows the composition of macronutrient and micronutrient solution applied during the running of the cauliflower experiment..

Tab. 1. Cauliflower macro and micro nutrient solution composition (100 l)
Sastav rastvora sa makro i mikro hraniva za uzgoj karfiola (100 l)

Solution	Fertilisers	Quantity	
		until 21.02.'05	after 21.02.'05
A	Calcium nitrate (15,5% N, 20% Ca)	2 kg	
	Potassium nitrate (13,5% N, 46% K_2O)	0,5 kg	2 kg
	Iron chelates (4,5% Fe)	200 g	200 g
B	Potassium nitrate (13,5% N, 46% K_2O)	0,5 kg	
	Potassium phosphate (34 K_2O, 52% P_2O_5)	350 g	4 kg
	Micro elements	300 g	300 g

Every 10 days, NPK nutrients were analysed in drained solution, while in vegetative and radical organs of plants NPK content was analysed every 20 days.
The total nitrogen was analysed by an automatic distillation apparatus “Distillation links, UDK 140” using Kjeldhal method. Phosphorus was determined by Olsen method (method blue of molybdenum), while potassium was determined by photometry, using flame photometer (JENWAY PEP 7).

Statistical analyses were performed using one way Anova test and Duncan multiple range test.

Results and discussion

In this paper, an analysis of data that indicate the state of NPK nutrients during growing cycle of cauliflower grown in three inert substrates has been performed.

The N concentration in both vegetative and radical part during the cropping cycle is presented in Fig. 2.

Regarding the N concentration in the vegetative part and its variation during the cropping cycle, it followed more or less the same trend under the investigated substrates. Generally, in the cropping period between the 2nd week till the 8th week, N concentration was with fluctuating values without showing unique trend characterizing its status under the investigated substrates. This could be attributed to the differences in vegetative growth from one substrate to another. However, for all the investigated substrates, the vegetative growth attained its maximum nitrogen concentration values 10 weeks from transplanting when vegetative part was mostly developed. With the progress in cropping cycle 12 weeks from transplanting corresponding to the inflorescence head formation, there was a drastic drop in the nitrogen concentration, reaching a value at harvest time more or less similar to the one measured at the earlier growth stage, 2 weeks from transplanting.

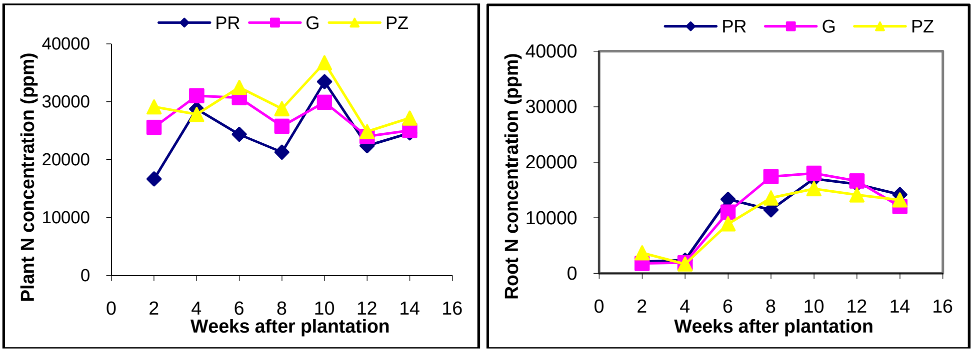

Fig.. 2. Evolution of N content in vegetative and radical part of cauliflower grown in three substrates

Razvoj sadržaja N u vegetativnim i korjenskim dijelovima karfiola uzgajanog na tri supstrata

Regarding the N concentration in the roots during the cropping cycle, it is clear that it followed a trend different from one concerning the vegetative part. Under the investigated substrates, at the earlier growth stages till the 4th week, N concentration was found in very small concentration with equal values under the investigated substrates. Two weeks later, in the 6th week, the N concentration in the roots was of relatively higher values with gradual increments reaching its maximum value on the 10th week, and then started gradually declining till the harvest time. The presence of N in the roots with concentration nearly 50% lower than in the vegetative part within the whole cropping cycle indicates high mobility of nitrogen and its transport to the vegetative growth with little accumulation in the roots.

Considering the total uptake of nitrogen in both vegetative and radical part under the investigated substrates, another picture will appear which is completely different from that regarding N concentration (Tab. 2.).

Tab. 2. Nitrogen exportation (mg·plant^{-1})

Unos azota (mg·biljka $^{-1}$)

Substrate	Perlite	Gravel	Pozzolana
Vegetative part	3961	4003	7229
Radical part	298	349	621
Total	4259 B	4352 B	7851 A

A, B – statistically significant difference on 0.01 probability level

The presented data indicate the highest N uptake is under pozzolana cultivation, which is significantly higher, 83% and 81%, than the one corresponding to perlite and gravel, respectively. This was also the case considering the N uptake by the roots. Total N uptake by the plants varied greatly under the different investigated substrates. There is a significant difference in the N uptake by plants between the pozzolana substrate and both perlite and gravel, whereas under perlite and gravel N uptake was nearly at the same values without showing any significant differences.

The P concentration in both vegetative and radical part during the cropping cycle is presented in Fig. 3.

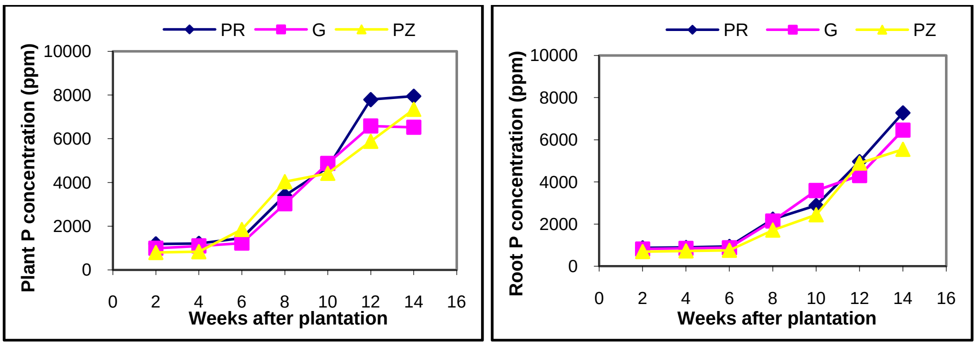

Fig. 3. Evolution of P content in vegetative and radical part of cauliflower grown in three substrates

Razvoj sadržaja P u vegetativnim i korjenskim dijelovima karfiola uzgajanog na tri supstrata

Regarding the P concentration in the vegetative part during the cropping cycle, it is quite clear that the trend it followed is similar under the investigated substrates. Phosphorus concentration was with low concentration and with a constant value in the early growth stages till the 6th week. With the progress in the vegetative growth, there was a gradual increment in its concentration reaching maximum values at the end of a vegetative cycle at the start of inflorescence head formation 12 weeks from transplanting, and then it kept nearly constant concentration until the harvest time.

Regarding the P concentration in the roots, it was characterized by a trend very similar to the vegetative part. However, the roots developed in the gravel substrates were with P concentration values slightly higher than the ones under perlite followed by those under pozzolana. Moreover, the presence of P concentration in the roots with the values very near to the ones of the vegetative part could be mainly attributed to its low mobility compared with other nutrients.

The P uptake in both vegetative and radical parts as well as the total P uptake is presented in Tab. 3.

Presented data indicate that among three substrates the highest P uptake was found to be under the pozzolana with values significantly 33% and 87% higher than the one obtained under perlite and gravel substrates, respectively. The same trend characterized the P uptake by roots. Under pozzolana, the P uptake by roots was with values 71% and 39% significantly greater than the ones under perlite and gravel substrates, respectively. Statistically, there is a significant difference in the total P uptake by the plants under the investigated substrates.

Tab. 3. Phosphorus exportation (mg·plant^{-1})
Unos fosfora (mg·biljka^{-1})

Substrate	Perlite	Gravel	Pozzolana
Vegetative part	1279	1044	1953
Radical part	153	187	261
Total	1432 B	1231 C	2214 A

A, B, C – statistically significant difference on 0.01 probability level

The K concentration in both vegetative and radical part during the cropping cycle is presented in Fig. 4.

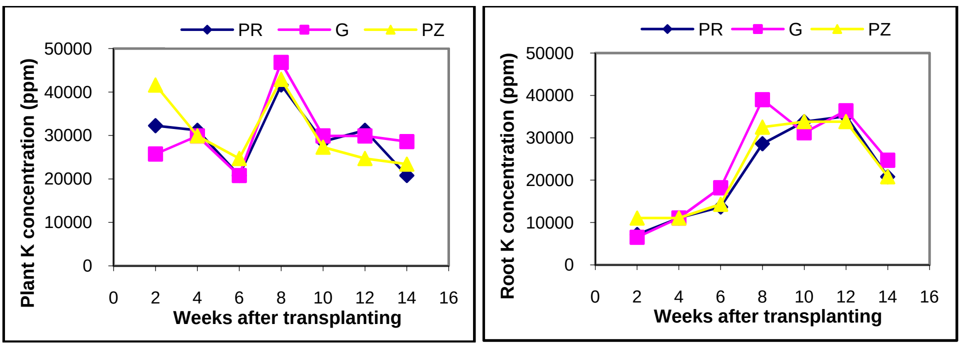

Fig.. 4. Evolution of K content in vegetative and radical part of cauliflower grown in three substrates
Razvoj sadržaja K u vegetativnim i korjenskim dijelovima karfiola uzgajanog na tri supstrata

The potassium status in vegetative part was fluctuating at the beginning of vegetative growth reaching its peak in the 8th week when inflorescence head formation started. With the progress in the cropping cycle, potassium concentration gradually decreased as harvest time was approaching due to potassium re-partition from leaves to formed heads.

In radical part, the first four weeks potassium concentration was more or less constant with slight increase and fluctuation after 6th week. Potassium reached its maximum values on the 8th week where roots were mostly developed, and then there was a gradual reduction in its values which continued till harvest time, but with concentration values nearly twice the ones at the initial growth stage.

Regarding the K uptake (Tab. 4.), it can be seen that K uptake followed a trend identical to the one concerning the N uptake under different substrates.

Similar to N and P uptake, the K uptake by the vegetative part is significantly 86% and 36% higher than the P uptake values under perlite and gravel substrates, respectively. This also holds true for the K uptake by roots, where the K uptake under pozzolana was of values nearly twice that for the perlite and nearly 36% more than that under gravel. This was statistically confirmed indicating that there is a significant difference in the K uptake by the growing plants due to the variation in inert substrates.

Tab. 4. Potassium exportation (mg·plant^{-1})
Unos kalijuma (mg·plant^{-1})

Substrate	Perlite	Gravel	Pozzolana
Vegetative part	3349	4576	6224
Radical part	437	716	978
Total	3786	5292	7202

On the basis of an analysis of the nutrients uptake by different plant components as well as the total uptake, we can come to a conclusion that the N, P and K uptake differ greatly according to the growing substrate media. Generally, the uptake of the nutrients N, P and K were at values exceeding the ones obtained under gravel, and those obtained under gravel were slightly higher than the ones calculated under perlite. This, in other words, means that the efficient use of the N, P and K fertiliser under the soilless culture technique could vary according to the variation in the investigated substrates. This point is of paramount importance when deciding on the nutrient formula to be used under the different soilless substrates.

Drainage nutrient solution was analysed for its N, P and K concentration periodically every 10 days covering all the cropping period (Fig. 5).

Regarding the N nutrient, it is quite clear that maximum losses occurred at the earlier growth stages, where nutrients were added at levels exceeding the actual plant requirements. In the middle growth stages, there was a reduction in N concentration due to the development in vegetative growth, then with the progress of cropping period it again showed another increase in its value due to the increase in the number of irrigation and as a result of an increase in the added N to meet the N requirements of the intensive vegetative growth. With the progress in vegetative growth, N was absorbed in greater amounts and as a result its concentration in the drained solution was gradually decreasing which continued showing minimum values, hence starting from the 8th week, where vegetative growth was completed, at the start of inflorescence head formation N was added at lower doses till the harvest time. The data also indicate that in the solution drained from the gravel substrate due to its high drainability, nitrogen was found in concentrations relatively higher than those measured under perlite and pozzolana substrate where N concentration in the drainage nutrient from both was more or less of the same values. Regarding the P concentration in the drained nutrient solution, it is clear that during the cropping cycle it followed a trend opposite to the one of the nitrogen.

At the beginning of a growing cycle, phosphorus content in drainage water was showing the lowest values due to the highest consumption by plants. In that period the root system was established. Reaching the inflorescence head formation phosphorus needs of plants increased and thus phosphorus content went down in drainage water. After the 7th week, phosphorus content in drainage water increased due to the changed nutrient solution and augmentation of phosphorus quantity.

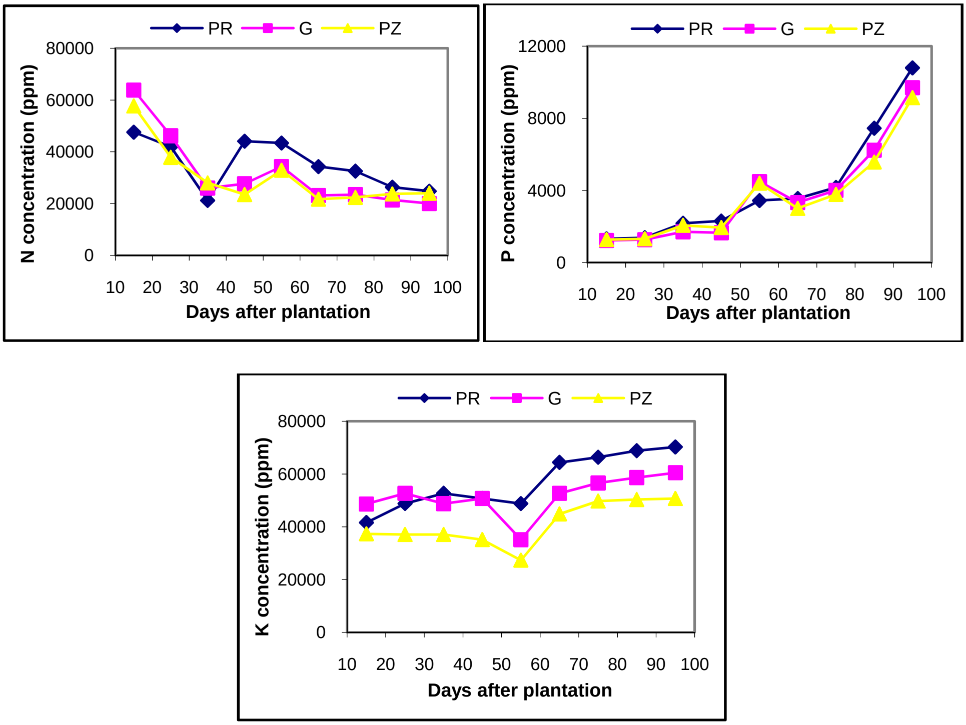

Fig. 5. Drainage water nutrient content during growing cycle
Sadržaj hraniva u procijednoj vodi tokom uzgoja

The potassium concentration in the drained solution during the cropping period followed a trend different from the ones concerning nitrogen and phosphorus.

Potassium content at the beginning of growing cycle was more or less constant until the 6th week where decline was recorded due to the intensive consumption by plants and the starting of inflorescence head formation. The minimum value was reached around 7th week. After that potassium content was rising again due to changed nutrient solution and augmentation of potassium quantity.

Nutrient balance was calculated using formula:

Nutrient balance = Input (fertilisers) – Output (fertilisers)

Nutrient balance as well as NPK nutrients efficiency is given in Tab. 5 and Tab. 6.

The presented data show that losses concerning the three elements N, P and K are very acceptable, where maximum losses in the case of K were only 11.6%.

Regarding the phosphorus, the losses were more or less negligible, only 3% of the added. This was also the case or the nitrogen being in losses not exceeding the 10%. In the soilless culture technique and particularly under the open system one of the problems is the concentration of nutrients in the drained solution and especially the nitrate concentration and its impact on the ground water quality. However, under appropriate nutrient management such problems can be avoided.

Tab. 5. Nutrient balance in hydroponics
Balans hraniva u hidroponskom uzgoju

Nutrient	Total drained (g)	Amount applied (g)	Total absorbed (g)
N	874	9100	8226
P	102,6	3640	3537,4
K	1345,5	11580	10234,5

Tab. 6. Nutrient efficiency
Efikasnost hraniva

Nutrient	Nutrient efficiency (%)	Losses (%)
N	90,4	9,6
P	97,2	2,8
K	88,4	11,6

In the mean time, the nutrient drained solution being with reasonable nutrient concentration and relatively low EC values can be reused safely for the irrigation of most crops without any deterioration in the soil productivity and crop production.

Conclusion

The highest nutrient consumption was recorded 8-12 weeks after cauliflower seedlings transplantation. Nutrient losses were reduced to a minimum because of possibility of precise control and manipulation of fertilisers, which can not be controlled in the traditional cultivation. From macronutrients used in this experiment, the highest losses were recorded in potassium (11.6%). The highest nutrient efficiency was achieved by use of phosphorus fertilisers that was about 97.2%.

Due to the good nutrient management, there have not been high nutrient losses, which in turn did not cause ground water pollution.

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Sadržaj NPK hraniva u vegetativnim organima karfiola (*Brasica oleracea var. botrytis* L.) gajenog na hidroponski način

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Sažetak

Eksperiment je sproveden u stakleniku Mediteranskog agronomskog instituta u Bariju (IAMB) koji se nalazi u jugoistočnoj Italiji. Glavni cilj ovog istraživanja je bio evaluacija sadržaja makrohraniva (NPK) u vegetativnim organima karfiola gajenog u tri inertna substrata (perlit, gravel i pozolana). Gubici hraniva su bili jako mali zahvaljujući dobrom upravljanju kao i kontroli primjene hraniva. Najveću efikasnost u primjeni hraniva je imao fosfor (97,2%), dok je najveći gubitak hraniva imao kalijum (11,6%). Dobijeni gubici nisu izazvali veliko zagađenje zemljišta i podzemnih voda.

Ključne riječi: hraniva, substrati, kalijum, karfiol.

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