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Influence of increased doses of microelements in hydroponic nutrient solution on the yield of *Capsicum annuum* L. fruits and their capsaicin content

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Abstract

The Wrocław version of hydroponic culture was applied. The content of particular microelements (Cu, B, Mn, Mo, Zn) or several of them jointly was increased ten times (to 6 mg/l) as compared to the standard composition of the nutrient solution. It was found that the yield of fruits and of capsaicin per plant was significantly higher with 10 times increased content of Cu and B or Cu+B+Mo or Cu+Mn+Mo or B+Mn+Mo. Moreover, Cu and Mn applied alone or in combinations with other microelements in 10-fold increased proportion caused a marked increase of capsaicin content in the dry matter of the fruit. It is suggested that the proportions of microelements should be chosen individually for each plant species and for each type of agroclimatic conditions.

INTRODUCTION

Capsaicin obtained from the fruits of *Capsicum annuum* L. is a raw material used in the production of various drugs with a rather wide application (Muszyński, 1957). Owing to the compounds accompanying capsicin and similar in structure to it, as for instance dihydroxycapsaicin, homocapsaicin of homodihydroxcapsaicin (Tyihak et al., 1966; Leete and Louden, 1968) as well as the presence in the fruit of a number of vitamins (Cholnoky, 1937; Špaldon, 1948), the fruits of *Capsicum* are so far the only source of capsaicin for therepeutic purposes, although a synthetic capsaicin has been obtained.

The amount of capsaicin in *Capsicum* fruits is a varietal trait and may amount from 0.01 to 0.4 per cent (Skąpski, 1955; Blaim et al., 1957; Gertig and Olszak, 1957; Michna, 1968). It also de-

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pends on the climatic conditions, for instance Buchi and Hippenmeier (quoted after Blaim et al., 1957) demonstrated that the amount of capsaicin increases in the fruits when the weather is dry and sunny. Accumulation of capsaicin may also be influenced by soil moisture, the season or the time of day (Quagliotti, 1971). Capsaicin content is also dependent on the degree of ripeness of the fruits (Borkowski et al., 1957a; Michna, 1966; Balbaa et al., 1968) and of the method of their drying (Borkowski et al., 1957b).

In some few studies it was attempted to increase the capsaicin amount in the fruits by fertilization. Tschirch (quoted after Czabajski and Załęcki, 1967) mentions that the capsaicin level is favourably influenced by NP fertilization. This correlation, however, has not been confirmed by other authors (Czabajski and Załęcki, 1967; Golczet al., 1970).

The present study was undertaken to test the influence of quantitatively differentiated fertilization with microelements on the yield of *Capsicum* fruits and on their capsaicin content.

METHODS

The experiments were performed in a glasshouse from May 25 to October 6, 1974. The plants were grown in Wrocław version of hydroponic culture (Gumińska, 1966). *Capsicum annuum* seeds were sown directly into the hydroponic matrix. A nutrient medium of routine composition and matrix described in another paper were used (Nowak, 1980a), other methodical details are described in the same paper.

In the routine nutrient medium the amount of particular microelements was 10-fold increased (6 mg/l of the given compound) according to the scheme shown in Figure 1. At the beginning of the experiment 100 mg of water-soluble sodium humate was added to the nutrient medium in each replication. In the course of the whole vegetation period each plant received 18 g mineral salts in the form of the basic medium, which was the optimal dose (Nowak, 1980b).

Tap water was used in the experiment containing microelements in the following quantities (mg/l): copper 0.03-0.035, boron 0.008-0.01, manganese 0.08-0.1, molybdenum 0.005-0.006, zinc 0.07-0.08.

Copper was determined by the colorimetric method with the use of diethyldithiocarbanate, zinc by the same method with the use of ditizone (Hermanowicz et al., 1967), boron by the carmine method, molybdenum by the rhodanate method (Marczenko, 1968) and manganese by the colorimetric method with a silver catalyser (Gomółka and Szypowski, 1975).

During the experiments protective agents against aphids were applied: Nogos GEC 50 and Mszycol. The experiments were run under the microcolimatic conditions described in Table 1.

The fresh weight of the fruits, dry weight of fruits, the per cent of mature fruits, capsaicin content in the fruits and its yield were determined.

Table 1

Outdoor climatic conditions during the vegetation season

Month	t (°C)	t_{max}	t_{min}	t<13°C	r.h. (%)	S (h)
VI	17.6	19.2	13.7	2	76	130.9
VII	18.2	21.3	14.8	0	79	131.1
VIII	21.2	25.6	16.9	0	86	181.3
IX	15.2	18.7	10.8	8	87	150.7
mean or total from 25 V to 6 X	17.7	21.0	13.9	13	82	634.3

Explanation of symbols: t — mean air temperature, t_{max} — mean maximum air temperature, t_{min} — mean minimum air temperature, t<13°C — number of days and nights with mean air temperature 13°C, S — insolation (in hours).

Within each combination (treatment) 6 replications were performed. One replication consisted of one plant growing in one jar. Statistical calculations (of fruit yield) were done by analysis of variance (Ulińska, 1957). The significance of differences between all pairs of means was estimated by Duncan's multiple range test (Waller and Duncan, 1969). As regards capsaicin content the error of the method of determination was calculated on homogeneous material.

RESULTS

In order to simplify the description of results, the notations Cu, B, Mn, Mo and Zn will denote in the further text that these elements were present in the hydroponic solution in 10-fold increased amounts (6 mg/l) of each, and the remaining substances in routine amounts (0.6 mg/l).

The methods of treatment of *Capsicum annuum* strongly influenced the fruit yield. The harvest of fresh fruit weight increased under the influence of Cu, B and Zn, whereas the remaining two microelements Mn and Mo reduced it (Fig. 1). When two microelements were used jointly, Cu with B increased the yield to a higher degree than Cu

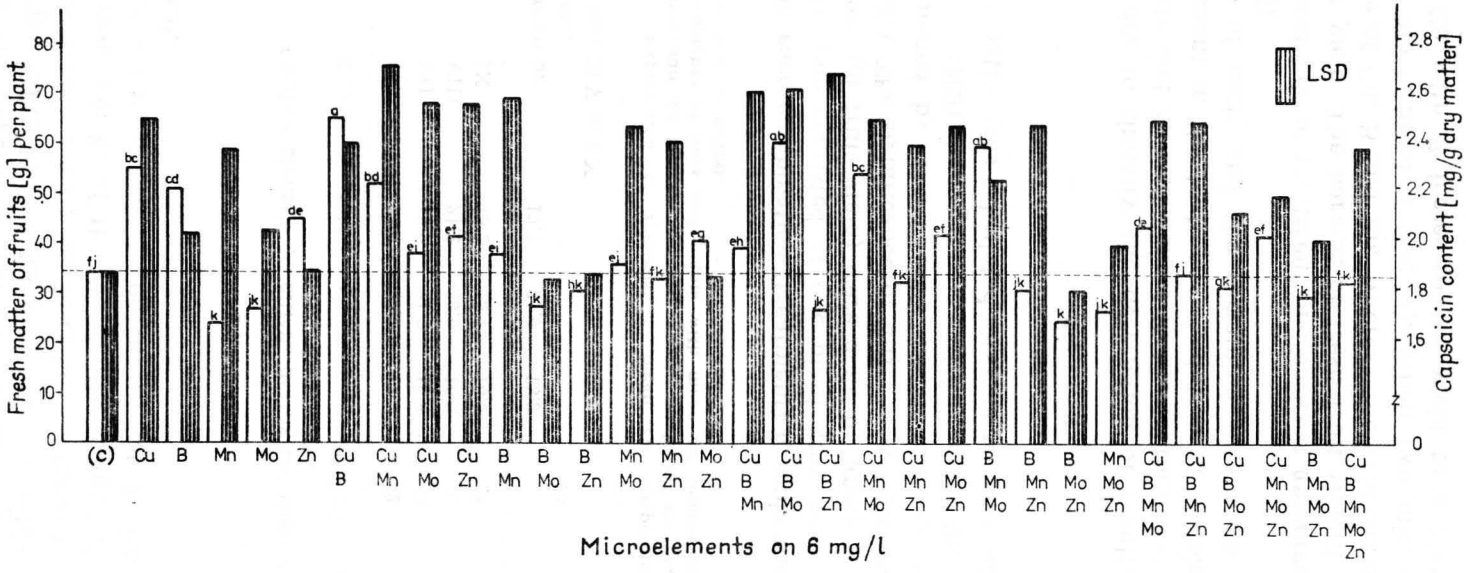

Fig. 1. The influence of 10-fold increased amounts of particular microelements (Cu, B, Mn, Mo, Zn) in hydroponic nutritive solution on the yield of fruits per plant and on the capsaicin content in dry matter of *Capsicum annuum* L. fruits

The symbol of a given microelement below a column means that it was given in the amount 6 mg/l whereas the all others were given in the amount 10-fold lower; (c) — control

alone (additive effect). The stimulating effect of Cu+Mn was similar to that of Cu alone. In other combinations of two elements their action was not significant. In simultaneous application of 3 microelements only Cu+B+Mo, Cu+Mn+Mo and B+Mn+Mo markedly increased the fruit yield. The influence of these combinations was similar to that of Cu+B and Cu alone. The combination Cu+Mo+Zn also showed a tendency to increasing the yield. B+Mo+Zn diminished the yield. Their action was similar to that of Mn alone. A reducing tendency was also observed when Cu+B+Zn, B+Mn+Zn and Mn+Mo+Zn were used. Increased amounts of 3 microelements in the remaining combinations were without effect. When 4 substances were applied simultaneously only Cu+B+Mn+Mo increased the fruit yield. The remaining combinations as well as the application of the 5 microelements in a high dose had no influence.

Capsaicin content in the fruits (Fig. 1) depended strongly on the quantitative composition of microelements in the nutrient medium. Cu and Mn either alone or in combination with other microelements increased the capsaicin content in the fruits. An exception were the combinations: Mn+Mo, Mn+Zn and Mn+B+Mo in which the stimulating action of Mn was not manifested. The remaining microelements (B, Mo and Zn) had no influence either when singly added or jointly.

The dry weight content in fruits did not depend on the treatment with microelements and amounted from 14.77 to 16.1%. The number of ripe fruits varied from 92 to 100%. The capsaicin yield of one plant was 6.5 to 24.1 mg and was the higher the larger was the fruit yield and the capsaicin content in them.

DISCUSSION

Treatment with increased amounts of microelements in the hydroponic nutrient solution (6 mg instead of 0.6 mg/l) influenced the capsaicin yield indirectly by increasing the fruit yield and directly by increasing the capsaicin content in them.

The effect of increased amounts of microelements on the fresh weight of the fruits depended on the quantitative interrelations between all the microelements in the medium. When Cu, B or Zn content was increased in the hydroponic solution, these proportions between the microelements stimulated the yield. Simultaneous increase of the amounts of Cu and B gave an additional stimulating effect, whereas simultaneously increased B and Zn amounts had no influence on the fruit yield although each of these elements used separately increased the yield.

These results confirm the numerous data indicating a positive in-

fluence of microelements on the quantity and quality of the yield of a number of other plants (Sójkowski, 1971). They show also necessity to establish optimal proportions between the microelements in the mixture for every plant species and for the given agroclimatic conditions.

The rise of capsaicin level in the fruits evoked by Cu or Mn may be explained by their indirect influence on biosynthesis of this substance. Cu and Mn, namely, stimulate amino acid biosynthesis (Sójkowski, 1971), and some of the latter (phenylalanine, valine, methionine) may be precursors for capsaicinoids synthesis (Leete and Louden, 1968).

It would seem that the dependence of the capsaicin level in the *Capsicum annuum* fruits on climatic conditions (Hasenbusch, 1948; Quagliotti, 1971) may be attributed, among other causes, to the differences in copper and manganese uptake connected with climatic conditions. It is known for instance that in dry and warm years copper utilisation by plants is high on dried boggy soils (Sójkowski, 1971). This problem requires further study, the more so since hardly any data are available on the influence of microclimatic factors on the utilisation and function of microelements.

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Wpływ zwiększonych dawek mikroelementów w pożywce hydroponicznej na plon owoców i zawartość w nich kapsaicyny u *Capsicum annuum* L.

Streszczenie

Stosowano hydroponiczną uprawę pieprzowca rocznego w wersji wrocławskiej. W pożywce o składzie podstawowym, zawierającej mikroelementy w ilości po 0,6 mg/l, zwiększano dziesięciokrotnie ilości poszczególnych mikroelementów

(Cu, B, Mn, Mo i Zn) w różnych kombinacjach. Stwierdzono, że najkorzystniejszą pożywką dla hydroponicznej uprawy pieprzowca, ze względu na plon owoców i wydajność kapsaicyny z rośliny, jest pożywka zawierająca w zwiększonych ilościach miedź i bor lub łącznie oba te pierwiastki, oraz że miedź i mangan w zwiększonych ilościach wpływa korzystnie na akumulację kapsaicyny w suchej masie owoców. Wpływ miedzi i manganu stymulujący zawartość kapsaicyny w owocach obserwowano także gdy w mieszaninie znajdowały się inne pierwiastki w zwiększonych ilościach. Wyjątek stanowiły Mn+Mo+Zn oraz Mn+B+Mo, które nie stymulowały zwiększenia zawartości kapsaicyny. Sugeruje się, że proporcje mikroelementów w mieszaninie powinny być ściśle dobrane dla każdego gatunku rośliny i dla określonych warunków agroklimatycznych.