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Influence of nitrogen, phosphorus and potassium on chemical composition and activity of some enzymes in celery during its growth

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Abstract

The influence of N, P, K supply on the contents of dry mass, chlorophyll (*a*+*b*), vitamin C, saccharides and the activities of peroxidase (E.C.1.11.1.7), catalase (E.C.1.11.1.6), and acid phosphatase (E.C.3.1.3.2) in leaves of celery plants during their growth stages was investigated. A correlation between the amount of N, P, K and the chemical composition and catalytic activities of enzymes was found.

Introduction

The nutritive value of vegetables is a result of the action of different interrelated factors, the most important of which are the genetic ones. Mineral fertilization, which is important for growth and yield, also influences the chemical composition of vegetables. The main criteria for proper fertilization with macro- and microelements are chemical analysis of leaves (Nowosielski 1972) and determination of plant enzymatic activities. Because of their physiological action on growth and development catalase, peroxidase and acid phosphatase (Stanislawski 1963, Macháčková *et al.* 1975) were chosen for testing the effects of N, P, K fertilizers on the enzymatic system.

Material and methods

Celery (*Apium graveolens* L.) plants were grown in a greenhouse in pots filled with 4.5 kg of sandy soil containing 11 - 13 % fine particles, 1.5 % of humus, pH 6.3, and different concentrations of N, P, K in the soil [g m^{-3}]:

N1 - 45	P1 - 100 (P_2O_5)	K1 - 55 (K_2O)
N2 - 90	P2 - 200 (P_2O_5)	K2 -110 (K_2O)
N3 -180	P3 - 400 (P_2O_5)	K3 -220 (K_2O)

Soil moisture was kept constant. Plant material for chemical analysis was collected three times in monthly. Ash components were analysed after the growth period

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(September 30). Saccharide content in dry matter was measured using the Luff-Schoorl method (Rutkowska 1981). The content of chlorophylls ($a+b$) was measured in fresh matter according to Bruinsma (1963) and that of vitamin C using Tillmans method (Rutkowska 1981).

The samples of fresh celery leaves for enzyme activity measurements were prepared according to Gurgul (1982). Peroxidase activity was measured using the method of Gardiner and Cleland (1974), that of catalase using the method of Bergmayer (1963) and that of acid phosphatase using the method of Brandenberger and Hanson (1963).

Results

An increase in N-dose resulted in an increase in chlorophyll content during the whole period of celery growth (Table 1). At the highest N3-dosage the increase in the chlorophyll ($a+b$) content was 57.0 % in comparison with the control. The maximum levels of saccharides (3.17 %) and vitamin C (152.9 mg%) were obtained at the intermediate N2-dosage (Table 1). During the whole period of growth an increase in

Table 1. The influence of nitrogen, phosphorus and potassium supply on the contents of chlorophyll, saccharides and vitamin C in celery leaves in different growth phases.

	Chlorophyll ($a+b$) [mg g^{-1}(f.m.)]				Saccharides [% of dry m.]				Vitamin C [mg%]			
	81 d	110 d	140 d	mean	83 d	113 d	145 d	mean	82 d	111 d	141 d	mean
Control	0.664	1.177	1.906	1.249	3.20	2.10	2.00	2.43	95.04	116.60	117.84	109.50
N1	1.219	1.714	1.952	1.628	3.90	2.80	2.70	3.13	118.80	128.16	168.96	138.63
N2	1.371	1.847	2.038	1.752	3.80	2.80	2.90	3.17	129.36	157.69	171.60	152.88
N3	1.436	2.234	2.213	1.961	3.30	2.20	2.00	2.50	121.44	156.46	134.64	137.51
LSD for $P = 0.95$ for N	0.03				0.08				4.38			
P1	0.901	1.530	1.832	1.422	3.20	2.50	2.10	2.63	79.20	128.13	124.08	110.47
P2	0.962	1.717	2.037	1.572	3.40	2.40	2.30	2.70	110.88	152.77	147.84	137.16
P3	0.792	1.227	1.410	1.143	3.60	3.40	2.80	3.27	95.04	147.84	150.48	
LSD for $P = 0.95$ for P	0.03				0.06				3.54			
K1	0.781	1.794	2.140	1.571	3.60	2.30	2.40	2.77	110.88	134.64	177.41	140.98
K2	1.020	1.687	1.690	1.466	4.20	2.50	2.50	3.07	124.08	163.68	187.26	158.34
K3	0.794	0.905	0.948	0.883	4.30	3.60	4.70	4.20	161.04	176.88	192.19	176.70
LSD for $P = 0.95$ for K	0.03				0.05				3.45			
LSD for $P = 0.95$ for phases	0.04				0.07				4.00			

peroxidase activity was observed with N-dose increasing to N2. For catalase the N1 dose was most appropriate. The activity of acid phophatase gradually rose with increasing nitrogen level up to N3 (Table 2). The experiments with phosphorus showed that the intermediate dose P2 increases the contents of chlorophyll ($a+b$) and

vitamin C by *ca.* 25 %. The sugar (total sacharides) content increased with an increase of phosphorus level (Table 1). Increasing P dose gradually increased the activities of peroxidase, catalase and acid phosphatase (Table 2). Increasing doses of potassium positively influenced the contents of sugar and vitamin C (Table 1). The most effective dose of potassium for chlorophyll content was K1, in K2 the stimulation was less expressed and K3 was even inhibitory (Table 1). The effect of K on enzymatic activity was irregular, stimulation was observed at several stages of growth (Table 2).

Table 2. The influence of nitrogen, phosphorus and potassium supply on the activities of peroxidase, catalase and acid phosphatase in celery leaves in different growth phases.

	Peroxidase [$\Delta A\ s^{-1}$]			Catalase [$g(H_2O)\ kg^{-1}\ s^{-1}$]			Acid phosphatase [$g(P)\ kg^{-1}$]		
	84 d	112 d	mean	90 d	119 d	mean	88 d	117 d	mean
Control	0.0017	0.0020	0.0018	0.598	0.769	0.683	4.31	2.00	3.16
N1	0.0018	0.0025	0.0021	0.599	0.851	0.725	5.13	2.88	4.01
N2	0.0048	0.0029	0.0038	0.604	0.796	0.700	5.13	2.88	4.01
N3	0.0022	0.0017	0.0019	0.634	0.796	0.715	6.13	3.13	4.63
LSD for $P = 0.95$ for N			0.0001			0.022			0.18
P1	0.0017	0.0022	0.0019	0.610	0.723	0.667	4.25	2.75	3.50
P2	0.0019	0.0022	0.0020	0.653	0.769	0.711	4.88	2.75	3.82
P3	0.0020	0.0024	0.0024	0.659	0.872	0.766	4.25	3.13	3.63
LSD for $P = 0.95$ for P			0.0001			0.026			0.13
K1	0.0016	0.0022	0.0019	0.634	0.796	0.715	4.38	3.38	3.88
K2	0.0020	0.0026	0.0023	0.610	0.787	0.699	4.63	3.38	4.01
K3	0.0020	0.0027	0.0023	0.604	0.759	0.682	5.00	3.88	4.44
LSD for $P = 0.95$ for K			0.0001			0.020			0.12
LSD for $P = 0.95$ for phases			0.0001			0.032			0.18

Discussion

Both under- and over-optimum levels of N, P, K lead in celery to evident changes in the synthesis of the products tested and the catalytic activity of enzymes (Tables 1 and 2). Among the macroelements, nitrogen was the most important for growth of the plants, as shown by the correlation between the increase of ash components in plants and the fertilizer dose. The influence of P and K on the increase of ash content was not so evident. These results are in agreement with other findings (Gurgul 1982, Michalik 1985, Czuba and Mazur 1988). The highest level of chlorophyll ($a+b$) was found at the highest dose of N3, medium levels of phosphorus P2 and the lowest potassium dose. The importance of N for pigment synthesis has been found, for instance by Lewandowska and Skąpski (1977), Karczmarczyk and Devlin (1985) and Zbieć *et al.* (1989). The uptake and utilization of P and K depends on the presence of inorganic nitrogen compounds (Michalik 1985). Higher nitrogen supply significantly

increased the sugar and vitamin C contents. Similarly Jabłońska-Ceglarek (1980) and Osińska *et al.* (1982), found a beneficial influence of N-fertilization of celery on the content of saccharides. Gurgul (1982), found that increase in N-fertilization between 0 and 300 g m^{-2} (kg ha^{-1}) induced a systematic increase of sugar concentration in red cabbage, that not in Italian cabbage. Michalik (1985) found that with carrot medium dosages of nitrogen were the most effective for sugar content. According to Gurgul (1982) and Kolota and Sciążko (1987), high N-doses do not favour accumulation of vitamin C in plants. In our experiments the N2 dosage was optimal for vitamin C content in celery, as well as high P and K doses at low N feeding. Similar results were obtained by Elkner and Michalik (1982), Michalik and Elkner (1987), Drążkowski (1978) and by Warcholowa (1978) in their experiments on the effect of P and K fertilization on the quality of cabbage, borecole and lettuce. The level of feeding with nutrients causes several changes in physiological processes in plants, which are evident in the activities of enzymatic systems (Gurgul 1982, Zbięć *et al.* 1986, 1989). In our pot experiment, there was a clear relation between the doses N2-N3, P2-P3, K2-K3, and the activities of peroxidase, catalase and acid phosphatase. The interdependence of the enzymatic systems in plants, their mineral nutrition and the yield has also been reported by Satsukiewich (1974), Mengel (1977), Gurgul (1982) and Zbieć *et al.* (1986, 1989).

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