Effect of conditions of locality, variety and fertilization on the content of ascorbic acid in potato tubers

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ABSTRACT

The effect of conditions of locality, variety and fertilization on ascorbic acid (AA) content in potato tubers was investigated in precise field trials in 2004 and 2005 in the Czech Republic. From four localities and in the two-year average the highest AA was statistically determined in the locality of Přerov nad Labem with the highest average temperature values during both experimental years (by 6.7 to 11.5% higher in comparison to other localities). Similarly, the effect of variety was also very significant; Marabel variety had the highest AA content (207.2 mg/kg fw) and exceeded other seven varieties by 15–49%. A negative effect on AA content in tubers was observed in the case of an increased intensity of N fertilization (at 180 kg N/ha AA decrease was lower by 6.1% compared to doses 100 kg N/ha). On the contrary, a favourable effect was determined at increased levels of potassium and magnesium fertilization (at 166 kg K/ha and 60 kg Mg/ha AA increase was by 6.2% higher compared to the levels of 108 kg K/ha and 30 kg Mg/ha).

Keywords: ascorbic acid; potatoes; locality; variety; fertilization

Ascorbic acid (AA) contained in potato tubers attracts attention as a significant source of vitamin C in human nutrition. It possesses significant physiological efficiency, for example as an antiscorbutic factor and an important natural antioxidant. Ascorbic acid is the major, naturally occurring inhibitor of enzymatic browning of potatoes (Lachman et al. 2000). The study of Chu et al. (2002) estimated that vitamin C extracted from an unidentified potato obtained from a grocery store contributes to 13.3% of total antioxidant activity. Also Hamouz et al. (2006) confirm a strong antioxidant activity of ascorbic acid. In two recent surveys of potato genotypes, AA concentrations varied between 11 and 30 mg per 100 g fw in North American varieties and breeding lines (Love et al. 2003), and between 18 to 36 mg in six European varieties and 27 breeding lines (Dale et al. 2003).

Ascorbic acid content in freshly harvested potato tubers is strongly influenced by dynamics of changes of its concentration in the tubers during the vegetation period. In most cases these changes are a consequence of the reaction of potato varieties to climatic conditions and ways of agricultural engineering. After the harvest AA concentration decreases during storage and is further degraded by cooking and by potato processing into food products (Weber and Putz 1999). Varietal genotype has a significant effect on AA content, as was shown in the field experiment with 26 German varieties by Weber and Putz (1999). In the experiments of Zgórska and Frydecka-Mazurczyk (2000) AA content approved itself as a rather labile characteristic; it was affected by genotype (24–33%), however, the year of cultivation showed a significantly higher impact (56–67%). Pawelzik et al. (1999) investigated the effect of locality,

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which influenced AA content only in two of four varieties; the effect of variety prevailed over the effect of locality. During twelve years Nowacki et al. (2000) investigated the effect of the sum of precipitation on the AA content. With approximately hundred varieties, they recorded higher AA content (22.1 mg/100 g fw) in dry years than in wet years (18.9 mg/100 g fw). Many authors describe a negative effect of nitrogen fertilization on the AA content (Takebe and Yoneyama 1992, Rogozińska and Wojdyla 1996, Nowacki et al. 2000). However, Lin et al. (2004) discovered a little effect of nitrogen fertilization on the AA content; only high doses of nitrogen that lead to the yield depression significantly reduced the content of AA. Two sources of potassium fertilizer, KCl and K_2SO_4 significantly increased the ascorbic acid content in the experiments carried out by Mondy and Munshi (1993). Nowacki et al. (2000) also determined favourable effects of potassium fertilization in the form K_2SO_4 and phosphorus fertilization on the AA content, while Rogozińska and Wojdyla (1996) obtained inconsistent and non-significant results for potassium fertilization.

The aim of this study was to examine the influence of locality, genotype and fertilization with inorganic fertilizers (N, P, K) on the AA content in potato tubers.

MATERIAL AND METHODS

Precise field trials were conducted in the years 2004 and 2005 in four localities in the Czech Republic (Přerov nad Labem, Praha-Suchdol, Lípa, Stachy) with different altitude; Impala, Karin, Ditta and Saturna varieties were cultivated in a unified way according to the standards common for agricultural engineering. In addition, in Lípa locality, Agria, Asterix, Magda and Marabel varieties were cultivated. Basic characteristics of the localities are described in Table 1.

As forecrop winter wheat was used in these experiments; the autumn manure was ploughed under the dose of 30 t/ha together with P and K fertilizers in the doses specific to the reserves of nutrients in the soil. In spring, nitrogen fertilizers were spread on the harrowed plot in 2/3 of the total dose (120 kg N/ha) and the rest of the dose was applied after emerging of the vegetation. The plot was spaded into the depth of 15–18 cm and the drills were formed. Proper trials were based in four parallels in the spacing of 75 × 30 cm, and the area of parcel 3 m (4 rows) × 7.2 m. The preemergent herbicide Afalon 45 SC (linuron 450 g) at the dose of 1.5 l/ha was applied before growing of bunches. Before the integration of vegetation one insecticide treatment against Colorado potato beetle was performed as well as 5–7 fungicide treatments against late blight according to the requirements of individual localities.

The second trial was based in the Valečov locality (Table 1), where the influence of different fertilization levels with N, P, K, Mg nutrients was investigated. The trial was carried out with Ditta and Karin varieties, agricultural engineering was (with exception of inorganic fertilizers) the same as in the first experiment. Fertilization variants were as follows: variant 1 – without fertilization with industry fertilizers; variant 2 – 100 kg N/ha, 44 kg P/ha, 108 kg K/ha, 30 kg Mg/ha; variant 3 – 100 kg N/ha, 44 kg P/ha, 166 kg K/ha, 60 kg Mg/ha; variant 4 – 180 kg N/ha, 44 kg P/ha, 108 kg K/ha, 30 kg Mg/ha.

After the harvest, in the stage of physiological maturity, tubers from parallels of every experiment were sampled for laboratory analyses; these were performed at the Department of Chemistry

Table 1. Characterization of experimental localities

Locality	Level above sea (m)	Average annual temperature (°C)	Annual sum of precipitation (mm)	Soil type	Soil category
Přerov n/L.	178	8.8	622	TBS	sl–l
Praha-Suchdol	286	8.2	510	TBS	l
Lípa	505	7.7	632	PGAC	sl
Stachy	860	6.3	755	BPS	ls
Valečov	460	6.9	649	PGAC	sl–l

Soil categories: TBS – typical brown soil, PGAC – pseudogleyic acid cambisol (brown gleysol), BPS – cryptopodzol (brown podzolic soil); soil texture class: sl – sandy loamy, ls – loamy sandy, l – loamy

of the Czech University of Agriculture in Prague. AA content was determined polarographically on the micropolarograph Eko-Tribo Polarosensor (CR). Obtained results were statistically analyzed using the variance analysis (ANOVA), with a more detailed evaluation done by means of the Fisher test in computer programme SAS (version 8.02) at the level of significance $P = 0.05$.

RESULTS AND DISCUSSION

Effect of locality

As the average of both years from four experimental localities, significantly highest AA content was determined in the Přerov n/L. locality (Figure 1). In the other localities, lower AA levels in tubers in the average of both years were recorded (in Lípa by 6.7%, in Suchdol by 7.4% and in Stachy by 11.5%). One of the factors contributing to the highest AA content in Přerov n/L. was the weather with the highest temperatures and low precipitation during vegetation periods of the experimental years (Table 2). Our result is in accordance with conclusions resulting from experiments of Sawicka and Mikos-Bielak (1995), where high air temperatures during vegetation favourably stimulated vitamin C accumulation in the tubers of very early potato varieties. Also Jablońska-Ceglarek and Wadas (2005) came to the same conclusion in their six-year experiment. Together with climatic conditions the effect of sandy loamy brown soil in the Přerov n/L. locality could affect the results; a significant difference was reported compared to the Suchdol locality with similar climatic conditions, but loamy soil. It is in accordance with the results obtained by Mondy et al. (1979). Also Pawelzik et al. (1999) documented the effect of locality on the AA content. The year of cultivation had a significant effect on the AA content. In the dry year 2004 a higher AA content (by 8%) was determined compared with 2005; in the vegetation period of 2005, in average of all localities, the sum of precipitation was by 36% higher. These results confirm conclusions of Nowacki et al. (2000) obtained in a long-term AA content investigation during dry and wet years in the period 1974–1997.

Effect of variety

The AA content in tubers of different varieties in the Lípa locality ranged from 136.3 to 211.8 mg/kg fw and the effect of variety was well demonstrated. In average of both years (Table 3) the highest AA content (207.2 mg/kg fw) was found in Marabel variety, which significantly exceeded Saturna, Magda, Impala, Agria, Asterix and Ditta varieties (by 15 to 49%). The second ranked Karin variety; it exceeded the same varieties as Marabel variety except Ditta variety (the third in the order of sequence). Agria variety was another one that reached higher AA content than the average value.

Marabel, Karin, Ditta and Agria varieties, with the highest AA concentration in the tubers, belong to semi-early varieties; Impala and Magda varieties are very early; Saturna and Asterix, with the lowest AA content, are semi-late varieties intended for manufacturing of potato chips or French fries. AA concentrations in potatoes obtained in our experiments correspond to the results published by other authors (Zgórska and Frydecka-Mazurczyk 2000, Dale et al. 2003, Love et al. 2003). Our results also confirmed the significant effect of variety on

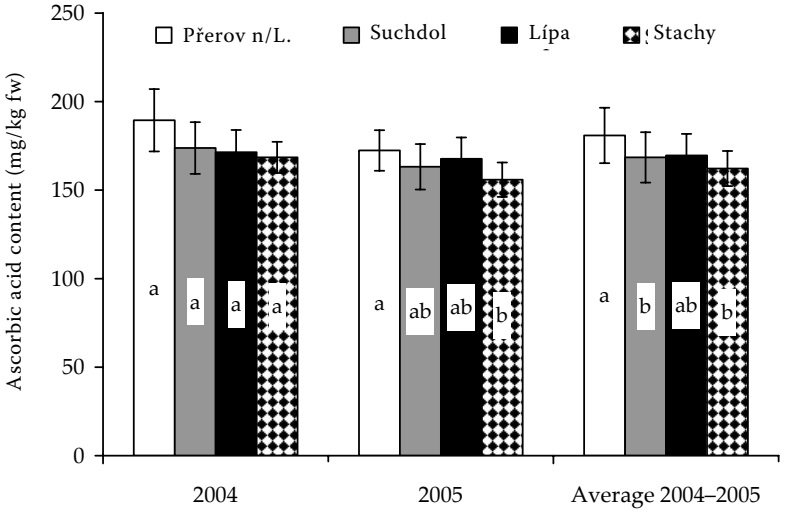

Figure 1. Effect of locality on the content of ascorbic acid (mg/kg fresh weight); vertical lines represent SD (4 replicates), means with the same letter are not significantly different ($P \geq 0.05$)

Table 2. Mean monthly temperatures (°C) and sums of precipitation (mm) in the vegetation period in the years 2004 and 2005 in the experimental localities

Locality/ Month	Stachy		Lípa		Přerov n/L.		Suchdol	
	(°C)	(mm)	(°C)	(mm)	(°C)	(mm)	(°C)	(mm)
2004								
April	4.9	71	8.1	54	10.5	25	10.1	0
May	6.8	106	10.5	71	13.4	33	12.1	24
June	11.1	142	14.8	80	17.2	86	16.4	104
July	12.6	79	16.7	52	19.4	53	17.8	52
August	14.2	56	17.9	50	20.1	51	19.4	66
September	9.7	85	12.3	46	14.5	31	14.9	37
April–September	9.9	539	13.4	353	15.9	279	15.1	283
2005								
April	5.0	78	8.7	32	13.7	38	10.8	15
May	9.2	85	12.8	61	14.2	73	13.7	82
June	12.6	95	15.9	33	18.3	67	17.5	84
July	13.4	186	17.4	170	19.3	148	18.7	107
August	11.3	213	15.5	87	17.0	71	16.6	67
September	10.5	112	7.9	53	15.7	31	15.6	69
April–September	10.3	769	13.0	436	16.4	428	15.5	424

AA content that was described by Weber and Putz (1999), Zgórska and Frydecka-Mazurczyk (2000) and Pawelzik et al. (1999).

Effect of mineral fertilization

AA content was conclusively affected by different levels of mineral fertilization (Figure 2). A positive effect on the AA content was reported with the enhancement of potassium dose to 166 kg K/ha with a simultaneous increase of magnesium dose to 60 kg Mg/ha (variant 3). In the year 2004 it was only a tendency, but in 2005 as well as in average of both years the result was confirmative. AA content increase in variant 3 in the year 2005 was 8.7% and in average of the years 2004–2005 it was 6.2% compared to the control variant 2. The favourable effect of potassium fertilization on the AA content is in accordance with conclusions of Nowacki et al. (2000) and Mondy and Munshi (1993).

Further, it is apparent from our results (variant 4) that an enhanced level of nitrogen fertilization (180 kg N/ha) had a negative effect on the AA

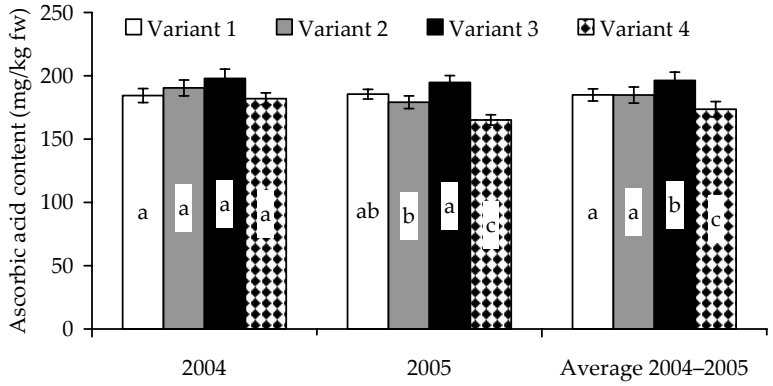

Figure 2. Effect of the level of mineral fertilization (fertilization variants) on the content of ascorbic acid (mg/kg fresh weight) in the Valečov locality; vertical lines represent SD (4 replicates), means with the same letter are not significantly different ($P \geq 0.05$)

Variant 1–4 see Material and Methods

Table 3. Effect of variety on the content of ascorbic acid (mg/kg fresh weight) in the Lípa locality

Varieties	2004		2005		Average 2004–2005	
	mg/kg fw	significance	mg/kg fw	significance	mg/kg fw	significance
Saturna	141.6	b	136.3	b	138.9	f
Magda	156.8	ab	158.6	bc	157.7	bcf
Impala	162.6	abd	163.7	bc	162.9	abc
Agria	170.8	abd	177.4	ac	174.1	ab
Asterix	177.7	acd	156.1	bc	166.9	abc
Ditta	183.7	acd	176.4	ac	180.1	ae
Karin	197.5	cd	195.1	a	196.3	de
Valfi	197.6	cd	145.3	b	151.2	cf
Marabel	211.8	c	202.6	a	207.2	d
Average of varieties	175.8		164.8		170.3	

$LSD_{0.05}$ = 35.24 (2004), $LSD_{0.05}$ = 29.54 (2005), $LSD_{0.05}$ = 21.53 (average 2004–2005); means with same letter are not significantly different ($P \geq 0.05$)

content. It decreased by 4.5% and 7.8% in 2004 and 2005, respectively, compared to the control variant, and in average of both years it was statistically significant (Figure 2). Thus the observations of majority of authors who investigated this problematic (Takebe and Yoneyama 1992, Rogozińska and Wojdyla 1996, Nowacki et al. 2000) have been confirmed.

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