Influence of Variety and Cultivation on Mineral Elements and Protein Content of Asparagus (*Asparagus officinalis* L.)

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Abstract

The aim of this research work was to study the effect of variety and cultivation region on mineral elements and protein content of white asparagus spears (*Asparagus officinalis* L.). Therefore an extended field survey was conducted in the regions of Braunschweig (Lower Saxony) and Erfurt (Thuringia). Statistically significant differences between cultivation regions were found for Ca, Mg and sulphate. Additionally, spear samples of crop performance experiments with new varieties and genotypes in Lower Saxony and Schleswig-Holstein were analyzed. For nitrate and sulphate significant differences were found between varieties in Schleswig-Holstein. In Lower Saxony, genotypical differences were determined for nitrate, sulphate, Ca, S, Fe, Zn, Mn and Cu.

INTRODUCTION

White asparagus (*Asparagus officinalis* L.) is an important vegetable crop in Germany, with a production area of about 12,000 hectare (Anon, 2002). The selection of a variety is crucial for the successful commercial production, because asparagus is a perennial crop (Nichols and Fisher 1999). The economical profit depends on the variety and differences may be as high as three times in terms of total yield and even seven times in marketable yield (Nichols and Fisher, 1999). Variety and growth conditions will, however, not only affect crop productivity, but also spear quality (Poll, 1995; Paschold et al., 1996 and Mullen et al., 1999).

Asparagus is a medicinal plant, which has a diuretic effect and is beneficial for humans with heart problems (Leung and Foster, 1996). The quality assessment of new varieties is an important part of any research program. Information on genotypical and regional differences in the content of primary and secondary compounds of asparagus is limited. It was the aim of this research work to study the influence of cultivation region and variety on quality parameters such as protein, nitrate, sulphate and the mineral composition of white asparagus in Germany.

MATERIALS AND METHODS

Experimental Design

In 2000 an extended field survey was conducted in the regions of Braunschweig (52°19.0`N; 10°29.1`E) and Erfurt (51°01.4`N; 11°02`E). Spear samples were taken simultaneously on 15 May from 24 production fields in the area of Braunschweig and 27 samples were collected in the region of Erfurt.

In 2001 spear samples of different asparagus varieties and genotypes (Ariane, Eposs, Gijnlim, Hannibal, Ramada, Ramos, Ramses, Rapid, Ravel, Stamm 12, Stamm 14, 17/24, 17/30 and 96012) were taken in crop performance trials on 11 May in Burgwedel (52° 37.4' N; 9° 50.2' E), Lower Saxony. At Wiemersdorf (53° 52.7' N; 10° 20.6' E) in Schleswig-Holstein samples from in total five varieties (Boonlim, Eposs, Gijnlim, Huchels Alpha and Thielim) were taken on 15 May. Both experiments were laid out in a completely randomized design with four repetitions in Burgwedel and three repetitions in Wiemersdorf.

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Sample Preparation

The spear samples were carefully cleaned with distilled water and cut to a length of 15 cm. Afterwards, the samples were dried at 80 °C until constancy of weight and fine-ground to a particle size < 0.12 mm employing an ultra-centrifugal mill (RETSCH ZM 1).

Chemical Analysis

The total nitrogen content was determined according to the *Kjeldahl* method. Nitrate and sulphate were extracted by de-ionized water and determined colorimetrically according to Kuecke and Schnug (1996) and Novozamsky et al. (1986), respectively. A dry ashing procedure was applied in order to determine the total content of K, Ca, P, Mg, Cu, Fe, Mn, and Zn: the dry sample material (0.5 g) was incinerated at 490 °C for 16 hours. After cooling to room temperature 10ml 2N HCl were added and afterwards the solution was completely evaporated on a hot plate. Then 10 ml 2N HCl were added and the solution quantitatively transferred into 50 ml volumetric flasks, made up to volume with de-ionized water and finally filtered (Schleicher & Schuell 593 1/2). For determination atomic absorption spectroscopy (AAS) was employed for Fe, Zn, Mn, and Cu, flame emission spectroscopy for K and Ca and colorimetry for P. S was determined by X-ray fluorescence spectroscopy according to Schnug and Haneklaus (1999).

Statistical Analysis

The analysis of variance using the General Linear Model (GLM) was performed by SPSS program version 10 (Anon, 1998).

RESULTS

Influence of the Cultivation Region on Spear Quality Parameters

Data presented in table (1) showed that regional differences in the composition of asparagus spears were significant only for Ca, Mg and sulphate. In case of Ca and Mg the mean concentration was 400 µg g^{-1} and 100 µg g^{-1}, respectively higher in the area of Braunschweig. Though, not only the soil pH of 6.9 was significantly higher in the region of Erfurt than in Braunschweig with pH 5.8, but also the plant available Mg content with 154 µg g^{-1} compared to 28 µg g^{-1} (unpublished data), the uptake of Ca and Mg of the asparagus spear was significantly lower. Whether this was related to a dilution effect because of a higher productivity in the Erfurt region remains open. In figure 1 mean nutritional values of asparagus (Souci et al., 2000; Makus, 1994) were set in relation to the measured parameters of the field survey and the experiments with different varieties.

The results reveal that the concentration of P, Ca, Fe, Zn and Cu and the protein content was distinctly lower than the corresponding nutritional values in both regions (Souci et al., 2000).

Nitrate is one of the most important non-protein N compounds, which particularly enriches in conductive plant tissue such as stems (Mills and Benton Jones, 1996). Makus (1995) reports in this connection that green asparagus spears have a lower NO_3 content than white asparagus spears. Excess N fertilization increases the nitrate content and thus diminishes crop quality. Furthermore increased N losses to the environment can be expected. Striking is that the nitrate concentrations were distinctly above the nutritional value of 1015 µg g^{-1} NO_3 which is supposed to be optimum for plant growth; maximum values were more than three times higher.

Influence of the Variety on Spear Quality Parameters

The protein content and mineral composition of the spears was similar in all varieties and differences proved to be only significant for nitrate and sulphate in Wiemersdorf, Schleswig-Holstein (Table 2). The varieties Huchels alpha and Gynlim showed the highest nitrate content (2177 µg g^{-1}) and the variety Boonlim the lowest (1237 µg g^{-1}).

Not only sulphate, but also the total S contents of the varieties Eposs and Gijnlim are significantly lower on the experimental site in Schleswig-Holstein than in Lower Saxony (Table 2 and 3). The sulphate content of the variety Eposs grown in Schleswig-Holstein was more than 70 % lower than in Lower Saxony (Table 3). On an average the S concentration of all varieties was 0.45 % S in Schleswig-Holstein and 0.59 % in Lower Saxony.

At the experimental site in Burgdorf, Lower Saxony statistically significant genotypical differences were found for S, Ca, NO_3, SO_4, Fe, Mn and Cu (Table 3), but none for protein, N, P and K. The data showed that the variety Ramos and the genotype 96012 had the lowest NO_3 content and the variety Ravel the highest SO_4 content.

The nitrate content of spears from production fields was on an average 500 µg g^{-1} higher than in the experiments with different varieties. Under controlled experimental growth conditions only the Fe and Cu concentration was lower than the nutritional value of 105 and 23.5 µg g^{-1}, respectively (Figure 1). Comparative values from other investigations are rare, because varieties differ between countries as well as growth conditions, sampling date and sample preparation.

DISCUSSION

The effect of the cultivation region on the composition of asparagus spears was significant only for Ca, Mg and sulphate. Besides different cultivation measures and soil properties, different genotypes contributed to the variation of the composition (Table 1). The influence of the variety/genotype on quality parameters of asparagus was evident (Table 2 and 3). With view to consumer demands those varieties are preferable which accumulate less nitrate (Table 2 and 3) though fertilizer practices have a strong effect on this parameter, too (Figure 1). The nitrate content on production fields was in the range of leaf vegetables such as spinach and endive (Souci et al., 2000).

The fact that the total S concentrations were significantly lower in varieties grown in Schleswig-Holstein could be related to lower S depositions in this area where severe S deficiency is a major nutrient disorder, and the fact that asparagus is usually grown on light sandy soils, which provide lower amounts of plant available S than heavier soils (Schnug and Haneklaus, 1998). Under these circumstances it can be expected that the content of S containing secondary metabolites such as glutathione will decrease, too. Asparagus is rich in glutathione with 4 mg g^{-1} (dw) compared to other vegetables such as broccoli (0.7 mg g^{-1}), spinach (0.7 mg g^{-1}) or tomato (1.9 mg g^{-1}) (Pressman, 1997). In studies with other crops it was shown that the S supply had a strong impact on the glutathione content (De Kok et al., 1981; Schnug et al., 1995). Glutathione is an anti-oxidant and supposed to play a key role in the metabolism of xenobiotics and carcino-genesis in the human body (Richie, 1992). Furthermore, S containing secondary com-pounds are known to play a major role for sensory features (Holberg et al. 1999), but so far no relationship between total S content and such metabolites could be proved.

Literature Cited

SPSS 1998. SPSS für Windows, Release 8.0.0. Online-Hilfe. Anon 2002. www.Spargelseiten.de

De Kok, L.J., Kan, J.L. de, Tanczos, O.G. and Kuiper, P.J.C. (1981): Sulphate induced accumulation of glutathione and frost-tolerance of spinach leaf tissue. Physiol. Plant. 53, 435-438

Holberg, E., Ulrich D., Standhardt D. and Kecke S. 1999. Evaluation of *Asparagus officinalis* L. flavour quality for breeding purposes. Acta Hort. 479:135-140.

Krarup, H. A. and Krarup, L.J.P. 1984. Quality parameters and chemical composition of green and white asparagus. Agro. Sur. 15(2):54-61.

Kücke, M. and Schnug, E. 1996 Advantages of nitrate determination by use of E. coli cells in different matrices. Commun. Soil Sci. Plant Anal. 27 (1996) H. 5-8:977-991.

Leung, A.Y. and Foster, S. 1996. Encyclopedia of common natural ingredients used in food, drugs and cosmetic, 2nd ed. John Wiley & Sons Inc. New York.

Makus, D.J. 1994. Mineral nutrient composition of green and white asparagus spears.

HortScience 29(12):1468-1469.
Makus, D.J. 1995. Response in green and white asparagus to supplemental nitrogen and harvest date. HortScience 30(1):55-58.
Mills, H.A. and Benton Jones, J. 1996 Plant Analysis Handbook II. MicroMacro Publ., Inc., Athens, Georgia.
Mullen, R.J., Viss, T.C. and Whitely, R.S. 1999. Asparagus cultivar evaluation trials in the Northern San Joaquin Valley of California. Acta Hort. 479:177-181.
Nichols, M.A. and Fisher, K.J. 1999. Improving the efficiency of cultivar evaluation of asparagus. Acta Hort. 479:157-161.
Novozamsky, I., Van Ech, R., Van der Lee, J.J., Houba, V.J.G. and Temminghoff, E. 1986. Determination of total sulphur and extractable sulphate in plant materials by inductivity-coupled plasma atomic emission spectrometry. Commun. Soil Sci. Plant Anal. 17:1147-1157.
Paschold, P.J., Hermann, G. and Artelt, B. 1996. Comparison of international asparagus cultivars under Rhine-Valley condition in Germany. Acta Hort. 415:257-262.
Poll, J.T.K. 1995. The influence of cultivar, plant population and location on asparagus yield and spear weight during forcing. Asparagus Research Newsletter 12(1/2):17-22.
Pressman, A.H. 1997. The GSH phenomenon: Nature’s most powerful antioxidant and healing agent: Glutathione. Marten press, New York.
Richie, J.P. 1992. The role of glutathione in aging and cancer. Experimental Gerontology 27(5-6):615-626.
Schnug, E., Haneklaus, S., Borchers, A. and Polle, A. 1995. Relations between sulphur supply and glutathione and ascorbate concentrations in *Brassica napus*. Z. Pflanzenernähr. Bodenk. 158:67-69.
Schnug, E. and Haneklaus, S. 1998. Diagnosis of sulphur nutrition. In: Schnug, E. and Beringer, H. (ed.): Sulphur in Agro-Ecosystems. Vol. 2 of the series ‘Mineral Nutrition in Ecosystems’, Kluwer Academic Publ. Dordrecht, 1-38.
Schnug, E. and Haneklaus, S. 1999. Diagnosis of the Nutritional Status and Quality Assessment of Oilseed Rape by x-ray Spectroscopy. Proc. 10th Int. Rape seed Congress Sept. 26-29, 1999, Canberra, (CD-ROM).
Souci, S.W., Fachmann, W. and Kraut, H. 2000. Food composition and nutrition tables. Medpharm, Stuttgart, Germany.

Tables

Table 1. Influence of the cultivation region on protein and mineral elemental concentrations of asparagus spears.

			Macro-nutrients (%)											
Region			**N**	**cv**	**P**	**cv**	**S**	**cv**	**K**	**cv**	**Ca**	**cv**	**Mg**	**cv**
Braunschweig			4.25 a	7.0	0.38 a	5.5	0.52 a	15.4	2.90 a	9.5	0.24 b	21.9	0.09 b	14.3
Erfurt			4.41 a	6.1	0.39 a	12.3	0.52 a	16.9	2.82 a	15.9	0.20 a	24.5	0.08 a	22.1
			Micro-nutrients											
	Protein	**cv**	**NO_3**	**cv**	**SO_4**	**cv**	**Fe**	**cv**	**Mn**	**cv**	**Zn**	**cv**	**Cu**	**cv**
	%	**%**	**$\mu g\ g^{-1}$**	**%**	**$\mu g\ g^{-1}$**	**%**	**$\mu g\ g^{-1}$**	**%**	**$\mu g\ g^{-1}$**	**%**	**$\mu g\ g^{-1}$**	**%**	**$\mu g\ g^{-1}$**	**%**
Braunschweig	26.57 a	7.0	2381 a	29.3	266 a	46.7	66.7 a	11.1	14.2 a	22.9	51.1 a	9.6	12.3 a	16.1
Erfurt	27.56 a	6.1	2277 a	26.1	337 b	24.5	59.9 a	16.7	13.5 a	18.1	52.5 a	7.0	16.6 a	16.9

Note: numbers with different characters indicate statistically different means at the 5% level (Tukey test); cv - coefficient of variation

Table 2. Genotypical differences of protein and mineral elemental concentrations in asparagus spears grown in Schleswig-Holstein.

Variety	**Protein**	**N**	**P**	**S**	**K**	**Ca**	**Mg**
	---------------------------------- % ----------------------------------						
Boonlim	30.7 a	4.92 a	0.68 a	0.45 a	4.35 a	0.39 a	0.14 a
Eposs	31.2 a	4.99 a	0.75 a	0.49 a	3.99 a	0.35 a	0.15 a
Gijnlim	29.4 a	4.70 a	0.75 a	0.42 a	4.40 a	0.35 a	0.16 a
H. Alpha	29.5 a	4.72 a	0.74 a	0.47 a	3.93 a	0.34 a	0.15 a
Thielim	28.9 a	4.63 a	0.64 a	0.43 a	4.43 a	0.39 a	0.17 a
	NO_3	**SO_4**	**Fe**	**Mn**	**Zn**	**Cu**	
	---------------------------------- $\mu g\ g^{-1}$ ----------------------------------						
Boonlim	1237 a	50 ab	60.1 a	8.2 a	56.3 a	19.4 a	
Eposs	1863 b	146 c	54.0 a	9.2 a	59.6 a	18.2 a	
Gijnlim	2177 c	83 b	54.1 a	7.3 a	56.9 a	17.8 a	
H. Alpha	2177 c	26 a	46.3 a	8.5 a	60.4 a	17.4 a	
Thielim	1566 b	23 a	47.8 a	7.3 a	52.5 a	20.7 a	

Note: numbers with different characters indicate statistically different means at the 5% level (Tukey test)

Table 3. Genotypical differences of protein and mineral elemental concentrations in asparagus spears grown in Lower Saxony.

Variety/ Genotype	**Protein**	**N**	**P**	**K**	**S**	**Ca**	**Mg**
	---------- % ----------						
Ariane	30.4 a	4.86 a	0.66 a	3.80 a	0.63 ab	0.64 ab	0.16 a
Eposs	32.8 a	5.25 a	0.78 a	4.03 a	0.62 ab	0.32 a	0.17 a
Gijnlim	30.2 a	4.83 a	0.76 a	4.21 a	0.56 ab	0.34 a	0.15 a
Hannibal	28.1 a	4.49 a	0.59 a	2.79 a	0.53 ab	1.10 bc	0.16 a
Ramad	31.7 a	5.08 a	0.67 a	3.03 a	0.64 ab	1.07 bc	0.17 a
Ramos	31.9 a	5.11 a	0.76 a	4.21 a	0.62 ab	0.33 a	0.16 a
Ramses	27.9 a	4.47 a	0.63 a	3.81 a	0.58 ab	0.59 a	0.16 a
Ranger	31.9 a	5.11 a	0.76 a	3.75 a	0.56 ab	0.32 a	0.18 a
Rapid	28.4 a	4.54 a	0.63 a	4.22 a	0.51 a	0.32 a	0.15 a
Ravel	30.2 a	4.84 a	0.68 a	4.14 a	0.61 ab	0.28 a	0.17 a
Stamm 12	30.8 a	4.93 a	0.75 a	2.76 a	0.59 ab	1.53 c	0.17 a
Stamm 14	30.0 a	4.80 a	0.65 a	3.03 a	0.60 ab	1.26 c	0.16 a
17/24	30.9 a	4.94 a	0.79 a	4.44 a	0.66 b	0.36 a	0.16 a
17/30	31.2 a	4.99 a	0.75 a	3.51 a	0.59 ab	0.29 a	0.15 a
96012	30.4 a	4.86 a	0.67 a	4.28 a	0.60 ab	0.37 a	0.14 a
	NO_3	**SO_4**	**Fe**	**Mn**	**Zn**	**Cu**	
	---------- $\mu g\ g^{-1}$ ----------						
Ariane	2067 ad	831 cd	92.3 c	21.7 c	59.7abc	7.3 ab	
Eposs	2609 d	502 ab	85.5 bc	23.4 c	60.8 abc	14.3 bd	
Gijnlim	2023 ad	715 bcd	93.4 c	17.2 ab	71.8 c	8.3 abc	
Hannibal	2477 cd	516 ab	92.5 c	20.1 bc	47.6 a	7.0 ab	
Ramad	1906 ad	692 bcd	103.2 c	22.4 c	62.5 abc	9.4 abc	
Ramos	1114 a	644 bc	107.8 c	24.4 c	67.5 bc	9.1 abc	
Ramses	1686 ad	566 abc	94.4 c	21.0 bc	55.9 ab	5.2 a	
Ranger	1627 abc	711 bcd	103.1 c	22.4 c	63.5 bc	7.1 ab	
Rapid	1598 abc	350 a	102.2 c	22.2 c	54.7 ab	11.0 abc	
Ravel	1744 ad	949 d	104.1 c	22.9 c	53.7 ab	5.6 a	
Stamm 12	2316 bcd	706 bcd	97.3 c	20.7 bc	59.0abc	5.3 a	
Stamm 14	1437 ab	552 abc	103.1 c	21.1 bc	56.0 ab	4.1 a	
17/24	1510 abc	833 cd	64.2 ab	15.8 a	69.2 bc	21.1 d	
17/30	1363 ab	688 bcd	59.5 a	13.5 a	55.9 ab	20.3 d	
96012	1305 a	657 bc	64.1ab	15.2 a	56.8abc	15.1 cd	

Note: numbers with different characters indicate statistically different means at the 5% level (Tukey test)

Figures

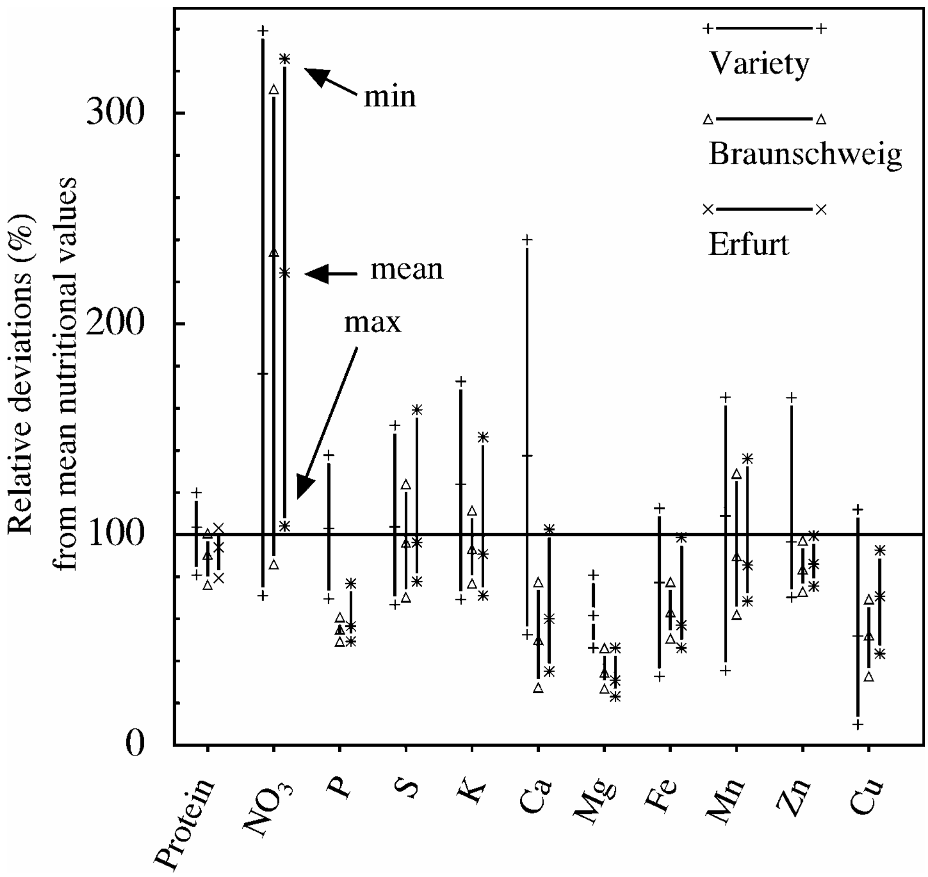

Fig. 1. Variation of quality parameters of white asparagus relatively to mean nutritional values (Souci et al., 2000; Makus, 1994) in dependence on region and variety (100 % = 29.4 % protein, 1015 µg $g^{-1}NO_3$, 0.69 % P, 0.54 % S, 3.11 % K, 0.4 % Ca, 0.07 % Mg, 105.2 µg g^{-1} Fe, 15.8 µg g^{-1} Mn, 61.1 µg g^{-1} Zn and 23.5 µg g^{-1} Cu).