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Concentrations of some chemical components in white asparagus spears depending on the cultivar and post-harvest irrigation treatments

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ABSTRACT

The effect of post-harvest irrigation and genotype on the quality components of white asparagus spears was investigated. The field experiment was conducted in 2003-2008 on a very light soil in the Bydgoszcz region. The research was based on a two-factorial split-plot design with randomly selected sub-main blocks. The first studied factor was irrigation applied as two treatments: drip irrigation and microsprinkler irrigation. Non-irrigated plants were tested as the control. The second factor considered was genotype represented by three male cultivars of the garden asparagus: 'Gijnlim', 'Ramos' and 'Vulkan'. The irrigation started after the harvest of the spears, while the concentrations of chemical ingredients were measured in the white spears collected in the next growing period. The level of the tested components was significantly influenced by both factors studied. The average amounts of dry matter, potassium, iron and nitrates measured in the white spears were 6.37%, 268.9 mg 100 g^{-1} f.m., 0.29 mg 100 g^{-1} f.m. and 62.1 mg kg^{-1} f.m., respectively. Compared to the control, both irrigation treatments considerably increased the dry matter and potassium contents. The irrigation reduced the amount of nitrates, although the microsprinkler irrigation gave better results than the drip irrigation. The highest concentrations of potassium and iron were measured in the spears of 'Ramos', especially in the case of drip-irrigated (potassium) and non-irrigated (iron) plants. The amount of dry matter was high in the spears of 'Ramos', while 'Vulkan' presented a low tendency to accumulate nitrates.

Keywords: *Asparagus officinalis*, drip irrigation, dry matter, iron, microsprinkler irrigation, nitrates, potassium

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INTRODUCTION

Garden asparagus (*Asparagus officinalis* L.) is a vegetable appreciated due to its unique flavour, low calorific value and also the high amounts of nutrients and minerals (Moreno-Rojas et al., 1992; Anastasios, 2004; Knaflewski, 2005). Asparagus is a dicotyledonous, perennial, herbaceous species of the Asparagus family. The root system of asparagus plants, called the crown, consists of fleshy and fibrous roots. The fleshy roots are responsible for the absorption and storage of nutrients. In turn, the fibrous roots, whose only function is the uptake of nutrients, are produced by the fleshy roots each spring and die in the autumn. During the spring, the buds located in the upper part of the crown form young shoots, called spears, which are the edible parts of the asparagus plant. White asparagus spears are grown in ridges covered with soil, without exposure to sunlight (Knaflewski, 2005; Orłowski et al., 2008).

Asparagus plants are relatively resistant to a water deficit during the growing of assimilation shoots. However, a long-term drought may adversely affect the quality and yield of spears (Knaflewski, 2000; Podymiak, 2005; Stępka, 2005; Orłowski et al., 2008). Light soils, which dry and warm up quickly in the spring, are suitable for growing white asparagus spears because they facilitate the formation of soil ridges and the harvesting of spears. However, on very light soils a deficit of the capillary water is observed, so rainfall is there the only source of water for the plants. Therefore, irrigation of asparagus cultivated on a light soil increases the yield of spears, which improves the profitability of the production of this vegetable. For asparagus watering, the drip irrigation technique is one of the most effective because the water is supplied directly to the root system, which limits water loss due to evaporation from the soil surface (Rolbiecki and Rolbiecki, 2008; Rolbiecki and Rolbiecki, 2012; Rolbiecki, 2013).

The aim of the research was to investigate the effect of drip irrigation and microsprinkler irrigation of asparagus plants performed during a post-harvest period on the amounts of dry matter and minerals, such as potassium and iron, as well as nitrates in white spears collected in the next growing period. Three male cultivars of asparagus: 'Gijnlim', 'Ramos' and 'Vulkan', grown on a light soil, were studied.

MATERIAL AND METHODS

The field study was conducted in Kruszyn Krajeński near Bydgoszcz (53°04'53″ N, 17°51'52″ E) in the years 2003-2008. The experiment was carried out on a light soil of quality class V-VI according to the adopted soil classification (black degraded soil classified as a weak rye complex and a very weak rye complex). The water content in the upper layer of the soil (0-50 cm) was only 57.5 mm, while the effective water retention capacity was 29.3 mm.

The two-factorial experiment was designed as a split-plot arrangement that included randomized sub-blocks. The first factor was irrigation applied as two treatments, i.e. drip irrigation and microsprinkler irrigation. Non-irrigated plants were studied as the control. The second factor was genotype, under which three male cultivars 'Gijnlim', 'Ramos' and 'Vulkan' of garden asparagus (*Asparagus officinalis* L.) were tested. The plants were cultivated in order to harvest white spears. The irrigation treatments were performed during a post-harvest period, whereas the amounts of chemical components were measured in the white spears collected during the next growing period.

Table 1. Mean monthly air temperature (°C) during the 2003-2008 growing periods in relation to the long term average for 1981-2010

Years	Months						Mean for
	IV	V	VI	VII	VIII	IX	IV-IX
Mean for 1981-2010	7.8	13.3	16.1	18.6	17.9	13.1	14.5
2003	6.4	14.4	17.6	19.2	18.4	13.6	14.9
2004	7.5	11.3	14.7	16.4	17.9	12.7	14.0
2005	7.4	12.2	14.9	19.4	16.3	14.8	14.2
2006	7.1	12.5	16.8	22.4	16.6	15.2	15.1
2007	8.5	13.8	18.2	18.0	17.8	12.4	14.8
2008	7.6	13.2	17.6	19.2	17.8	12.4	14.6
Mean for 2003-2008	7.4	12.9	16.6	19.1	17.5	13.6	14.6
Difference	-0.4	-0.4	+0.5	+0.5	-0.4	+0.5	+0.1

Table 2. Total precipitation (mm) during the 2003-2008 growing periods in relation to the long term average for 1981-2010

Years	Months						Total for
	IV	V	VI	VII	VIII	IX	IV-IX
Mean for 1981-2010	27	39	54	65	53	44	282
2003	13	12	34	90	18	11	178
2004	12	44	36	43	86	25	245
2005	25	70	31	40	21	18	203
2006	45	64	22	31	115	42	317
2007	8	49	103	112	60	36	367
2008	25	3	32	47	82	26	215
Mean for 2003-2008	21	40	43	60	64	26	254
Difference	-6	1	-11	-5	11	-18	-28

The experiment was performed in four replications; each included 36 plots. The area of each plot was 14.5 m^2. The plants of asparagus were planted in rows spaced 1.8 m apart. Each row contained 23 plants; the distance between the plants was 0.35 m. The plots with different irrigation treatments were separated by additional rows of asparagus plants.

The surface watering of assimilation shoots (post-harvest irrigation) was carried out using a drip line of the 'T-Tape' type, where the distance between the drippers was 20 cm and the output of water was about 5 dm^3 m^{-1}. The microsprinkler irrigation was performed using mini-sprayers of the 'Hadar' type produced in Israel, with a working pressure of 1 bar, and the output was about 50-60 dm^3 h^{-1}. The start of irrigation was determined, according to the guidelines of the Institute in Geisenheim (Germany), by the soil water potential measured with a tensiometer (Paschold and Weithaler, 2000). The irrigation treatments started after the harvest of white spears (around 20 June) and finished at the end of August, as recommended by Hartmann (1981) and Paschold et al. (2002). During the post-harvest period, the assimilation shoots of asparagus plants grow intensively and the plants accumulate nutrients (Knaflewski, 2005).

The highest doses of the water supplied to the asparagus plants, 128 and 163 mm using drip irrigation, and 155 and 195 mm using microsprinkler irrigation, were in the years 2003 and 2005, respectively; the atmospheric precipitation was then the lowest. The mean doses of the water supplied to the plants in the years 2003-2008 were 116 and 154 mm when the drip irrigation and microsprinkler irrigation, respectively, were performed.

The mean air temperature during the growing period in the years 2003-2008 (14.6°C) was close to the long-term average for the years 1981-2010 (14.5°C) (Tab. 1). The lowest mean air temperature during the growing period (14.0°C) was recorded in 2004, while the highest in 2005 (15.1°C). The mean air temperature measured in the years 2003-2008 in June, July and September was higher by 0.5°C, while in April, May and August – lower by 0.4°C, compared to the long-term average for the corresponding months of the years 1981-2010. The average total rainfall during the growing period in the years 2003-2008 (254 mm) was lower by 28 mm than the long-term average for 1981-2010 (282 mm) (Tab. 2). The lowest total rainfall in the period between April and September was in 2003 – 178 mm, which was only 63% of the average total precipitation for the years 1981-2010. The highest amount of rainfall during the growing period was in 2007 – 367 mm, which was 130% of the average total precipitation for the years 1981-2010.

The fertilization treatments were adjusted to the results of soil analysis. The phosphorus and potassium fertilization supplemented the amounts of these minerals to the level of 100-120 kg P_2O_5 ha^{-1} and 200-250 kg K_2O ha^{-1}. The nitrogen fertilization (120 kg N ha^{-1}) was applied in three doses of 40 kg N ha^{-1}. The fertilizers used in the study were ammonium sulphate (34%), potassium salt (55%) and granulated triple superphosphate (46%).

Total dry matter, potassium, iron and nitrates were measured in white asparagus spears. The analysis of quality traits were based on representative samples of 10 spears chosen randomly from different plants from each replication. The total dry matter content of the asparagus spears was determined using the drying technique according to the methodology

of the Association of Official Analytical Chemists (AOAC, 2002). The level of potassium was analyzed by Atomic Absorption Spectrometry (Welz and Sperlin, 1999). The amount of iron was measured by the colorimetric method using a UV-VIS Metertech SP-8001 spectrophotometer (Adams, 1995). The nitrate content was determined by the ionoselective method using the CX-731-Elmetron equipment according to PN-C-04576-10:1986.

The results were subjected to general analysis of variance. Statistical analysis was carried out using two-factor variance analysis (ANOVA) with the software STATISTICA (version 12.5). The synthesis of multiple experiments was performed in the mixed error model. Significant differences between the means of the tested characteristics were determined with Tukey's test at a significance level of $p = 0.05$.

RESULTS

The dry matter content measured in the white asparagus spears was significantly dependent on both the irrigation and the genotype (Tab. 3). The level of dry matter in the spears collected from the drip-irrigated plants was much higher than in the case of the non-irrigated control. However, the amounts of dry matter in the spears of microsprinkler-irrigated and control plants were similar. The cultivars 'Ramos' and 'Vulkan' presented a comparable level of dry matter, 6.63 and 6.42%, respectively, while in the spears of 'Gijnlim' the level of dry matter (6.04%) was considerably lower than in the spears of 'Ramos'.

The potassium content estimated in the white asparagus spears was significantly influenced by the irrigation treatments as well as the cultivars (Tab. 4). The highest level of this chemical element was contained in the spears of 'Ramos'. In the cultivars 'Gijnlim' and 'Vulkan' similar amounts of potassium were measured. The drip irrigation treatment was the most beneficial for the level of potassium accumulation. However, in the spears of the control and microsprinkler-irrigated plants comparable amounts of potassium were found. The evaluation of the interactions between the studied factors indicated that drip irrigation increased the level of potassium, especially in the cultivar 'Ramos'.

The asparagus cultivars studied in the experiment significantly differed in terms of the iron content in the white spears (Tab. 5). The highest amount of this chemical element was measured in the

Table 3. Total dry matter content (%) in white asparagus spears

Treatment	Cultivar	Year of study						Mean for 2003-2008
		2003	2004	2005	2006	2007	2008	
Without irrigation (control)	Gijnlim	5.91	5.72	5.91	5.62	6.22	5.64	5.84
	Ramos	7.86	6.41	5.81	5.42	6.35	5.92	6.29
	Vulkan	6.40	6.32	6.04	6.31	6.97	6.28	6.34
	Mean	6.72	6.15	5.92	5.78	6.51	5.95	6.16
Drip irrigation	Gijnlim	6.02	5.98	6.33	6.22	6.10	6.78	6.24
	Ramos	6.97	6.94	6.21	6.33	7.01	6.91	7.23
	Vulkan	6.41	6.42	6.51	6.62	6.84	6.72	6.59
	Mean	6.47	6.45	6.35	6.39	6.65	6.80	6.69
Microsprinkler irrigation	Gijnlim	6.30	5.80	6.05	5.91	6.21	5.96	6.04
	Ramos	6.07	6.71	6.31	6.32	6.54	6.34	6.38
	Vulkan	6.09	6.33	6.42	6.21	6.47	6.52	6.34
	Mean	6.15	6.28	6.26	6.15	6.41	6.27	6.25
Mean	Gijnlim	6.08	5.83	6.10	5.92	6.18	6.13	6.04
	Ramos	6.97	6.69	6.11	6.02	6.63	6.39	6.63
	Vulkan	6.30	6.36	6.32	6.38	6.76	6.51	6.42
	Mean	6.45	6.29	6.18	6.11	6.52	6.34	6.37
$LSD_{0.05}$								
Irrigation (I)								0.49
Cultivar (II)								0.48
Interaction (I × II)								ns
Interaction (II × I)								ns

LSD – least significant difference (Tukey's confidence half-interval) at $p < 0.05$; ns – not significant at $p < 0.05$

Table 4. Potassium content (mg 100 g^{-1} f.m.) in white asparagus spears

Treatment	Cultivar	Year of study						Mean for 2003-2008
		2003	2004	2005	2006	2007	2008	
Without irrigation (control)	Gijnlim	240.0	220.0	240.0	210.0	230.0	220.0	230.0
	Ramos	310.0	320.0	270.0	280.0	300.0	260.0	290.0
	Vulkan	250.0	250.0	260.0	240.0	250.0	230.0	250.0
	Mean	266.7	263.3	256.7	243.3	260.0	236.7	256.7
Drip irrigation	Gijnlim	250.0	260.0	290.0	280.0	310.0	270.0	280.0
	Ramos	280.0	290.0	310.0	320.0	330.0	300.0	310.0
	Vulkan	260.0	300.0	290.0	300.0	310.0	280.0	290.0
	Mean	263.3	283.3	296.7	300.0	316.7	283.3	293.3
Microsprinkler irrigation	Gijnlim	260.0	240.0	280.0	270.0	250.0	230.0	260.0
	Ramos	270.0	250.0	260.0	290.0	270.0	240.0	260.0
	Vulkan	240.0	250.0	270.0	250.0	260.0	250.0	250.0
	Mean	256.7	246.7	270.0	270.0	260.0	240.0	256.7
Mean	Gijnlim	250.0	240.0	270.0	253.3	263.3	240.0	256.7
	Ramos	286.7	286.7	280.0	296.7	300.0	266.7	286.7
	Vulkan	250.0	266.7	273.3	263.3	273.3	253.3	263.3
	Mean	262.2	264.4	274.4	271.1	278.9	253.3	268.9
$LSD_{0.05}$								
Irrigation (I)								21.0
Cultivar (II)								10.0
Interaction (I × II)								17.0
Interaction (II × I)								25.0

Explanations: see Table 3

Table 5. Iron content (mg 100 g^{-1} f.m.) in white asparagus spears

Treatment	Cultivar	Year of study						Mean for 2003-2008
		2003	2004	2005	2006	2007	2008	
Without irrigation (control)	Gijnlim	0.35	0.18	0.19	0.21	0.22	0.30	0.24
	Ramos	0.49	0.29	0.24	0.55	0.33	0.34	0.37
	Vulkan	0.34	0.26	0.23	0.24	0.25	0.30	0.27
	Mean	0.40	0.24	0.22	0.33	0.27	0.31	0.30
Drip irrigation	Gijnlim	0.41	0.23	0.27	0.29	0.37	0.38	0.32
	Ramos	0.42	0.26	0.26	0.28	0.28	0.31	0.30
	Vulkan	0.35	0.18	0.24	0.26	0.34	0.30	0.26
	Mean	0.39	0.22	0.26	0.28	0.33	0.33	0.30
Microsprinkler irrigation	Gijnlim	0.31	0.19	0.22	0.27	0.27	0.32	0.26
	Ramos	0.32	0.20	0.29	0.28	0.26	0.29	0.27
	Vulkan	0.33	0.21	0.26	0.26	0.31	0.29	0.28
	Mean	0.32	0.20	0.26	0.27	0.28	0.30	0.27
Mean	Gijnlim	0.36	0.20	0.23	0.26	0.29	0.33	0.28
	Ramos	0.41	0.25	0.26	0.37	0.29	0.31	0.32
	Vulkan	0.34	0.22	0.24	0.26	0.30	0.30	0.27
	Mean	0.37	0.22	0.25	0.29	0.29	0.31	0.29
$LSD_{0.05}$								
Irrigation (I)								ns
Cultivar (II)								0.04
Interaction (I × II)								0.07
Interaction (II × I)								0.07

Explanations: see Table 3

Table 6. Nitrate content (mg kg^{-1} f.m.) in white asparagus spears

Treatment	Cultivar	Year of study						Mean for 2003-2008
		2003	2004	2005	2006	2007	2008	
Without irrigation (control)	Gijnlim	69.50	63.00	68.20	71.40	78.50	67.40	69.67
	Ramos	78.30	71.50	73.50	73.10	74.20	75.80	74.40
	Vulkan	65.90	60.30	62.60	68.40	79.10	61.90	66.37
	Mean	71.23	64.93	68.10	70.97	77.27	68.37	70.14
Drip irrigation	Gijnlim	67.10	63.00	52.10	55.20	64.70	58.30	60.07
	Ramos	68.30	58.60	63.20	63.40	67.60	55.40	62.75
	Vulkan	62.20	63.00	56.20	59.60	59.40	57.20	59.60
	Mean	65.87	61.53	57.17	59.40	63.90	56.97	60.81
Microsprinkler irrigation	Gijnlim	65.90	64.20	51.10	51.10	56.20	58.40	57.82
	Ramos	63.40	53.10	60.40	55.80	57.70	56.10	57.75
	Vulkan	61.00	38.00	55.50	56.70	42.80	48.90	50.48
	Mean	63.43	51.77	55.67	54.53	52.23	54.47	55.35
Mean	Gijnlim	67.50	63.40	57.13	59.23	66.47	61.37	62.52
	Ramos	70.00	61.07	65.70	64.10	66.50	62.43	64.97
	Vulkan	63.03	53.77	58.10	61.57	60.43	56.00	58.82
	Mean	66.84	59.41	60.31	61.63	64.47	59.94	62.10
$LSD_{0.05}$								
Irrigation (I)								5.29
Cultivar (II)								3.86
Interaction (I × II)								ns
Interaction (II × I)								ns

Explanations: see Table 3

cultivar 'Ramos'. The amount of iron detected in the cultivars 'Gijnlim' and 'Vulkan' was on the same level. However, a strong influence of drip irrigation on iron accumulation was noted in 'Gijnlim', where a significant interaction was observed.

Both factors studied in the experiment affected the level of nitrates (Tab. 6). The cultivar 'Vulkan' accumulated a noticeably smaller amount of nitrates than 'Ramos'. In turn, the spears of 'Gijnlim' and 'Ramos' contained similar amounts of nitrates. Both irrigation treatments significantly reduced the amounts of nitrates in white asparagus spears; consequently, the highest level of these compounds was detected in the spears of the non-irrigated control plants.

DISCUSSION

The beneficial effect of post-harvest irrigation on the growth of asparagus assimilation shoots and consequently on the yield of the spears in the next growing period had been reported by Kaufmann (1977), Bussell (1985), Hartmann (1985), Jerez (1990), Kaufmann (1990), Ferreyra et al. (1995) and Paschold et al. (1999). Based on a field experiment, in which 31 cultivars of asparagus were studied, Rolbiecki and Rolbiecki (2008) had found a significant influence of drip irrigation on the biometric characteristics of assimilation shoots and on the yield of spears in the next growing period. Also, in a study presented by Rolbiecki (2013), a significant influence of irrigation on the yielding of asparagus plants grown on a very light soil had been observed. The results of the current study showed a positive effect of post-harvest irrigation of asparagus plants on the quality compounds in white spears. The drip irrigation of the tested cultivars, grown on a light soil in the region of Bydgoszcz, notably increased the amounts of dry matter and potassium, as well as decreased the level of nitrates. The high irrigation requirements of plants grown in the Bydgoszcz region had previously been published by Rolbiecki et al. (2007), Rolbiecki and Rolbiecki (2007), Rzekanowski et al. (2007), Stachowski and Markiewicz (2011), Żarski et al. (2013).

Asparagus spears are considered a rich source of nutrients, including minerals (Kunachowicz et al., 2005). However, Moreno-Rojas et al. (1992) had observed a reduction in the concentration of minerals along with a decrease in the diameter of spears, especially when it was smaller than 9 mm. Moreover, significant differences in the

amounts of mineral components depending on the part of the plant were observed; the highest amounts of minerals were in the tips of the spears. The relationship between the amount of mineral components and the analyzed fragment of the spear was also reported by López et al. (1996).

The growing conditions of asparagus plants notably affect the mineral content of the spears; green spears, resulting from cultivation without cover, contain higher amounts of N, K, P, S, Na and Zn, but similar levels of Fe, Al, Cu, as compared to white spears grown in the dark, or blanched. Also the method of cultivating asparagus influences the chemical composition of the spears. The greenhouse growing of asparagus, where plastic or sawdust is used as the building material for the ridges, improves the accumulation of minerals in the fleshy roots. Higher amounts of minerals in white spears of asparagus grown in the greenhouse, compared to traditional cultivation, had been reported by Makus (1994).

In the present study, the levels of potassium and iron were 268.9 and 0.29 mg 100 g^{-1} f.w., respectively. On the other hand, Xiong et al. (2005) had observed higher amounts of potassium and iron, 300 and 0.7 mg 100 g^{-1} f.w., respectively. However, currently, only the edible white asparagus spears were tested, while Xiong et al. (2005) had analyzed whole green plants. According to the Regulation (EU) No. 1169/2011, the recommended daily doses of potassium and iron are 2000 and 14 mg, respectively. Consequently, the consumption of 300 g of asparagus spears covers 40.4% and 6.2% of the daily potassium and iron requirements for adults, respectively.

The main sources of harmful nitrates in food consumption are vegetables (Wichrowska, 2007; Pobereżny et al., 2015). According to the recommendations of the FAO/WHO Expert Committee on Food Additives (JECFA 2002), the daily intake of nitrates by an adult should not exceed 3.7 mg per kg of body weight, that is, 260 mg of nitrates a day for a man with a weight of 70 kg. Asparagus is a vegetable that generally accumulates a low amount of nitrates in the edible spears. Additionally, the irrigation treatments applied in the current experiment significantly reduced the amounts of these chemical compounds by 13% in the drip-irrigated plants and by 21% in the microsprinkler-irrigated ones, as compared to the non-irrigated control. The significant reduction in the nitrate level in vegetable crops as a result of irrigation had already been reported by Rolbiecki et al. (2000).

CONCLUSIONS

1. Drip irrigation of asparagus plants notably increased the amounts of dry matter and potassium in blanched spears.
2. In the white spears of 'Ramos' and 'Vulkan', a high level of dry matter was observed, but 'Gijnlim' contained a significantly lower amount of this nutritional ingredient than 'Ramos'.
3. The highest levels of potassium and iron were measured in the white spears of 'Ramos'. Drip irrigation increased the level of potassium in the spears of 'Ramos' and the level of iron in those of 'Gijnlim'.
4. The irrigation treatments significantly reduced the amounts of nitrates in white asparagus spears. 'Vulkan' presented a much lower tendency to accumulate nitrates than 'Ramos'.

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