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YIELDING OF WHITE AND GREEN ASPARAGUS IN THE OPEN FIELD AND IN THE TUNNEL IN THE FIRST TWO YEARS OF HARVEST

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Abstract. Asparagus (*Asparagus officinalis* L.) may be cultivated either for white or for green spears, the latter method started to prevail in the world in the last years. The aim of the study was a comparison of yielding of white and green asparagus *cv.* 'Ravel' in the open field and in the PE tunnel. The weight, number and diameter of spears in the total, marketable and non-marketable yields in the first and second harvest year were assessed. Total and marketable yield of white asparagus was higher than that of green one, but the latter formed significantly more spears in the total and nonmarketable yield. The yield and number of spears obtained in the tunnel was significantly higher than with no cover. Marketable spears constituted on average 77.8% of yield weight and 63.0% of the total number of spears and the values for both cultivation methods were similar. Mean weight and diameter of white spears were higher than those of the green ones.

Key words: *Asparagus officinalis* L., white spears, green spears, weight, diameter, PE foil

INTRODUCTION

Asparagus (*Asparagus officinalis* L.) is a perennial vegetable with edible young shoots, called 'spears'. They are much appreciated for a unique taste and flavour, as well as high content of antioxidants and other health promoting agents. Spears may be white or green in colour. Some purple cultivars have also been introduced recently. White spears are grown in the dark, usually covered with sandy ridges; green and purple shoots are exposed to sunlight. Green asparagus started to dominate in the world in recent years, mainly due to its greatest producers China and Peru [Benson 2012]. Cultivation of green asparagus is less laborious. Green spears are more tender – do not require peeling, and contain more vitamins than the white ones. These assets of green asparagus were the main reason of its increasing popularity in the world. In Poland white asparagus prevails. The relatively low consumption grows steadily, especially in

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the western part of the country, where the crop is mostly cultivated [Knaflewski 2005, Benson 2008]. Asparagus is grown predominantly in the open field. Ridges often are covered with PE foil. Sometimes PE tunnels are used in order to obtain earlier and higher yields [Poll 1990, Makus and Gonzales 1991, Adam 2000, Ziegler 2005, anon. 2008, 2011, Benson 2008, 2012, Cermeño et al. 2008, Chinn 2012]. So far very few studies compared the two cultivation methods. Most works focused on one method – either for white or for green spears.

The aim of the study was to compare yielding of white and green asparagus cultivated in the open field and in a PE tunnel in the first and second year of harvest.

MATERIAL AND METHODS

The experiment was conducted in the Felin Experimental Farm of University of Life Sciences in Lublin (N 51º13', E 22º38') on a medium heavy grey-brown podzolic soil of loess origin, formed of a medium silty loam. Asparagus plants of 'Ravel' *cv*. were cultivated without covers and in a PE (UV-4, three – layer film, 0.185 mm thick) high tunnel (7 m width × 4 m height × 26 m length). The transplants were planted in 2008, in the distance of 30 × 200 cm, 15 plants per plot of 9 m^2 each. On the plots with white asparagus prior to the formation of ridges the soil in the interrows was mixed by a rotary tiller with sand and peat (40 kg and 90 l per 1 m^2 respectively). Ridges 30 cm high were formed as soon as the heads of first spears became visible on the soil surface – in the field on 5 April in 2011 and 2012, and about 2 weeks earlier in the tunnel. The harvests in the open field lasted from 22 April to 16 May in 2011 and to 19 June in 2012, and in the tunnel from 14 April till 6 May in 2011 and from 5 April to 19 June in 2012. Marketable spears at least 18 cm long were harvested, as well as all non-marketable ones – with loose heads, deformed, too thin (less than 8 mm in diameter) or damaged. Standard fertilization and crop protection practices were followed. The content of the main mineral elements in the soil was in the range of the optimum for asparagus (K – 200–220, P – 100–120, Mg – 90–100 $mg \cdot dm^{-3}$. Surface drip irrigation was applied in the tunnel, it was turned on when soil water potential reached -50 kPa. The experiment was set as a completely randomized blocks design in two replicates.

Table 1. Mean temperatures (ºC) in the open field and in the tunnel in the spring of 2011 and 2012 and multiyear averages (1951–2005)

Year	Month	Open field 10 days averages			Month averages	Multiyear month averages	Tunnel 10 days averages		
		I	II	III			I	II	III
2011	March	-2.6	4.3	5.2	2.4	1.1			
	April	9.1	8.1	13.6	10.2	7.4		15.7	23.7
	May	8.8	15.8	17.9	14.3	13.0	13.4		
2012	March	-0.1	5.7	7.2	4.4	1.1			
	April	3.8	9.0	15.7	9.5	7.4		16.2	25.1
	May	16.1	12.4	16.6	15.0	13.0	28.3	19.7	28.8
	June	14.7	18.5	18.6	17.3	16.2	25.4	30.8	31.0

The results were analyzed with ANOVA for a three factorial design, where factor A was method of cultivation (ridges – white spears, no ridges – green spears), B – place of cultivation (open field, tunnel), C – harvest year. The significance of differences was established by the Tukey test at $\alpha = 0{,}05$. The number and weight of spears in the total, marketable and non-marketable yield, as well as mean weight and diameter of marketable spears relative to the method and place of culture were compared.

The weather conditions at the start of plants' vegetation in both years favoured the early growth of the spears. The mean temperatures in March and April were higher than multiyear averages by 118 and 38% respectively in 2011 and by 300 and 28% in 2012 (tab. 1). The rainfall levels in April and May 2011 were lower than multiyear averages by about 30 and by 15% in April 2012.

RESULTS AND DISCUSSION

The yields of white spears were higher than those of green ones (tab. 2, fig. 1). Total and marketable yield of white asparagus amounted to 12.23 and 9.33 t·ha^{-1} respectively, and of green asparagus 9.49 and 7.11 t·ha^{-1}. According to Knaflewski [1990, 1994] yield and weight of green asparagus spears are usually lower than those of white. Makus [1995] obtained higher yields of white spears, but Cermeño et al. [2008] of green ones. Jishi and Tanaka [2009] stated no difference between the two cultivation methods in regard of yield level. In the study of Cermeño et al. [2008] marketable yield of green spears of *cv.* 'Ravel' was 15 t·ha^{-1}, and of white spears only 8 t·ha^{-1}. In the study of Kałużewicz et al. [2010] the yields of this cultivar approached those of 'Gijnlim', which was the most productive of the tested cultivars. The mean total yield of four years was

Table 2. Total, marketable and non-marketable yield of green and white spears of asparagus in the tunnel and in the open field in 2011–2012

Method place ofcultivation		Yield (t· ha^{-1})								
		total			marketable			non-marketable		
		2011	2012	mean	2011	2012	mean	2011	2012	mean
No ridges	field	2.54	11.84	7.19bc	1.89	8.34	5.11bc	0.65	3.50	2.07a
	tunnel	7.08	16.49	11.78 ab	6.15	12.05	9.10ab	0.92	4.44	2.68a
Ridges	field	4.70	14.07	9.38bc	4.11	8.45	6.28bc	0.59	5.62	3.10a
	tunnel	8.75	21.42	15.08 a	8.06	16.70	12.38a	0.68	4.71	2.70a
Mean	no ridges	4.81b*	14.17a	9.49b	4.02c	10.20ab	7.11b	0.79b	3.97a	2.38a
	ridges	6.73b	17.75a	12.23a	6.09bc	12.58a	9.33a	0.63b	5.17a	2.90a
Mean	field	3.62c	12.96b	8.29 b	3.00c	8.39b	5.69b	0.62b	4.56a	2.59a
	tunnel	7.91c	18.95a	13.43 a	7.11bc	14.38a	10.74a	0.80b	4.57a	2.69a

*Means in the column followed by the same letter do not significantly differ at $p < 0.05$

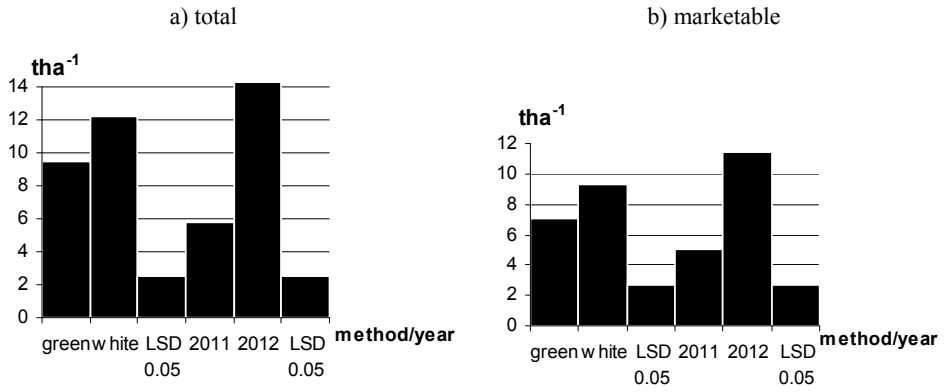

Fig. 1. Total and marketable yield of green and white spears (mean for 2011–2012) and in the first and second harvest year irrespective of place of cultivation (t·ha^{-1})

9.2 t·ha^{-1}, and marketable yield 8 t·ha^{-1}. In the international asparagus cultivars trials (IACT) the yield of 'Ravel' white spears in the first year (two years after planting) was 1.1 t ha^{-1} in Spain [Cermeño 2005] and 2.6 t·ha^{-1} in Poland, where in the second year it increased to 4.5 t·ha^{-1} [Rolbiecki 2008]. In case of harvests one year after planting the yield in Holland was 3.6 t·ha^{-1} [Mulder 2005, Mulder and Larvijsen 2008] and 2.8 t·ha^{-1} in Germany [Paschold et al. 2008] and 10.6 and 6.3 t·ha^{-1} respectively in the second year.

The yields in the tunnel irrespective of cultivation method amounted to 13.43 t·ha^{-1} (total) and 10.74 t·ha^{-1} (marketable) and were significantly higher (by 62% – total and by 89% – marketable) than those in the open field (tab. 2). The yield of white spears (15.08 t·ha^{-1}) in the tunnel was higher than that of green ones (11.78 t·ha^{-1}) but the difference was not statistically significant. In the study of Fanasca et al. [2009] marketable yield under cover at high density of the plants (41600 per ha) for different cultivars ranged from 22.88 to 31.62 t·ha-1. However in another Italian experiment [Caruso et al. 2012] the yield amounted to 115 t·ha-1. Higher and earlier yields in the tunnel than in the open field were stated by Vakis et al. [1975] and Ragab [2003], only slightly higher by Poll [1990], not differing by Knaflewski et al. [1999] and lower by Duranti et al. [2001]. Yielding in the tunnel started about 7–10 days earlier than in the open field. Poll [1990] reported 6 days earlier start of the harvest in the tunnel, Knaflewski et al. [1999], Ziegler [2005], Cermeño et al. [2008] by 16–21 days – in case of green spears, and by 5 days in case of white.

Method of cultivation affected the number of spears in the total, but not in the marketable yield (tab. 3 and 4). From a single plant 35.9 white or 43.8 green spears (mean 663 000 per ha) were collected, of which 55.9% (370 400 per ha) were marketable. In the study of Cermeño et al. [2008] fewer spears per plant of *cv.* 'Ravel' were collected, and green spears were also more numerous (25 per plant) than white ones (16 per plant). However in case of other cultivars more white spears were formed. In the experiment of Jishi and Tanaka [2009] the number of green marketable spears was higher than that of the white ones. Method of cultivation affected significantly the number of non-marketable spears. Green spears were more numerous (21.6 per plant and 360 200 per ha) than white (13.5 per plant and 225 900 per ha).

Table 3. Number per plant of white and green asparagus spears in total, marketable and non-marketable yield in the tunnel and in the open field in 2011–2012

Method place of cultivation		Total yield			Marketable yield			Non marketable yield		
		2011	2012	mean	2011	2012	mean	2011	2012	mean
No ridges	field	12.5	58.0	35.3c	7.9	26.4	17.1bc	4.6	31.6	18.1ab
	tunnel	23.5	81.3	52.4a	18.0	36.4	27.2a	5.4	44.9	25.2a
Ridges	field	12.6	50.4	31.5c	9.3	28.0	18.7b	3.3	22.4	12.8b
	tunnel	19.0	61.5	40.3b	16.3	35.6	26.0ab	2.7	25.9	14.3b
Mean	no ridges	18.0	69.7	43.8a	13.0	31.4	22.2a	5.0	38.2	21.6a
	ridges	15.8	56.0	35.9b	12.8	36.0	22.33a	3.0	24.2	13.6b
Mean	field	12.6	54.2	33.4b	8.6	27.2	17.9b	3.9	27.0	15.4b
	tunnel	21.3	71.4	46.4a	17.2	36.0	26.6a	4.0	35.4	19.7a

Table 4. Number per m^2 of green and white spears in total marketable and non-marketable yield in the tunnel and in the open field in 2011–2012

Method place of cultivation		Total yield			Marketable yield			Non-marketable yield		
		2011	2012	mean	2011	2012	mean	2011	2012	mean
No ridges	field	20.8	96.6	58.7b	13.2	44.0	28.6c	7.6	52.6	30.1ab
	tunnel	39.1	135.5	87.3a	30.1	60.7	45.4a	9.1	74.8	41.9a
Ridges	field	20.9	84.1	52.5a	15.5	46.7	31.1bc	5.4	37.3	21.4b
	tunnel	31.7	102.5	67.1a	27.2	59.4	43.3ab	4.4	43.1	23.8b
Mean	no ridges	30.0c	116.0a	73.0a	21.6b	52.3a	37.0a	8.3c	63.7a	36.0a
	ridges	26.3c	93.3b	59.8b	21.4b	53.1a	37.2a	4.9c	40.2b	22.6b
Mean	field	20.9c	90.3b	55.6b	14.6d	45.3b	29.8b	6.5b	45.0a	25.7b
	tunnel	35.4c	119.0a	77.2a	28.6c	60.0a	44.3a	6.7b	59.0a	32.9a

Marketable spears constituted 77.8% of the total yield and the shares were similar for both cultivation methods (tab. 5). Also in the study of Cermeño [2005], this share did not differ, however for 'Ravel' *cv.* it was even higher – 83% in the first year. Kałużewicz et al. [2010] obtained for this cultivar 87% of marketable yield in four years of harvesting. According to Knaflewski [1994] nonmarketable yield of green spears is much higher than of white, due to the tendency of loosening the green spears' heads. In the studies concerning green asparagus of 'Gijnlim' *cv*. this share varied from 7.7 to 54.5% [Knaflewski et al. 1998, 2000, 2001, 2008, Nichols and Fisher 1999, Jinsong 2002, Knaflewski and Krzesiński 2002, Krarup and Contreras 2002].

Table 5. Share of marketable and non-marketable spears in the total yield of asparagus (%)

Method place of cultivation		Marketable yield			Non-marketable yield		
		2011	2012	mean	2011	2012	mean
No ridges	field	74.4	70.4	72.4	25.6	29.6	27.6
	tunnel	86.9	73.1	80.0	13.1	26.9	20.0
Mean		80.6	71.8	76.2	19.3	28.2	23.8
Ridges	field	87.4	60.0	73.7	12.6	40.0	26.2
	tunnel	92.2	78.0	85.1	7.8	22.0	14.9
Mean		89.8	67.0	79.4	10.2	31.0	20.6
Mean	field	80.9	65.2	73.1	19.1	34.8	26.9
	tunnel	89.5	75.5	82.5	10.4	24.5	17.4

Table 6. Share of marketable and non-marketable spears per one plant of asparagus (%)

Method place of cultivation		Non-marketable			Marketable		
		2011	2012	mean	2011	2012	mean
No ridges	field	63.5	45.5	54.5	36.5	54.5	45.5
	tunnel	76.9	44.9	60.9	23.1	55.1	39.1
Ridges	field	74.0	55.6	64.8	26.0	44.4	35.2
	tunnel	86.0	57.9	71.9	14.0	42.1	28.0
Mean	no ridges	70.2	45.1	57.7	29.8	54.9	42.3
	ridges	80.0	56.8	68.4	20.0	43.2	31.6
Mean	field	68.8	50.5	59.7	31.2	49.4	40.3
	tunnel	81.4	51.3	66.4	18.6	48.6	33.6

Table 7. Mean weight and diameter of green and white marketable spears in the tunnel and in the open field in 2011–2012

Method place of cultivation		Weight (g)			Diameter (mm)		
		2011	2012	mean	2011	2012	mean
No ridges	field	15.07	18.67	16.87b	11.42	10.26	10.84c
	tunnel	19.46	18.30	18.88b	12.77	9.99	11.38bc
Ridges	field	24.58	24.56	24.57a	12.57	13.14	12.85ab
	tunnel	27.30	22.96	25.13a	13.60	12.74	13.17a
Mean	no ridges	17.27b	18.48b	17.88b	12.09a	10.13b	11.11b
	ridges	25.94a	23.76a	24.85a	13.08a	12.94a	13.01a
Mean	field	19.83a	21.61a	20.72a	11.99a	11.70a	11.84a
	tunnel	23.38a	20.63a	22.00a	13.09a	11.36a	12.27a

The number of marketable spears from one plant for both cultivation methods did not differ significantly, the mean was 22.3 white spears per plant (68.4% of all spears) and 22.2 (57.7%) green spears per plant (tab. 2 and 5). In the study of Rolbiecki [2008] the mean in the first two years of harvest was only 11 white spears of 'Ravel' *cv.* from one plant.

As in many other studies [Knaflewski et al. 2000, 2001, Mulder 2005, Paschold et al. 2008, Rolbiecki 2008] the yield and number of spears in the second harvest year was significantly higher than in the first (tab. 2, 3, 4). Yield quality in the first year was superior to that in the second, the mean share of non-marketable yield in the total in 2011 was 15%, whereas in 2012 it increased to 30% (tab. 5). The difference may be a result of higher temperatures in May in the second year of harvest.

Mean weight and diameter (24.85 g and 13.01 mm respectively) of a white spear were significantly higher than those of a green one (17.88 g and 11.11 mm) (tab.7). Makus [1995] and Jishi and Tanaka [2009] also stated higher weight of white spears as compared to green ones (13.3 and 10.9 g respectively), and Cermeño [2005] – their larger diameter (18 mm white, 14 mm green). The mean weight of a marketable green spear *cv*. 'Ravel' was 29 g [Kałużewicz et al. 2010], and of white (mean of the first and second harvest year) 39.5 g [Mulder 2005], 28.6 g [Rolbiecki 2008] or just 15 g and 9.5 mm in diameter [Kmitiene et al. 2009].

CONCLUSIONS

1. The total and marketable yield of white asparagus spears was significantly higher than that of green ones. Green spears had lower mean weight and diameter than the white ones.

2. Yield in the tunnel was significantly higher than in the open field.

3. Cultivation method did not affect the number of spears in the marketable yield; the number of non-marketable green spears was higher than of white ones.

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PLONOWANIE ZIELONYCH I BIELONYCH WYPUSTEK SZPARAGA UPRAWIANEGO W POLU I W TUNELU FOLIOWYM W PIERWSZYCH DWÓCH LATACH ZBIORU

Streszczenie. Szparag (*Asparagus officinalis* L.) może być uprawiany na wypustki bielone lub zielone; w ostatnich latach na świecie zaczął dominować ten drugi sposób uprawy. Celem badań było porównanie plonowania szparaga lekarskiego odmiany Ravel w uprawie na bielone i zielone wypustki w gruncie i w tunelu foliowym. Oceniono masę, liczbę i średnicę wypustek w plonie ogółem, handlowym i niehandlowym w pierwszym i drugim roku zbioru. Plon ogółem i handlowy bielonych wypustek był istotnie wyższy niż zielonych, natomiast liczba zielonych wypustek w plonie ogółem i niehandlowym była większa w porównaniu z bielonymi. Plon i liczba wypustek z uprawy w tunelu były istotnie większe niż w gruncie. Wypustki handlowe stanowiły średnio 77,8% masy i 63,0% liczby wypustek i wartości te były zbliżone dla obu metod uprawy. Wypustki bielone miały średnio większą masę i średnicę niż zielone.

Słowa kluczowe: *Asparagus officinalis* L., wypustki bielone, wypustki zielone, masa wypustki, średnica wypustki, folia PE

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