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SUITABILITY OF SIXTEEN ASPARAGUS CULTIVARS FOR GROWING IN POLISH ENVIRONMENTAL CONDITIONS

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ABSTRACT

Green spear yield of 16 asparagus cultivars originating from six countries was assessed from 2011 to 2013. There were considerable differences in total, marketable and early yields between the cultivars. The quality of harvested spears also varied remarkably. On average, the highest mean total and marketable yields from 3 years of investigation came from Dutch cultivars 'Gijnlim' and 'Cumulus' and German cv. 'Mondeo'. The lowest yields were found in New Zealand cultivars 'Pacific Challenger' and 'Pacific 2000'. The greatest mean marketable spear weight was recorded for 'Cumulus', whereas the smallest spear weight was obtained from 'Pacific 2000', 'H666' and 'NJ 953'. Cultivars 'Gijnlim', 'Cumulus' and 'Mondeo' produced the highest early yields, while 'Pacific 2000' and 'Pacific Challenger' produced the lowest.

In order to determine the dependence between summer stalks size of tested cultivars in the preceding year and their yields in the following year, regression equations and their correlation coefficients were estimated. The size of summer stalks was expressed as plant growth index, which was the multiplication of height and total cross-sectional area of summer stalks. There was a significant and positive correlation between plant growth index of tested cultivars and their yields in the next vegetation period. The correlation coefficients between these two parameters amounted to 0.62 and 0.68 in 2011/2012 and 2012/2013, respectively.

Key words: *Asparagus officinalis*, cultivar, yield, growth index

INTRODUCTION

Asparagus is a well-known and commonly grown vegetable not only in Europe, but also in other parts of the world. China and Peru were the world's biggest asparagus producers in 2012 (FAOSTAT 2014). Cultivation methods of asparagus vary depending on regions and their climatic conditions. Asparagus is grown mainly for green spears in North and South Americas (Benson 2008), while in Europe cultivation of white asparagus is more common. Germany is the greatest asparagus producer in Europe (Knaflewski et al. 2011). The annual asparagus production amount in Poland is around 5000 tons and a major part of it is exported to Germany. Although growing green asparagus is becoming increasingly popular in Poland, its production accounts for only small percentage of total asparagus production (Knaflewski et al. 2011). Asparagus yield, to a great extent, depends on interaction between cultivar characteristics and the climatic conditions. Studies on the suitability of asparagus cultivars grown in different parts of the world have been conducted for more than 30 years within the International Asparagus Cultivar Trial – Nichols (1997), Benson (2002), Jinsong (2002), González (2012). So far, all cultivars grown in Poland come from abroad, mostly from the Netherlands and Germany and some from France and Spain. However, not all foreign-bred cultivars are suitable for the Polish climatic conditions. Therefore, evaluation of yielding of cultivars of different origin in one exper-

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iment seems necessary to get knowledge on their yielding potential in particular growing conditions.

MATERIALS AND METHODS

Field trial establishment

A field trial for harvesting green asparagus spears of 16 cultivars was established (Table 1) on the podsolic soil, the arable layer of which was loamy sand underlying sandy loam, in July 2008. A few months before planting 100 kg·ha^{-1} of P_2O_5, 200 kg·ha^{-1} of K_2O and 1500 kg·ha^{-1} of dolomite were applied before soil cultivation. Available macronutrients content before planting in 0.03 N CH_3COOH amounted to: P – 80 mg·dm^{-3}, K – 200 mg·dm^{-3}, Mg – 50 mg·dm^{-3} and pH of soil/water suspension was 6.5.

Table 1. Asparagus cultivars included in this study and their origins

Cultivar	Origin
Avalim White Angel Cumulus Ginjlim	The Netherlands
Guelph Millennium HP 149	Canada
Mo 2/12 Mondeo Ramires Rapsody	Germany
Pacific Challenger Pacific 2000	New Zealand
NJ 953	USA
Victor H 666 Ercole	Italy

Three-month-old greenhouse transplants were planted in the field. Fifteen transplants of each cultivar at a space of 1.8 × 0.4 m and a depth of 20 cm in each plot were planted. The harvest began in 2011 when plants were 4-year-old. The second and third harvests were conducted in 2012 and 2013. Spears were harvested when they reached the height of about 22 cm above the soil.

Total, marketable and early yield

The marketable yield obtained until 15th May in each year was considered as the early yield. The sum of Extra Class, Class I and Class II was considered as marketable yield and the sum of marketable and unmarketable yields constituted total yield. Yield of each quality class, early, marketable and total were expressed in kg·ha^{-1} while mean spear weight in grams.

Quality classification

A number of spears, in particular, classes and a fresh weight of spears in each class were determined. Extra class included spears of diameter >16 mm, with closed, compact heads, straight or very slightly bent. Spears of diameter >8 mm, with heads compact or slightly loose, slightly bent but the bent radius could not exceed 1 cm for each 10 cm bend were counted as Class I. Spears of diameter >6 mm with slightly loose heads, strongly crooked with the bent radius smaller than 2 cm for each 10 cm bent diameter were classified as Class II. Very thin, hollowed, cracked and extremely bent spears with loose heads were qualified as unmarketable.

Growth index

For each cultivar, height and diameter of summer stalks of five plants in each plot were measured at the end of the vegetation period in autumn 2011 and 2012. Growth index was calculated by multiplying total cross-sectional area and height of summer stalks. The summer stalk cross-sectional area was calculated using the following formula:

$$\sum_{i=1}^{n} \pi r_i^2$$

(r = radius of a summer stalk; n = number of summer stalks)

Statistical analysis

A completely randomized block design with five replications was used in the trial.

All yield parameters were analysed by ANOVA and the means were separated by the Newman–Keul's test 5%. For the analyses, the statistical program 'STAT' was applied. Correlation coefficients and regression equations were estimated by Excel Microsoft Corp.

RESULTS AND DISCUSSION

Yield and spear quality

The earliest harvesting was recorded in 2011 and the latest in 2013 (Table 2). The late harvest was caused by very low temperatures in early April 2013 (Table 3). In the first 2 weeks of April in 2013, the average daily air temperature was almost three times lower and the average minimum daily air temperature was 12 times lower than in 2011. Growth of asparagus spears strongly depends on temperature. According to Bouwkamp and Mc Cully (1975), the minimum temperature for the growth of asparagus spears was 4.4°C, while Blumenfield et al. (1961) found it to be 7.2 °C. It was reported by Nichols and Woolley (1985) that there was a linear correlation between the temperature range from 10 to 30 °C and the growth of asparagus spears from 1 to 20 cm. The results obtained by Dean (1999) showed that the maximum spear elongation occurred at 30 °C (0.51 cm·h^{-1}). Wilson et al. (1999) stated that cultivars differed in their responses to temperature.

Table 2. The beginning and the end of harvest in particular years of the field trial

Year	Harvest		
	Beginning	End	Duration (days)
2011	21.04	2.06	42
2012	23.04	10.06	48
2013	28.04	18.06	51

Table 3. Minimal and mean daily air temperature during the first 2 weeks of April and during the whole harvest period from 2011 to 2013

Year	Daily air temperature (°C)	
	Minimal	Mean
	The first two weeks of April	
2011	6.1	10.2
2012	2.8	7.9
2013	0.5	3.5
	The whole harvest period	
2011	8.3	14.9
2012	9.7	15.6
2013	10.7	15.5

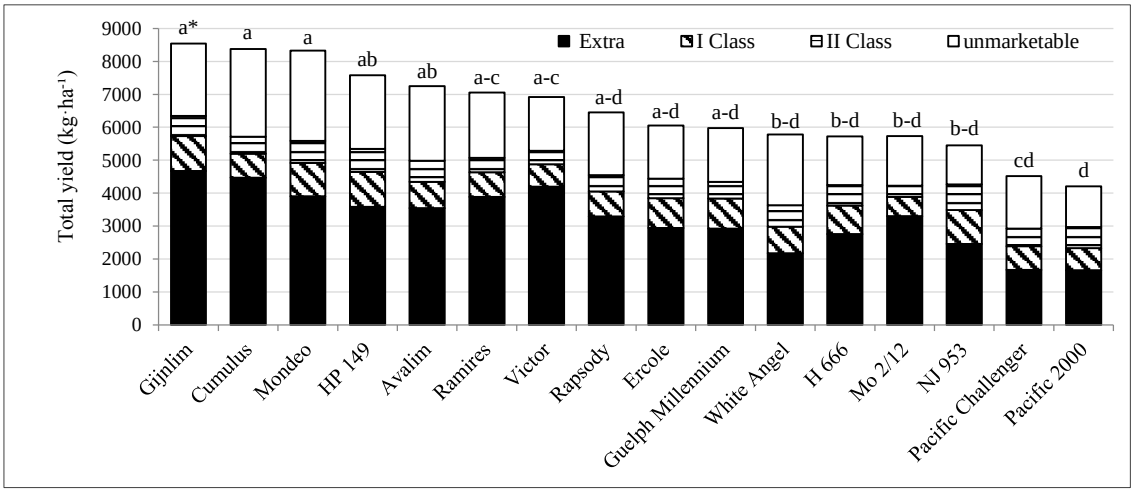
The highest total and marketable yields were obtained in cultivars 'Gijnlim', Cumulus' and 'Mondeo'; whereas the lowest in 'Pacific Challenger' and 'Pacific 2000' cultivars (Table 4, Fig. 1). The total yield of 'NJ 953' was also very low. Mulder and Lavrijsen (2008) also reported a very high yielding ability of 'Gijnlim', which reached more than 12000 kg·ha^{-1} as early as in the second year of harvest. According to their study, 'Rapsody' (over 10000 kg·ha^{-1}) 'Avalim' and 'NJ 953' (over 9000 kg·ha^{-1}) were characterised by a very high yield. The high yielding ability of 'Gijnlim' was also reported by Paschold et al. (2008) and by Drost (2002). In the study of Rodkiewicz (2011), not only 'Gijnlim', but also other Dutch cultivars 'Backlim', 'Horlim' and 'Thielim' were characterised by very high yielding ability. Zhu et al. (2013) concluded that of 28 asparagus cultivars, 'Gijnlim' gave not only the highest total and marketable yields, but also the highest yield in the Extra class.

Cermeño et al. (2008) reported that 'NJ 953' and 'Ercole' were among the highest yielding cultivars in Spain. 'NJ 953' was one of the cultivars with the highest marketable yield. High yielding performance of 'NJ 953' was also confirmed by González (2008, 2012) in Chile. However, in our study, 'Ercole' was ranked only as 9th and 'NJ 953' as 14th among 16 cultivars. Araki et al. (2012) found that Dutch cultivars, especially 'Gijnlim' and 'Avalim', produced very high total yields in Japan. Both of them, as well as 'Pacific 2000', gave also a high marketable yield. In our experiment, 'Pacific 2000' gave the lowest total and marketable yields. According to Araki et al. (2012), mean spear weight of 'Gijnlim' and 'Avalim' ranged from 24 to 25 g while that of 'Pacific 2000' amounted to 17 g. Similar mean spear weights of 'Gijnlim' and 'Avalim' were obtained in our study (Table 4), whereas mean spear weight of 'Pacific 2000' reached only 14 g and it was even lower than the results reported by Araki et al. (2012). Our study also revealed considerable differences between particular cultivars in the share of marketable yield in the total yield (Table 4). Cultivar 'NJ 953' turned out to have the biggest share of marketable yield in the total yield (78.5%) of all cultivars whereas 'White Angel' the smallest (63.1%).

Table 4. Total and marketable yields and mean spear weight of 16 asparagus cultivars (mean of 2011-2013)

Cultivar	Yield (kg·ha^{-1})		Marketable yield (%)	Mean spear weight (g)
	Total	Marketable		
Gijnlim	8540 a*	6340 a	74.2	22.8 b-e
Cumulus	8380 a	5710 ab	68.1	31.1 a
Mondeo	8310 a	5590 ab	67.3	22.5 b-e
HP 149	7580 ab	5350 ab	70.6	22.4 c-e
Avalim	7240 ab	4980 ab	68.8	25.2 b-d
Ramires	7050 a-c	5070 ab	71.9	24.2 b-d
Victor	6890 a-c	5290 ab	76.8	25.8 bc
Rapsody	6450 a-d	4550 a-c	70.5	22.8 b-e
Ercole	6050 a-d	4440 a-c	73.4	19.5 ef
Guelph Millennium	6000 a-d	4340 a-c	72.3	20.2 d-f
White Angel	5770 b-d	3640 bc	63.1	22.9 b-e
H 666	5730 b-d	4250 a-c	74.2	19.3 ef
Mo 2/12	5710 b-d	4230 a-c	74.1	27.2 b
NJ 953	5440 b-d	4270 a-c	78.5	16.0 fg
Pacific Challenger	4510 cd	2920 c	64.7	15.0 g
Pacific 2000	4210 d	2970 c	70.5	14.0 g

*Means followed by the same letter do not differ at p = 0.05 according to Newman-Keuls test



*Means followed by the same letter do not differ at p = 0.05 according to Newman-Keuls test

Fig. 1. Yield structure of 16 asparagus cultivars (mean of 2011-2013)

In our experiment, considerable differences in the early yield between particular cultivars were found (Table 5). The highest early yield was observed in 'Gijnlim', while that in 'Cumulus' and 'Mondeo' was slightly lower. Two New Zealand cultivars, 'Pacific Challenger' and 'Pacific 2000' were characterised by the lowest early yield. Earliness of cultivars 'Gijnlim' and 'Mondeo' was also confirmed by Paschold et al. (2008). In their study, 'Gijnlim' and 'Ravel' were the earliest of 14 asparagus cultivars evaluated and they were closely followed by 'Mondeo'. Cultivar 'Rapsody' was described as a mid-early one, which corresponded with the results from our study. In the experiment conducted by Zhu et al. (2013), 'Gijnlim' and 'Hannibal' were the earliest of 28 cultivars. The share of early yield in marketable yield of 'Gijnlim' reached about 56% in their study, whereas in our study it

was slightly lower and amounted to 50%. Conversely, 'Mondeo' had the highest share of early yield in the marketable yield, but 'Mo 2/12' the lowest in our study.

The correlation between plant growth index and yield

Moon (1976) stated that yield of spears in the next vegetation period strongly depended on the number of summer stalks in the previous year. Knaflewski (1994) stated that from such traits as number, height and weight of stems, their cross sectional area, circumference of the crown area from which stalks emerged; crown circumference was the parameter most correlated with yield.

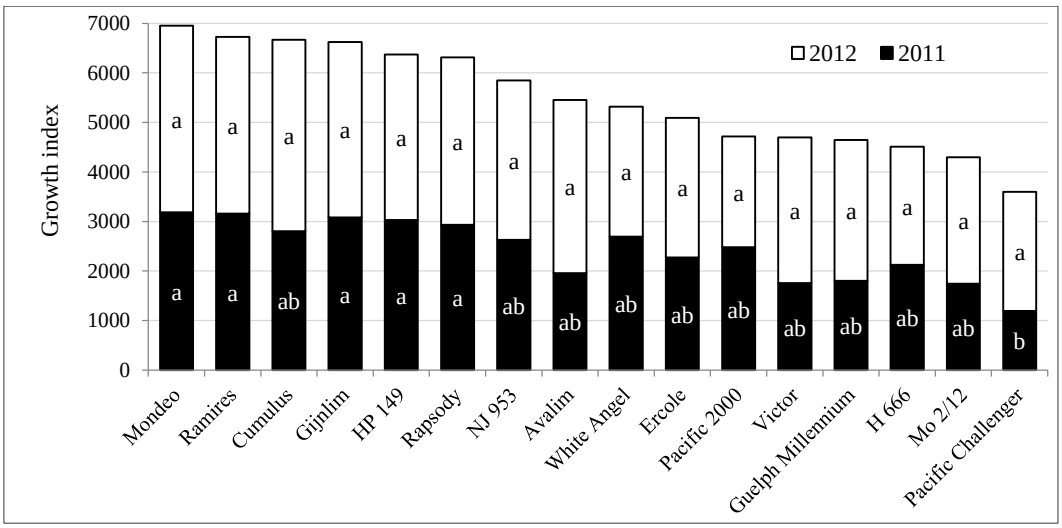
The dependence between summer stalk size of plants in the preceding year and the yield of spears in the following year was also studied by Araki et al. (2012). Dry weight of summer stalks was found to be highly correlated with the total and marketable yields and mean spear weight and the correlation coefficients amounted to 0.713, 0.586 and 0.544, respectively.

In this study, 'Mondeo', 'Ramires', 'Cumulus' and 'Gijnlim' were characterised by the highest growth index, whereas 'Pacific Challenger' by the lowest (Fig. 2). A positive correlation was observed between plant growth index of tested cultivars in the preceding year and their yield in the successive vegetation period (Fig. 3).

Table 5. Early yield of 16 asparagus cultivars (mean of 2011-2013)

Cultivar	Early yield		Cultivar	Early yield	
	kg·ha^{-1}	Early yield as % of marketable yield		kg·ha^{-1}	Early yield as % of marketable yield
Gijnlim	3210 a*	50.6	Ercole	2080 b-e	46.8
Cumulus	3090 ab	54.1	Guelph Millennium	2160 b-e	49.8
Mondeo	3050 ab	54.5	White Angel	1810 c-e	49.7
HP 149	2770 a-c	51.8	H 666	2050 b-e	48.2
Avalim	2580 a-d	51.8	Mo 2/12	1640 de	38.8
Ramires	2700 a-c	53.3	NJ 953	2040 b-e	47.8
Victor	2560 a-d	48.4	Pacific Challenger	1390 e	47.6
Rapsody	2140 b-e	47.0	Pacific 2000	1410 e	47.5

*Means followed by the same letter do not differ at p = 0.05 according to Newman-Keuls test



Means followed by the same letter do not differ at p = 0.05 according to Newman-Keul's test

Fig. 2. Growth index of 16 asparagus cultivars (2011 and 2012)

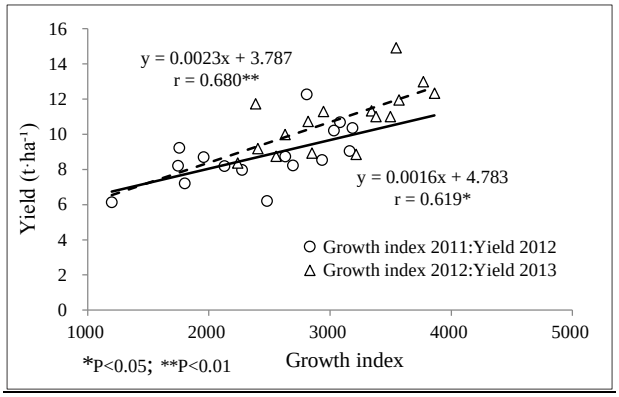


Fig. 3. Correlation between summer stalks growth index of sixteen cultivars in 2011 and 2012 and their total yield in 2012 and 2013

CONCLUSIONS

1. Cultivars 'Gijnlim', 'Cumulus' and 'Mondeo' were characterised by the highest total and marketable yields, whereas 'Pacific Challenger' and 'Pacific 2000' by the lowest.
2. 'Cumulus' produced spears of the greatest mean weight, while 'Pacific 2000' and 'NJ953' of the smallest.
3. The highest early yield was observed in 'Gijnlim' and slightly lower in 'Cumulus' and 'Mondeo' while the lowest in 'Pacific 2000' and 'Pacific Challenger'.
4. Growth index of tested cultivars in the previous year was found to be positively correlated with the yield in the following year.

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