THE EFFECT OF DATE OF PLANTING SEEDLINGS AND POLYPROPYLENE FIBRE COVERING ON THE YIELD AND ECONOMIC EFFICIENCY OF MELON

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ABSTRACT

Melon is a little popular vegetable to grow in Poland, due to high climatic requirements. Ensuring appropriate thermal conditions for plants growth is possible with relatively late planting seedlings. However, late planting does not guarantee high yield of good quality fruit. The factor enabling the earlier planting seedlings and improving the conditions of growth is the use of flat covers. The field experiment was conducted in 2008–2010 in central-eastern Poland. The effect of planting seedlings of melon 'Malaga F_1' (15 May, 25 May and 4 June) and the length of polypropylene fibre 17 g·m^{-2} covering (by 4 and 8 weeks from planting, until harvest, control without covering) on the yield and economic efficiency of melon cultivation in the field was investigated. Most preferably the yield level and profitability of melon cultivation were influenced by planting seedlings on the 15 May and covering by 4 weeks. However, earlier planting decreased the share of marketable fruits in the total number of fruits. The highest share in the costs structure of melon cultivation had the costs of human labour.

Keywords: *Cucumis melo* L., cultivation date, economic efficiency, polypropylene fibre, yield

INTRODUCTION

Melon belongs to the thermophilic vegetables with high environmental requirements, therefore, treatments, which improve climate conditions are necessary in its production [Majkowska-Gadomska 2009]. An important problem in the field melon cultivation in Poland is the late date of planting seedlings (1st 10 days of June) due to its sensitivity on the low air and soil temperature. In the colder years, fruit from plants planted at this time, does not reach maturity before the autumn frost. In the field cultivation an important element of agricultural technology, protecting thermophilic vegetables against unfavorable thermal conditions, is flat polypropylene fibre covering. Covering provides better thermal and moisture conditions for plants, resulting in an acceleration of the yield [Siwek and Lipowiecka 2003, Lamont 2005, Hamouz et al. 2006, Majkowska-Gadomska 2009, Rosa 2014].

Previous studies Kosterna et al. [2009] and Majkowskiej-Gadomskiej [2009, 2010] have shown that by the use of flat covers in Poland it is possible to obtain a satisfactory yield of mature, valuable and tasty fruits of melon, even if the summer months were characterized by lower than the long-term air temperature.

Barrier to the availability of melon fruit for a wide range of consumers is its high price. According to Waterer [2003, 2010], Yilmaz et al. [2011] and Benincasa et al. [2014] the main cost of melon cultivation is the cost of covers and hand fruit harvesting.

The study aimed to determine the effect of differentiated date of planting seedlings and the date of polypropylene fibre removal on the yield and economic efficiency of melon cultivation in the climatic conditions of central-eastern Poland.

MATERIAL AND METHODS

The experiment was conducted in 2008–2010 in central-eastern Poland (51°53'N, 22°27'E). The experiment was established as a split-block design with four replicates. The area of one plot for harvest was 12 m². The influence of two factors was investigated: I. the date of melon seedlings planting: 4th of June – traditionally recommended in Poland, 25th of May – date accelerated by 10 days, 15th of May – date accelerated by 20 days; II. Plants covering: by 4 and 8 weeks after planting seedlings, to fruits harvest, control without covering.

The field experiment was carried out on the soil classified as Podzols [World reference… 2014]. Soil was characterized by a humus level of 37–43 cm. Mean content of organic carbon was 2.1%, the value of pH determined in H_2O was 5.80. Macroelements content in 1 dm³ in the arable layer was as follows: 14 mg $N-NH_4$; 20 mg $N-NO_3$; 19 mg P_2O_5; 145 mg K_2O; 797 mg Ca; 76 mg Mg.

Melon seedlings 'Malaga' were grown in non-heated greenhouse. The seeds were sown 4 weeks before the date of planting seedlings i.e. 17th of April, 27th of April and 7th of May. During the seedlings growth, solution of liquid foliar feeds Florovit at 0.5% was applied, which represent a multi-nutrient fertiliser. Forecrop for melons was corn grown for silage. Soil preparation included deep plowing and harrowing in early spring. In the first 10 days of May mineral fertilization was applied. The nutrient content in the soil was made up to the optimum level for cucumber [in mg·dm⁻³]: 70 N, 80 P, 200 K, 80 Mg, 1500 Ca [Sady 2000]. These standards are also accepted for field-grown melon. Melon belongs to the same botanical family, and has similar requirements for fertilisation. Fertilizers were mixed with the soil using the aggregate cultivar. The melon seedlings were planted on the soil covered with black polypropylene nonwoven, at a spacing of 80×100 cm.

Fruit harvesting was performed gradually, as fruit ripened. During the last harvest all the fruits, also unripe were collected. During the harvest the total yield [kg·m⁻²], marketable yield [kg·m⁻²], number of marketable fruits [no.·m⁻²], average weight of marketable fruit [kg] were determined. On the basis of the obtained results the percentage share of marketable yield in the total yield and number of marketable fruits in total number of fruits were calculated.

The results of the experiment were statistically analyzed by ANOVA following the mathematical model for the split-block design. Significance of differences was determined by the Tukey test at the significance level of $P \leq 0.05$.

The paper also analyzes the economic cultivation of melon according to accepted by the European Union standard gross margin method (SGM) [Augustyńska-Grzymek et al. 2000]. The concept of SGM allows to avoid deviations caused by variability quantify and valuable size of production e.g. resulting from the bad weather and the variation of costs incurred for its production. The gross margin was calculated as a difference between the yield value obtained from 1 ha of melon cultivation and direct costs of production. Melon production value is the sum of the main product value, which is in the traded on the market, determined according to sales prices. The calculation of production value does not include the area payment. The purchase costs of multitray for seedling production and the costs of polypropylene fibre were divided into three years, because at their proper use and storage can be used for 3 seasons. The other elements of direct costs of production were fixed to the growing cycle of melon. They included the costs of material (sowing material, peat substrate, mineral fertilizers, plant protection means, black polypropylene fibre for soil mulching), as well as human and mechanical labour outlays, established on the basis of technology used in the experiment, labour consumption of individual measures in production conditions of the Agricultural Experimental Station in Zawady. Economic evaluation was based on the price from 2015. The value of melon production was the ratio of fruits yield (expressed by the number of fruits per 1 ha) and the price of a single fruit, which was established as 5.00 PLN. It was the mean price from the end of July to the end of September in the Lublin Wholesale Market in Elizówka and the Warsaw Agri-Food Wholesale Market in Bronisze [www.fresh-market.pl].

RESULTS AND DISCUSSION

In 2008, despite relatively balanced thermal conditions and uniform distribution of precipitation, the lowest total and marketable yield of melon fruits was obtained. The marketable fruits were also characterised by the lowest weight. The highest total and marketable yields and the

most marketable fruits from 1 m^2 were obtained in 2010, which was characterised by the most favourable thermal conditions during the growth period of melon. In 2009 marketable yield was lower than in 2010, but simultaneously the marketable fruits in 2009 were characterised by the highest weight (Table 1).

The total yield of melon fruits amounted to average 4.94 kg·m^{-2}, and marketable yield 4.24 kg·m^{-2} (Table 2). In a study conducted in the climatic conditions of Poland by Grudzień and Górecki [2001] the total yield of melon fruits was lower by 3.71 kg·m^{-2}, and by Majkowska-Gadomska [2010] by 3.60 kg·m^{-2}. However, the marketable yield of 'Malaga' obtained by Grudzień and Górecki [2001] was lower by 1.70 kg·m^{-2}. The melon yield in the present study was lower than achieved by Ibarra et al. [2001], which amounted to 8.25 kg·m^{-2}, however, the cited authors' studies were conducted in more favourable climatic conditions (central Mexico).

The acceleration of planting seedlings by 10 and 20 days significantly increases the total and marketable yield. Compared to the traditional planting date (4th of June) an increase in the total yield amounted to 17 and 28%, and in marketable yield 16 and 25%.

Covering contributed to a significant increase in the total and marketable yield of melon compared to cultivation without covering. Irrespective of the date of planting seedlings the total yield increased by 160–171% and marketable yield by 292–309%. In the study by Majkowska-Gadomska [2010] covering 14–18 days contributed to a nearly double increase in marketable yield of melon 'Malaga F$_1$'compared to harvested from the control without cover. Increase of melon yield as a result of covering was also noted in Mexico by Ibarra et al. [2001], South Korea's by Shin et al. [2009] and in central Italy by Benincasa et al. [2014]. In the weather conditions of Poland it was found that the application of flat covers has a beneficial yielding effect in the cultivation of many species of thermophilic vegetables. As a result of covering increase of yields were noted by Grudzień and Rumpel [1998] in bell pepper cultivation, Wierzbicka and Kuskowska [2000] in cucumber, Kosterna [2014] in tomato and Rosa [2014] in sweet corn cultivation. In the present study, covering plants for 4 weeks contributed to a significant increase in marketable yield. Longer covering had no significant influence on the yield level. Also Ibarra et al. [2001] found an increase in marketable yield of melon as a result of covering (by 93–130%), however, elongation of covering from 10 to 20 and 32 days did not cause a significant increase of yield. Similarly, Santos et al. [2015] did not note differences in the yield of melon covered by 18, 21, 24, 27 and 30 days after planting. However, in the study by Ibarra-Jiménez et al. [2001] elongation of melon covering from 14 to 24 and 31 days and from 31 to 41 days caused a significant increase in marketable yield of melon fruits.

Table 1. Yields of melon in the years of study

Years	Total yield (kg·m^{-2})	Marketable yield (kg·m^{-2})	Number of marketable fruits (no·m^2)	Weight of marketable fruit (kg)
2008	4.28 a*	3.60 a	2.5 a	1.46 a
2009	5.09 b	4.29 b	2.5 a	1.71 c
2010	5.44 b	4.83 c	2.9 b	1.65 b

* Values within columns followed by the same lowercase letters are not significantly different at P ≤ 0.05

Table 2. Yields of melon (mean for 2008–2010)

Covering	Total yield (kg·m^{-2})				Marketable yield (kg·m^{-2})			
	Date of planting seedlings			Mean	Date of planting seedlings			Mean
	15 May	25 May	4 June		15 May	25 May	4 June	
Control	2.18 a*	2.29 a	2.16 a	2.21 a	1.14 a	1.28 a	1.51 a	1.31 a
By 4 weeks after planting	6.51 b	5.95 b	4.92 bc	5.79 b	5.69 b	5.34 b	4.44 bc	5.16 b
By 8 weeks after planting	6.57 b	5.95 b	4.72 b	5.75 b	5.79 b	5.25 b	4.34 b	5.13 b
To harvest	6.81 c	5.85 b	5.35 c	6.00 b	6.00 b	5.36 b	4.73 c	5.36 b
Mean	5.51 C**	5.01 B	4.29 A	4.94	4.66 C	4.31 B	3.73 A	4.24

* Values within columns followed by the same lowercase letters are not significantly different at P ≤ 0.05
** Values within rows followed by the same uppercase letters are not significantly different at P ≤ 0.05

In the conducted study the share of marketable yield in the total yield amounted to average 81.7% (Figure 2) and was similar to the one found by Majkowska-Gadomska [2010] 81.5% and Kruk [1995] 80.3% and significantly higher than in research conducted by Grudzień and Górecki [2001], where it was at the level of 63.4%. In the weather conditions of Mexico the share of marketable yield in the total yield amounted to 78.0% [Ibarra-Jiménez et al. 2001] and 83.0 % [Ibarra et al. 2001]. In the present study the share of marketable fruits in the total number of fruits amounted to average 77.4% (Figure 2).

The acceleration of planting seedlings by 10 and 20 days compared to the date recommended in the literature (4th of June) decreased the share of marketable yield in the total yield by 4.1 and

6.5% and the number of marketable fruits in the total number of fruits by 3.2 and 3.9%. Irrespective of the date of planting seedlings, use of covers influenced on the increase the share of marketable yield and the number of marketable fruits compared to the control plot without covering on average by 30%. Ibarra et al. [2001] as a result of covering was noted an increase of marketable yield in the total yield from 13.5 to 20.2%, however in the study by Ibarra-Jiménez et al. [2001] the share both in the covered and uncovered cultivation was similar (75–79%).

The number of marketable fruits of melon amounted to average 2.6 no·m^{-2} (Table 3). Earlier planting by 10 and 20 days compared to the June date contributed to a significant increase in the number of marketable fruits. In all dates
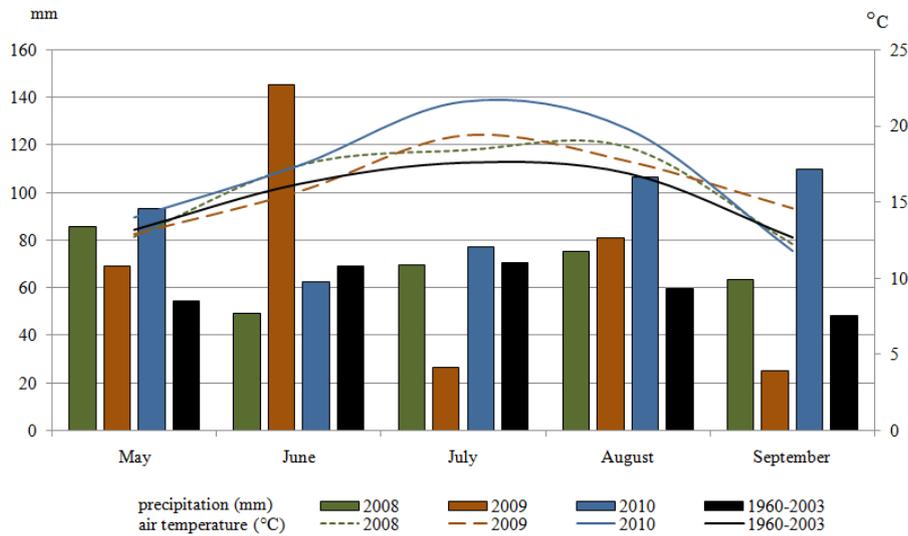

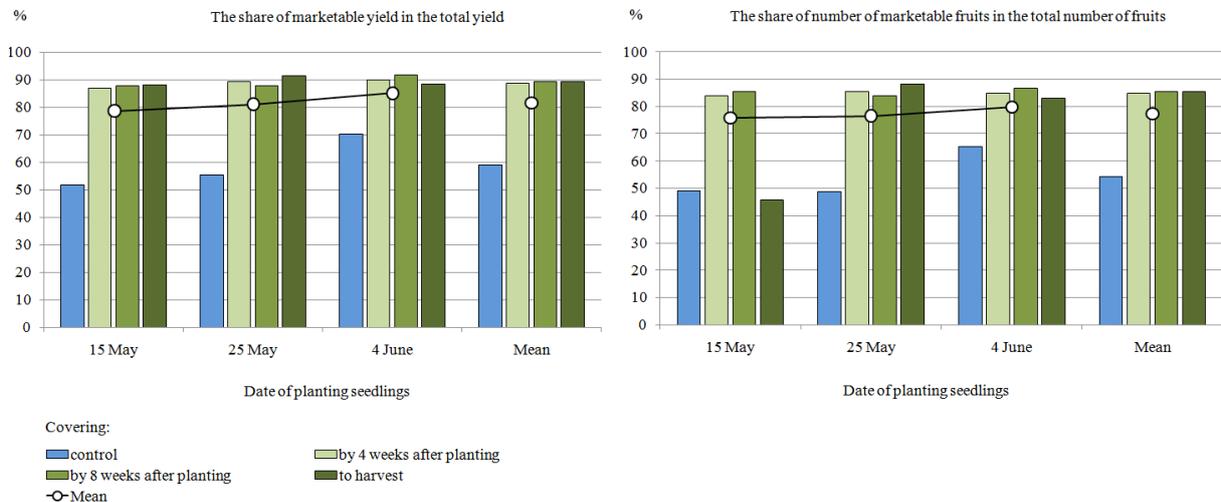**Figure 1**. Weather conditions in the years of study

Figure 2. The share of marketable yield in the total yield (mean for 2008–2010)

171

Table 3. Number and weight of marketable fruits (mean for 2008–2010)

Covering	Number of marketable fruits (no.·m⁻²)				Weight of marketable fruit (kg)			
	Date of planting seedlings			Mean	Date of planting seedlings			Mean
	15 May	25 May	4 June		15 May	25 May	4 June	
Control	0.8 a*	0.8 a	1.0 a	0.9 a	1.47 a	1.53 a	1.55 a	1.52 a
By 4 weeks after planting	3.4 b	3.3 b	2.9 b	3.2 b	1.68 b	1.61 ab	1.53 a	1.61 ab
By 8 weeks after planting	3.5 b	3.2 b	2.7 b	3.1 b	1.68 b	1.64 b	1.60 a	1.64 b
To harvest	3.5 b	3.2 b	2.9 b	3.2 b	1.70 b	1.70 b	1.62 a	1.67 b
Mean	2.8 C**	2.6 B	2.4 A	2.6	1.63 B	1.62 AB	1.58 A	1.61

*, ** Explanations as in table 2

of planting seedlings, covering regardless of the length, influenced significantly on the increase in the number of marketable fruits compared to the control without covering. In the study by Ibarra-Jiménez et al. [2001] covering the melon plants with polypropylene fibre by a period between 24 to 41 days caused increase the number of fruits per plant compared to control without cover, however Santos et al. [2015] did not find a significant influence of covering on the number of fruits.

The weight of marketable melon fruit amounted to an average of 1.61 kg (Table 3). Majkowska-Gadomska [2010], in the research conducted in the less favorable environmental conditions, obtained the fruits of melon 'Malaga F_1' with a lower average weight (1.32 kg). Also Kosterna et al. [2009] found that average weight of six large-fruit melon from the field cultivation conducted in the similar conditions was lower and amounted to 1.13 kg. The marketable fruits from covered plants were characterized by higher weight compared to obtained from uncovered plants. Depending on the length of covering the increase in marketable fruit weight ranged from 0.09 kg at the covering by 4 weeks to 0.15 kg at the covering to harvest. Also the study results by Majkowska-Gadomska [2010] indicate that average weight of melon fruit 'Malaga F_1' from covered cultivation was by 0.25 kg higher than the weight of fruits from uncovered plants. In the author's own research a significant increase in the marketable weight of fruit as a result of covering was achieved from the plants planted on the 15th and 25th of May (respectively by 14–15.6% and 5–11%), however the length of covering not modify significantly this feature. In the case of plants planted on the 4th of June, both the length of polypropylene fibre covering and just covering is not affected in a significant way on the weight of the marketable fruit. This suggests that together with the increases of temperature a positive impact of covering on the weight of the melon fruit decreases. This is confirmed by

the research by Santos et al. [2015], who in the more favourable than Polish climatic conditions for the cultivation of this plant did not receive significant changes in the weight of the marketable fruit as a result of covering.

Direct production costs of melon were variable depending on the method of cultivation (covering with polypropylene fibre or without covering), the date of cover removal and the date of planting seedlings (Table 4). Differentiation elements of these costs were the costs of purchasing polypropylene fibre and also labour costs (placing and removing covers from the field, harvest, transport and packaging of fruits) and the cost of package directly related to the level of yields of melon planted in individual dates. The yield was higher, the incurred costs of harvesting and packaging of melon fruits were higher. Irrespective of the date of planting seedlings, the costs of melon cultivation without covering were lower by 50% on average, compared to cultivation with polypropylene fibre. The highest direct costs incurred for the cultivation of melon planted on the 15th of May and covered by 8 weeks after planting seedlings and to the fruits harvest (71865 PLN·ha⁻¹). The highest share in the structure of direct costs (71.6–72.6%) had the cost of human labour during seedling production, the cultivation of melon in the field and its harvesting and preparation for sale. The dominant share of costs of human labour in the structure of melon cultivation costs is also indicated by Waterer [2003] and Yilmaz et al. [2011]. In the author's own research, depending on the cultivation combination outlays of labour, ranged from 956 to 2160 man hours ·ha⁻¹. Assuming the cost of human labour as 24.00 PLN per hour (valuation according to the Agricultural Experimental Station in Zawady), it gives the amount ranged from 22944 to 51840 PLN·ha⁻¹. The share of human labour costs in the labour costs (human labour + mechanical labour) amounted to average 96% and was higher to the found in the study by

Table 4. The structure of direct costs (PLN·ha^{-1}) in melon cultivation depending on the date of planting seedlings and length of covering (mean for 2008–2010)

Specification	Covering			
	Control	C4*	C8	CH
The costs of seedlings preparation				
Peat substrate	400	400	400	400
Multi-tray **	221	221	221	221
Fill of multi-tray	384	384	384	384
Melon seeds	410	410	410	410
Sowing	192	192	192	192
Florovit	30	30	30	30
Watering and feeding of seedlings	480	480	480	480
Removal of tops	144	144	144	144
The costs of melon cultivation in the field				
Winter plowing	260	260	260	260
Harrowing	80	80	80	80
Mineral fertilizers	1865	1865	1865	1865
Fertilizers spreading	130	130	130	130
Cultivation unit	190	190	190	190
Black polypropylene fibre **	1760	1760	1760	1760
Black polypropylene fibre placing	7200	7200	7200	7200
Planting seedlings	6000	6000	6000	6000
Polypropylene fibre **	–	1440	1440	1440
Polypropylene fibre covering	–	4800	4800	4800
Covering and uncovering for the application of plant protection means	–	–	1440	1440
Plant protection means	396	396	396	396
Spraying of plant protection means	376	376	376	376
Removal of polypropylene fibre	–	1920	1920	1920
Removal of black polypropylene fibre	2400	2400	2400	2400
The costs of harvest and packaging depending on the number of fruits harvested from the plants planted in different dates				
15 May	6144	26112	26880	26880
25 May	6144	25344	24576	24576
4 June	7680	22272	20736	22272
The costs of transport melon from the field				
15 May	160	800	800	800
25 May	160	720	720	720
4 June	240	640	560	640
The costs of package depending on the number of fruits harvested from the plants planted in different dates				
15 May	2667	11333	11667	11667
25 May	2667	11000	10667	10667
4 June	3333	9667	9000	9667
Total direct costs				
15 May	31889	69323	71865	71865
25 May	31889	68142	68481	68481
4 June	34171	63657	62814	65097

* C4 – by 4 weeks after planting, C8 – by 8 weeks after planting, CH – to harvest

** ⅓ costs of multi-tray, polypropylene fibre and black polypropylene fibre application

Yilmaz et al. [2011], in which amounted to 88% costs of labour in the melon cultivation.

The highest value of melon production (175000 PLN) and the highest gross margin per 1 ha (103135 PLN) was obtained for melon cultivated from seedlings planted on the 15th of May and covered with polypropylene fibre by 8 weeks after planting or until the harvest (Table 5). The highest gross margin per 1 fruit and gross mar-gin per 1 PLN of incurred costs (2.95–2.96 PLN and 1.44–1.45 PLN) were calculated for melon planted on the 15th of May and covered with poly-propylene fibre, irrespective of the date of its re-moval. In the conducted experiment, profitability index of melon production ranged from 125 to 245% (Figure 3). Yilmaz et al. [2011] also point to a high profitability of melon production in the conditions of Turkey. In the climatic conditions of

Table 5. Value, direct costs and gross margin (PLN) of melon production depending on the date of planting seedlings and length of covering (mean for 2008–2010)

Specification	Date of planting seedlings											
	15 May				25 May				4 June			
	Control	C4*	C8	CH	Control	C4	C8	CH	Control	C4	C8	CH
Number of marketable fruits per 1 ha	8000	34000	35000	35000	8000	33000	32000	32000	10000	29000	27000	29000
Production value (PLN)	40000	170000	175000	175000	40000	165000	160000	160000	50000	145000	135000	145000
Total direct costs per 1 ha (PLN)	31889	69323	71865	71865	31889	68142	68481	68481	34171	63657	62814	65097
Direct costs of 1 melon fruit production	3.99	2.04	2.05	2.05	3.99	2.06	2.14	2.14	3.42	2.20	2.33	2.24
Gross margin per 1 ha (PLN)	8111	100677	103135	103135	8111	96858	91519	91519	15829	81343	72186	79903
Gross margin per 1 melon fruit (PLN)	1.01	2.96	2.95	2.95	1.01	2.94	2.86	2.86	1.58	2.80	2.67	2.76
Gross margin per 1 PLN of costs (PLN)	0.25	1.45	1.44	1.44	0.25	1.42	1.34	1.34	0.46	1.28	1.15	1.23

* C4 – by 4 weeks after planting, C8 – by 8 weeks after planting, CH – to harvest
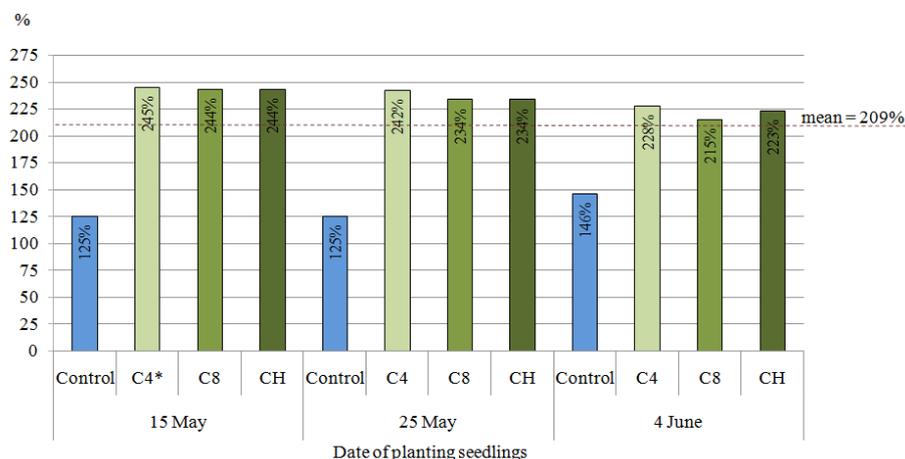
* C4 – covering by 4 weeks after planting, C8 – covering by 8 weeks after planting, CH – covering to harvest

Figure 3. Profitability index (%) of melon cultivation

Poland, high profitability of cucumbers cultivation under covers was noted Siwek et al. [2003], tomato and eggplant Gunerka et al. [2014]. Irrespective of the date of planting seedlings of melon use of covers with polypropylene fibre was a factor increasing the profitability of crops in comparison with the cultivation without covering. The higher economic effect was achieved by planting melon seedlings on the 15th of May and covered with polypropylene fibre (244–245%). The later was date of planting seedlings, the increase in profitability index as a result of covering was lower. High average profitability index of melon production at the level of 209%, especially in the era of continuous reduction of the profitability of agricultural production, at the increasing market requirements can provide an incentive for Polish agricultural producers to take an interest in its cultivation.

CONCLUSIONS

1. Weather conditions have a significant influence on the yield of melon 'Malaga F1'. In all years of the study yields achieved in the weather conditions of central-eastern Poland were satisfying. In these conditions is possible cultivation of melon in the field from seedlings planted on the 15th of May.

2. The earliest planting date had the most beneficial effect on the total and marketable yield and average weight of the marketable fruit. From the plants planted in both dates in May significantly more fruits were obtained from the cultivation area than from the plants planted on the 4th of June.

3. The total and marketable yield and average weight of the marketable fruit from covered plants was significantly higher than from un-

covered plants. The length of covering had no significant effect on these yield parameters. For the size and quality of the yield was essential to protect plants against unfavorable weather conditions during the first four weeks after planting to the field. Irrespective of the length of covering, the share of marketable yield in the total yield increased compared to uncovered plants.

4. Economic analysis of the cultivation of melon showed the close relationship between the level of achieved yield of melon and incurred human labour outlays per unit area.

5. The higher economic effect was obtained from the seedlings planted on the 15th of May and covered with polypropylene fibre by 4 weeks.

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