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The yield of eggplant depending on climate conditions and mulching

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ABSTRACT

The field production of eggplant in moderate climates is difficult as it depends heavily on thermal conditions. Eggplant is a species that is sensitive to low temperatures, and temperatures below 16ºC constrain the growth of young plants. Other disadvantageous factors include: temperatures that are too high, water shortage and excessive soil humidity. The growth conditions for eggplant can be improved by using mulches. The purpose of the experiment was the assessment of eggplant cropping while using synthetic mulches of polyethylene foil and polypropylene textile. The research took five years (2008-2012) and on the basis of the obtained results it was possible to determine the influence of weather conditions on the yielding of this species. It was proven that eggplant cropping significantly depended on the air temperature and the amount of rainfall during the vegetation period. The highest yield was observed when the average air temperature was high and at the same time rainfall was evenly distributed throughout the vegetation season. It also turned out that the agro-technical procedure which significantly increased eggplant fruit cropping was mulching the soil with polyethylene black foil, or transparent foil, previously having applied a herbicide.

Key words: air temperature, polyethylene foil, polypropylene textile, rainfall, *Solanum melongena* L.

INTRODUCTION

Eggplant is a vegetable of great economic importance in countries with tropical and subtropical climates. It is also grown in the south of Europe. Its characteristic feature is a root system of a medium range; its demand for water is greatest during the blooming and fruit-forming periods (Ertek et al. 2006). In dry, warm climates, high yields can be obtained during cultivation with the use of irrigation. The maximum yield achieved by Aminifard et al. (2010) in a region where annual rainfall amounts to 91-120 mm, with air humidity of 37%, at an altitude of 1470 m, using irrigation until soil humidity reached 65%, was 3713 g from one plant. The field production of this species is also possible in moderate climates. However, it depends heavily on weather conditions. Eggplant is sensitive to frost and the growth of young plants is constrained by temperatures below 16ºC. What also affects the profitability of plant production is the length of the vegetation period, which should come to 120 days (Chen and Li 1997). The growth of eggplant may slow down when the temperature is too high (> 30ºC), there is not enough water, or in the case of excessive humidity combined with a high temperature. According to Chen and Li (1997), in such conditions the vegetative growth of plants is enhanced.

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Growth conditions can be improved by using synthetic mulches. Their beneficial influence on soil humidity and temperature as well as on microbiological life in the soil was observed by Diaz Perez et al. (2007), Siwek et al. (2007) and Moreno and Moreno (2008). Wien and Minotti (1987) noticed the positive reaction of vegetables to an increase of temperature in the root sphere. Brown and Channell-Butcher (2001) stress that this especially refers to species that are very demanding as to the temperature. Mulches protect the plantation against weed infestation, prevent water and wind erosion of soil, as well as leaching nutrients out of the reach of plant roots (Kołota and Słociak 2003, Romić et al. 2003, Moreno and Moreno 2008). Thanks to the modification of conditions around the plants, e.g. light conditions, mulches may contribute to the decrease of the amount of pathogens on vegetables (Toscano et al. 1979, Diaz Perez et al. 2007).

MATERIAL AND METHODS

The research was conducted in the years 2008-2012 in the Research Station belonging to the Department of Horticulture at Wroclaw University of Environmental and Life Sciences (51º19'N, 17º03'E). The one-factor experiment was established in a randomised block design, in three replications, on black degraded soil of pH 7.25 and a nutrient content of 130 mg K dm^{-3} and 200 mg P dm^{-3}. Air temperature and the amount of rainfall were recorded on the Research Station of the experiment site. The temperature was registered electronically

Table 1. Mean air temperature and sum of rainfall during the eggplant growing period in 2008-2012

Year	Months	Temperature (°C)					Rainfall (mm)				
		10-day period			mean monthly temperature	deviation from mean monthly temperature for the years 1971-2000	10-day period			sums of rainfall	deviation from monthly sums of rainfall for the years 1971-2000
		1st	2nd	3rd			1st	2nd	3rd		
2008	May	14.9	16.3	16.9	16.0	+2.5	1.4	-	-	1.4	-55.6
	June	22.3	17.8	22.2	20.7	+4.4	-	2.9	20.6	23.5	-55.5
	July	21.0	20.7	23.3	21.7	+3.6	52.2	27.7	5.8	85.7	-5.3
	August	22.3	20.9	18.1	20.3	+2.5	16.6	61	19	96.6	+32.6
	September	20.6	11.6	11.5	14.6	+1.0	9.5	0.7	17.6	27.8	-23.2
2009	May	15.3	15.7	16.5	15.8	+2.3	1.6	15.6	37.0	54.2	-2.8
	June	15.2	17.2	18.6	17.0	+0.7	5.4	21.0	52.9	79.4	+0.4
	July	21.2	21.1	20.6	21.0	+2.9	32.1	69.8	14.0	115.9	+24.9
	August	21.9	21.4	20.7	21.3	+3.5	79.3	12.7	2.0	94.0	+30.0
	September	18.2	16.8	15.6	16.9	+3.3	3.1	-	3.9	7.0	-44.0
2010	May	13.2	11.6	14.8	13.3	-0.2	29.8	77.2	27.5	134.5	+77.5
	June	18.6	16.0	17.9	17.5	+1.2	13.4	11.4	-	24.8	-54.2
	July	20.4	23.3	19.3	21.0	+2.9	7.0	34.6	37.5	79.1	-11.9
	August	19.8	19.3	17.5	18.8	+1.0	16.2	14.0	43.8	74.0	+10.0
	September	12.6	12.5	12.2	12.5	-1.1	26.0	11.8	51.0	88.8	+37.8
2011	May	10.5	16.0	17.9	14.9	+1.4	6.7	13.9	20.8	41.4	-15.6
	June	20.4	18.7	18.3	19.1	+2.8	3.9	4.5	13.5	21.9	-57.1
	July	18.2	20.5	16.3	18.2	+0.1	65.5	40.0	47.7	153.2	+62.2
	August	19.3	19.4	19.5	19.4	+1.6	1.6	11.6	9.5	22.7	-41.3
	September	17.3	16.1	14.5	15.9	+2.3	20.9	0.9	-	21.8	-29.2
2012	May	16.4	13.3	17.8	15.9	+2.4	10.5	2.5	7.5	20.5	-36.5
	June	14.1	18.6	18.8	17.2	+0.9	26.9	40.5	9.7	77.1	-1.9
	July	22.4	17.3	20.6	20.1	+2.0	31.8	19	20	70.8	-20.2
	August	20.7	18.9	19.6	19.7	+1.9	13	21.5	13.9	48.4	-15.6
	September	16.8	14.3	13.5	14.8	+1.2	13.2	31.8	-	45	-6.0

in a continuous way, while the rainfall was measured using Hellmann's rain meter. The obtained data were compared with those from the Institute of Meteorology and Water Management for the long-term period of 1971-2000 (Tab. 1). The following mulches were used in the cultivation of eggplant: black and transparent polyethylene foil, 0.05 mm thick, and black polypropylene textile with a weight of 60 g m^{-2}. Before covering the soil with transparent foil, the soil surface was sprayed with napropamide + metribuzin (900 + 350 g ha^{-1}) mixtures. Herbicide was incorporated, using harrow on the soil at a 3 cm depth. The control objects were plots with no mulching applied. The seedlings of eggplant cultivar Epic F_1 were produced in a greenhouse. The seeds were sown on 28-30 March into seed boxes, and seedlings at the stage of having completely unfolded cotyledons were transplanted to pots with a diameter of 10 cm. The growing medium for the seedlings was peat substrate. The vegetables were planted in the field in strips, in a spacing of 140 × (60 × 50) cm (planting dates in Tab. 2). The size of one plot was 4 m^2 (2 × 2 m). Immediately before planting the seedlings, the field was fertilised with nitrogen in the form of ammonium nitrate in the amount of 150 kg N ha^{-1}. The eggplant fruit were picked every 5-7 days (Tab. 2). Each year and each time the fruits were picked, the marketable yield was assessed and on this basis it was possible to calculate the total marketable yield, as well as the early yield. It was assumed that the early yield was the fruit yield from the first three crops.

The aim of the conducted research was to assess the influence of mulching on eggplant yielding, as well as to determine the most advantageous weather conditions for the yielding of this species, on the basis of the relationships observed throughout the years. The results of the experiment were subjected to statistical analysis, using the Tukey test for a significance level of p = 0.05.

RESULTS AND DISCUSSION

It was proven on the basis of the obtained research results that there are significant differences in eggplant yielding depending on the actual weather conditions (Tab. 3). This confirms the opinion of Kashyap et al. (2003), who said that eggplant yielding is determined to a large extent by the environment, especially by the temperature. The year 2012 was the most favourable for eggplant yielding. From the moment of planting the seedlings until the final crops, the average air temperature remained at a level of 17.6ºC, the rainfall was rather evenly distributed and its total amount was 241.3 mm. High temperatures in the 2nd and 3rd 10-day periods of June and in the 1st 10 days of July (18.6ºC-22.4ºC) resulted in abundant blooming and fruit formation (Tab. 1). According to Chen and Li (1997), the optimal temperature for eggplant growth is between 21-29ºC, whereas for Lawande and Chavan (1998) it is 22-30ºC and at night it should be 18-24°C. Moderate rainfall that occurred in the 1st and 2nd 10-day periods of June 2012 accelerated the process of root taking by plants and contributed to their intensive growth. The temperature recorded in the 1st and 2nd 10 days of September was 2ºC higher on average than the long-term mean. Thanks to such weather conditions, fruit yields started earlier than in the previous years and they could be continued regularly until mid-September (Tab. 2). It should be emphasised that the amount of eggplant fruit yielded at the end of August and in September was much larger than in other years (Fig. 1). In 2012, the total yield of eggplant, independently of the type of the mulch used, amounted to 43.73 t ha^{-1}, with the early yield constituting 8.2%. This could be compared to the yield of eggplant cultivated in Iran with the use of irrigation but without fertilising with N (Aminifard et al. 2010).

The total yield obtained in 2011 was 10% smaller than in 2012. The percentage of the early yield was 25.9%. As is shown in Fig. 1, the amount

Table 2. Characteristics of the eggplant growing season in 2008-2012

Year	2008	2009	2010	2011	2012
Planting date	02.06.	25.05.	28.05.	30.05.	02.06.
Harvest period (from first to last harvest)	11.07.-23.09.	22.07.-30.09.	14.07.-14.09.	06.07.-13.09.	29.06.-14.09.
Harvest number	9	4	10	9	12
Days					
– from transplanting to first harvest	39	58	47	37	27
– the period of fruit harvesting	75	71	63	70	78
– the vegetation period	114	129	110	107	105

Table 3. The yield of eggplant in subsequent years, dependent on the type of mulch, in 2008-2012, (t ha^{-1})

Yield	Type of mulch	2008	2009	2010	2011	2012	Mean
Early	black PE foil	3.70	0.10	2.58	10.33	3.21	3.99
	transparent PE foil	5.03	0.30	2.96	13.71	3.38	5.08
	black PP agrotextile	5.27	0.20	3.50	9.71	3.42	4.42
	control, without mulches	5.10	0.30	3.05	7.00	4.33	3.96
	mean	4.78	0.23	3.02	10.19	3.58	4.36
	$LSD_{\alpha=0.05}$ for:						
	years (I)						1.28
	type of mulch (II)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	interaction I×II						n.s.
Total	black PE foil	8.40	11.02	13.63	43.50	46.63	24.63
	transparent PE foil	13.85	8.50	16.00	42.81	42.33	24.70
	black PP agrotextile	14.50	9.63	11.92	38.75	38.71	22.70
	control, without mulches	12.97	1.37	12.53	32.29	47.25	21.28
	mean	12.43	7.63	13.52	39.34	43.73	23.33
	$LSD_{\alpha=0.05}$ for:						
	years (I)						2.40
	type of mulch (II)	n.s.	5.44	1.87	6.15	n.s.	2.29
	interaction I×II						5.03

of eggplant fruit picked was bigger each time than in the year 2012 until the 1st 10 days of August 2011. However, later one could observe a falloff. In 2011, the average air temperature and total rainfall were similar to those from 2012. Rainfall was unevenly distributed. In June, after planting the seedlings, the temperature held more or less on the level of 19.1ºC, but the rainfall was 3.6 times lower than usual in this month. Such conditions extended the period between planting the seedlings and the first fruit yield by 10 days. Very high rainfall was recorded in July; it exceeded the average long-term total by 62.2 mm, while in August there was an shortage of 41.3 mm. In such weather conditions, using mulches appeared to favour eggplant yielding. In cultivation using the PE foil and PP textile mulches the yield was greater when compared to that obtained from the control plots, on average by 33.6% and 20%, respectively.

The eggplant yield was comparable in the years 2008 and 2010 (Tab. 3). However, it was 3.4 times smaller on average compared to the greatest yield obtained in 2012. This might be caused by less favourable weather conditions. In 2008, the period of fruit picking was relatively long, but at the same time the period between seedling planting and the first fruit yield was extended (compared to 2012). In that year, the thermal conditions were optimal for

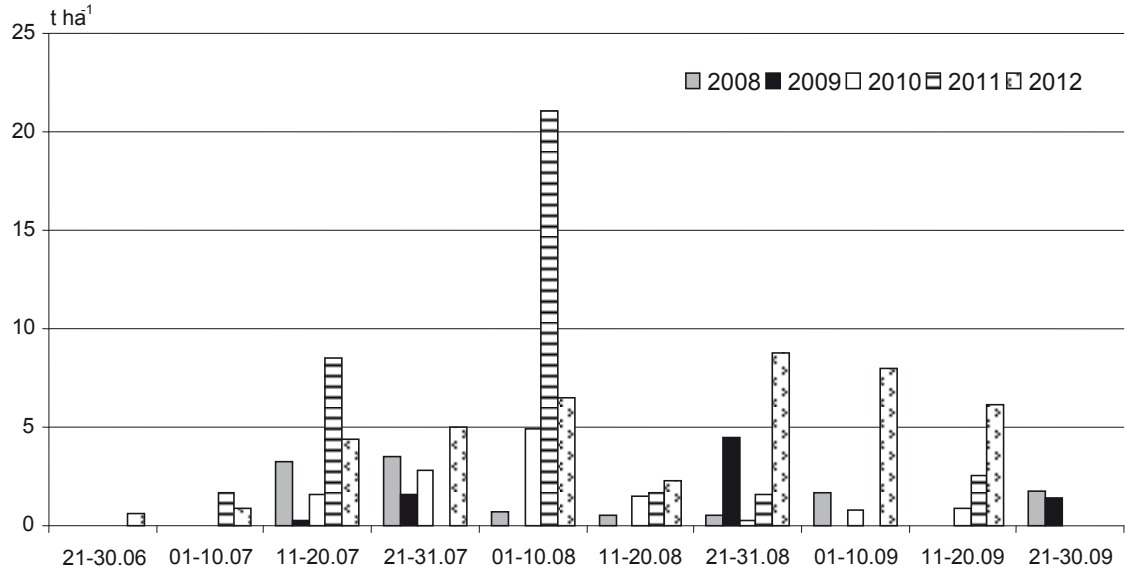

Figure 1. The yield of eggplant in terms of successive harvests in 2008-2012, t ha^{-1}

eggplant growth throughout the vegetation period (Tab. 1). The average temperature in June, July and August was by 4.4ºC, 3.6ºC and 2.5ºC higher than the long-term means. On the other hand, there were long periods with very low rainfall or no rainfall at all. In that year, no significant influence of mulching on eggplant yielding was confirmed. Disadvantageous weather conditions in 2010 were as follows: lower than average temperatures in the 2nd 10-day period of June and from the 3rd 10 days of August until mid-September, as well as low rainfall in June and in the 1st 10 days of July. As a result, the period of fruit picking was 15 days shorter compared with the year 2012 and the period between planting the seedlings and the first fruit yield was 20 days longer. In those weather conditions, the plants cultivated on transparent foil produced yields that were significantly bigger (by 26.1%) as compared to other objects.

Retarded plant growth and delayed intensive yielding in 2009 resulted from relatively low temperatures after planting the eggplant, at the turn of May and June. Still, the crucial disadvantageous factor was the high rainfall that occurred in the 3rd 10-day period of June, in the 1st and 2nd 10-day periods of July and in the 1st 10 days of August. It constrained the pollination of flowers and made the flowers and fruit buds fall. A temporary excess of water within the reach of the root system inhibited plant growth. Those unfavourable weather conditions extended the period between planting the seedlings and the first yield more than twice, and caused the marketable yield of eggplant fruit to decrease 5.7 times when compared to the best year, 2012. Eggplant cultivation with mulches counteracted the negative effect of weather conditions (mostly thermal), especially in 2009 (Tab. 3). Soil temperature increases under mulches were confirmed by Diaz Perez et al. (2007) and Moreno and Moreno (2008). The yield of eggplants in that treatment was seven times higher than in the control. The negative influence of chilly periods or large day and night temperature fluctuations, especially when combined with worse light conditions, on the vitality of pollen and fruit formation was confirmed by Chen and Li (1997), Uzun (2006) and Kowalska (2008).

The conditions for vegetable growth can be improved by using various agro-technical solutions, e.g. soil mulching. On the basis of the conducted research we found that independent of the type of mulch used, the total eggplant fruit yield was on average 12.8% bigger than in the control. A statistically significant increase in the total yield was observed in cultivation on polyethylene, black and transparent foil, by 15.9% on average. The influence of mulches on the early yield of eggplant was not statistically proven, but we noticed that in the cultivation on transparent foil and on black polypropylene textile, this yield was on average 28.3% and 11.6% bigger than in traditional cultivation, respectively. An increase in the yield of tomato and pumpkin cultivated on black polyethylene foil mulch was observed by Brown and Channell-Butcher (2001) and by Gordon et al. (2008), and of lettuce cultivated on transparent and black foil by Siwek et al. (2007).

As a result of the presented long-term research, taking into consideration the climate conditions, the field production of eggplant in Poland may fail. For that reason, it is mainly introduced is cultivation in greenhouses and foil tunnels (Ambroszczyk et al. 2008, Markiewicz et al. 2008, Michałojć and Buczkowska 2008, Buczkowska 2010). In the field production of eggplant, any procedures that diminish the influence of stress conditions might improve the species' growth and yielding. As Kashyap et al. (2003) reported, breeding new transgenic cultivars may also reduce the influence of abiotic factors such as weather conditions on eggplant growth and yielding. Cultivars that are tolerant of stress conditions, such as drought or chill, were obtained, for example, through the introduction of the bacterium gene responsible for the synthesis of the compound mannitol-1-phospho dehydrogenase (Prabhavati et al. 2002).

CONCLUSIONS

1. The fruit yielding of eggplant cultivated in the field in a moderate climate depends significantly on weather conditions. High temperature and evenly distributed rainfall throughout the vegetation period in 2011 and 2012 were favourable conditions for eggplant yielding.
2. The highest yield of fruit, an average of 43.73 t ha^{-1}, was collected in 2012. This year had the longest harvest period (78 days) and the shortest period from transplanting to the first harvest of eggplant fruit (27 days).
3. Mulching the soil with polyethylene black foil or transparent foil after previously having applied a herbicide was a beneficial agro-technical treatment that significantly increased the fruit yielding of eggplant.

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