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THE EFFECT OF TEMPERATURE ON THE BROCCOLI YIELD AND LENGTH OF THE PERIOD FROM HEAD INITIATION TO HARVEST

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Abstract. Temperature is a factor which strongly affects the yield and broccoli head quality. Temperature determines the date of head initiation and thus affect the length of vegetation period. An experiment the aim of which was to assess the impact of temperature on the yield and the length of the period from the broccoli head initiation until the beginning and end of harvest as well as the length of the harvest period was carried out in years 1997–1999. The seedlings of cv. Fiesta were planted in April, May, June and July. The phase of head initiation was determined on the basis of analyses of microscopic preparations. The highest total yield was obtained from May and June planting dates, the highest marketable yield was recorded in the case of the May date planting. A higher correlation was found between the sum of temperature and mean daily air temperature in the period from the initiation to the beginning and end of harvest and mean weight of marketable heads than between temperature and the total yield. The highest correlation was determined between the mean air temperature and the number of days from the head initiation to the last harvest.

Key words: *Brassica oleracea* var. *italica*, growth conditions, generative phase, date of harvest

INTRODUCTION

Broccoli is a plant that strongly responds to climatic conditions, especially to temperature. Growth conditions have a decisive impact on the level and, in particular, on the quality of the yield [Heather et al. 1992, Björkman and Pearson 1998, Birch et al. 2000]. Furthermore, climatic conditions also determine the length of the vegetation period. Babik and Elkner [1997] claim that the difference in the duration of the vegetation period in the same cultivar planted at identical dates in two consecutive years may

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amount even up to 2 weeks. Temperature has a strong influence on the transfer from the vegetative to generative phase of the plant development [Gaus and Taylor 1969, Fellows 1997, Mourao and Brito 2000, Kałużewicz et al. 2002]. Numerous researchers carried out investigations aiming at the identification of temperatures most favourable for the head initiation [Diputado and Nichols 1989, Wurr et al. 1995, Grevsen and Olesen 1999, Tan et al. 2000] as well as at the determination of the conditions which reverse this process [Fontes et al. 1967]. On the other hand, few papers were devoted to the determination of the effect of cultivation conditions on the length of the period from the moment of head initiation until its harvest.

The objective of this research project was to determine the impact of temperature on broccoli yield and the length of the period from the head initiation to harvest and the length of the harvest period.

MATERIAL AND METHODS

The experiment was carried out on the field of the Department of Vegetable Crops situated in the Experimental Station "Marcelin in 1997–1999. Broccoli seedlings cv. 'Fiesta' were produced in multiple pots of 5 cm diameter filled with peat substrate. Seedlings were planted out in the field at the stage of 5 leaves in the randomised block design in 4 replicates. In consecutive experimental years, 25 seedlings were planted out in experimental plots at 0.5 × 0.5 m spacings at four dates (tab. 1). An additional plot comprising 100 plants was established to accompany each experimental plot and its aim was to provide material for apex collection to determine the phase of head initiation. In 1997, every 3–4 days 8 apices, while in years 1998 and 1999 – 4 apices were collected in order to estimate their stage of development.

Table 1. Dates of planting of broccoli seedlings of cv. 'Fiesta' in 1997–1999
Tabela 1. Terminy sadzenia brokuła odmiany 'Fiesta' w latach 1997–1999

Year – Rok	Planting date – Termin sadzenia
1997	21 April, 10 May, 12 June, 9 July
1998	8 April, 12 May, 19 June, 21 July
1999	8 April, 6 May, 10 June, 9 July

The obtained microscopic preparations were subjected to histological assessment. The date of head initiation assumed as the day on which at least half of the examined apices were found to be at the early generative phase was determined for each date of planting.

The harvest began when the heads were well developed and buds reached the size of about 2 mm. Marketable yield consisted of heads of minimal diameter reached 9 cm and showed no quality defects. Loose heads made up of nonuniform buds, uneven surface and small size (with the diameter smaller than 9 cm) were treated as non-marketable yield.

The length of the period from head initiation to the first and last harvest as well as the length of the harvest period were determined. For each of the above-mentioned periods, the sum of temperature and correlations between mean daily air temperatures in these periods and their lengths were calculated. Correlation coefficients were calculated between the sum and mean air temperatures in the period from head initiation to the beginning and end of harvest, on the one hand and the total yield and mean marketable head weight, on the other.

Meteorological data from the entire experimental period were obtained from the Meteorological Station Poznań-Ławica situated approximately 2 km from the Experimental Station.

RESULTS AND DISCUSSION

Total and marketable yield. The highest total yield was obtained from May and June planting dates (17.7 to 17.1 t·ha^{-1} respectively) and significantly smaller ones – from April and July plantings (tab. 2). The highest total yield was recorded in 1998, while the smallest – in 1997. The greatest yield variability was recorded in June planting dates (13.4 to 22.2 t·ha^{-1}), while the smallest – when seedlings were planted out in July (13.7 to 15.5 t·ha^{-1}). Kunicki et al. [1997] confirmed small total yield differences at two consecutive harvest years in the case of 'Fiesta' cultivar cultivated from seedlings planted in July, whereas differences in yield of cv. 'Colonel' amounted to 10 t·ha^{-1}, and yield of cv. 'Packman' to 9 t·ha^{-1}.

Table 2. Total, marketable yield and mean marketable head weight of broccoli broccoli cv. 'Fiesta' in 1997–1999

Tabela 2. Plon ogólny i handlowy oraz średnia masa róży handlowej brokuła odmiany 'Fiesta' w latach 1997–1999

	Year Rok	Planting date – Termin sadzenia				Mean Średnia
		April kwiecień	May maj	June czerwiec	July lipiec	
Total yield Plon ogólny, t·ha^{-1}	1997	12.4 d	15.7 c	13.4 de	15.5 de	14.3 c
	1998	17.9 b	18.2 b	22.2 a	13.7 cde	18.0 a
	1999	14.6 cde	19.3 b	17.1 c	14.7 cd	16.4 b
	mean – średnia	15.0 b	17.7 a	17.6 a	14.6 b	
Marketable yield Plon handlowy	1997	12.3 d*	15.2 bcd	21.1 d	15.1 bcd	13.7 a
	1998	16.6 bc	16.2 bc	21.9 a	5.7 e**	15.1 a
	1999	14.1 cd	17.8 b	12.9 d	14.9 bcd	14.9 a
	mean – średnia	14.3 b	16.4 a	15.6 b	11.9 c	
Mean marketable head weight Średnia masa róży handlowej, g	1997	315 f*	422 cd	327 ef	409 d	368 b
	1998	443 bcd	386 de	620 a	388 de	459 a
	1999	378 de	499 b	475 bc	408 d	440 a
	mean – średnia	379 c	436 b	474 a	402 c	

*means followed by the same letter do not differ significantly at P = 0.95 – średnie oznaczone tą samą literą nie różnią się pomiędzy sobą istotnie przy P = 0,95

**low marketable yield was caused by the occurrence of bacterial rot in heads – niski plon handlowy był powodowany bakteryjną zgnilizną główek

The highest marketable yield (tab. 2) was recorded in the case of the May date plantings (16.4 t·ha^{-1}), lower when broccoli seedlings were planted out in April and June and the lowest – for July plantings (11.9 t·ha^{-1}). The smallest variations in levels of marketable yield between planting dates were observed in 1997 (12.1–15.2 t·ha^{-1}) and the highest (5.7–21.9 t·ha^{-1}) – in 1998.

The highest mean head weight (tab. 2) during the entire period of experiments was obtained when seedlings were planted out in June (474 g) and the lowest – when seedlings were planted out in April and July (378–402 g). In years 1998 and 1999 the mean weight of marketable heads amounted to 459 and 440 g, respectively. The above values differed significantly from mean head weights recorded in 1997 (368 g).

Number of days from the initiation until the first and last harvest and the length of the harvest period. The number of days from the initiation to the beginning of harvest was nearly identical for May and June dates of seedling planting out and amounted to 36–37 days (tab. 3). In the case of the remaining two dates, this period was 41 days when seedlings were planted out in April and 44 days in July. In years 1998 and 1999 the period from the initiation to the beginning of harvest, on average, amounted to 42 days, whereas in 1997 it lasted 35 days. In experiments on broccoli cultivated in the field, Grevsen [1998] found that differences between planting dates regarding the length of the period from the initiation to the harvest reached up to 34%. In our experiments, small, only a few days long, differences occurred in the length of this period between dates of plantings in 1997 and several-day long (up to 25%) in 1998.

Tabela 3. Długość okresu od sadzenia do pierwszego i ostatniego zbioru oraz długość okresu zbiorów u brokuła odmiany 'Fiesta' w latach 1997–1999

Table 3. Number of days from the initiation to the first and last harvest, length of harvest period of broccoli cv. 'Fiesta' planted at four dates in 1997–1999

	Year Rok	Planting date – Termin sadzenia				Mean Średnia
		April kwiecień	May maj	June czerwiec	July lipiec	
Number of days from the head initiation to first harvest Liczba dni od inicjacji róży do pierwszego zbioru	1997	37	35	35	32	35
	1998	41	35	39	52	42
	1999	44	39	36	49	42
	mean – średnia	41	36	37	44	
Number of days from the initiation to the last harvest Liczba dni od inicjacji róży do ostatniego zbioru	1997	50	39	37	44	43
	1998	46	42	46	64	50
	1999	50	49	46	55	50
	mean – średnia	49	43	43	54	
Length of harvest period, days Długość okresu zbiorów, dni	1997	13	4	2	12	8
	1998	5	7	7	12	8
	1999	6	10	10	6	8
	mean – średnia	8	7	6	10	

The longest, during the entire time of investigations, period from the initiation to the last harvest was recorded when seedlings were planted out in July (54 days); it was 5 days shorter when they were planted out in April and by 11 days shorter when the seedlings were planted in May and June (tab. 3). On average, in 1998 and 1999, the period from the initiation to the end of harvest amounted to 50 days, while in 1997 – 43 days.

The harvest period lasted from 6 days when seedlings were planted out in June to 10 days when they were planted in July (tab. 3). On average, in individual experimental years the same length of the harvest period (8 days) was recorded.

Sum of temperature in the period from the initiation to the beginning and end of harvest and during harvest period. The sum of heat units is a parameter on the basis of which it is possible to characterise the length of individual periods of plant growth [Warnok 1970, Perry et al. 1990, Grevsen 2000].

The sum of temperature during the period from the initiation to the beginning of harvest depended on the planting date and year of investigations (tab. 4). The sum of temperature was the highest when seedlings were planted out in July (597 day-degrees), slightly lower when seedling were planted in June (575) and the lowest when seedlings were planted out in April and May (473 and 484 day-degrees, respectively). These results confirm those reported by Default [1997] who obtained the lowest sum of temperature calculated for the period from planting until the first harvest in the case of spring planting dates. Differences in sum temperature between the spring planting date and planting carried out in July and August were even twice as high in the case of some cultivars.

Table 4. Sum of temperature from the head initiation to the first, last harvest and during the harvest period of broccoli cv. 'Fiesta' in 1997–1999

Tabela 4. Suma temperatury od inicjacji do pierwszego zbioru i ostatniego zbioru oraz w okresie zbiorów brokuła odmiany 'Fiesta' w latach 1997–1999

	Year Rok	Planting date – Termin sadzenia				Mean Średnia
		April kwiecień	May maj	June czerwiec	July lipiec	
Sum of temperature from the head initiation to the first harvest, day-degrees Suma temperatury od inicjacji róży do pierwszego zbioru, stopniodni	1997	410	501	506	525	486
	1998	545	433	597	534	527
	1999	463	520	621	732	584
	mean – średnia	473	485	575	597	
Sum of temperature from the head initiation to the last harvest, day-degrees Suma temperatury od inicjacji róży do ostatniego zbioru, stopniodni	1997	558	554	536	637	571
	1998	614	529	661	570	594
	1999	537	698	791	806	708
	mean – średnia	570	594	663	671	
Sum of temperature during the harvest period, day-degrees Suma temperatury w okresie zbiorów, stopniodni	1997	148	54	30	111	86
	1998	69	96	63	35	66
	1999	74	179	171	75	125
	mean – średnia	97	110	88	74	

In experiments carried out by Kar and Uzun [2000], the sum of temperature for the period from the initiation to harvest was considerably lower in comparison with the presented trial and fluctuated from 300 to 400 day-degrees.

The sum of temperature in the period from the initiation until the end of harvest fluctuated from 594 day-degrees when seedlings were planted out in May to 671 day-degrees when plantings were made in July (tab. 4). From among the compared three experimental years, the highest sum of temperature (708 day-degrees) was recorded in 1999 and the lowest – in 1997 (571 day-degrees).

The highest sum of temperature during the period of broccoli head harvest was observed in the case of seedlings planted out in May (109 day-degrees), while the lowest – those planted in July (74 day-degrees) (tab. 4). When seedlings were planted out in June, the sum of temperature amounted to 88 day-degrees and when in April – to 97 day-degrees. Year 1999 was characterised by the highest sum of temperature during harvest (125 day-degrees, whereas 1998 – by the lowest (66 day-degrees).

Relationships between air mean daily temperature and sum of temperature and the total yield and mean marketable head weight of broccoli. The highest, but non-significant, correlation coefficients occurred between the sum of temperature from the head initiation to the beginning and end of harvest, mean daily temperature from the initiation to the beginning and end of harvest and the mean weight of the marketable head. Equally high, although non-significant, was the correlation coefficient between the mean daily temperature from the initiation until the end of harvest and the total yield (tab. 5).

Table 5. Correlation coefficients (r) between sum of temperature and mean daily air temperature and total yield and mean weight of marketable broccoli heads of cv.' Fiesta' in 1997–1999

Tabela 5. Zależność (r) między średnią dobową i sumą temperatury powietrza a wielkością plonu ogólnego i średnią masą róży handlowej

	Total yield Plon ogólny t	Mean head weight Średnia masa róży g
Sum of temperature from initiation to the first harvest Suma od inicjacji do początku zbiorów	0.23	0.46
Sum of temperature from initiation to the last harvest Suma od inicjacji do końca zbiorów	0.30	0.50
Mean daily temperature from initiation to the first harvest Średnia temperatura od inicjacji do początku zbiorów	0.37	0.46
Mean daily temperature from initiation to the last harvest Średnia temperatura od inicjacji do końca zbiorów	0.41	0.43

Table 6. Correlation coefficients between mean daily air temperature and number of days from the initiation to the first and last harvest and the number of harvest days in broccoli cv. 'Fiesta' in 1997–1999

Tabela 6. Współczynniki korelacji pomiędzy średnią dobową temperaturą powietrza, a liczbą dni od inicjacji do pierwszego i ostatniego zbioru oraz liczbą dni zbioru u brokuła odmiany 'Fiesta' w latach 1997–1999

Daily mean temperature Średnia dobowa tempeartura, °C	Number of days Liczba dni
From initiation to first harvest Od inicjacji do początku zbioru	-0.49*
From initiation to last harvest Od inicjacji do końca zbiorów	-0.57*
During the harvest period W okresie zbiorów	-0.36*

* correlation coefficients (r) significant at P = 0.05 – współczynnik korelacji istotny na poziomie istotności P = 0,05

Correlation between mean daily air temperature and number of days from the initiation to the first day of harvest till the end of harvest and the number of harvest days in broccoli cv. 'Fiesta' in years 1997–1999. A significant negative correlation was found between the mean daily temperature in the period from the initiation until the first day of harvest (r = -0.49) until the end of harvest (r = -0.57) as well as between the mean daily temperature and the length of the harvest period (r = -0.36) (tab. 6).

CONCLUSIONS

1. The highest total yield was obtained from May and June planting dates, the highest marketable yield was recorded in the case of the May date planting.
2. A higher correlation was found between the sum of temperature and mean daily air temperature in the period from the initiation to the beginning and end of harvest and mean weight of marketable heads than between temperature and the total yield.
3. A similar mean length of the period from the initiation to the beginning and end of harvest was found when seedlings were planted out in May and June.
4. The comparison of individual periods of cultivation showed considerable variability in sum of temperature in periods from the initiation to the first and last harvest as well as the length of the harvest period.
5. The higher was the mean daily air temperature, the shorter was the time from the head initiation until the beginning and end of harvest. Moreover, the period of harvest was also shorter.

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WPŁYW TEMPERATURY NA WIELKOŚĆ PLONU BROKUŁA I DŁUGOŚĆ OKRESU OD INICJACJI RÓŻY DO ZBIORU

Streszczenie. Temperatura jest czynnikiem, który silnie wpływa na wielkość i jakość plonu brokuła. Determinuje również termin zainicjowania róży, wpływając przez to na długość okresu wegetacji. Doświadczenie, którego celem była ocena wpływu temperatury na wielkość plonu brokuła i długość okresu od zainicjowania róży do początku i końca zbiorów oraz długość okresu zbiorów, przeprowadzono w latach 1997–1999. W każdym roku prowadzenia doświadczenia rozsadę brokuła odmiany 'Fiesta' wysadzano w czterech terminach: kwiecień, maj, czerwiec i lipiec. Fazę inicjacji róży określono na podstawie analizy preparatów mikroskopowych. Największy plon ogólny uzyskano, gdy posadzono rośliny w maju i czerwcu, a największy plon handlowy przy sadzeniu roślin w maju. Stwierdzono wyższą zależność między sumą i średnią dobową temperaturą powietrza w okresie od inicjacji do początku i końca zbiorów, a średnią masą róży handlowej niż między temperaturą a wielkością plonu ogólnego. Najwyższą zależność stwierdzono między średnią dobową temperaturą powietrza, a liczbą dni od inicjacji do ostatniego zbioru.

Słowa kluczowa: *Brassica oleracea* var. *italica*, warunki wzrostu, faza generatywna, termin zbioru

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