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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of biological Sciences 3 (6): 915-919, 2000

Study on Determination of Planting Time for Some Cauliflower Cultivars (*Brassica oleracea* var. *botrytis*) Under Samsun Ecological Conditions by Using Plant Growth and Developmental Models Based on Thermal Time

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Abstract: In this study, it was aimed to determine the effects of different planting times (01 July, 15 July and 01 August) on the growth and developmental components of some cauliflower cultivars (Snow King, White Cliff, White Rock, White Latin, Me & Carillon, SG 4004 F1 and Serrano) by using plant growth and developmental models. From the results of the present study, it was revealed that thermal time elapsing from planting to curd initiation should be high (about 1200°C days) to stimulate vegetative growth while thermal time elapsing from curd initiation to the harvest should be low (around 200°C days) in terms of curd weight. The highest curd weight and yield were obtained from the plants of the first planting time, namely 01 July, compared to the other planting times (15 July and 01 August). Although there were no significant differences between the cultivars, the highest yield was obtained form Cv. Me & Carillon (13.25 t ha^{-1}), SG 4004 F1 (13.14 t ha^{-1}) and White Rock (11.51 t ha^{-1}) respectively.

Key words: Cauliflower, planting time, thermal time.

Introduction

Although people in Turkey has a high vegetable consumption habit, cauliflower consumption is as low as 1 kg per person per year (Anonymous, 1988). In many countries, cauliflowers have been grown as summer, autumn and winter crops (Biggs, 1992). However, cauliflower earns high profit to the growers in our country when grown both during spring and autumn periods (Bayraktar, 1981).

To date, there have been no serious attempts for determining the cultivars that could be adapted to the Black sea region and the most convenient planting times of this crop. The importance of these researches come from the fact that curd weight and quality of cauliflower crops depend firstly on the climate and cultivation methods (Pearson, 1992). Hadley *et al*. (1983a, b) reported that there was a marked difference between optimum temperature range needed for the time from planting to curd initiation and the optimum temperature range needed for curd growth of cauliflowers. Tindall (1992) reported that cauliflowers subjected to temperatures above 25°C show decolouration in addition to having leafy and soft curds. It was also revealed that there was a close relationship between temperature ranges during early growing period, curd quality and planning production of cauliflowers. In recent years, simulation models based on temperature have been used to predict the time from planting to curd initiation (Pearson, 1992). Studies on determining optimum temperatures for curd growth in cauliflower showed that there was a positive correlation between curd growth period and mean temperatures during the period from 15 to 20 days after curd initiation Grevsen and Olesen (1994a). A study examining the response of 10 different cauliflower cultivars, grown from 31 March to 15 May at one month intervals to temperature and photoperiod, revealed that cultivars could be grouped differently in terms of maturity (Yadav *et al*., 1995). Therefore, it is obvious that there is a reasonable profit to find out suitable planting times of cauliflowers depending on varying climatic conditions.

Curd growth periods of cauliflower have been calculated by using simple mathematical models based on thermal time (degree days) (Monteith, 1981) and logarithm of curd diameter (Wurr *et al*., 1990a, b and 1991). In a previous study, juvenule phase and proceeding from planting to curd initiation in cauliflower have been investigated by calculating thermal time fromplanting to curd initiation (Pearson, 1992). In this study, thermal time requirements (with a base temperature of °C) of 6 cauliflower cultivars varied from 26 to 83°K days, while other cultivars required 250°K days. These cultivars also had 12 and 17 to 19 leaves before curd initiation in addition to having a positive linear relationship between curd growth period and increasing temperatures. On the other hand, Grevsen and Olesen (1994b), indicated that optimum temperature was 12.8°C, while base and maximum temperatures were 0°C and 25.6°C for cauliflowers respectively. A study by Pearson (1992) revealed that there was a positive relationship between proceeding to curd initiation (1/days to first curd initiation) and mean temperatures for 43 cauliflower cultivars. The same study, showed that curd initiation rate in the population increased with temperature up to 14°C and declined thereafter.

The objective of this study is therefore to determine the most suitable planting time in cauliflower grown under Samsun ecological conditions by utilising plant growth and developmental models.

Materials and Methods

This study was carried out in both field and laboratories of Ondokuz Mayýs University, Faculty of Agriculture, Department of Horticulture from spring to autumn. Seven cauliflower cultivars (Snow King (C1), White Cliff (C2), White Rock (C3), White Latin (C4), Me & Carillon (C5), SG 4004 F_1 (C6) and Serrano (C7)) were used in the study. Seedling of the cultivars were grown in open seed beds by sowing seeds in lines 10 cm apart (3 g of seeds per square meter). Seeds were sown three times at 15 day intervals starting from 23 April. Planting was made in raised beds (1 m wide, 10 m long) by single row planting method. A distance of 60 cm in rows and 60 cm between rows were maintained and seedlings with seven true leaves were used in planting. In the study, the following plant growth, development and yield parameters were investigated; thermal time requirement from planting to curd initiation and from curd initiation to harvest, leaf number, mean leaf weight (g), mean root weight (g), plant height (cm) curd shape index (curd length/curd width), curd weight (g) and yield (t/ha). A simple model of the effects of temperature on the growth and development of cauliflower (Pearson, 1992) was also adapted to the present study. Thermal time for both from planting to curd initiation and from curd initiation to harvest was calculated with a base temperature of 2.8°C. Randomised block design with split blocks and three replications was applied to the experiment (Duzgunes *et al.*, 1987). Data analyses and graph drowings were carried out by using the MSTAT and the EXCEL computer programmes, respectively.

Results and Discussion

Thermal time elapsing from planting to curd initiation: As seen in Fig. 1, in general, thermal time elapsing from planting to curd initiation declined with delayed planting times. Leaf number per plant declined with the delayed planting times (Table 1). At the first planting time (01 July), vegetative growth was enhanced by the effect of low mean temperatures compared to the other planting times, namely 15 July and 01 August. It was also found that increasing temperatures at the second and third planting times caused the plants to have shorter vegetative growth periods. Marked differences amongst the cultivars grown for same planting times were also found (Fig. 1).

Pearson (1992) also revealed that thermal time (with a base temperature of 0°C) from curd initiation to harvest in cauliflowers grown at different planting times (March, April, May, June and July) declined as planting was delayed. Same worker also found that curd growth period in cauliflowers was reduced with the plantings from March to the middle of April and increased with the plantings up to June. In the present study, it was found that thermal time required from planting to harvest was high while this value was low for the second planting time and high again for the third planting time. Therefore the result obtained from the present study showed similarity to Pearson (1992) findings. A study examining six different cauliflower cultivars for four different planting times showed that when weather conditions were favourable, first harvest could be made 67 days after planting while this value varied from 78 to 94 days after planting for later plantings (Cebula and Kalisz, 1997a).

Thermal time elapsing from curd initiation to harvest: Results from the present study showed that thermal time elapsing from curd initiation to harvest varied from 100 to 1083°C days depending on planting time and cultivars. A study by Pearson (1992) showed that thermal time requirement of the tested cauliflower cultivars was around 296°C days. In the same study, an additional of 100 to 150°C days were required for the cultivars to mature. In the present study, when the second and third planting times were compared, it can be seen that the lowest thermal time requirement was obtained from the plants of the third planting time with an exception that C3 cultivar did not accord with the general trend. From the above result, we could say that the lower thermal time the plants required for vegetative growth the earlier they mature such as they required lower thermal time from curd initiation to harvest. Moreover, the same finding could be resulted from less vegetative growth caused by lower mean leaf number per plant. When the first and second planting times were compared, we can conclude that thermal time requirements from curd initiation to harvest were variable depending on the cultivars (Fig. 2). At the second planting time, four out of the cultivars tested had increased thermal time requirement while the other cultivars had lower thermal time requirement compared to the first planting time. From these results, the duration of cauliflower growth from planting to harvest can be determined by combining the thermal time from planting to curd initiation and the thermal time from curd initiation to harvest.

Curd weight: Curd weight of the plants at the first planting time (01 July) was the highest compared to the second and third planting times (Fig. 3). This was followed by the third and the second planting times, respectively (Table 1). The reason for having the highest curd weight at the first planting time could be the fact that plants grown at the first planting time had higher vegetative growth to enhance curd weight. At the second planting time, lower vegetative growth namely, leaf number per plant,

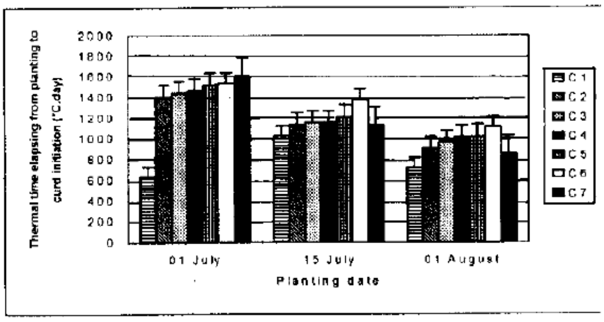

Fig. 1: The variations in thermal time elapsing from planting to curd initiation for the cultivars grown at different planting dates. Error bars represent standard errors of the mean and were placed at the level P<0.05

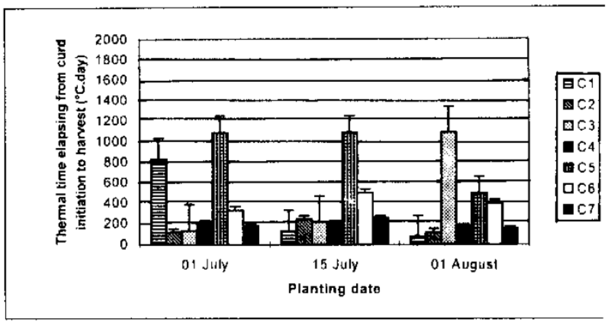

Fig. 2: The variations in thermal time elapsing from curd initiation to harvest for the cultivars grown at different planting dates. Error bars represent standard errors of the mean and were placed at the level P<0.05

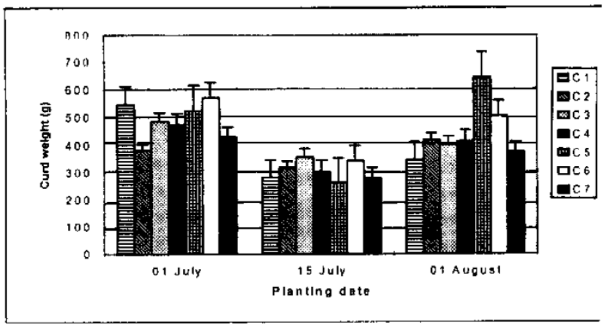

Fig. 3: The variations in curd weight (g) for the cultivars grown at different planting dates. Error bars represent standard errors of the mean and were placed at the level P<0.05

mean leaf weight, mean root weight and height and higher temperatures resulted in lower curd weight. The plants grown at the third planting time had the lowest leaf number per plant. On the contrary, they had higher mean leaf weight, root weight and

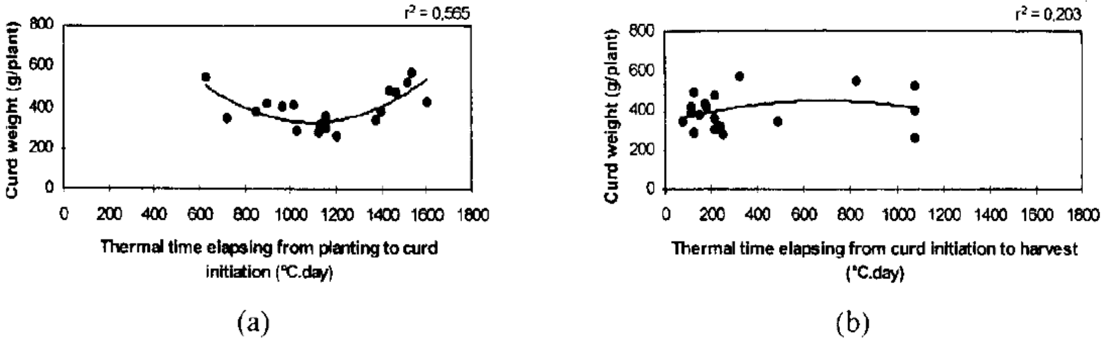

Fig. 4: The relationships between curd weight (g/plant) and thermal time elapsing from planting to curd initiation (a), and from curd initiation to harvest (b) (°C days)

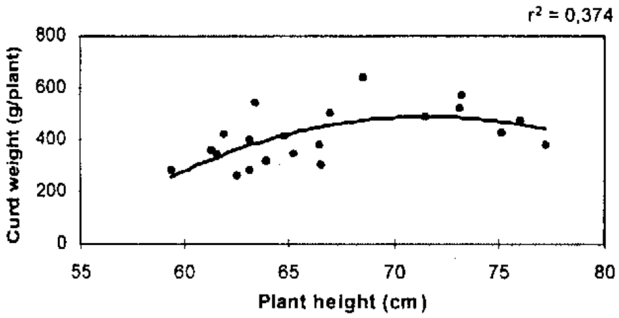

Fig. 5: The relationship between plant height (cm) and curd weight (g/plant). Data were gathered from all the cultivars grown at different planting dates

plant height compared to the second planting time in addition to the fact that higher temperatures prevailed during reproductive phase and increased curd growth period resulted in higher curd weight per plant. Temperatures above an optimum during curd growth were reported to cause the plants to have shorter curd growth period and less curd weight. On the other hand, Grevsen and Olesen (1994a) found a positive linear relationship between curd growth period in cauliflower and the temperatures above an optimum of 12.8°C.

Relationship between curd weight and thermal time: Results from the present study showed that there was a quadratic relationship ($r^2 = 0.565$) between curd weight and thermal time from planting to curd initiation as well as a quadratic relationship between thermal time from curd initiation to harvest and curd weight (Figure 4a and b). In general, plants required 600 to 1600°C days to initiate curd depending on the cultivars. As seen in Figure 4a, curd weight declined with increasing thermal time up to 1200°C days and increased after this point up to 1600°C days. Plants from the first planting time showed more vigorous vegetative growth and had more leaves formed on the stem before curd initiation compared with the plants from other planting times.
The reason for this was lower temperatures and light intensities, prevailed during this period. As a result of the above event, plant duration in the plants from the first planting time got longer and plant leaves utilised from photosynthesis for longer period in addition to increasing curd weight and yield accordingly.
In the light of the data from the present study, we can say that it should be recommended to the grower that growing cauliflower at high temperatures results in lower yield as a result of reduced vegetative growth. Hence, thermal time requirements should be taken into consideration to have higher yield or earliness. If earliness is wished, periods during which high temperatures causing the plants to have less leaf number before curd initiation prevail should be chosen. A study on the effects of different planting times on plant development, yield and curd quality of some cauliflower cultivars showed that marketable curd weight varied from 506.5 g (Christmas White) to 1365.0 g (Olympus). The first one was recommended to be grown as early cultivar while the latter one was offered to be used as late season cultivar (Padem *et al.*, 1996). It can be concluded that temperatures during vegetative growth of the cauliflower plants should be higher than those of curd growth for higher yield.

Relationships between curd weight and plant height: As plant height was plotted against curd weight per plant for all data gathered from the plants of all planting times, it was found that there was a quadratic relationship ($r^2 = 0.374$) between plant height and curd weight such as curd weight increased with plant height up to 70 cm and declined after this value (Fig. 5).

The effect of different planting times on some plant growth and yield parameters: As seen in Table 1, planting times had a significant ($P<0.01$) effect on leaf number per plant. In addition to a significant ($P<0.05$) effect of cultivars on leaf number per plant, there was also an interactive effect of planting time and cultivar ($P<0.01$) on leaf number. The highest leaf number (27.01) was obtained from the plants from the first planting time (01 July). This was followed by the plants from the second (20.31) and the third (17.17) planting times. In a study, it was found that there were large differences between experiments in term of mean leaf number formed at curd initiation of cauliflower, which ranged from 22 to 36.7 per plant (Wurr *et al.*, 1988). The results obtained showed similarities with their conclusions.
On the other hand, it was found that there were significant ($P<0.01$) differences between planting times and the cultivars in term of mean leaf weight per plant. The highest mean leaf weight per plant (28.33 g) was obtained from the plants of the third planting time (01 August). The plants of the first and the second planting times followed this by 25.86 and 21.45 per plant respectively (Table 1). There have also been significant effects of the planting times and the cultivars on mean root weight (g), such as the highest mean root weight (137.86 g) was obtained from the plants of the first planting time. In all planting times, the lowest mean root weight (72.67 g) was obtained from C1. Plant height was found to be affected by planting times ($P<0.01$) and the cultivars ($P<0.05$). There was an interactive effect of planting time and the cultivar ($P<0.05$) on plant height (Table 1). The highest plant height (73.14 cm) was obtained from the plants of

Table 1: Changes in mean growth and yield parameters of different cauliflower cultivars grown at different planting times

Cultivars	Leaf number per plant				Mean leaf weight (g)				Mean root weight (g)			
	Planting times				Planting times				Planting times			
	01 July	15 July	01 August	Mean	01 July	15 July	01 August	Mean	01 July	15 July	01 August	Mean
C1	20.00 de	26.73 abc	18.07 de	21.60 ab	21.21	14.86	25.14	20.40 b	84.33	66.67	67.00	72.67 c
C2	28.00 ab	19.87 de	18.33 de	22.07 ab	25.61	23.71	25.46	24.59 ab	126.67	90.00	84.67	100.44 b
C3	27.27 ab	17.07 de	15.27 de	19.87 b	30.24	25.79	24.22	26.75 ab	152.00	104.67	95.33	117.33 ab
C4	26.60 abc	17.87 de	14.73 e	19.73 b	26.62	27.35	31.46	28.48 a	136.67	81.33	84.47	100.82 b
C5	29.70 a	20.93 cde	21.93 bcd	24.19 a	24.13	18.40	34.83	25.79 ab	136.67	83.33	92.67	104.22 b
C6	28.00 ab	19.40 de	16.60 de	21.33 b	25.10	16.64	25.61	22.45 ab	180.67	110.00	118.33	136.33 a
C7	29.53 a	20.33 de	15.27 de	21.71 ab	28.10	23.43	32.60	28.04 a	148.00	97.33	98.00	114.44 ab
Mean	27.01 a	20.31 b	17.17 b		25.86 ab	21.45 b	28.33 a		137.86 a	90.48 b	91.50 b	
LSD (P)	3.333	Significance	1%		5.097	Significance	1%		35.19	Significance	1%	
LSD (Cv.)	2.479	Significance	5%		5.981	Significance	1%		24.49	Significance	1%	
LSD(PxCv.)	5.758	Significance	1%		-	Significance	NS		-	Significance	NS	

	Plant height (cm)				Curd index (Curd length/curd width)				Yield (t/ha)			
	Planting times				Planting times				Planting times			
	01 July	15 July	01 August	Mean	01 July	15 July	01 August	Mean	01 July	15 July	01 August	Mean
C1	63.40 ef	59.47 f	65.27 def	62.71 b	0.72 a	0.61 abc	0.59 a-d	0.64 a	15.18	7.85	9.61	10.88
C2	77.20 a	63.93 ef	59.70 f	66.94 a	0.44 d-g	0.42 d-g	0.66 ab	0.51 b	10.61	8.87	11.62	10.37
C3	71.53 a-d	61.33 ef	63.20 ef	65.36 ab	0.38 efg	0.37 efg	0.34 efg	0.37 c	13.52	9.89	11.13	11.51
C4	76.00 a	66.53 c-f	64.83 def	69.12 a	0.35 efg	0.46 c-f	0.31 fg	0.37 c	13.17	8.45	11.49	11.03
C5	73.10 abc	62.53 ef	68.60 b-e	68.08 a	0.34 efg	0.42 d-g	0.28 fg	0.35 c	14.57	7.30	17.88	13.25
C6	75.60 ab	61.60 ef	67.00 c-f	68.07 a	0.34 efg	0.35 efg	0.27 g	0.32 c	15.87	9.50	14.03	13.14
C7	75.13 ab	63.20 ef	66.47 c-f	68.27 a	0.50 b-e	0.44 c-g	0.37 efg	0.44 bc	11.94	7.80	10.46	10.07
Mean	73.14 a	62.66 b	65.01 b		0.44	0.44	0.40		13.55 a	8.52 c	12.32 b	
LSD (P)	4.815	Significance	1%		-	Significance	NS		1.017	Significance	1%	
LSD (Cv.)	3.658	Significance	5%		0.122	Significance	1%		-	Significance	NS	
LSD(PxCv.)	6.336	Significance	5%		0.157	Significance	5%		-	Significance	NS	

NS: non-significant, there are no significant differences between the means with the same letter the first planting time (01 July). This was followed by the plants of the third (01 August) and the second (15 July) with 65.01 and 62.66 cm, respectively. Among the cultivars, the lowest plant height (62.71 cm) was obtained from the plants of C1. There were no significant differences between the other cultivars.

It was found that planting times had a significant impact ($P<0.01$) on yield (t ha^{-1}). The highest yield (t ha^{-1}) was obtained from the plants of 01 July planting (13.55 t ha^{-1}) while the plants of 15 July planting gave the lowest yield (8.52 t ha^{-1}) (Table 1). When we consider all plant growth components depending on planting times, it can be said that the highest values of leaf number per plant, mean leaf weight per plant, mean root weight per plant and mean plant height were obtained from the plants of the first planting time (01 July) while the lowest values of the same parameters except the highest leaf number per plant was obtained from the plant of 15 July planting. According to the above observations, plants of both the first and the third planting times had better vegetative growth compared to the plants second of planting time. As a result of this, plants from the second planting time (15 July) gave the lowest yield. Many researchers also indicated that curd weight was higher in cauliflower plants grown at early periods of growing season (Yadav *et al.*, 1995, Cebula and Kalisz, 1997a and b) compared to the plants grown at later periods. As it can be seen in Table 1, there were no significant differences between planting times in terms of curd index. However, it was found that there were significant differences between the cultivars ($P<0.01$) for curd index in addition to an interactive effect of the planting times and cultivars ($P<0.05$) on curd index.

To conclude, the present study is the first to be carried out in the Blacksea region on determining the most suitable plantings times of cauliflowers considering both either high yield or earliness. Many clues were brought in light in this study and should be gone over by more intensive studies to use in crop growing and decision making. The results from the present study can be used for forthcoming modelling studies on cauliflowers in the Blacksea and other regions of Turkey.

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