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QUANTITATIVE EFFECTS OF PLANTING TIME ON VEGETATIVE GROWTH OF BROCCOLI (*BRASSICA OLERACEA* VAR. *ITALICA*)

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Abstact

This study was carried out in the research field of The Black Sea Agricultural Research Institute in Turkey from spring to winter, 1999. Cv. Platini, which is known as sprouting broccoli, was used in the study. Seedlings were raised in module seed trays. Planting procedure was repeated for the times, viz., 25 April (first, P1), 27 May (second, P2) and 27 June 1999 (third, P3). The aim of the study was to see a clear picture of the effects planting times (growing periods) on plant growth parameters, viz., leaf thickness (LT), leaf area (LA), total plant dry weight (TPDW), leaf weight ratio (LWR), stem weight ratio (SWR), root weight ratio (RWR), specific leaf area (SLA), leaf area ratio (LAR), net assimilation rate (NAR) and relative growth rate (RGR) and plant growth accordingly. The results showed that LWR decreased with time after planting while SWR increased with time. Generally, later planting times resulted in higher SWR and LWR while early planting times had higher RWR. Both LAR and SLA declined with ontogeny. Earlier planted plants had higher LAR and SLA. NAR and RGR were found to be lower with earlier plantings. LA and TPDW varied with planting times and ontogeny. Both LA and TPDW increased with time after planting and plants from earlier plantings had lower LA and TPDW values. LT was higher at later planting times and increased with time. Significant positive and negative relationships were also found between plant growth parameters.

Introduction

Broccoli belongs to the genus *Brassica*, which includes a wide range of crop plants derived from the Mediterrarean sea cabbage and modified over the years by selection and breeding. Broccoli (*Brassica oleracea* var. *italica*) is one of the major crop plants in this genus. The curd of broccoli is formed from a compact flower head and produces a green curd that rapidly develops into a mass of fertile flower buds (Biggs, 1993). Unless the broccoli plant experiences the appropirate weather conditions, it will not change fom a vegetative to a reproductive phase, and thus it will not produce a head. Weather conditions following floral initiation can also have a major effect on the quality of the head produced. The physiological age, leaf number before curd initiation and temperature environment affect curd initiation and head quality (Tindall, 1992; Phillips & Rix,1995).

Optimum temperature requirements of broccoli is in the range of 18-24 ^{0}C (Tindall, 1992; Grevsen, 1998). Growth processes show multiplicative relations with time and are thus more easily defined in terms of their relative rates (relative growth rate, net assimilation rate, etc.) (Bjorkman & Pearson, 1998). Growth is a fundamental biological activity. We can define the net growth rate of a plant as the difference between two opposing processes. One of these processes is the gross rate of gain in mass and the other the rate of loss in mass (Charles-Edwards *et al*., 1981). The proportion of the new dry matter partitioned between the different plant parts and the duration of growth are two

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important parameters to predict crop yield. The length of time for which a crop grows vegetatively is an important determinant of the amount of vegetative material produced. Quantitative studies of plant or crop growth are commonly based upon the analysis of sequential harvest data (Charles-Edwards *et al*., 1981).

Causton *et al*., (1978) suggested that there are various advantages associated with fitting mathematical functions to plant growth data such as providing a convenient summary of the data, calculating a series of estimates of the growth attribute being less disturbed by biological variability and providing useful information if the function fitted is based on some biologically meaningful model. When plants are grown in culture the aim is often to achieve the best possible growth, by removing all environmental constraints. In other words, we provide optimal environmental conditions where the plant's inherent growth rate can be expressed. Most physiological work is carried out in conditions that are at least an attempt to create such an optimum (Fyffe & Titley, 1989; Fitter & Hay, 1993; Uzun *et al*., 1998).

Although factors controlling curd initiation have been the subject of a number of experimental and theoretical studies the present carried out to investigate vegetative growth of broccoli plants as influenced by different planting times as a result of changing growing conditions.

Materials and Methods

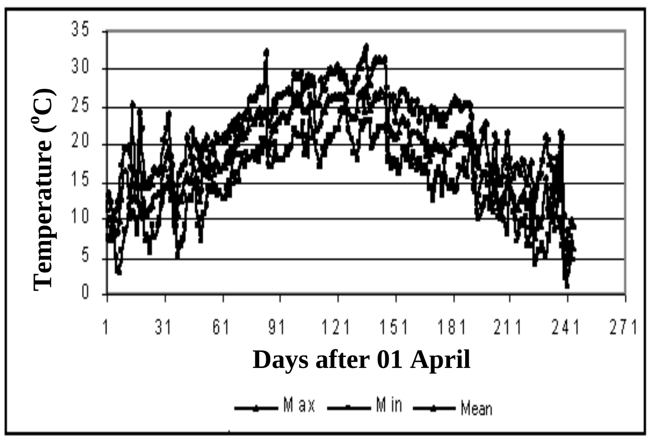
This study was carried out in the research field of The Black Sea Agricultural Research Institute, from spring to winter, 1999. Cv. Platini, which is known as sprouting broccoli, was used in the study. Seedlings were raised in module seed trays (45 cells, 5*5 cm). Seed sowing procedure was repeated for different times, viz., 25 March, 3 May and 3 June 1999. Planting was made in raised beds (1 m wide, 5 m long) by double row planting method. A distance of 50 cm in rows and 50 cm between rows were maintained and seedlings with four true leaves were used in planting. Planting dates were 25 April (P1), 27 May (P2) and 27 June (P3).

Considering soil analysis, 3 tonnes of farmyard manure per da were applied to the research field in addition to the application of 60 kg composed fertiliser (15:15:15) and 20 kg of ammonium sulphate per da. The plant growth parameters investigated were: dry weights of leaves, stems, roots of the plants (in order to determine leaf (LWR), stem (SWR), root weight ratios (RWR)), leaf area (LA), leaf thickness (LT), specific leaf area (SLA), leaf area ratio (LAR), net assimilation (NAR), relative growth rate (RGR) and interrelations of the growth components for the plants. Drying processes of different plant parts was implemented by drying the samples at 80^{o}C in an oven. Determination methods of the selected growth parameters are given in Table 1. The values of environmental conditions (temperature and photoperiod) of the location where the research was carried out are given in Fig. 1.

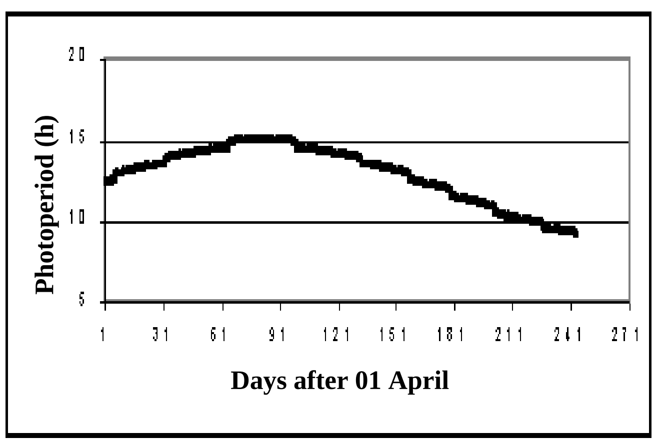
The experiment was carried out in randomised block design with split blocks with three replications. Data analyses and graph drowings were carried out by using MSTAT, EXCEL and the SlideWrite 2.0 computer programmes, respectively.

Table 1. Determination methods of some vegetative plant growth parameters for quantitative analysis in broccoli.

Parameters	Determination methods
Leaf area (LA)	LA (cm^2)=-5.44+1.63*Leaf length (cm)+3.05*Leaf width (cm), (Uzun & Celik 1999)
Specific leaf area (SLA)	SLA (cm^2g^{-1}) = Total leaf area (cm^2)/Total leaf dry weight (g)
Leaf area ratio (LAR)	LAR ($cm^2g^{-1)}$ =Total plant leaf area (cm^2)/Total plant dry weight (g)
Net assilation rate (NAR)	NAR = 1/LA*dA/dt (g cm^{-2} d^{-1})
Relative growth rate (RGR)	RGR = NAR*LAR (g $g^{-1}d^{-1}$)
Leaf Thickness (LT)	LT = 1/Specific Leaf area (SLA)
Leaf weight ratio (LWR)	LWR = Total leaf dry weight (g)/Total plant dry weight (g)
Stem weight ratio (SWR)	SWR = Total stem dry weight (g)/Total plant dry weight (g)
Root weight ratio (RWR)	RWR = Total root dry weight (g)/Total plant dry weight (g)



(a)



(b)

Fig. 1. Changes in (a) daily temperatures (°C) (maximum, minimum and average) and (b) photoperiod (h) from April to November 1999.

Results and Discussion

Leaf, stem and root weight ratios (LWR, SWR, and RWR)

In general, leaf weight ratio (LWR) which is the ratio of total leaf dry weight to total plant dry weight declined with plant age (days after planting) for all planting times (Fig. 2a). There was a clear tendency that leaf weight ratio was found to be higher with later planting times. Stem weight ratio (SWR) increased with time after planting for all planting times (Fig. 2b). However, the delay in planting time resulted in higher stem weight ratio values. Changes in root weight ratio for all planting times during ontogeny (plant growth) showed differences between planting times (Fig. 2c). However, later planting times gave lower root weight ratio values. It has been reported that there was no clear evidence of increasing LWR with increasing temperature but the present studies showes that LWR declines with time after planting since more dry matter is expected to be accumulated in plant stems (DeKoning, 1994; Kurklu, 1994; Uzun, 1996).

The increase in SWR with later plantings in spring and time after planting can be explained with the dry matter allocated to the plant stem with ontogeny, increasing temperature and light intensity (Uzun, 1996). It has been reported that increasing temperatures decrease RWR of many crop plants (Bjorkman & Pearson, 1998) which is in accordance with the results obtained from the present study.

Specific leaf area (SLA) and Leaf area ratio (LAR)

Specific leaf area (SLA) for all planting times declined with increasing plant age (Fig. 3a). The decline in specific leaf area with plant age was slower when plants were grown with later planting times.

The highest specific leaf area was obtained from the plants grown at the first planting time (P1) followed by P2 and P3. To see a more clear picture of the effects planting times (growing periods) on plant growth, we should relate the planting times to changing temperature and photoperiod values recorded during the experiment (Fig. 1). As a result of this, an order for planting times in terms of temperature and photoperiod (light intensity accordingly) can be set. For this reason, P1, P2 and P3 can take place from lower to higher temperature and photoperiod respectively. Leaf area ratio (LAR) also declined throughout growing periods for all planting times (Fig. 3b). Similar relationship as specific leaf area was found between leaf area ratio and days after planting for all planting times (P1, P2 and P3). Hay & Walker, (1989) and Uzun (1996) has reported that SLA and LAR of many crop plants increase with an increase in temperature and decline with ontogeny.

Net assimilation rate (NAR) and Relative growth rate (RGR)

Fig. 4a shows the changes in net assimilation rate (NAR) with time after planting for each of the three growing periods. Net assimilation rate was generally lower with earlier planting times. Although there was marked differences in net assimilation rate up to 50 days after planting, a closer trend in changes with different planting times was obtained after this time.

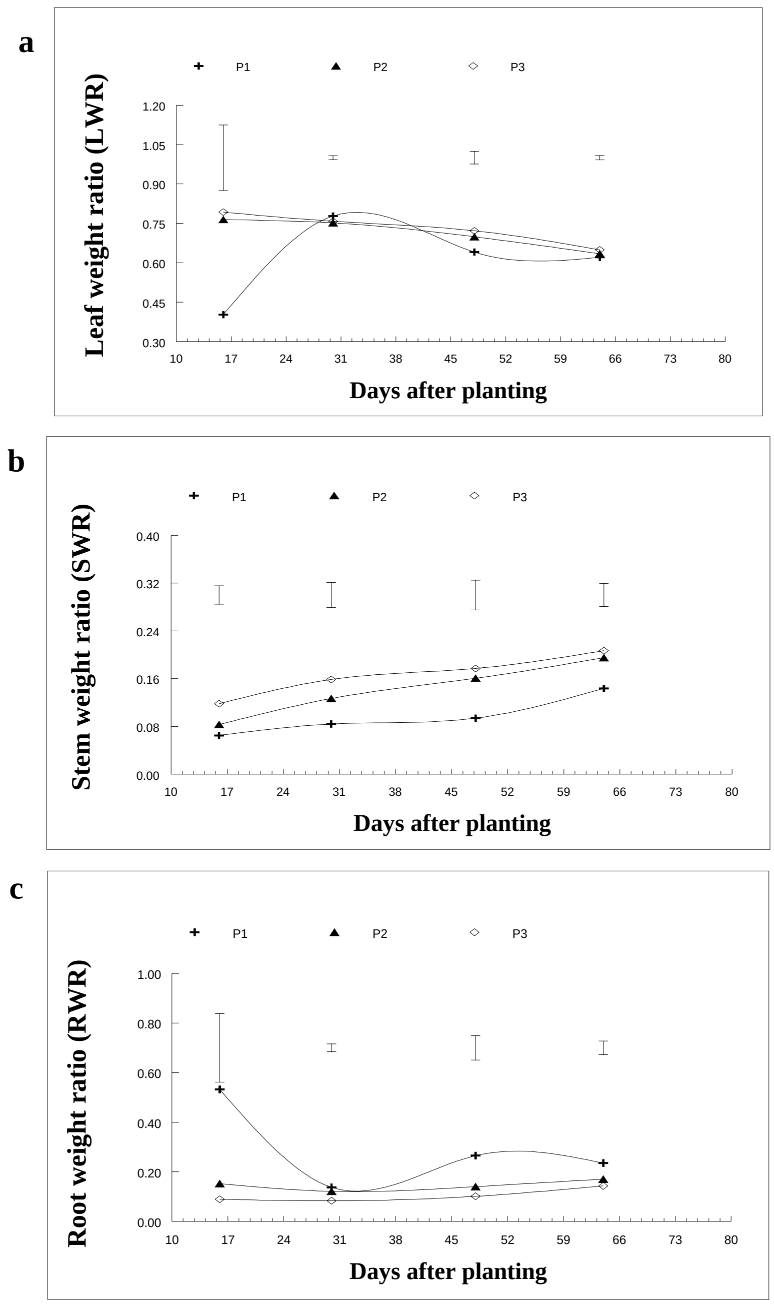
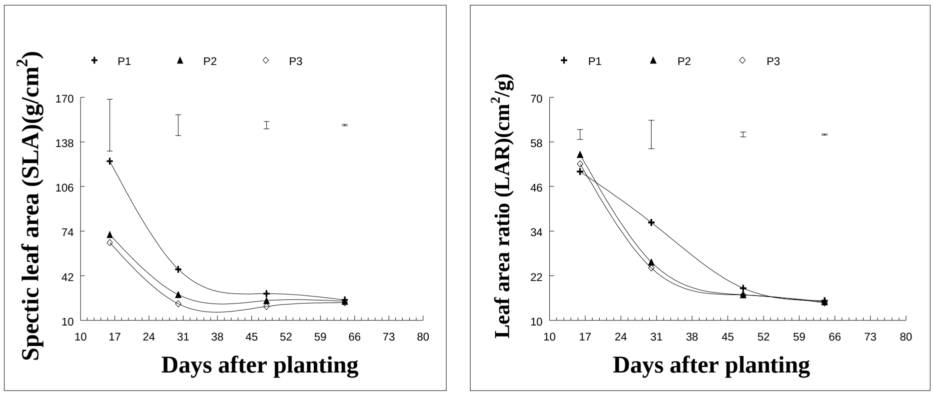
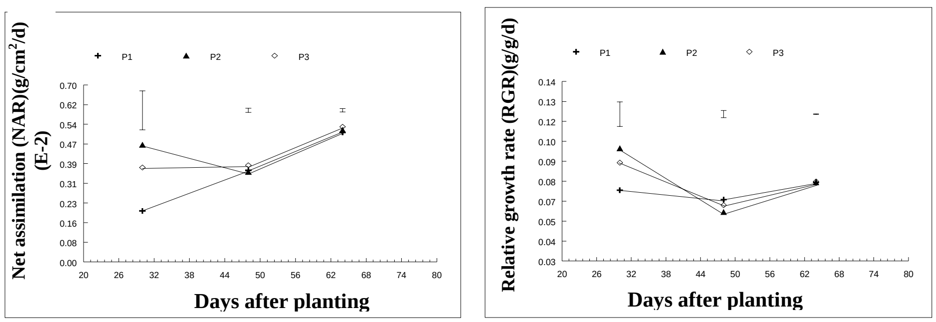


Fig. 2. Changes in (a) leaf weight ratio (LWR), (b) stem weight ratio (SWR) and (c) root weight ratio (RWR) in broccoli with days after planting for all planting times (P1, P2 and P3). Error bars represent standard error of means, $p<0.05$).



(a) (c)

Fig. 3. Changes in (a) specific leaf area (SLA) and (b) leaf area ratio (LAR) of broccoli with days after planting (ontogeny). Bars represent standard error of means, ($p<0.05$).



(a) (b)

Fig. 4. Changes in (a) net assimilation rate (NAR) and (b) relative growth rate (RGR) of broccoli with days after planting (ontogeny) for all planting times (P1, P2 and P3). Bars represent standard error of means, ($p<0.05$).

Relative growth rate (RGR) declined with time to reach a minimum at around 50 days after planting for all planting times (Fig. 4b) and increased thereafter. However, the decline in relative growth rate with time up to 50 days after planting was sharper than the increase after this time. There are several evidences that higher light intensiy and temperature increase NAR up to a maximum and decline after that point. The sharper increase in NAR results in lower total yield and shorter plant duration (Fitter & Hay, 1993).

Leaf area (LA), Total plant dry weight (TPDW) and Leaf thickness (LT)

In general, leaf area (LA) of broccoli plants showed a curvilinear increase with time after planting for all planting times (Fig. 5). There was also a sigificant difference between leaf area of plants grown at the first planting time (P1) and those of plants grown at the second (P2) and the third (P3) planting times. The highest leaf area values were obtained from plants of the third planting time (P3). The second (P2) and the first (P1) planting times followed this value respectively.

Total plant dry weight (TPDW) of broccoli plants showed similar changes with days after planting as total plant dry weight (Fig. 5b). Leaf thickness (LT) increased in the leaves of plants grown at later planting times (Fig. 5c). Leaf thickness of the plants from the second (P2) and the third (P3) were found to be insignificant while there was a marked difference between leaf thickness of these plants and those of the plants grown at the first planting time (P1).

Leaf thickness increases with higher light intensity. Since the structure of plant leaves changes under differing light levels such as shade leaves are thinner than sun leaves for many crop plants (Fitter & Hay, 1987; Hay & Walker, 1989).

Interrelations between the growth parameters

In order to obtain a general picture of the effect of different growing periods (P1, P2 and P3) on growth parameters pairwise correlation coefficients were calculated for the data obtained from all growing periods. The correlation between RGR and NAR was found to be insignificant although there was a positive relationship between these parameters (Table 2). Significant and negative relationships were found between LWR and RWR, LWR and NAR, SWR and RWR, SWR and SLA, SWR and LAR, SLA and NAR, LAR and NAR, LAR and LT, LAR and LA, LAR and TPDW, SLA and LT, SLA and LA, SLA and TPDW (Table 2). On the other hand, significant and positive relationships were found between LT and LA, LT and TPDW, LT and SWR, LT and NAR, LA and TPDW, LA and SWR, LA and NAR, TPDW and SWR, TPDW and NAR, SWR and NAR, RWR and SLA, SLA and NAR (Table 2). There are reports that increasing light intensity increased NAR and decreased LAR (Hay & Walker, 1989; DeKoning 1994; Uzun, 1996; Uzun, 1997). The increase in SLA and LAR can be related to leaf thickness such as increasing LAR or SLA result in thinner leaves. Threfore, negative relationships were found between NAR, NAR and SLA in the present study.

The results from the present study shows the relationships between plant growth and yield in broccoli as influenced by environmental factors.

Table 2. Correlations between the growth parameter examined in the present study (LT, LA, TPDW, LWR, SWR, RWR, SLA, LAR, NAR and RGR).

Parametrs	LT	LA	TPDW	LWR	SWR	RWR	SLA	LAR	NAR
RGR	-0,01	-0,13	-0,09	0,07	-0,005	-0,07	-0,005	0,08	0,11
LT		0,71***	0,65***	0,02	0,72***	-0,19	-1***	-0,93***	0,60***
LA			0,99***	-0,02	0,69***	-0,03	-0,45**	-0,71***	0,49**
TPDW				-0,04	0,68***	-0,01	-0,38*	-0,66***	0,53**
LWR					0,01	-0,85***	-0,23	0,001	-0,45*
SWR						-0,25*	-0,53***	-0,56***	0,47*
RWR							0,49**	0,06	0,03
SLA								0,72***	-0,47*
LAR									-0,56**

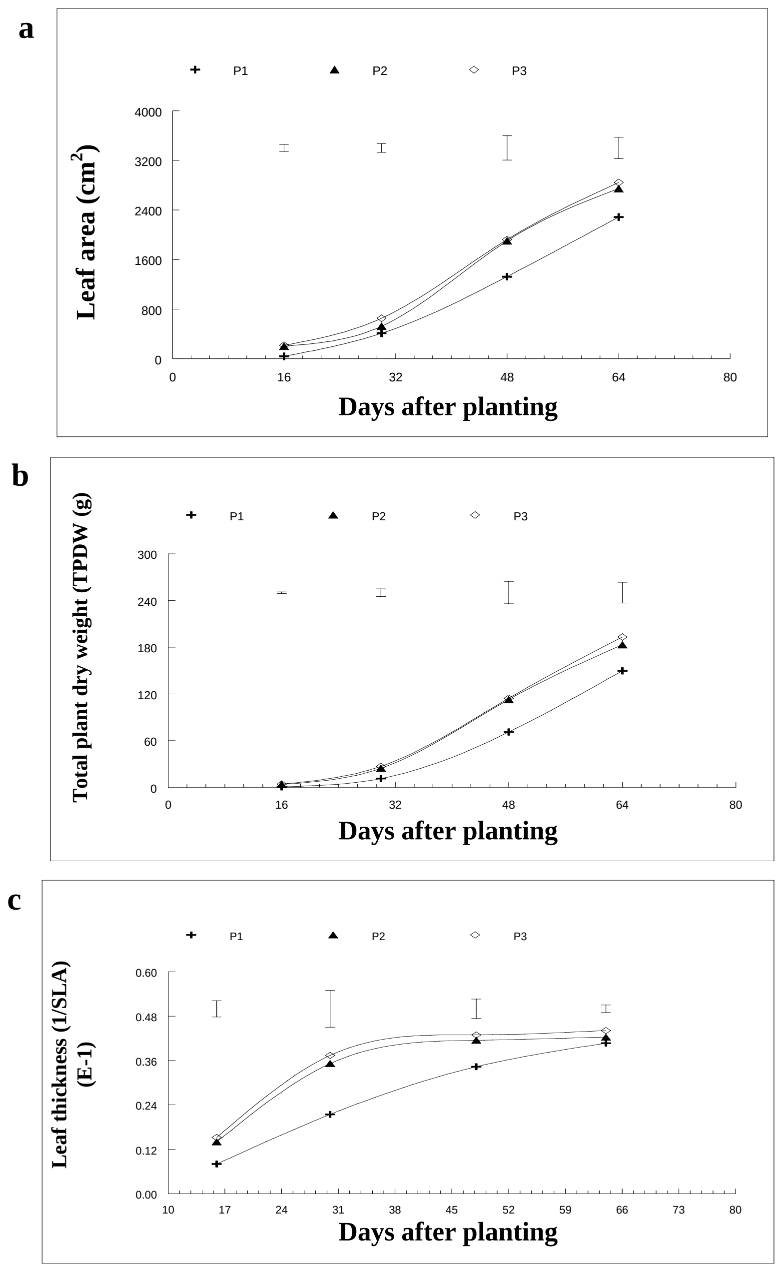


Fig. 5. Changes in (a) leaf weight ratio (LWR), (b) stem weight ratio (SWR) and (c) root weight ratio (RWR) in broccoli with days after planting for all planting times (P1, P2 and P3). Bars represent standard error of means, $p<0.05$).

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