Asian Journal of Plant Sciences

ISSN 1682-3974

science alert

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Asian Journal of Plant Sciences 3 (2): 223-230, 2004
ISSN 1682-3974

Determination of the Relationship Between the Sowing Times and Plant Light Interception in Red Podded Bean Growing

Ahmet Balkaya, Sezgin Uzun and [1]M. Serhat Odabas
Department of Horticulture, [1]Department of Field Crops,
Faculty of Agriculture, Ondokuz Mayis University, Samsun, Turkey

Abstract: This research was carried out to determine the most appropriate sowing time in Spring under the ecological conditions of Samsun, Turkey during growing period of red podded bean in open field by benefiting from the relationships between plant growth and development, plant light interception. Therefore, four cultivars (Toya, Gitan, Barbunya oturak, Sirik-97), which have been currently started being grown in this region were sown in three different sowing times (16 April, 1 May and 16 May) at 2001 and 2002 years. The plant height, the stem diameter and leaf number were the highest for the plants from seed sowing on 16 April and 1 May. It was also determined that when sowing time was late, there was slight decrease in the plant height, the stem diameter and leaf number. It was determined that there was a significant and positive relationship (R=0.88) between the plant leaf number and pod yield. The highest plant light interception values were measured on 16 April and 1 May sowings however it changed according to the cultivars. When sowing time was late, plant light interception values in all cultivars decreased. According to the results of this research, it can be recommended that the seeds could be sown between 16 April and 1 May in order to have maximum growth and development of the cultivars and also to have top quality and high yield in red podded bean growing.

Key words: Red podded bean, sowing time, light interception, plant growth, pod yield

INTRODUCTION

Red podded bean (*Phaseolus vulgaris* L.) has an important role in human nutrition and is also a delicious type of vegetable. It can be consumed in different ways such as fresh pod, immatured pod and dried seed. In addition it can be consumed as tinned food and dried pod. The total production of legume vegetable species in Turkey is 648.000 tons. In this production fresh bean has the largest share (75.6%) and red podded bean has a share 6.9% with 45 tons annually[1]. The Black Sea Region is one of the places where red podded bean is grown widely. Samsun, situated in this region, ranks second with a 4.92 tons of red podded bean in Turkey. In Samsun, the local cultivars is commonly grown in red podded bean growing[2]. In a research carried out in this region, it was observed that there were considerable differences among the local cultivars with regard to yield and pod features. It has been started recently to grow some cultivars imported by some private seed firms.

In terms of regions to determine the sowing and planting time has an is importance with regard to utilise the light potential of the regions. When the light is suitable, forming a leaf canopy that is able to intercept the light is a significant factor affecting the yield[3]. In annual summer crops, sowing time must be planned in order to benefit from the light at a maximum level. In the periods when the light is high, the plant must produce enough leaves in order to intercept the light[4]. As sowing time is late, the plant can not benefit from the light and temperature that are necessary for growth and development and as a result of this, yield loss may arise. The plants of the seeds germinating tardily will be shaded by the plants of the seeds germinating earlier when using direct seed sowing grows them. In the end, the plants will compete for light and non-uniform quality product and low yield will be obtained. For that reason in red podded bean growing, some seed characteristics are effective as well as ecological factors in order to obtain quality and yield[5].

The plant development consists of different phases such as seed sowing, planting, period until the first blossoming, the rate of blossoming, the number of the leaf, growing process of plants, and time to harvesting[6]. The factors such as light and temperature have effects on these phases. Crop yield can be characterized as a function of an organism's: 1) adaptation to its environment; 2) ability to effectively harvest light with the

Corresponding Author: Ahmet Balkaya, Department of Horticulture, Faculty of Agriculture, Ondokuz Mayis University, Samsun, Turkey E-mail: abalkaya@omu.edu.tr

photosynthetic apparatus and 3) ability to partition and translocate photosynthate to the economic organs. These processes are measured in various ways by breeding programs. Phenological adaptation is best measured by days to maturity and the concomitant days to flower and of pod fill[7].

Temperature has also an effect on red podded bean quality. Temperature affects the plant development pattern and timing as well as plant growth and development and metabolism[8]. It has been stated by different researchers that for development, dwarf beans require minimum 12-13°C and snap beans require 14-15°C, maximum growth is at 30°C, at higher temperature growth slows down, flower drop increase and this prevents forming of the seed[9-11]. Yield in bean depends on first blossoming date and the temperature on the previous and the next day, because the viability rates of the first flowers are higher[12,13]. In a research on 78 bean genotypes it was determined that genotypes which are susceptible to photoperiod had higher blossoming time of the plant with high temperatures and longer daytimes. In addition, in a research it was observed that rising temperatures reduced the time necessary for blossom bud development[14].

Since photosynthesis is necessary for plant life, light interception is an important factor in plant growing. In defining agricultural productivity of a land, photosynthetic active radiation (PAR) coming in different times of the year has an important effect. The light use of efficiency of annual total PAR value differs as to latitudinal degree and researches on determining their annual dry matter production in accordance with the unit PAR value of every country as to cultivars are abundant[3].

Red podded bean has been sown in spring season in this region. However, among the farmers there is no exact date for sowing time. For this reason it has been sown from the beginning of April to the middle of May. In this research light interception was examined in red podded bean growing as to various sowing times. In various sowing times, growth, development and yield of this crop were also examined.

MATERIALS AND METHODS

This research was carried out in the land and laboratory of Department of Horticulture, Faculty of Agriculture, Ondokuz Mayis University during 2001 and 2002.

In the research totally four cultivars were used namely, consisting dwarf forms Toya (V1), Barbunya oturak (V2), climbing forms Sirik-97 (V3) and Gitan (V4).

The seeds were sown on 16 April (the first sowing), 1 May (the second sowing) and 16 May (the third sowing) in 2001 and 2002.The seeds of dwarf cultivars were sown at the distances of 50x20 cm and the seeds of climbing cultivars at the distances of 70x40 cm. 20 plants were grown in each plot. The experiment was planned in accordance with the Random Block Design as three replications. The data were analysed by Excel 7.0 and MSTAT programme. The following parameters were investigated in this research:

- Plant height (cm): The distance from the ground to the highest leaf was described as the plant height.
- Stem diameter (mm): The stem diameter of the plants was measured with digital compass.
- The number of leaves (number): The numbers of the leaves, which are big enough for photosynthesis in each plant were determined.
- Plant light interception (%): In flowering and harvesting period in order to determine plant light interception with a'Sun Scan Canopy Analyser (Delta T Devices)' it was measured from the top of the plants (from three points) and bottom of the plants (from three points).
- Pod colour: In the harvested pods, brightness of ground colour was measured with a colorimeter Minolta Choromometre brand. The pod colour measurement was evaluated as to this scale; L: the rate of brightness, +a: red, -a: green and +b: yellow and -b: blue. Besides, pod colours in all cultivars used in this research were determined.
- Average pod weight and pod yield: Fresh red podded beans were harvested at a week intervals. The yield values (g) per plant were found by weighing the pods harvested from each plant. For each sowing period, 20 pods taken from each plant were weighed and the values of average pod weight were determined.

The daily temperature and humidity values were obtained from Samsun Meteorology Office close to the research land. Correlation analysis was made to determine the relations among some plant characteristics in red podded bean cultivars[15].

RESULTS

Changes in temperature, humidity and photoperiod: Data related to average temperature (°C), average relative humidity (%) and photoperiod values (hour) determined daily after seed sowing during the research are shown in Fig. 1 and 2.

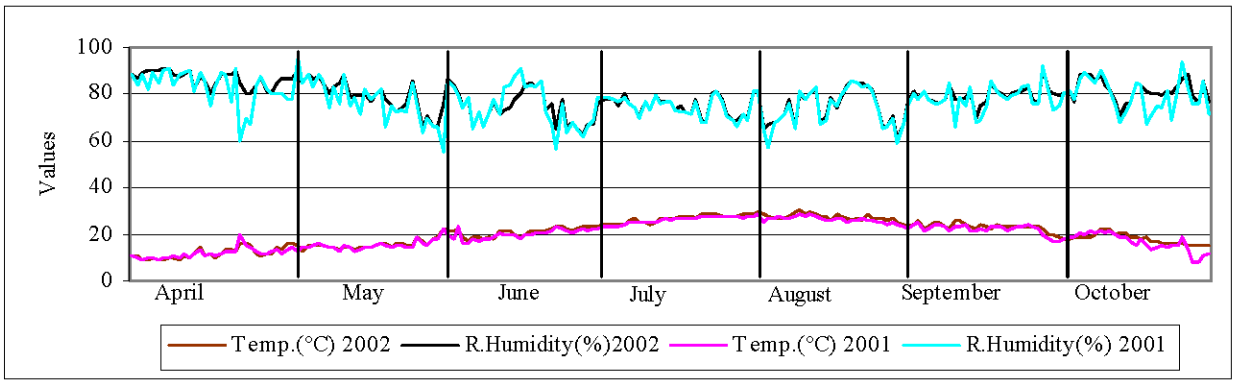

Fig. 1: The change of temperature and relative humidity variation as to months during the research

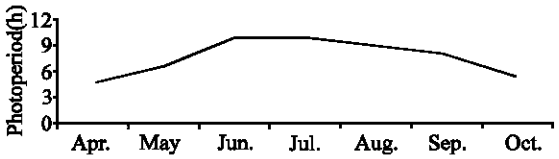

Fig. 2: The changes in photoperiod duration as to months during the research (mean values of two years)

In open field growing, the temperature at seed sowing is one of the ecological factors that lead to differences among the field emergence of the bean cultivars[28]. The mean temperatures of two years among the seed sowing times, it was found to be 11.8°C in the first sowing time (16 April), 13.6°C in the second sowing time (1 May) and 14°C in the third sowing time (16 May) (Fig. 1). The temperatures measured in the sowing times were sufficient for the red podded bean seeds to germinate and to emerge. Emergence rates of the cultivars were found to be between 70-90% as to the sowing times for two years.

During the experiment, temperature increase has caused the relative humidity to decrease. Mean relative humidity values for both year have changed as 75% in the first sowing time (16 April), 77.3% in the second sowing time (1 May) and 71.7% in the third sowing time (16 May). Following the temperature increases in summer months, relative humidity values have decreased in June and reached the lowest degrees in July and August (Fig. 1).

As seen in Fig. 2, in the first sowing time, the photoperiod, which is too short, increased in a linear way in contrast to other sowing times and this increase continued until mid-June. In summer season, the speed of the increase in the photoperiod duration was at a low rate, but there was an obvious decrease after August.

Plant height: The change of plant height, is given in Fig. 3 for the first year and Fig. 4 for the second year. The

Table 1: Brightless and colours of the red podded bean cultivars

Cultivars	Sowing time	L	a	b	Pod color
Toya	S1	113.41	-39.79	30.14	Red
	S2	94.72	-43.05	28.70	Red
	S3	79.63	-38.71	31.68	Red
Barbunya	S1	101.77	-35.78	30.13	Red
Oturak	S2	101.10	-49.01	36.17	Red
	S3	93.55	-40.49	29.59	Red
Sirik 97	S1	102.93	-62.57	41.07	Red
	S2	94.33	-48.09	29.65	Red
	S3	93.15	-49.63	31.53	Red
Gitan	S1	95.11	-37.96	27.76	Red
	S2	83.27	-35.90	27.90	Red
	S3	75.81	-31.57	25.33	Red

dwarf type cultivars (Toya and Barbunya oturak) showed a similar increase in plant height for all the sowing times. For all the sowing periods, a rapid increase in the plant height of all cultivars happened from the seed sowing time to the 51 days. Since the 63 days, the increase in plant height of the cultivars has slowed down. When plant height was taken into consideration, it was determined that the growth of dwarf cultivars, grown in the second sowing time, had higher plant height compared to the other sowing time. For climbing type cultivars, the plant height of cv. Sirik 97 was higher than cv. Gitan for all sowing times and both years (Fig. 3 and 4). Cv. Sirik 97 and cv. Gitan, showed a rapid growth from sowing to 51 days after sowing but a slowing down and becoming fixed in these cultivars were determined 63 days after sowing (Fig. 3 and 4).

Due to their sowing time, when the growth performance of all cultivars was evaluated together, the highest plant height (200 cm around) was obtained for the second sowing time (1 May) for each years. This case should be explained by the increase in temperature up to acceptable level and then rate of increase in plant height slowed down after this level.

It was determined that high relative humidity observed during the second sowing period (1 May) had positive effects on vegetative development of the plant and plant height was higher than all the other sowing times in all cultivars.

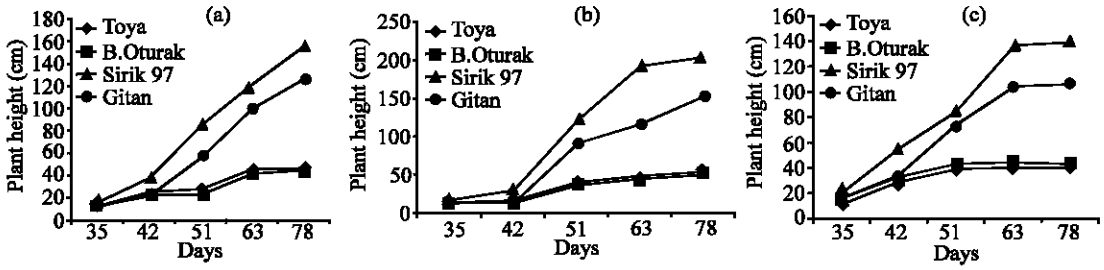

Fig. 3: Plant height changes according to sowing times: (a) 1st sowing time, (b) 2nd sowing time, (c) 3rd sowing time in 2001

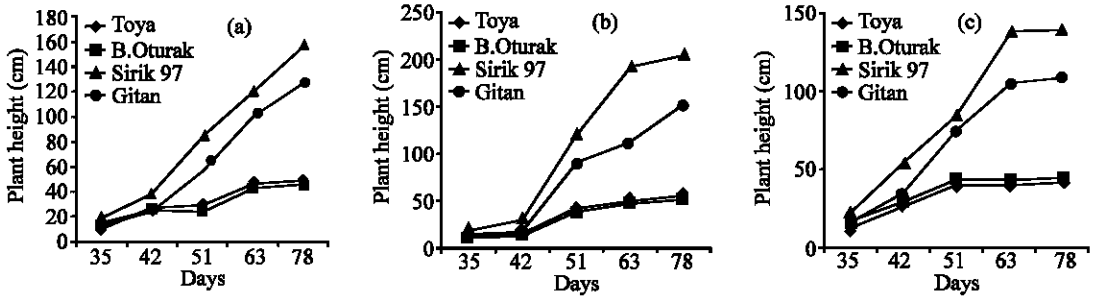

Fig. 4: Plant height changes according to sowing times: (a) 1st sowing time, (b) 2nd sowing time, (c) 3rd sowing time in 2002

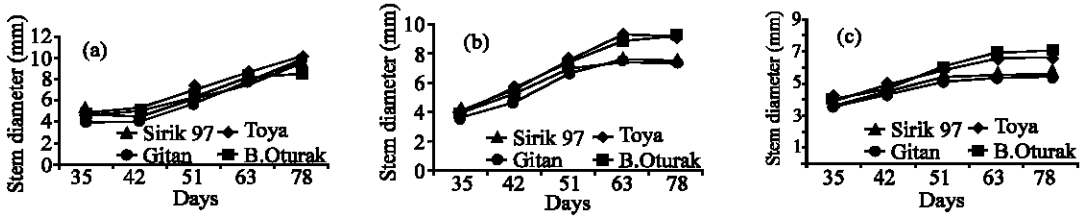

Fig. 5: The stem diameter change according to sowing time (a) 1st sowing time, (b) 2nd sowing time, (c) 3rd sowing time in 2001

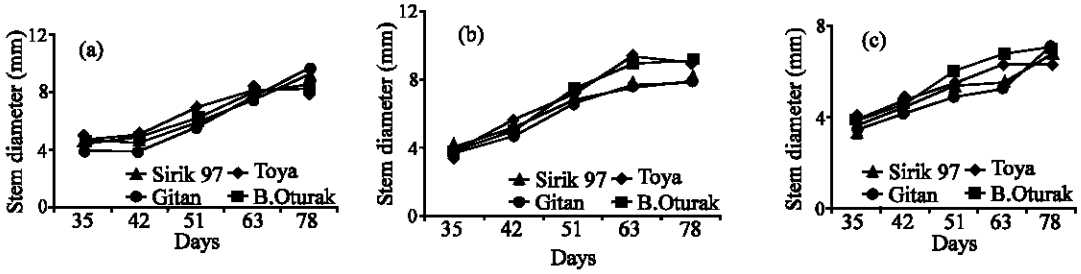

Fig. 6: The stem diameter changes according to sowing time (a) 1st sowing time, (b) 2nd sowing time, (c) 3rd sowing time in 2002

Stem diameter: It was determined that the stem diameter of the climbing and dwarf type cultivars was similar at the first sowing time (16 May) when the relationship between the days after sowing and stem diameter was examined (Fig. 5 and 6). It was also observed that at the second (1 May) and third (16 May) sowing time, dwarf forms Bursa oturak (V2) and Toya (V1) reached the highest stem diameter in 2001-2002. In addition, it was determined that at three sowing times from seed sowing to 63 days after sowing, stem diameter increased and the increase slowed down after time. According to results for two years, as seed sowing times were late, stem diameter of the cultivars decreased (Fig. 5 and 6).

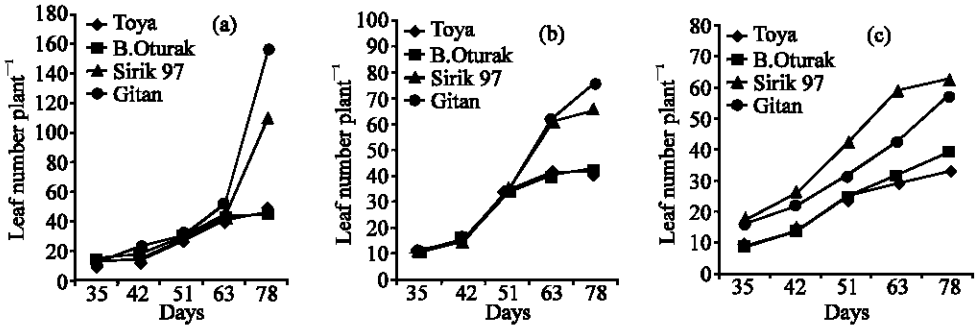

Fig. 7: The number of leaves according to cultivars (a) 1st sowing time, (b) 2nd sowing time, (c) 3rd sowing time in 2001

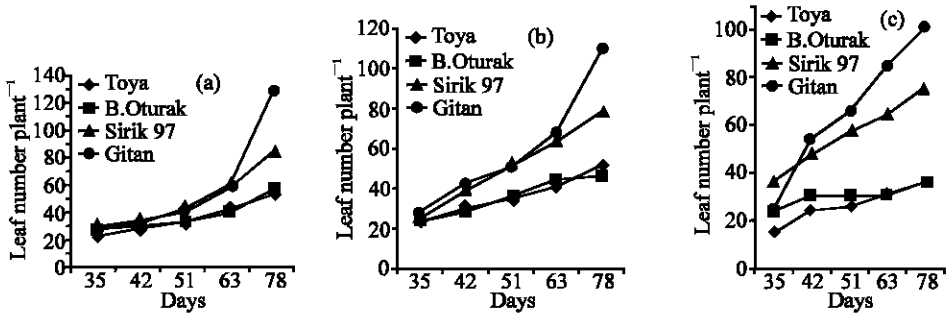

Fig. 8: The number of leaves according to cultivars (a) 1st sowing time, (b) 2nd. sowing time, (c) 3rd. sowing time in 2002

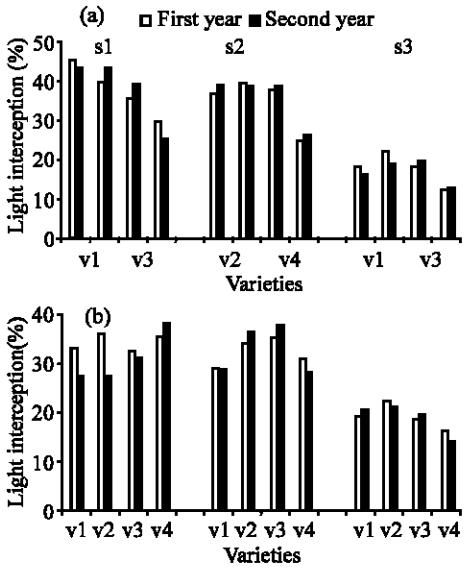

Fig. 9: Flowering period according to sowing times (9a) and light interception on harvest time (9b)

The number of leaves: The number of leaves per plant of red podded bean grown for the sowing times and the days after sowing are shown in Fig. 7 and 8. Generally, the highest increase in the number of leaves in dwarf cultivars occurred between 42 and 51 days after sowing for both years. In dwarf cultivars different results were obtained regarding the number of leaves as to the sowing times. The number of leaves of both cultivars for the third sowing time was less than the other sowing times. It was determined that the later the sowing time, the less the number of leaves in all cultivars (Fig. 7 and 8). In climbing cultivars an increase occurred in respect to the number of leaves between 51 and 63 days after sowing and this increase continued rapidly from 63 days until 78 days after sowing. It was determined that, as for dwarf cultivars, there was a considerable decrease in the number of leaves of climbing cultivars depending on the delay of sowing time.

Plant light interception: The environment of a plant is controlled by two factors regarding light density. One is the position of the leaves within the plant canopy and the other is the light use of efficiency of these leaves[3]. Light interception rates of the cultivars (%) in flowering and harvesting periods were determined in 2001 and 2002 (Fig. 9). The highest light interception (48.3%) was measured at the first sowing time in Toya cultivar for the flowering period. Gitan cultivar had the lowest light interception for all sowing times in flowering periods for both years (Fig. 9). When the light interception values were examined in flowering period regarding sowing times, it was determined that the light interception at the first and the second sowing times was higher than the third

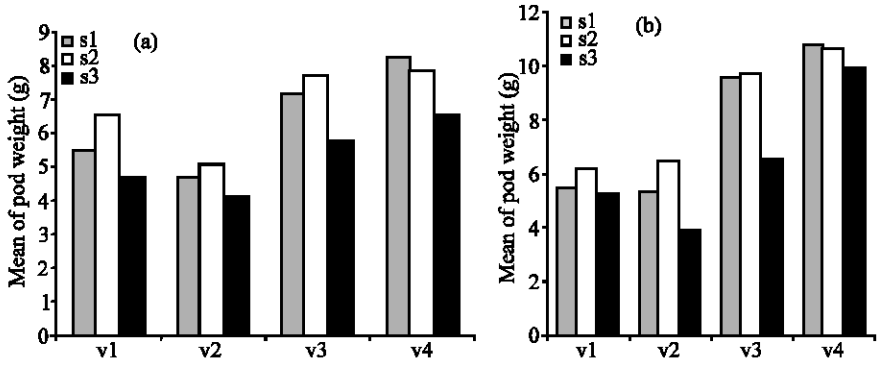

Fig. 10: Average pod weight according to cultivars (a) 1st year, (b) 2nd year

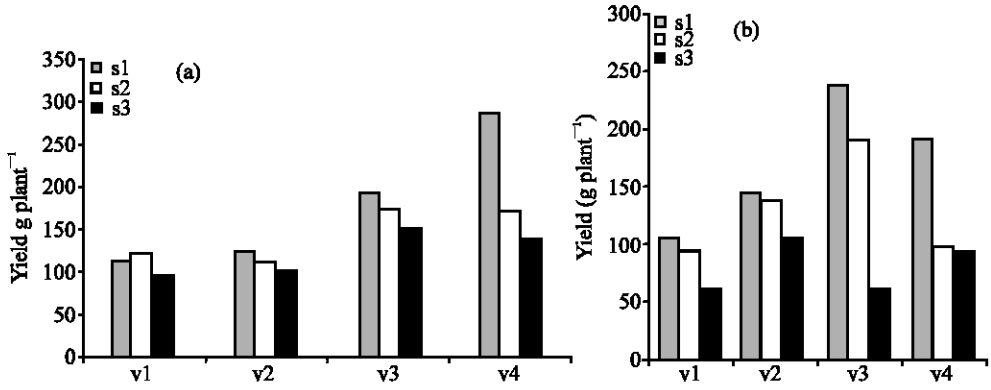

Fig. 11: Yield (g plant^{-1}) according to cultivars (a) 1st year, (b) 2nd year

sowing time for all cultivars. Similar results of light interception were obtained for harvesting period. At the first sowing time, in harvesting period the highest light interception was determined in Gitan (36%) and at the second sowing time in Sirik 97 (39.4%) and in Barbunya oturak (39.2%). In harvest period the lowest light interception values were determined at the third sowing time (Fig. 9). As the sowing times delayed, the plant light interception rates decreased at 2001 and 2002 years.

Pod colour: The data about average of two years brightness and colouring of fresh pods are presented in Table 1 which revealed that pod brightness in all cultivars is at the highest values in the first sowing time and at the lowest values in the third one. This may result from the fact that light density is higher in the first and second sowing times than in the third one. In accordance with the results of calorimetric in pods, the second sowing time (May 1) was determined to be the time in which the green colour is best preserved and the chlorophyll content is the highest in the Toya, Barbunya oturak and Gitan cultivars. On the other hand, it was determined that the green colour was best preserved in the first sowing time in Sirik 97 cultivar. Therefore, the fact that the b values in Table 1 are low is significant with respect to fresh consumption. Because, the increase in the b values indicates that the maturity period is over. The red podded bean cultivars have traces on the surface of pods. It was found out that the colour of pods was red in all cultivars.

Average pod weight and pod yield: Of the cultivars used in the research, the dwarf ones had short (10-12cm) pods and the climbing ones had long (>14 cm) pods[27]. The average weight of pods (g) in the red podded cultivars as to the sowing times is presented in Fig. 10. It was determined that, compared to the other sowing times, the heaviest as to the average pod weight are the Toya Barbunya oturak and Sirik 97 cultivars, in the second sowing time and the Gitan cultivar, in the first sowing time.

The highest yield values for the red podded bean cultivars were obtained at the highest value in the first and second sowing times and at the lowest value in the third sowing time (Fig. 11). It was determined that average pod yield usually more less in the third sowing time as the other sowing times at two years results. As the sowing time delayed, it was observed that the yield values per plant reduced.

DISCUSSION

Temperature and relative humidity changes during seed sowing in legume crops has an important effect on seed quality. Rainfall during seed sowing and emergence in spring season, reduced emergence rate. Imbibition damage in bean seeds has occurred, on account of heavy rain in spring period in Samsun for some years. Because of this, while determining the seed sowing time in the region, this factor must also be taken into consideration. In another research carried out on the seed quality characteristics of the red podded bean cultivars used in the experiment, it has been found that their emergence rates are higher when compared to the white cultivars because of their colourful testa structures and their resistance to imbibitions[16]. The temperature during fruit set period is also effective for optimum pod yield and seed development. The temperature recommended in this period is 18-25°C[17]. The flowering periods of the cultivars used in the research have taken place between the temperature levels as pointed out in the literature in all sowing times and no problem has been detected in the cultivars regarding the pod development.

It was also stated that there was an interaction between the length of the day, the temperature and the characters determining the yield; such as the number of leaves on bean, plant height, the diameter of the stem and the harvest index[18]. For this reason, the effects of the parameters on growth, development and yield, determined in the literature, are examined in details in the present study.

With respect to the plant growth pattern, although the cultivars showed similar performance, the increase in their growth was not the same for all sowing times. It was stated by many researchers that high temperatures, especially with light intensity, increased the plant height in many vegetable crops[6,19].

Stem diameter in vegetable crops namely tomato and aubergine had a significant effect on yield such as crop yield increased up to a critical stem diameter and declined thereafter[4]. According to correlation analysis, there was no significant relationship between increasing stem diameter and yield in dwarf and climbing cultivars.

In the studies carried out by many researchers, it was stated that the number of leaves and pods in bean are the most important components affecting yield[20,21]. It was determined that there was a significant and positive correlation (R=0.88) between the number of leaves and yield on red podded bean cultivars. The number of leaves declined as the sowing time delayed and the accumulation of dry matter was low resulting in less yield compared to other sowing times.

Light is a significant factor for developing (morphologically and anatomically) of plant cells as well as growth with photo periodical effect[22]. When they are deprived of their need of most available light, plants gradually reduce their functions. As light density increases net assimilation also increases. In accordance with the correlation analysis, though not significant statistically, it was determined that there was a positive correlation (R=0.88) between fresh pod yield and plant light interception. Light interception in the first and second sowing times was high enabling the average pod weight and yield values to be higher than in the third sowing time.

It was determined that average pod yield usually more less in the third sowing time as the other sowing times. The reason for this is that the temperature increasing during the growing period affects the pollination, fertilization and fruit set of the red podded bean flowers negatively, in case of late sowing times and as a result, in comparison with the other sowing times, pod production is lower.

A research was carried out in Maritsa Vegetable Research Institute in Plovdiv, Bulgaria in order to determine the effect sowing time on yield and quality in fresh bean. In this research Valja and Zarya cultivars were used. When Valja cultivar was sown in the middle of June, yield increased. On the contrary when it was sown in July, yield decreased. When Zarya cultivar was sown in the middle of June, there was no change in yield, but when it was sown in July, yield decreased[23]. A research was done in the northeast of Kyushu in Japan in order to determine the effects of the summer sowing on the seed quality of the azuki bean. It was offered that seed sowing must be between the end of July and the middle of August in order to obtain the best seed quality in this region[24]. In the studies on fresh bean sowing times, carried out in various regions of Turkey, the Black Sea region exclusive, it was determined that the delay of the sowing time caused a reduction in the production of fresh pod[21,25,26]. When the yield is evaluated individually, the seed-sowing is recommended to be carried out on April 15 for Barbunya oturak and Sirik 97 and on May 1 for Toya. However, to take advantage of early yield, it may be recommended to sow seeds on April 15 for cv. Toya. In the third sowing time, both the average pod weight and the yield values per plant were lower than the other sowing times.

In the ecological conditions in Samsun, red podded bean growing carried out in open field is risky as soil is not sufficient due to heavy rainfall in the periods prior to April 15 and as the emergence rates are low even if seed sowing is carried out. Therefore, it is more important to perform seed-sowing in the periods in which plants can obtain their ecological requirements, from mid-April. It was determined that pod weight and yield per plant decreased, because of late seed sowing.

It was also determined that delaying sowing time with no irrigation resulted in lower yield per plant. In the ecological conditions in Samsun, the results suggested to sow red podded bean seeds between April 16 and May 1.

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