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The Influence of Temperature on Growth and Yield of Green Beans for Processing

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Abstract: This research was carried out between in 2004 and 2005 at Odemis Technical Training College of Ege University in Odemis, Izmir to investigate the effects of sowing dates and windbreak treatments on growth and yield of 4 varieties of processing bean (*Phaseolus vulgaris* vars. Amboto, Gina, Nassau and Volare). Also, the heat summations (thermal time) were determined for all cultivars. The heat summations were calculated for different periods as (a) from emergence to harvest, (b) from emergence to beginning of flowering and (c) from beginning of flowering to harvest. The highest yield (12783.7 kg ha^{-1}) was obtained by early sowing in July. It was observed that delaying the sowing date decreased the yield (10926.7 kg) in 2005. Yields showed a decreasing tendency as sowing dates get closer to autumn. Amboto variety with windbreak gave the highest yields in both years as 12501.0 and 12413.8 kg ha^{-1}, respectively. 1552.6°C day in Gina and Nassau, 795.3°C day in Gina and 958.7°C day in Volare were calculated as the highest thermal times for a, b and c, respectively.

Key words: Sowing date, windbreak, thermal time

INTRODUCTION

Turkey with its suitable ecological condition produces ca 582,000 t of green beans (http://www.tuik.gov.tr). Green bean is an important crop for fresh market especially for canning and frozen industry in Turkey. It is well known that the highest pod quality is reached before maximum yield in green beans. Pods grow by cell enlargement and reach the maximum length when seed development is still insignificant. After this stage, pod composition changes rapidly with increasing dry matter content and seed length (Philippon and Rouet-Mayer, 1974; Le Bohec and Baraer, 1976; Ferreira *et al*., 2006). Under short season condition that is characterized by early autumn frost, low night temperatures and dry conditions, appropriate crop duration in which sowing date is an important determinant is essential for successful cropping. Site-specific factors, cultural practices and sowing date influence yield and yield characteristics. Selection of the most suitable variety and sowing date and applying cultural practices appropriate for the region help to increase quality and yield. Among various factors, optimum sowing date and best variety are of primary importance to obtain potential yield (Amanullah *et al*., 2002).

Growth and development of crop are strongly dependent on temperature (Reath and Wittwer, 1952; Ritchie and NeSmith, 1991; Ferreira *et al*., 1997; Bonhomme, 2000; Kar and Uzun, 2000; Murua, 2002). The concept of heat unit summations or degree days has been used for many years for vegetable production especially for crops where life span affects quality in the field (Default *et al*., 1989; Dufault, 1997). Heat unit summations have been used in many vegetable crops, such as corn (Arnold, 1959), beans (Lorenz and Maynard, 1988), collards (Dufault *et al*., 1989), cucumber

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(Perry *et al*., 1986; 1990), peppers (Perry *et al*., 1993) and tomatoes (Warnok and Isaac, 1969; Warnok, 1970; Wilson and Barnett, 1983; Wolf *et al*., 1986). Temperatures are used to calculate heat sums, degree-days, growing degree-days or thermal time. The most common thermal time calculation is the degree-day. Degree day units are often used in agronomy essentially to predict the lengths of different development phases (Yoldas and Esiyok, 2005). The developmental stages of green beans can be estimated with a high rate of accuracy if a reduction of thermal time accumulation, due to high temperature, is taken into account (Ferreira *et al*., 1997, 2000). Information related to the total degree days required for a crop to reach maturity is often provided by the company selling the seeds. The prediction of the appropriate harvest date is important for farm management and to optimize the flow of raw matter in processing plants.

The objective of this study was to search the effect of sowing date and windbreak on bean growth, yield and yield components. The study also quantified the temperature response of four bean cultivars (Amboto, Gina, Nassau and Volare) during various stages of development.

MATERIALS AND METHODS

Experiments

The study is carried at University of Ege, Izmir (38°16' N, 27°59' W), Turkey in 2004 and 2005 to determine the effect of sowing dates and temperature on growth and yield of bean varieties; Amboto (Syngenta Seed), Gina (May Seed Company), Nassau (Holland-Select Seed Company) and Volare (May Seed Company). The experiments were laid out as a split-split plot design with three replications for each plot. Main plots were windbreak treatments: with windbreak (WB) plots with wind-break fulfilled by maize sown around the plots and no windbreak (NWB). Sub-plots were the sowing dates and sub-sub plots composed of varieties. Seeds were sown in well prepared soil on 23 July 2004 (SD1) and 27 August 2004 (SD1) in the first year and 29 July 2005 (SD1) and 29 August 2005 (SD2) in the second year. Seeds of each variety were sown at between row distances of 0.75 m and on-row of 5 cm throughout the growing period, hand-weeding and other agricultural practices including irrigation were done according to Vural *et al*. (2000) whenever necessary. According to soil tests, fertilizers were broadcast each year before sowing. Generally, following each sowing, irrigation was done to obtain a good field emergence. On each harvest date, pods were harvested by hand.

Data Analysis

Samples of edible parts were collected for measurements and analysis. Mean values of the three replicates were used for analysis. Yield was evaluated as total of all harvests and expressed as kg per ha. Samples of fresh pods were weighed, dried at 70°C for 48 h and re-weighed for measurements for Dry Matter (DM). The result was expressed as percentage of fresh weight. Plant height was also measured at harvest. The data were evaluated using TARIST statistical package programmer (Acikgoz *et al*., 1994).

The thermal time was evaluated for different periods as: from emergence to harvest (a), from emergence to beginning of flowering (b) and from beginning of flowering to harvest (c). In the experiment, the cardinal temperatures calculated during the developmental process between emergence and pod development were 4.2°C as base temperature and 28.4°C as ceiling temperature (Ferreira *et al*., 1997). Air temperature data were collected daily by an automatic weather station (Odemis Weather Station) located near the experimental site. Despite several methods for calculating degree-days, the simplest is to average the daily maximum and minimum temperatures, subtract the base temperature and add the resulting number to the summation (Yoldas, 2003; Tan *et al*., 2000). Degree days are calculated as:

$$\text{Degree days accumulated} = [(\text{Maximum+Minimum daily temperature})/2] - \text{Base temperature}$$

RESULTS AND DISCUSSION

Early sowing increased yields in 2004 and 2005 when compared to the later sowings (Table 1). In late sowing, yield decreased also because of a shorter vegetation period.

Cultivars and windbreak effect in general were statistically significant on all parameters for all sowing dates. Wind and high temperature stress during flowering and pod filling reduced yield and pod shape which is an important quality parameter for processing industry. Significantly better results were obtained in treatments with WB. Yield was significantly higher with WB than NWB for both years with differences of 0.1-0.9%, respectively. Treatment effect was noted as highly significant and windbreak helped to achieve maximum yield (11646.4 kg ha^{-1}) which was followed by no windbreak (11555.8 kg) in 2004 (Table 1). This result shows similarity to the findings of Meinke *et al*. (2002).

Yield reduction was observed by Nielsen (2002) with late planting as planting date is advanced or delayed from the optimum. Late planting has negative consequences on yield because the reproductive stage occurs when weather conditions are less favorable. The reproductive period of common bean plants coincide with the highest summer temperatures and this causes abscission of many buds and flowers that results in a significant decrease of productivity. Similar results were reported by Agtunong *et al*. (1992), Pastenesm and Horton (1999) and Petkova *et al*. (2007).

Duration of days (from emergence to beginning of flowering, from beginning of flowering to harvest, from emergence to harvest) and thermal time: Rodrigo *et al*. (1977) could not obtain a single relationship between pod quality variables and thermal time; though such relations existed when sowing dates were analyzed separately. The use of a calendar date to forecast the time of harvest seems better than using the length of the season. The yield and time of development can be predicted from the harvests of early maturing varieties (Rodrigo *et al*., 1977; Hamer, 1991). Under Odemis (Izmir/Turkey) conditions, the time from emergence to first flower ranged between 21 to 52 days for all sowing dates (Table 2). This results are similar to Mcdonald *et al*. (1994)'s and Smithson *et al*. (1998)'s findings. All phenological stages considered (sowing to emergence, emergence to flowering, flowering to harvest maturity) depended upon accumulated thermal time.

Table 1: Growth, yield and yield components

	Yield (kg ha^{-1})		Plant height (cm)		Dry matter (%)	
Treatments	2004	2005	2004	2005	2004	2005
Cultivars (C)						
Amboto	12501.0	12049.8	31.54	33.90	16.16	6.81
Gina	11345.0	11481.3	39.67	40.68	14.75	7.26
Nassau	11012.8	11761.4	28.83	30.83	15.95	7.44
Volare	11545.5	12128.3	34.49	36.12	16.13	7.94
LSD	686.0**	355.0*	4.11**	3.29**	0.73**	0.13**
Sowing Dates (SD)						
SD1	11869.3	12783.7	34.99	37.00	15.33	7.72
SD2	11332.9	10926.7	32.28	33.76	16.16	7.01
LSD	339.3**	437.7**	1.95**	2.22**	0.36**	0.08**
Windbreak treatments (WB)						
Windbreak	11646.4	12413.8	34.96	36.45	16.40	7.65
No windbreak	11555.8	11296.6	32.31	34.31	15.09	7.08
LSD	ns	437.7**	1.95**	1.63*	0.37**	0.08**
Interactions						
C	**	*	**	**	**	**
SD	**	**	**	**	**	**
WB	ns	**	**	*	**	**
C×SD	**	**	ns	ns	**	**
C×WB	**	**	**	*	**	ns
SD×WB	**	**	ns	ns	**	**
C×SD×WB	**	**	ns	ns	**	**

ns: No significant difference. **Significant at 0.1% level, *Significant at 0.5% level

Table 2: Time from emergence to first flower ranged between 21 to 52 days for all sowing dates

	Sowing date I						Sowing date II					
	Emergence to harvest (a)		From emergence to beginning of flowering (b)		From beginning of flowering to harvest (c)		Emergence to harvest (a)		From emergence to beginning of flowering (b)		From beginning of flowering to harvest (c)	
Varieties	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
Windbreak treatments												
Ambato	83	79	34	39	49	40	59	48	28	21	31	27
Gina	85	83	35	43	50	40	56	50	26	25	30	25
Nassau	89	73	39	33	50	40	63	56	30	27	33	29
Volare	77	72	30	34	47	38	56	46	27	25	29	21
No-windbreak treatments												
Ambato	91	76	41	35	50	41	56	47	26	23	30	24
Gina	92	79	40	39	52	40	56	53	26	26	30	27
Nassau	92	84	41	42	51	42	62	47	24	25	38	22
Volare	88	74	37	34	51	40	64	49	24	24	40	25

(a): Duration of days from emergence to beginning of flowering, (b): From beginning of flowering to harvest, (c): From emergence to harvest (days)

Table 3: Thermal time requirement for the period different periods

	Sowing date I						Sowing date II					
	Emergence to harvest (a)		From emergence to beginning of flowering (b)		From beginning of flowering to harvest (c)		Emergence to harvest (a)		From emergence to beginning of flowering (b)		From beginning of flowering to harvest (c)	
Varieties	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
Windbreak treatments												
Ambato	1434.3	1307.0	638.0	724.8	796.3	582.2	955.6	705.3	476.2	359.3	479.4	346.0
Gina	1466.3	1340.1	656.5	795.3	809.8	544.8	896.8	727.0	441.2	423.9	455.6	303.1
Nassau	1508.2	1257.2	733.0	624.3	775.2	632.9	999.9	792.2	507.9	455.0	492.0	337.2
Volare	1323.7	1246.4	564.0	640.8	759.7	605.6	896.8	688.3	458.2	423.9	438.6	264.4
No-windbreak treatments												
Ambato	1537.8	1280.3	767.0	658.3	770.8	622.0	896.8	696.4	441.2	392.3	455.6	304.1
Gina	1552.6	1307.0	751.0	724.8	801.6	582.2	896.8	765.4	441.2	439.7	455.6	325.7
Nassau	1552.6	1350.0	767.0	775.8	785.6	574.2	985.6	696.4	405.2	423.9	580.4	272.5
Volare	1493.4	1266.0	695.5	640.8	797.9	625.2	1014.0	715.2	405.2	408.1	608.8	307.1

(a): From emergence to harvest, (b): From emergence to beginning of flowering, (c): From beginning of flowering to harvest. (Thermal time (°C) for windbreak and no-windbreak treatment)

In this study, the thermal time was calculated as 264.4-608.8°C from first flowering to harvest for late sowing dates (Table 3). Similar values were found by Ferreira *et al*. (2006) (range 210-520°C days). Thermal time requirement for the period between emergence to flowering ranged between 359.3-795.3°C days for different cultivars and for the period between sowing to maturity as 762.3-1641.2°C days. Olivier and Annandale (1998) found 770 to 890°C days, 1370 to 1450°C days, for the two periods, respectively.

In the second year, for the first sowing date, the thermal time range was 564.0-795.3°C days, near to values reported by Rajin *et al*. (2003) (629°C days from emergence to flowering). Heat-tolerant varieties with higher productivity and good quality are needed to make bean cultivation sustainable (Petkova *et al*., 2007). A decreasing trend in accumulated growing degree-days was observed with a delay in sowing. The developmental stages of green beans can be predicted with accuracy when a reduction of thermal time accumulation, due to high temperature, is taken into account (Ferreira *et al*., 1997, 2000, 2006). Ferreira *et al*. (2006) found that stronger correlations could be obtained if thermal time was evaluated from the beginning of the flowering period and not from sowing and that thermal time had to account for a high temperature reduction of thermal time accumulation (Ferreira *et al*., 1997). Developmental stage was then the most important factor to drive pod quality variables. Plant population and sowing date practically did not change the relationships obtained between bean quality variables and thermal time after first flowering.

CONCLUSION

The results obtained in this study revealed that when sowing is delayed until the end of August, the yield will decrease significantly. Late sown beans will mature around late October or November which is not suitable for the experimental region because of unfavorable weather conditions during harvest. WB or no WB does not in itself result in better bean quality or weight but its advantages are mainly of an ecological nature. Results show that, Amboto×SD1×WB is the best combination in this study. So, we recommended that this combination for similar ecological conditions.

If the reproductive period of bean coincides with high summer temperatures then due to abscission of buds and flowers there is a significant decrease of productivity. In late sowing, growth, yield and yield components decrease because of a short vegetation period. Delayed planting decreased the number of days as well as the thermal time from emergence to harvest. The analysis of the effects of developmental stage on bean quality variables showed that stronger relationships could be obtained if thermal time was evaluated from the beginning of the flowering period and not from sowing and that thermal time had to account for a high temperature reduction of thermal time accumulation. The yield and timing of development can be estimated from the harvests of bean varieties. Using the information, the approximate maturity date of the crop can be predicted by using the average number of degree days in the particular month for particular location. The developmental stages of processing beans can be predicted with thermal time accumulation.

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