Turkish Journal of Agriculture and Forestry

Volume 26 | Number 3 Article 4

1-1-2002

Root Yield and Quality of Sugarbeet in Relation to Sowing Date, Plant Population and Harvesting Date Interactions

RAMAZAN ÇAKMAKÇI

EROL ORAL

Turk J Agric For
26 (2002) 133-139

Root Yield and Quality of Sugarbeet in Relation to Sowing Date, Plant Population and Harvesting Date Interactions

Ramazan ÇAKMAKÇI
Erzurum Şeker Fabrikası, 25700, Ilıca, Erzurum - TURKEY

Erol ORAL
University of Manas, Bişkek, KIRGIZISTAN

Received: 22.06.2001

Abstract: Sowing date, plant density and harvest date are important factors affecting root yield and quality of sugar beet (*Beta vulgaris* L.). The effects of sowing date (beginning of April, mid-April, the end of April, mid-May, and the end of May), plant density, and harvest date (the end of September and mid-October) on sugar beet yield and quality were studied in trials in the Eastern Anatolia region on a loam soil in 1994-97. Variation in plant density was obtained by combining two seed distances and two target emergence percentages. Plant populations for the different treatments reached 55 500, 73 000, 88 900 and 103 600 plants ha^{-1}. Each day that sowing was delayed from mid-April to the end of May resulted in a 703 and 134 kg/ha decrease in root and sugar yield, respectively. A delay in emergence of 43 days from the beginning of May reduced sugar content by 10.9% and estimated extractable sugar content by 15.2%. The maximum differences between large and small plant densities were leaf yield 37.9%, sugar content 5.6%, estimated extractable sugar content 9.6%, root yield 15.8%, and recoverable sugar yield 29.7%. Sugar beet grown at high densities should be harvested later; whereas, crops at low densities should be harvested at the beginning of the harvesting period.

Key Words: Sugar beet, sowing date, harvest date, plant population, root yield- quality

Ekim Tarihi, Bitki Sıklığı ve Hasat Tarihi İnteraksiyonunun Şeker Pancarının Verim ve Kalitesi Üzerine Etkisi

Özet: Bitki sıklığı, ekim ve hasat tarihi şeker pancarı verim ve kalitesini etkileyen önemli faktörlerdir. Bu çalışmada Doğu Anadolu Bölgesinde 1994-97 yıllarında tınlı toprakta ekim tarihi (Nisan başı, Nisan ortası, Nisan sonu, Mayıs ortası ve Mayıs sonu), bitki sıklığı ve hasat zamanının (Eylül sonu ve Ekim ortası) şeker pancarı verim ve kalitesine etkisi araştırılmıştır. İki tohum ekim mesafesi ve iki farklı çimlenme gücüne sahip tohum kullanılarak dört farklı bitki sıklığına ulaşılmıştır. Hektara bitki sayısı, işlemlere göre 55 500, 73 000, 88 000 ve 103 600 olmuştur. Nisan ortasından Mayıs sonuna kadar ekimde geç kalınan her bir gün için hektara kök ve şeker veriminin 703 ve 134 kg azalacağı belirlenmiştir. Mayıs başlangıcından itibaren bitki çıkışının 43 gün geç kalması ile şeker oranı % 10.9, arıtılmış şeker oranını ise % 15.2 azalmıştır. Yaprak verimi, şeker oranı, arıtılmış şeker oranı, kök ve arıtılmış şeker verimi bakımından yüksek ve düşük sıklıklar arasında sırasıyla % 37.9, 5.6, 9.6, 15.8 ve 29.7 farklılık belirlenmiştir. Sık pancarların geç, seyrek pancarların ise hasat periyodunun başlangıcında sökümünün uygun olacağı belirlenmiştir.

Anahtar Sözcükler: Şeker pancarı, ekim tarihi, hasat tarihi, bitki sıklığı, kök verimi ve kalitesi

Introduction

Early sowing in the spring, plant density and late harvest in the presence of prerequisite plant establishment optimise yields. Late sowings enhanced percentage emergence and shortened emergence time (Durr and Boiffin, 1995), but developing soil moisture deficit later reduced emergence and increased gaps in plant stands (Jaggard et al., 1995). However, early sowing (Castillo and Lopez Bellido, 1986) and high plant establishment (Draycott et al., 1974) provided better leaf growth per unit area throughout the growing season. Studies from different locations and years showed that late and poor emergence in earlier sowings and short vegetation period in late sowings rapidly reduced sugar beet root yield (Minx and Rikanová, 1987; Akçin, et al., 1992; Märländer, 1992; Durrant et al., 1993). Late sowings especially decreased sugar content, white sugar content, and white sugar yield (Märländer, 1992; Smit, 1993; Lauer, 1997).

For high root and sugar yield, plant establishment should be 70 000-110 000 plants/ha (Bürcky and Winner, 1986; Er and Inan, 1989; Smit, 1993;

Akınerdem et al., 1994; Märländer and Röver, 1994; Lauer, 1995). In late sowings, the presence of gaps considerably reduced root yield and quality (Draycott et al., 1974; Minx and Rikanová, 1987; Minx, 1993) although yields were lower in late sowings irrespective of plant population. Higher plant population did not compensate for the reductions in yield in late sowings (Smit, 1993; Lauer, 1995) due to shorter growth period and exorbitant leaf growth in higher plant populations (Märländer and Röver, 1994). As plant population increased, sugar content (Märländer, 1992; Çakmakçı et al., 1998), and clear juice purity were also (Smith and Martin, 1977) enhanced. The lower plant populations and presence of many gaps in the field reduced the quality mainly of sugar content and white sugar yield as a result of increased impurity content (Märländer, 1990; Minx, 1993; Lauer, 1995; Çakmakçı et al., 1998).

Delay in harvest also enhanced root yield, sugar, and extractable sugar content (Er and Inan, 1989; Märländer, 1992; Lauer, 1995). The time period acquired by early sowings in spring was of more importance than the time extended by late harvests in autumn (Märländer, 1992; Lauer, 1997).

This experiment was undertaken in order to investigate the interactive effects of sowing date, plant population and harvesting date on plant growth, root yield and quality of sugar beet. Relationships were also investigated between yield and quality parameters as affected by the above factors so that producers and the sugar beet industry may use them to estimate yield and quality at different sowing dates, plant populations and harvest times.

Materials and Methods

This field study was carried out in Erzurum in order to investigate the yield and quality of sugar beet cv. Eva in relation to sowing date, plant population, and harvesting date in the years between 1994 and 1997. The experimental soil was loamy with 2.1-2.4% organic matter and 2.8-3.1% $CaCO_3$ content (pH= 7.9). Soil P_2O_5 and K_2O contents were 77.9-81.2 $kg.ha^{-1}$ and 773-787 $kg.ha^{-1}$ respectively. The experimental field received 80 kg of P_2O_5 ha^{-1}, 2/3 of which was applied during deep ploughing in autumn and 1/3 in spring prior to disk harrowing. Nitrogen at a rate of 100 kg $N.ha^{-1}$ was applied, the first half of which during disk harrowing in spring and the remaining half before hoeing when the plants reached the 6 leaf stage.

The experimental design was a randomized complete block design with a split split plot arrangement. Five different sowing dates were allocated to the main plot, four target plant densities to the split-plots, and two harvest dates to the split-split plot. There were five replicates. The main plot was 18.0 m x 9.0 m. Each split-split plot measured 2.25 x 9.0 m (=20.25 m^2). Rows were 45 cm apart. The first sowing was done as soon as the soil conditions permitted and other sowings followed at approximately 14-day intervals (Table 1). Variation in plant density was obtained by combining two seed distances (approximately 8 and 15 cm) and two target emergence percentages (approximately 89% and 53%). The latter were obtained by adding heat killed seed in different proportions to the normal seed (Neeb, 1967; Bürcky and Winner, 1986; Minx and Rikanová, 1987; Smit, 1993).

Table 1. Sowing dates and emergence of sugar beet.

Years	1st Sowing (S_1)		2nd Sowing (S_2)		3rd Sowing (S_3)		4th Sowing (S_4)		5th Sowing (S_5)	
	Sowing Dates	Emer. Dates	Sowing Dates	Emer. Dates	Sowing Dates	Emer. Dates	Sowing Dates	Emer. Dates	Sowing Dates	Emer. Dates
1994	27.3	12.4	11.4	27.4	26.4	9.5	15.5	27.5	27.5	9.6
1995	30.3	18.4	12.4	1.5	24.4	9.5	14.5	26.5	29.5	15.6
1996	4.4	22.4	17.4	4.5	28.4	12.5	16.5	29.5	29.5	13.6
1997	5.4	28.4	16.4	6.5	26.4	9.5	15.5	27.5	27.5	11.6
Mean	1. 4	20. 4	14. 4	2. 5	26. 4	10. 5	15. 5	27. 5	28. 5.	12. 6

After emergence, the number of plants established was counted and thinning was performed by hand so as to leave intra-row spacing between a minimum of 15 cm and a maximum 40 cm (Minx, 1993; Minx and Rikanová, 1987). The area covered by plant and intra-row spaces more than 40 cm between the plants were measured in order to calculate the empty spaces (i.e. gaps) per plot. The gap rate expresses, from the total length of rows, the percentage of the proportion of the sum of distances exceeding the distance fully utilisable by the plants.

Plots were irrigated five times depending on the visual inspection of plants starting from first half of July until 2-3 weeks prior to harvest. Harvesting was done on 26 September (H1) and on 16 October (H2) in all years. Specimens were taken at 15-day intervals between 1 June and 26 September in all years in order to investigate the development of leaf area index and model leaf growth. Data were also collected at harvest on leaf yield (LY), root yield (RY), sugar content (SC), clear juice purity (CJP), α-amino N, sodium (Na) and potassium (K) contents. Estimated extractable sugar content (EESC) and recoverable sugar yield (RSY) were calculated as (Reinefeld et al., 1974): EESC (%) = SC (%) - [0.343 (Na + K) + 0.094 α-amino N + 0.29]; RSY($t.ha^{-1}$) = (EESC/100) x root yield ($t.ha^{-1}$).

Collected data were subjected to analysis of variance, correlation, and regression using MSTATC Statistical Package and mean separation was performed by the LSD test. The chi-square test (Gomez and Gomez, 1984) was used to verify homogeneity of variance before combining data. Analysis were also carried out among the parameters investigated on the basis of four years' data.

Results

Emergence was completed in 19, 18, 14, 12, and 15 days after sowing respectively, from the first to the last sowing date (Table 1). Plant establishment and population was largely affected by initial emergence, which may be used to estimate the eventual plant population at harvest. Reductions in plant populations throughout the season after thinning were not in line with the initial seedling establishment (Table 2).

Over four years, the period between sowing and harvest varied from 120 to 203 days while it was between 103 and 187 days from emergence to harvest date. Average plant populations at harvest were 75 750, 83 250, 87 000, 83 500 and 71 750 plants ha^{-1} for sowing dates (S_1, S_2, S_3, S_4 and S_5), and 55 500, 73 000, 88 900 and 103 600 plants ha^{-1} for the plant densities (D_1, D_2, D_3 and D_4), respectively (Table 2). The rate of gaps decreased in high levels of field emergence and establishment, and increased in higher seed spacing. Incrementing the density from 55 500 to 73 000, 88 900 and 103 600 plant ha^{-1} decreased the final areas of the largest leaves, from 580 to 525, 450 and 405 cm^2, and increased LAI from 4.3 to 4.7, 4.8 and 4.8, respectively. In the first sowing, the maximum value of LAI was 5 (1 August), in the second it was 5.1 (15 August), and it was 4.9 (1 September) and in the third. The earlier sowings increased leaf yield (LY) rapidly between early and mid-July, levelled until mid-August, and then decreased gradually by mid-October. Leaf yield was positively correlated with harvest stand (Eq. 1). The highest LY were obtained from early harvest and denser stands (Eq. 2). The following equations (Eq. 1-2) were calculated in order to estimate LY by means of time between emergence and harvest (EH), and plant stand at harvest (HS).

$$LY = - 2.64 + 5.69 \times 10^{-4} HS - 1.62 \times 10^{-9} HS^2, (r^2 = 0.80^{**}) \quad (1)$$

$$LY(\pm 3.17) = 7.91 + 3.15 \times 10^{-4} HS - 8.79 \times 10^{-3} EH, (r^2 = 0.89^{**}) \quad (2)$$

On average, the date from four years results indicate that mid-April was the optimum sowing date. Compared with sowing in mid-April, root yield decreased by 7.16, 19.89 and 31.19 $t.ha^{-1}$ respectively, in the sowings at the end of April, mid-May, and end of May. Depending on delays in the days of sowings (d), root yield losses (RYloss) in the sowing of mid-April (S_2) (Eq. 3), end of April (S_3) (Eq. 4) and mid-May (S_4) (Eq.5) can be estimated using the following equations:

$$RYloss = 30.2 + 52.63 d + 0.3782 d^2, (r^2 = 0.98^{**}) \quad (3)$$

$$RYloss = - 1751.4 + 202.47 d - 2.267 d^2, (r^2 = 0.96^{**}) \quad (4)$$

$$RYloss = 366 + 22.75 d + 2.75 d^2, (r^2 = 0.99^{**}) \quad (5)$$

Root yield was positively associated with field emergence, plant population, number of days from emergence to harvest, but was negatively associated with gap rate (Eq. 6-8). The following equation could be used for the estimation of RY:

Table 2. Combined analysis of sugar beet yield and quality response to sowing date, plant density and harvest date during 1994 to 1997. †

	HS	GR	LY	RY	SC	CJP	Na	K	α-N	EESC	RSY
	Plants/ha	(%)	(t/ha)	(t/ha)	(%)	(%)	(mmol/100 g root)			%	(t/ha)
Sowing Dates											
S1	75750	13.93	29.92	61.69	18.99	89.01	0.63	4.73	1.71	16.70	10.34
S2	83250	10.29	33.90	62.27	19.00	89.11	0.57	4.67	1.68	16.75	10.46
S3	87000	7.96	36.89	55.11	18.61	88.65	0.68	4.87	1.90	16.24	8.98
S4	83500	10.72	32.31	42.38	17.85	88.13	0.76	5.04	2.05	15.38	6.56
S5	71750	18.21	27.86	31.08	16.81	87.24	0.86	5.29	2.26	14.20	4.45
LSD (0.01)	580	0.35	0.39	0.46	0.08	0.12	0.04	0.07	0.06	0.09	0.10
Target Plant Density											
D1	55500	29.05	23.97	44.74	17.71	87.44	0.93	5.35	2.32	15.05	6.86
D2	73000	11.44	30.34	50.52	18.12	88.25	0.74	4.99	1.99	15.68	8.05
D3	88900	7.05	35.02	53.62	18.47	88.87	0.61	4.73	1.75	16.18	8.82
D4	103600	0.87	38.57	53.15	18.71	89.15	0.53	4.61	1.63	16.50	8.90
LSD (0.01)	560	0.34	0.43	0.41	0.07	0.11	0.03	0.06	0.06	0.08	0.09
Harvest Dates											
H1	80300	12.25	33.26	47.35	17.88	88.02	0.77	5.11	2.03	15.39	7.43
H2	80300	12.19	30.69	53.66	18.62	88.83	0.63	4.73	1.81	16.32	8.89
LSD (0.01)	333	0.21	0.36	0.29	0.05	0.08	0.02	0.04	0.04	0.06	0.06
Source D.F.					ANOVA						
Year (Y 3	**	**	**	**	**	**	**	**	**	**	**
(B/Y) 16	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sowing (S) 4	**	**	**	**	**	**	**	**	**	**	**
Yx S 12	**	**	**	**	**	**	**	**	**	**	**
Error a 64											
Density(D) 3	**	**	**	**	**	**	**	**	**	**	**
Y x D 9	**	**	**	**	*	**	**	**	NS	**	**
S x D 12	**	**	**	**	NS	**	**	**	NS	NS	**
Y x S x D 36	**	**	**	**	NS	**	NS	**	**	NS	**
Error b 240											
Harvest(H) 1	NS	NS	**	**	**	**	**	**	**	**	**
Y x H 3	NS	NS	**	*	**	*	NS	**	**	**	*
S x H 4	NS	NS	**	*	**	**	NS	NS	NS	**	**
Y x S xH 12	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
D x H 3	NS	NS	**	**	**	NS	NS	NS	NS	*	**
Y x D x H 9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x D x H 12	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
YxSxDxH 36	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Error c 320											
Total 799											

†*, ** Significant at 0.05 and 0.01 probability levels, respectively. NS: not significant

RY = - 39.26 + 0.246 ($\pm$ 1.2x10^{-2}) FE + 0.532 ($\pm$ 7.9x10^{-3}) EH, (r^2= 0.93**) (6)

RY($\pm$ 4.25) = 21.18 + 0.526 EH – 0.357 GR, (r^2 = 0.95**) (7)

RY($\pm$ 4.58) = -42.53 + 0.535 EH + 1.94 x 10^{-4} HS, (r^2 = 0.94**) (8)

Depending on delays in the day of sowing (d), sugar content loss in the sowings of S_2 (Eq. 9), S_3 (Eq. 10) and S_4 (Eq. 11) may be estimated using the following equations:

SCloss = 0.05 + 0.02255 d + 0.00053 d^2, (r^2 = 0.77**) (9)

SCloss = - 1.97 + 0.18136 d + 0.00199 d^2, (r^2 = 0.87**) (10)

SCloss = 0.85 - 0.05 d + 0.005 d^2, (r^2 = 0.54**) (11)

When all the data were considered, delaying harvest by 20 days from 26 September increased SC 3.6, 3.1, 3.9, 4.4, and 5.4 % in the sowing dates of S_1, S_2, S_3, S_4 and S_5 and 3.7, 3.9, 4.3 and 4.6% in the plant densities of D_1, D_2, D_3 and D_4. Sugar content was positively associated with the number of days between emergence and harvest, and plant density at harvest (Eq. 12-13). The four-year data suggest that SC and clear juice purity (Eq. 14-15) may be, with a reasonable precision, predicted using the following equations:

SC ($\pm$ 0.42) = 11.27 + 0.027 FE + 0.038 EH, (r^2 = 0.92**) (12)

SC($\pm$ 0.39) = 10.89 + 0.039 EH + 2.17 x 10^{-5} HS, (r^2 = 0.93**) (13)

CJP ($\pm$ 0.53) = 80.93 + 0.033 EH + 3.4 x 10^{-5} HS, (r^2 = 0.89**) (14)

CJP ($\pm$ 0.26) = 94.33 - [0.1428 x (Na + K + a-N) x 100/ SC], (r^2 = 0.98**) (15)

The relationship between CJP and impurity content was linear (Eq. 15). Late sowing causes low plant stands, higher levels of gap rates, and increases in Na, K, and α-amino N contents. The lowest Na, K, and α-amino N values were obtained from the mid-April sowings, whereas the highest values came from sowings at the end of May. Impurity contents increased as sowing was delayed from mid April (Table 2).

Decreases in yield as a result of later sowing were not affected by plant density. Compared to the sowing in mid-April, SC decreased by 2.1, 6.4, and 11.5%, with sowing at the end of April, mid-May and the end of May, respectively. EESC also decreased by 3.0, 8.2 and 15.2%, respectively. Moreover, EESC decreased by 9.6% as plant stand fell from 103 600 to 55 500 ha^{-1}, in contrast to a 5.5% reduction in SC. On the average of four years, when gaps increased from 0.87% to 29.05% SC and EESC decreased 5.3% and 8.8%, respectively. Higher reductions in EESC than the reductions in SC with delayed sowing were related to increases in non-sugar contents, low plant densities and irregular plant distributions associated with later sowings. According to the averages of all the data, delaying harvest for 20 days from 26 September caused increases in EESC of 5.2, 4.6, 5.8, 6.5 and 8.7% in the sowing dates of S_1, S_2, S_3, S_4 and S_5, and 5.8, 5.9, 6.2 and 6.3% in the plant densities of D_1, D_2, D_3 and D_4, respectively.

In view of four years' results, delaying sowing from the optimum date of mid-April to the end of April, mid-May and the end of May reduced recoverable sugar yield by 1.48, 3.91 and 6.0 t.ha^{-1}, respectively (Table 2). Losses in the RSY dependent on the delays in sowings days could be estimated using the below equation for the sowing dates of S_2 (Eq. 16), S_3 (Eq. 17) and S_4 (Eq. 18):

RSYloss= 2.62 + 11.796 d + 0.0345 d^2, (r^2 = 0.96**) (16)

RSYloss= - 336.94+ 41.597 d - 0.4989 d^2, (r^2 = 0.94**) (17)

RSYloss= 118.0 - 1.5083 d + 0.6583 d^2, (r^2 = 0.63*) (18)

Sugar yield was 6.3, 7.4, 8.0 and 8.0 t.ha^{-1} in the harvest on 26 September in the plant densities of D_1, D_2, D_3 and D_4, respectively but 7.40, 8.74, 9.63 and 9.79 t.ha^{-1}, respectively, in the harvest on 16 October corresponding to increases of 17.2, 18.6, 20.3 and 22.0%, respectively. Highly significant plant density x harvest date and sowing date x harvest date interactions for RY, SC, and RSY indicated that a beet crop with lower plant population and early sowing should be harvested at the beginning and a crop with the highest plant population and late sowing at the end of the harvesting period (Table 2). Early sowing and late harvest produced the greatest RSY. Sugar yield increased in line with field emergence, the time period between emergence and harvest, and plant population at harvest. The following equation could be used for the estimation of RSY:

$$RSY(\pm 0.91) = -9.83 + 5.59 \times 10^{-2} FE + 0.1 EH, \quad (r^2 = 0.94^{**}) \qquad (19)$$

$$RSY(\pm 0.87) = -10.57 + 0.1 EH + 4.4 \times 10^{-5} HS, \quad (r^2 = 0.95^{**}) \qquad (20)$$

Discussion

Early sowing enhanced plant growth and leaf number per unit area. Despite adequate plant growth in early sowings, RY decreased due to inadequate plant number and uneven distribution. In the late sowings, RY also decreased because of a short vegetation period and below optimum plant stands. Yield in the first sowing was restricted by cold, while in the last sowing it did not develop adequate leaf area.

Root and recoverable sugar yield decreased progressively as sowing was delayed after mid–April (Eq. 3, 16). Delaying sowing from mid-April to the end of May resulted in the loss of 6-9% and 8.3-9.7% RY and RSY, respectively, for each week. When sowing was delayed from mid-April and mid-May to the end of May, a loss of RSY occurred 134 and 162 $kg.ha^{-1}.day$ (Eq. 16,18), respectively, each day's delay in sowings with a decrease of 0.06°S in SC (Eq. 9). This result was in line with other studies (Märländer, 1992; Smit, 1993; Lauer, 1997).

In the late sowings, yield and quality fell as intra-row spaces increased and a short vegetation period could not compensate for losses in yield irrespective of plant population gaps in the field negatively affected yield and quality. Recoverable sugar yield increased in line with increases in plant population and uniformity, which was reported also by others (Draycott et al., 1974; Minx and Rikanová, 1987; Minx, 1993).

When plant density reached above optimum levels, RSY declined due to reduction in RY even though SC increased. Root and sugar yields decreased when the distances between plants were irregular (Eq. 7). Wider plant spacing always resulted in lower SC. As plant population decreased and gap rate increased, poor quality plants developed and non-sugar content increased leading to EESC and hence RSY (Märländer, 1990; Lauer, 1995; Çakmakçı et al., 1998).

Early sowing and late harvest produced the greatest yield. Over four years, a later harvest date resulted in greater RY, SC, and RSC, while impurities decreased. The data indicate, therefore, that early sown and thinner stands should be harvested at the beginning of harvest season but late sown and denser stands should be harvested later. Delaying harvest for 3 weeks increased average RY by 13.3% and RSY by 19.7%. RY, CJP, and SC increased while LY, Na, K and α-amino N content decreased as harvest was delayed. Delaying sowing 15 days after mid-April depressed root and white sugar yields that could only be recovered by 33 and 27 day delays in harvest respectively. Root yield increased with increasing plant density but was decreased by plant distribution or gaps.

References

Akçin, A., M. Mülayim, B. Yıldırım, B. Sade, A. Tamkoç and M. Önder, 1992. Şeker pancarında (*Beta vulgaris saccharifera*) çeşit ve ekim zamanının verim, verim unsurları ve kalite üzerine etkileri. Doğa-Tr. J. Agric. and Forestry, 16, 731-743.

Akınerdem, F., B. Yıldırım, M. Mülayim and M. Babaoğlu, 1994. Şeker pancarında (*Beta vulgaris* L.) seyreltmesiz ekimle optimum bitki sıklığının tespiti ve bunun verim ve kaliteye etkisi. Doğa, Tr. J. Agric. and Forestry, 18, 21-25.

Bürcky, K., und C. Winner, 1986. Einfluß der Bestandesdichte auf Ertrag und Qualität der Zuckerrübe bei unterschiedlichem Erntetermin. J. Agron. and Crop Sci., 157 (4), 264-272.

Castillo Garcia, J.E., and L. Lopez Bellido, 1986. Growth and yield of autumn-sown sugar beet: Effects of sowing time, plant density and cultivar. Field Crops Research, 14, 1-14.

Çakmakçı, R., E. Oral, and F. Kantar, 1998. Root yield and quality of sugar beet (*Beta vulgaris* L.) in relation to plant population. J. Agron. and Crop Sci., 180, 45-52.

Draycott, A.P., M.J. Durrant, and D.J. Webb, 1974. Effects of plant density, irrigation and potassium and sodium fertilizers on sugar beet. J. Agric. Sci. Camb., 82, 251-259.

Durr, C., and J. Boiffin, 1995. Sugarbeet seedling growth from germination to first leaf stage. J. Agric. Sci. Camb., 124, 427-435.

Durrant, M.J., S.J. Mash, and K.W. Jaggard, 1993. Effects of seed advancement and sowing date on establishment, bolting and yield of sugarbeet. J. Agric. Sci., 121 (3), 333-341.

Er, C., and H. Inan, 1989. The effect of plant density and harvesting time on yield and quality of sugar beet at different climatically regions. Sugar, 125, 39-47.

Gomez, K.A., and A.A. Gomez, 1984. Statistical procedures for agricultural research. 2nd ed. John Wiley and Sons, New York.

Jaggard, K.W., M. Limb, and G.H. Proctor, 1995. Sugar Beet: A Grower's Guide. Sugar Beet Research and Education Committee. London.

Lauer, J.G., 1995. Plant density and nitrogen rate effects on sugar beet yield and quality early in harvest. Agron. J. 87, 586-591.

Lauer, J.G., 1997. Sugar beet performance and interactions with planting date, genotype, and harvest date. Agron. J. 89 (3), 469-475.

Märländer, B., 1990. Einfluß der bestandesdichte auf ertrags- und qualitätskriterien sowie über mögliche ursachen der konkurrenz in zuckerrübenbeständen. J. Agron. and Crop Sci., 164 (2), 120-130.

Märländer, B., 1992. Hoher Ertrag und hohe Qualitat - ein Widerspruch beim Anbau von Zuckerrüben? Zuckerind. 117 (11), 908-912.

Märländer, B., und A. Röver, 1994. Einfluß von Sorte und Bestandesdichte auf ertrag und Qualität von Zuckerrüben – ein Beitrag zur Lichtkonkurrenz. Zuckerind. 119 (1), 39-47.

Minx, L. 1993. The effect of row spacing on the productive utilization of distances between plants by the sugar beet stand. Rostlinna Vyroba 39 (6), 531-541.

Minx, L., and J. Rikanová, 1987. Yield depression of sugarbeet caused by gaps in stands sown on different dates. Rostlinna Vyroba 33 (9), 959-964.

Neeb, O., 1967. Methodische hinweise zur erzielung unterschiedlicher feldaufgange mit einem einzelnen saatgutposten. Zucker, 20, (10), 269-272.

Reinefeld, E., A. Emmerich, G. Baumgarten, C. Winner, und U. Beiss, 1974. Zur Voraussage des Melassezuckers aus Rübenanalysen. Zucker, 27, 2-15.

Smit, A.L., 1993. The influence of sowing date and plant density on the decision to resow sugar beet. Field Crops Res., 34 (2), 159-173.

Smith, A.L., and S.S. Martin, 1977. Effects of plant density and nitrogen fertility on purity components of sugarbeet. Crop Sci., 17, 469-472.