Bolting, Fresh Root Yield, and Soluble Solids of Sugar Beets as Affected by Sowing Date and Gibberellin Treatment

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Sugar Beets are normally sown in Northern Greece in February-March. Fall sowing, although advantageous in many ways (i.e. easier seed-bed preparation, earliness, longer operation period for sugar factories), is not practiced because of weed control difficulties and winter injury. However, the main constraint of fall sowing is bolting which results in low root and sugar yields and hinders sugar extraction in the factory.

Bolting is caused by low temperatures such as 2-12° C for 40 days (17) followed by long photoperiod. Genetic control of bolting resistance has been generally recognized (14); however, this resistance is also controlled by the environmental conditions under which maternal seed-producing plants have been grown (1, 12). Gibberellin, when applied to the center of the rosette, may stimulate bolting (6) although subsequent seed formation is rare unless plants have previously been thermally induced (18). Sugar beets are amoung those species needing high gibberellin doses to show any effect on growth and development (5) but the mechanism of this substance's action is not yet sufficiently known (7).

We conducted this study to obtain information on varietal differences in bolting resulting from fall sowing and/or gibberellin. This information would be useful to the breeder and seed producer as well as to the sugar industry wishing to know more about the relationship of bolting to fresh root yield and percent total soluble solids.

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MATERIALS AND METHODS

The experiments were conducted at the University Farm of Thessaloniki, Greece in the 1971-72 and 1972-73 seasons. Five varieties were used, namely, Monohil, KWS 13, Hill Standard, Mezzano "AU poly" and Mezzano "AU." The two latter were bred for bolting resistance in Italy. Sowing dates and the number of days from sowing to germination for both seasons as well as time of first gibberellin application for the second season are shown in Table 1.

Table 1.--Sowing dates, number of days from sowing to germination in both seasons, and dates of first gibberellin applications in the second season.

First season		Second season		
Sowing dates	Days from sowing to germination	Sowing dates	Days from sowing to germination	Dates of first gibberellin application
		Nov. 22, 1972	23	Apr. 25, 1973
Dec. 8, 1971	27	Dec. 19, 1972	58	May 2, 1973
Jan. 13, 1972	41	Jan. 25, 1973	54	May 2, 1973
Feb. 9, 1972	14	Feb. 24, 1973	24	May 9, 1973
Mar. 14, 1972	11	Mar. 27, 1973	10	May 16, 1973

In the first season a split-plot design was used with the four sowing dates as main plots and the five varieties as sub-plots. In the second season one more sowing date was added. Also, two gibberellin treatments were included (500 ppm and control); thus, the design was a split-split plot with sowing dates in the main plots, varieties in the sub-plots and gibberellin in the sub-sub-plots. Three replications were used each season. Inter-row spacing was 0.50 m and intrarow 0.25 m (theoretical population of 8,000 plants/ha). Each plot consisted of one row only, 7m long.

Potash salt of the gibberellin acid (GA_3) was used ("Berelex" from I.C.I. Plant Protection Ltd.). Gibberellin was applied as a foliar spray four times or once per week beginning at the six- to eight-leaf stage.

Bolted plants and plants that set seed were counted at weekly intervals, and root fresh weights were separately recorded after harvest. Percent total soluble solids as measured by a refractometer was determined for at least five samples of each plot.

Some of the data on "percent of bolted plants" showed very low values or even zero; therefore this set of data was transformed to arcsin % (8). Since the actual plant population differed among plots, we applied a covariance analysis to adjust root yields (16).

RESULTS AND DISCUSSION

1. Bolting

a. Bolted plants (total). In the first season all bolted plants set seed. In the second season significant differences were found among sowing dates with regard to bolting percentage, with maximum values in the November and minimum in the March sowing (Table 2, Figure 1). Gibberellin increased bolting from 11.8% to 98.7% and masked variety genetic differences (Table 3). Therefore, in this study gibberellin was substituted for cold stimulus in the later sowing dates as in the studies of Gaskill (6) and of Margara (10).

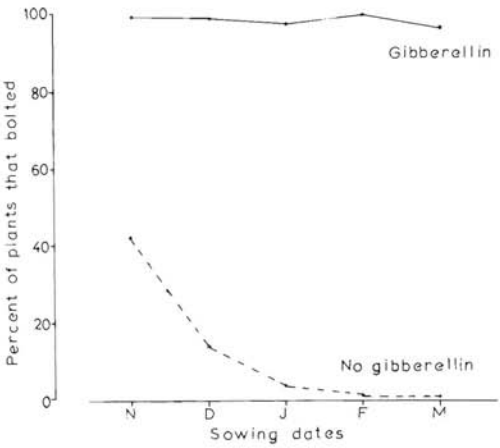

Figure 1.--Gibberellin effect on bolting percentage at five sowing dates (Second Season).

Table 2.--Effect of sowing date and variety treatments on percent of plants that bolted and percent of plants that set seed (First and Second Seasons).

	Sowing dates for untreated plants											
	November			December			January			February		
	1st Season[a]	2nd Season		1st Season	2nd Season		1st Season	2nd Season		1st Season	2nd Season	
Varieties	Bolters	Bolters	Seed Setting	Bolters	Bolters	Seed Setting	Bolters	Bolters	Seed Setting	Bolters	Bolters	Seed Setting
	%	%	%	%	%	%	%	%	%	%	%	%
Monohil	-	50.3 cb	26.3 ab	15.3 cd	7.2 c	4.3 c	3.5 a	9.1 a	1.9 a	0	1.3 a	0.6aa
KSW 13	-	62.4 a	25.8 b	24.6 b	14.1 ab	8.7 ab	2.5 b	5.2 b	1.3 a	0	0 a	0 a
Hill Standard	-	54.8 b	34.7 a	34.5 a	16.5 a	9.5 ab	3.6 c	1.3 b	1.3 a	0	2.5 a	1.2 a
Mezzano "AU poly"	-	17.3 e	11.7 d	12.2 d	14.8 a	11.1 a	1.2 d	0 b	0 a	0	0 a	0 a
Mezzano "AU"	-	23.2 d	15.1 cd	4.7 e	13.6 b	9.3 ab	0 e	1.3 b	1.3 a	0	0 a	0 a

a-All bolters in the first season set seed. (No bolters were observed among the plants originated from the March sowings).
b-Values followed by different letters differ significantly at the 0.05 level. Comparisons are among values of same column.

Table 3.--Bolting of the five varieties tested with and without gibberellin applications (Second Season).

Varieties	Varieties mean	
	No gibberellin	Gibberellin
	% bolters	
Monohil	13.50 b[a]	98.66 a
KWS 13	16.34 a	96.79 a
Hill Standard	15.01 ab	99.23 a
Mezzano "AU poly"	6.41 c	98.93 a
Mezzano "AU'	7.61 c	99.75 a

a-Values followed by different letters differ significantly at the 0.05 level. Comparisons are among values of same column.

A sowing season x variety interaction occurred. Variety differences increased as the low temperature periods increased with maximum differentiation at the November sowing (Table 2). The two Mezzano varieties started to bolt later. Their period of bolting was longer and they had a lower percentage of bolters as compared to the others.

b. Plants that set seed. In both seasons variety and sowing date differences were observed (Table 2). The number of days from sowing to germination differed among the varieties used. Reflecting cold resistance. Varieties that germinated faster under low temperatures showed higher cold resistance and lower bolting percentage, thus confirming the results of Ludvan and Virag (9) and of Campbell and Mast (3). Variety x sowing date interaction for bolting percentage was also observed. Mezzano "AU poly" reacted differently than the other varieties except in the January sowings.

Gibberellin had no effect on percentage of plants that set seed. Thus, the date suggests that the type of Gibberellin (GA_3) used did not assist sugar beet production within one year, but it can partially substitute for cold stimulus as far as induction of bolting is concerned. On the other hand, it can shorten vegetative period so as to enable synchronization of flowering of early and late varieties when crossing between them is desirable (10, 18). According to

Campbell (2) gibberellin can assist screening for bolting resistance in the absence of inductive climatic conditions.

c. Comparisons between seasons. In both seasons bolting percentages were less within early to later sowing dates. No differences between seasons regarding the effect of sowing date on seed set were observed. According to Steyevoort (17) a mean day temperature of 2-12°C for 40 days is needed to induce bolting. This criterion was used in computing the data of Table 4. A linear regression equation of bolting percentage on number of days with the 2-12°C mean temperature range was computed: i.e., $Y = -5.89 + 0.18X$. The linear correlation coefficient was 0.84 and statistically significant.

Table 4.--Days with mean temperatures of 2-12°C from sowing to end of April and respective bolting percentages (First and Second Seasons).

Sowing dates	First season		Second season	
	Days with mean temp. 2-12°C	Bolting	Days with mean temp. 2-12°C	Bolting
		%		%
December	108	18.26	95	13.21
January	72	2.13	70	2.03
February	52	0	42	0.74
March	20	0	13	0

Results did not differ between the two seasons because the number of days with average daily temperature of 2-12°C was virtually the same in both seasons, i.e., from December 1 to April 31 it was 110 days in the first season and 112 days in the secons.

2. Fresh Root Yield

a. Nonbolted plants. In the first season, differences in yield were observed only among varieties but not among sowing dates. Mezzano "AU" yielded more and Mezzano

"AU" poly" less than all others. In the second season sowing dates showed differences while varieties did not. Sowings in November yielded less than sowings in January. Gibberellin increased root yields slightly from January and February sowings. The use of gibberellin to increase yield appears uneconomical at present.

b. Bolted plants (total of second season). Sowing date and variety differences are shown in Table 5. Montaruli (11) and Sneddon (15) stated that fall and generally early sowings yield more than later ones. However, in our study, the plants from November sowing yielded less because of their higher bolting percentage. Yield was greater in the early spring sowings. Intermediate sowing dates gave greater yields due to early leaf canopy development. Plants assimilated for a longer period thus translocating more assimilates to the storage roots. Moreover, seed set was low; therefore, few stored assimilates, if any, had to be translocated back to the tops from the roots.

Table 5.--Adjusted fresh root yield means of total number of bolted plants (Second Season).

Sowing date	Yield kg/plot	Variety	Yield kg/plot
November	16.40 ac[a]	Monohil	17.07 c
December	17.86 abc	KWS 13	18.70 ab
January	19.64 abc	Hill Standard	16.77 c
February	19.33 b	Mezzano "AU poly"	19.38 ab
March	17.14 c	Mezzano "AU'	19.50 ab

a-Values followed by different letters differ significantly at the 0.05 level. Comparisons are among values of same column.

Gibberellin interacted both with sowing dates and with varieties. Sowing date influenced treated plants more that the untreated. A second order interaction among gibberellin, sowing dates, and varieties was obtained showing that varieties did not react similarly at the same combinations of sowing season and gibberellin treatment. The variety Mezzano "AU" sown in January and treated with gibberellin showed the highest yield. All varieties yielded more in the January and February sowings when treated with gibberellin.

c. Total number of plants (nonbolted and bolted). Second season. The response of bolted plants to gibberellin differed from the response of nonbolted ones. In bolted plants greater yielded with gibberellin application was observed in the February sowing. Without gibberellin greater yield was obtained from nonbolted plants originated from the January sowing. Gibberellin x variety x bolting interaction on root yield was also observed. Bolted plants of the two mezzano varieties treated with gibberellin yielded more than the others.

3. Percent total soluble solids

The only differences found were among varieties (Table 6). Varieties which showed high bolting resistance showed lower values. A small difference was also shown between bolted plants treated with gibberellin (15.9%) and nonbolted plants untreated with gibberellin (15.2%). This difference is probably due to increase in hydrolytic enzyme synthesis caused by gibberellin as found in barley -y Chrispeels and Warner (4). Also Paleg (13) reported an increase in reduc-

Table 6.--Mean percent total soluble solids for the five varieties tested (Second Season).[1]

	% Total soluble solids		
Variety	Bolted plants Gibberellin	Bolted plants No gibberellin	Nonbolted plants No gibberellin
Monohil	15.94	15.61	15.42
KWS 13	16.84	16.50	16.00
Hill Standard	16.21	16.16	
Mezzano "AU poly"	15.03	14.67	14.42
Mezzano "AU"	14.91	14.52	14.65

Note: Comparisons of means were made by the use of t-test.

ing sugar content in barley endosperm starch as a result of gibberellin treatment.

Differences among sowing dates were not the same in gibberellin treated compared to non-treated plants, except for February. Generally higher values were obtained in treated plants (Figure 2).

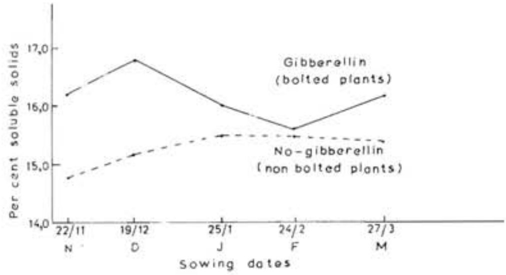

Figure 2.--Sowing date effect on percent soluble solids in gibberellin treated and non-treated plants.

CONCLUSIONS

The following conclusions may be drawn from this study:

a. Bolting was higher in the fall and, generally, in the early sowings and was associated with lower root yields. The January and February sowings were agronomically the most appropriate under the conditions of this study. Sowing date did not affect percent total soluble solids

b. Variety differentiation with regard to bolting became more marked as the thermal induction period increased. Therefore, selection for bolting resistance must be conducted under thermally inductive conditions.

c. Plants did not bolt when exposed to mean temperatures of 2-12°C for less than 40 days. However, percent bolting increased linearly with number of days above 40 having mean temperatures of 2-12°C. The performance of plants did not differ substantially between the two growing seasons probably because the latter did not differ much in their temperature regimes.

d. Bolting resistance was positively related to number of days from sowing to germination and to cold resistance of young plants while it was negatively related to earliness of bolting and percent total soluble solids.

e. Gibberellin complemented the cold stimulus and masked varietal differences in bolting but did not affect percent of plants that set seed. Thus gibberellin (at least the type used) could not promote seed production.

f. Although gibberellin increased fresh root yield and percent total soluble solids the increases were too small to be considered of any practical consequence.

g. Gibberellin interacted with sowing date for bolting, fresh root yield, and percent total soluble solids.

SUMMARY

Five varieties were tested at several sowing dates (between November and March) and at two gibberellin treatments in Thessaloniki, Greece, for two consecutive growing seasons.

Early sowings gave higher percentages of plants that bolted and set seed. Variety differences were also observed with respect to percent of plants that set seed. Bolting resistance was positively correlated to germination rate under low temperatures and to cold resistance of young plants, while it was negatively correlated to percent total soluble solids and to earliness of bolting. January and February were found to be the sowing dates with the lower bolting percentage and higher root yield.

Gibberellin substituted partially for the cold stimulus and increased bolting percentage, but had no effect on seed set. It also increased slightly root yield of plants

sown in January and February. Percent total soluble solids differed amont varieties and increased in the bolters when gibberellin had been applied in the young seedlings.

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