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EFFECT OF SOWING DATE AND PLANT DENSITY ON BOLTING OF FOUR SUGAR BEET (*Beta vulgaris* L.) VARIETIES

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Abstract

This experiment was conducted in Homs Agricultural Research Station, Homs, Syria during 2007/2008 and 2008/2009 seasons to study the effect of sowing date and plant density on bolting for four sugar beet varieties, tow are monogerm varieties i.e. Parade and Etna, while the other are multigerm varieties i.e. Nadir and Mammoth. Three sowing dates were applied, began from 15/9 to 15/10, the interval between the sowing dates was 15 days. Three plant densities were executed (133 000, 100 000 and 80 000 plantha^{-1}). Split plot design was used with three replicates. The combined analysis exhibited the significant effect of varieties (V), sowing dates (S), and plant densities (D) on all types of bolting (Early, medium, late and total). Least significant test (L.S.D $_{0.05}$) clarified that early autumn sowing (15/9 and 1/10) increased total bolting percent 74.86 and 44.88 % respectively, as compared with date (15/10) 15.57% (control). The plant density (133 000 plant ha^{-1}) decreased total bolting percent 43.56% as compared with the other plant densities (80 000 and 100 000 plant ha^{-1}) 46.35 and 45.40% respectively. The results showed that the monogerm varieties were superior and more resistant to bolting as compared with the multigerm ones.

Keywords: Sugar beet, bolting, plant density, sowing date

Introduction

Sugar beet is cultivated throughout the world, accounting for about 30% of world sugar production and is becoming strong contender for bio-fuel production (Panella, 2010). It is mainly grown in warm regions (latitude of 30-60 °N), where sugar cane is not a viable option and is cultivated as either a spring or winter crop in the cooler (e.g., northern European) and warmer (e.g., California Imperial Valley) climates, respectively. Only a few subtropical countries including Morocco, Egypt and India are known to grow and process beet alongside sugarcane (Biancardi and Lewellen, 2010).

In Syria sugar beet is the only source of sugar, the total area is about 6 thousand hectares (217 hectares in winter time, and 6179 hectares in autumn time), which produced 316855 tons of roots, while the yield is 49.5 ton ha^{-1} (Syria, Ministry of Agriculture and Agrarian Reform, 2013).

Sugar beet is a short-term crop of about 6 months, in subtropical latitudes, such as Mediterranean and North African countries, sugar beet is sown in autumn, taking advantage of winter rain, and is harvested at the beginning of the summer (autumn sugar beet) (Maurin, 2005). In autumn-sown sugar beets, low winter temperature increases the risk of bolting (Campbell 2002; Maurin, 2005). *Beta vulgaris* flowers includeboth biennial and annual types. The annual growth habit is characterized by bolting without vernalization and is controlled by dominant alleles of the bolting gene *B* (Munerati, 1931). Other dominant bolting loci have been identified and mapped in sugar beet (Buttner et al. 2010). Thus, large number of studies indicated embryogenic potential at temperatures at or nearer to 25 °C for tuberous varieties, which are stored at lower temperatures to suppress bolting, which indirectly means growth suppression (Neelwarne, 2013).

The definition of bolting is a shoot elongation that marks the visible onset of floral transition which is followed by flower formation and seed set. In biennial root crops, such as sugar beet (*Beta vulgaris* L.) avoidance of flowering is of fundamental importance for high yields and good quality. Since the early years of beet cultivation ~200 y ago, breeders have been strictly selecting against early bolting because root yield and root quality of flowering plants is low (Dally et al. 2014).

Bolting tendency in the crop species *Beta vulgaris*, which includes the sugar beet, is a complex trait governed by various environmental cues, which including prolonged periods of cold temperatures over winter (vernalization) and photoperiod. Sugar beet crop requires cold-induced vernalization period (4-10°C for about 4-8 weeks) followed by long day length in order to flower and thus produce seeds (Abo-Elwafa et al. 2013). Abo-Elwafa et al. (2013) concluded that there were large differences among varieties in tendency to bolting. For the more resistant varieties, no beet bolted with a light phase of 14h.day^{-1}and even under continuous light, the plants only bolted if they had been chilled for 28 or 42 days. One of the major controlling factors on flowering of beet after vernalization is the day length (Lexander, 1980).

In addition, it has been reported (Hogaboam, 1982) in the USA that cultivars differ in bolting response. The same author indicated that a continuous light setting with 14h resulted in a bolting response in some cultivars. Also, it was reported (Smit, 1982) in the Netherlands, that there were differences among varieties in bolting percentage. It was further noted Smit (1983) that the older plants would have been vernalized more effectively and the opposite was true. Sowing dates had marked the effect in the cultivars unsusceptible to bolting. In addition, the workers in Japan stated that bolting rate varied between sowing dates (Abe et al. 1994).

In Japan, Abe et al. (1997) revealed that the susceptible lines exhibited high levels of bolting of more than 90% with the early sowing. Bolting percentage was low in the highly resistant lines, but relatively high in the moderately resistant lines.

In Egypt, El Manhaly et al. (2000) studied the effect of four sowing dates (started from mid of July till the 1st of November) of 32 sugar beet genotypes on bolting. They found a significant differences among sowing dates in terms of bolting, the genotypes that sown in the mid of July had the lowest bolting percentages, as follow, nine genotypes had no bolters, four genotypes with 1-2 % of bolting, eight genotypes with 2.9-5% bolting, and the rest with 10% bolting.

El Manhaly et al. (2000) confirmed that the most important factor that enhances bolting in sugar beet is the genetic factor represented by the genotype, but in the presence of proper environmental conditions.

Bolting is the main obstacle in sugar beet fields, if the crop exposed to low temperatures during autumn time sowing in Syria, bolting causes some disturbs sugar beet harvesting and creates physical and chemical problems in the process of sugar extraction in the factory (Hosseinian et al. 2014), besides its bad impact on yield and quality of sugar beet, also causes a big economic loss to the farmers, therefore this study was conducted to determine the causes of this phenomena, to be aware how to overcome this problem in sugar beet fields. According to that the purposes of the study were to:

-Study the effect of sowing date and plant density on bolting of four sugar beet varieties.

-Specify the proper sowing date, plant density, and variety to get the least bolting percentage.

Materials and methods

The experiment was carried out in Homs Agricultural Research Center, General Commission for Scientific Agricultural Research (GCSAR), Homs, Syria, during 2007/2008 and 2008/2009 seasons. Four sugar beet genotypes were used, two were monogerm and two were multigerm, the source of those genotypes and their sensitivity to bolting were clarified in Table 1.

Table (1): The source of sugar beet genotypes, and their bolting sensitivity

Genotype	Germity	Source	Bolting sensitivity*
Parade	monogerm	USA	Resistant
Etna	monogerm	Denmark	Sensitive
Nadir	multigerm	Belgium	Resistant
Mammoth	multigerm	Denmark	Sensitive

Source of genotypes information, sugar beet department (GCSAR)

Three sowing dates were conducted stated from 15/9 to 15/10 and 15 days was the interval between each date of sowing, it should be mentioned that 15/10 is the recommended date for the autumn time in Syria (Al Jbawi et al., 2009), and three plant densities were used (Table 2).

Table (2): Plant densities treatments

Treatment of plant density D	Distance between plants cm	Plant area cm^2	Plant density Thousand plant. ha^{-1}
D1	15	750	133
D2	20	1000	100
D3	25	1250	80

The distance between plants in the same row according to the experiment were 15, 20, and 25 cm, while the distance between rows was fixed and equal to 50 cm. The recommended plant density of sugar beet in Syria is 100 000 plant.ha^{-1} (50 X 20) (Al Jbawi et al. 2009). The plot size was 32 m^2, number of rows per plot was 8 rows, row length was 8 m, 4 m was the width of the plot. The soil classifies as sandy clayed, medium content of organic matters, high potassium and phosphorous content, because of that no potassium and phosphorous fertilizers addition, Nitrogen fertilizer was added in a level of 200 unit per hectare (Al Jbawi, et al. 2009) in a form of urea 46% (435 kg urea ha^{-1}) depending on soil analysis, with three dozes, the first doze was before sowing, the second one was after thinning, while the third doze of urea was after one month after thinning. The previous crop was wheat. Sugar beet was harvested after 240 days after sowing.

Studied traits:

1-Total bolting percentage: Counting the bolted plants in each treatment at the end of the growing season, it was calculated as follow:

Total bolting percentage%=(Number of bolted plants in a specific area/Total number of plants in a specific area) X 100

2-Early bolting percentage %= Counting bolted plants that usually appeared at April in each treatment, it was calculated as follow:

Early bolting percentage%=(Number of bolted plants in a specific area/Total number of plants in a specific area) X 100

3-Medium bolting percentage %= Counting bolted plants that usually appeared at May in each treatment, it was calculated as follow:

Early bolting percentage%=(Number of bolted plants in a specific area/Total number of plants in a specific area) X 100

4-Late bolting percentage %= Counting bolted plants that usually appeared at June in each treatment, it was calculated as follow:

Early bolting percentage%=(Number of bolted plants in a specific area/Total number of plants in a specific area) X 100

Experiment design and statistical analysis:

Split plot design was used with three replications to analyze the source of variations (ANOVA), and the interaction. The statistical programme Genestat. 12 was used for each season and the combined analysis also (Gomez and Gomez, 1984). Least significant difference was used at 5% level of probability.

Results and Discussion

The effect of sowing date, plant density and genotype on:

1-Early bolting percentage %:

It is very important to mention that the high bolting values had a negative indication, it means that the increase in bolting, which is a negative phenomena in *Beta vulgaris* fields does not mean a good indicator, it is better when this percent as low as possible.

The results of combined analysis (Table 3) indicates a significant differences between sowing dates in terms of early bolting percentage, the sowing date on 15/10 (2.89%) surpassed significantly the other sowing dates 19/9 and 1/10 (20.44 and 14.29%) respectively. The results also exhibits that the plant density 133 000 plant.ha^{-1} reduced early bolting percentage about 14% as compared the plant density 80 000 plant ha^{-1}.

Table (3): The effect of sowing date and plant density on early bolting percentage of four sugar beet varieties

Variety (V)	Plant density (D) Plant ha^{-1}	Sowing date (S)		
		15/9	1/10	15/10
Parade	133 000	18.33	11.50	0.50
	100 000	17.50	11.67	1.00
	80 000	21.17	9.83	1.50
	Mean	19.00	19.00	19.00
Etna	133 000	15.50	11.50	0.50
	100 000	19.50	13.17	1.00
	80 000	19.50	13.00	1.50
	Mean	18.17	12.56	1.00
Nadir	133 000	18.00	13.50	3.00
	100 000	21.67	12.00	3.50
	80 000	22.17	17.00	5.00
	Mean	20.61	14.17	3.83
Mammoth	133 000	25.00	15.50	6.00
	100 000	22.00	24.83	6.00
	80 000	25.00	18.00	5.17
	Mean	24.00	19.44	5.72
General mean		20.44	14.29	2.89
General mean of plant density Plant ha^{-1}		133 000	100 000	80 000
		11.57	12.82	13.24
General mean of varieties		Parade	Etna	Nadir	Mammoth
		10.33	10.57	12.87	16.39
LSD (P < 0.05)		S =1.66 , V =1.36 , D =1.45 S * V =2.37, S* D =2.40, V* D =2.68 S * V * D =4.66			

S, D and V means: Sowing date, plant density and varieties, respectively.

Table (3) shows the significant superiority of monogerm varieties Parade and Etna (10.33 and 10.57%) respectively, as compared with the multigerm varieties Nadir and Mammoth (12.87 and 16.39%). This result confirms the importance of genetic factor (El manhaly et al., 2000; Abo-Elwafa et al. 2013), the combined analysis indicates also that the lowest early bolting percentage achieved when Parade and Etna varieties were sown on 15/10 in distances 15X50 cm (133 000 plant.ha^{-1}).

2-Medium bolting percentage %:

Table (4) clarifies a high significant differences between sowing dates, and the sowing date 15/10 has the lowest medium bolting percentage (6.38%), as compared with the dates 15/9 and 1/10 (20.94 and 13.47%) respectively. The results also shows insignificant differences between plant densities, but in terms of varieties, Parade variety gives the lowest medium bolting percentage significantly (10.80%), then Etna variety (14%), next Nadir variety (12.22%), and lastly Mammoth variety (17.37%).

The lowest medium bolting percentage was achieved when Parade variety was sown on 15/10, and plant density was 133 000 plant ha^{-1}, on the other hand the highest medium bolting percentage was achieved when Etna variety was sown on 15/9, and the plant density was 133 000 plant ha^{-1}.

Table (4): The effect of sowing date and plant density on mediumbolting percentage of four sugar beet varieties

Variety (V)	Plant density (D) Plant ha-1	Sowing date (S)		
		15/9	1/10	15/10
Parade	133 000	21.00	11.67	2.00
	100 000	20.00	11.50	2.50
	80 000	15.50	9.50	3.50
	Mean	18.83	10.89	2.67
Etna	133 000	27.00	14.00	2.50
	100 000	24.50	14.00	3.50

	80 000	24.00	13.00	3.50
	Mean	25.17	13.67	3.17
Nadir	133 000	14.50	16.17	5.00
	100 000	17.00	16.17	5.50
	80 000	16.00	13.17	6.50
	Mean	15.83	15.17	5.67
Mammoth	133 000	22.50	14.50	15.50
	100 000	24.00	12.50	12.50
	80 000	25.33	15.50	14.00
	Mean	23.94	14.17	14.00
General mean		20.94	13.47	6.38
General mean of plant density Plant ha^{-1}		133 000	100 000	80 000
		13.86	13.46	13.29
General mean of varieties		Parade	Etna	Nadir	Mammoth
		10.80	14.00	12.22	17.37
LSD (P < 0.05)		S =2.37, V =1.03, D =ns S * V =2.49, S* D =2.43, V* D =1.87 S * V * D =3.60			

S, D and V means: Sowing date, plant density and varieties, respectively

3-Late bolting percentage %:

Late bolting percentage ranged between 6.31% on 15/10 sowing date, to 33.47% on 15/9 sowing date significantly, this may bedue to the variation in environmental conditions, in

terms of temperatures basically (Zobinko, 1989),besides the effect of sowing date on bolting rate (Abe et al. 1994). Plant density 133 000 plant.ha^{-1} surpassed significantly (18.12%) the other plant density 80 000 plant ha^{-1} (19.82%), while the differences were not significant between 133 000 and 100 000 plantha^{-1} (Table 5). Also late bolting percentage ranged from 18.04% in Nadir variety to 20.78% in Parade variety. The lowest value of late bolting percentage (2.5%) was achieved when the plant density was 133 000 planha^{-1}, and Parade variety was sown on 15/10, but sowing Parade variety on 15/9 with plant density of 80 000 plant ha^{-1} gave the highest late bolting percentage (41.17%). It is obvious that bolting % was low in the highly resistant varieties, but high in the susceptible varieties (Abe et al. 1997).

Table (5): The effect of sowing date and plant density on late bolting percentage of four sugar beet varieties

Variety (V)	Plant density (D) Plant ha-1	Sowing date (S)		
		15/9	1/10	15/10
Parade	133 000	33.00	24.67	2.50
	100 000	35.83	21.50	4.00
	80 000	40.50	20.00	5.00
	Mean	36.44	22.06	3.83
Etna	133 000	34.17	14.50	3.50
	100 000	38.83	13.50	4.50
	80 000	41.17	14.67	4.67
	Mean	38.06	14.22	4.22
Nadir	133 000	33.67	15.00	6.00
	100 000	27.00	16.50	8.00
	80 000	32.17	14.50	9.50

	Mean	30.94	15.33	7.83
Mammoth	133 000	26.00	16.00	8.50
	100 000	30.17	17.50	10.00
	80 000	29.17	17.00	9.50
	Mean	28.44	16.83	9.33
General mean		33.47	17.11	6.31
General mean of plant density Plant ha^{-1}		133 000	100 000	80 000
		18.12	18.94	19.82

General mean of varieties	Parade	Etna	Nadir	Mammoth
	20.78	18.83	18.04	18.20
LSD (P < 0.05)	S =1.57, V =1.55, D =1.18 S * V =2.57, S* D =2.05, V* D =2.41 S * V * D =4.12			

S, D and V means: Sowing date, plant density and varieties, respectively

3-Total bolting percentage %:

The combined analysis of the two seasons indicates the significant superiority of 15/10 (15.57%) date of sowing, which is the recommended sowing date for autumn time in Syria, as compared with the other sowing dates 15/9 and 1/10 (74.86 and 44.88%) respectively. The high bolting percentage of sugar beet varieties when it is sown on 15/9 may due to the length of photoperiod during the day which accompanied with low temperatures 6 to 8 degrees for 6 to 10 weeks (Lexander, 1980; Abo-Elwafa et al. 2013).

The plant density 133 000 plant.ha^{-1} surpassed significantly in terms of total bolting percentage (43.56%) the plant density 80 000 plant ha^{-1} (46.35%), while the differences were not significant between the densities 133 000 and 100 000 and also between 100 000 and 80 000 plant ha^{-1} (Table 6).

Table (6): The effect of sowing date and plant density on total bolting percentage of four sugar beet varieties

Variety (V)	Plant density (D) Plant ha-1	Sowing date (S)		
		15/9	1/10	15/10
Parade	133 000	72.33	47.83	5.00
	100 000	73.33	44.67	7.50
	80 000	77.17	39.33	10.00
	Mean	74.28	43.94	7.50
Etna	133 000	76.67	40.00	6.50
	100 000	82.83	40.67	9.00
	80 000	84.67	40.67	9.67
	Mean	81.39	40.44	8.39
Nadir	133 000	66.17	44.67	14.00
	100 000	65.67	44.67	17.00
	80 000	70.33	44.67	21.00
	Mean	67.39	44.67	17.33
Mammoth	133 000	73.50	46.00	30.00
	100 000	76.17	54.83	28.50
	80 000	79.50	50.50	28.67
	Mean	76.39	50.44	29.06
General mean		74.86	44.88	15.57
General mean of plant density		133 000	100 000	80 000

Plant ha^{-1}	43.56		45.40	46.35
General mean of varieties	Parade	Etna	Nadir	Mammoth
	41.91	43.41	43.13	51.96
LSD (P < 0.05)	S =4.66, V =2.16, D =1.96 S * V =4.97 ,S* D =4.79, V* D =3.79 S* V * D =7.20			

S, D and V means: Sowing date, plant density and varieties, respectively

The monogerm variety Parade achieved the lowest total bolting percentage (5%) when it sown on 15/10, and the density was 133 000 $plantha^{-1}$, on the other hand the highest total bolting percentage was achieved when the variety Etna variety was sown on 15/9, and the density 80 000 $plantha^{-1}$.

Conclusion

1-The combined analysis of the two seasons confirmed the superiority of the sowing date 15/10 for all kinds of bolting (total, early, medium, and late), so we consider the date 15/10 the proper sowing date in autumn time in the middle area of Syria.

2-In general the monogerm varieties were more resistant to bolting, thus we recommend sowing monogerm varieties in autumn season.

3-We recommend to sow sugar beet using the distances 15 X 50 cm to reduce bolting percentage, because the plant density 133 000 $plantha^{-1}$ gave the lowest bolting percentage for all kind of bolting.

4-We recommend to study the effect of late sowing of sugar beet (after 15/10) on bolting percentage.

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