World Journal of Agricultural Research, 2013, Vol. 1, No. 5, 90-95
Available online at http://pubs.sciepub.com/wjar/1/5/4

DOI:10.12691/wjar-1-5-4

Effect of Root Age and Day-Length Extension on Sugar Beet Floral Induction and Fertility

Salah F. Abo-Elwafa[1,2,*], Husein M. Abdel-Rahim[2], Adel M. Abou-Salama[2], El-Mahdy A. Teama[2]

[1]Plant Breeding Institute, Christian-Albrechts University of Kiel, Germany
[2]Agronomy Department, College of Agriculture, Assiut University, Egypt
*Corresponding author: abou-elwafa@plantbreeding.uni-kiel.de

Received September 25, 2013; Revised September 30, 2013; Accepted October 10, 2013

Abstract Bolting tendency in the crop species *Beta vulgaris*, which includes the sugar beet, is a complex trait governed by various environmental cues, including prolonged periods of cold temperatures over winter (vernalization) and photoperiod. This work was carried out as a part of a series of experiments on sugar beet floral induction under Egyptian conditions as part of the effort to breed and select sugar beet cultivars adapted to local environmental conditions. Ten diploid cultivars were sown in the field at three dates on 15th, 30th July and 15th August to provide roots at the ages of 120, 135 and 150 days, and harvested on the 15th of December. The roots were vernalized at 4°C for 45 days before replanting in the field. Extended *vs.* natural day-length were applied 3 weeks after replanting. Data was collected on flowering behavior, pollen fertility seed setting and seed germination. The results indicate that cultivars' responses are the main factor that controlled the response to the imposed treatments. The response of cultivars varied according to root age, and day-length treatments. In most of the flowering cultivars, extended day-length improved the measured traits. Older root age also tended to enhance the measured traits with minor exceptions. The findings of this work are a step towards the definition of techniques that can be used to start a sugar beet breeding program under Egyptian conditions.

Keywords: *sugar beet, bolting, flowering, fertility, floral induction, Beta vulgaris*

Cite This Article: Salah F. Abo-Elwafa, Husein M. Abdel-Rahim, Adel M. Abou-Salama, and El-Mahdy A. Teama, "Effect of Root Age and Day-Length Extension on Sugar Beet Floral Induction and Fertility." *World Journal of Agricultural Research* 1, no. 5 (2013): 90-95. doi: 10.12691/wjar-1-5-4.

1. Introduction

Sugar beet is the second source of sugar in Egypt. It was introduced to the Egyptian agricultural system in the early 1980's. Currently, it covers an area of about 72,305 ha [21]. The crop requires cold-induced vernalization period (4-10ºC for about 4-8 weeks) followed by long day length in order to flower and thus produce seeds. Such conditions are not available in Egypt. Thus, Sugar beet growing in Egypt depends on imported seeds. During the last few years new approaches were developed to select beet varieties under conditions warmer than the European conditions where most varieties are selected and commercially produced.

Reports covering sugar beet flowering in the Northern hemisphere are numerous. However, in Egypt such reports are scarce. This is due to the difficulty in inducing sugar beet to flower under Egypt conditions. One of the major factors controlling flowering of beet after vernalization is the day length [16]. In addition, it has been reported [15] 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 [18] in the Netherlands, that there were differences among varieties in bolting %. It was further noted [19] that the older plants would have been vernalized more effectively and the opposite was true. Sowing dates had marked effect in the cultivars unsusceptible to bolting. Extension of the light phase induced more bolting. At 14h/day photoperiod, bolters appeared only after chilling for 42 or 28 days. 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 and even under continuous light, the plants only bolted if they had been chilled for 28 or 42 days. In addition, workers in the USA [17] reported that there was an almost parallel relation between fruit weight and germination.

Still in the USA, other workers [12] found a general relationship between sugar beet seed set and *in vitro* pollen germination. Pollen viability is affected by season and cultural conditions. The ability of pollen to germinate on artificial medium is widely used as a test of viability. It has been shown [13] that there are significant differences among varieties in pollen viability. In Alexandria, Egypt, it was found [6] that the number of days from replanting, seed index, single plant seed yield and germination % differed significantly among genotypes owing to day length. In addition, workers [11] in Japan stated that bolting rate varied between sowing dates. Other workers [1] in Japan revealed that the susceptible lines exhibited high levels of bolting of more than 90% with the early sowing. Bolting % was low in the highly resistant lines, but relatively high in the moderately resistant lines. In the UK, it was found [5] that plant age plays a significant role in invoking the bolting response. There were differences among varieties in response to bolting. Furthermore, in Egypt, it was revealed [7] that root age affects the bolting and flowering of sugar beet. Flowering % increased with extended day length. In addition, it was equally revealed [3] in kaliobia, Egypt, that photoperiod had a significant effect on flowering %, days from replanting to flowering, single plant seed yield, total seed yield, seed index and germination %. The least number of days from replanting to flowering and the highest values of the other traits were obtained when 14h/day photoperiod was applied. An intensive breeding effort by seed companies has resulted [4] in the availability of a wide range of monogerm varieties, adapted to various climatic conditions and disease & pest pressures.

This work was carried out as a part of a series of experiments on sugar beet flowering initiation. It aims to lay the foundation for a procedure of floral induction control of sugar beet under Egyptian conditions as part of the effort to breed and select sugar beet cultivars adapted to the environmental conditions of the area.

2. Materials and Methods

2.1. Plant Material and Growing Conditions

The experiment was carried out at Assiut University Experimental Farm at latitude 27ºN. Ten diploid cultivars namely: C 14, C 146, C 205, C 211, C 221, C 261, C 283, C 9622, C 9720, US H11 were kindly supplied by Dr. John Kern, Crystal Sugar Company, North Dakota, USA.

Seeds of these cultivars were sown in the field at three dates on 15th, 30th July and 15th August using normal sugar beet cultivation practices except that the space between hills was 10 cm. Roots of all sowing dates were harvested on the 15th of December and vernalized at 4ºC for 45 days. At the end of the vernalization treatments, 20 roots were replanted in rows spaced 75cm and distance between hills was 50cm. Four replicates were used for this part of the experiments. Day-length extension treatment was carried out by providing artificial illumination to extend day length to 14 hours/day using 100-w incandescent units suspended about 1m above the surface of the soil. The average light intensity at night above the soil was approximately 2222 Foot -candle [9]. Extended day length (EXT) was done 3 weeks after replanting for 45 days. Roots were also replanted under natural day-length (NAT) conditions to serve as the second day- length treatment. All other processes were carried out as recommended for sugar beet in the region.

2.2. Data Collection and Statistical Analysis

The data recorded were: Bolting %, number of days from transplanting to bolting, pollen viability estimated as % of germinated pollen grains, single plant seed yield (g), seed index (100 seeds), and seed germination %.

Pollen germination test was carried out as described in [14] using medium composed of Calcium nitrate (300 rag/l), Boric acid (100 rag/l), and sucrose (300 rag/l). Pollen grains were placed on a glass slide and two drops of the medium were added. The slide was placed over a wet filter paper in a closed Petri dish for 1-2 hours at room temperature. Data on pollen grain germination were taken by counting 4 fields under 40 × magnifications using a Lomb light microscope (Figure 1). Seed germination tests were performed according to a specified technique [2].

The experimental design was a split block with 4 replicates. Each of the two day-length extension treatments was treated as a separate experiment. Within each experiment, root age was assigned to the main plots and cultivars were allocated as the sub-plots. The data of the two day-length experiments were subjected to combined analysis of variance. Due to the existence of many null observations, data were transformed using arcin method before being subjected to the statistical analysis. The statistical analysis was performed [10] and the means of significant treatments were compared using Revised LSD at 5% probability level [20].

3. Results and Discussion

3.1. Bolting Rate

Data in Table 1 indicates that root age, day-length extension, cultivars and their interactions had highly significant effects on bolting % in both seasons. In general terms, considering the means of the main factors *per se* is not a valuable system due to the existence of null response in some cultivars. Thus, the discussion would rather concentrate on the response to root age, day-length extension within each cultivar for more accurate handling of the results. Means listed in Table 1 show that the oldest roots (150 days) recorded the highest bolting %. This may be explained by previous findings [5], which indicated that plant age plays a significant role in invoking the bolting response. In addition the chemical composition of older roots may affect its response to vernalization. Artificial illumination (14h) was generally higher than natural day-length in terms of bolting %.

The oldest roots under artificial illumination produced the highest bolting % in the 1st season, while in the 2nd season the highest percentage resulted from plants of 135 days age with artificial illumination.

Both C 146 and C 221 cultivars scored the highest bolting % in both seasons. These two cultivars seem to have minimum root age and day-length requirements as they flowered under all treatment combinations. This might be due to the genetic make-up of these particular cultivars that are sensitive to vernalization and photoperiod efficiently. C 146 cultivars under artificial illumination and plants of 120 days age (3rd plant age) of C 146 cultivar under artificial illumination resulted in the highest bolting % in both seasons. Cultivars were the most effective factor in these interactions.

In addition, it seemed that there are some cases where natural day-length was more effective than extended day-length; where C211 flowered under 135 days old roots.

These findings suggest that varietal differences should be examined more in order to define the best treatment needed for each cultivar to be able to use it in the breeding program.

Table 1. Effect of root age and photoperiod on bolting % of sugar beet

Root age	cultivar	Bolting %						Days from replanting to bolting					
		Day length treatments						Day length treatments					
		1st growing season			2nd growing season			1st growing season			2nd growing season		
		Ext.	Nat.	Mean	Ext.	Nat.	Mean	Ext.	Nat.	Mean	Ext.	Nat.	Mean
120 days	C 14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 146	100.0	43.7	71.8	81.2	68.7	75.0	48.2	51.5	49.8	52.2	55.2	53.7
	C 205	50.0	0.0	25.0	37.5	0.0	18.7	55.2	0.0	27.6	59.0	0.0	29.5
	C 211	0.0	37.5	18.7	0.0	31.2	15.6	0.0	55.2	27.6	0.0	55.2	27.6
	C 221	93.7	87.5	90.6	87.5	75.0	81.2	52.5	59.0	55.7	57.0	59.0	58.0
	C 261	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 283	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 9622	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 9720	93.7	0.0	46.8	81.2	0.0	40.6	56.0	0.0	28.0	60.2	0.0	30.1
	USH11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean		33.7	16.9	25.3	28.7	17.5	23.1	21.2	16.6	18.9	22.8	16.9	19.9
135 days	C 14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 146	81.2	81.2	81.2	87.5	75.0	81.2	50.2	53.7	52.0	54.0	57.2	55.6
	C 205	0.0	31.2	15.6	0.0	31.2	15.6	0.0	56.7	28.3	0.0	59.0	29.5
	C 211	87.5	0.0	43.7	81.2	0.0	40.6	51.5	0.0	25.7	54.2	0.0	27.1
	C 221	81.2	75.0	78.1	75.0	68.7	71.8	52.5	57.5	55.0	55.2	60.0	57.6
	C 261	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 283	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 9622	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 9720	37.5	0.0	18.7	68.7	62.5	65.6	55.2	0.0	27.6	57.2	61.0	59.1
	US H11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean		28.7	18.7	23.7	31.2	23.7	27.5	20.9	16.8	18.9	22.1	23.7	22.9
150 days	C 14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 146	87.5	68.7	78.1	62.5	68.7	65.6	50.0	53.0	51.5	54.0	55.2	54.6
	C 205	81.2	25.0	53.1	0.0	0.0	0.0	55.2	53.2	54.2	0.0	0.0	0.0
	C 211	75.0	43.7	59.3	0.0	25.0	12.5	55.7	59.2	57.5	0.0	59.2	29.6
	C 221	68.7	75.0	71.8	56.2	75.0	65.6	57.0	57.7	57.3	60.5	59.2	59.8
	C 261	0.0	0.0	0.0	0.0	68.7	34.3	0.0	0.0	0.0	0.0	59.2	29.6
	C 283	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 9622	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 9720	31.2	0.0	15.6	0.0	0.0	0.0	59.7	0.0	29.8	0.0	0.0	0.0
	US H11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean		34.4	21.2	27.8	11.9	23.7	17.8	27.8	22.3	25.0	11.5	23.3	17.4
Combined over all root ages	C 14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 146	89.5	64.5	77.0	77.0	70.8	73.9	49.5	52.7	51.1	53.4	55.9	54.6
	C 205	43.7	18.7	31.2	12.5	10.4	11.4	36.8	36.6	36.7	19.6	19.6	19.6
	C 211	54.1	27.0	40.6	27.0	18.7	22.9	35.7	38.1	36.9	18.0	38.1	28.1
	C 221	81.2	79.1	80.2	72.9	72.9	72.9	54.0	58.0	56.0	57.5	59.4	58.5
	C 261	0.0	0.0	0.0	0.0	22.9	11.4	0.0	0.0	0.0	0.0	19.7	9.8
	C 283	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 9622	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 9720	54.1	0.0	27.0	50.0	20.8	35.4	57.0	0.0	28.5	39.1	20.3	29.7
	US H11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean		32.3	18.9	25.6	23.9	21.7	22.8	23.3	18.5	20.9	18.8	21.3	20.0

Revised LSD 5%	Bolting %		Days from replanting to bolting	
	2nd growing season	1st growing season	2nd growing season	1st growing season
Photoperiod (P)	**	**	**	**
Plant age (A)	3.63	5.31	4.32	4.36
A× Photoperiod (P)	5.13	7.51	6.10	6.16
Cultivars (C)	4.70	6.87	0.93	0.43
P × C	6.64	9.81	1.31	0.60
A × C	8.13	12.02	1.61	0.74
P × A × C	11.50	17.00	2.28	1.05

3.2. Number of Days from Replanting to Bolting

Statistical analysis of data showed that plant age, photoperiod, cultivars and their interactions had highly significant effects on Number of days from replanting to bolting in both seasons (Table 1).

Means presented in Table 1 revealed that within flowering cultivars extending day-length tended to reduce the number of days from replanting to flowering. However, in some case, particularly under younger root age, plants exposed to extended day-length failed to flower as indicated by the response of C 211 and C 261 in the second season. An opposite trend was observed for C 283 and C 9720 in the first season. These data suggest that cultivars are the major contributors to flowering response in sugar beet.

Thus, it is important in planning for the breeding season to adjust planting and replanting dates to be able to have flowering of different cultivars at the same time to carry successful crossing campaign.

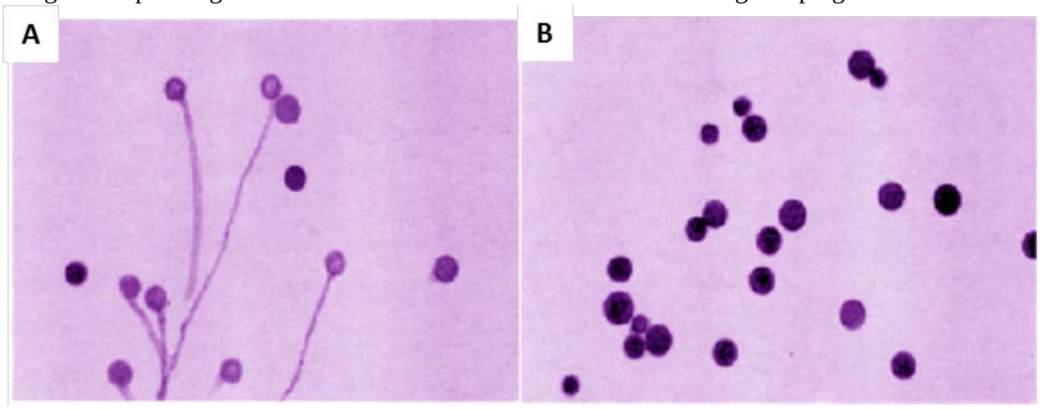

Figure 1. Germinated (A) and non-germinated pollen (B) of sugar beet at individual fields (40 × magnification)

Table 2. Effect of root age and photoperiod on pollen viability % and single plant seed yield (g) of sugar

Root age	cultivars	Pollen viability %						Single plant seed yield (g/ plant)					
		Day length treatments						Day length treatments					
		1st growing season			2nd growing season			1st growing season			2nd growing season		
		Ext.	Nat.	Mean	Ext.	Nat.	Mean	Ext.	Nat.	Mean	Ext.	Nat.	Mean
120days	C 146	32.7	32.5	32.6	36.2	33.2	34.8	79.7	0.0	39.9	67.2	98.0	82.6
	C 205	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 211	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 221	34.5	31.7	33.1	39.2	33.0	36.1	80.0	93.7	86.9	78.5	100.0	89.3
	C 261	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 9720	37.5	0.0	18.7	41.7	0.0	20.9	30.0	0.0	15.0	82.7	0.0	41.4
Mean		17.5	10.7	14.1	19.5	11.0	15.3	31.6	15.6	23.6	38.1	33.0	35.5
135days	C 146	35.0	30.2	32.6	36.5	30.2	33.4	79.7	93.7	86.8	95.0	118.7	106.9
	C 205	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 211	27.0	0.0	13.5	33.2	0.0	16.6	47.5	0.0	23.8	92.5	0.0	46.3
	C 221	27.2	26.7	27.0	32.5	34.5	33.5	48.7	64.7	56.8	66.0	75.2	70.6
	C 261	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 9720	0.0	0.0	0.0	33.7	34.2	34.0	0.0	0.0	0.0	52.2	89.5	70.9
Mean		14.9	9.5	12.2	22.7	16.5	19.6	29.3	26.4	27.9	51.0	47.2	49.1
150days	C 146	0.0	0.0	0.0	43.5	34.2	38.9	90.5	95.2	92.9	60.2	93.7	77.0
	C 205	50.0	36.2	43.1	0.0	0.0	0.0	87.5	0.0	43.8	0.0	0.0	0.0
	C 211	34.7	0.0	17.3	0.0	0.0	0.0	94.0	0.0	47.0	0.0	0.0	0.0
	C 221	37.0	0.0	18.5	35.0	32.2	33.6	90.2	87.7	89.0	72.7	95.2	84.0
	C 261	0.0	0.0	0.0	0.0	33.5	16.8	0.0	0.0	0.0	0.0	73.0	36.5
	C 9720	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean		20.3	6.1	13.2	13.1	16.7	14.9	60.4	30.5	45.5	22.2	43.7	32.9
Combined over all root ages	C 146	22.6	20.9	21.7	38.7	32.5	35.7	83.3	63.0	73.2	74.1	103.5	88.8
	C 205	16.7	12.1	14.4	0.0	0.0	0.0	29.1	0.0	14.6	0.0	0.0	0.0
	C 211	20.6	0.0	10.3	11.0	0.0	5.5	47.1	0.0	23.6	30.8	0.0	15.4
	C 221	32.9	19.5	26.2	35.5	33.2	34.4	73.0	82.0	77.5	72.4	90.1	81.3
	C 261	0.0	0.0	0.0	0.0	11.1	5.6	0.0	0.0	0.0	0.0	24.3	12.2
	C 9720	12.5	0.0	6.2	25.1	11.4	18.3	10.0	0.0	5.0	45.0	29.8	37.4
Mean		17.5	8.7	13.1	18.4	14.7	16.6	40.4	24.2	32.3	37.1	41.3	39.1

Revised LSD 5%	Pollen viability		Single plant seed yield (g/ plant)	
	2nd growing season	1st growing season	2nd growing season	1st growing season
Photoperiod (P)	**	**	**	**
Plant age (A)	1.57	1.23	2.01	1.93
A× Photoperiod (P)	2.22	1.74	2.85	2.73
Cultivars (C)	1.76	1.23	2.24	2.65
P × C	2.48	1.74	3.16	3.75
A × C	3.04	2.13	3.87	4.60
P × A × C	4.30	3.01	5.47	6.50

Table 3. Effect of root age and photoperiod on single plant seed yield (g/ plant) and germination % of sugar beet

Root age	cultivars	Seed index						Germination %					
		Day length treatments						Day length treatments					
		1st growing season			2nd growing season			1st growing season			2nd growing season		
		Ext.	Nat.	Mean	Ext.	Nat.	Mean	Ext.	Nat.	Mean	Ext.	Nat.	Mean
120days	C 146	1.7	0.0	0.8	1.0	1.7	1.3	65.7	0.0	32.8	71.5	61.7	66.6
	C 205	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 211	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 221	1.0	1.0	1.0	2.0	1.2	1.6	67.5	61.7	64.6	68.2	66.5	67.3
	C 261	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 9720	1.5	0.0	0.7	2.0	0.0	1.0	65.2	0.0	32.6	65.2	0.0	32.6
Mean		0.7	0.2	0.4	0.8	0.5	0.7	33.1	10.3	21.7	34.2	21.4	27.7
135days	C 146	1.5	1.5	1.5	2.0	1.5	1.7	65.0	60.5	62.7	69.7	66.7	68.2
	C 205	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 211	2.0	0.0	1.0	2.0	0.0	1.0	68.7	0.0	34.3	67.0	0.0	33.5
	C 221	2.0	1.5	1.7	1.7	2.0	1.8	68.7	63.7	66.2	65.7	59.7	62.7
	C 261	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C 9720	0.0	0.0	0.0	2.0	1.5	1.7	0.0	0.0	0.0	61.0	59.7	60.3
Mean		0.9	0.5	0.7	1.3	0.8	1.0	33.7	20.7	27.2	43.9	31.0	37.4
150days	C 146	1.7	1.7	1.7	1.7	1.7	1.7	69.0	63.5	66.2	68.5	64.0	66.2
	C 205	2.0	0.0	1.0	0.0	0.0	0.0	70.5	0.0	35.2	0.0	0.0	0.0
	C 211	2.0	0.0	1.0	0.0	0.0	0.0	69.7	0.0	34.8	0.0	0.0	0.0
	C 221	2.0	2.0	2.0	2.0	2.0	2.0	69.2	63.7	66.5	63.2	64.0	63.6
	C 261	0.0	0.0	0.0	0.0	2.0	1.0	0.0	0.0	0.0	0.0	58.2	29.1
	C 9720	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean		1.3	0.6	1.0	0.6	1.0	0.8	46.4	21.2	33.8	22.0	31.0	26.5
Combined over all root ages	C 146	1.6	1.0	1.3	1.5	1.6	1.6	66.5	41.3	53.9	69.9	64.1	67.0
	C 205	0.6	0.0	0.3	0.0	0.0	0.0	23.5	0.0	11.7	0.0	0.0	0.0
	C 211	1.3	0.0	0.6	0.6	0.0	0.3	46.1	0.0	23.0	22.3	0.0	11.1
	C 221	1.6	1.5	1.5	1.9	1.7	1.8	68.5	63.0	65.7	65.7	63.4	64.5
	C 261	0.0	0.0	0.0	0.0	0.6	0.3	0.0	0.0	0.0	0.0	19.4	9.7
	C 9720	0.5	0.0	0.2	1.3	0.5	0.9	21.7	0.0	10.8	42.0	19.9	31.0
Mean		0.9	0.4	0.7	0.9	0.7	0.8	37.7	17.4	27.5	33.3	27.8	30.5

	Seed index		Germination %	
	2nd growing season	1st growing season	2nd growing season	1st growing season
Photoperiod (P)	**	**	**	**
Plant age (A)	0.1	0.1	0.46	0.58
A× Photoperiod (P)	0.15	0.13	0.65	0.82
Cultivars (C)	0.13	0.12	0.71	1.06
P × C	0.18	0.18	1.00	1.50
A × C	0.22	0.21	1.23	1.84
P × A × C	0.32	0.30	1.74	2.60

3.3. Pollen Viability Percentage

Results presented in Table 2 showed that all factors and their interactions exhibited highly significant effects on pollen viability in both seasons. Cultivars response was the dominant factor in shaping the response to the other factors under investigation.

Data in Table 2 indicates that those cultivars that flowered varied in their response in terms of pollen viability. Some cultivars failed to produce viable pollen particularly under younger root age conditions (120 days) such as C 211. In the case of cultivars that flowered under all treatment combinations (C 146) pollen viability was generally improved under extended day-length in most cases. Still in some cases the cultivar failed to produce viable pollen.

The results suggest the need of monitoring the welfare of male organs as a result of flowering induction treatments to be able to secure male fertile plants for the crossing.

3.4. Single Plant Seed Yield (g)

Data in Table 2 reveals that root age and day-length extension exhibited a highly significant effect on cultivars' response in terms of single plant seed yield in both seasons.

Seed setting could be altered by male or female organ fertility. It could also be altered due to incompatibility among pollen grains and stigmas. This was evident in this experiment as some cultivars that flowered with viable pollen failed to set seeds such as the case of C 146 under natural day length with root age of 120 days.

A similar observation was recorded for the same cultivar at 150 days old roots in the first season of experimentation. In other cases C 211 successfully set seeds despite its recorded non-viable pollen at 150 days age of roots under natural day-length. The relationship between extending day-length and the amount of seeds produced by single plant was not always following a single specific trend. However, the older the age of roots when its vernalization treatment started, the more seeds that were produced. This could be explained by the extra assimilates stored in the roots as their age increases, that could be directed to the formation of flowers and seeds. The maximum amount of seeds was produced from C 146 with 135 days old roots under natural day-length in the second season.

3.5. Seed Index

Data in Table 3 indicates that root age, day-length extension, cultivars and their interactions had highly significant effects on seed index in both seasons. Seed index value varied from 1.0 to 2.0 g for all the cultivars that successfully set seeds. Over all flowering plants, seed index was minimal when roots were vernalized at younger age of 120 days. However, extending day-length within those flowering cultivars seemed to have variable effects in changing the seed index value. Some cultivars' seed indices decreased while others increased and a third group was not affected. This indicates that the genetic differences within these cultivars are the dominant factors controlling this trait.

C 221 cultivar was superior in both seasons. Plants of 150 days age from C 221 cultivar resulted in the highest seed index in both seasons. Both C 146 and C 221 cultivars under artificial illumination resulted in the highest seed index in the 1st season. Meanwhile, in the 2nd season the highest values resulted from both C 146 and C 221 cultivars under both artificial and natural illumination.

3.6. Seed Germination Rate

Statistical analysis of data indicated that root age, photoperiod, cultivars and their interactions had highly significant effects on seed germination in both seasons (Table 3).

Means listed in Table 3 show that plants exposed to extended day-length produced higher seed germination % except for those of C 221 at 150 days where the recorded germination % was similar. Within the flowering cultivars, increasing root age at vernalization significantly improved seed germination. This could be due in part to the extra assimilates stored in older roots that could be directed to the formation of seeds that could allow for higher seed germination.

4. Conclusion

The findings of this work are a step towards the definition of techniques that can be used to start a sugar beet breeding program under Egyptian conditions. The results indicate that cultivars' responses are the main factor that controlled the response to floral transition. The response of cultivars varied according to root age, and day-length treatments. In most of the flowering cultivars, extended day-length as well as older roots improved the measured traits. However, there are needs to examine more cultivars and genetic resources to establish a valid program in the near future.

Acknowledgement

We are indebted to Dr. John Kern, Crystal Sugar Company, North Dakota, USA for his help in this research through providing us with sugar beet seeds.

References

[1] Abe, J., G.P. Guan and Y. Shimamoto (1997). A marker assisted analysis of bolting tendency in sugar beet (*Beta vulgaris*, L.). *Euphytica*, 94: 137-144.

[2] Agrawal, R. L. (1980). Seed germination, p. 449-474. In Seed technology. 2nd ed. Oxford & IBH Publishing Co. PVT. LTD., 66 Janpath, New Delhi, India.

[3] Atia, A.E. (2000). Sugar beet (Beta vulgaris, L) seed production and its viability in Egypt. M.Sc. Thesis, Fac. Agric., Ain Shams Univ.

[4] Chatin, P., Gokhale, D., Nilsson, S. and Chitins, A. (2004). Sugar beet growing in tropical areas: A new opportunity for growers and the sugar industry. Proc. Internl. Symp. On Sustainable Sugarcane & Sugar Production Technology, Nanning, P.R. China, pp 175-179 (2004).

[5] Debenham, G.B., P.M. Van Roggen, S.J. Yallop and T.H. Thomas (1997). The influence of seed size and plant age at vernalizaton on bolting and flowering in sugar beet. Proc. of the 63rd Autumn IIRB Congress, Nov. 1997.

[6] El-Talkhawy, N. M. (1992). Studies on the flowering of some sugar beet varieties. Ph.D. thesis Fac. Agric. Saba Basha, Alex. Univ.

[7] Farag, M. A. (1997). Flowering and seed production of sugar beet. Egyptian Society of Sugar Technologists, 28th annual conference, 2-4 Dec., 1997.

[8] Gaber, A.A. and A.H. Nour (1981). Effect vernalization on flowering and seed setting in sugar beet. *J. Agr. Res. Review*, 8: 73-84.

[9] Gaskill, John O. (1963). Comparison of the fluorescent and incandescent lamps for promotion of flowering in sugar beet seedlings. *J. Am. Soc. Sugar Beet Technol.*, 12 (7): 623-634.

[10] Gomez, K. and A.A.Gomez (1984). Statistical procedures for agricultural research. Awiley Interscience Puplication, John Wiley & Sons. Inc. New York, USA.

[11] Guan-Guoping, Abe, J., Shimamoto,Y. and Guan, GP. (1994). Genetic analysis of bolting tendency in sugar beet. *Proc. of the Japanese Society of Sugar Beet Tech.*, 36: 145-151.

[12] Hecker, R. J., P. C. Stanwood and C.A. Soulis (1986). Storage of sugar beet pollen. *Euphytica*, 35: 777-783.

[13] Hecker, R. J. (1988). Pollen characteristics of diploid and tetraploid sugar beet. *J. Sugar Beet Res.*, 25 (1): 55-62.

[14] Hecker, R. J. and M. McClintock (1988). Sugar beet pollen germination *in vitro*. *J. Sugar Beet Res.* 25 (1): 42-54.

[15] Hogaboam, G.J. (1982). Early induction of flowering in sugar beets. *Agron. J.* 7 (4): 151-152.

[16] Lexander, K. (1980). Present knowledge of sugar beet bolting mechanisms. Proc. of the 63rd Winter IIRB Congress, 245-257.

[17] Morris, P. C., D.G. Grierson and W. J. Whittington. (1985). The influence of fruit structure on germination of sugar beet (*Beta vulgaris*). Seed Sci. & Technol.,13, 41-51.

[18] Smit, A.L. (1982). Influence of temperature and day length on bolting in sugar beet. Proc. Of 45th Winter Congress of the International Institute for Sugar Beet Research, pp. 25-36.

[19] Smit, A.L. (1983). Influence of external factors on growth and development of sugar beet (Beta vulgaris, L.). Ph.D. Thesis, Center for agricultural publishing and documentation, Wageningen Univ., Nether Lands.

[20] Waller, R.A and D.B. Duncan (1969). A bays rule for the symmetric multiple comparison problem. *Amer. State. Assoc. J.* Dec., 1485-1503.

[21] FAO (2012). www.fao.org.