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Growing Season is an Essential Factor in Seed Production and Quality of Melon

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ABSTRACT

Six melon market-types were used in two greenhouse experiments to examine the effects of growing season on seed production and quality. In the first experiment (2005-2006) melon plants were sown on different dates in order to reach fruit and seed development at mid-fall, -winter, -spring and -summer. In the second experiment fruit and seed development occurred either in the spring-summer or in the fall-winter season. The main effect in the summer season under greenhouse conditions was a significant decrease in fruit number per plant. The average fruit number per plant in summer decreased by 47, 45 and 29% as compared to fall, spring and winter seasons, respectively. In the winter season, fruit size and the number of fully-developed seeds per fruit were significantly lower as compared to the other seasons. The average fruit weight in winter was 42, 51 and 48%, and the number of fully-developed seeds was 10, 12 and 11% in comparison to relevant values in fall, spring and summer seasons, respectively. Mean seed yields per plant were 16.9, 3.2, 14.1 and 8.9 g in fall, winter, spring and summer in the first experiment, and 5.4 and 17.0 g in fall-winter and spring-summer in the second one. Winter-grown seeds had lower quality than seeds which developed in the other seasons as expressed by germination percentages and germination rate. In most cultivars, melon seeds showed at least some degree of partial and conditional dormancy, expressed by germinability improvement after some time of storage. Melon seed storage at high temperature (40°C) for up to 18 months had no deleterious effect on germinability, but storage at freezing temperature (-18°C) of seeds developed in the spring-summer season caused a significant delay in germination of some cultivars.

Keywords: fruit yield components, germination percentage, germination speed, seed dormancy, seed yield components

INTRODUCTION

Cucurbit crops (*Cucurbitaceae*) are naturally adapted to warm climate and are sensitive to chilling injury. The chill injury threshold for most cucurbit species is about 12°C and the intensity of injury depends upon how low the temperature is and exposure time (Bradow 1990; Baninasab 2009). Sensitivity of cucurbits to low-temperature was reported for all developmental phases starting from seed germination (Harrington and Kihara 1960; Jennings and Saltveit 1994), through seedling and adult plants (Wang 1985; Bradow 1990; Yu *et al*. 2002) and ending at fruit maturation and post-harvest storage (Tatsumi and Murata 1981; Wang 1994; Yang *et al*. 2003). In the Middle East the year is clearly divided to four climate seasons (**Table 1**); spring (March – May), summer (June – August), fall (September – November) and winter (December – February). Winter-grown cucurbits in this region are often restricted by low temperature and irradiation as well as by reduced pollination. Cool and cloudy weather on the one hand, and high temperatures on the other, decrease the activity of insects (pollen vectors) and viability of pollen grains (Iapichino and Loy 1987; Maestro and Alvarez 1988; Nepi and Pacini 1993; Stanghellini *et al*. 2002; Stanghellini and Schultheis 2005). In many cases of extreme temperatures, there is no concurrence between pollinator's activity and blooming time, which reduces pollination and fruit set (Orr and Eisikowitch 1988). The growing demand for cucurbit fruits year round in the last decades has shifted much of the production from the open field to protected glasshouses and plastic tunnels. For example, in Israel the entire production of slicing cucumber has been moved from out-door into different types of walk-through tunnels. This same trend has been taking place in the recent years with summer squash. This transition has been supported by many research studies in order to maximize fruit yield and quality under these new developing systems. Another recent change in growing many vegetables has been a transition from open-pollinated cultivars to hybrids. The high cash value of hybrid seed makes it very attractive for producing seeds also out of its natural season under protected conditions. However, little attention has been given to date to growing cucurbit crops out of the main season for seeds, and there is a lack of knowledge about the effects of sub-optimal conditions on seed production and quality.

The main goal of the present study was to determine the effects of different growing seasons, under protected conditions, on seed production and seed quality of six market-types of melon. A second goal was to evaluate the effects of storage temperature on maintaining seed quality.

Table 1 Main characteristics of annual seasons in the Middle East.

Season	Temperature	Irradiation	Precipitation
Spring (March-May)	Medium-High	High	Low
Summer (June-August)	High	High	None
Fall (September- November)	Medium-High	Medium-High	Low
Winter (December- February)	Low	Medium-Low	Medium-High

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MATERIALS AND METHODS

Two greenhouse experiments (A and B) were conducted at the Newe Ya'ar Research Center (northern Israel) to determine the effects of growing season and cultivars on seed yield and seed quality and the effects of seed storage temperature on seed quality maintenance in melon.

Genetic material

Six open-pollinated melon cultivars, representing the most common market-type groups, were used in the present study as follows: a) 'Persia 202' - (P202), a birdsnest-type melon (Nerson and Paris 2008) originating from Iran and characterized by a bush growth habit and a concentrated fruit-set and yield maturation, b) 'Noy Yizre'el' - (NY), a local cultivar derived from the 'Ha'Ogen' group, which was used as the maternal parent in the original 'Galia' hybrid, c) 'Ananas Yoqne'am' – (ANY), a local cultivar developed from old germplasm used in the Middle East and well adapted to dryland farming, d) 'Perlita' – (PER), an old American cantaloupe belonging to the "western shipper" group, having a heavy net and orange flesh, e) 'Noy Amid' – (NA), a local casaba-type cultivar having a yellow football-shaped fruit and long shelf-life, and f) 'Tam Dew' – (TAD), a honeydew melon from Texas with round off-white fruit and green flesh. Cultivars a, b, c and d belong to subspecies *Reticulatus*, while cultivars e and f are from subspecies *Inodorous*.

Growing seasons

In the first experiment (A), the six cultivars were sown on four dates on the first day of September and November 2005 and March and May 2006. These dates were selected in order to get fruit and seed development in mid fall, winter, spring and summer, respectively. In the second experiment (B), there were only two sowing dates: 1st October, 2007 and 1st April, 2008. In the first date fruits and seeds developed in the fall-winter season, and on the second date in the spring-summer season.

Cultural practices

In both experiments, melons of the six cultivars were sown in 55-L containers (five plants per container) filled with organic rich potting-mix (coconut palm residue – 80% and tuff gravel – 20%). The experiments were conducted in an insect-free, partial controlled glasshouse where day temperature never exceeded 28°C (by ventilation) and night temperature never dropped below 16°C (heating by hot water pipe system). The plants were trailed on wire and the primarily branches were pruned up to the 15^{th} node. All the upper pistillate flowers were hand-pollinated using self male flowers. Pollination in each plant was conducted during a two week period and an average of 10-15 pistillate flowers were pollinated in each plant. The experimental design was randomized blocks with four replicates of five plants (one container) each. Each fruit was harvested at full-mature stage according to rind color change and/or appearance of abscission tissue. The mature fruit was weighed and its seeds were extracted (two days of fermentation followed by intensive washing and 7 days of drying at ambient air temperature). The dry seeds of each fruit were divided into fully-developed and empty groups. Seeds of each group were counted and weighed and after recording these parameters the seeds of each replicate were pooled into a common seed lot. Germinability (final germination percentage and mean days to germination) of each seed lot was determined by a standard germination test (four replicates of 50 seeds in 9-cm Petri dish, 7 days of incubation at 25°C, in darkness). In the first experiment, germination tests were conducted at extraction time (0) and after 3, 6, 12, 24, 36 and 48 months of storage at 10°C and 45% relative humidity. In the second experiment, germination test were conducted at extraction and after 3, 6, 9, 12 and 18 months of storage at -18, +10, +25 and +40°C.

Table 2 Effect of growing season on the duration (days) of the vegetative (sowing to pollination) and the reproductive (pollination to fruit maturation) phases in six cultivars of melon from different market-type groups (experiment A).

Growing season	P202	NY	ANY	PER	NA	TAD	Season mean
Vegetative phase (days)							
Fall	43 kl	45 j-l	40 l	49 h-l	43 kl	39 l	43 C
Winter	65 c-e	73 bc	81 b	96 a	70 cd	64 d-f	75 A
Spring	56 e-i	61 e-g	54 g-j	55 f-j	58 e-h	55 f-j	56 B
Summer	43 kl	48 i-l	52 g-k	48 i-l	49 h-l	43 kl	47 C
Cultivar mean	52 B	57 AB	57 AB	62 A	55 AB	50 B	
Reproductive phase (days)							
Fall	43 g-j	45 e-i	54 bc	51 c-f	44 f-i	50 c-g	48 B
Winter	51 c-f	62 a	53 bd	50 c-g	50 c-g	59 ab	54 A
Spring	40 h-k	52 c-e	47 c-h	44 f-i	33 k	46 d-h	44 BC
Summer	34 jk	42 g-k	48 c-h	34 jk	36 i-k	44 f-i	40 C
Cultivar mean	42 B	50 A	50 A	45 AB	41 B	50 A	

Table 3 Effect of fruit and seed development season on fruit number per plant, mean fruit weight (g) and fruit yield per plant (kg) in six cultivars of melon from different market-type groups (Experiment A).

Growing season	P202	NY	ANY	PER	NA	TAD	Season mean
Fruit number per plant							
Fall	1.6 d	2.2 c	1.0 ef	2.8 a	1.2 e	1.0 ef	1.63 A
Winter	1.0 ef	2.8 a	0.6 g	1.0 ef	0.8 fg	1.2 e	1.23 B
Spring	2.4 b	1.6 d	1.0 ef	2.2 c	1.0 ef	1.2 e	1.57 A
Summer	1.2 e	1.0 ef	0.8 fg	1.0 ef	0.6 g	0.6 g	0.87 C
Cultivar mean	1.55 B	1.90 A	0.85 C	1.75 A	0.90 C	1.00 C	
Mean fruit weight (g)							
Fall	531 gh	717 ef	1071 c	526 gh	711 ef	1507 a	844 A
Winter	251 m	359 j-m	430 h-k	289 lm	502 g-i	323 k-m	359 C
Spring	449 h-j	575 g	1198 b	407 i-l	616 fg	950 d	699 B
Summer	456 h-j	519 g-i	1021 cd	946 d	715 ef	810 e	744 B
Cultivar mean	422 C	542 B	930 A	542 B	636 B	897 A	
Fruit yield per plant (kg)							
Fall	0.85 f	1.58 a	1.07 b-d	1.47 a	0.85 f	1.51 a	1.22 A
Winter	0.25 k	1.00 c-e	0.26 k	0.29 jk	0.40 h-k	0.39 i-k	0.43 D
Spring	1.08 b-d	0.92 ef	1.20 b	0.89 ef	0.62 g	1.14 bc	0.97 B
Summer	0.55 gh	0.52 g-i	0.82 f	0.95 d-f	0.43 h-j	0.49 g-i	0.62 C
Cultivar mean	0.68 C	1.00 A	0.84 B	0.90 AB	0.57 C	0.88 B	

Statistical analysis

Each set of data was subjected to a 2-way ANOVA (cultivars and seasons). Significant differences among treatments ($P = 0.05$) were determined by Duncan's multiple range test and are presented by lower-case letters. Significant differences among the means of the main factors are presented by different capital letters.

RESULTS

Effect of growing season on life-cycle

Life-cycle duration of all six cultivars was significantly affected by growing season; shortest in summer (77-100 days) and longest in winter (116-146 days) (**Table 2**). The local casaba NA and the birdsnest P202 had in most cases the shortest life-cycle, mainly due to a relatively short reproduction phase. The cantaloupe cultivar PER had an extremely long vegetative phase when it was sown in late fall and grown in winter. Significant differences among cultivars in vegetative phase duration were recorded only in winter, whereas differences in reproductive phase duration were evident in all seasons. The mean duration time of the vegetative phase out of the whole life-cycle was 50-58% for the different cultivars and 47-58% for the different seasons.

Effect of reproductive growing season on fruit yield per plant

Fruit production per plant was significantly affected by the reproductive growing season. The highest fruit yield was obtained when fruit developed in the fall and the lowest in winter (**Table 3**). Low winter temperatures markedly decreased fruit weight and to a lesser extent fruit number. Fruit yield per plant in summer was also lower than in fall, but in this case the high summer temperatures adversely affected fruit-set (fruit number) in all cultivars, but fruit size (weight) only in NY and TAD. On average, largest fruits developed in fall and smallest fruits in winter. Fruit weight in fall was 4.7-fold higher than in winter in TAD, but only 1.4-2.5-fold higher in the other five cultivars. The largest differences in fruit number per plant across the four seasons were recorded in cultivars NY and PER.

Table 4 Effect of fruit and seed developing season on seed yield (g) per plant in six cultivars of melon from different market-type groups.

Growing season	P202	NY	ANY	PER	NA	TAD	Season mean
Experiment A							
Fall	14.06 d	21.68 a	17.06 c	16.33 c	12.17 ef	20.15 b	16.91 A
Winter	1.48 k	8.55 gh	1.95 jk	2.01 jk	2.12 jk	3.28 j	3.23 D
Spring	17.14 c	16.09 c	13.63 d	14.36 d	9.92 g	13.35 de	14.08 B
Summer	11.69 f	8.89 g	7.56 hi	12.13 ef	6.90 i	6.20 i	8.90 C
Cultivar mean	11.09 B	13.80 A	10.05 B	11.21 B	7.78 C	10.74 B	
Experiment B							
Fall - Winter	2.26 f	7.72 e	7.48 e	1.75 f	6.76 e	6.73 e	5.45 B
Spring - Summer	22.31 a	19.35 b	18.38 b	16.35 c	10.63 d	15.20 c	17.04 A
Cultivar mean	12.28 AB	13.53 A	12.93 A	9.05 C	8.69 C	10.96 B	

Table 5 Effect of fruit and seed developing season on fully-developed seed number per fruit, on mean seed weight (mg) and on empty seeds (%) in six cultivars of melon from different market-type groups (experiment A).

Growing season	P202	NY	ANY	PER	NA	TAD	Season mean
Fully-developed seeds per fruit							
Fall	213 h	392 b	438 a	273 fg	340 c	476 a	355 A
Winter	18 jk	65 i	44 ij	39 i-k	10 k	27 jk	34 C
Spring	190 h	329 cd	272 fg	291 ef	252 g	340 c	279 B
Summer	276 fg	299 ef	193 h	397 b	311 de	336 cd	302 B
Cultivar mean	174 D	271 AB	237 BC	250 BC	228 C	295 A	
Mean seed weight (mg)							
Fall	40.1 b	26.0 gh	39.1 bc	16.8 j	31.9 ef	39.2 bc	32.2 A
Winter	38.9 bc	28.8 fg	30.8 f	23.3 hi	38.0 bc	29.6 fg	31.6 A
Spring	38.6 bc	28.8 fg	45.9 a	20.2 ij	36.1 cd	32.6 d-f	33.7 A
Summer	37.3 bc	28.8 fg	47.9 a	30.7 f	35.6 c-e	30.0 fg	35.0 A
Cultivar mean	38.7 AB	28.1 D	40.9 A	22.7 E	35.4 BC	32.8 CD	
Empty seeds (% of total seeds)							
Fall	8 g	1 i	1 i	5 h	2 i	7 gh	4 BC
Winter	72 b	42 e	54 d	59 c	76 a	72 b	62 A
Spring	2 i	1 i	9 g	2 i	12 f	9 g	6 B
Summer	1 i	1 i	2 i	1 i	2 i	2 i	1 C
Cultivar mean	21 A	11 C	16 B	17 B	23 A	22 A	

Table 6 Effect of fruit and seed developing season on fully-developed seed number per fruit, on mean seed weight (mg) and on empty seeds (%) in six cultivars of melon from different market-type groups (experiment B).

Growing season	P202	NY	ANY	PER	NA	TAD	Season mean
Fully-developed seeds per fruit							
Fall – Winter	63 g	204 e	156 f	134 f	162 f	245 d	161 B
Spring - Summer	261 d	371 b	490 a	381 b	311 c	482 a	383 A
Cultivar mean	162 D	287 BC	323 AB	257 C	236 C	363 A	
Mean seed weight (mg)							
Fall – Winter	24.2 f	25.1 f	33.8 c	11.0 g	29.5 de	26.0 ef	24.9 B
Spring - Summer	45.9 a	31.8 cd	49.1 a	26.5 ef	38.3 b	37.9 b	38.2 A
Cultivar mean	35.0 B	28.4 C	41.4 A	18.7 D	33.9 B	31.9 BC	
Empty seeds (% of total seeds)							
Fall – Winter	62 a	27 e	50 b	42 c	45 c	33 d	43 A
Spring - Summer	12 fg	5 h	9 gh	12 fg	16 f	7 gh	10 B
Cultivar mean	37 A	16 C	29 B	27 B	30 B	20 C	

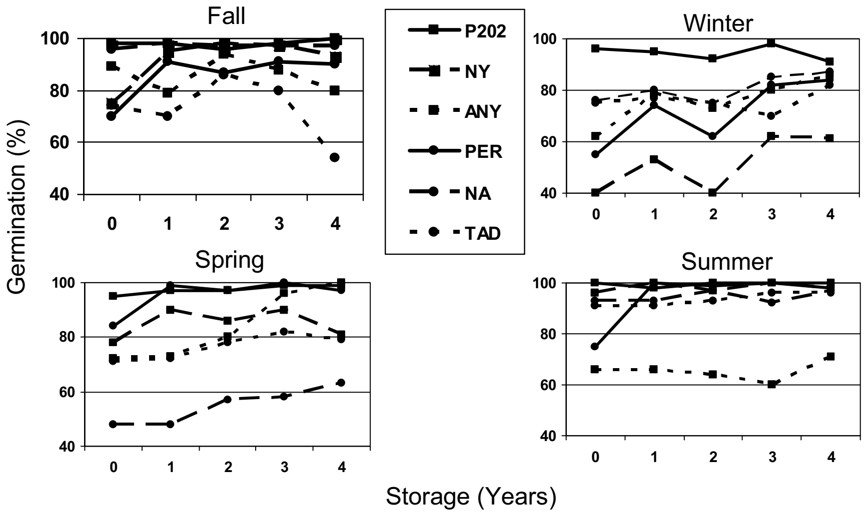

Fig. 1 Effect of fruit and seed development season on germination (%) at harvest (time 0) and after storage (10°C) in six market-types of melon (Experiment A).

Effect of reproductive growing season on seed yield per plant

In Experiment A, the mean seed yield per plant for the six cultivars was highest in fall; 1.2-, 1.9- and 5.2-fold greater than in spring, summer and winter, respectively (**Table 4**). In Experiment B, mean seed yield per plant grown in the spring-summer season was 3.1-fold greater than in the fall-winter season. There were significant interactions between cultivars and seasons with respect to seed yield (Experiment A), but in all cultivars the highest yield was achieved in fall (A) and in spring-summer (B) and the lowest yield in winter (A) and in fall-winter (B) seasons. The average seed yield per plant, for all seasons, was highest in both experiments in cultivar NY and lowest in NA.

Seed yield components

The number of fully-developed seeds per fruit and the percentage of empty seeds were significantly affected by the season of seed development (**Tables 5, 6**). These effects were wider in experiment A (in which seed development occurred in the middle of each season) than in experiment B. Seed development in winter significantly decreased the number of fully-developed seeds and increased the percentage of empty seeds. In experiment A, mean seed weight of P202 and NY was unaffected by growing season, whereas various different interactions between seed weight and cultivar were recorded for ANY, PER, NA and TAD. In Experiment B, seed weight of all the six cultivars was significantly higher in the spring-summer than in the fall-winter season. There were large differences among cultivars and significant interactions with growing season with respect to seed number per fruit and to mean seed weight.

Germination percentage and germination rate

The growing season had significant effects on germination percentage as well as on germination rate. The average germination percentages at harvest were 84, 67, 75 and 87% in fall, winter, spring and summer, respectively (**Fig. 1**), and 68 and 88% in fall-winter and spring-summer seasons, respectively (**Fig. 2**). In most cases, and especially in cultivars NY and PER germination percentages were significantly higher after storage for one year. The average germination percentages, after storage for one year increased from 72 to 84% in NY, and from 71 to 91% in PER (**Fig. 1**). In general, seed germination percentages did not decrease after four years of storage at 10°C and 40-50% relative humidity. There were large differences among cultivars, and many interactions between cultivars and seasons with respect to

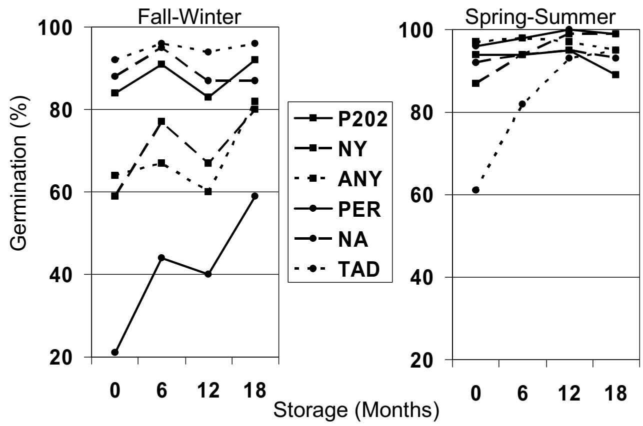

Fig. 2 Effect of fruit and seed development season on germination (%) at harvest (time 0) and after storage (10°C) in six market-types of melon (Experiment B).

germination percentage. Highest germination percentages were recorded in accession P202 which were always above 90%, regardless of season and storage duration. Germination percentages of NY, NA and ANY were extremely low in winter, spring and summer seasons, respectively, as compared to the other three seasons.

Mean days to germination, at seed harvest, were affected by growing season in all cultivars except P202 (**Figs. 3, 4**). All cultivars had the fastest germination by seeds which developed in summer. Slowest germination rates were recorded for NY and TAD by seeds that developed in fall and for NA by seeds that developed in spring. Similar to germination percentage, storage of seeds generally improved their germination quality when measured by germination speed (MDG). Mean days to germination, at harvest, were 3.3, 3.2, 3.2 and 2.7 in fall, winter, spring and summer, and decreased to 2.9, 2.9, 2.9 and 2.4, respectively, after one year at storage (**Fig. 3**). There were large differences among cultivars with respect to germination rate, and in general, there was a positive association between germination percentage and germination speed. P202 which had the highest germination percentage was also the accession with the fastest germination speed and both parameters were almost unaffected by growing season or by storage.

Seed storage temperature and germinability

The effect of seed storage temperature on germination percentage and germination speed was variable in different

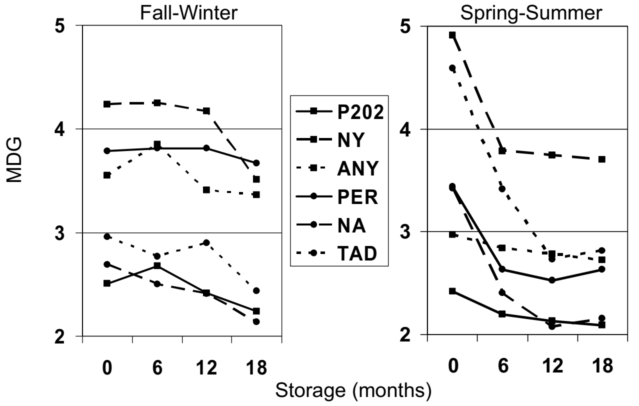

Fig. 4 Effect of fruit and seed development season on mean days to germination (MDG) at harvest (time 0) and after storage (10°C) in six market-types of melon (Experiment B).

cultivars. The Persian line P202 which has the highest and quickest germination (**Fig. 5** and **6**, respectively) was unaffected by seed storage temperature. However, P202 seeds produced in the spring-summer season tended to have higher germination percentages and faster germination rates than seeds produced in the fall-winter season. In the other three cultivars the positive effects of the spring-summer growing season on germination percentage and rate was larger than in P202. In ANY, similar to P202, seed storage temperature did not significantly affect germination percentage or germination rate. In contrast, seed storage at freezing temperature (-18°C) had a marked effect on germination of NY and PER. Seeds of these cultivars produced in spring- summer season and exposed to freezing storage condition had lower germination percentages and slower germination rate and these effects were increased by storage duration. This influence of freezing temperature was not observed for seeds produced in the fall-winter season. A complementary experiment (data not shown) revealed that the negative effect of freezing temperature storage in NY and PER was on germination speed which was significantly slowed down, while the final germination percentage (after 14 days of incubation) was unaffected.

DISCUSSION

Fruit yield per plant is dependent upon two components; fruit number per plant and the mean fruit weight. Seed yield per plant is dependent upon three components; fruit number per plant, mean seed number per fruit and mean seed weight. Maximum fruit and seed yield will be achieved by the highest multiplication product of yield components. In most cases increasing of one component may result in a decrease of another one, thus the highest yield will be always obtained by the best combination of its components. Growing seasons in the Middle East have large climatic differences, mainly in daily temperatures and in light intensities and photoperiod. These differences affect cucurbit crops not only in the open field, but also, to a lesser extent, under protected cultivation. The results of the present study demonstrate that melons grown in summer season in a glasshouse have a limited fruit-set (**Table 3**). In the winter there are even more limitations for melon seed production. First, the fruits in winter are smaller (**Table 3**), and second the number of fully-developed seeds per fruit are very low (**Table 5**).

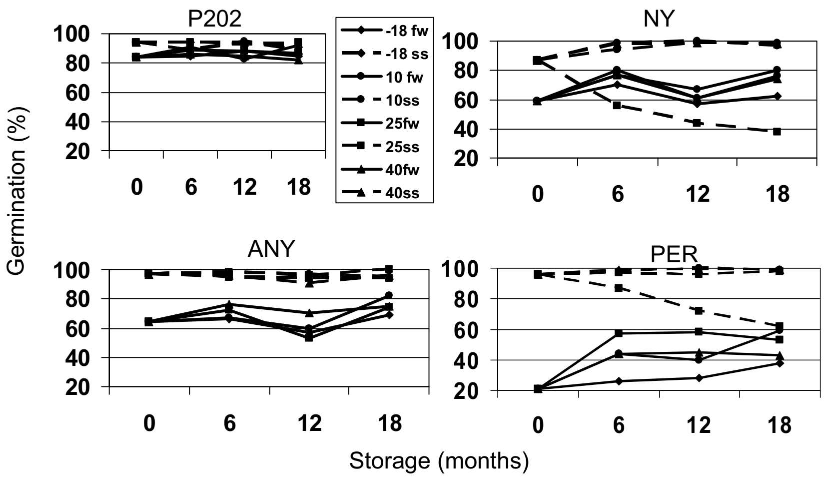

Fig. 5 Effect of seed storage temperature on germination (%) in four market-types of melon grown in fall-winter (fw) or in spring-summer (ss) season (Experiment B).

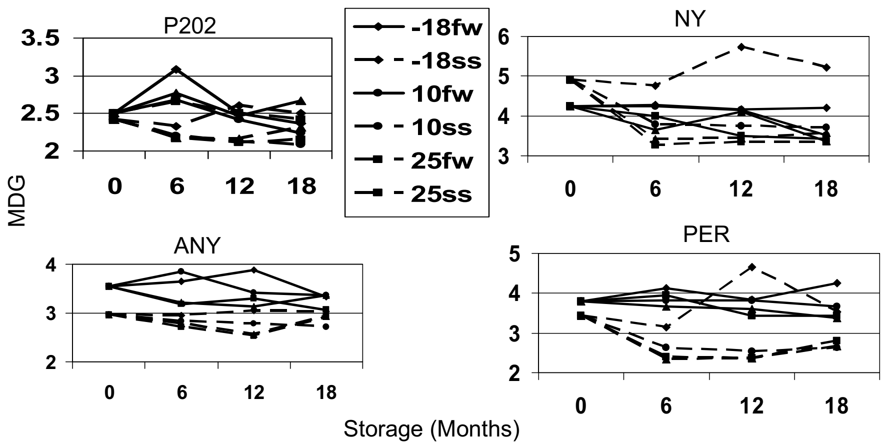

Fig. 6 Effect of seed storage temperature on mean days to germination (MDG) in four market-types of melon grown in fall-winter (fw) or in spring-summer season (Experiment B).

The result of these seasonal limitations is low and extremely low seed yields in the summer and the winter seasons, respectively, compared to high seed yields in the fall and spring seasons (**Table 4**). The results of the present study, with respect to seasonal effects on melon seed yield components, fully confirm an earlier study (Nerson 2009).

An overview of melon seed germinability with respect to growing season shows that seed developing in winter are inferior in both yield and quality. In most cases, seed that develop in winter have lower germination percentages (**Figs. 1, 2**) and slower germination rates (**Figs. 3, 4**), as compared with other seasons. These effects are generally reduced during storage but are still evident, to some degree, four years after harvest. Interactions were observed between cultivars and growing seasons with respect to germinability. For example, very low germination of NA in spring and of ANY in summer, illustrate the complexity of this character. In most cultivars, and in most seasons (except summer), germination percentage and rate increased after a 6-12 month storage period. This phenomenon was most significant in cultivars NY and PER but was evident in other cultivars (except P202) as well. Dormancy is a very common survival mechanism in wild species seeds (Baskin and Baskin 2004). Domestication of plants generally acted to eliminate this negative trait in terms of agricultural requirements. However, many crop species still have this trait, and major efforts have been invested in understanding how to break seed dormancy. Several research studies have mentioned the existence of dormancy in cucumber (Watts 1938; Ali *et al.* 1991; Weston *et al.* 1992; Amritphale *et al.* 1993), but there is a lack of information concerning other cucurbits. In previous studies (Nerson 2004, 2009), it was shown that in some cases melon seeds are dormant and their germination improved after storage. The data of the present study strongly support this observation, suggesting that this phenomenon may be described as a partial and conditional dormancy. It is partial because only a portion of the seeds were dormant at seed harvest, and it is conditional because it was clearly apparent in winter but was almost nonexistent in summer. This dormancy pattern is also cultivar dependent and was clearly evident in NY and PER and completely absent in P202.

Seed longevity is much influenced by storage conditions, especially by temperature and relative humidity (Nerson 2007). Storage of watermelon seeds at 40°C is considered to be harmful and result in a rapid reduction in their germination capability (Demir and van de Venter 1999). The results of the present study show that melon seed storage at such a high temperature, for at least 18 months, did not decrease their germinability, in all tested cultivars. It can be concluded that for short to medium-term storage of melon seeds, room temperature will be generally adequate. On the other hand, storage of melon seeds at freezing temperature (-18°C) may be detrimental in some cultivars grown at certain seasons (**Figs. 5, 6**). Storage at freezing temperature may inhibit germination rate but has no negative influence on the final germination percentage. This suggests that under freezing conditions, one or more components which are involved in germination becomes nonfunctional and that there is a time period required for repair process after seed defrost. It is unclear why only NY and PER seeds produced during the spring-summer season were negatively affected by freezing storage temperature. It may be connected to the fact that these cultivars are the most dormant and that summer produced seeds are generally at top quality and at this position they are more sensitive to freezing temperature stress.

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