Journal of Applied Horticulture, 11(1): 35-40, January-June, 2009

Sucrose synthase and acid invertase activities in relation to the floral structures abortion in pepper (*Capsicum annuum* L.) grown under low night temperature

Néji Tarchoun[1]*, Salah Rezgui[2] and Abdelaziz Mougou[2]

[1]*Centre Régional des Recherches en Horticulture et Agriculture Biologique BP47- 4042 Sousse, Tunisia,*
[2]*Institut National Agronomique de Tunisie (INAT) 43, av. Charles Nicolle 1082 cité mahrajène Tunis- Tunisia.*
**E-mail*: *ntarchoun@yahoo.fr/ tarchoun.neji@inat.agrinet.tn*

Abstract

Effects of low night temperature were investigated on two local hot pepper varieties ('Beldi' and 'Baklouti') grown at day/night temperature of either low night temperature regime (25°C/10°C) or optimum night temperature regime (25°C/20°C). The negative effect of low night temperature on floral structure differentiation was registered on both varieties. The deleterious effect was more sensitive on bud stage than on flower buds stage. Abortion of these structures was less important in 'Beldi' than in 'Baklouti'. Floral structure abortion induced by low night temperature was negatively and significantly correlated with soluble acid invertase activity on 'Beldi' (r=-0.82), while on 'Baklouti', both sucrose synthase and insoluble acid invertase activities were correlated with floral abortion (r=-0.78). Under low night temperatures, sucrose synthase and soluble acid invertase activities were reduced to 50%, while the insoluble acid invertase activity was reduced by more than 90%. Enzymatic activities and flowers abortion correlation show a differential response between these two parameters and the developmental stages of flowers.

Key words: Abortion, bud and flower, hot pepper, low night temperature, sucrose synthase, acid invertase.

Introduction

Flowers retention and fruit set are highly sensitive to environmental factors in many species (Van Doorn and Stead, 1997). High temperature, drought, low light condition or failure of pollination are important factors that may induce abortion (Aloni *et al.*, 1997; Heuvelink and Korner, 2001; Marcelis *et al.*, 2004). These environmental stresses may alter photosynthetic activity (Havaux, 1993; Kitroongrung *et al.*, 1992) and carbohydrate partitioning (Aloni *et al.*, 1991a; Schaffer *et al.*, 1987) causing an imbalance between source-sink structures (Geiger *et al.*, 1996; Minchin and Thorpe, 1996).

Relationships between carbohydrate partitioning and floral structures are studied in few species. Photosynthetic competition between reproductive and vegetative sink seems to play a role in the abortion of *Vecia faba* flowers (Aufhammer *et al.*, 1987). Turner and Wien (1994) and Aloni *et al.* (1996) indicated that competition for assimilates between flowers and adjacent young leaves may partially determine flowers abortion in pepper. Then, abortion seems to be dependant not only on the source strength but also on sink strength (assimilate demand) of competing organs.

Several studies indicate that reproductive organs abortion depends on differentiation stages of these organs and the stress type. In fact, under shade conditions, Wien *et al.* (1989) noted that open flowers were the most susceptible organs to abortion, while Aloni *et al.* (1991b), applying heat stress on sweet pepper, concluded that flower buds were more susceptible to abortion. Applying shade and heat stress at different stages of flower differentiation, Marcelis *et al.* (2004) noted that flowers/fruits of sweet pepper were susceptible to abortion few days before anthesis.

Sucrose synthase and acid invertase were found to regulate phloem unloading (Geiger and Servaites, 1991). The magnitude of the activities of both enzymes was suggested as a reliable measurement of sink strength (Black, 1993; Jenner and Hawker, 1993) but was highly dependant on environmental stress (Roitsch, 1999; Sturm and Tang, 1999). Complex mechanisms have to be assumed which integrate the expression of the enzymes involved in carbohydrates production in source tissue and the regulation of source-sink relationship (Roitsch, 1999).

Investigation on low night temperature effect on abortion of vegetable floral structures is however scarce; the present experiment was conducted to determine the effect of low night temperature on sucrose synthase and acid invertase activities in relation to the floral structures abortion in hot pepper.

Material and methods

Plant material and growth conditions: Seeds of two hot pepper varieties ('Beldi' and 'Baklouti' from INRAT, Tunisia) were sown in elevated trays containing fertilized peat (NPK, 12-14-24) and allowed to germinate in a growth chamber at 25°C ± 2°C. Seedlings, at 6- 8 leaf stage, were transplanted into 12 liters pots, one plant per pot, containing the same substrate with a layer of about 2 cm of clay (Argex 4/10) and transferred to growth chamber with day/night temperatures of either low night temperature regime (25°C/10°C) or optimum temperature regime (25°C/20°C). The photoperiod was 16 h with light intensity of 250 ± 5 µmol m^{-2} s^{-1} (PAR). The relative humidity was maintained at about 70 ± 5%. Ten plants per variety were placed, at random, in each chamber and were watered when needed and fertigated with Nutri chem (N:P:K 22:5: 11) at 1 g L^{-1}.

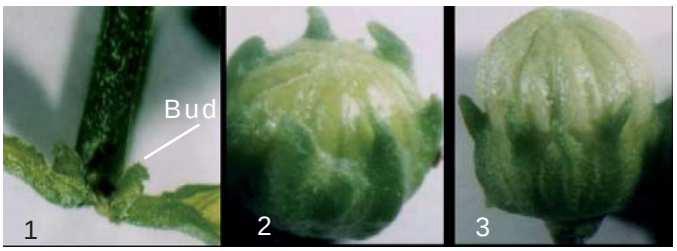

Fig. 1. Floral growth stage based on the dimension and morphological criteria: bud (stage A) [1] , flower bud (stage B) [2] and flower bud (stage C) [3] corresponding Fig.1.

Floral structures sensitivity to low temperature (experiment 1): Evaluation of the floral structures sensitive to low night temperature was performed by the transfer of 3 plants of each variety from optimal to low night temperature regime (25/20°C to 25/10°C) and inversely. These plants were acclimated at least seven days in either condition prior to transfer to growing condition. Three developmental stages were carried out using a dimensional and morphological criteria:

- Stage A corresponding to the bud stage,
- Stage B corresponding to the floral bud with 3-4 mm diameter and 4-5 mm height (green petals welded to sepals, 4-5 days before anthesis),
- Stage C corresponding to floral buds with diameter ≥ 4 mm, height ≥ 5 mm (white petals lightly welded to sepals, 2-3 days before anthesis) (Fig. 1).

Under low night temperature, these three floral structures present, usually, a highly abortion percentage compared to the flowers at anthesis stage; so the late developmental stage was not considered in this experiment.

Based on the developmental period of either stage (Tarchoun, 2003), the transfer period of plants was determined to seven nights. Before transferring the plants of 'Beldi' and 'Baklouti' varieties, 10 to 15 buds and 6-10 floral buds for each stage were studied to follow their evolution. The treatment was repeated three times.

Effect of temperature was evaluated using abortion percentage of buds (stage A) while abortion percentage of flower buds (stages B and C) was calculated based on flower buds development of stage B to stage C and the flower buds development of the stage C to pre-anthesis flowers (stage D). The abortion percentage was calculated three and five days after transfer.

Enzyme activity essays (experiment 2): Determination of sucrose synthase and acid invertase activities was carried out on floral structures at stage A, B and C and compared to the ovary at anthesis stage. Tissue samples of 200-300 mg fresh weight, collected in morning from each growth chamber, were ground in the mortar containing 3 mL of medium extraction: 25 mM HEPES buffer (N-2hydroxyethylpepirazine-N2-2ethansulphonic acid) pH 7.2; 2 mM DDT (DL-Dithiothreitol) ; 5 mM $MgCl_2$ and 3 mM DIDCA (diethyldithiocarbamic acid) as antioxidant (Aloni *et al.*, 1991b).

Sucrose synthase activity, in cleavage sense, was determined as follows: After extraction, the mixture was centrifuged at 10000 g for 30 min at 4°C. Aliquots of 200 µL of the supernatant were incubated for 30 min at 37°C in the medium containing 200 mM sucrose, 5 mM UDP, 50 mM HEPES buffer (pH 7). Reaction was stopped after boiling for 3 min. Fructose content was determined by the addition of 3 mL of dinitrosalicylic acid reagent (1% dinitrosalicylic acid, 0.2% phenol, 0.05% bisulfate sodium and 1% NAOH) according to Schaffer *et al.* (1987). To reactivate the reaction, tubes were placed on boiling water bath for 5 min; before cooling, 1 mL of Rochelle salt (potassium sodium tartrate) was added to stabilize the reaction (Miller, 1959).

Soluble and insoluble acid invertase activities were determined by comparable extraction procedure as described for sucrose synthase and the supernatant was collected and placed at 0°C. The pellet was washed three times by the same buffer and centrifuged at 10000 g at 4°C, the supernatant was eliminated in each centrifugation. The later pellet was suspended in 3mL of the extraction medium added to NaCl (1M) and placed at 0°C for 1 hour.

Aliquots of 100µL of both the supernatant (soluble acid invertase) and the suspended pellet (insoluble cell wall acid invertase) were incubated in 1 mL 0.1N phosphate citrate buffer (pH 5) and 20 mM sucrose. The incubation was carried out for 1h at 37°C and was terminated by the addition of 1 mL dinitrosalicylic acid reagent (Aloni *et al.*, 1991b). After boiling for 5 min, 1 mL of Rochelle salt was added (Miller, 1959). Sucrose synthase and acid invertase activities were determined colorimetrically at 580 nm of the optic density.

Statistical analysis: The experiment was carried out as split-split-plot design with temperature as main factor and varieties as the second factor (sub-plot) and the floral structures represent the smallest experimental unit (sub-sub-plot). Analysis of variance was performed by SAS system (1985), means were separated by LSD, and floral structures abortion was analyzed per date. The relationship between enzymatic activity and floral structures abortion was estimated by Pearson correlation coefficient using proc corr of SAS (1985).

Results

Experiment 1

Buds sensitivity to low night temperature: Fig. 2 illustrates the buds development to flowers-buds on 'Beldi' and 'Baklouti' varieties after the transfer of plants from 25/20°C to 25/10°C and vice versa. Temperature effect was significant from the third day of treatment and was stabilized at the fifth day for both temperatures regimes and varieties. The transfer from optimal night temperature to low thermal-conditions caused an increase in buds abortion on the two varieties especially on 'Baklouti'. Fifteen percent of buds aborted after three days and reached 82 and 88% at the fifth day for 'Beldi' and 'Baklouti', respectively (Fig. 2.1). The reciprocal transfer favoured significant decrease of buds abortion and the abortion rate depended on varieties (Fig. 2.2).

Flower buds sensitivity to low night temperature: The development evolution of flower buds is represented in Fig. 3. Transferring pepper plants from 25/20°C to 25/10°C and 3 days after treatment, flower buds expressed increased abortion of 56 and 69% for 'Beldi' and 'Baklouti' respectively. This abortion was more important at the fifth day of treatment and reached 86 to 91% for 'Beldi' and 'Baklouti', respectively (Fig. 3.1). Although at the end of treatment period, flower buds at stage C aborted less than those at stage B; differential behaviour was noted on both local

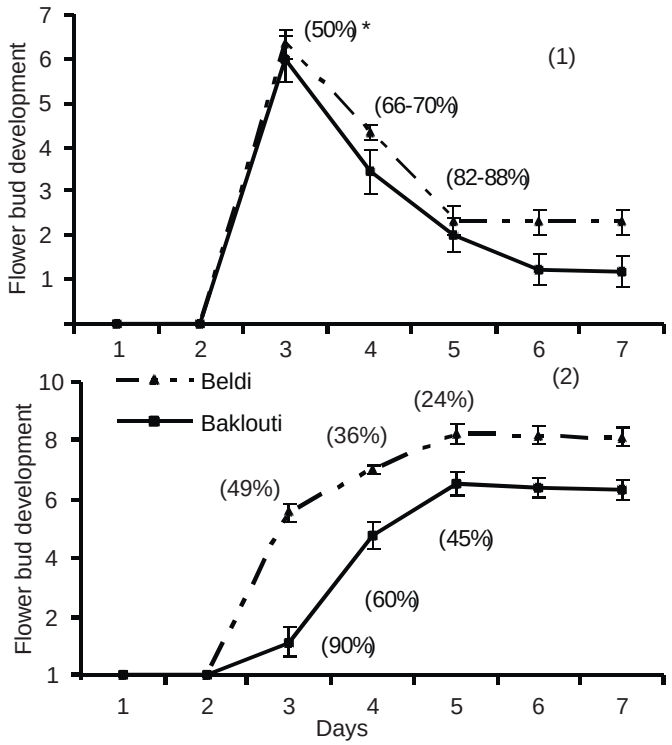

Fig. 2. Development evolution of buds to flower buds on 'Beldi' and 'Baklouti' varieties following plant transfer from 25/20°C to 25/10°C (1) and *vice versa* (2). * Numbers between brackets represent the bud abortion percent after 3, 4 and 5 days of treatment.

varieties. These flower buds at stage C seem to be more tolerant to low night temperature than those at stage B (Fig. 3.2).

The reciprocal transfer (from 25/10°C to 25/20°C) appeared to stabilize abortion at the fifth day of treatment as well as for the two-stage of flower buds with a slight difference between both varieties (Fig. 3.3 and 3.4).

Floral structures sensitivity after three and five days of the treatment: The lowest percentage abortion of floral structure was noted under constant optimal night temperature 25/20°C after either 3 or 5 days of treatment, while the highest abortion percentage was recorded following the transfer from 25/20°C to 25/10°C (Table 1). Low night temperature enhanced abortion of floral structure that varied from 47 to 74% after 3 and 5 days respectively, while the reciprocal transfer (from low to the optimal night temperature regime) reduced this abortion percentage to 34%.

The floral structure sensitivity was strongly dependent on varieties (Table 2). 'Beldi' showed lower abortion percentage than 'Baklouti' that seems to be more sensitive to low night temperature; it presented 48% of floral structure abortion after 5 days of treatment. Temperature x varieties interaction was not significant. These results describe the response of both varieties grown during winter season under unheated greenhouse. The most pronounced effect of low night temperature was noted on

Table 1. Abortion percentage of floral structure after 3 and 5 days of the treatment at different temperature regime, constant 25/20°C, transfer from 25/20°C to 25/10°C and inversely

Treatment	3 days	5 days
constant 25/20°C	13.9b*	25.9c
Transfer from 25/20°C to 25/10°C	47.2a	74.5a
Transfer from 25/10°C to 25/20°C	42.2a	33.9b
LSD	6.9	4.7

* means not followed by the same letter are significantly different at $P \leq 0.05$

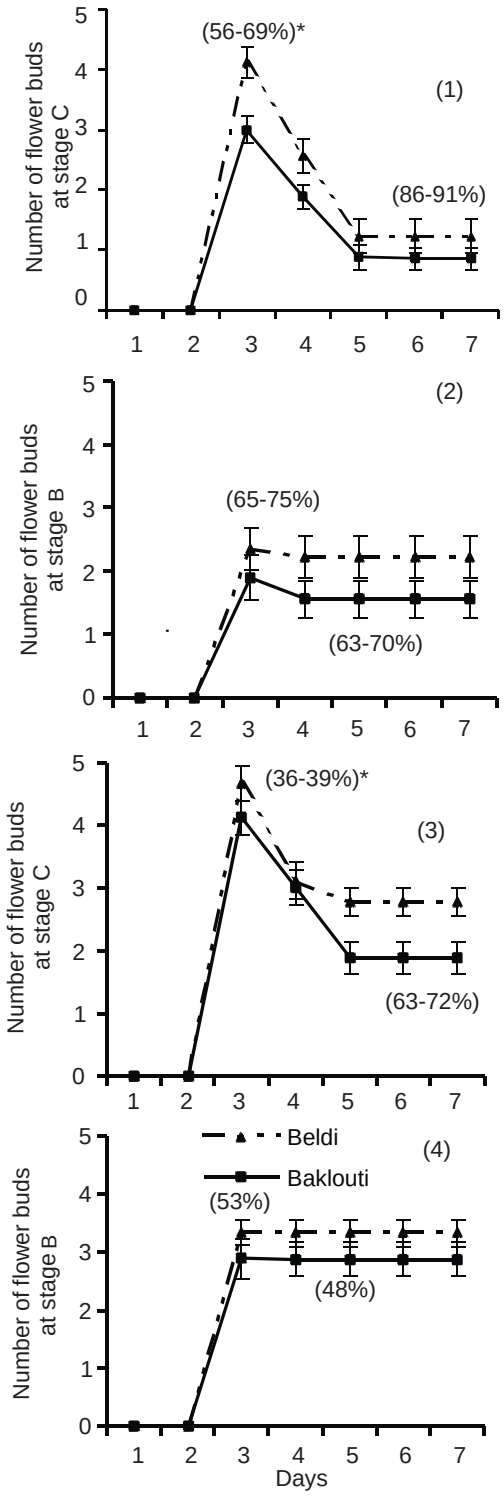

Fig. 3. Development evolution of flower buds, on 'Beldi' and 'Baklouti' varieties, at stage C and at the pre-anthesis stage (D) following plant transfer from 25/20°C to 25/10°C (1and 2) and *vice versa* (3 and 4). *numbers between brackets represent the flower bud abortion percent after 3 and 5 days of treatment.

buds and flower buds at stage B compared to those at stage C, as well as after 3 or 5 days of the transfer. The highest abortion of floral structure was recorded on buds (stage A) that ranged from 43.5 to 50.2% after 3 and 5 days of the treatment, respectively, while the lowest percent abortion was noted on flower buds at stage C (Table 3). The differential sensitivity of floral structure to low night temperature could be explained by the enzymatic activity variation.

Table 2. The average of floral structure abortion on 'Beldi' and 'Baklouti' after 3 and 5 days of the transfer from optimal night temperature regime (25/20°C) to low night temperature regime (25/10°C)

Variety	3 days	5 days
'Beldi'	31.5b*	41.2b
'Baklouti'	37.4a	48.3a
LSD	5.7	5.4

* means not followed by the same letter are significantly different at $P \leq 0.05$

Table 3. Differential sensitivity of floral structure abortion to low night temperature after 3 and 5 days of the transfer from optimal night temperature regime (25/20°C) to low night temperature regime (25/10°C)

Stage/organ	3 days	5 days
Buds (stage A)	43.5a*	50.2a
Flower buds (Stage B)	37.7b	50.1a
Flower buds (Stage C)	2.1c	33.8b
LSD	3.8	3.1

* means not followed by the same letter are significantly different at $P \leq 0.05$

Experiment 2

Effect of low night temperature on sucrose synthase and acid invertase activities: The activity of the sucrose synthase (the sucrose cleaving enzyme) and soluble and insoluble acid invertase (expressed on a fresh weight basis) was strongly dependent on temperature regime (Table 4). On the other hand, 50 to 90% of the acid invertase activity was found in the soluble fraction either at optimal or at low night temperature regime. The lowest activity was noted on the insoluble part of acid invertase under temperature regime of 25/10°C.

Effect of varieties on enzymatic activity: Enzymatic activity depends on varieties. In fact, enzymatic activity of 'Beldi' was found to be superior to that on 'Baklouti' (Table 5). Sucrose synthase activity was greatly suppressed in 'Baklouti' (3.4 µmol $gfwt^{-1}$ min^{-1}) compared to 'Beldi' (6.6 µmol $gfwt^{-1}$ min^{-1}). Insoluble and soluble acid invertase followed a similar pattern, but less pronounced for the soluble fraction.

Enzymatic activity in different floral structures: Table 6 shows that enzymatic activity depends on the floral structures. In fact, in flower ovaries (at the anthesis stage), this activity was more intense than in buds (stage A) and flower buds (stage B) and less pronounced in flower buds at stage C. The activity of the soluble acid invertase appears to be more important than other enzymes for all floral structures and it is characterized by an increasing gradient according to the evolution of these structures. The insoluble acid invertase activity shows a different behaviour; it indicates a decrease between buds stage and flower buds stage and takes an increasing trend until the ovary.

Table 4. The effect of low night temperature on sucrose synthase and acid invertase activities expressed on µmol $gfwt^{-1}min^{-1}$ evaluated on different pepper flower structures

Temperature	Sucrose synthase	Soluble acid invertase	Insoluble acid invertase
25/20°C	6.5a*	22.0a	11.8a
25/10°C	3.6b	11.1b	0.8b
LSD	1.7	2.5	0.9

* means not followed by the same letter are significantly different at $P \leq 0.05$

Table 5. The average enzymatic activity expressed on µmol $gfwt^{-1}$ min^{-1} evaluated on pepper flower structure of two local hot pepper varieties 'Beldi' and 'Baklouti'

Variety	Sucrose synthase	Soluble acid invertase	Insoluble acid invertase
'Beldi'	6.6a*	18.9a	8.4a
'Baklouti'	3.4b	14.2b	4.3b
LSD	0.9	3.3	2.1

* means not followed by the same letter are significantly different at $P \leq 0.05$

Inspite of the similar activity for the sucrose synthase, buds and flower buds express an opposite activity for the soluble and insoluble acid invertase. On the other hand, sucrose synthase and soluble acid invertase activities were more intense in flower buds at stage C as compared to the previous structures. Abortion of these floral structures seems to be controlled differentially by one or the other type of enzymes.

Low night temperature reduced sucrose synthase activity in 'Baklouti' by 53% and by 38% in 'Beldi' (Table 7). Under low night temperature of 10°C, reduction of soluble and insoluble acid invertase activities was more pronounced than sucrose synthase activity. The insoluble fraction of acid invertase was more affected in both 'Beldi' and 'Baklouti' varieties with 1 to 0.7 µmol $gfwt^{-1}$ min^{-1}, respectively.

Table 6. The enzymatic activity expressed on µmol $gfwt^{-1}$ min^{-1} on four different pepper flower structures, buds (stage A), flower buds (stage B and C) and flower ovaries at anthesis

Stage/organ	Sucrose synthase	Soluble acid invertase	Insoluble acid invertase
Buds (stage A)	2.9c*	10.7c	4.0b
Flower buds (stage B)	2.0c	15.9b	2.3c
Flower buds (stage C)	4.6b	19.4a	4.8b
Ovaries	10.5a	20.2a	14.2a
LSD	1.0	2.7	1.1

* means not followed by the same letter are significantly different at $P \leq 0.05$

Table 7. Sucrose synthase and acid invertase activities expressed on µmol $gfwt^{-1}$ min^{-1} on 'Beldi' and 'Baklouti' varieties grown under optimal night temperature regime (25/20°C) or low night temperature (25/10°C)

Enzyme	'Beldi'		'Baklouti'	
	25/20°C	25/10°C	25/20°C	25/10°C
Sucrose synthase	8.2±2.1*	5.1±0.2	4.7±1.0	2.2±0.3
Soluble Acid invertase	26.1±7.1	11.8±4.9	17.9±5.2	10.4±3.2
Insoluble Acid invertase	15.7±6.0	1.0±0.2	7.9±1.5	0.7±0.08

* means ± SE (n= 12 replications)

Relationships between floral structures abortion and enzymatic activity: Correlation coefficient between floral structures abortion in 'Beldi' and 'Baklouti' grown under optimal night temperature regime (25/20°C) or low night temperature (25/10°C) and enzymatic activity revealed that, under low night temperature, the abortion of 'Baklouti' floral structures was associated negatively with sucrose synthase and insoluble acid invertase (r=-0.78**), while for 'Beldi', this coefficient was only significant for soluble acid invertase (r=-0.82**). However, under optimal temperature regime (25/20°C) floral structures abortion of 'Beldi' and 'Baklouti' was associated to the insoluble and soluble acid invertase, respectively (Table 8). Moreover, the abortion of different floral structures seems to be dependant on the enzyme type. In fact, buds abortion was associated mainly to the acid invertase activity as well as in 'Beldi' and 'Baklouti', while sucrose synthase activity controlled the flowers buds (stage B) abortion. Although abortion of flower buds (stage C) depended on the varieties; soluble and insoluble acid invertase controlled

Table 8. Pearson correlation coefficients between floral structures abortion in 'Beldi' and 'Baklouti' grown under optimal night temperature regime (25/20°C) or low night temperature (25/10°C) and enzymatic activity expressed as µmol g fwt^{-1} min^{-1}

	'Beldi'			'Baklouti'		
	Sucrose synthase	Soluble acid invertase	Insoluble acid invertase	Sucrose synthase	Soluble acid invertase	Insoluble acid invertase
25/20°C	-0.13 ns	-0.44 ns	-0.70*	-0.13 ns	-0.72*	-0.49 ns
25/10°C	-0.12 ns	-0.82**	-0.17 ns	-0.78**	-0.35 ns	-0.78**

* , ** significant differences at $P<0.05$ and $P<0.01$ respectively, ns- differences not significant at $P>0.05$

this abortion in 'Baklouti' while only insoluble fraction of acid invertase was associated with flower buds abortion in 'Beldi'.

Discussion

The physiological processes like photosynthesis, metabolism of sugars and translocation of assimilate have been studied under stress conditions. Important progress has been made in quantifying and modeling synthesis and distribution of assimilates in leaves of fruits tree species (Grossman and Dejong, 1994; Wermelinger *et al.,* 1991) and of the vegetable species (Heuvelink, 1995; Marcelis, 1996; Marcelis *et al.,* 1998). However, the floral structures: buds and floral buds, more particularly of the vegetable species cultivated under low night temperature, had little attention.

The floral structures abortion at various differentiation stages has been more common under low light intensity and/or high temperature in several Solanaceous crops, including pepper (Aloni *et al.,* 1996; 1997) and tomato (Heuvelink, 1996). The sensitivity of the floral structure to low night temperature was exhibited when plants were transfered from optimal condition (25/20°C) to low night temperature (25/10°C) and reciprocally (experiment 1). A greater abortion rate had been noted after three days of this treatment. This result suggests an early effect of temperature on these structures. A similar response has been recorded by Aloni *et al.* (1991b) who observed that the development of buds is affected by the high temperatures (>30°C) during the first 6 hours post treatment and a complete growth stopping took place after 24h of heat stress.

The abortion of buds and flower buds at stages B and C has been found to be dependent on temperature regime and variety, and within the same variety, on the floral differentiation stages (Fig. 2, 3). The low night temperatures (25/10°C) enhances buds and flower buds abortion which is more pronounced for buds than flower buds at stage B and less for those at stage C. The abortion of floral structures was more pronounced in 'Baklouti' than in 'Beldi'. This differential behaviour of varieties tested has been found in close association with enzymatic activity that was strongly reduced by the night temperature of 10°C (Table 4). Indeed, the activities of both enzymes, sucrose synthase and the soluble and insoluble acid invertase, were significantly higher under temperature regime of 25/20°C and were more expressed in 'Beldi' than in 'Baklouti'. This result suggests that, in addition of the temperature effect, other factors such as, the genetic aspect seems to regulate the metabolic activity. In fact, under light stress conditions (shading of 60%), Shiffriss *et al.* (1994), studying the abortion of flowers of inbred lines and hybrids F1 and F2 of pepper in segregation, had noted variable abortion rates between these different types of plant material and concluded that some genetic factors are responsible.

Geiger *et al.* (1996) showed that distribution of assimilates is controlled by at least two enzymes: sucrose synthase and acid invertase and this distribution is controlled by the strength of sink organs. It seems, however, that this distribution is governed by the intensity of the organ strength. Buds (stage A) and flower buds at stage B presented the weakest enzymatic activity in comparison to ovaries at anthesis stage, while flower buds at stage C had intermediate position (Table 6). The differential abortion of these structures would be, particularly, attributed to the activity of these two enzymes that may serve as an indicator for the organs strength (Sun *et al.,* 1992).

Heuvelink (1995) and Marcelis *et al.* (1998) reported that the temperature is an important factor affecting the distribution of assimilates in plants, while light and the CO_2 level affect the strength of the source organs. On the other hand, Bertin (1995) suggested that the abortion of the tomato inflorescences, before the anthesis may be due to the competition for assimilate between the young vegetative organs and the last inflorescences. For other researchers (Sato *et al.,* 2001) the floral buds abortion (before the anthesis) at the tomato seems to result in a competition of assimilates between fruits and flowers of the same bunch or the superior bunch. In this investigation, result suggests that the floral structure abortion is attributed to a poor translocation capacity of assimilates. Furthermore, a direct effect of the temperature regime is suggested. Varying sink strength by changing the number or position of early-formed fruits affected abortion in sweet pepper flowers and the abortion rate showed a linear relationship with the growth rate of the earlier formed competing fruits (Marcelis *et al.,* 2004). This abortion induction may be caused by competition for available assimilates by dominance due to the production of plant growth regulators from the developing fruits, or by a combination of them (Heuvelink and Korner, 2001; Marcelis and Baan Hofman-Eijer, 1997)

The competition for the assimilate translocation between the young leaves and flowers also constitutes a reason of the flower abortion (Van Doom and Stead, 1997) since these young leaves constitute a more powerful sinks than the adjacent flowers (Aloni *et al.,* 1991a, 1991b). However, Turner and Wien (1994) did not report such effect, since leaves suppression did not improve flowers retention. This controversy assumes that the floral structure abortion would rather be assigned to a competition between the floral structures at different differentiation stages.

Flowers, at anthesis stage, have been considered as a strong sinks (Black 1993; Marcelis 1996). In the present study (Table 6), except for insoluble acid invertase, the most intense enzymatic activity has been found in the ovaries; this could explain their low abortion under low night temperature. Working under high temperature, Aloni *et al.* (1997) found more intense activity of sucrose synthase at post-anthesis stage.

The analysis of the association between the floral structures abortion and the enzymatic activity revealed that, at low night temperature, abortion control suggests a genetic effect; thus, the soluble acid invertase seems to control abortion in 'Beldi' variety, whereas on 'Baklouti' variety the combination of sucrose synthase and insoluble acid invertase controls this phenomenon (Table 8).

The abortion of buds seems to be associated with acid invertase activity especially its soluble fraction and to a lesser extent with insoluble fraction either in 'Beldi' or 'Baklouti'. Sucrose synthase seems to be responsible of the flowers buds (stage B) in both varieties. Compared to the flowers at anthesis stage, studies on floral structure abortion at the first stages of differentiation (buds and flower buds) in relation to the metabolic activity are scarce.

The amplitude of variation of flower structures to abortion is attributed to the simultaneous effects of the endogenous factors (metabolic activity) and of the exogenous factors (environmental factors). The later factor optimize the availability and the distribution of assimilates between the different organs of the plant. The abortion of buds and flowers buds under low night temperatures of 10°C, associated to a low enzymatic activity, support this hypothesis.

References

Aloni, B., T. Pashkar and L. Karni, 1991a. Nitrogen supply influences carbohydrates partitioning in pepper seedlings and transplant development. *J. Amer. Soc. Hort. Sci*., 116: 995-999.

Aloni, B., T. Pashkar and L. Karni, 1991b. Partitionning of [14]-C sucrose and acid invertase activity in reproductive organs of pepper plants in relation to their abortion under heat stress. *Ann. Bot.*, 67: 371-377.

Aloni, B., L. Karni, Z. Zaidman and A.A. Schaffer, 1996. Changes of carbohydrates in pepper (*Capsicum annuum* L.) flowers in relation to their abortion under different shading regimes. *Ann. Bot.,* 78: 163-168.

Aloni, B., L. Karni, Z. Zaidman and A.A. Schaffer, 1997. The relationship between sucrose supply, sucrose cleaving enzymes and flower abortion in pepper. *Ann. Bot.*, 79: 601-605.

Aufhammer, W., I. Gotz and M. Peter, 1987. Yield performance in field bean (*Vicia faba* L.) in relation to interactions between inflorescence at different nodes. *J. Agri. Sci.*, 105: 662-664.

Bertin, N. 1995. Competition for assimilates and fruit position affect fruit set in indeterminate greenhouse tomato. *Ann. Bot.*, 75: 55-65.

Black, C.C., 1993. Sink strength: it is real or measurable ? *Plant Cell Envir*., 16: 1037-1038.

Deng, X., S.A. Weinbaum, T.M. DeJong and T.T. Muraoka, 1991. Pistillate flower abortion in 'Serr' walnut associated with reduced carbohydrate and nitrogen concentrations in wood and xylem sap. *J. Amer. Soc. Hort. Sci.*, 116: 291-296.

Geiger, D.R., K.E. Koch and W.J. Shieh, 1996. Effect of environmental factors on whole plant assimilate partioning and associated gene expression. *J. Exp. Bot*., 47: 1229-1238.

Geiger, D.R. and J.C. Servaites, 1991. Carbon allocation and response to stress. In: *Response of Plants to Multiple Stress*. Mooney H.A. *et al.* (Eds) Academic press, San Diego. p. 103-125.

Grossman, Y.L. and T.M. Dejong, 1994. Peach: a simulation model of reproductive and vegetative growth in peach trees. *Tree Physiol*., 14: 329-345.

Havaux, M. 1993. Rapid photosynthetic adaptation to heat stress triggered in potato leaves by moderately elevated temperatures. *Plant Cell Environ.*, 16: 461-467.

Heuvelink, E. 1995. Effect of temperature on biomass allocation in tomato (*Lycopersicon esculentum*). *Physiol. Plantarum,* 94: 447-452.

Heuvelink, E.1996. Dry matter portioning in tomato: validation of a dynamic simulation model. *Ann. Bot.*, 77: 71-80.

Heuvelink, E. and O. Korner, 2001. Parthenocarpic fruit growth reduces yield fluctuation and blosson-end rot in sweet pepper. *Ann. Bot.*, 88: 69-74.

Jenner, C.F. and J.S. Hawker, 1993. Sink strength: soluble starch synthase as a measure of a sink strength in wheat endosperm. *Plant Cell Environ.*, 16: 1023-1024.

Kitroongrung, N., S. Jodo, J. Hisai and M. Kato, 1992. Photosynthesis characteristics of melon grown under high temperature. *J. Jap. Soc. Hort.. Sci*., 61: 107-114.

Marcelis, L.F.M. 1996. Sink Strength as a determinant of gray matter partitioning in the whole plant. *J. Exp. Bot*., 47: 1281-1291.

Marcelis, L.F.M. and L.R. Baan Hofman-Eijer, 1997. Effect of seed number on competition and dominance among fruits in *Capsicum annuum* L. *Ann. Bot.*, 79: 687-693.

Marcelis, L.F.M. , E. Heuvelink and J. Goudriaan, 1998. Modeling biomass reduction and yield of horticultural crops: a review. *Scientia Hortic.*, 74: 83-111.

Marcelis, L.F.M., E. Heuvelink, L.R. Baan Hofman-Eijer, J. Den Bakker and L.B. Xue, 2004. Flower and fruit abortion in sweet pepper in relation to source and sink strength. *J. Exp. Bot.*, 55: 2261-2268.

Miller, G.L. 1959. Use of dinitrosalycilic acid reagent for determination of reducing sugars. *Ann. Chem*., 3: 426-428

Minchin, P.E.H. and M.R. Thorpe, 1996. What determines carbon partitioning between competing sites? *J. Exp. Bot*., 47: 1293-1296.

Roitsch, T. 1999. Source-sink regulation by sugar and stress. *Current Opinion Plant Biol*., 2: 198-206.

Statistical Analysis System, 1985. *SAS User's guide Statistics*. Ed. Cary, NC.

Sato, S., M.M. Peet and R.G. Gardner, 2001. Formation of parthenocarpic fruit, undeveloped flowers and aborted flowers in tomato under moderately elevated temperatures. *Scientia Hortic.*, 90: 243-254.

Schaffer, A.A., B. Aloni and E. Fogelman, 1987. Sucrose metabolism and accumulation in developing fruit of sweet and non-sweet genotypes of Cucumis. *Phytochemistry*, 26: 1883-1887.

Shiffriss, C., M. Pilowsky and B. Aloni, 1994. Variation in flower abortion of pepper under stress shading conditions. *Euphytica*, 78: 133-136.

Sturm, A. and G.Q. Tang, 1999. The sucrose-cleaving enzymes of plants are crucial for development, growth and carbon partitioning. *Trends Plant Sci.*, 4: 401–407.

Sun, J., T. Loboda, S.S. Sung and C.C. Jr Black, 1992. Sucrose synthase in wild tomato *Lycopersicon chmielewskii*, and tomato fruit strength. *Plant Physiol.*, 98: 1163-1169.

Tarchoun, N. 2003. Etude de la floraison et de la nouaison en conditions de basses températures nocturnes et leur déterminisme génétique chez le piment (*Capsicum annuum* L.). Thèse de Doctorat d'Etat en Sciences Agronomiques de l'INAT- Tunisie, 188pp.

Turner, A.D. and H.C. Wien, 1994. Photosynthesis, dark respiration and bud sugar concentrations in pepper varieties differing in susceptibility to stress-induced bud abortion. *Ann. Bot.*, 73: 623-628.

Van Doom, W.G. and A.D. Stead, 1997. Abortion of flowers and floral parts. *J. Exp. Bot.*, 48: 821-837.

Wermelinger, B., J. Baumgartner and A.P. Gutterrez, 1991. A demographic model of assimilation and allocation of carbon and nitrogen in grapevines. *Ecol. Modeling,* 53: 1-26.

Wien, H.C., A.D. Turner and S.F. Yang, 1989. Hormonal basis for low light intensity induced flower bud abortion of peppers. *J. Amer. Soc. Hort. Sci*., 114: 981-985.