Factors influencing citrus fruit scarring caused by *Pezothrips kellyanus* (Thysanoptera: Thripidae)

Authors: Cristina Navarro-Campos[1*], Apostolos Pekas[1,2], Amparo Aguilar[1] & Ferran Garcia-Marí[1].

[1]Instituto Agroforestal Mediterráneo (IAM), Universidad Politécnica de Valencia, Camino de Vera s/n, 46022, Valencia, Spain.

[2] Biobest Belgium N.V., R&D Department, Ilse Velden 18, 2260 Westerlo, Belgium

*Correspondence: crinacam@posgrado.upv.es ; telephone: (+34) 963 879 251; fax number: (+34) 963 877 331

Abstract:

Kelly's citrus thrips (KCT) *Pezothrips kellyanus* (Bagnall) (Thysanoptera: Thripidae) is a recently recorded cosmopolitan citrus pest, causing fruit scarring that results in downgrading of fruit. Due to the detrimental effects caused on fruits by KCT, we wanted to study some of the factors influencing fruit scarring. Specifically, the objectives were: (1) to determine the fruit development stage when citrus fruits are damaged by KCT and the population structure of KCT during this period, (2) to study the influence of temperature on intensity of damage, and finally, (3) to identify alternative host-plants. KCT populations on flowers and fruitlets and alternate plant hosts were sampled in four citrus orchards from 2008 to 2010. The percentage of damaged fruits was also recorded. The exotic vine *Araujia sericifera* (Apocynaceae) was recorded as a new host for KCT. Thrips scarring started to increase at 350-650 degree-days (DD) above 10.2ºC, coinciding with a peak abundance of the second instar larval stages over all three years of the study. The maximum percentage of larval stages of KCT was observed in the three years at about 500 DD, a period which corresponds to the end of May or early June. Variation in the severity of fruit scarring appeared to be related to air temperature. Temperature likely affects the synchronization between the peak in abundance of KCT larvae, and the period when fruitlets are susceptible to thrips damage. Temperature can also influence the survival and development of KCT populations in citrus and other host plants in the citrus agro-ecosystem.

Key words: Kelly's citrus thrips, fruit scarring, temperature, degree-days, *Araujia sericifera*, population structure

1 Introduction

Since the decade of 1990, Kelly's citrus thrips (*Pezothrips kellyanus* (Bagnall)) (Thysanoptera: Thripidae) (thereafter KCT) has been reported as a new important economic pest of citrus in southern Australia, New Zealand, and several countries of the Mediterranean Basin, namely Italy, Greece, Portugal, Turkey, Cyprus (Blank and Gill 1997; Marullo 1998; Mound and Jackman 1998; Orphanides 1998; Varikou et al. 2002; Franco et al. 2006; Vassiliou 2007). In Spain, citrus fruit damage by *P. kellyanus* was first observed in 2007 (Navarro-Campos et al. 2011). Until that time, only *Heliothrips haemorrhoidalis* (Bouche) and *Scirtothrips inermis* Priesner (Thysanoptera: Thripidae) had occasionally caused damage to citrus fruits in localized areas of Spain (Gomez-Clemente 1952; Lacasa et al. 1996; EPPO 2005). The fruit damage caused by *H. haemorrhoidalis* consists of grey scars, generally in the area where mature fruits come in contact, which are sprinkled with black spots of excreta (Blank and Gill 1997; Smith et al. 1997). On the other hand, *S. inermis* causes rind scarring on citrus fruits, a symptom which is similar to those produced by other species of *Scirtothrips,* such as *Scirtothrips citri* (Moulton) or *Scirtothrips aurantii* Faure, and also by KCT (Lacasa et al. 1996; Smith et al. 1997).

Given that KCT has only recently become economically relevant, there is limited published information about basic aspects of its ecology and damage potential. Adults and larvae of KCT are normally found in large numbers in the flowers of various citrus varieties (Blank and Gill 1997; Conti et al. 2001; Costa et al. 2006; Teksam and Tunç 2009; Navarro-Campos et al. 2011). Mature second-instar larvae of KCT drop from the citrus canopy to the leaf litter and soil, where they pupate in the upper 2 cm soil-layer (Baker et al. 2002). Newly emerged adults, paler in color than the black mature adults, move up from the soil into the tree canopy to feed and reproduce (Mound and Jackman 1998). In contrast with *S. citri* and *S. aurantii*, two other thrips species also damaging citrus which insert their eggs into young and soft tissues of leaves, stems or fruits (Horton 1918; Grout et al. 1986; EPPO 2005), KCT inserts its eggs generally in flower parts, mostly in the petals, or in mature fruits (Baker et al. 2002). The rind scarring caused by thrips in citrus is mostly produced by the second instar larvae after petal fall (Wiesenborn and Morse 1986; Rhodes and Morse 1989). Larvae congregate under the calyces of the young fruitlets where they feed. The resultant damage to the rind appears in the form of silvery scars under the calyx. As the fruit grows this damaged area expands across the surface of the fruit (Baker 2006). The scarred mature fruits are consequently downgraded for the fresh market (Blank and Gill 1997). In the case of KCT, the period when damage occurs has not been accurately determined. The determination of this period throughout the growing season, and, most importantly, its association with yearly climatic data, i.e. sum of degree days above the developmental threshold of KCT, will enable us to predict years with higher damage and eventually act preventively against this pest. Moreover, there is little information on the abundance and the population structure (life stages) of KCT when damage occurs. Knowledge of this information would be of additional help for KCT pest management.

Interannual variation in fruit scarring has commonly been observed in thrips damaged citrus. It has been related with air temperatures in the case of *S. citri*. Cool weather during early March and warm weather during bloom were associated with higher percentages of scarred fruit (Schweizer and Morse 1997). Interannual variation has also been observed in KCT (Perrotta and Conti 2008; Vassiliou 2010). In this species, temperatures could influence KCT in a different manner because adults establish in flowers in order to breed, whereas *S. citri* and *S. aurantii* are leaf-living species which establish on new foliage as well as on young fruit (Horton 1918; Grout et al. 1986, Blank and Gill 1997).

KCT adults have been found on numerous plant species (Froud et al. 2001; EPPO 2006; Webster et al. 2006; Vassiliou 2010). However, in thrips it is important to differentiate between incidental and breeding host plants (Reitz et al. 2011). Many plants serve as incidental hosts for thrips supplying refuge and food for adults, but a plant is defined as a breeding host only if both adults and larvae are present (Mound and Marullo 1996; Froud et al. 2001). Records of breeding KCT larvae have been registered only for a few unrelated plant species, usually with white and sweetly scented flowers, including *Hymenosporum flavum* F. Muell., *Pittosporum tobira* (Thunb.) W.T. Aiton, *Westringia fruticosa* (Willd.) Druce, *Jasminum* spp., *Lonicera* spp., and *Gardenia jasminoides* Ellis (Kirk 1987; Mound and Jackman 1998; Froud et al. 2001; Baker 2006; Vassiliou 2010). Given that breeding sites for KCT are not available all year round in citrus trees and as pollen is a key factor for development and reproduction of KCT (Varikou et al. 2012), it is crucial to identify alternative breeding hosts (with pollen) in the citrus ecosystem that may contribute to the survival of KTC between the flowering periods of two consecutive years. Controlling KCT populations on alternative host plants prior to the citrus blooming will avoid the KCT migration from these plants to citrus trees.

Thus, the objectives of this study were: (1) to determine the fruit development stage to determine the fruit development stage when citrus fruits are damaged by KCT and the population structure of KCT during this period, (2) to study the influence of temperature on KCT populations and intensity of fruit scarring, and finally, (3) to identify potential alternative host-plants used by KCT for reproduction.

2 Material and methods

2.1 Sampling sites

Thrips populations and damage were studied in four citrus orchards from 2008 to 2010. All of the orchards were commercial citrus plantations, with 11 to 15-yr-old trees in full production, situated in an extensive citrus monoculture region south of the city of Valencia, in eastern Spain (39º 11’ N, 0º 22’ O, 11 m altitude). The climate is Mediterranean with mild winters and dry summers. The orchards selected had high thrips damage the previous year. Two orchards were of sweet orange (*Citrus sinensis* (L.) Osbeck) (Valencia Late variety) and two orchards were of hybrid Ortanique (*C. sinensis* x *C. reticulata*). The size of each orchard ranged from 0.5 to 2 ha, being each orchard a replicate. The sampled area of the orchard (5 x 5 trees in each orchard) had not been treated with pesticides for at least six months and was not treated during the sampling period.

2.2 Fruit damage caused by KCT

The percentage of fruits damaged by KCT was recorded by randomly sampling 50 fruits from the exterior of the canopy per orchard (five per tree from 10 different trees). This sampling was carried out weekly from the beginning of the fruit development period (May 12th in 2008, May 17th in 2009 and June 11th in 2010) until the end of June, and fortnightly from July to October. Fruit damage was recorded in two categories, “damage” and “severe damage”. “Damage” was considered any kind damage, i.e. when fruits showed any scar (mild or severe) caused by KCT, including slight scars. “Severe damage” was considered only severe damage, i.e. when scars on the fruit consisted of a complete ring around the calyx or a wide partial ring with other minor scars on the fruit surface. Fruit damage caused by KCT was differentiated from similar damage caused by other insects such as *Anatrachyntis badia* Hodges (Lepidoptera: Cosmopterigidae) or from scarring caused by wind according to Lacasa et al. (1996), Bedford (1998) and Navarro-Campos et al. (2010).

2.3 KCT population sampling procedure

On each orchard, fifty newly opened citrus flowers or fruitlets were randomly collected from the exterior part of the canopy (five flowers per tree from 10 different randomly selected trees). Each flower or fruitlet was immediately placed individually inside a 20 ml plastic container with a screw top having 10 ml of 70% ethanol. This sampling was repeated weekly from the beginning of the flowering period (March 13th in 2008, March 26th in 2009 and April 6th in 2010) until the end of June during the three years of the study. In total, 2,450 flowers and 3,746 fruitlets were collected. In the laboratory, flowers and fruitlets were carefully searched and all postembryonic developmental stages of thrips were extracted using a fine brush and identified under a stereomicroscope. Microscope slides were prepared in order to identify KCT larvae (Heinze PVA). Male and female adults and second instar larvae were identified on the basis of the descriptions of Mound and Walker (1982), Kirk (1987), Milne et al. (1997) and Vierbergen et al. (2010). First instar larvae were identified according to the description by Navarro-Campos et al. (2012).

2.4 Climatic data

Daily air temperature data were obtained from four meteorological stations situated 0-5 km away from the orchards where the study was carried out. The sum of degree-days was calculated by accumulated daily mean temperature above 10.2ºC starting on January 1st for each year, according to the developmental threshold for KCT established by Varikou et al. (2009).

2.5 Alternative host plants for KTC

When available, flowers of plant species growing inside the citrus orchards or in adjacent roadsides were collected and examined for the presence of KCT immature and adults for the three years of the study. The number of samples collected from each plant species ranged from two to eight. Each sample consisted of 5-20 flowers, collected in paper bags and carried to the laboratory. The flowers were placed in Berlese funnels for 48 h. Adults and larvae of KCT moved away from the light/heat source down the funnel and fell into a 20 ml black plastic container with 70% ethanol. Afterwards, KCT larvae and adults were identified (see above) and counted under a stereomicroscope.

2.6 *Statistical Analysis*

A two-way analysis of variance (ANOVA) was used to compare the percentage of damaged and severely damaged fruits at the end of the fruit growing period (mean from August to September) between the three years studied, including year as the main factor and orchard as the block factor, in a randomized block design. Percentages were arcsine transformed before analyses in order to meet the normality criteria and variance homogeneity. We also used two-way ANOVA to compare the KCT abundance per flower and per fruitlet between years, including orchard as the block factor. Data were $\log_{10}(x + 1)$ transformed before analyses. For both analyses, means were compared using Fisher's least significant difference (LSD) test with significance level set at $\alpha = 0.05$. All Statistical analyses were performed using Statgraphics 5.1 software (Statgraphics 1994).

3 Results

3.1 Appearance of fruit damage caused by KCT and population structure during this period

The first appearance of fruit damage caused by KCT differed between the three years of the study. Damage appeared earlier in 2008 and 2009 (350-450 degree-days (DD) corresponding to May) than in 2010 (650 DD, June) (Fig. 1). The percentage of damaged fruits increased progressively from May to July, between 350 and 1200 DD. Between August and October the percentage of damaged fruits remained more or less constant resulting in the final damage observed at harvest in October.

The proportion of larval stages in KCT populations varied considerably during the period when thrips were present on flowers and fruitlets, but in general was higher in 2008 and 2009 compared with 2010 (Fig. 2). Overall, the maximum percentage of larval stages of KCT was observed in the three years at about 500 DD, a period which corresponds to the end of May or early June.

The percentage of immature stages decreased afterwards dropping almost to zero as fruit growth progressed. The proportion of males fluctuated also widely during this period, being higher than the proportion of females during or at the end of the petal fall period, at about 300 DD, the three years of study (Fig. 2).

3.2 Internannual variation in fruit damage caused by KCT

The percentage of fruit damage per orchard at harvest ranged between the four orchards sampled from 41.2 ± 2.0 to 77.8 ± 1.9 in 2008, from 23.0 ± 3.0 to 67.5 ± 3.3 in 2009, and from 10.0 ± 2.1 to 23.5 ± 3.0 in 2010. Pooling data from all the orchards, the mean percentage of fruits damaged or severely damaged by KCT at harvest was the highest in 2008, intermediate in 2009 and the lowest in 2010 (F = 16.68; df = 2, 11; P = 0.003 and F = 14.27; df = 2, 11; P = 0.006, for damaged and severely damaged fruits, respectively) (Table 1).

Table 1. Percentage (mean ± SE) of citrus fruits damaged or severely damaged by KCT and number (mean ± SE) of KCT individuals (adults and larvae) per sample unit (flower or fruitlet) for 2008, 2009 and 2010. Data obtained from four citrus orchards sampled from August to October in eastern Spain. Inside each column, means followed by different letters differ significantly at P < 0.05 (Fisher protected LSD).

	Fruit damage by KCT		**KCT abundance**	
Year	**% damaged**	**% severely damaged**	**Flower**	**Fruitlet**
2008	60.78 ± 9.66 a	35.46 ± 4.74 a	2.21 ± 1.08 a	0.39 ± 0.15 a
2009	41.88 ± 9.22 a	20.25 ± 4.99 b	2.26 ± 1.46 a	0.20 ± 0.08 ab
2010	16.63 ± 2.83 b	5.00 ± 0.79 c	0.35 ± 0.20 b	0.04 ± 0.02 b

The population abundance of KCT (adults and larvae) in flowers and fruitlets was significantly different in the three years studied (Table 1). The mean number of thrips per flower, observed at about 200-350 DD, was much higher in 2008 and 2009 than in 2010 (F = 5.78; df = 2, 11; P = 0.04). KCT populations on fruitlets, observed within the period from 250 to 700 DD, were significantly higher in 2008 than in 2010, being intermediate in 2009 (F = 7.05; df = 2, 11; P = 0.03).

A relationship was observed between the sum of degree-days on January 1st and the percentage of severe fruit damage at harvest (r = 0.98, df = 2, P < 0.05). The highest sum of degree-days was observed in 2008 (618 DD), the year when most severe damage was observed (35%), followed by 2009 (573 DD) when damage was intermediate (20%), whereas the lowest sum of degree-days was observed in 2010 (548 DD) when only 5% of damage was detected.

3.3 Alternative host plants

Breeding populations of KCT were detected in several non-citrus host plants located inside or in the vicinity of the citrus orchards sampled (Table 2). Both larval instars and adult KCT were found in great numbers on jasmine (*Jasminum officinale* L.), Japanese honeysuckle (*Lonicera japonica* Thunb.), Japanese cheesewood (*P. tobira*) and white bladderflower (*Araujia sericifera* Brot.). Among these plant species, *A. sericifera* is a new host record for KCT.

Four second instar larvae (L2) of KCT were encountered in a sample of 20 flowers of Bermuda buttercup (*Oxalis pes-caprae* L.), a common and widespread cover crop in Mediterranean citrus orchards during the winter period. Only adults of KCT were found on *Narcissus* sp., *Passiflora edulis* Sims., *Nerium oleander* L., *Diplotaxis erucoides* (L.) DC. and *Malus domestica* Borkh. Since immature thrips were not present in the flowers of these five plant species, they should be considered as incidental rather than breeding hosts for KCT (Table 2).

Table 2. Adult and immature KCT (mean ± SE) extracted from plant samples (with 5 to 20 flowers per sample) located inside or in the vicinity of citrus orchards.

Host species	Family	Flowering period	No.of samples	No. of flowers	adult KCT/flower	immature KCT/flower	% of samples with immature KCT
Jasminum officinale L.	Oleaceae	Apr-Nov	5	57	23.05 ± 7.11	5.54 ± 3.28	100[a]
Lonicera japonica Thunb.	Caprifoliaceae	May-Aug	4	35	29.37 ± 6.93	4.25 ± 1.61	100[a]
Pittosporum tobira (Thunb.) W.T. Aiton	Pittosporaceae	Mar-Apr	5	50	11.16 ± 5.13	2.36 ± 1.12	100[a]
Araujia sericifera Brot.	Apocynaceae	Mar-Oct	5	50	1.58 ± 0.75	0.52 ± 0.24	80[a]
Oxalis pes-caprae L.	Oxalidaceae	Sep-May	8	110	0.09 ± 0.05	0.04 ± 0.03	12.5[b]
Narcissus tazetta L.	Amaryllidaceae	Dic-Apr	2	10	3.2 ± 1.60	0	0
Passiflora edulis Sims.	Passifloraceae	Apr-May	3	15	1.47 ± 1.01	0	0
Nerium oleander L.	Apocynaceae	May-Sep	8	80	0.37 ± 0.19	0	0
Diplotaxis erucoides (L.) DC.	Cruciferae	Jan-Dec	7	70	0.11 ± 0.09	0	0
Malus domestica Borkh.	Rosaceae	Apr-May	2	35	0.07 ± 0.07	0	0
Eriobotrya japonica (Thunb.) Lindl.	Rosaceae	Sep-Jan	4	45	0	0	0

[a] First and second larval instars were present
[b] Only second instar

4. Discussion

For all three years of the study, the fruit damage caused by KCT started to increase during the beginning of the fruit development period, at about 350-650 DD. Interestingly, the relative abundance of the immature KCT stages, and particularly of second instar larvae, peaked at around 300-500 DD. Second instar larvae are considered the KCT stage responsible for damage caused to citrus fruits (Baker et al. 2002; Navarro-Campos et al. 2012). In this period of the year a week corresponds to approximately 50 DD and petal fall occurs at 200-300 DD. Thus, damage by KCT is most likely produced from the first until the fifth week after petal fall. During this period it is crucial to monitor the abundance of KCT larvae on fruitlets in order to decide whether an insecticide treatment is required. Baker et al. (2002) also reported that most of the rind damage caused by KCT in Australia occurred during the four to five weeks following petal fall. Likewise, the economic damage caused by *S. citri,* a citrus thrips species that causes similar damage to KCT, was highly correlated to the second instar activity during the first 3-6 weeks after petal-fall (Rhodes and Morse 1989).

Daily air temperatures during winter and spring were lower in 2010 compared with 2008 and 2009, and this could explain the lower thrips damage observed in 2010. First, in 2010 there were seven weeks in which mean temperatures were below 10.2 ºC, the developmental threshold for KCT (Varikou et al. 2009) (Fig. 3A). This could strongly reduce the population development of KCT adults overwintering on citrus orchards or alternative host plants, and consequently the abundance of immature KCT instars (the most harmful stages). Second, at the end of May there were approximately 100 degree-days more accumulated in 2008 compared with 2010 (Fig. 3B). Given that 75.8 degree-days are required for immature development in KCT (Varikou et al. 2009), one more generation of larvae could develop until that critical moment in 2008 with respect to 2010, and consequently, more damage would be expected.

Our results suggest that the final amount of fruit scarring caused by KCT is influenced by the synchronization of two factors, the peak of proportion of immatures in thrips populations and the suitability of fruitlets for thrips feeding. Interestingly, this synchronization varied between the three years of our study. In 2008 and 2009 the percentage of KCT immature stages during the petal fall period was > 60%, whereas it was 20% during the same period in 2010. Similarly, the percentage of KCT immatures on developing fruits remained high (> 50%) in 2008 and 2009, but not in 2010. This synchronization was considered also important regarding fruit scarring caused by *S. citri* in citrus in California (Schweizer and Morse 1997).

It is important to highlight the differential effect of weather conditions on KCT and *S. citri*. *Scirtothrips* spp are considered for many years the most important thrips species damaging citrus in many areas of the world and it is common practice to use information regarding its pest management as applicable to KCT or other citrus thrips, but there are important differences among the species. According to Schweizer and Morse (1997), cold weather during early March and warm weather during citrus blooming are associated with high levels of fruit scarring caused by *S. citri*. They argue that cold weather in early March may ensure timely hatching of diapausing eggs and could also prolong the period during which the young citrus leaves are suitable for *S. citri* feeding and survival during the first larval generation. But *S. citri* develops only on soft tissue of young fruit, tender leaves and shoots of citrus and overwinters in the egg stage inside the leaf tissue (Horton 1918; Schweizer and Morse 1997), whereas KCT develops primarily on citrus flowers, and to a lesser extent on small fruitlets and mature fruits (Baker et al. 2002; Perrotta and Conti 2008). Moreover, KCT overwinters on mature fruits or alternative hosts. In addition, according to Lovatt et al. (1984) who modeled the blooming phenology of Washington Navel oranges using a threshold of 9.4ºC, KCT (with a threshold of 10.2ºC) follows the phenological stages of the host plant more closely than *S. citri,* which has a higher developmental threshold of 14.6 ºC (Tanigoshi et al. 1980).

Other factors that might also contribute to the variation in the abundance of KCT populations on flowers and fruitlets include strong wind and precipitations during the critical period when damage is produced. Both factors were not determined in the present study, but their influence has been observed for other citrus thrips species (Lewis 1935; Lewis 1997). Finally, the presence of adequate feeding-breeding sites located near citrus orchards could also determine major abundances of the thrips on citrus flowers or fruitlets (Perrotta and Conti 2008; Varikou et al. 2009; Vassiliou 2010).

In non-annual crops, early season thrips populations depend largely on the capacity of resident adults to overwinter within the crop (Lewis 1997). Furthermore, the migration of polyphagous thrips pests from non-crop surrounding hosts into the cropping systems has been documented by several authors (Chellemi et al. 1994; Northfield et al. 2008; Schellhorn et al. 2010). Adjacent plants that could act as reservoirs of KCT populations can increase the percentage of citrus damage registered in citrus orchards.

Navarro-Campos et al. (2011) highlighted the importance of alternative breeding hosts for KCT such as mature citrus fruits, isolated lemon trees and jasmine plants inside or in the surroundings of the citrus orchards. According to Vassiliou (2010), in Cyprus, lemon trees situated in residential areas close to citrus orchards are important feeding sources and refuges for KCT populations. Several non-crop species have been cited as host of KCT (Froud et al. 2001; EPPO 2006; Webster et al. 2006; Vassiliou 2010). Ours is the first study to report the invasive plant species *A. sericifera* as a breeding host for KCT. According to Varikou et al. (2009), host plants other than citrus inside or in the vicinity of citrus orchards can sustain breeding KCT populations year-round because of their frequent blooming, and reinvasion into orange orchards could also occur from these reservoirs. The plants that we have identified as host plants for KCT show a more extended flowering period than orange or hybrids trees. Some of these plants, such as *J. officinale*, produced flowers until the end of autumn. Thus, this plant could act as a breeding site for KCT when the flowering period of oranges and hybrids has finished. On the contrary, although four second instar larvae of KCT were encountered in a sample of 20 flowers of Bermuda buttercup (a widespread cover crop in Mediterranean citrus orchards during the winter period), we did not consider this species as breeding host for KCT since no first instar larvae were found. Moreover, the plants were situated under citrus trees, from where second instar larvae might have accidentally fallen down on flowers of this plant (Mound and Marullo, 1996; Froud *et al.* 2001).

In conclusion, the occurrence and intensity of damage caused by KCT varied considerably between the three years of the study. Variation in population abundance and damage caused by KCT appeared to be related to air temperature during late winter and early spring. Temperature likely affects the synchronization between the peak in abundance of KCT larvae, and the period when fruitlets are susceptible to thrips damage. Temperature can also influence the survival and development of KCT populations in citrus and other host plants in the citrus agro-ecosystem. The relationships between temperature (degree-days), the period when fruits are damaged and the population structure of KCT, provides relevant and useful information to assist with managing the pest. Monitoring programs of *P. kellyanus* on small fruits, or management of alternative hosts, should be adjusted according to the temperature during late winter and early spring.

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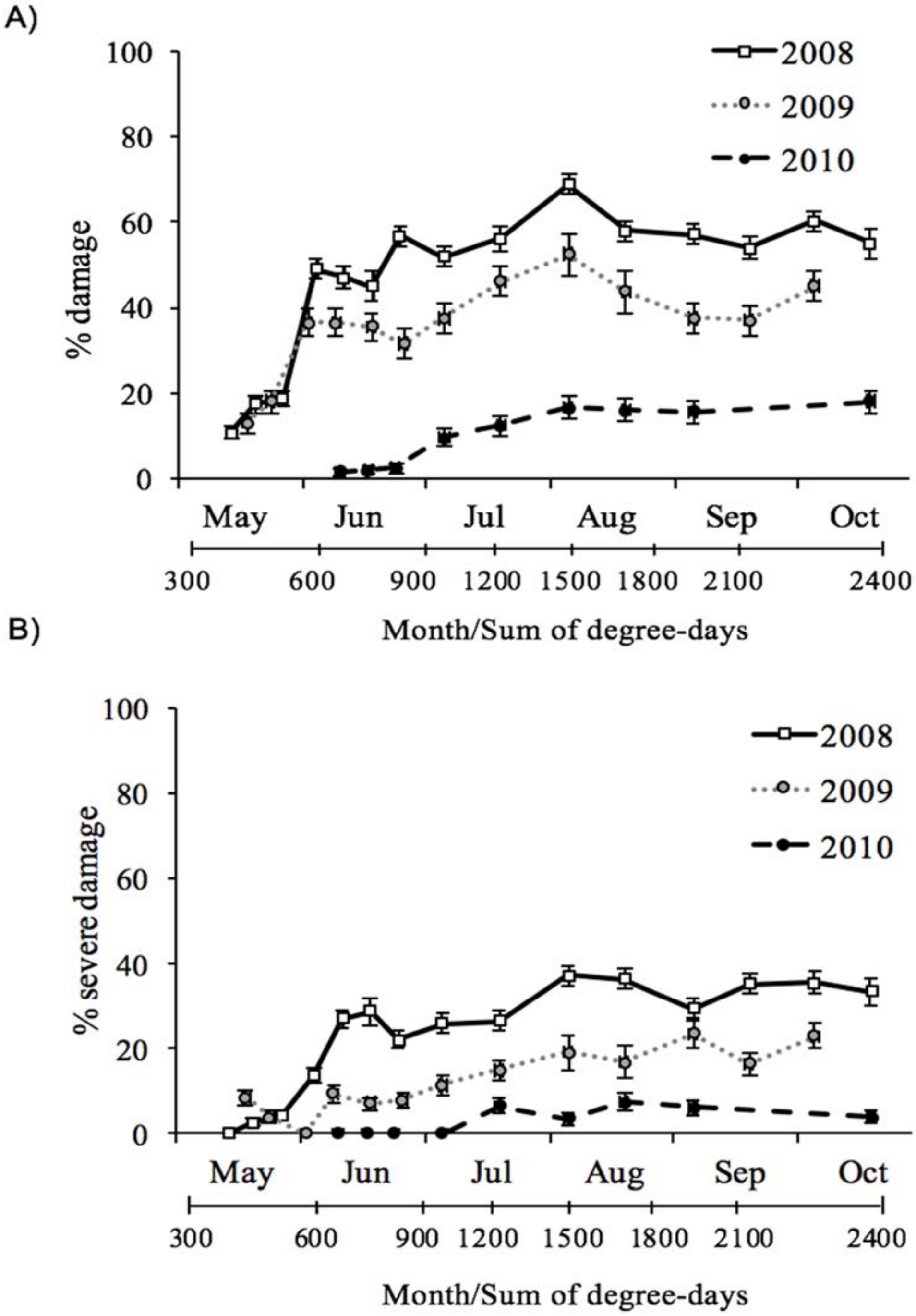

Fig. 1. Percentage (mean ± SE) of fruits (A) damaged or (B) severely damaged by KCT in 2008, 2009 and 2010. Fruit damage was recorded in two categories, “damage” and “severe damage”. “Damage” was considered any kind of damage, i.e. when fruits showed any scar (mild or severe) caused by KCT. “Severe damage” was considered only severe damage, i.e. when scars on the fruit consisted of a complete ring around the calyx or a wide partial ring with other minor scars on the fruit surface. Data collected from four citrus orchards in eastern Spain sampled weekly from the beginning of fruit development period to end of June, and fortnightly, from July to October. On the secondary horizontal axis the mean of sum of degree-days for the three years of study is presented (calculated starting from January 1st, > 10.2º C).

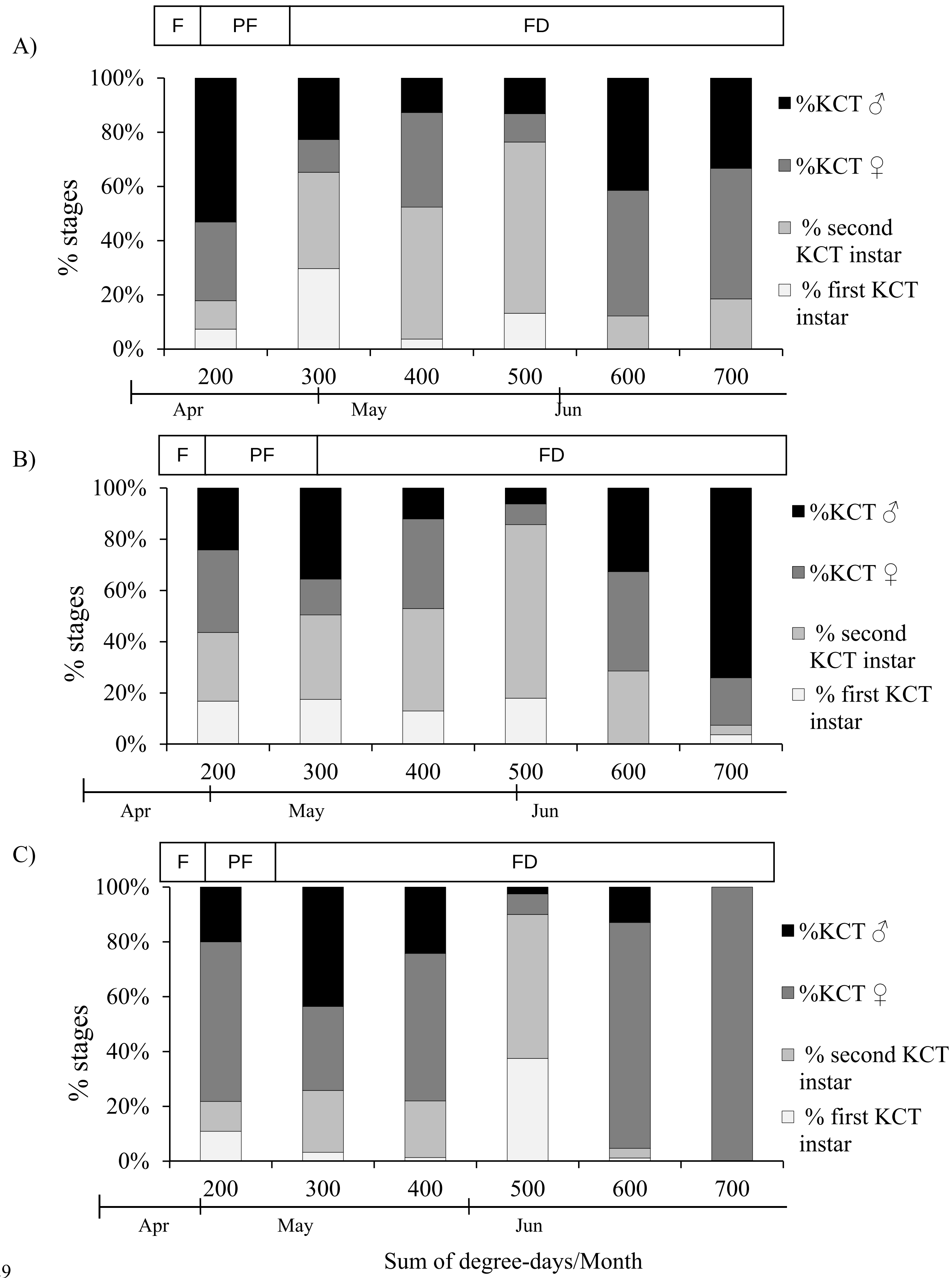

Fig. 2. Proportion of instars and sexes of KCT on citrus flowers and fruitlets sampled in four orchards in eastern Spain in (A) 2008, (B) 2009 and (C) 2010. On the horizontal axes the degree-days (calculated starting from January 1st) and the corresponding months are presented. Above each graph the length of the flowering period (F), petal fall period (PF) and fruit developing period (FD) is presented. Note that these periods are different between the years.

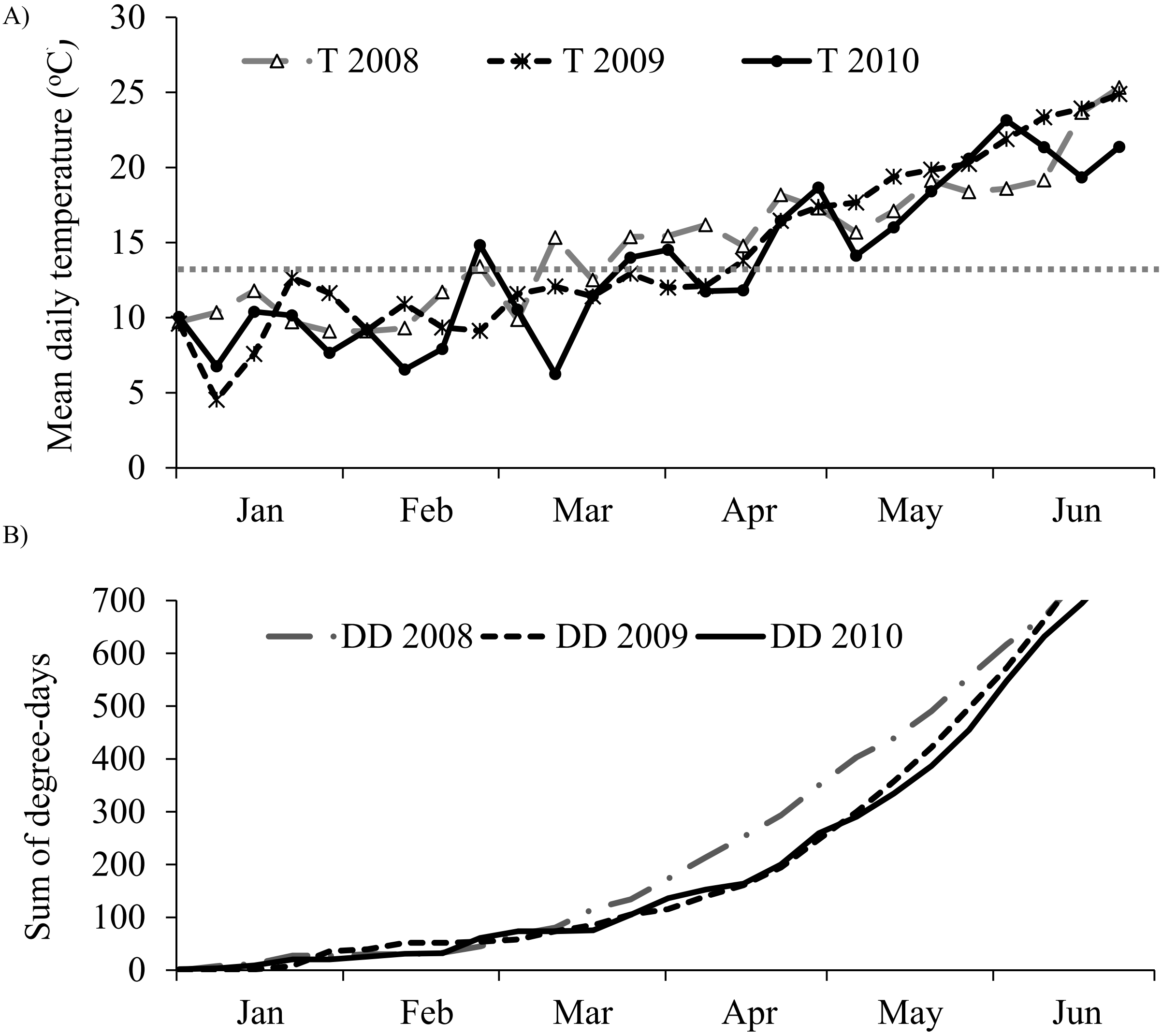

Fig. 3. (A) Mean weekly temperatures and (B) sum of degree-days calculated as the sum of the daily mean temperature above 10.2ºC from January to June in 2008, 2009 and 2010. Mean temperature values obtained from four weather stations located in the study area.