February 2011, Volume 5, No.2 (Serial No.33)
Journal of Agricultural Science and Technology, ISSN 1939-1250, USA

# Feasibility of Growing Olives on Selected Sites along Coastal Texas

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Received: June 10, 2010 / Accepted: August 19, 2010 / Published: February 15, 2011.

**Abstract:** The purpose of this study was to assess the feasibility of growing olives along coastal Texas where the winter temperatures are relatively mild compared to most olive growing regions. For this purpose five sites along the Texas coastline (Seadrift, Galveston, Brazoria, Santa Fe, and Orange) were evaluated for feasibility of growing olives. In addition, two non-coastal sites (Carrizo Springs and Weslaco) were also included in the study for comparative purposes. Flowering and fruiting data were collected during four seasons starting from the 2005-2006 until the 2008-2009 season. In addition to the flowering and fruiting data, half-hourly temperature data were also collected at each site during each season. The results indicate that while olives can grow on all of the sites tested, there is a greater probability of success for commercial growing of olive between and along coastal sites where large scale experiment are highly recommended for rigorous evaluation of potential for commercial production of olives in these areas. In conclusion, there is a good probability that olives could be grown along the northeast coastline of Texas.

**Key words:** Arbequina, flowering, fruiting, olive, Texas.

## 1. Introduction

With growing awareness of the health benefits of olive oil, the demand for olive oil in the US could grow tenfold based on per capita consumption of olive oil in Greece (18 kg per year per capita) [1]. With increasing demand for olive oil there is interest among Texas growers to cultivate olives in Texas to meet increasing demands of olive oil. However, historically olives have not been grown in Texas, and earlier researchers discouraged olive cultivation because in their assessment there is no suitable site in Texas where olives could be grown productively [2]. This conclusion was based on the assumption that there are few areas in southern and coastal Texas that meet the chilling requirement for optimal flowering in olives [2].

Like many other fruit trees, olives require vernalizations, and therefore, Hartmann and associates conducted a series of studies to determine the range of chilling conditions for induction of flowering in olives [3-8]. They determined that chilling temperatures below 7.2 ℃ are critical for flowering in several olive cultivars because none of the cultivars studied flowered when they did not receive any chilling hours at or below 7.2 ℃ [6]. In addition, it was shown that the "optimum temperatures" for flowering and fruiting in olives require night temperatures between 2 ℃-4 ℃, and daytime temperatures between 15.5 ℃-19 ℃ [7]. Later, Denney and McEachern (1983) extended minimum temperature range for optimal flowering between 1.7 ℃-4.4 ℃ but narrowed the maximum to between 15.6 ℃-18.3 ℃ [9]. Hundreds of chilling hours were found necessary for optimal flower production in olives [6]. There are very few places in southern and coastal Texas where optimal chilling temperatures, as described above, could occur for an extended period of time during the winter months. For central, northern, and western Texas, where such chilling temperatures could be achieved, the problem is that freezes (below -8 ℃) could occur 1-3 times in a

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decade which could severely damage olive trees [2].

In 2005 we observed that extensive flowering and fruiting in "Arbequina" olives could be achieved at temperatures above 7.2 ℃, and later showed that "Koroneiki" could also flower under similar conditions [10-13]. We later showed that the reason for absence of flowering in southern Texas was not due to lack of nighttime chilling temperatures, as proposed previously, but perhaps due to the inhibiting high daytime temperatures. This hypothesis was proved correct because flowering and fruiting in southern Texas was achieved by evaporative cooling as well as shading [12]. Further studies showed that maximal flowering was achieved at nighttime temperatures ranging from 4.4 ℃ to 7.8 ℃ [14]. It was thus hypothesized that several sites along coastal Texas may be suitable for growing olives (especially the "Arbequina" cultivar) where daytime temperatures mostly remain below 26.6 ℃, and hundreds of chilling hour below 8 ℃ occur during the winter months.

To test this possibility, several sites along the Texas coastline were selected to study if flowering and fruiting could be achieved over four consecutive growing seasons. The site of the first commercial olive grove at Carrizo Springs, Texas (about 200 miles North West of Gulf of Mexico) and a site near Weslaco, Texas (where flowering only rarely occurs) were also included in the study for comparisons. Results of four years data collection on the flowering and fruiting of olive trees at these sites and corresponding pattern of temperature changes during induction periods are presented here.

## 2. Materials and Methods

### 2.1 Study Area

Two year old "Arbequina" (standard) trees in 4 L pots were obtained from DeLio Olive Co., Visalia, CA. Fifty replicate trees of this cultivars were planted at each of the following Texas sites (latitude; longitude; elevation) in the fall of 2004: (1) Seadrift (W 96.71; N 28.48; 4.9 m); (2) Brazoria (W 95.63; N 29.03; 6.1 m);

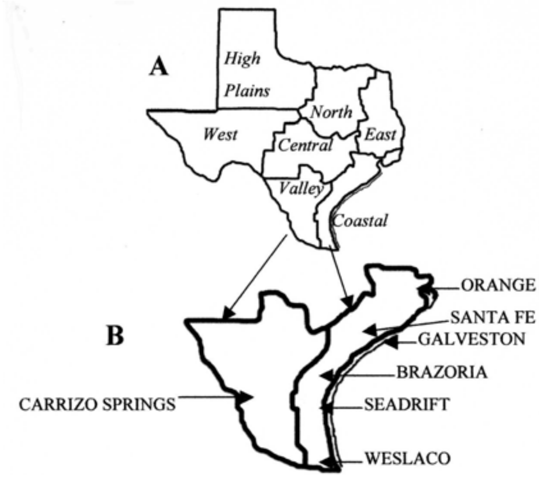


**Fig. 1 (A) Map of Texas, USA, and the boundaries of Texas Valley based on Texas State Travel guide published by Texas Department of Transportation, (B) specific sites where olives were grown.**

(3) Santa Fe (W 95.10; N 29.35; 7.6 m); (4) Galveston (W 94.88; N 29.30; 1.5 m); and (5) Orange (W 93.87; N 29.56; 3.04 m). These sites were selected based on their milder daytime temperatures during winter months (due to their proximity to the coast) and greater suitability for flowering in "Arbequina" olives [10, 11, 13]. A commercial olive farm of 20,000 "Arbequina" trees of clone I-18 in Carrizo Springs, "Texas Olive Ranch" (W 99.73; N 28.41; 186 m) was also included in the study. Although we did not plant new trees here, data was collected from 1000 (randomly selected) trees. In addition, flowering and fruiting data from an established grove (n = 60) in Weslaco, Texas (W 97.93; N 26.16; 24 m) were also used for comparative purposes. Test sites are indicated on the Texas map in Fig. 1.

### 2.2 Methods

Temperature data at half-hour intervals were collected from each site from December 1st through February 28th using HOBO® data loggers (H08-006-04, Hoskin Scientific Limited, 4210 Morris drive, Burlington, Ontario Canada), then downloaded and exported for processing. From one channel, two half-hour data points were averaged and used to calculate the hourly temperatures which were later used for further processing and reporting; the data from the second channel were used only as a backup if needed. By February 28, inflorescence development had already occurred at each site and therefore the induction period was considered over. Scoring for the extent of inflorescence and fruiting was done in the spring and during the summer, respectively, following our previously published method [15]. Briefly, a visual scoring system was used to score individual trees by two individuals. Plants were scored for the extent of flowering and fruiting from 0-10. A score of 1 indicated very minimal flowering or fruiting while a score of 10 equated to very extensive flowering or fruiting. Trees that scored 0 had no visible flowers or fruits.

*2.3 Data Analysis*

Scoring data related to flowering and fruiting was added to an excel spread sheet to determine percentage of trees that flowered and fruited at each site during four year period. In addition, scoring data was grouped into two groups: one group included trees that scored between 1 and 4, and the second group included trees with scores ranging 5-10. Percentage of trees falling in each group at each site for each year was determined to asses light flowering and fruiting (scores 1-4) and moderate to extensive flowering and fruiting (scores 5-10) for comparative purposes. Temperature data was also exported to excel spread sheets and hours of inhibitory temperatures (> 26, 30, and 35 ℃) as well as hours of various levels of chilling temperatures (< 8, 7, 5, and 3 ℃) at each site during each year of the study period were calculated to assess the relationship of temperature regimes with the extent of flowering and fruiting.

## 3. Results and Discussion

Flowering occurred at all Texas coastal sites (Seadrift, Galveston, Brazoria, Santa Fe, and Orange ) during the four-year evaluation period except at Santa Fe in 2008 (Table 1). These data support our previous experimental findings and hypothesis, that some of the coastal sites in Texas previously considered unsuitable for olive cultivation due to lack of chilling, based on previously established standards [2-9], have the potential for growing olives [10-15]. These, findings warrant large scale trials (managed as small commercial farms) at 2-3 sites from Sea Drift to Orange to fully evaluate commercial potential of growing olives in these areas.

The extent of flowering and fruiting did vary among different sites (Tables 1 and 2). In Brazoria (south of Santa Fe site), the extent of fruiting did not reflect extensive flowering observed at this site. Reduced fruit set at this site could be attributed in part to the management practices of the cooperator at that site who followed organic methods. Apparently, the plant growth was quite normal here but recent leaf analyses indicated deficiencies in micro nutrients, especially boron. Boron is known to be involved in olive fruit set [16]. Thus, it is likely that such management factors might have contributed to lower fruit set at the Brazoria site.

The poor performance of our trees at Galveston is perhaps due to frequent rains and poor drainage at this particular site and its very close proximity to the shoreline (100-200 meters). Originally, however, we had discovered and reported several olive trees in Galveston (25 year or older; cultivar unknown) around a house (2-4 kilometers from the shoreline) that had been regularly flowering and fruiting extensively in this climate [10, 11]. Those trees continued to flower and fruit extensively until hurricane Ike destroyed most of them, although a few survivors flowered and produced fruit quite extensively in 2009. Thus, while temperature conditions will allow growing olives in this site, it is not a viable commercial site being on island prone to hurricanes and expensive land prices.

The 2006-2007 season had the best olive crop as extensive flowering and fruiting occurred at almost all sites, even in Weslaco where flowering only rarely occurs (Tables 1 and 2). Thus, the climatic conditions

**Table 1 Percent of trees that flowered at different test sites and average score for the extent of flowering at each site during four seasons (2006 to 2009).**

| Test site | Year | Percent of trees that flowered at any level | Percent trees that flowered at different score ‡ levels | | Average score of flowering trees ± SE |
|---|---|---|---|---|---|
| | | | 5-10 | 1-4 | |
| Seadrift | 2006 | 63 | 20 | 43 | 3.87 ± 0.38 |
| | 2007 | 86 | 69 | 17 | 7.27 ± 0.41 |
| | 2008 | 78 | 45 | 33 | 5.59 ± 0.35 |
| | 2009 | 65 | 33 | 33 | 5.83 ± 0.45 |
| Brazoria | 2006 | 37 | 0 | 37 | 2.77 ± 0.28 |
| | 2007 | 90 | 45 | 45 | 5.56 ± 0.46 |
| | 2008 | 95 | 54 | 41 | 5.89 ± 0.41 |
| | 2009 | 73 | 51 | 22 | 6.59 ± 0.49 |
| Santa Fe | 2006 | 63 | 16 | 47 | 3.67 ± 0.39 |
| | 2007 | 96 | 72 | 23 | 7.29 ± 0.39 |
| | 2008 | 9 | 0 | 9 | 2.50 ± 0.50 |
| | 2009 | 50 | 26 | 24 | 6.11 ± 0.56 |
| Galveston | 2006 | 31 | 9 | 23 | 4.18 ± 0.74 |
| | 2007 | 60 | 44 | 17 | 6.83 ± 0.53 |
| | 2008 | 68 | 49 | 19 | 7.28 ± 0.61 |
| | 2009 | | Hurricane Ike wiped out all the trees | | |
| Orange | 2006 | 74 | 15 | 59 | 3.80 ± 0.65 |
| | 2007 | 77 | 58 | 19 | 6.84 ± 0.65 |
| | 2008 | 55 | 21 | 33 | 4.89 ± 0.67 |
| | 2009 | 57 | 43 | 14 | 6.75 ± 0.48 |
| Carrizo | 2006 | 0 | 0 | 0 | 0.00 ± 0.00 |
| Springs | 2007 | 99 | 89 | 10 | 9.80 ± 0.02 |
| Texas olive | 2008 | 0 | 0 | 0 | 0.00 ± 0.00 |
| Ranch | 2009 | 14 | 5 | 9 | 4.75 ± 0.16 |
| Weslaco | 2006 | 0 | 0 | 0 | 0.00 ± 0.00 |
| | 2007 | 79 | 37 | 42 | 4.76 ± 0.38 |
| | 2008 | 0 | 0 | 0 | 0.00 ± 0.00 |
| | 2009 | 0 | 0 | 0 | 0.00 ± 0.00 |

‡ Scores are based on a visual inspection of individual trees. A score of 0 indicates no flowers observed while a score of 10 indicates most extensive flowering.

in 2006-2007 season were quite suitable for olive cultivation, and therefore may provide important insight into the parameters (e.g., extent and distribution of inhibitory temperatures during inductive periods) for determining feasibility of olive cultivation. Since there was little flowering and fruiting in Carrizo Springs in 2006, 2008, and 2009 seasons we compared temperatures profiles for these years with those from 2007 (December 2006-February 2007. By the middle of February 2007, inflorescences were visible at all sites). The number of hours of inhibitory high temperatures (> 26 ℃) were only about one half and one third in 2007 compared to 2008 and 2009 in Carrizo Springs and Weslaco, respectively (Table 3). This was reflected by drastically reduced (or negligible) flowering and fruiting in 2008 and 2009 compared to 2007 at both sites (Tables 1 and 2). These findings are consistent with our previous results showing that when "Arbequina" trees are subjected to a few hours of 26 ℃ every day during the inductive period (even if nighttime temperatures were ≤ 8 ℃), flowering and fruiting is strongly inhibited [13]. Since the number of hours > 26 ℃ at coastal sites during each season under this study were less than the number of hours >

**Table 2 Percent of trees that fruited at different test sites and average score for the extent of fruiting at each site during four seasons (2006 to 2009).**

| Test site | Year | Percent of trees that fruited at any level | Percent trees that fruited at different score levels[‡] | | Average score of fruiting trees ± SE |
|---|---|---|---|---|---|
| | | | 5-10 | 1-4 | |
| Seadrift | 2006 | 45 | 18 | 27 | 4.91 ± 0.52 |
| | 2007 | Trees fruited quite well but the scoring data were lost | | | |
| | 2008 | 66 | 18 | 48 | 4.46 ± 0.39 |
| | 2009 | 53 | 33 | 20 | 5.52 ± 0.46 |
| Brazoria | 2006 | 3 | 0 | 3 | 2.00 ± 0.00 |
| | 2007 | 5 | 0 | 5 | 3.00 ± 1.00 |
| | 2008 | 56 | 24 | 32 | 4.86 ± 0.51 |
| | 2009 | 59 | 27 | 32 | 4.73 ± 0.51 |
| Santa Fe | 2006 | 26 | 5 | 21 | 3.60 ± 0.75 |
| | 2007 | 89 | 49 | 40 | 5.62 ± 0.37 |
| | 2008 | 9 | 0 | 9 | 2.50 ± 0.50 |
| | 2009 | 50 | 18 | 32 | 5.29 ± 0.75 |
| Galveston | 2006 | 0 | 0 | 0 | 0.00 ± 0.00 |
| | 2007 | 14 | 4 | 10 | 4.00 ± 0.87 |
| | 2008 | 14 | 0 | 14 | 2.80 ± 0.49 |
| | 2009 | | Hurricane Ike wiped out all the trees | | |
| Orange | 2006 | 56 | 30 | 26 | 5.47 ± 0.66 |
| | 2007 | 73 | 38 | 35 | 5.10 ± 0.59 |
| | 2008 | 42 | 9 | 33 | 4.14 ± 0.61 |
| | 2009 | 63 | 34 | 29 | 5.48 ± 0.55 |
| Carrizo | 2006 | 0 | 0 | 0 | 0.00 ± 0.00 |
| Springs | 2007 | 99 | 94 | 5 | 9.45 ± 0.05 |
| Texas olive | 2008 | 0 | 0 | 0 | 0.00 ± 0.00 |
| Ranch | 2009 | 18 | 6 | 12 | 4.23 ± 0.14 |
| Weslaco | 2006 | 0 | 0 | 0 | 0.00 ± 0.00 |
| | 2007 | 63 | 12 | 51 | 3.61 ± 0.33 |
| | 2008 | 0 | 0 | 0 | 0.00 ± 0.00 |
| | 2009 | 0 | 0 | 0 | 0.00 ± 0.00 |

[‡] Scores are based on a visual inspection of individual trees. A score of 0 indicates no fruits observed while a score of 10 indicates most extensive fruiting.

26 ℃ at Weslaco in 2007 (except once in Seadrift when they were equal to Weslaco), most of the coastal sites appear suitable for growing olives based on the fact that they do not experience large number of hours of inhibitory high temperatures during the inductive period; Santa Fe, Galveston, and Orange being the best sites based on this parameter (Table 3).

Since the number of hours > 26 ℃ were quite high at Carrizo Springs (96 hr) even in the best year of 2007, we studied the distribution of these hours during the inductive period in 2007 and compared it with distribution patterns in other years at this site and at all other sites (Fig. 2). It is apparent from these high temperature profiles that while inhibitory high temperatures (> 26 ℃) frequently occurred throughout the inductive periods at Carrizo Springs in 2006, 2008, and 2009, only in 2007 were there minor interruption of temperature > 26 ℃; i.e. one or two interruption of temperature > 26 ℃ but < 28 ℃ during a period of 43 days in the inductive cycle (Fig. 2). Similarly, in Weslaco, peaks of inhibitory temperatures (> 26 ℃) were spread throughout the inductive periods in every season except in 2007, i.e. the only year when the trees flowered and fruited (Fig. 2). From these data, we deduce that a period of approximately 43 days without high temperature interruptions (with the exception of one or

**Table 3 Number of hours trees were subjected to different temperature categories during winter induction periods at different test sites during four season (2006-2009).**

| Test Site | Year | Inhibiting high temperature | | | Inductive chilling temperature | | | |
|---|---|---|---|---|---|---|---|---|
| | | >26 ℃ | >30 ℃ | >35 ℃ | <8 ℃ | <7 ℃ | <5 ℃ | <3 ℃ |
| | | | Hours[1] | | | Hours | | |
| Seadrift | 2006 | 35 | 2 | 0 | 405 | 319 | 184 | 71 |
| | 2007 | 52 | 1 | 0 | 575 | 452 | 310 | 149 |
| | 2008 | 36 | 1 | 0 | 204 | 122 | 80 | 38 |
| | 2009 | 12 | 0 | 0 | 379 | 318 | 187 | 111 |
| Brazoria | 2006 | 44 | 1 | 0 | 563 | 473 | 393 | 258 |
| | 2007 | 2 | 0 | 0 | 682 | 554 | 399 | 252 |
| | 2008 | 23 | 0 | 0 | 514 | 409 | 296 | 159 |
| | 2009 | 7 | 1 | 0 | 572 | 488 | 368 | 252 |
| Santa Fe | 2006 | 20 | 0 | 0 | 546 | 405 | 263 | 179 |
| | 2007 | 2 | 0 | 0 | 651 | 527 | 346 | 176 |
| | 2008 | 26 | 1 | 0 | 440 | 335 | 238 | 102 |
| | 2009 | 12 | 0 | 0 | 379 | 318 | 187 | 111 |
| Galveston | 2006 | 11 | 1 | 0 | 213 | 141 | 84 | 31 |
| | 2007 | 1 | 0 | 0 | 450 | 319 | 162 | 60 |
| | 2008 | 11 | 0 | 0 | 291 | 181 | 93 | 17 |
| | 2009 | | | | | | | |
| Orange | 2006 | 22 | 0 | 0 | 636 | 535 | 394 | 251 |
| | 2007 | 10 | 0 | 0 | 800 | 666 | 473 | 309 |
| | 2008 | 22 | 0 | 0 | 599 | 485 | 366 | 215 |
| | 2009 | 6 | 0 | 0 | 693 | 615 | 507 | 357 |
| Carrizo | 2006 | 108 | 27 | 0 | 478 | 353 | 232 | 133 |
| Springs | 2007 | 96 | 26 | 5 | 695 | 529 | 319 | 189 |
| | 2008 | 192 | 62 | 5 | 526 | 429 | 294 | 192 |
| | 2009 | 162 | 42 | 3 | 525 | 421 | 298 | 162 |
| Weslaco | 2006 | 134 | 11 | 0 | 140 | 113 | 48 | 5 |
| | 2007 | 52 | 0 | 0 | 194 | 143 | 68 | 14 |
| | 2008 | 196 | 12 | 0 | 125 | 82 | 27 | 4 |
| | 2009 | 150 | 11 | 0 | 128 | 93 | 29 | 3 |

[1]Temperatures were constantly recorded at half-hour intervals.

two minor interruptions of inhibitory temperatures as seen in Carrizo Springs in 2007) during the inductive period would produce good flowering and fruiting in "Arbequina" olive trees. Pursuing this information about peaks of high inhibitory temperatures during the inductive period we find that temperature patterns in almost all coastal sites (especially Orange, Santa Fe and Galveston) fit quite well to the temperature patterns in Carrizo Springs and Weslaco for 2007. Thus, the distribution and intensity of inhibitory temperatures (> 26 ℃) during the inductive period could strongly impact on the extent of flowering and fruiting in olives, and this parameter should be thoroughly investigated in future large-scale experiments, i.e. the effects of extent and repetition of inhibitory interruptions. This information can then be used to develop models for more accurate assessing of sites for olive cultivation. The preliminary data presented in this report sheds light on the feasibility of growing olives in coastal Texas, and point to the need for large scale experiments in coastal sites for developing olive industry in Texas and in other areas of similar climate.

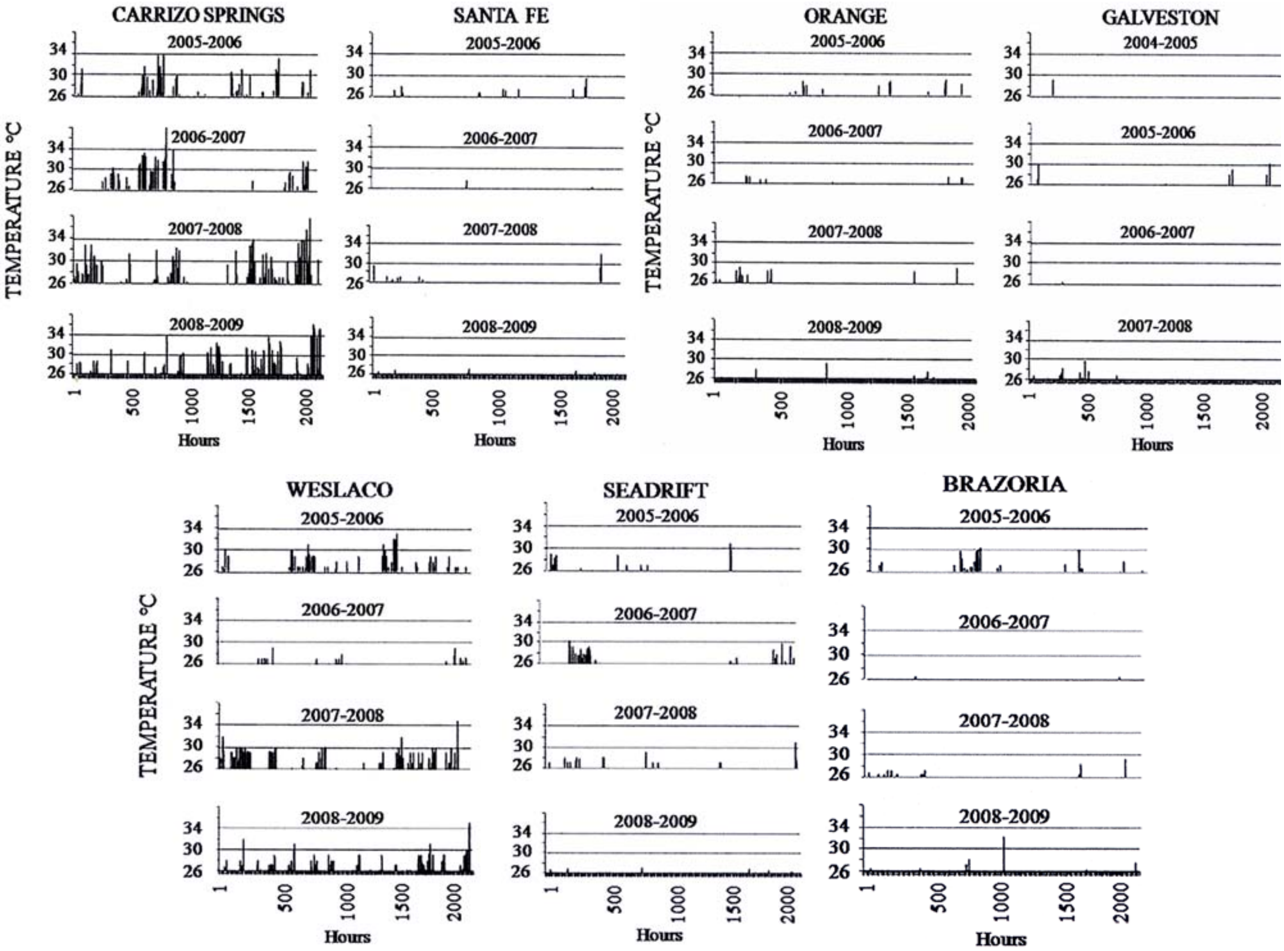


**Fig. 2 Profiles of inhibitory high temperatures (> 26 ℃) at different sites during 4-year evaluation period (2006-2009).**

The number of hours of chilling temperatures in various categories (< 8, < 7, < 5, and < 3 ℃) at Weslaco during the 2007 season (when it flowered extensively there) are less in each category when compared to hours of respective category at coastal sites during different season (Table 3). This shows that the selected coastal sites usually have adequate chilling for induction of flowering; and therefore, quantity of chilling hours will not be restrictive to grow olives in these areas.

## 4. Conclusions

We conclude from the flowering and temperature data that there is a high probability of growing of olives successfully, especially "Arbequina", at various sites on coastal Texas, particularly between Santa Fe and Orange. Large scale experiments around these sites will fully evaluate the potential for commercial production of olives in these areas. The temperature parameters we used here should also be further evaluated and expanded to develop models that may be applicable to other parts of the world with similar climates for evaluating local sites for olive cultivation.

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