Project Number: 94-I6

1994 Annual Report
Regulated Deficit Irrigation for Almond

David A. Goldhamer, Mario Viveros, Beth Teviotdale,
and Walt Bentley

Introduction

The California almond industry faces the real possibility of limited irrigation water supplies due to increased competition for water from the municipal and environmental sectors. Whereas traditional irrigation scheduling has the goal of irrigating to fully meet the water use (ETc) of the orchard and to avoid stressing the trees, there simply may not be enough water available to accomplish this in the future. The question then will not be irrigating to prevent tree-water stress, it will be **when** can the orchard be most safely stressed and to what degree (**how much** water should be applied). Moreover, recent research by Goldhamer and Beede (1992) in pistachio, Lampinen et. al. (1994) in prune, Girona et. al. (1993) in peach, and Williams (1993) in grape show that fruit trees and vines can be deprived of water without affecting yield of marketable product.

In 1993, we initiated a project to evaluate regulated deficit irrigation (RDI) on mircrosprinkler-irrigated, shallow rooted trees in the southern San Joaquin Valley. This combination of irrigation method, rooting zone, and location in the state results in rapid development of tree water stress upon deficit irrigation. This situation differs from that of Prichard et. al. (1993) who worked with deep rooted, sprinkler-irrigated trees in San Joaquin Co. where stress development was much slower. Our RDI regimes were developed based on previous work suggesting that irrigation can be safely reduced during the 4-6 week period before harvest and about 4 weeks after harvest. Since orchard water use is highest during the preharvest period, potential water savings are greatest at that time.

With limited water supplies, emphasizing preharvest irrigation to maximize nut size must be weighed against applying water just before and after harvest to promote successful flower bud development. The most important yield component in almond production is nut load (# of nuts/tree) which must be maintained if any RDI regime is to be successful. Observations of flowering and fruit set next season are needed to assess the effects of 1993's RDI regimes on sustained productivity. However, RDI in almond appears promising based on both Prichard's work and our first year results.

Objectives

To test RDI strategies that apply seasonal totals of 22, 28, and 34 acre-inches/acre (deficits of 18, 12, and 6 acre-inches/acre/year, respectively) on cvs. Non Pareil and Carmel in a multiyear field study on shallow rooted, microsprinkler-irrigated trees. The goal of this project is to identify an RDI regime that saves water while not reducing nut yields or quality and thus can be used in normal water availability years.

Material and Methods

Nine deficit irrigation regimes and a fully irrigated control are being evaluated in a large scale (51 acres) field study in Kern Co. Three seasonal irrigation amounts (22, 28, and 34 inches), each applied with 3 different stress timing regimes, are being evaluated in addition to the control that applies 40 inches (Table 1). The "A" treatments impose stress primarily before harvest and emphasize reserving water for postharvest irrigation; the "B" regimes do just the opposite--emphasizing preharvest irrigation with little water left for postharvest. The "C" treatments impose the stress over the entire season. Regardless of the seasonal irrigation amount, care is taken to provide as much water as possible in the 4 week period just before and after harvest. This is to enhance hull split and successful floral bud development, respectively. There are 6 replications of each irrigation regime for a total of 60 plots. Each plot contains 12 each of Non Pareil and Carmel trees. There is one guard tree on the outside of each plot that will receive the same irrigation regime.

Irrigation is with microsprinklers. Each treatment is imposed by engineering the irrigation system to apply different amounts of water while irrigating at the same frequency. This is accomplished by using different combinations of operating pressures and microsprinkler sizes (flow rates). The goal is for each irrigation regime to wet the same surface area. Water meters are used to quantify irrigation amounts.

To evaluate the impact on commercial nut quality, large size samples (1500 lbs) are collected and run individually through a high speed commercial huller. The output of kernels and in-shell nuts are weighed and subsamples taken to a commercial sheller for USDA analysis of kernel quality. This analysis allows for true economic analysis of the RDI regimes on grower revenue.

Results

Non Pareil. First year (1993) Non Pareil results showed that individual kernel weight was lower when RDI was initiated before mid June following full irrigation. While smaller nuts translate into smaller yields, measured Non Pareil kernel yields for all RDI regimes were not statistically lower than the control. Hull split and the quality of commercially-hulled nuts (chipped, broken, and rejects) were also not affected. Mummy nuts tended to be lower for the more severe RDI regimes. Hull rot was reduced even under the least severe RDI regimes (Teviotdale) while mite levels were unchanged (Bentley).

Predawn leaf water potential (LWP) generally reflected the timing and magnitude of the Non Pareil deficit irrigations (Figs. 1-4). Non Pareil tree predawn LWP ranged widely; from about -5.0 bars during full irrigation early in the season to about -35.0 bars just prior to harvest in certain RDI treatments. This is a wider range than other deciduous trees. Note that Non Pareil predawn LWP also declined prior to Carmel shaking; even in the Control regime. This did not occur last season and is not desirable. It illustrates that either inadequate water was applied prior to cutoff for tree shaking or that the period between Carmel cutoff and shaking to too long.

Second year (1994) individual kernel weight was significantly lower when less water was applied preharvest; the "A" treatments (Table 2). For example, 22A was 1.04 gm/kernel compared with 1.24 gm/kernel for the control. Providing more water preharvest at the expense of postharvest irrigation (the "B" treatments) increased individual kernel weight. However, irrigation at a constant deficit rate over the season (the "C" treatments) resulted in the largest kernels. For example, 34A, B, and C had individual kernel weights of 1.10, 1.2, and 1.22 gms/kernel, respectively. The "A" and "B" regimes resulted in a greater impact on kernel weight than shell weight. For example, with 28B, individual kernel weight relative to the control was reduced by 9.7% (1.12 vs. 1.24 gms/kernel) while shell weight was virtually unchanged. This resulted in lower kernel/nut ratios for most of the "A" and "B" treatments. No differences in kernel/nut ratio was observed in the "C" regimes.

Hull splitting was reduced and partial split and hull tight nuts increased only in 22A. No significant differences were noted in kernel shrivel or NOW kernel damage (data not shown). Commercial hulling and kernel quality analysis was not completed by the submission deadline for this report.

There were no statistically significant differences in nut load (Table 2). However, note that the 2 lowest nut loads occurred in 22B and 28B; the treatments that biased stress toward postharvest. Interestingly, the 2 highest nut loads were in treatments 22A and 28A; the regimes that biased stress toward preharvest. These trends will be monitored closely in years 3 and 4 of this study to identify if the "A" and "B" treatments tend to increase and decrease nut loads, respectively.

Kernel yields were significantly lower only in treatment 22B. The smaller individual kernels in the "A" treatments were offset by the higher nut loads. It should be pointed out that this is only the 2nd study year and additional years are needed to establish sustained effects. We suspect that the impact of any reduced shoot growth on subsequent nut load may not be evident until study year 3.

Kernel data from the commercial hulling of Non Pareil nuts is shown in Table 3. Foreign material was variable and higher than the control only in 28A. There were no significant differences in rejects. There was **less** kernel damaged with the RDI regimes relative to the control. Thus, our concern that stressed nuts, particularly those with tight hulls (as in 22A), would incur more damage during processing appears to be unfounded.

Carmel. This cv. suffers from the fact that orchard irrigation is geared to Non Pareil harvest. Thus, in late July or early August, the irrigation is cutoff for a period of time in order to shake and harvest the Non Pareil trees. This results in tree water stress to the Carmels. This is evident in 1994 (year 2) predawn LWP (figs. 5-8). As with Non Pareil, predawn LWP usually reflects the timing and magnitude of the RDI regimes.

Individual kernel and shell weights were lowest for the "A" regimes and with the exception of the kernels for 34A, significantly lower than the control (Table 4). The "C" treatments generally had the highest individual kernel and shell weights within each of the 3 RDI regimes. As opposed to the Non Pareils, the "A" regimes generally had the highest kernel ratios; significantly higher than the control in 28A and 34A. In no RDI case was the kernel ratio significantly lower than the Control.

Carmel hull splitting was much more affected by the RDI than was Non Pareil. Again, this was due to the stress associated with water deprivation during the Non Pareil harvest. However, only 22A had significantly lower full splits and higher hull tights than the control.

As with the Non Pareils, 2nd year tree nut load was not significantly different with any treatments. However, the "B" treatments in the 28 and 34 inch sets had lower nut loads than the other regimes in each of their series. Total kernel yields were significantly lower in all 22 inch regimes and in 28A and 28B. The "C" regimes had the highest kernel yields within each grouping presumably due to the better maintenance of tree water status through August (figs. 5-7).

Conclusions

No conclusion are possible after just 2 study years due to the carry over effects of stress-related processes such as shoot and spur growth on subsequent seasons' production. However, it appears that the Non Pareil "A" and "C" treatments in the 22 and 28 inch sets and the "B" and "C" regimes in the 34 inch series have performed best. With Carmels, the "C" regimes are best so far. Additional study years are required before definitive conclusions can be reached.

Literature Cited

Girona, J. M. Mata, D. A. Goldhamer, R. S. Johnson, and T. M. DeJong. 1993. Patterns of soil and tree water status and leaf functioning during regulated deficit irrigation scheduling in peach. J. Amer. Soc. Hort. Sci. 118(5):580-586.

Goldhamer, D. A. and R. Beede. 1993. Results of four years of regulated deficit irrigation on deep rooted pistachio trees. Annual Report of the California Pistachio Industry, 1992-93 Crop Year. California Pistachio Commission, Fresno, CA. pp. 107-110.

Lampinen, B., S. M. Southwick, K. A. Shackel, and D. A. Goldhamer. 1994. The effects of water deprivation during different phynological stages of fruit development on prune fruit yields and quality. J. Amer. Soc. Hort. Sci. (submitted).

Prichard, T. L. 1993. Effects of water supply and irrigation strategies on almonds. Proceedings of the 21st Annual Almond Research Conference. Fresno, CA. pp. 29-35.

Williams, L. E. 1993. Irrigation amounts needed to optimize yields of thompson seedless grapevines. Annual Report of the California Table Grape Commission, Fresno CA.

Table 1. Almond regulated deficit irrigation (RDI) treatments.

DATES	CONTROL	34A		34B		34C		28A		28B		28C		22A		22B		22C	
	Normal	RDI	App.	RDI	App.	RDI	App.	RDI	App.	RDI	App.	RDI	App.	RDI	App.	RDI	App.	RDI	App.
	ETc	%	Water	%	Water	%	Water	%	Water	%	Water	%	Water	%	Water	%	Water	%	Water
	(inches)		(inches)		(inches)		(inches)		(inches)		(inches)		(inches)		(inches)		(inches)		(inches)
Mar 1-15	0.5	100	0.5	100	0.5	85	0.5	100	0.5	100	0.5	70	0.4	100	0.5	100	0.5	55	0.3
Mar 16-31	1.1	100	1.1	100	1.1	85	1.0	100	1.1	100	1.1	70	0.8	100	1.1	100	1.1	55	0.6
Apr 1-15	1.4	100	1.4	100	1.4	85	1.2	100	1.4	100	1.4	70	1.0	100	1.4	100	1.4	55	0.8
Apr 16-30	1.8	100	1.8	100	1.8	85	1.5	100	1.8	100	1.8	70	1.2	50	0.9	50	0.9	55	1.0
May 1-15	2.3	100	2.3	100	2.3	85	2.0	50	1.1	100	2.3	70	1.6	50	1.1	50	1.1	55	1.3
May 16-31	3.0	100	3.0	100	3.0	85	2.6	50	1.5	100	3.0	70	2.1	50	1.5	50	1.5	55	1.7
Jun 1-15	3.2	50	1.6	100	3.2	85	2.7	50	1.6	50	1.6	70	2.2	50	1.6	50	1.6	55	1.7
Jun 16-30	3.4	50	1.7	100	3.4	85	2.9	50	1.7	50	1.7	70	2.3	50	1.7	50	1.7	55	1.8
Jul 1-15	3.8	50	1.9	50	1.9	85	3.2	50	1.9	50	1.9	70	2.6	0	0.0	50	1.9	55	2.1
Jul 16-31	3.9	100	3.9	100	3.9	85	3.3	50	2.0	50	2.0	70	2.7	50	2.0	50	2.0	55	2.2
Aug 1-15	3.4	100	3.4	100	3.4	85	2.9	100	3.4	100	3.4	70	2.4	50	1.7	100	3.4	55	1.9
Harvest																			
Aug 16-31	3.3	100	3.3	100	3.3	85	2.8	100	3.3	100	3.3	70	2.3	100	3.3	100	3.3	55	1.8
Sept. 1-15	2.7	100	2.7	100	2.7	85	2.3	100	2.7	100	2.7	70	1.9	100	2.7	50	1.3	55	1.5
Sept. 16-30	2.2	100	2.2	100	2.2	85	1.9	100	2.2	50	1.1	70	1.5	100	2.2	0	0.0	55	1.2
Oct 1-15	1.5	100	1.5	0	0.0	85	1.3	100	1.5	0	0.0	70	1.1	50	0.8	0	0.0	55	0.8
Oct 16-31	1.1	100	1.1	0	0.0	85	1.0	50	0.6	0	0.0	70	0.8	0	0.0	0	0.0	55	0.6
Nov 1-15	0.6	100	0.6	0	0.0	85	0.5	0	0.0	0	0.0	70	0.4	0	0.0	0	0.0	55	0.3
TOTAL	**39.3**		**34.1**		**34.1**		**33.4**		**28.3**		**27.8**		**27.5**		**22.5**		**21.8**		**21.6**

Table 2. Non Pareil Nut Quality and Yield Parameters for 1994 (Year 2).

	Individual Full Hull Split			Hull Splitting				
Treatment	Kernel wt. (gms)	Shell wt (gms)	Kernel/Shell +kernel ratio	Full Split (%)	Partial Split (%)	Hull tight (%)	Nut load (#/tree)	Total kernel yield (lbs/acre)
22A	1.04 a	0.54 ab	0.66 a	88.5 a	6.3 a	5.2 a	13879	2175 abc
22B	1.05 a	0.52 a	0.67 bcd	99.6 b	0.0 b	0.4 b	12585	2033 a
22C	1.08 ab	0.51 a	0.68 d	99.5 b	0.0 b	0.5 b	13076	2164 ab
28A	1.03 a	0.52 a	0.67 abc	99.5 b	0.0 b	0.5 b	14431	2282 abc
28B	1.12 bc	0.57 bc	0.67 ab	99.1 b	0.2 b	0.7 b	12551	2167 ab
28C	1.18 cd	0.56 bc	0.68 d	99.5 b	0.1 b	0.5 b	13076	2361 abc
34A	1.10 ab	0.57 bc	0.66 a	99.6 b	0.0 b	0.4 b	13607	2288 abc
34B	1.20 d	0.58 bc	0.68 cd	98.9 b	0.0 b	1.1 b	13667	2505 c
34C	1.22 d	0.58 c	0.68 cd	99.1 b	0.0 b	0.9 b	13133	2458 bc
Control	1.24 d	0.58 c	0.68 d	48.7 b	0.4 b	0.9 b	13084	2499 bc
							NSD	

In each data column, numbers not followed by the same letter are significantly different at the 5% confidence level using Duncan's multiple range test. NSD indicates no significant differences.

Table 3. Non Pareil Commercial Hulling Parameters for 1994 Kernels.

Treatment	Foreign material (%)	Total rejects (%)	Damaged kernels (%)
22A	2.84 abc	1.11	4.46 ab
22B	2.60 a	2.10	2.65 a
22C	3.98 abcd	1.22	3.70 ab
28A	6.30 d	1.62	5.48 ab
28B	2.67 ab	1.61	3.09 a
28C	5.99 bcd	1.92	5.00 ab
34A	4.56 abcd	1.65	1.82 a
34B	3.57 abcd	1.18	5.58 ab
34C	6.16 cd	0.79	4.62 ab
Control	4.41 abcd	1.58	8.46 b
		NSD	

In each data column, numbers not followed by the same letter are significantly different at the 5% confidence level using Duncan's multiple range test. NSD indicates no significant differences.

Table 4. Carmel Nut Quality and Yield Parameters for 1994 (Year 2).

Treatment	Individual Full Hull Split: Kernel wt. (gms)	Shell wt (gms)	Kernel/Shell +kernel ratio	Hull Splitting: Full Split (%)	Partial Split (%)	Hull tight (%)	Nut load (#/tree)	Total kernel yield (lbs/acre)
22A	0.88 a	0.47 ab	0.65 abcd	53.6 a	6.3 b	40.1 d	16720	2092 a
22B	0.96 bc	0.49 ab	0.67 bcd	89.9 de	1.4 a	8.7 ab	16871	2426 abc
22C	0.95 abc	0.51 abc	0.65 abc	76.8 bc	3.5 ab	19.7 c	17821	2467 abc
28A	0.92 ab	0.44 a	0.67 cd	92.2 e	0.7 a	7.1 a	17225	2376 ab
28B	0.96 bc	0.52 bc	0.65 abcd	87.4 cde	2.6 ab	9.9 abc	16846	2395 abc
28C	1.01 cd	0.54 bcd	0.65 abc	78.7 bcd	2.6 ab	18.7 bc	17870	2645 bcd
34A	1.00 cd	0.47 ab	0.68 d	90.5 de	1.9 ab	7.6 a	18722	2803 cd
34B	1.05 d	0.64 e	0.63 a	75.4 b	5.2 ab	19.4 c	16809	2586 bcd
34C	1.05 d	0.56 cd	0.66 bcd	80.9 bcde	1.7 a	17.5 abc	18959	2946 d
Control	1.04 d	0.59 de	0.64 ab	85.8 bcde	1.9 ab	12.4 abc	18946	2959 d
							NSD	

In each data column, numbers not followed by the same letter are significantly different at the 5% confidence level using Duncan's multiple range test. NSD indicates no significant differences.

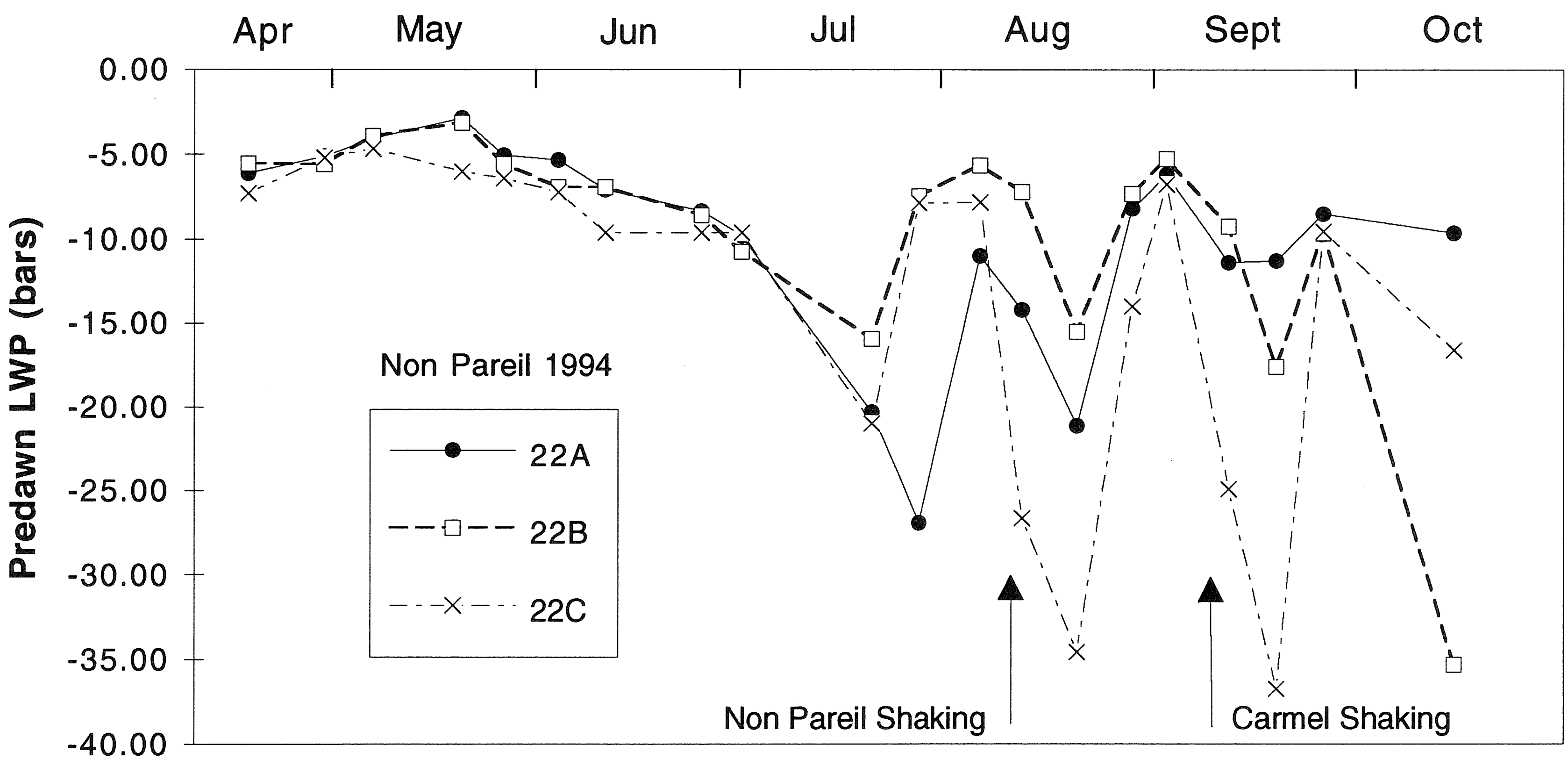

Figure 1. Predawn leaf water potential for the Non Pareil 22 inch per season series in study year 2.

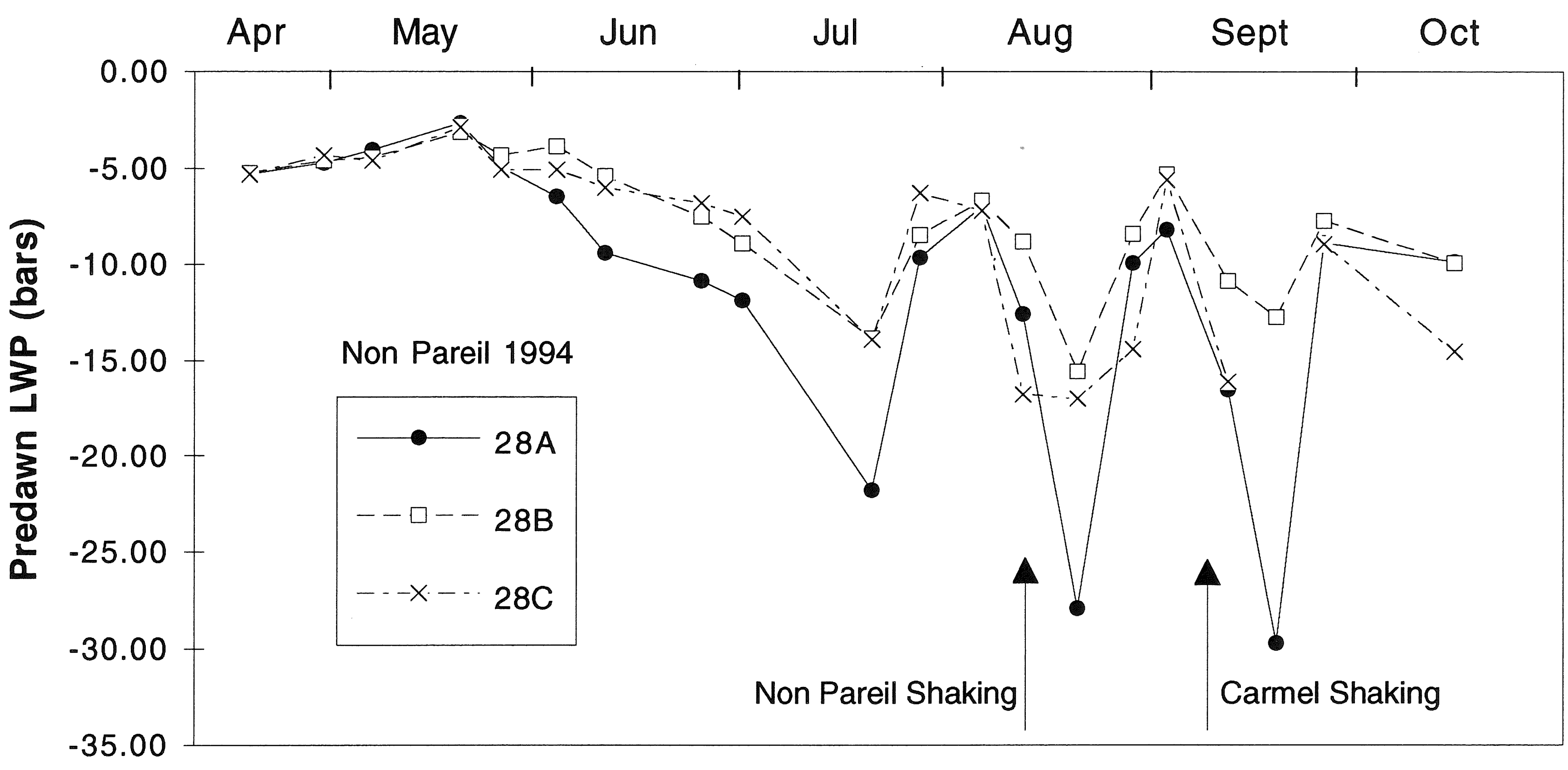

Figure 2. Predawn leaf water potential for the Non Pareil 28 inch per season series in study year 2.

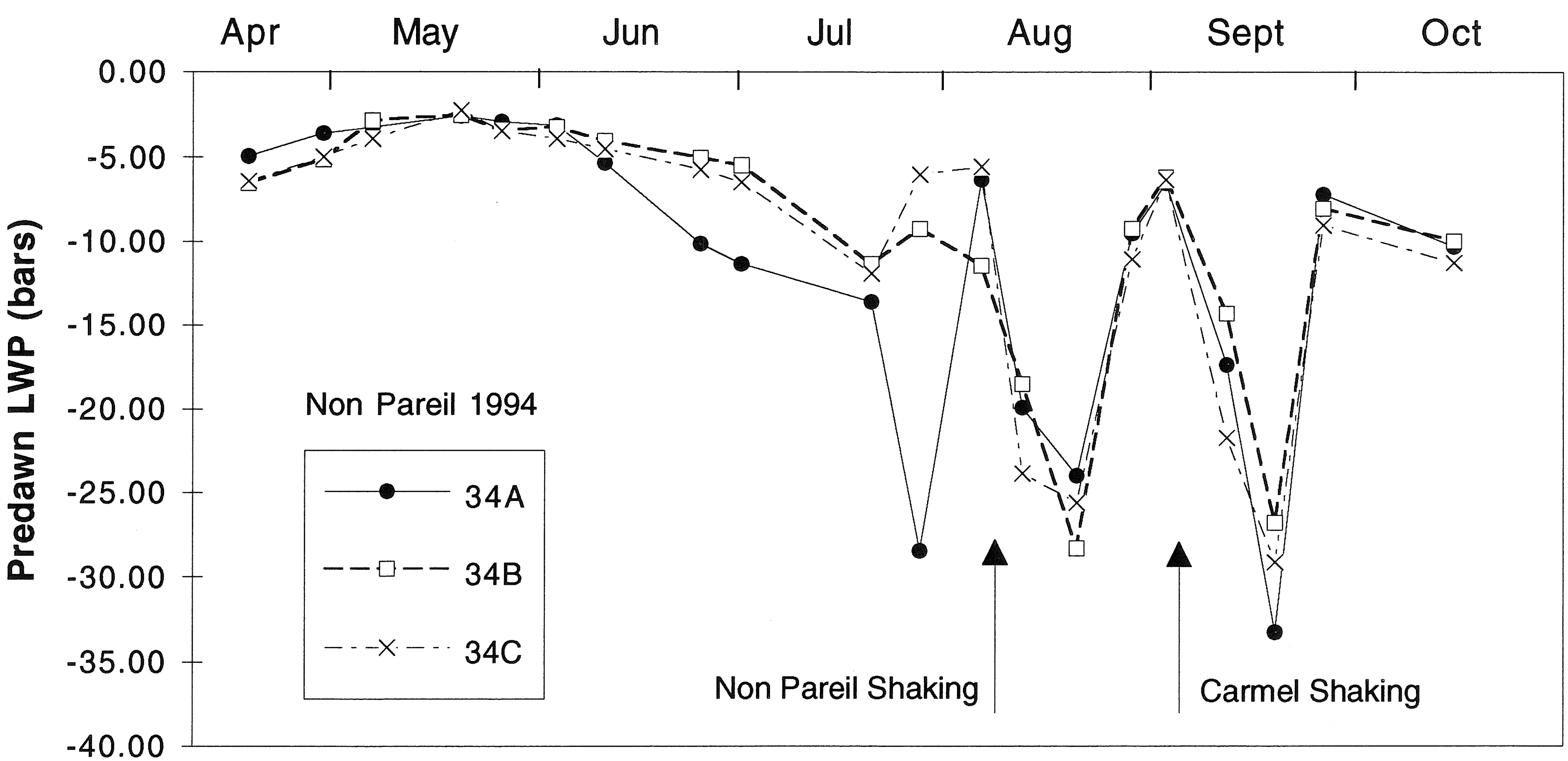

Figure 3. Predawn leaf water potential for the Non Pareil 34 inch per season series in study year 2.

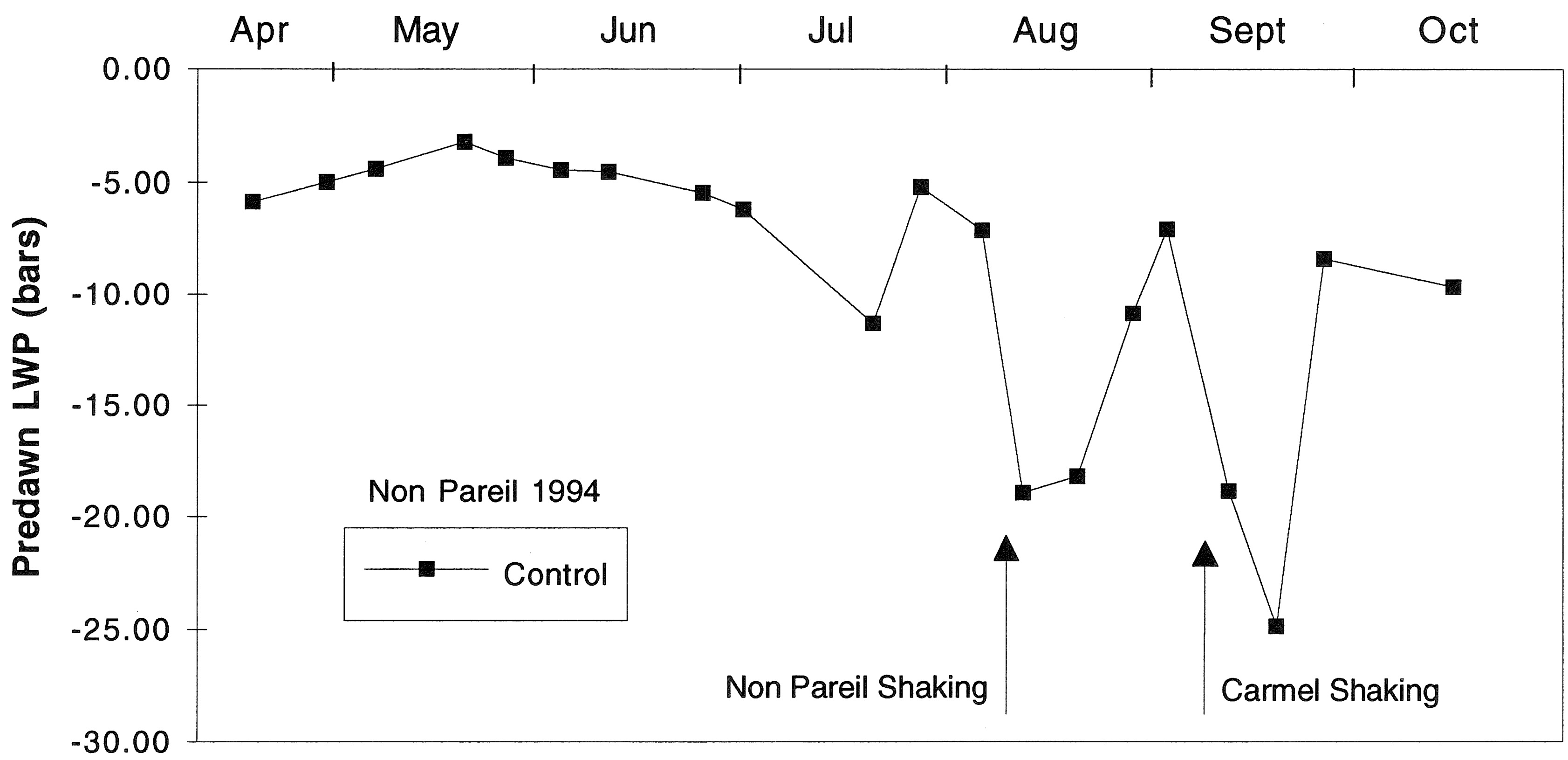

Figure 4. Predawn leaf water potential for the Non Pareil control series in study year 2.

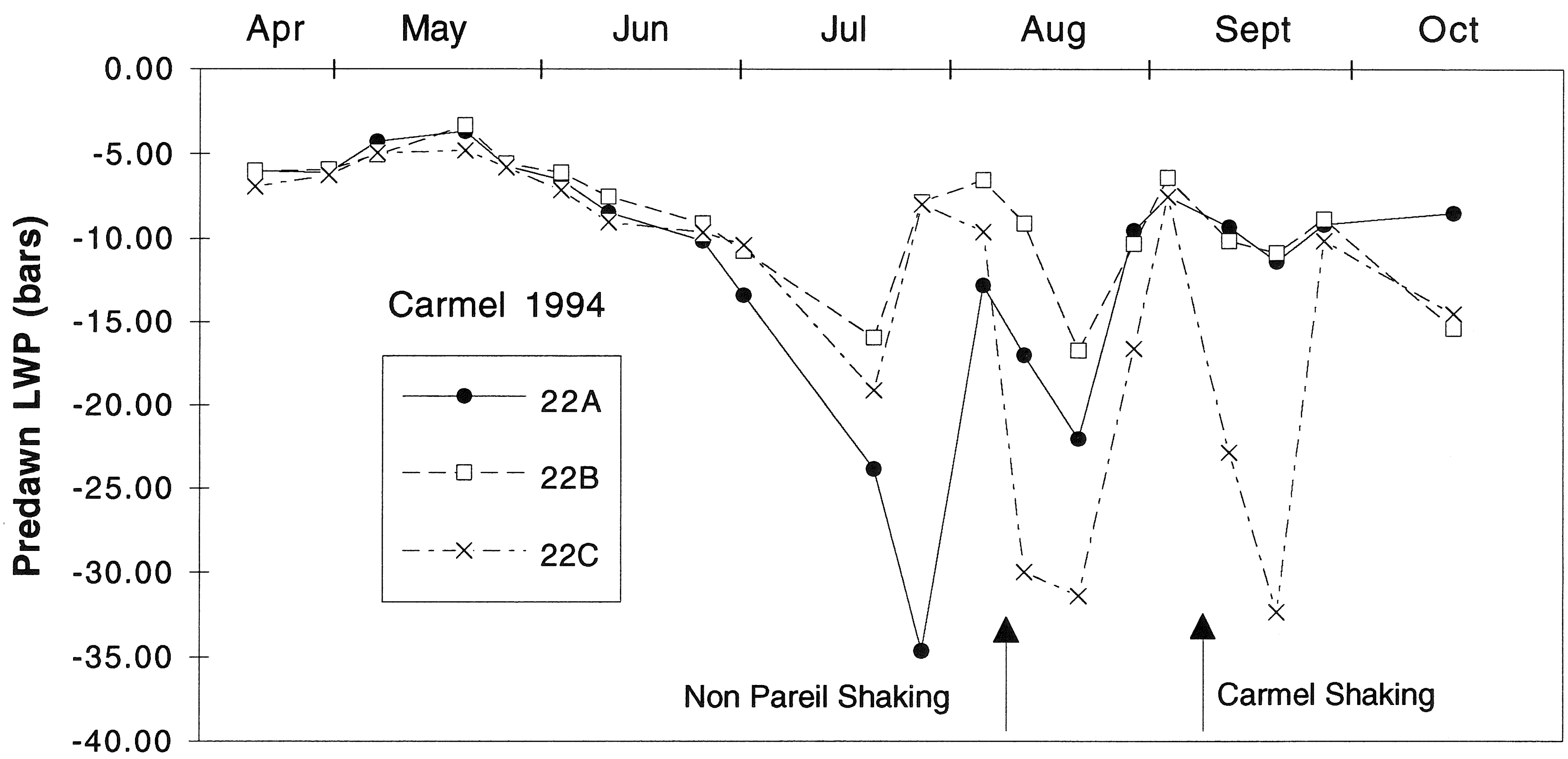

Figure 5. Predawn leaf water potential for the Carmel 22 inch per season series in study year 2.

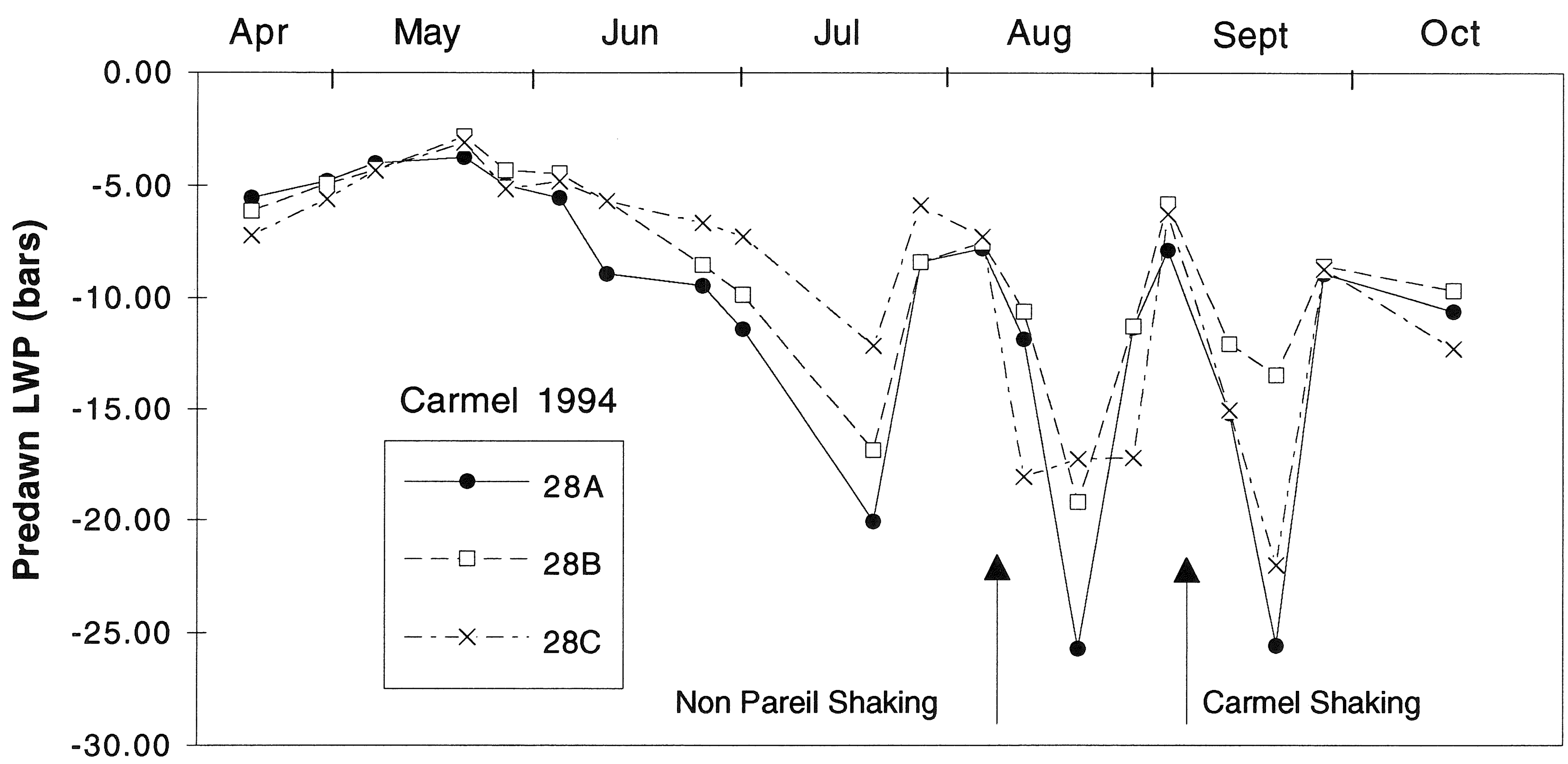

Figure 6. Predawn leaf water potential for the Carmel 28 inch per season series in study year 2.

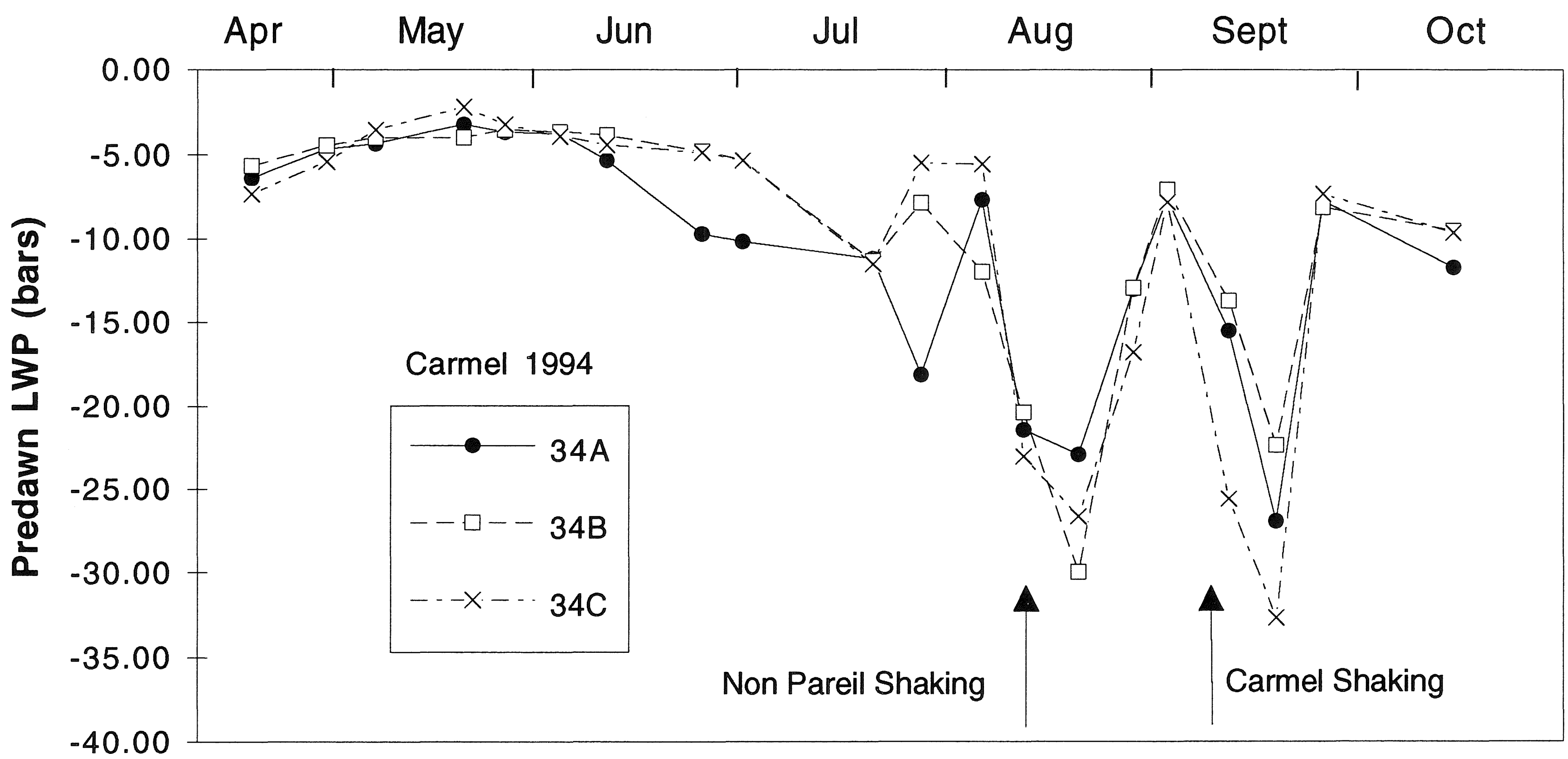

Figure 7. Predawn leaf water potential for the Carmel 34 inch per season series in study year 2.

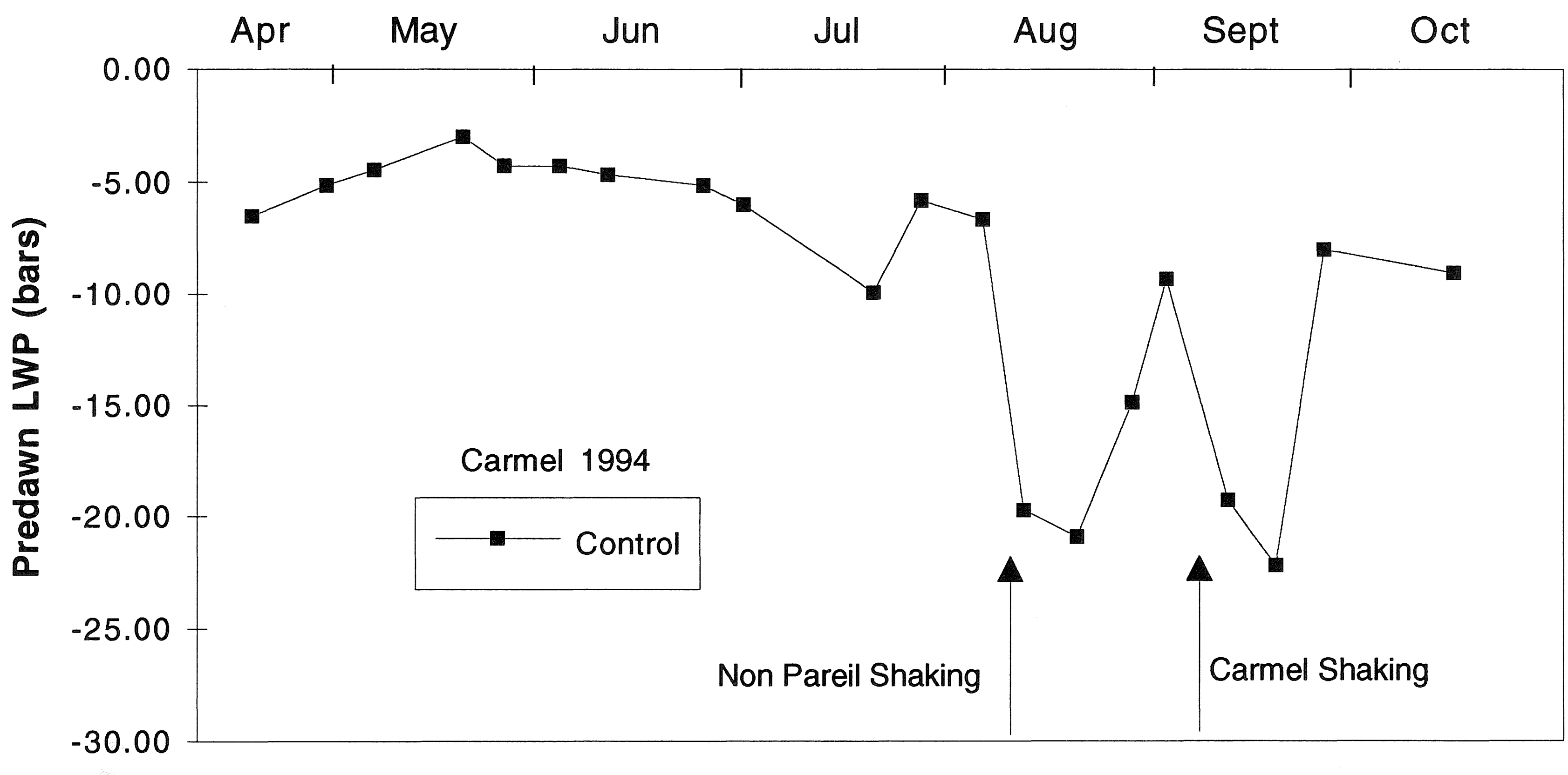

Figure 8. Predawn leaf water potential for the Carmel control series in study year 2.