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IRRIGATION CUTOFF AND DROUGHT IRRIGATION STRATEGY EFFECTS ON ALMOND

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OBJECTIVES

This project consists of two separate areas of study -- variable irrigation cutoff periods prior to harvest and drought irrigation strategies. The objectives of each study are as follows:

Cutoff experiments

To evaluate the effect of eight irrigation cutoff periods on long term sustained almond tree productivity. This includes both basic and applied aspects. We will attempt to identify how water stress influences the plant processes that affect yield, the yield components, and tree barking.

Drought Irrigation Strategy Experiments

To evaluate irrigation management regimes to be used when water supplies are limited. Assuming that 16 acre-inches/acre of water are available, monitoring tree performance using four different strategies, including applying the greatest amounts of water during periods of maximum vegetative and reproductive growth.

This report covers first year results of each of the above studies.

PROCEDURE

Cutoff Experiments

This work began in 1989 with mature orchards in Kern and Fresno Counties with cvs. Nonpareil and Carmel. Both sites were previously well irrigated.

Kern County Site. Eight cutoff treatments were established with six replications of each (Table 1). Plots were six rows wide and eight trees deep (48 trees per plot). The outside rows and the last two trees on the ends of each plot served as borders, leaving the inner 16 trees (eight each of NonPareil and Carmel) as the monitored trees.

Low volume sprinklers were used for irrigation. Irrigation scheduling was under the control of the cooperating grower who used a water budget technique with the appropriate almond crop coefficients. Irrigation frequency was generally once every four days. Irrigation cutoff was accomplished by crimping the spaghetti tubes of designated sprinklers.

Periodic measurements were made of predawn leaf water potential primarily to ascertain the rate of plant water stress development. Diurnal measurements of leaf water potential and stomatal conductance were made in midsummer. Neutron probe access tubes were installed to a depth of 10 ft on one tree in each plot in three of the replications. Measurements were made periodically over the season to determine soil water profiles. Dendrometer screws were installed on four trees per plot to determine trunk growth rates beginning in 1990.

Beginning in late June, weekly NonPareil nut samples were collected to determine the rate of kernel development and hull splitting. Ten nuts on each of the eight monitored trees per plot were removed, and transported to the lab. Hull split was rated as unsplit (no evidence of splitting), partial (1/4 inch or less split), or full split. Twenty nuts per plot were then cracked out and fresh and dry weights of the kernels recorded.

At harvest, cumulative nut weights of four tree sections were taken with a weighing nut buggy. Subsamples of each of four tree block were taken and analyzed for hull splitting, nut component weights, and NOW damage.

After the NonPareil harvest, the nuts (mummies) remaining in the monitored trees after shaking were counted on a per tree basis to determine the influence of cutoff on harvestability.

Post harvest irrigation management was designed to evaluate the effects of post harvest water deprivation on tree performance. Reps 2, 4, and 6 received no post harvest water while reps 1, 3, and 5 were irrigated based on the water budget. This regime resulted in the Carmel trees in reps 2, 4, and 6 being irrigated twice between NonPareil and Carmel harvests.

Fresno County Site. Four irrigation cutoff regimes (approximately 1, 3, 5, and 7 weeks prior to harvest) were evaluated with six replications of each. Plots contained five NonPareil and Carmel trees with the end trees serving as borders. Polyethylene sheeting placed to a depth of 4 ft between the plots isolated the irrigation treatments since small orchard size prevented the use of border trees.

Irrigation scheduling and management were as described for the Kern site.

Due to adverse weather, the NonPareil trees suffered a crop failure in 1989 and were not monitored for tree performance. The Carmel trees were monitored as described above for predawn leaf water potential and harvest information.

Based on high variability observed in this orchard in 1989, the NonPareil crop failure, and the additional post harvest irrigation end Carmel work initiated at the Kern Co. site, the Fresno Co. orchard will be abandoned in 1990.

Each year, a large number of almond trees sustain bark damage from shakers leading to loss of production. In almonds, damaged bark can expose the cambial tissue to ceratocystis fungus. In this experiment a fruit firmness gauge was used to measure the strength of adhesion between the bark and wood (bark strength) of discs made from 1/2 inch caliper branches of almond trees. Bark strength values were determined on Aug. 7 which was 4 days prior to shaking. The number of days since irrigation cut-off varied from 4-53.

Drought Irrigation Strategy Experiment

This work took place in a drip irrigated, Fresno Co. orchard and was conducted by Tim Smith in partial fulfillment of his M.S. degree from CSU, Fresno. In addition to the fully irrigated control, the following four irrigation regimes that applied a total of 16 inches for the season were tested: full irrigation until 16 inches were applied followed by complete cutoff; irrigation at the 75% crop ET (ET_c) rate until 16 inches were applied; irrigation at the 50% ET_c until 16 inches applied; and a controlled deficit irrigation (CDI) strategy of 16 total inches but designed to apply the most water during high fruit wood and nut growth periods: 80% ET_c through mid May, then 60% ET_c to mid June; 40% ET_c to late June, followed by 60% ET_c to harvest.

Harvest evaluation for yield and quality was similar to that described above.

RESULTS

Cutoff Experiment (Kern)

In-season monitoring and harvest data indicate that the two most sensitive yield components to early cutoff are hull splitting and to a lesser extent, nut size. Weekly hull split measurements shown in Fig. 1 illustrate that the rate of hull split depends on both time during the season and the length of the cutoff period. For example, split nuts in the control treatment (no plant stress) accounted for 45.4 and 79.6% of the tree nut load on August 2 and August 8, respectively. On the other hand, trees subjected to cutoff on July 21 (28 days prior to harvest) had 25.6 and 28.4% hull split nuts on the sample days.

Nut size, was only mildly affected by irrigation cutoff during this first year of work. Dry weight accumulation in the developing kernels (meats) with time over the season is shown in Fig. 2 and for clarity, only four treatments are presented. Only the earliest cutoff resulted in an appreciably lower rate of kernel growth. Kernels in this extreme cutoff (June 15, 63 days before harvest) had achieved nearly their full weight of about 0.95 gm by mid July while non-stress nuts increased in weight from 1.0 to 1.1 gm between mid July and early August.

Harvest and yield component data is shown in Table 1. Note that gross yields (field-dried) were related to the length of the cutoff period. However, the only statistically significant difference (5% confidence level) was between the earliest and latest cutoff. Evaluation of hull split in Table 1 is expressed by the characterization of nut type as follows: full split = greater than half the hull open along the suture; partial = less than half the hull open; hull tight = no split. The presence of hull tights at harvest was directly related to the length of water deprivation with greater than 50% of the tree nut load being hull tights with the earliest cutoffs versus less than 1% with the control. It should be noted that the size of the nuts (data not shown) characterized as partial splits and hull tights was greater in the earlier cutoff treatments, which suggests that hull splitting under developing plant water stress is related to nut size.

The above explanation assumes that the imposition of early tree stress resulted in the hull splitting process being arrested over a relatively wide range of nut sizes -- large as well as small nuts in the tree were affected. In trees where the cutoff was delayed, the developing water stress influenced hull splitting on primarily the smaller nuts. In other words, in the later stages of nut development, the tree prioritized those nuts destined for hull split in favor of the larger nuts.

Hull tight nuts create a quality problem at the processor resulting in penalties to the grower. Our experimental samples were too small for commercial processing, so determining the degree of penalties was not possible. Thus, we express harvest meat yields in Table 1 two ways -- with and without meats from hull tight nuts included. When all nut types are considered, there was a trend toward lower meat yields with increased cutoff period length but the differences were not statistically significant. Excluding hull tight meats resulted in significantly lower yields for the 63, 56, and 49 day cutoffs.

Yield and yield component data for the Carmel tree is shown is Table 2. Since the block was split into two post harvest water regimes, Table 2 contains separate data for post NonPareil harvest irrigation (A) and performance without post NonPareil harvest irrigation (B).

A clearly beneficial influence of applying post NonPareil water occurred on hull splitting. The least severe cutoff regime (treatment 8) received two additional days of irrigation and this resulted in about 71% of the harvested nuts having fully split hulls. This compares with hull splitting of only about 27% when no additional post NonPareil harvest water was applied. This greater than two-fold difference in hull splitting indicates that when possible, pollinizer trees that are harvested after the primary cultivar should be irrigated between the two harvests. We recognize that this is most likely with drip or other high frequency irrigation system. However, the dramatic difference in hull split shown in Table 2 indicates that the extra effort necessary to apply an additional surface or sprinkler irrigation prior to the Carmel harvest may be worthwhile.

The fact that cutoff effects on orchard productivity other than hull splitting were generally minor this season is consistent with behavior observed in other deciduous trees during the first year of water deprivation. It should be emphasized that effects on fruit wood development and carbohydrate storage this year may appreciably affect fruiting and production next year.

Late in the season, hull rot was observed on a small number of nuts in late cutoff treatments, suggesting a relationship with tree humidity levels. Stick tights (nuts left after shaking) tended to be greatest for both the early and late cutoffs and least for the medium cutoffs although the differences were not statistically different.

The bark strength in the wettest treatment (4 days since irrigation cut-off) was statistically lower than the bark strength in all other treatments (Figure 3) indicating that bark strength does increase after irrigation cut-off. There was little difference in bark strength of cut-offs from 9 to 53 days, although the decline in bark strength after 25 days may indicate that extreme levels of irrigation cut-off may actually reduce bark strength.

Only one out of 2304 trees in the experiment experienced bark damage during shaking. However, by the time of shaking the wettest treatment was also 8 days since irrigation cut-off and its bark strength may not have been different from the other treatments at this time. Thus, it appears that bark strength changes rapidly after irrigation cut-off, and future studies will concentrate on the timing and the physiological basis for this change.

Drought Irrigation Strategies Experiment

Harvest data for this first year are shown in Table 3. The deficit irrigation regimes that resulted in early season water deprivation resulted in generally lower gross and meat yields. This suggests that early season nut development is important to achieve top potential yields. The CDI regime yielded nearly identical values as the control, indicating that it may be a viable drought irrigation strategy. However, continued evaluation of this study is necessary to investigate carryover effects of this year's CDI plant water stress on following seasons' productivity.

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Table 1. NonPareil harvest yields and yield components.

TREATMENT #	CUTOFF TREATMENT (days before harvest)	GROSS HARVEST YIELD lbs/acre	HARVESTED NUT TYPE Full split	Partial split	Hull tight	TOTAL MEAT YIELD including hull tights	excluding hull tights	STICK TIGHTS No./tree	HULL ROT[1/] No./tree
			---% by number---			---- lbs/acre ----			
1	63	4976 a	26.6	19.7	53.7	1385 a	644 a	31.5 a	0
2	56	5422 ab	23.1	14.9	62.0	1528 a	667 a	38.7 a	0.2 a
3	49	5601 abc	51.5	15.3	33.2	1568 a	1083 b	50.7 a	0.3 a
4	42	5601 abc	66.6	12.6	20.8	1603 a	1185 bc	17.9 a	0.7 a
5	35	5845 bc	80.6	6.5	12.9	1605 a	1420 cd	21.4 a	1.2 a
6	28	5979 bc	89.7	2.5	7.8	1611 a	1526 d	49.1 a	3.7 ab
7	21	6160 bc	98.8	0.2	1.0	1645 a	1598 d	32.3 a	4.4 bc
8	14	6337 c	99.5	0.0	0.5	1655 a	1632 d	24.8 a	5.0 c

[1/] Observed at eye level around tree.

* Means not followed by the same letter are significantly different at the 5% confidence level.

Table 2. Harvest data for cv. Carmel.

(A) No post NonPareil harvest irrigation.

	Treatment 1	2	3	4	5	6	7	8
Initial tree load (#/tree)	14212 a	13105 a	15700 a	13826 a	13053 a	13896 a	14586 a	13219 a
Ave. wt. of nut (g/nut)	2.25 e	2.56 cd	2.47 d	2.63 bcd	2.80 ab	2.70 cb	2.88 ab	2.90 a
Gross yield (lb/tree)	70.33 b	73.00 b	85.41 ab	79.83 ab	80.36 ab	82.75 ab	89.72 a	83.83 ab
Total yield of kernel (lb/tree)	25.14 ab	23.67 b	29.80 a	26.85 ab	27.33 ab	29.04 ab	30.59 ab	29.00 ab
Total yield of kernel without hull tights (lb/tree)	0.14 b	0.30 b	2.25 b	2.25 b	4.85 b	3.31 b	3.90 b	9.70 a
Average % of each nut type								
Full split	0.7	0.9	7.7	7.6	15.5	7.6	11.6	27.4
Partial split	0.5	1.3	1.4	1.6	1.6	5.4	2.6	3.8
Hull tight	99.1	98.0	93.2	92.6	83.7	88.8	85.7	68.8

Table 2. (Continued)

(B) Receiving post NonPareil harvest irrigation.

	Treatment							
	1	2	3	4	5	6	7	8
Initial tree load (#/tree)	14218 a	14128 a	13874 a	13035 a	14802 a	12968 a	13036 a	13608 a
Ave. wt. of nut (g/nut)	2.48 c	2.44 c	2.57 bc	2.65 cb	2.62 bc	2.73 ab	2.86 a	2.91 a
Gross yield (lb/tree)	72.41 a	75.50 a	78.60 a	76.58 a	84.58 a	78.00 a	81.61 a	87.04 a
Total yield of kernel (lb/tree)	25.27 ab	24.58 b	25.94 ab	25.48 ab	30.54 a	26.66 ab	27.56 ab	28.20 ab
Total yield of kernel without hull tights (lb/tree)	6.47 b	7.90 b	3.64 b	6.05 b	5.96 b	8.56 b	21.10 a	21.64 a
Average % of each nut type								
Full split	25.6	30.9	11.4	17.5	16.6	27.3	72.9	70.5
Partial split	1.5	2.5	2.7	3.4	2.9	4.1	1.9	3.3
Hull tight	73.2	66.6	85.9	79.2	80.6	68.6	25.5	26.8

Table 3. Drought strategy yield and yield component data.

Treatment #	Treatment	Irrigation cutoff	Total applied water (acre-in/acre)	Fruit wt. (lbs/tree)	Full splits (%)	Full splits meat yield (lbs/tree)	Individual nut wt. (gms/nut)
1	Control	late August	38	185 a	99 a	46 a	4.6 a
2	Full ETc	mid June	16	152 b	38 b	16 d	3.3 c
3	75% ETc	late June	16	131 b	85 a	29 c	3.9 bc
4	50% ETc	late August	16	162 ab	99 a	36 bc	4.1 ab
5	CDI	late August	16	185 a	87 a	39 ab	4.3 ab

* Means not followed by the same letter are significantly different at the 5% confidence level.

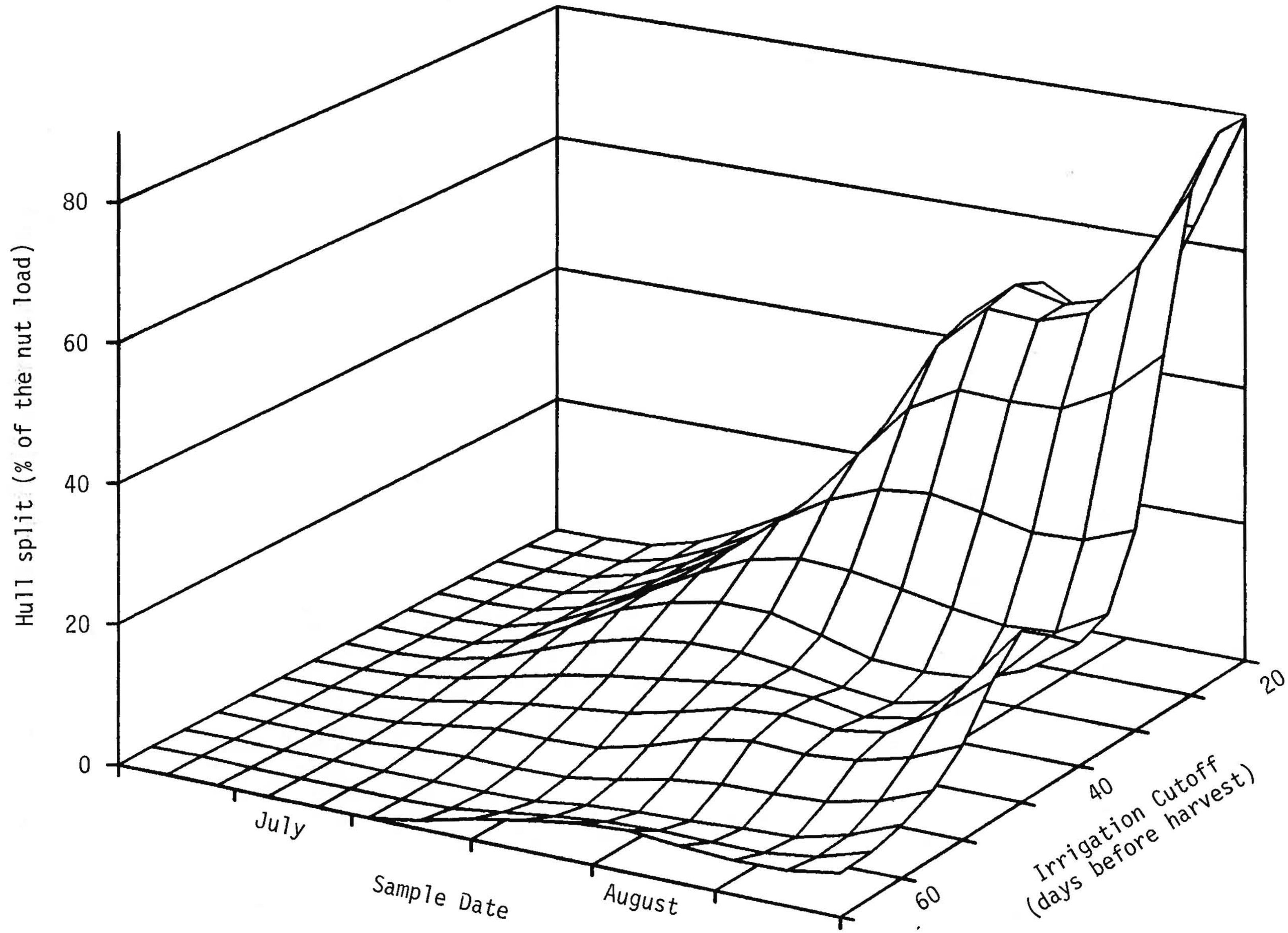

Fig. 1. Influence of irrigation cutoff on the rate of hull split over the season.

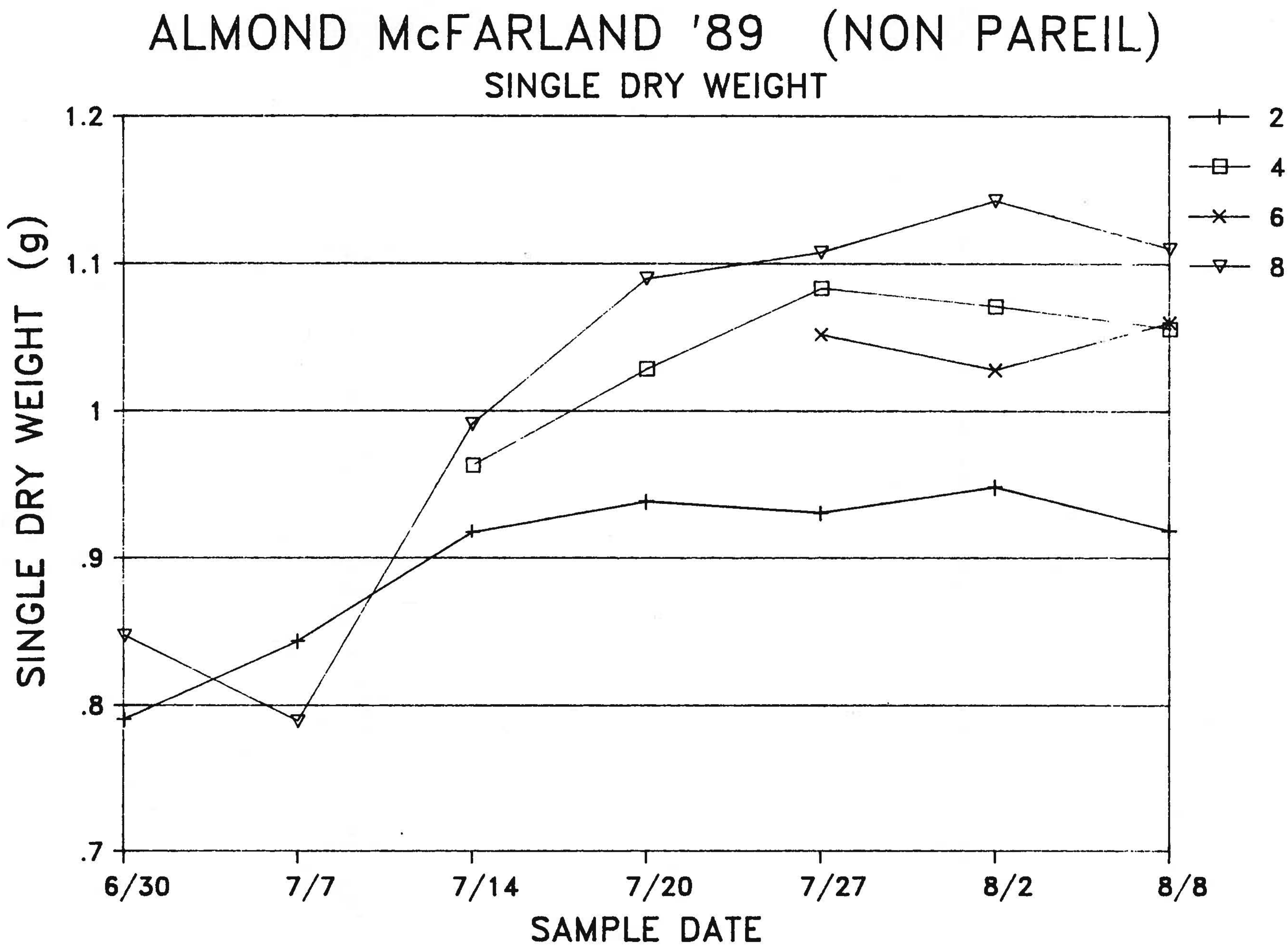

Fig. 2. Rate of kernel dry weight gain over the season for cutoff treatment numbers 2, 4, 6, and 8.

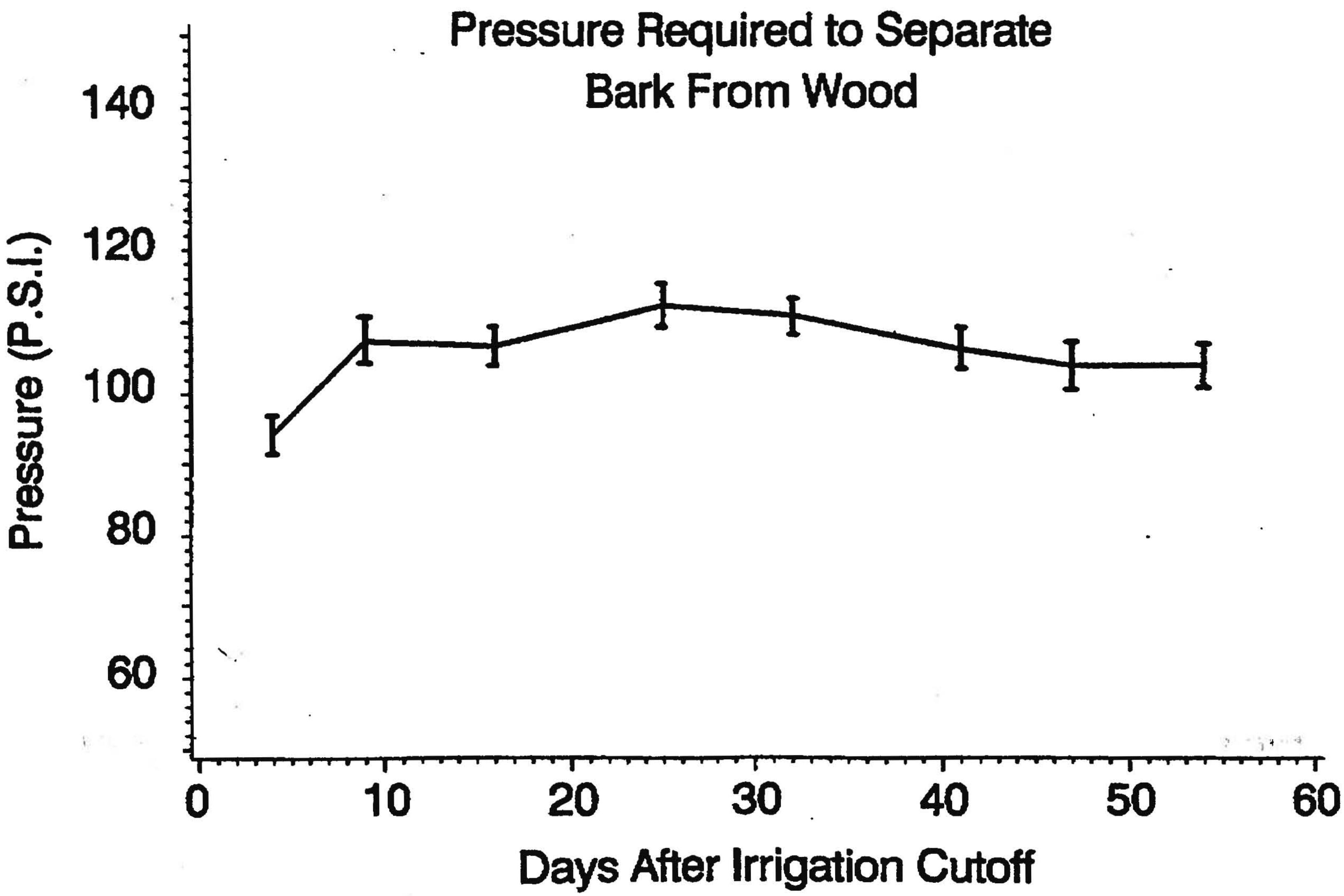

Fig. 3. Relationship between bark strength and time after irrigation cutoff.