

WHY ARE WISCONSIN CRANBERRY YIELDS DECLINING?

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As with most crops, yields of cranberry increased dramatically during much of this century. Wisconsin cranberry acreage yielded about 20 bbls/acre through the first 30 years of the century, after which a steady increase began. Between 1960 and the early 1980s, yields increased nearly 3 bbls/acre each year (Fig. 1). Following the record statewide yield average in 1982, however, the per acre yield of cranberry in Wisconsin appears to be declining, nearly 20% below early 1980 yields and 50 bbls/acre below that expected if the 1960- 1980 rate of increase had continued. While all crop yields fluctuate from year-to-year and 10-year periods of little increase are in the Wisconsin cranberry record, the decrease that began in the early 1980s appears to be more than just bad luck. With the accumulated value of these missing berries in excess of \$120 million, an explanation is needed. The cause may be due to circumstances beyond our control, or it may be due to factors that improved management and directed research can overcome. A number of possible reasons for the decrease are being considered by a team of UW-Madison researchers. In this paper, I investigate the evidence that the yield decline is more than just chance, and test a number of candidate causes.

Cranberry Technology

One possible explanation is that the new technologies that propelled the yield increase from the 1930s to the 1980s are no longer being introduced, or are wearing-out. By technology, I mean the application of knowledge, be it through design and use of machines and chemicals, or better understanding of how to best manage both pests and the crop. Technologies such as chemical fertilizers, overhead irrigation, water harvesting, and chemical pest control provided great advantages and yield improvements. Are we out of new tricks? Do technologies wear out? In the case of fertilizers and irrigation, improvements are permanent. Chemical pest control can be lost through regulatory changes and genetic mutation of weeds, insects, and diseases. For example, new wheat varieties must constantly be created, to maintain resistance to ever-changing disease organisms.

If a general loss of technology was to blame, other cranberry-producing areas might be suffering the same yield loss as is Wisconsin. However, this does not

appear to be the case (Fig. 2). Other states are certainly not in decline, and may be continuing to increase yield per acre. The most rapid increase in Fig. 2 occurred in Oregon, but their industry is but one-tenth of ours, crops of the early 1980s were poor there, and yields fluctuated wildly in recent years. A technology loss might show up first in Wisconsin if growers here had more quickly and thoroughly adopted it, compared to growers elsewhere. If this is the case, peak yields followed by decrease will occur in other states in the coming years.

Effect of Young Beds

Cranberry, like other perennial crops, requires a number of years of growth to reach full productivity. Because young plantings are harvested before reaching full production, they contribute less-than-average yields to the statewide value. How much influence new beds have on average yield depends on the rate at which they are added to the harvested acreage, and the length and amount of yield reduction due to their youth. Oregon's small industry leads the nation in growth rate (Table 1), with Wisconsin a close second. To estimate the effect of expansion on statewide yields, I made a calculation. Two assumptions were required: how the productivity of a bed increases with age, and why harvested acreage is growing. For the first assumption, I guessed that new plantings are harvested the fourth season after planting, that they yield only 35% of a fully-productive bed, and full yield occurs when a bed is eight years old. For the second, I assumed that each annual increase in harvested acreage (approximated by a smooth curve in Fig. 3) was due to addition of four-year-old beds. If these approximations are reasonable, new acreage reduced 1993 statewide yields by about 8%, compared to early 1980 yields. Recovery of statewide yields from this effect depends on how much new acreage is brought into production in the coming years. For example, if no new beds are harvested, the effect will disappear in 4 years, as all beds reach full productivity. Thus, new plantings account for almost half of the yield deficit below early 1980 productivity, but productivity will recover from this effect as new beds mature and the rate of addition of new acreage slows.

Table 1. Rate of increases in harvested cranberry acreage in the U.S.

State	1993 harvested area (acres)	% Increase 1982-93
Massachusetts	13,140	17
New Jersey	3,490	20
Oregon	1,540	73
Washington	1,510	37
Wisconsin	11,330	62

Individual Beds

Is more of the yield deficit due to other unknown factors related to how the statewide average is calculated? Such effects will not be present in records of individual beds; if yields are decreasing in typical, mature producing beds, we must look to weather, pest management, or crop factors to explain the rest of the statewide decrease. Four marshes kindly supplied yield data for as long as available on a total of 20 beds. The eight beds of Searles in the dataset (Fig. 4a) all appear to be yielding less than they did in 1982. The tendency of Searles for biennial bearing (alternating high and low yields) is apparent in most beds when year-to-year variation is traced (points from three marshes were connected by dashed lines). Such cycles in other fruit crops are largely controlled by new varieties or chemical thinning of blossoms. Perhaps these Searles beds are relatively old, and cranberries, like all living things, slow down with age. The, perhaps, younger Stevens beds (Fig. 4b) were mixed in their yield trend over the past decades. It appears that the statewide yield decrease is reflected in records of individual beds, suggesting that technological or weather factors are contributing.

Influences of Weather

Is the weather of the recent decade to blame? Agricultural climatologists believe that the period from the mid- 1950s through the mid- 1970s were unusually favorable for crop production in the Midwest US. Around 1974, the climate may have returned to a more normal state of greater variability (Baker et al. 1993). While this behavior can be seen (or at least imagined) relatively easily in corn production records, no similar pattern is immediately evident in Wisconsin cranberry production records (Fig. 1). However, weather of 1982-present may

have differed from that of 1970- 1981 in ways that were somehow damaging to Wisconsin cranberries.

Several research teams have attempted to understand how weather affects cranberry production. Morzuch et al. (1983), a team of economists, used early observations of Massachusetts cranberry specialists to attempt to separate the effects of technology and weather on yield increases of the 1970s. Degaetano and Shulman (1987) used a statistical “correlation hunt” to identify important weather influences on cranberry yield. They identified as favorable: warm temperatures mid-May to late June and mid-October to mid-November, sunny skies during May and June, and cold during February and March. Poor yields were associated with early springs and hot summers. However, none of these models are very convincing.

When we study weather effects, they are usually considered to be noise, or fluctuations, on top of a strong upward yield trend powered by technological innovation. Understanding the technology trend is difficult because adoption of improved techniques does not happen immediately on all of the state’s acreage. Records of yield must somehow be corrected for the impacts of technology, before the effects of weather can be studied. A little imagination can go a long way toward explaining a set observations.

To test the hypothesis that unfavorable weather contributed to the yield decrease of the past 12 years, I compared their weather to that of the 12 years prior to 1982. Two scenarios (we would call them models) of the role of technology were studied: (1) that the trend of 1960-82 continued, and (2) that no new technology was adopted after 1982. The yields observed during 1970-93 were subtracted from both hypothesized technology trends (Fig. 5), to show the remaining variation. The scenarios are identical in Fig. 5 until 1982, that is they follow the straight line on Fig. 1. After 1982 yield departures are greater for (1), since it is the equivalent of the straight line in Fig. 1 continuing upward until 1993, rather than a horizontal trend line for 1982-93, as is (2).

Six weather factors were tested for influence on cranberry yield: 1) thermal time (degree day, base 45°F) accumulation for April, May, and June (AMJ) of the harvest year; 2) like 1), but for the year prior to the harvest year; 3) thermal time accumulation for July, August, and September (JAS); 4) like 3), but for the year prior to the harvest year; 5) total rainfall from mid-June through mid-July; and 6) number of rain days during the same period. Based on earlier studies, spring warmth may affect current season bud development and growth of the next season’s fruiting uprights. Summer and fall warmth may affect fruit growth and development of next season’s buds. Finally, rain during flowering may reduce fruit set (Peltier 1954), perhaps due to decreased activity of pollinating insects.

Results are presented in Fig. 6, 7, 8 and 9. The figures show yield departures

from the technology trend lines vs. the relevant environmental variable; solid points indicate values from 1970-81 and open circles are from 1982-93. Figure 6 shows how spring warmth (AMJ degree days) influenced yield departures for the two time periods. Assuming a constant increase in technology (Fig. 6a), the vertical positions of the points indicate that yields in 1970-81 were generally below the longer term 1960-82 trend (this can also be seen in Figs. 1 and 5). Additionally, as one would also guess from Figs. 1 and 5, yields for 1982-93 were substantially below the constant increase trend. Because of the essentially random pattern of the points, it does not appear that spring warmth affected yield during either time interval. The lower panel of Fig. 6 shows again that 1970-81 yields were below the 1960-82 technology trend. Additionally, the assumption that 1982 technology applied to 1982-93 resulted in mostly negative departures (points below the horizontal line of zero yield departure). This suggests that the technology model of “no new tricks after 1982” is optimistic--maybe a negative technology trend is needed to explain the data. There might be a tendency for greater AMJ degree days to lead to positive yield departures.

A similar analysis is possible for Fig. 7. The arrangement of data points more closely resembles a shotgun pattern than did Fig. 6, so it appears that between thermal time during JAS of the harvest year is not strongly related to yield, for either of the technology assumptions. Yield departure and thermal time accumulations during AMJ or JAS of the year preceding the harvest year also failed to show a useful relationship, and are not presented here.

Possible effects of rain during pollination are shown in Figs. 8 and 9. As is usually the case with rainfall records, data points in Fig. 8 tend to be clumped toward one end of the graph. Values from the 1982-93 period tend to be at the extremes (high and low), lending support to the idea that the climate is becoming more variable. The pattern of points is not in conflict with the idea that drier is better during pollination, but do not strongly support it, either. The number of days of rain during this period (Fig. 9) are more evenly distributed than were rainfall totals. In the top panel, little relationship is apparent. The technology model in the lower panel, however, reorganizes the pattern so as to suggest that fewer rainy days are better, as one would guess. This demonstrates how important it is to find an appropriate technology model when studying weather impacts.

Summary

Cranberry yields per land area in Wisconsin appear to be decreasing, a trend that began in the early 1980s. Nearly half of the decrease can be explained by the rapid increase in young harvested acreage over the time period. However, individual beds for which long yield records are available reflect the statewide decrease, so other factors, such as the lack of new technology, or the aging of

current technologies, must be at work. Comparison of key weather variables in the 12 years preceding and following the apparent change in yield trend did not reveal clear differences between the time periods. Further analysis of yield and weather records is required, perhaps through use of a deterministic cranberry crop model. By this, I mean a model that is derived from expert opinion and research results on specific aspects of the crop's reactions to weather. The decrease in Wisconsin cranberry yields appears to be more than a chance occurrence, and is a challenging and important question. Expanded teamwork, both among researchers and between researchers and growers, is needed.

Literature Cited

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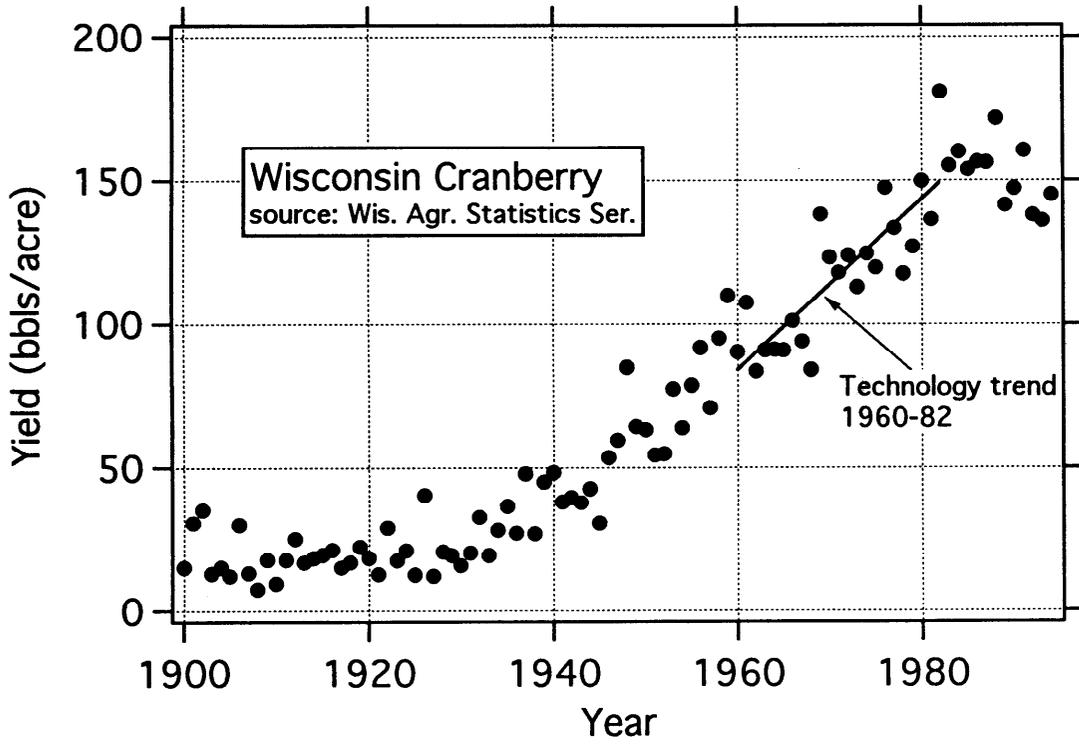


Fig. 1. Yields of cranberry in Wisconsin, 1900-1993

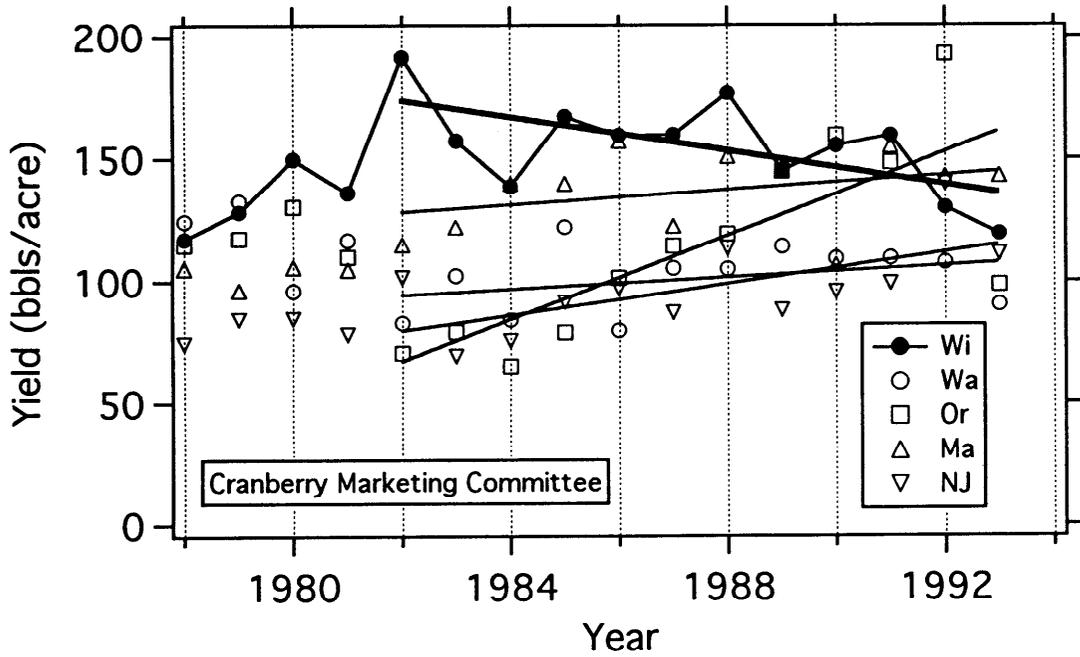


Fig. 2. Yields of cranberry in the five major producing states.

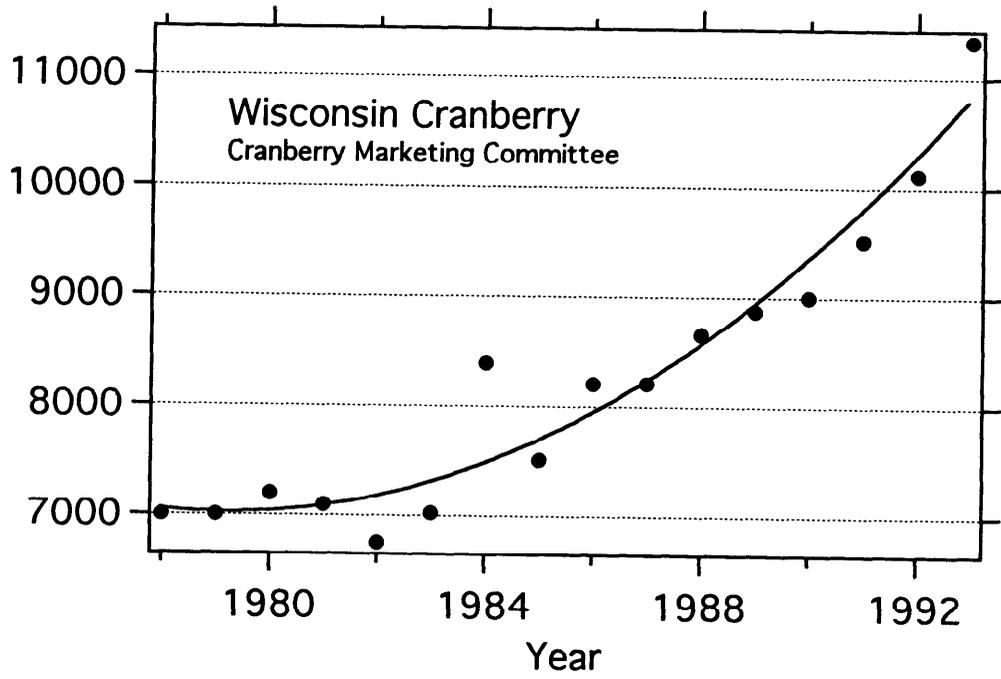


Fig. 3. Harvested cranberry acreage in Wisconsin

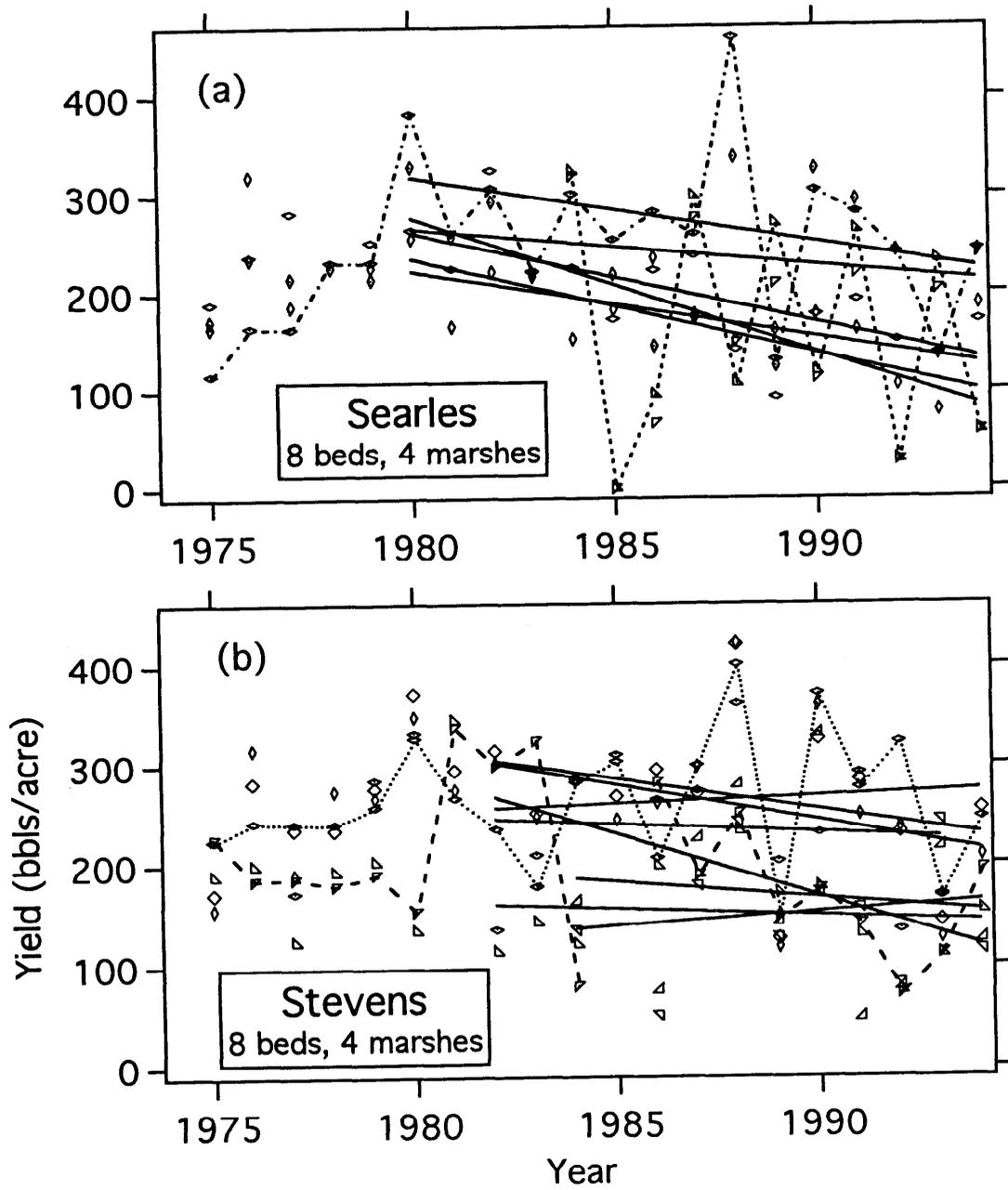


Fig. 4 Yields of individual cranberry beds in Wisconsin for two varieties: (a) Searles, (b) Stevens.

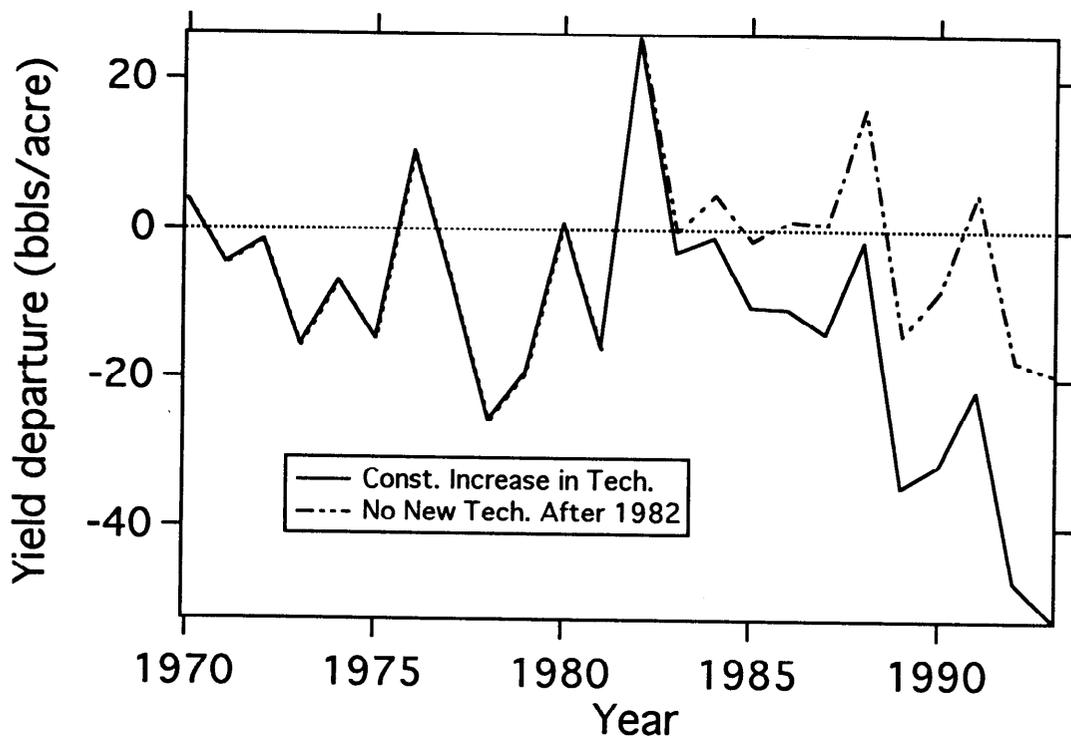


Fig. 5. Departures of Wisconsin cranberry yields from two assumed technology-driven trend lines.

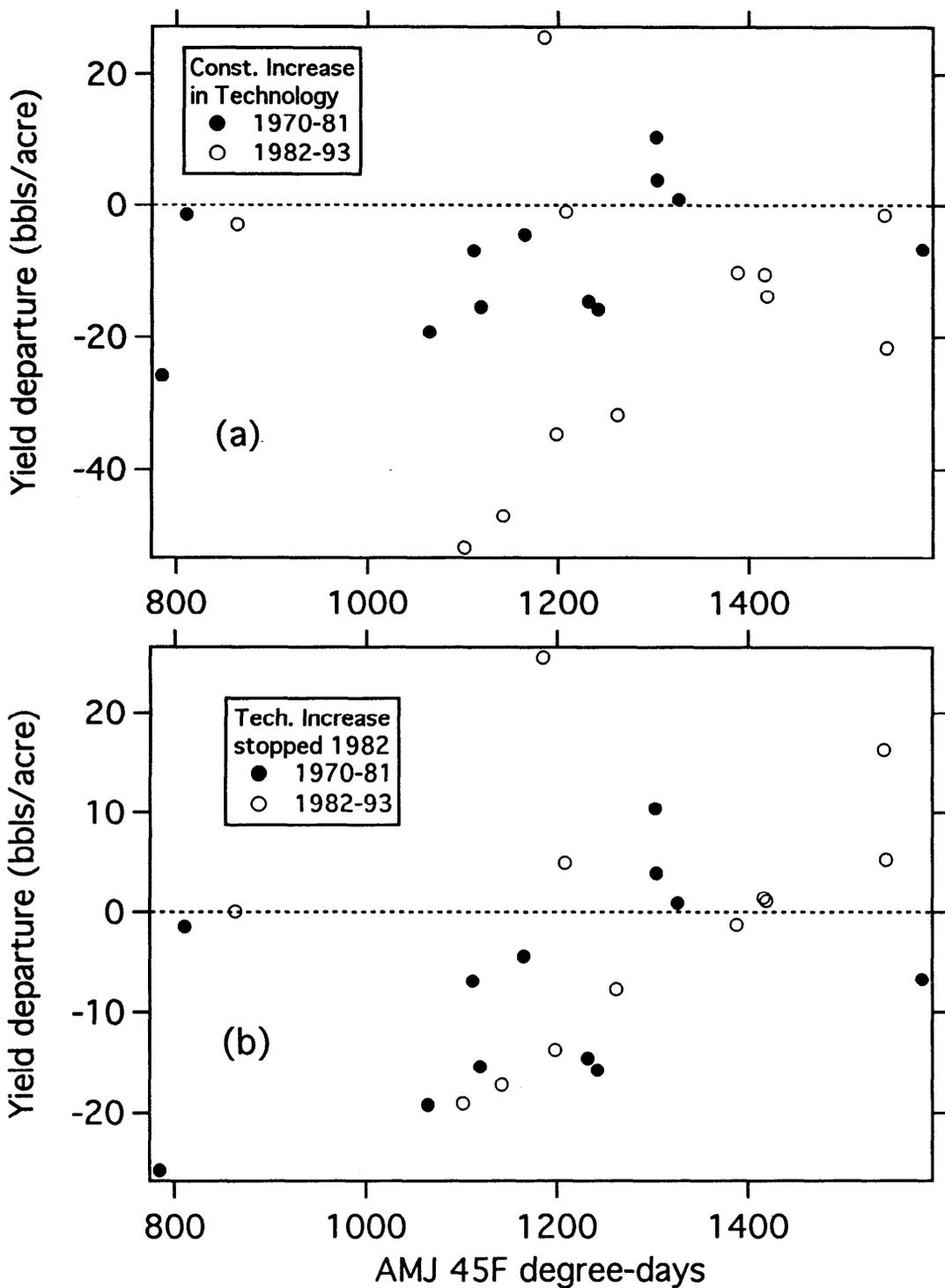


Fig. 6. Relationship of Spring (April-May-June) thermal time accumulations to departures of cranberry yield from two hypothesized technology trends: (a) assuming technology continued to increase yields at the rate observed 1960-82, (b) assuming no new technology was introduced after 1982.

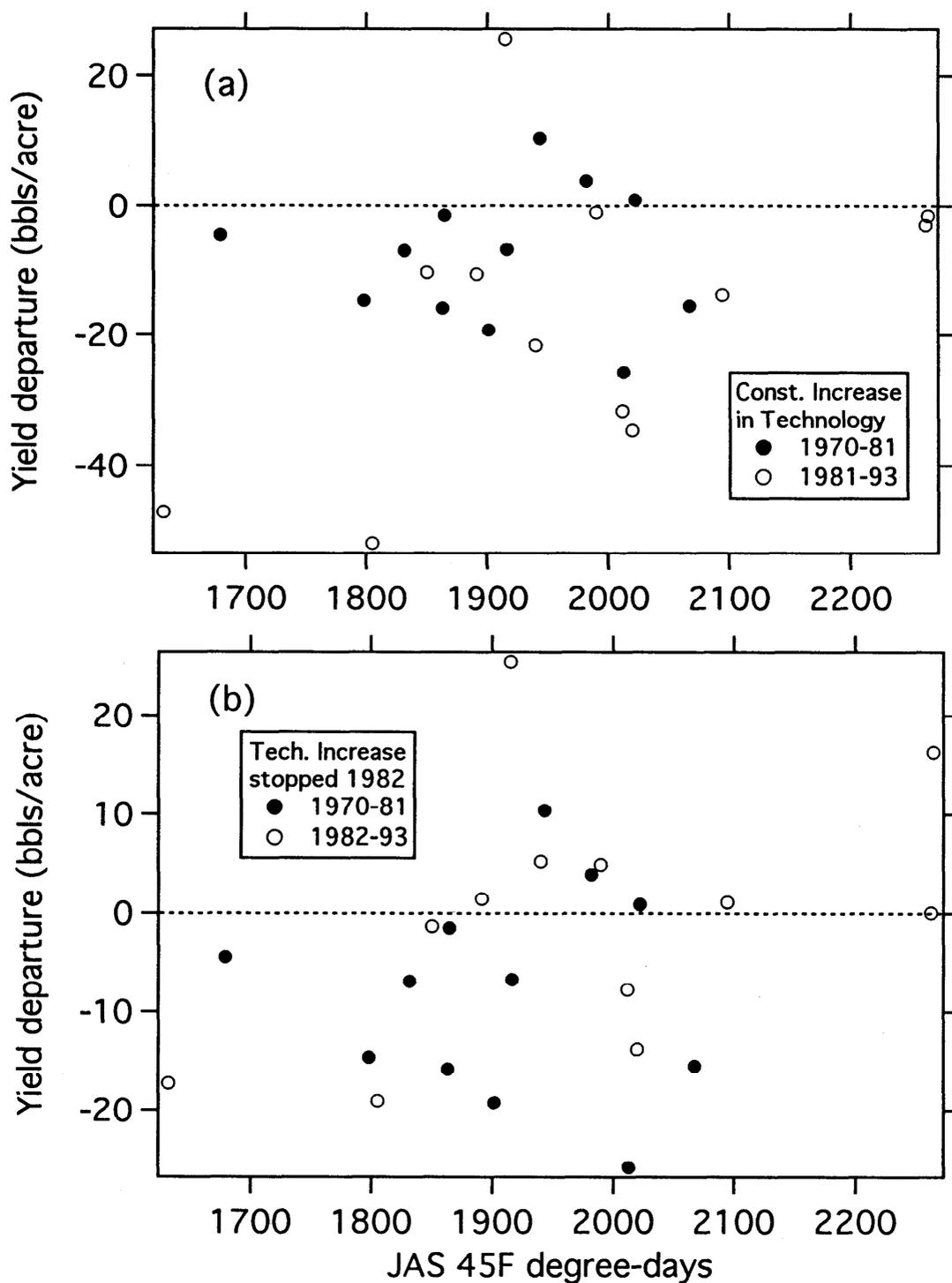


Fig. 7. Relationship of Summer (July-August-September) thermal time accumulations to departures of cranberry yield from two hypothesized technology trends: (a) assuming technology continued to increase yields at the rate observed 1960-82, (b) assuming no new technology was introduced after 1982.

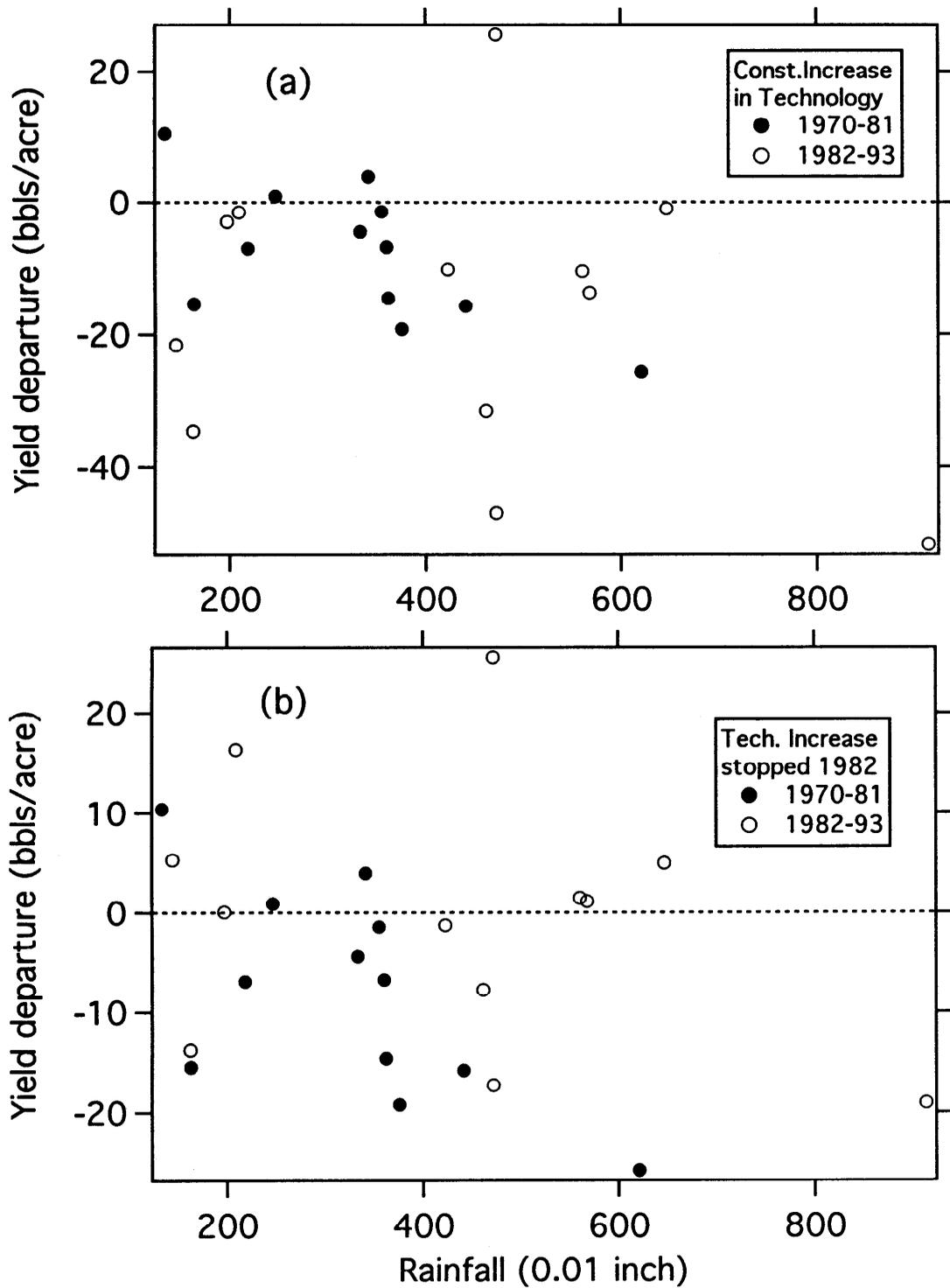


Fig. 8. Relationship of rainfall during pollination (mid-June to mid-July) to departures of cranberry yield from two hypothesized technology trends: (a) assuming technology continued to increase yields at the rate observed 1960-82, (b) assuming no new technology was introduced after 1982.

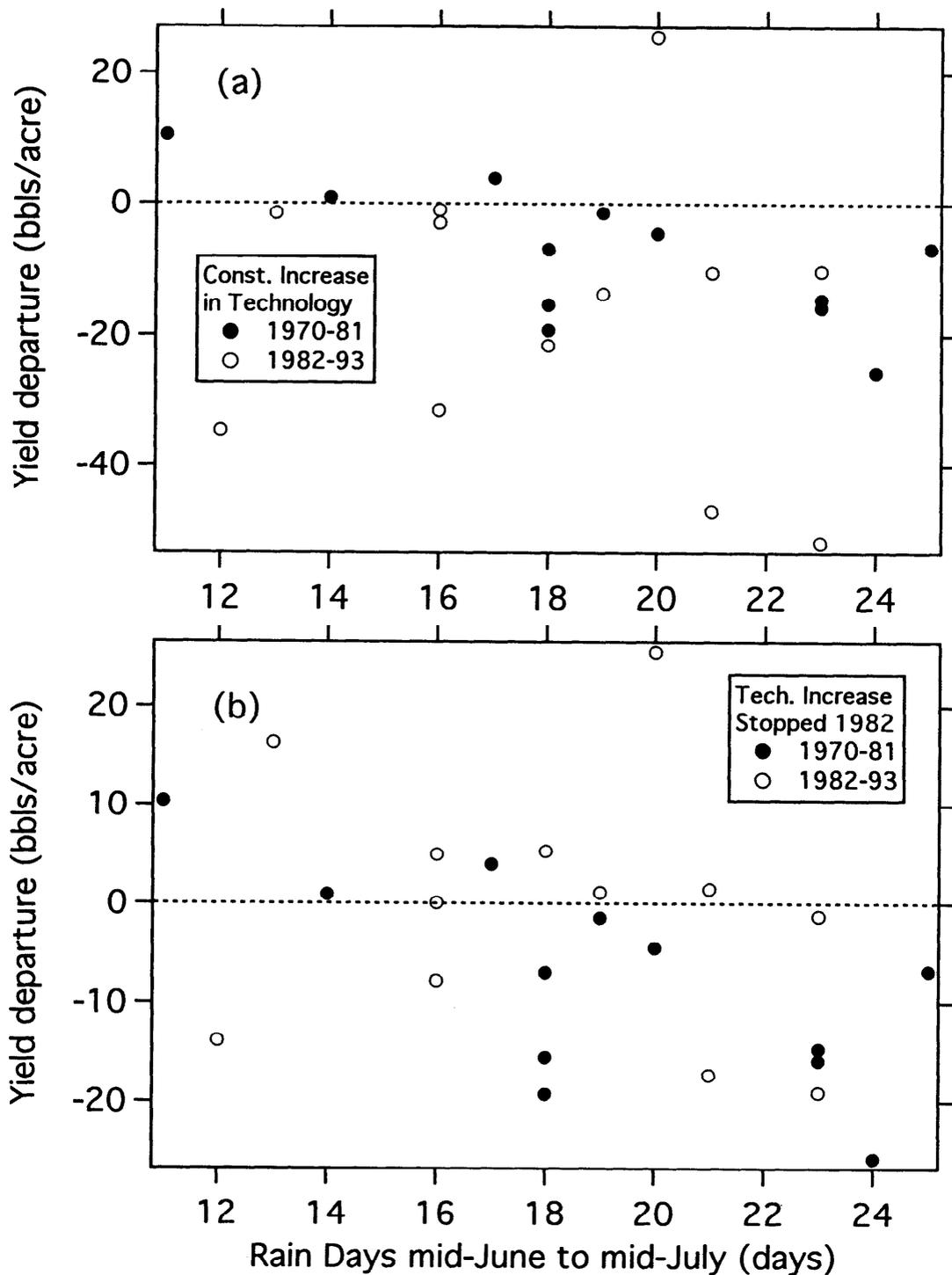


Fig. 9. Relationship of days of rain (mid-June to mid-July) to departures of cranberry yield from two hypothesized technology trends: (a) assuming technology continued to increase yields at the rate observed 1960-82, (b) assuming no new technology was introduced after 1982.