pounds per cow per day was maintained for 14 days with no adverse effects.

Conclusions

These results indicate that feeding citrus pulp to lactating dairy cows can lead to false or unconfirmed positive tests for penicillin when bulk tank milk is screened for antibiotics with the Angenics Spot Test. Our data demonstrate that false positives occur within 48 to 72 hours of initiating a relatively low level of citrus feeding (7 pounds as fed or 2.1 pounds of dry matter per cow per day).

False positives occurred with the feeding of both navel and Valencia oranges. Other field observations have indicated that false positives occur with both dry and wet citrus pulp. Little information is available on lemon pulp. Feeding dried lemon peel did not result in false positives for penicillin with the Spot Test in bulk tank milk samples taken recently from a large commercial dairy in Kings County.

The Charm Test and *B. stearothermophilus* disc assay produce absolute values above or below which a milk sample is considered positive or negative for antibiotics. The Angenics Spot Test requires subjective visual interpretation by a trained technician. This may cause inconsistencies in results of milk tests by different milk processing plants or by different technicians in the same plant. The 12 days of weak positive response to citrus pulp feeding in the first feeding period of this study reflects the subjective nature of the test. It took that long for the technician conducting the assay to decide that the test looked absolutely positive.

It is possible that the Angenics Spot Test detects a substance in milk that is in some way chemically related to penicillin, although negative disc assay tests indicate no antibiotic activity. The substance appears to occur in milk as a result of citrus feeding. It is also possible that the Spot Test is not specific for penicillin and that the antigen used in the test reacts with a natural constituent in citrus or a metabolite of the natural constituent in milk. Another University of California experiment is in progress to determine whether the condition causing false positive tests for penicillin could have a detrimental effect on cheese yield.

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Economic incentives for irrigation drainage reduction

John Letey ❑ Ariel Dinar ❑ Keith C. Knapp

A tiered water pricing policy could give farmers an incentive to avoid excessive irrigation

Public concern about environmental problems related to the disposal of agricultural drainage waters in California led to the adoption of Order WQ85-1 by the State Water Resources Control Board. One outcome of the order was a recommended interim water quality objective that would limit selenium to 5 parts per billion (ppb) in the San Joaquin River. The technical committee making the recommendation also stated that the interim water quality objective could be achieved without treatment of agricultural drainage water if subsurface drainage from existing tile-drained areas in the drainage study area were reduced from the existing 0.7 acre-foot per acre (8.4 inches) to 0.45 acre-foot per acre (5.4 inches).

Reports by a University of California Committee of Consultants and the Agricultural Water Management subcommittee of the San Joaquin Valley Drainage Program concluded that the proposed reduction of drainage flows was feasible and suggested adjustments in water management leading to the reduction. Actual drainage flow reduction, however, will only be achieved after farmers adopt the proposed management practices. As with any business, agricultural management decisions are driven by economic considerations. We conducted a research project analyzing economic incentives that might lead to adoption of the recommended practices.

Incentives

Reduction of drainage flows to avoid costly treatment processes represents an economic incentive to the agricultural community as a whole, but would not necessarily translate into individual farmer incentive. For example, a few farmers could reduce their drainage volumes to the target value and still have to contribute to costly treatment processes if the group as a whole did not reach the target value. Conversely, a few farmers who did nothing to reduce drainage volumes could benefit if the majority reduced volumes sufficiently to meet the overall goal. The drainage discharge goal is more likely to be achieved if the incentive is directed towards individual farmers.

Monitoring drainage flows from individual farms and penalizing those who exceed the discharge limit would provide a direct incentive. Such monitoring would be costly, however, and possibly unfair because of subsurface lateral water flows making it difficult to identify the source of the discharge.

Since drainage waters are generated by irrigation, placing a surcharge on irrigation water might indirectly provide an incentive for individual farmers to reduce drainage volumes. Increasing the price of irrigation water could also provide revenue for drainage water disposal. Our research considered both aspects of a surcharge, but this report addresses only the incentive to reduce drainage volumes into the San Joaquin River. Discharge would be free if the standards were met.

Drainage volumes are not directly related to irrigation volumes over the entire range of water application. Irrigation equal to or less than crop evapotranspiration (ET) results in very low drainage flows, but irrigation in excess of ET contributes significantly to drainage flows. A tiered irrigation water pricing policy in which water amounts greater than ET are priced higher than those less than ET might be appropriate to induce reduced drainage volumes. A flat fee increase on all irrigation water is an alternative policy. We compared both policies, which we refer to hereafter as tiered and flat fee.

Analysis

We selected cotton for analysis, because it is grown on more acreage than any other crop in the area. Crop-water production functions were computed from experimental data reported by scientists from the U.S. Department of Agriculture Water Management Laboratory in Fresno, California. Maximum crop ET was 28.7 inches, and we used this value as the cutoff point for imposing the tiered water pricing policy; that is, the first 28.7 inches of irrigation water would be provided at the usual base irrigation water price, and a higher premium price would be imposed for greater quantities.

The water quantity and drainage volume that would maximize farmer profits

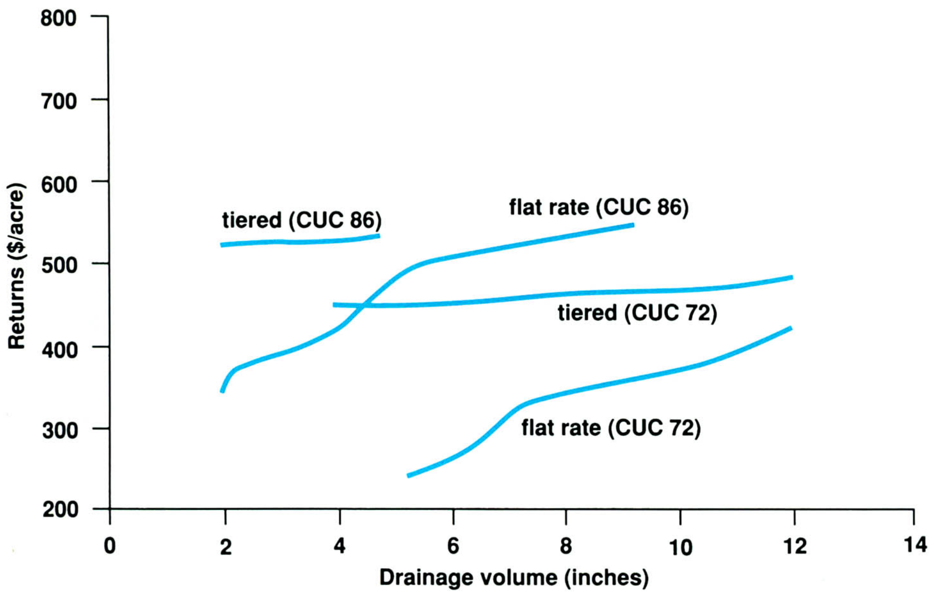

Fig. 1. Compared with a flat fee, tiered water pricing would permit farmers to reduce drainage with less loss in profits. Profits would be higher under the more uniform irrigation system for a given pricing policy.

were computed under a series of price levels for both pricing policies. Cotton prices were assumed to be 75 cents a pound. Computations were done for irrigation uniformities with Christiansen's Uniformity Coefficients (CUC) of 72 and 86. CUC is an index of irrigation uniformity with 100 representing perfectly uniform irrigation. A value of 72 is typical of some furrow-irrigated fields, and 86 or slightly higher can be achieved with well-designed and operated linear-move sprinkler or drip systems.

Results

Increasing the price of irrigation water by either policy would result in decreased water application, crop yield, and drainage volumes. Our computations provided relationships between profits, defined here as returns to land and management, and drainage volumes for the two water pricing policies and two irrigation uniformities (fig. 1). Two significant features of the results are that (1) decreased drainage flows would be induced with less loss to farmer profits by the tiered than by the flat rate pricing policy, and (2) profits would be higher under the more uniform irrigation system for a given water pricing policy.

Profits would be higher under tiered pricing than under the flat rate, because the optimal applied water would be dependent only on the cost of the last increment. This result is consistent with the economic principle that water is applied at the point where the marginal benefit (benefit from the last increment of water) equals the marginal cost (cost of the last increment of water). For example, in the case of an irrigation system with a uniformity of 72 and a water price of $96 per acre-foot, the computed optimal applied water was 30 inches and the drainage volume was 5 inches. This result was independent of whether all water was priced at $96 (flat fee) or whether it was on a tiered schedule with the first 28.7 inches at the $12 rate and higher quantities at the $96 rate. Under the flat rate, the farmers must pay the higher rate for all irrigation water, but with the tiered rate they get the majority of the water at the lower base price, thus the difference in farmer profits.

Rather large reductions in drainage volumes can be induced by the tiered pricing policy with a relatively small decrease in profitability because of the very strong incentive to apply very little water at the premium price. The tiered water pricing policy is clearly superior to the flat rate policy when the only purpose is to motivate drainage flow reduction.

Surplus funds

Increasing the irrigation water price above the base level by either policy would result in surplus revenues from the sale of irrigation water. Who is entitled to the surplus funds? Inasmuch as the price increase was to bring about reduced water application and the policy could be implemented at relatively low cost, the surplus might most appropriately be returned to the farmers based on units of irrigated land area.

Return of the "surplus" to the farmers would not reduce their incentive to reduce drainage volumes, because their payments would be based on irrigation amount and returns on irrigated area, regardless of applied water. This approach would penalize poor water management and benefit good water management, because the good manager could receive a larger monetary refund than was paid for the premium-priced water.

Conclusion

In drawing conclusions from this study, a number of factors must be considered: (1) The analysis was for cotton, which can tolerate some water stress without drastic yield reduction. Drainage flow reduction might be more costly for farmers growing crops that are more sensitive to water stress. (2) The analysis assumed that all plant-available water came from irrigation. Stored precipitation in the soil must be considered in choosing the applied-water value for tiered pricing. A logical procedure is to subtract the stored precipitation in the root zone from the maximum crop ET. The tiered price would be imposed for water contents greater than this value. This consideration makes implementation of the policy more complex because of the variability of precipitation patterns over time and in different areas. (3) The analysis assumed that the farmer could control the amount of applied water at each irrigation. "Over-irrigation," as might result from surface irrigation systems during pre-irrigation when soil infiltration rates are very high, would lead to a combination of higher drainage volumes and lower farmer profits than indicated by the results. The tiered water pricing policy, however, would provide a strong incentive for the farmer to avoid these "excessive" irrigations.

The specific values we have reported might thus need some adjustment, but the basic conclusions remain intact. Drainage reductions can be induced and goals for the San Joaquin River achieved by water pricing, and the tiered pricing policy should be more acceptable to farmers than the flat rate policy. Furthermore, the option of returning "surplus" funds to the farmers should make the policy attractive to them, particularly those who consider themselves to be good irrigation managers. Indeed, this policy rewards the good farmers, whereas the better farmers tend to be comparatively penalized in a system that directs the economic incentives to the agricultural community as a whole rather than to individual farmers.

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