index were relaxed to a level double that of the base standard, district costs would be minimized by continuing the spraying program and significantly curtailing the source reduction program.

The linear programming model was also used to evaluate the impact on mosquito population indices, district costs, and the least-cost combination of control methods when pesticide effectiveness (resistance) was varied. In the model, district costs increased rapidly when pesticide effectiveness dropped below 50 percent (resistance increased) (table 3). As effectiveness declined, greater and greater reliance would have to be placed on constructing sumps, ponds, and ditches to minimize costs while maintaining population indices within acceptable limits. Interestingly, the model indicates that *A. nigromaculis* light-trap night counts would drop to zero with this heavy emphasis on source reduction.

Implications

The findings of the abatement models imply that, even though pesticides used for mosquito control usually reduced mosquito population levels, they were too extensively used, given the alternatives. Although source reduction activities were generally more economically efficient in controlling mosquitoes, the models suggest that the effect of these activities was underestimated and that they were not efficiently substituted for chemical control in the district. Based on the models, we recommend that mosquito control districts deemphasize pesticides and substitute various source reduction activities for unnecessary pesticide applications. This recommendation does not mean complete substitution of source reduction for use of pesticides in the control agencies' abatement programs, because in emergency cases, such as epidemics, pesticides must be employed to reduce mosquito populations immediately.

In the past, pesticides to replace those that have become ineffective against mosquitoes were more readily available than they are at present or will be in the future. It can be expected that the substitution of more source reduction for unnecessary pesticide applications would help in preserving pesticide effectiveness by reducing the amount of selection pressure on mosquitoes.

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Tomatoes make efficient use of applied nitrogen

Francis E. Broadbent □ Kent B. Tyler □ Donald M. May

Processing tomatoes in California typically do not require heavy applications of nitrogen to attain maximum yields, presumably because they are able to use available soil nitrogen efficiently. A field trial was conducted in 1979 on Panoche clay loam at the University of California West Side Field Station using ^{15}N-depleted ammonium sulfate to measure fertilizer uptake efficiency and to distinguish between soil and fertilizer nitrogen utilized by the crop.

The variety UC 82 B was planted on 60-inch beds on March 7 and sprinkler-irrigated the following day to germinate the seed. Furrow irrigation was used after seedling emergence and stand establishment. All plots received 100 pounds of starter fertilizer 11-48-0 per acre at planting and 100 pounds phosphorus (P) as treble superphosphate at thinning time. The plants were thinned to clumps 10 to 12 inches apart and fertilized on April 25 with labeled nitrogen (N) at 0, 50, 100, 150 and 200 pounds per acre. Additional plots received 50 or 100 pounds N per acre plus 1 pound per acre of nitrapyrin nitrification inhibitor. Petioles were sampled at approximately three-week intervals during the season and analyzed for total and nitrate-N. Measurement of the isotopic composition of these forms of N permitted calculation of the amount of fertilizer-derived N present.

The tomatoes were harvested on August 1. In 25-square-foot sub-plots, whole plant samples were taken by pulling plants and shaking off the fruit for analysis of tissue and fruit. Fruit yields were obtained by harvesting the remaining 300 square feet of each plot with a mechanical harvester. Yield and quality determinations included total yield; average fruit weight; percentages of red, green, and cull fruit; soluble solids; pH; and color.

Petiole analyses

Except on the 35-day sampling date (May 30), total N in the petioles did not provide a basis of differentiating between fertilizer treatments. However, there were significant differences in fertilizer N in petioles on all dates except 15 days. The most responsive index of nitrogen status of the plants was fertilizer-derived nitrate-N in the petioles. The pattern of decrease in labeled nitrate-N in petioles during the course of the season was influenced to a pronounced degree by the level of N supplied (fig. 1.).

At the 50- and 100-pound application rates, the quantity of labeled nitrate-N in the petioles could be described quite well by an equation of the form

$$N = at^b$$

where N = nitrate-N derived from the added fertilizer, t = days since the fertilizer was applied, and a and b are constants. The rate of decrease of labeled N in petiole nitrate calculated from these equations for the 50-pound N application fell from 2,025 ppm N per day at 15 days to 52 ppm N per day at 30 days. The corresponding rates of decrease for the 100-pound N level were 2,480 ppm N per day at 15 days and 83 ppm N per day at 30 days. At the 150- and 200-pound N levels, the kinetics of petiole nitrate were more complex, but the rates of decrease were much smaller and the decline delayed in comparison with the lower fertilizer levels. It is clear from the very rapid changes in petiole nitrate that, if this value is used as an index of nitrogen sufficiency, the time of sampling is critical. Moreover, it is not surprising that the variability among replicate samples is high. The overall coefficients of variation for estimates of petiole nitrate varied from 14.4 to 38.1 percent, and the corresponding values for labeled petiole nitrate from 20.9 to 74.6 percent.

In this experiment, the persistence of fertilizer N in petiole nitrate beyond 55 days after fertilization was an indication that the crop had more N than it needed.

Yield

Fruit yields increased up to the 150-pound N level (fig. 2), but yield increases beyond the 43.8 tons obtained with 50 pounds N were not statistically significant. Yields obtained through use of nitrapyrin in conjunction with the 50- and 100-pound N appli-

Processing tomatoes at early growth stage show differences due to fertilizer nitrogen application. The bed to the right received no nitrogen fertilizer.

Efficiencies of Fertilizer N Uptake by Tomatoes Calculated by the Isotope and Difference Methods

Fertilizer N Applied	N uptake efficiency	
	Isotope method	Difference method
lb/acre	%	%
50	53.7	12.2
100	63.5	50.6
150	59.5	47.2
200	59.8	41.0
50 + nitrapyrin	56.7	21.6
100 + nitrapyrin	60.5	58.1

cations did not differ significantly from yields obtained without the nitrification inhibitor. None of the fruit quality indicators measured was affected significantly by fertilizer treatment.

N uptake

The ability of the tomato crop to utilize soil N is clear. Even at the highest rate of applied N, the amount of soil N in the crop exceeded that derived from fertilizer (fig. 3). It may be noted that, although tomatoes are not considered as responsive to applied N as are other crops, such as corn, total utilization of N by the tomato crop is as great. At the 100-pound N rate, the above-ground portions of the crop used a total of 244 pounds N per acre, equivalent to 45 pounds N per ton of dry matter produced. Corn requires about 20 pounds N per ton dry matter. Of the 45 pounds per ton utilized by the tomato crop, only 11.7 pounds were obtained from the applied fertilizer. Nitrogen in the fruit accounted for 69 percent of the total.

Although the crop was not strongly dependent on fertilizer N, its uptake of the applied N was quite efficient, as shown in the table, in which all values obtained by the isotope method are above 50 percent. It is interesting to note that the presence of nitrapyrin did not significantly change uptake efficiency. At the 50-pound N level, efficiency was about 3 percent higher with nitrapyrin than without it; at the 100-pound N level, efficiency was about 3 percent lower with nitrapyrin.

The value of using isotopically labeled fertilizer to evaluate a given management practice is illustrated by comparing the efficiency values obtained by the isotope method as opposed to the traditional difference method. In the latter, N uptake by an unfertilized control is subtracted from that in fertilized plots as a measure of the fertilizer contribution. Although the difference method often overestimates N-utilization efficiency, in this case it gave values much lower than the actual ones. On the basis of the difference method data it might be concluded that nitrapyrin produced a significant advantage, whereas in fact this was not the case. The relatively low cost of ^{15}N-labeled fertilizer makes its use attractive for field trials with other crops, and the method provides information not otherwise obtainable.

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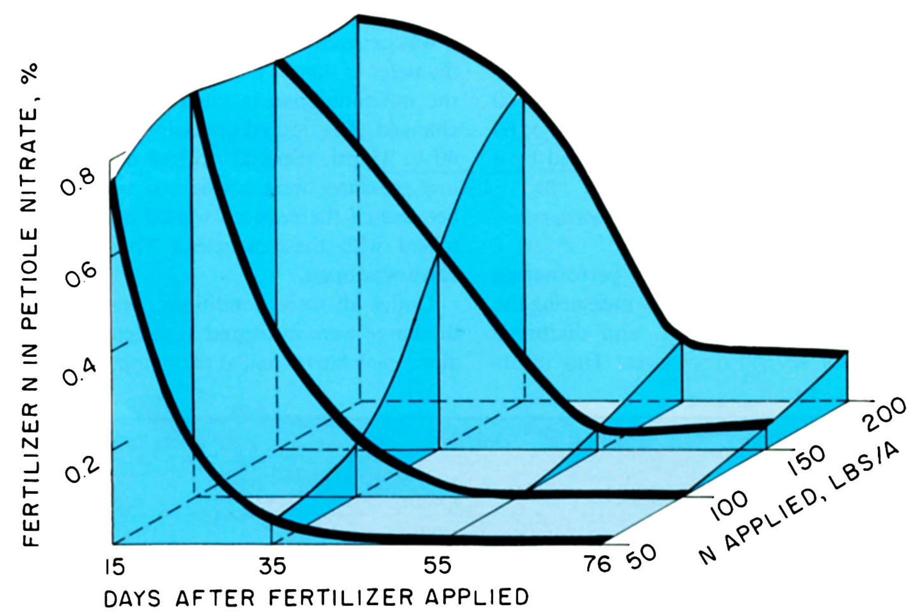

Fig. 1. Fertilizer N in petiole nitrate as affected by N application and time.

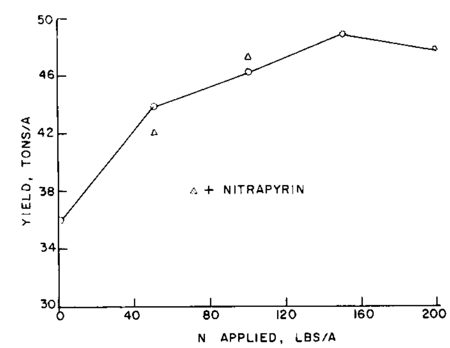

Fig. 2. Influence of applied N on yield.

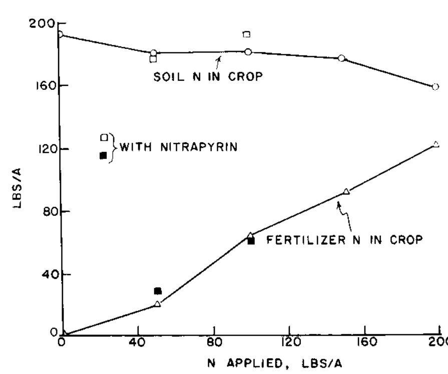

Fig. 3. Crop's uptake of soil and fertilizer N as affected by N applied.