14-N NITROGEN FERTILIZER TRACING EXPERIMENTS *in the San Joaquin Valley (1972-73)*

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This report describes the establishment of a long-term, field-scale nitrogen tracing experiment for fertilizer-nitrogen at the Kearney Field Station, Parlier. The isotopic 14-nitrogen (obtained from Los Alamos through the cooperation of the U. S. Atomic Energy Commission) has been found to be an effective, practical fertilizer-nitrogen tracer—and is expected to be of particular value in future experiments toward understanding the cycling of nitrogen through the environment.

SOCIETAL NEEDS for food and fiber that call for increasing use of fertilizer-nitrogen on agricultural lands have recently come into conflict with environmental considerations that indicate a need for lesser amounts of mineralized nitrogen (N) in the environment. This conflict places on agriculture the burden of accounting for the amount of fertilizer-N that may be lost to the environment. Obviously, compromises will have to be made in regard to N as an indispensable plant nutrient versus N as a water contaminant. Questions of water and energy conservation are also related to efficiences to be gained through fertilizers.

Since isotopic nitrogen can be used to trace the pathways taken by fertilizer-N, long-term experiments with isotopic 14-nitrogen (14-N) were started in the spring of 1972 at the Kearney Horticultural Field Station. These isotopic-N tracing experiments were designed to gain more accurate information about the fate of fertilizer-N after it is applied to soils, and they have shown that fertilizer-N can be traced successfully in the field.

Ordinary nitrogen atoms of the atmosphere, soils, plants and fertilizers always consist of two different nitrogen isotopes, or atoms, that are chemically alike in their reactivities, but different in mass by one atomic mass unit. The ratio of numbers of these isotopes is very nearly 271 atoms of 14-nitrogen to one atom of 15-nitrogen, as they occur in nature. Isotopic ratios can be measured readily with mass-spectrometer techniques.

Isotopic 14-nitrogen was separated in sufficient quantity at the Los Alamos Scientific Laboratories (LASL) during 1972–73 for full scale cropping experiments. Fertilization schedules began in April 1973 on 24 plots of 1/15 acre each at University of California's Kearney field station located near Parlier, Fresno County. The experiments were directed toward tracing fertilizer-nitrogen pathways in an irrigated, heavily-cropped, alluvial soil (Hanford sandy loam) of a kind that typifies much of the highly productive irrigation agriculture in the Western States.

Hybrid maize (corn) was selected as the test crop for three principal reasons: (1) its relatively high demands for fertilizer-N; (2) its increasing importance as a crop in irrigated regions; and (3) its undisputed position as the predominant crop species cultivated within the USA. Also, since maize is a row crop, its impacts upon the environment have elements in common with other row crops, such as vegetables, that require high amounts of fertilizer-N.

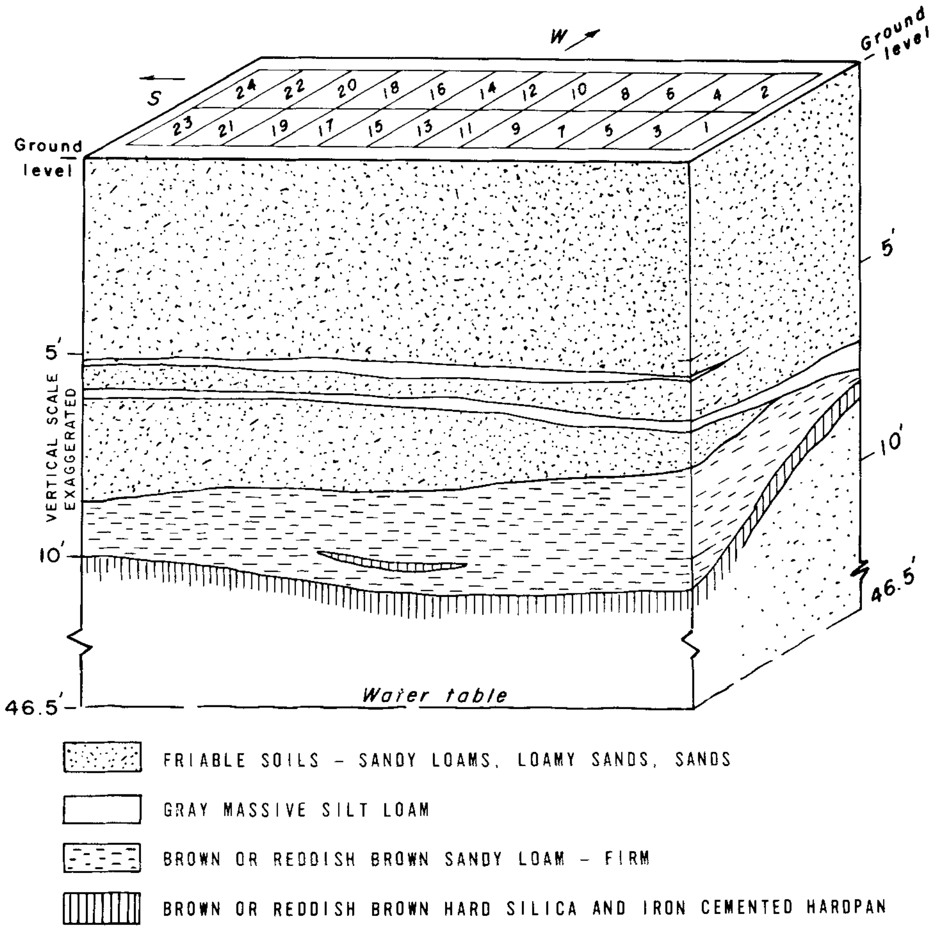
The field layout at the Kearney Station (see photo) was designed to provide plots large enough to be cultivated, planted, irrigated and harvested with commercially available farming equipment—so that the visible plots might be more convincingly relevant to agriculturists and others concerned with environmental impacts of agriculture. There was also the need to keep the plots small enough to allow laboratory types of control over experimental variables—thus bringing more of the factors of practical agricultural management realities into juxtaposition with the precision of laboratory-type experiments. Also considered, was the need to acquire numerical evaluations from intermediate-scale plantings to assist in improving the accuracy of forecasts of the fate of nitrogen from fertilizers, as predicted from computerized models of whole-farm operations.

Some departures from standard practices had to be made, however. Water applied by sprinkler irrigation, was carefully monitored. Thinning and weeding was done by hand. Precision applications were made of the 14-N labeled fertilizer. Frequent collections were made of samples of soil cores, irrigation water and plant materials.

For accuracy in placing the fertilizers, a mechanized, positive-displacement, piston-pump fertilizer-applicator was designed and built. Ammonium sulfate solutions were implanted within the soil with an accountable precision of one per cent—both in linear uniformity of placement, and in total nitrogen applied. Ammonium sulfate solutions were always dispensed at a fixed volume per row, with dilutions being made to give delivery rates between 33 and 333 lbs of 14-N per acre. This applicator, mounted on a garden tractor, performed remarkably well. The starting point of fertilizer-N tracing was established with the same degree of accuracy sought from chemical analytical work performed in the laboratory. All fertilizer allotments were made by weight measurements that were accurate to better than one per cent.

Spreading of irrigation water was (and will probably remain) the weakest point in the overall system. Under the best of circumstances, variabilities of less than ± 10% in distribution and penetration of irrigation water could rarely be achieved in any field situation. Compensation for changes in water distribution patterns induced by winds, plant heights, and sprinkler-head performances must be made mathematically from recordings of quantities, and qualities, of water supplied at any given time. Irrigation water monitoring was particularly important because any plant-available nitrogen in the irrigation water supply (about 2.5 ppm in this case) had to be accounted for in the final balance-sheets. Therefore, nitrogen contents of the well water were monitored throughout the irrigation season. During winter and early spring *rains*, glancing-angle photographic records of test plot surfaces were made to help determine the surface transfer potentials of rain water, from otherwise undetectable "high" and "low" spots within the test site. No rains occurred during the cropping season.

The isotopic 14-N plot layout at the Kearney Field Station.



The Kearney Horticultural Field Station plots are underlain by a slowly-permeable hardpan at 10 to 12 ft depths. The water table is at 46 ft (see sketch). Plots were treated with the 14-N fertilizer at six rates in split applications, the first application being 0, 33, 67, 100, 133, and 167 lbs, N per acre with the second application bringing the treatments up to the full levels of 0, 100, 200, 300, 400 and 500 lbs N per acre. Each treatment was replicated four times in a randomized block design giving individual treatment plots of 1/15 acre each. The first split-application was side dressed as an ammonium sulfate solution at the time of planting by drilling the solution into the soil in two side-rows 4 inches deep and 4 inches away from the seed-row. Thirty-eight days after first emergence, the remaining two-thirds was drilled between the corn rows with four chisels placed 6½ inches apart and 2 inches deep. All samplings of plant materials that are reported here took place before this second application so that the responses shown in table 1 and the graphs, are to N-fertilization rates of 0, 33, 67, 100, 133 and 167 lbs N per acre.

Slight differences of planting depth caused some plants to emerge seven days after planting, while other plants were delayed for another five days. Overhead sprinkling was started on the sixth day after planting, as an aid to seedling germination and emergence. This resulted in two sizes of plants, scattered evenly among the treatments and replications. At first sampling, individual plants were chosen from each of the two size groups with their identities being kept separate in the two stages of maturity (five days apart). These two sets were then sampled on the sixteenth day of first emergence, which was also the eleventh day from the second emergence. At the second sampling, 27 days after mean emergence date, the plants of different emergence times could not be distinguished from one another as to size. Therefore, all plants were considered to be at the third stage of maturity although they had a five-day range in ages. The samplings consisted of taking whole plants (above ground parts) chosen randomly from each treatment plot. The plant samples were then dried, ground and analyzed for total N and 14-N/15-N ratios.

From the isotopic-N ratios, the percentage of nitrogen in the corn plants which came from the applied fertilizer was calculated from the following formula: % Fert-N = 100 $(S_U - S_T)/(S_U - S_F/n)$—where: S_U = atom % 15-N in unfertilized plant; S_F = atom % 15-N in fertilizer (which is 0.0060%); and n = the plant discrimination factor between 14-N and 15-N. No discrimination was assumed between 14-N and 15-N—therefore: n = 1.

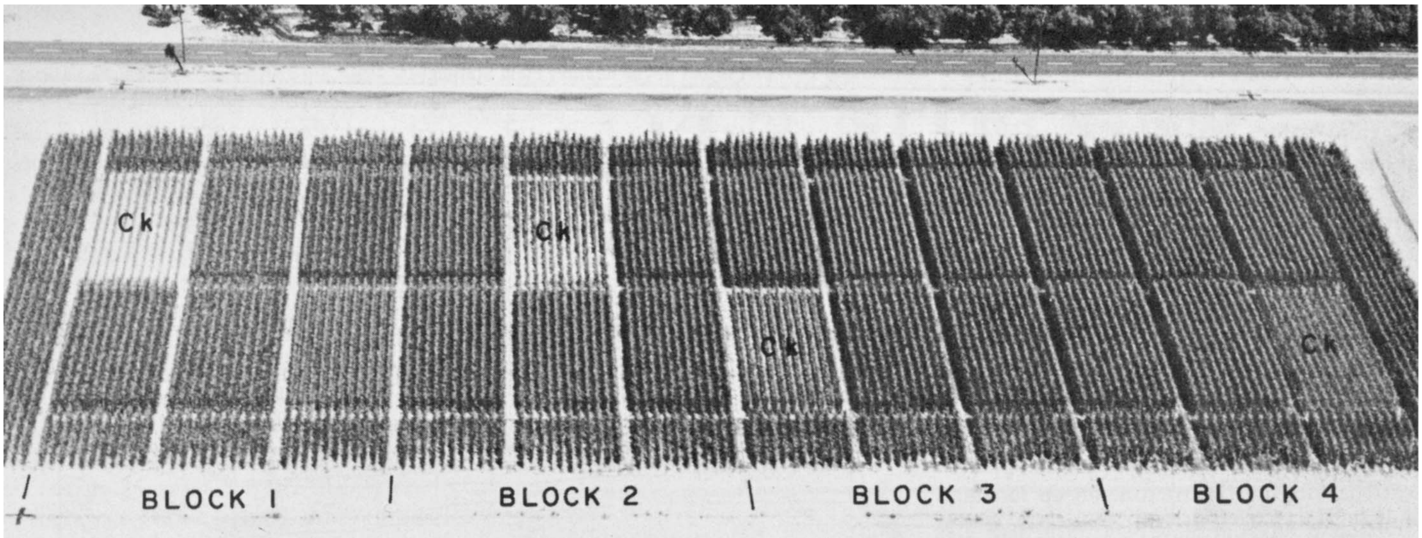
In using this formula, the isotope ratio in the unfertilized check plot within each block was used as the normal ratio for that particular replication. (Isotopic-N ratios in soils vary slightly from the isotopic ratio of atmospheric nitrogen.)

The success of isotopic 14-N tracing under field conditions was surprisingly evident from the isotope ratio analyses of the first set of samples collected from the 11-day-old plants.

Even with the lowest fertilization rate of 33 lbs of isotopic 14-N per acre, the relative abundance of 15-N found in young plants that had received 14-N fertilizer ranged between 0.0974 and 0.1458 atom per cent, as against the natural 15-N mean abundance of 0.3655 atom per cent found in the plants grown on unfertilized check plots. Since the routine analytical determinations of mass-ratios (made with a dual-collector, mass-ratio spectrometer) were good to about ± 0.002 percentage units of the minor 15-N abundance, measurement of the proportion of fertilizer-N in these particular samples was good to about 100 (± 0.002) /(0.366–0.146) = ± 0.91 per cent or better.

Although the mass-spectrometer had a capability for higher precision—at a cost of fewer samples being run for time expended—in the present instance not much was to be gained by pushing sensitivities or precision beyond ± 0.002 atom per cent of 15-N. Sensitivities of measurements were increased 10 times, however (to ± 0.0002 percentage units of the minor 15-N abundance), for the special purposes of determining 15-N background levels of soil organic matter in the soil profiles at the test-plot site, and also to determine the 15-N background levels of the 14-N fertilizers that were applied to the plots.

Conventional chemical analyses of whole shoots of maize at these earlier



Aerial photograph of the 14-N field test plots (check plots show increasing amounts of available soil-N from block 1 to block 4).—photograph taken July 17, 1973.

stages of growth (table 1), imply that the parts of root systems within the fertilizer treated volume were nearly saturated with respect to their ability to take in nitrogen. The mean N contents of plants from all fertilizer rates (except 0 rate) were 5.12%, 4.75% and 3.76% respectively for the samplings taken 11, 16, and 27 days after emergence. Also, the analyses showed plant-N increases of about 57%, 59% and 107% respectively above the N contents of the unfertilized check plants.

However (from the analyses of 14-N/15-N ratios in the plants), the plotted graphs unequivocally show that the amounts of plant-absorbed fertilizer-N ranged from 60% to 90%, rather than from 36% to 52%, as implied by the conventional approach.

The detailed tracings of fertilizer-N uptake by the plants from the isotopic 14-N fertilizer were quite impressive—particularly because of both the agreements, and departures, observed for replicate blocks as shown in the graphs. Also, table 2 shows that precision and sensitivity of isotopic 14-N tracing was significant at the 1 per cent level in revealing differences in (a) fertilizer-N uptake between 11 and 27 days after emergence, (b) the influence of fertilizer rate, and (c) influences of different levels of non-fertilizer soil-N. From the first sampling date, 11 days after emergence, 70.6% of plant-N came from fertilizer-N (average of all treatments). This percentage increased to 73.2% by the sixteenth day, and to 78.3% on the twenty-seventh day after emergence. These increasing proportions of fertilizer-N uptake occurred even though the root systems at 27 days were larger, and included volumes of soil beyond the diffusion zone of the side dressed fertilizer.

Table 2 also shows significant differences between replicate blocks in the percentage of plant-N derived from fertilizer-N. Aerial photographs of the plots (see photo) also showed evidence of differences in amounts of native soil-N among these blocks, in the following order: block 1 < block 2 < block 3 < block 4.

Both the statistical analyses and the final plottings of regression lines in the graphs were accomplished by means of a computerized plotting board that was programmed to make the statistical analyses directly from basic data inputs. Values of B in the equation $Y = AX + B$ of the regression lines suggest that the uptake of fertilizer-N applied within the range of the graphical model (bracketing 30 to 170 lbs N per acre) decreased in the order of block 1 > block 2 > block 3 > block 4. Extrapolations of fertilizer-N contained in plant-N at 30-lb fertilizer-N application rates for blocks 1, 2, 3 and 4 cross the Y axis at 74%, 73%, 70%, and 62% for the eleventh day after emergence; 77%, 75%, 72%, and 68% for the sixteenth day; and 78%, 76%, 68%, and 66% for the twenty-seventh day.

The low correlation coefficients in the graphs simply mean that the plant-N needs were largely satisfied at 30 lbs of N per acre or less. By the twenty-seventh day of postemergence however, each of the four blocks were responding significantly to the higher fertilization rates, as evidenced by the respective correlation coefficients of .848, .885, .922, and .748 for blocks 1 through 4.

These experiments are now being carried through the harvest phase. They will continue to yield detailed information on nitrogen uptake from fertilizers. Analyses of tracer isotopic-N in soil samples to be taken following harvest will result in a new departure for balance sheet calculations of N-distributions that will include fertilizer-N taken up by the corn plants, exported with saleable grain, and the amounts of fertilizer-N that enter into the soil-organic-matter pool.

TABLE 1. FERTILIZER-N UPTAKE BY CORN PLANTS AS IMPLIED BY CONVENTIONAL ANALYSES (TOTAL NITROGEN CONTENTS AS % OF DRY WEIGHT FROM PLANTS GROWN ON BLOCKS 1, 2, 3 AND 4)

Fertilization Rate lb N/acre	11 days after emergence				16 days after emergence				27 days after emergence			
	1	2	3	4	1	2	3	4	1	2	3	4
0	2.91	3.26	3.52	3.39	2.81	2.92	3.19	3.03	1.82	1.87	1.84	1.74
33	5.21	5.15	5.12	4.97	4.87	4.80	4.55	4.72	3.03	3.24	2.63	2.98
67	5.31	5.46	5.12	4.78	4.89	5.04	4.69	4.72	3.72	3.69	3.45	3.82
100	5.20	5.02	5.05	5.05	4.56	4.89	4.49	4.87	4.10	3.80	3.66	3.92
133	5.37	5.14	5.04	5.03	4.93	4.70	4.79	4.78	4.30	4.14	4.14	4.05
167	5.31	5.19	4.93	5.00	4.71	4.75	4.79	4.59	4.28	4.23	4.04	4.01
Mean % N (all replicates and treatments except 0)	5.12				4.75				3.76			
Mean % N (all replicates of 0 treatment)	3.27				2.99				1.82			
% plant N (net increase due to fertilization)	56.6				58.9				106.6			
% plant-N (imputed to fertilizer-N)	36.1				37.1				51.6			

These Kearney Field Station experiments represent one of the opening phases in a new era for tracing the routes taken by nitrogen after it is applied in the field as a fertilizer. They have been made possible by the recent breakthrough in very low-temperature cryogenic techniques whereby nitric-oxide gas (NO) is liquified and then distilled to separate the stable 14-N and 15-N isotopes that occur in nature. Thus a long-standing technological gap has been closed so that isotopic-N tracing techniques of the kind reported here may become common in the future.

These experiments are planned for five consecutive years of fertilization with traceable 14-N. Thereafter, tracing can be continued into the indefinite future without further additions of tracer nitrogen. Thus future questions relating to long term nitrogen uptake by crop plants may be answerable from these Kearney Field Station plots.

Contributions of fertilizer-N to plant-N: (a) 11 days after emergence of maize seedlings; (b) 16 days after emergence of maize seedlings; and (c) 27 days after emergence of maize seedlings.

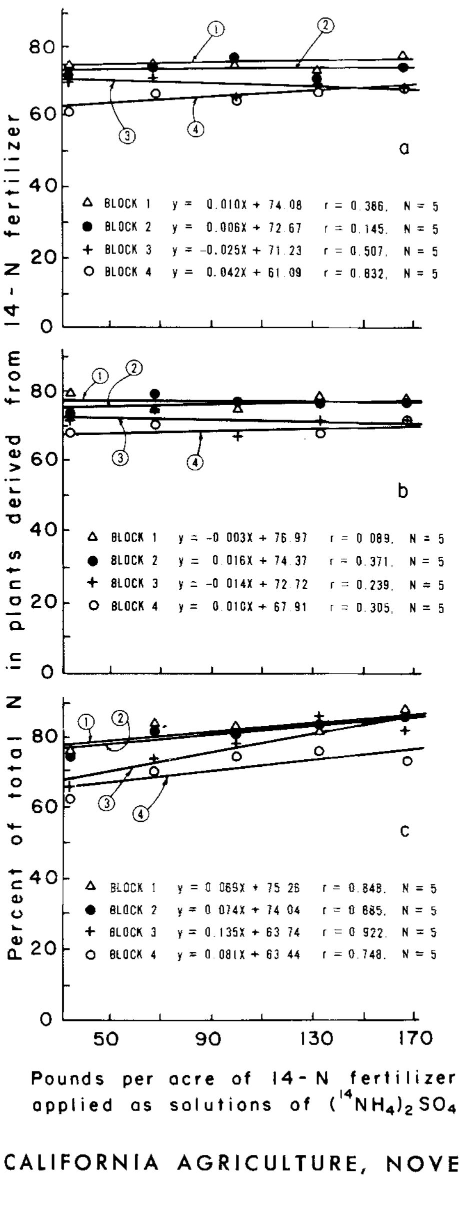


TABLE 2. PRECISION AND SENSITIVITY OF ISOTOPIC 14-N IN EARLY TRACING OF FERTILIZER-N UPTAKE BY MAIZE PLANTS

(A) Overall mean percentages of contained fertilizer-N found in plant-N at 11, 16 and 27 days

Days after emergence	11	16	27
% contained fertilizer in plant-N	70.6	73.2	78.3

(LSD .05 = 5.38; LSD .01 = 7.17)

(B) Overall mean percentages of contained fertilizer-N found in plant-N from various fertilizer-N treatments (all replications and all sample dates)

Pounds of isotopic 14-N applied per acre	0	33	67	100	133	167
% contained fertilizer-N in plant	0	70.6	74.8	73.8	75.1	76.0

(LSD .05 = 4.17; LSD .01 = 5.56)

(C) Overall mean percentages of contained fertilizer-N found in plant-N for all sample dates and all fertilization rates except zero.

Block number	1	2	3	4
% contained fertilizer-N in plants	77.8	76.9	72.4	68.9

(LSD .05 = 4.66; LSD .01 = 6.22)

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Weather effects on baits for controlling EUROPEAN BROWN GARDEN SNAILS IN CITRUS

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Weather conditions following bait treatments for the control of the European brown garden snail in citrus groves substantially influenced the ultimate effectiveness of carbamate molluscicides. Baits containing Mesurol were more effective under unfavorable conditions than the other carbamates used in the tests. Under optimum treatment conditions, all of the carbamate baits were effective, particularly those with metaldehyde inclusions.

SINCE THE CARBAMATE INSECTICIDE Isolan was first reported to possess molluscicidal properties, and with subsequent discoveries that several other carbamate compounds are also effective against mollusks, particularly snails, it has become increasingly apparent that the total effectiveness of these compounds is appreciably influenced by weather conditions during and immediately following their application. These observations have led to the usage of such warnings as "carbamate-based molluscicides should be applied during periods of high snail activity when warm drying weather following treatment is anticipated," or that "many treatment-affected snails, afforded protection of shade and dampness following treatment, may recover." While these statements were supported by repeated field observations, the actual differential of control achieved by similar carbamate treatments, when applied just before drying or non-drying weather conditions, had not been viably demonstrated in cooperative field trials. Although such comparisons could not be purposefully arranged, field tests undertaken in the spring of 1971, and in the spring of 1972 (involving comparable treatments) happened to provide such a comparison.

Immediately following the 1971 test applications, an unpredicted storm system moved into the general area. While no measurable precipitation fell, there was a heavy overcast and morning drizzle for a week following treatment applications. When the weather did clear, there were several more days that remained cold because of wind conditions. Conversely, following the 1972 test applica-