similar to those obtained in the spring trial.

Spring trial–1972

This trial compared a standard commercial granular row furrow treatment used without seed treatment, three seed treatment fungicides effective for Pythium and systemic Demosan fungicide. Acid-delinted Acala SJ-1 cotton seed was used in the 1972 trials and seed treatment rates were per 100 lbs of cotton seed (table 4). Three hundred cotton seeds were planted per replicate on April 25 and the plot was replicated six times. Rhizoctonia inoculum was applied in furrow at planting time as in previous experiments. Healthy appearing plants were counted on May 24.

PCNB-Terrazole granular used alone without seed treatment and Demosan plus either Dexon, Captan, or Arasan provided excellent control of Rhizoctonia seedling disease of cotton. Terra-Coat L-21 provided intermediate control of the disease as a combination material and was significantly better than Arasan used alone.

Summer trial–1972

Captan and Difolatan flowable were used with two rates of Vitavax F seed treatment and compared with the effective combination Arasan plus Demosan seed treatment. Acid-delinted Acala SJ-1 cotton seed was used in this trial and seed treatment rates were per 100 lb of cotton seed. Inoculations were made by Rhizoctonia in-furrow application at planting time. Three hundred cotton seeds were planted per replicate on June 7 and replicated five times. Healthy-appearing plants were counted on June 29 (table 5).

Arasan plus Demosan seed treatment was significantly better than all other treatments for the control of Rhizoctonia seedling disease of cotton. Intermediate in control was Captan and Difolatan used in combination with Vitavax. Doubling the amount of Vitavax used in the combination did not significantly increase control. Difolatan used alone provided the poorest control of Rhizoctonia seedling disease.

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USING ORGANIC

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EVEN THOUGH ORGANIC WASTES have been used as sources of nutrient elements for many centuries, a rational basis for their use has never been developed. Recommended rates have been based on experience and research planned without the ability to match application rates to the needs of crop plants, and with little information on the rate of biological decay of the organic materials.

Research on organic materials, particularly animal wastes, was popular previous to the availability of inexpensive inorganic N fertilizers following World War II. With a shift to the inexpensive inorganic N sources with their many advantages, the research on organics decreased. Interest and activity with organics has increased in the past 5 years largely as a result of the need for land disposal of large volumes of animal wastes. At present, the concern for animals wastes remains high, and in addition, interest in land disposal of municipal sludges has increased.

Field research presently underway with animal wastes and municipal sludges as sources of available N for plants is still based largely on experience. The usual approach is to add various amounts of wastes and to measure the amounts of N used by plants and the amounts of N in the soil in available and organic form. No theoretical basis for matching rates to crop needs has been proposed or tested for continued use over a period of years.

Agricultural land will be needed for disposal of wastes in the future. A scarcity of inorganic fertilizers may result from fuel shortages. In the future, organic sources of N will be needed to maintain optimum production of food and fiber as the supply of inorganics decreases; and it will be necessary to avoid excesses of nitrates because of the way this ion moves into surface and groundwaters. These are some of the reasons for a rational approach to determining application rates of organics. This study proposes an approach which is consistent with these needs and with the long-term use of organics as N sources.

Mineralization rates

Organically combined N must be mineralized before it can become available to plants. Thus, the rate of mineralization is the key to the rate of application of any given material. The yearly rates of mineralization are expressed as a series of fractional mineralizations of any given application, or the residual of that application. These are referred to hereafter as a *decay series*. For example, the decay series, 0.30, 0.10, .05, means that for any given application, 30% is mineralized the first year, 10% of the residual (that which was not previously mineralized) is mineralized the second year, and 5% of the residual is mineralized the third and all subsequent years. The same series is applied individually to each yearly application of organic N.

With this decay series, if 100 lbs N were added per acre per year, the mineralized N the first year would be 30 lbs per acre, the second year it would be 30 lbs from the second application and 7 lbs from the first application (10% of the residual, which is 70 pounds) for a total of 37 pounds per acre. During the third year the total N mineralized would be 30 ($.30 \times 100$) plus 7 (0.10×70) plus 3.2 (0.05×63) for a total of 40.2 lbs per acre. The total mineralization each year over a long period of time can be calculated in a similar fashion. Because these calculations become rather tedious, computer programs were developed to handle a number of decay series in combination with various rates and times.

WASTES AS NITROGEN FERTILIZERS

Constant input approach

The objective of the "constant input approach is to calculate the expected yearly N mineralized for given combinations of decay series, and constant rates of annual application of organic material. A number of decay series were studied but only those which were judged to be appropriate for five animal waste materials and one municipal sludge were selected for this report. These wastes are under consideration for use on irrigated lands of California valleys where the seasons are hot and long and where the winter temperatures in the soil seldom decrease to a low enough level to stop microbial decomposition of organic residues. Thus, the end number in each series is 0.06 or 0.05—a relatively high final rate of mineralization of the residual organic N, as compared with that expected in colder climates.

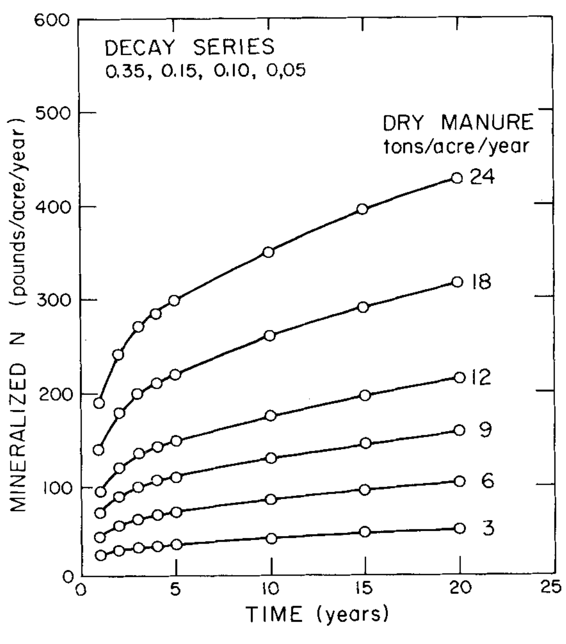
Table 1 presents data on the ratios of yearly mineralization to the application rates at constant inputs of N for six decay series for a 20-year period following the initial application. The multiplication of these ratios times the annual rate of application of N will give the lbs of N mineralized per acre per year for any specific year. For example, at a constant rate of 100 lbs of N per acre per year, the decay series 0.20, 0.10, 0.05 gives 20, 28, and 32 lbs N mineralized per acre per year, respectively, for the first, second and third years.

Graph 1 presents the relationships of the yearly mineralization rate; the time and yearly inputs of corral manure having 25% water, 1.5% N on a dry weight basis; and a decay series of 0.35, 0.15, 0.10, 0.05. In this case the yearly mineralization increases by a factor of 1.57 in 5 years, 1.86 in 10 years, 2.08 in 15 years and 2.26 in 20 years. Thus, to substitute this manure for inorganic N sources for a cropping system that needs 200 lbs of available N per acre per year, it would be necessary to add 24 tons the first year, and decrease the rate to less than 12 tons for the 20th year. If 24 tons were added continually, the requirements of the cropping system would be greatly exceeded after a few years. If 12 tons per acre were added per year as a constant rate of input the crops would be starved for a 15-year period before mineralization would be built up to the desired level.

Because of this gradual increase in yearly mineralization, as the residual organic N in the soil increases, constant rates of application of most organic N sources are not desirable. If a constant rate that will build up to the desired yearly mineralization is being used it can be supplemented with inorganic sources until the organic source can supply all that is needed.

The decay series 0.90, 0.10, and 0.05

GRAPH 1. YEARLY MINERALIZATION RATE IN RELATION TO TIME FOR VARIOUS CONSTANT RATES OF CORRAL MANURE HAVING 25% WATER AND 1.5% N ON A DRY WEIGHT BASIS.



GRAPH 2. YEARLY RATES OF APPLICATION OF MANURE, CONTAINING 25% WATER AND 1.5% N ON A DRY WEIGHT BASIS, REQUIRED TO MAINTAIN VARIOUS CONSTANT YEARLY RATES OF N MINERALIZATION.

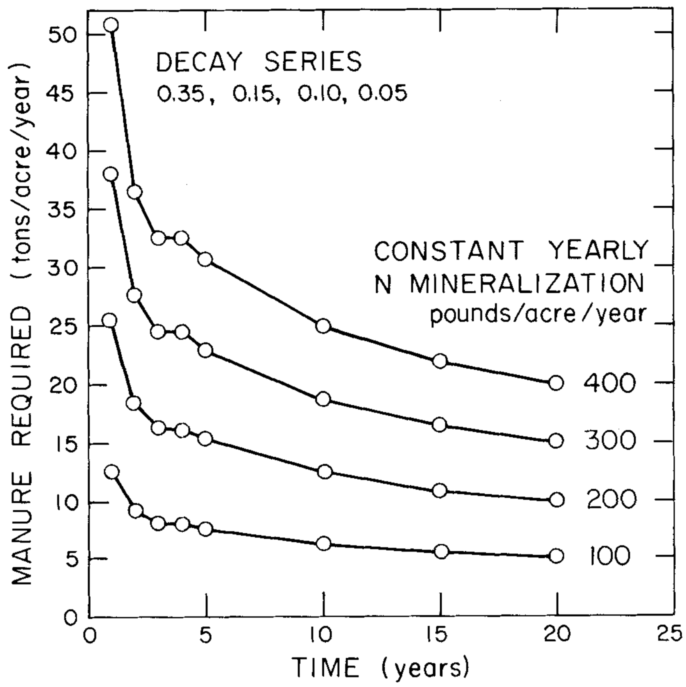


TABLE 1. RATIOS OF YEARLY MINERALIZATION RATES TO ANNUAL APPLICATION RATES OF ORGANIC WASTES AT CONSTANT ANNUAL INPUTS OF N FOR SIX DECAY SERIES FOR VARIOUS TIMES FOLLOWING THE INITIAL APPLICATION.*

Decay series	Typical material†	Time, years							
		1	2	3	4	5	10	15	20
		Mineralization/application ratio							
0.90, 0.10, 0.05	Chicken manure	0.90	0.91	0.92	0.92	0.92	0.94	0.95	0.96
0.75, 0.15, 0.10, 0.05	Fresh bovine waste, 3.5% N	0.75	0.79	0.81	0.82	0.83	0.87	0.90	0.92
0.40, 0.25, 0.06	Dry corral manure, 2.5% N	0.40	0.55	0.58	0.60	0.63	0.73	0.80	0.85
0.35, 0.15, 0.10, 0.05	Dry corral manure, 1.5% N	0.35	0.45	0.50	0.53	0.55	0.65	0.73	0.79
0.20, 0.10, 0.05	Dry corral manure, 1.0% N	0.20	0.28	0.32	0.35	0.38	0.52	0.63	0.72
0.35, 0.10, 0.05	Liquid sludge 2.5% N	0.35	0.42	0.44	0.47	0.50	0.61	0.70	0.77

* This ratio equals the pounds of mineralized N in any year per pound of N added per year.
† The N content is on a dry weight basis.

TABLE 2. RATIO OF YEARLY N INPUT TO ANNUAL N MINERALIZATION RATE OF ORGANIC WASTES AT CONSTANT YEARLY MINERALIZATION RATE FOR SIX DECAY SERIES FOR VARIOUS TIMES FOLLOWING INITIAL APPLICATION.*

Decay series	Typical material†	Time, years							
		1	2	3	4	5	10	15	20
		N input/mineralization ratio							
0.90, 0.10, 0.05	Chicken manure	1.11	1.10	1.09	1.09	1.08	1.06	1.05	1.04
0.75, 0.15, 0.10, 0.05	Fresh bovine waste, 3.5% N	1.33	1.27	1.23	1.22	1.20	1.15	1.11	1.06
0.40, 0.25, 0.06	Dry corral manure, 2.5% N	2.50	1.56	1.74	1.58	1.54	1.29	1.16	1.09
0.35, 0.15, 0.10, 0.05	Dry corral manure, 1.5% N	2.86	2.06	1.83	1.82	1.72	1.40	1.23	1.13
0.20, 0.10, 0.05	Dry corral manure, 1.0% N	5.00	3.00	2.9	2.44	2.17	1.38	1.13	1.04
0.35, 0.10, 0.05	Liquid sludge, 2.5% N	2.86	2.33	2.19	2.03	1.90	1.45	1.22	1.11

* This ratio equals pounds of N input required to maintain a constant annual rate of N mineralization.
† The N content is on a dry weight basis.

TABLE 3. TOTAL N INPUT REQUIRED TO MAINTAIN A YEARLY MINERALIZATION RATE OF 200 POUNDS PER ACRE/YEAR THROUGH A 20-YEAR PERIOD FOR TWO DECAY SERIES FOR EACH OF SIX TYPES OF WASTES.*

Material and decay series	Time, years							
	1	2	3	4	5	10	15	20
	Nitrogen input, lbs/acre/year							
Chicken manure								
0.90, 0.10. 0.075, 0.05, 0.04, 0.03	222	220	218	217	216	214	212	210
0.90, 0.10, 0.05	222	220	219	218	217	213	209	207
Fresh bovine waste, 3.5% N								
0.75, 0.15, 0.10, 0.075, 0.05, 0.04, 0.03	267	253	246	242	240	231	223	218
0.75, 0.15, 0.10, 0.05	267	253	246	244	241	230	221	215
Dry corral manure, 2.5% N								
0.40, 0.25, 0.06, 0.03	500	312	349	332	326	295	272	255
0.40, 0.25, 0.06	500	312	349	316	308	258	232	218
Dry corral manure, 1.5% N								
0.35, 0.15, 0.10, 0.075, 0.05, 0.04	571	412	367	343	336	291	270	240
0.35, 0.15, 0.10, 0.05	571	412	367	364	344	281	245	225
Dry corral manure, 1.0% N								
0.20, 0.10, 0.075, 0.05, 0.04, 0.03	1000	600	490	475	451	361	300	261
0.20, 0.10, 0.05	1000	600	580	489	437	277	225	208
Liquid sludge, 2.5% N								
0.35, 0.10, 0.06, 0.05, 0.04, 0.03	571	465	427	400	384	331	292	265
0.35, 0.10, 0.05	571	465	437	406	379	290	245	223

* The first decay series presented is meant to represent a slower rate of mineralization of the residual N from each yearly application.

is considered to be typical of organic materials in which the N is largely in the form of urea or uric acid which mineralize rapidly and easily. Such materials are nearly as available as inorganic sources. Chicken manure is considered to be nearly as available as inorganic sources and is thus listed as a typical example of this decay series. The series 0.75, 0.15, 0.10, 0.05 represents materials in which about 50% of the N is in the form of urea or uric acid; the other half consisting of N in the form of slowly mineralizable organic compounds. Fresh wastes from dairy cows or beef cattle are in this category.

The other four decay series are used to represent materials containing mostly slowly mineralizable organic N compounds, such as cattle or dairy manure that has accumulated and dried in corrals for various amounts of time, and digested municipal sludges. The specific decay series used here for sludge should not be considered appropriate for all municipal sludges. Some sludges have much lower N contents and thus have lower rates of decay.

Constant output approach

The "output" is the yearly mineralization of N. The objective of this approach is to determine the amounts of any given materials required per year to maintain given yearly rates of mineralization. Table 2 presents the ratio of yearly inputs to the annual N yearly mineralization rate, at a constant yearly mineralization rate for six decay series for a 20-year period. In this case the application rate for any specific year can be obtained by multiplying the ratio for that year times the yearly mineralization rate desired. For example, if a constant yearly mineralization rate of 100 lbs N per acre per year were desired, for a decay series of 0.40, 0.25, 0.06, the input rates would be 250, 156, 154 and 109 lbs per acre per year respectively for the first, second, fifth and twentieth years. Using these ratios the required amounts of any of the six materials can be calculated if the exact N and water contents are known.

Graph 2 presents the relationships among yearly rates of application, time and constant yearly rates of mineralization for manure containing 25% water and 1.5% N on a dry weight basis, and a decay series of 0.35, 0.15, 0.10, 0.05. To maintain a yearly output of 200 lbs of mineral N per acre per year, 25.5, 15.5, 12.5, 11 and 10 tons of manure per acre would be required for the first, fifth, tenth, fifteenth and twentieth years, respectively.

Table 3 presents data for the total N inputs required to maintain a yearly mineralization rate of 200 lbs N per acre per year for a 20-year period for two decay series for each of six types of wastes. The first decay series listed in each case is the more conservative in that the final member of the series is 0.03 or 0.04—considered to be appropriate for colder climates where decay would be slower. With chicken manure and fresh bovine waste, the two decay series gave essentially the same data. With the other materials the differences between the series were 15 to 55 lbs per acre per year during the twentieth year. The comparison for the dry corral manure at 2.5% N is the best because the two series differ by only one number. In this case the differences in input rates are 18, 37, 40 and 37 lbs N per acre per year for the fifth, tenth, fifteenth and twentieth years, respectively. Considering variability in the material and the difficulty in getting uniform field distribution, these differences probably have no practical significance.

If inorganic sources of N were to be completely replaced by organic sources for a given cropping system, this constant output approach would be much more desirable than the constant input approach. However, the limitations of the constant output approach might be the soluble salts that are added with the high rates of organics required during the first few years. In some moderately saline soils, the increment of salt added with the manure might be sufficient to reduce yields during the first few years.

Discussion

The decay series used here are largely the results of the combined judgment of the authors—except the series 0.40, 0.25, 0.06 which was taken from a field trial in the Coachella Valley, in which the availability of the N added as manure was compared with the availability of inorganic sources. The selected values are based on the authors' experiences in studying the decomposition of a variety of organic materials including animal wastes.

The data presented here are based on decay series that have not been tested in the field. They should be tested in well designed long-term field trials, but until such trials are completed, these data might be useful in planning waste disposal projects and for the development of a more rational use of organics as N sources. The approach used here could be applied to other materials and to other climates that would result in decay series other than those used in this report.

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Diagnosing POTASSIUM DEFICIENCY BY SOIL ANALYSIS

A. L. BROWN · JAMES QUICK · GERARD J. DE BOER

Soil analysis, especially nitric acid extraction of potassium appears to be a very useful means of diagnosing potassium-deficient soils in California. Studies reported here compared two analytical methods for determining soil potassium levels. Plant growth responses were determined by greenhouse pot tests.

CALIFORNIA SOILS have been naturally well endowed with potassium (K), for most plant species, including agricultural crop plants, as is common in arid and semi-arid regions of the world. Thus, K deficiencies have been relatively few, although some areas of deficiency were identified 20 or 30 years ago. The deficiency commonly occurs in small areas in a field, usually not uniformly over the whole field.

Greenhouse pot tests, field plots, and plant symptoms have all been used to identify the need for K fertilization. In addition, *or alternatively*, several soil tests have been used in the United States for diagnosing inadequate levels of K. The most common procedure is the extraction and determination of exchangeable K, using either normal ammonium acetate or normal sodium acetate solution. Both of these methods give approximately the same values for exchangeable K. Workers have found good relationships between this soil test and plant growth response, although there have been many exceptions.

Other procedures, such as extraction with nitric acid (HNO_3), have been investigated and found to be potentially useful as a means of assessing K availability to plants. In view of some limited success in preliminary trials with the HNO_3 procedure it was decided to compare this method with the exchangeable K method and conduct greenhouse pot tests using sweet corn as an indicator crop, with and without applied K. These tests were conducted at various times commonly in groups of 10 to 25 soils, and over a period of several years.

The soils were collected from widely distributed areas of California and primarily represented areas of irrigation agriculture. The procedure generally involved the growing of Golden Bantam T51 sweet corn in 6-inch pots containing 1600 g of air dry soil; to which was added 100 ppm N and 100 ppm P from ammonium sulfate and calcium phosphate, respectively. K was applied at 0 ppm and 200 ppm K from potassium sulfate. Treatments were in duplicate or triplicate. The corn plants were grown for about 6 weeks; then cut off about ½-inch above soil level, dried and weighed.

The collected soils were air dried, passed through a 2-mm mesh screen, and analyzed. Exchangeable K was deter-