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Recycling of Organic Wastes for a Sustainable Agriculture

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INTRODUCTION

A growing number of agricultural scientists, environmentalists, government officials, farmers, and both urban and rural laymen, have become increasingly alarmed over the potential vulnerability of the energy-intensive systems of food and fiber production which now characterize U.S. agriculture. During the past 40 years, conventional agriculture has become increasingly dependent upon petroleum-based, chemically-synthesized fertilizers and pesticides for crop protection and to supply plant nutrients. Certainly, these energy-intensive technologies have contributed greatly to this Nation's agricultural productivity. However, sharply escalating production costs associated with the increasing cost and uncertain availability of energy, i.e. fuel and fertilizers, have generated considerable interest in less expensive and more environmentally compatible production alternatives such as organic farming (USDA, 1980).

At a recent multi-agency workshop involving more than 100 prominent scientists and administrators, "Sustaining the Soil Productivity"[2] was unanimously selected as our foremost national agricultural research priority (Larson *et al.*, 1981). Today in the U.S. Corn Belt, which contains much of country's prime farmland, and where intensive row-cropping is practiced, the average annual soil loss from erosion exceeds 8 tons/acre (18 mt/ha) (Berg, 1979). This is about twice the maximum tolerable rate or so-called "T-value"

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[2]Soil Productivity as defined in "Soil", the 1957 USDA Yearbook of Agriculture, is "The capability of a soil for producing a specified plant or sequence of plants under a defined set of management practices. It is measured in terms of outputs or harvests in relation to the inputs of production factors for a specific kind of soil under a physically defined system of management."

that will sustain a reasonably high level of soil productivity. The apparent decline in soil productivity throughout the U.S. from excessive soil erosion, nutrient runoff, and loss of soil organic matter; the impairment of environmental quality from sedimentation and pollution of natural waters by agricultural chemicals; and the potential hazards to human and animal health and food safety from heavy use of pesticides, have also stimulated interest in organic farming systems of food production.

The purpose of this paper is to present some new perspectives and strategies for efficient and effective use of organic wastes to enhance sustainable systems of agriculture in both developed and developing countries.

TRADITIONAL USE OF ORGANIC WASTES AND RESIDUES IN AGRICULTURE

Most countries have traditionally utilized various kinds of organic materials to maintain or improve the tilth, fertility, and productivity of their agricultural soils. However, several decades ago organic recycling practices in some countries were largely replaced with chemical fertilizers which were applied to high yielding cereal grains that responded best to a high level of fertility and adequate moisture, including irrigation. Soil cultivation was also intensified to improve weed control and seedbed conditions. Consequently, the importance of organic matter to crop production received less emphasis, and its proper use in soil management was neglected, or even forgotten. As a result of this, and failure to implement effective soil conservation practices, the agricultural soils in a number of developed and developing countries have undergone serious degradation and decline in productivity because of excessive soil erosion and nutrient runoff, and the decrease in stable soil organic matter levels.

The most realistic approach for many of the developing countries to achieve sufficiency in food production and maximum crop yield potential is to accelerate efforts to halt the decline in soil productivity and to restore the productivity of degraded soils in the shortest possible time. A recent FAO assessment of organic recycling states that the improvement of soil productivity as a whole is expected to contribute about 60 percent of the increased food production that is currently needed worldwide (Hauck, 1981). Much of this goal can be achieved through proper management of agricultural and municipal organic wastes on land to protect agricultural soils from wind and water erosion and to prevent nutrient losses through runoff and leaching. Efficient and effective use of these materials as soil conditioners also provides one of the best means we have for maintaining and restoring soil productivity. The beneficial effects of organic wastes on soil physical properties as evidenced by increased water infiltration, water-holding capacity, water content, aeration and permeability, soil aggregation and rooting depth, and

2

by decreased soil crusting, bulk density, and runoff and erosion are widely known (USDA, 1957).

SURVEYS OF ORGANIC MATERIALS

Most of the countries lack reliable information as to the types, amounts, and availability of different organic wastes that might be utilized to improve the productivity of their agricultural soils. Such information is highly essential as a first step for successful planning and implementation of organic recycling programs. One such survey that could serve as a model is a recent report entitled "Improving Soils with Organic Wastes" submitted by the U.S. Department of Agriculture to the Congress on "the practicability, desirability, and feasibility of collecting, transporting, and placing organic wastes on land to improve soil tilth and fertility." This information was urgently needed because of the steadily increasing costs of energy, fertilizers, and pesticides to U.S. farmers and the problems of soil deterioration and erosion associated with intensive farming systems (USDA, 1978). The report contains detailed information on the availability of seven major organic waste materials for use in improving soil tilth and fertility, i.e., (a) animal manures, (b) crop residues, (c) sewage sludge, (d) food processing wastes, (e) industrial organic wastes, (f) logging and wood manufacturing wastes, and (g) municipal refuse. Information is reported on the quantity currently generated, present usage, potential value as fertilizers, competitive uses, and problems and constraints affecting their use.

A summary of the USDA report is presented in Table 1. A total of about 730 million dry metric tons of organic wastes are produced annually. This represents a national resource of significant economic value, and its proper and efficient use should be emphasized. About 50% of this total is comprised of crop residues, while about 22% is made up of animal manures. Thus, nearly three quarters of the total annual production of organic wastes in the U.S. is associated with crop residues and animal manures. The USDA report established that about 75% of these two wastes are currently being applied to land for improving soil productivity.

Once these surveys have been made countries within a region should exchange them for mutual interest and benefit. For example, wastes from several processing operations might be co-composted to produce higher quality organic amendments for soil improvement and plant growth. Data in these surveys should be kept current by updating at 2- to 3-year intervals because as cities and industries continue to grow, waste production will also increase. Both the United Nations Environment Programme (UNEP) and the Food and Agriculture Organization (FAO) have emphasized the need for basic information on waste generation and utilization in developing countries (FAO, 1977).

TABLE 1

Annual production of organic wastes in the United States, current use on land, and probability of increased use

	Total Production			
Organic wastes	Dry metric tons (× 1000)	% of total	Current use on land[a] (%)	Probability of increased use[b] on land
Animal manure	158,730	21.8	90	Low
Crop residues	391,009	53.7	68	Low
Sewage sludge and septage	3,963	0.5	23	Medium
Food processing	2,902	0.4	(13)	Low
Industrial organic	7,452	1.0	3	Low
Logging and wood manufacturing	32,394	4.5	(5)	Very low
Municipal refuse	131,519	18.1	(1)	Low
TOTAL	727,969	100.0	—	—

[a]Values in parentheses are estimates because of insufficient data.
[b]Medium indicates a likely increase of 20 to 50%, low indicates a 5 to 20% increase, and very low indicates less than 5% increase.

Recently, FAO published a world directory of institutions concerned with the utilization of agricultural residues (FAO, 1978a); a compendium of technologies for treatment of agricultural residues (FAO, 1978b); and a bibliography of papers and reports dealing with the utilization of agricultural residues (FAO, 1978c). More recently, FAO published a survey on the utilization of residues from agriculture, forestry, fisheries, and related industries which included responses from 57 countries (FAO, 1979). However, only a few countries were able to provide comprehensive information on the kinds and amounts of organic wastes or residues being generated, or their availability for utilization as soil amendments and organic fertilizers.

CONSTRAINTS AND POTENTIAL FOR INCREASED USE OF ORGANIC WASTES

Sewage sludge makes up about 0.5% of the total organic waste produced in the United States and approximately a quarter of it is currently applied to land. The other four wastes listed in Table 1 have not been used extensively on land because of certain competitive uses, high costs of collection, processing, transportation, and application; and because of constraints on usage related to certain chemical and physical properties. For example, (a) cotton gin trash and sugarcane bagasse are now increasingly sought as sources of fuel for burning, (b) some food processing wastes may have extremely high acidity or alkalinity that may adversely affect soil pH, (c) some sewage sludges contain excessive amounts of heavy metals and organic chemicals that may be toxic to plants or endanger the food chain after absorption and accumulation, and (d) shredded municipal refuse may contain considerable amounts of solid fragments (glass, plastic, and metal) that do not readily biodegrade and might detract aesthetically when applied to land.

The potential for increased use of organic wastes on land to improve the productivity of soils in the USA is low (Table 1). Only the use of municipal sewage sludge on land is expected to increase appreciably, but this increase is very small when compared on a national basis with the two largest waste categories, i.e., animal manures and crop residues.

The USDA (1978) report pointed out that there is a growing shortage of good quality organic wastes for use in maintaining and improving the productivity of our agricultural soils. The report cited a number of ways in which our limited amounts of organic wastes might be used more effectively as soil amendments. These include:

(1) Improving methods of collection, storage, and processing (e.g., composting) of animal manures to minimize the loss of nitrogen that often occurs in these operations.
(2) Applying manures to land that are presently being wasted.
(3) Applying crop residues to land that are not now being fully utilized.
(4) Increasing the use of sewage sludge on land.
(5) Increasing the use of the organic/compostable fraction of municipal refuse.

REINTRODUCTION OF ORGANIC FERTILISERS

Organic fertilizers, including animal manures, crop residues, green manures, and composts were traditionally and preferentially used in developing countries until the 1960s when chemical fertilizers began to gain in popularity. Chemical fertilizers became easily available and unlike organic fertilizers they were less bulky and, thus, easier to transport, handle, and store. They were also relatively inexpensive and produced more striking results than organic fertilizers, particularly during the era of the "Green Revolution" when crop varieties were introduced that responded best to heavy applications of chemical fertilizers. Thus, when the world energy crisis began in the early 1970s, chemical fertilizers had virtually replaced organic sources of crop nutrients in developing countries (FAO, 1975). Because of steadily rising energy costs, chemical fertilizers have become much more expensive than they once were, and now organic fertilizers have started to regain their lost popularity.

A significant consequence of these events, as Hauck (1978) points out, is that "in many countries that have recently been increasingly dependent upon mineral fertilizers, the technical knowledge of organic waste utilization has been lost. It is thus necessary to reintroduce the established techniques, to improve them, and to develop new practices conforming to modern technology."

The shift away from organic recycling practices also served to re-emphasize the value of, and need for, organic amendments for the short- and long-term improvement of cultivated soils and maintenance of soil productivity. Without regular additions of adequate amounts of organic materials to soils, there is increased leaching, erosion, and gradual deterioration of their physical properties. Moreover, as the soil degrades, there is a concomitant decrease in the crop use efficiency of chemical fertilizers, especially nitrogen.

Evironmental pollution has also become an international concern. Thus, proper processing and recycling of organic wastes as resources for agriculture can greatly reduce environmental pollution. Additional benefits include improved public health, conservation of resources, and better appearance of both urban and rural communities.

REINTRODUCTION OF BEST MANAGEMENT PRACTICES

Many farmers in developing countries have shifted toward intensive row cropping for short-term economic gain, and have thus neglected soil and water conservation practices. This has resulted in markedly increased soil erosion, extensive damage to cropland, sedimentation, and nutrient runoff and enrichment of surface waters. With increasing public concern for environmental pollution and agriculture's contribution to it, there is an urgent need to reintroduce those soil and crop management practices which have been cited as best management practices for controlling soil erosion and water pollution from cropland (USDA/EPA, 1975, 1976). These include the use of sod-based rotations, contouring, conservation tillage, cover crops, grassed waterways, and possibly others such as divided slope farming. Research and extension programs should be formulated and implemented, in both developed and developing countries, to demonstrate the cost/benefit relationships of conservation management practices. Aspects of multiple cropping systems such as double cropping, sequential cropping, and intercropping may also provide special means for controlling wind and water erosion, and for effective recycling of nutrients from crop residues (ASA, 1976).

COMPOSTING TO ENHANCE THE USEFULNESS AND ACCEPTABILITY OF ORGANIC WASTES

One way in which some of the problems associated with the utilization of various organic wastes (e.g. odors, human pathogens, and storage and handling constraints) can be resolved is by composting. Composting is an ancient practice whereby farmers have converted organic wastes into resources that provide nutrients to crops and enhance the tilth, fertility, and productivity of soils. Through composting, organic wastes are decomposed, nutrients are made available to plants, pathogens are destroyed, and malodors are abated. The historical aspects of composting have been thoroughly discussed in reviews by Gotaas (1956) and Golueke (1972).

Recently, the U.S. Department of Agriculture at Beltsville, Maryland, developed the highly successful Beltsville Aerated Rapid Composting (BARC) Method for composting sewage sludge, animal manures, municipal refuse, and pit latrine wastes (Willson *et al.*, 1980). This method has been widely adopted by both large and small municipalities throughout the United States for composting sewage sludge and solid waste. A number of developing countries have also adopted this technology for composting. The method is simple and relatively inexpensive, yet effective, and allows considerable trade-off between labor and capital.

Composts provide a more stabilized form of organic matter than raw wastes and can vastly improve the physical properties of soils. For example, addition of sludge compost to sandy soils will increase their ability to retain water and render them less droughty. In heavy-textured clay soils, the added organic matter will increase permeability to air, and increase water infiltration thereby minimizing surface runoff and increasing water storage. Addition of sludge compost to clay soils has been shown to reduce soil compaction, lower the bulk density, and increase the rooting depth.

Recent reports by Hornick *et al.* (1979, 1984) discusses the uses of sewage sludge compost for soil improvement and plant growth including (a) establishment, maintenance, and production of turfgrass and sod, (b) use in vegetable gardens, (c) production of field crops and forage grasses, (d) use on nursery crops and ornamentals, (e) use in potting mixes, and (f) reclamation and revegetation of disturbed lands. Recommendations are provided as to time, methods, and rates of compost application for different soils and management practices.

Some organic wastes may have chemical, physical, and/or microbiological properties that would greatly limit the extent to which they could be composted alone. For example, some wastes may have an extremely acidic or alkaline pH, others may have an unusually high or low C:N ratio, and still others may vary widely in their solids content. In such cases, selective co-composting of these wastes with sewage sludges, pit latrine waste or night soil,

7

municipal solid waste (i.e., garbage or refuse), crop residue, animal manures, food processing wastes and certain industrial wastes, may alleviate these deficiencies and provide a readily compostable mixture and higher quality product.

CONSIDERATION OF ORGANIC METHODS OF FARMING

According to a recent report on organic farming by the U.S. Department of Agriculture (USDA, 1980), there are several thousand farmers in the U.S. operating large- and small-scale commercial farms profitably with minimal or no use of chemical fertilizers or pesticides. They are referred to as organic farmers and, although there is considerable diversity in their individual farming methods, they collectively advocate that sustainable and successful farming systems are based primarily on the proper care and protection of the soil.

Organic farming employs basically a systems approach to farm management. On well-managed farms the various practices used are often interrelated so that each augments the other to form a complex but efficient production system. For example, a legume may be grown in a crop rotation not only to produce feed for animals but to control specific weeds and insects, and to supply nitrogen for grain crops that follow. Most organic farmers in the U.S. rely heavily on recycling of organic materials and use of green manure crops and legumes in the rotation to supply nutrients, and to maintain nutrient balances and soil organic matter. As a group, organic farmers are highly committed to protecting the soil resource which they do by regular use of sod-based rotations, legumes, animal manures, and other organic wastes. The USDA Report revealed that organic farming methods and practices were effective in controlling soil erosion and nutrient runoff and in minimizing environmental pollution. Organic farming is also practiced to a limited extent in other developed countries as well, including Japan and those of Western Europe.

The information in the USDA Report (1980) is highly relevant to a number of agricultural problems and concerns that exist today in both developed and developing countries, such as environmental pollution, the high cost of energy, the high cost and uncertain availability of chemical fertilizers, the lack of effective soil and water conservation practices, and the need for improving public health and food safety and quality. There is an urgent need to develop long-term, low-energy, biological, self-sustainable systems of farming in developing countries and developed countries as well. The extent to which some of the organic methods and practices used in more developed countries can be adapted beneficially in meeting this goal should be thoroughly explored.

SPECIAL MANAGEMENT PRACTICES FOR UTILIZATION OF ORGANIC WASTES ON LAND

Special management practices may be needed if we are to obtain the full value of organic wastes as soil amendments and as sources of plant nutrients. For example, the value of organic materials as fertilizers is increased if nutrient release through decomposition and mineralization coincides with the crop's nutrient requirement curve. The nutrient release pattern of organic materials can be controlled to some extent by proper timing of application, pretreatment methods such as composting, and by the method of application. For example, certain organic materials may decompose more slowly if left on the soil surface or concentrated in the soil than if thoroughly mixed in the tillage layer (Parr & Papendick, 1978).

There are many problems involved in handling and applying organic wastes to land because their physical characteristics are so variable. Such wastes are almost always bulky, and can range from liquids on one extreme to dry solid material on the other. Existing application technologies are often ineffective and fail to achieve the desired level of erosion control or increased crop production. Methods of application must be simple, inexpensive, energy conserving, and effective for nutrient recycling and erosion control.

An example of a particularly effective soil erosion control measure for sloping lands is that of vertical mulching, a procedure which incorporates organic materials such as crop residues into a vertical channel 30 to 40 cm deep and some 10 to 12 cm wide at the soil surface (Parr, 1959). The operation is usually conducted on the contour with intervals ranging from 5 to 10 m. A recent modification of this procedure is referred to as "slot mulch" and has been demonstrated as an effective means of controlling erosion on steeply sloping lands in the winter wheat area of eastern Washington State (Saxton *et al.*, 1981). Both techniques are highly effective in intercepting runoff, enhancing root penetration and development, and providing for effective water conservation and storage for crop use. Although several types of machines have been designed for these operations, similar results could be achieved using hand labor.

This concept of residue management may have application in developing countries for restoring the productivity of sloping lands that have suffered from severe soil erosion. Besides crop residues, other types of organic materials, including composts, could also be utilized in the vertical mulch or slot mulch procedures.

NON-TRADITIONAL SOIL AND PLANT ADDITIVES

There are a number of products that have been introduced into developing

9

countries, that are generally referred to as soil and plant additives, for which the manufacturers' claims greatly exceed the performance of the product (Weaver *et al.*, 1974; Dunigan, 1979; Weaver, 1979).

These products include (a) *microbial fertilizers* and *soil inoculants* which are purported to contain unique and beneficial strains of soil micoorganisms, (b) *microbial acivators* that supposedly contain special chemical formulations for increasing the numbers and activity of beneficial microorganisms in soil, (c) *soil conditioners* that claim to create favorable soil physical and chemical conditions which result in increased growth and yield of crops, and (d) *plant stimulants and growth regulators* that supposedly stimulate plant growth, resulting in healthier and more vigorous plants, and increased yields.

In most cases where researchers have evaluated these products using acceptable scientific and statistical methods they have been unable to demonstrate any significant yield increases. Such studies have also usually failed to provide evidence for any additional claims of benefit. It is noteworthy, however, that there are some legitimate products on the market that have stood the test of time. A classic example is the commercial preparation of the nitrogen fixing bacteria *Rhizobium* used for inoculating legume seeds.

The proper use of organic fertilizers, chemical fertilizers, lime, and specific rhizobia inoculum for legumes, when needed, will usually pay dividends to farmers. However, any product which promises to perform extraordinary processes in soils and plants, or to have magical and mysterious beneficial effects on plants and microorganisms when applied at very low rates of application should be viewed with caution and scepticism. Such products are invariably a poor investment, of little or no economic value, and cannot substitute for good farming methods and sound management practices in either developed or developing countries.

VALUE OF ORGANIC MATERIALS AS FERTILIZERS AND SOIL CONDITIONERS

The "value" of organic materials as fertilizers and soil conditioners is often misunderstood and has been the source of some controversy. The simplest and most common means of estimating the value of organic amendments is by assessing the current market value of the plant nutrients they contain. Usually this is done in terms of their macronutrient content, i.e., nitrogen, phosphorus, and potassium.

However, many organic materials contain other components which can contribute significantly to increased crop yields, including organic matter, secondary and micronutrients, and sometimes lime. In some cases, the organic matter fraction of a particular material may have a higher value than that of its

10

total nutrient content because of the beneficial effect of organic matter on soil physical properties and improvement of soil productivity. A brief clarification of the agronomic and economic values of organic materials follows.

The Agronomic Value

The agronomic value of an organic material is the increased crop yield or quality delivery from its application. There is a considerable amount of data in the literature which demonstrates the effect of organic materials on crop yield, but very little on crop quality. Crop yield response to additions of organic materials is highly variable and is dependent upon the crop, soil type, climatic conditions, management system, and the organic material used. In most cases, crop yield response to the addition of organic materials is non-linear. The greatest yield response is obtained with the first few increments of organic material, followed by progressively smaller yield increases with additional increments. Thus, as with chemical fertilizers and other production inputs, crop yield response to an organic amendment follows the law of diminishing returns, and is responsible for the decreased value per unit of the material with increased application rates. Obviously, both the agronomic and economic value per unit of organic material to the farmer are correspondingly higher at low, rather than high, application rates. Reliable estimates of the economic value of organic materials depends upon the accurate assessment of agronomic data relating the crop yield response to the application of a particular material.

The Economic Value

The economic value of an organic waste or residue to a farmer is the value of the increase in crop yield and/or crop quality that is derived from its use. Since the crop yield response to an organic amendment follows the law of diminishing returns, the average yield increase is always larger than the yield increase attributable to the incremental unit of organic material. If the price of the farmer's product is the same regardless of the quantity produced, which is usually the case, then the revenue derived from the average unit of organic material will be greater than the revenue from the incremental unit. Thus the value of the average unit of organic material will be higher than the value of the incremental unit of organic material.

Farmers can be expected to utilize organic materials to the point where the revenue from the incremental unit is equal to its price, assuming application is included in the price. They would certainly use no more than that quantity since additional application of the organic material would yield a loss.

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Likewise, they would not wish to use less since total profits would decline. Thus an estimate of the value of the incremental unit of organic material would be useful to farmers as well as public waste management agencies analyzing the marketability of a recycled product. However, public decision-makers should also be interested in estimates of the total economic benefits from resource recycling alternatives, such as composting, to compare them to destructive alternatives such as landfilling or incineration. Thus, an estimate of the value of the average unit of organic material would be the appropriate figure to use in public project analysis.

The rate at which organic materials decompose or mineralize in soil is highly variable but they do have a greater residual effect on soil fertility than most chemical fertilizers because of the slow-release character of the nitrogen and phosphorus components. Thus, a significant portion of the value of organic materials as fertilizers is their capacity to elicit yield responses from succeeding crops. This response must be accounted for to assess the true value of the material. Barbarika *et al.* (1980) estimated that the cumulative economic value of some organic materials applied to agricultural soils could be as much as five times greater in succeeding years than the value realized during the application year.

RESEARCH NEEDS

In addition to traditional organic materials such as animal manures and crop residues, developing countries are increasing their land application of municipal wastes (e.g., sewage sludges and effluents, and garbage) and industrial wastes (e.g., food processing and acceptable industrial organic wastes). Research is needed to determine how these wastes differ in their ability to improve the tilth, fertility, and productivity of soils.

Information is limited on the substitutability of one particular organic waste for another in soil improvement. Criteria should be developed by which the relative effectiveness of different organic wastes can be compared. For example, studies are needed to determine the following properties: decomposition rates for each waste under different soil regimes and cropping systems; rates at which plant nutrients are mineralized, recycled, and utilized by both current and subsequent crops; the potential toxic effects of certain wastes on plants and microorganisms; the impact of organic waste management on the control of plant insects and diseases; and the extent to which different wastes can effect desirable and residual improvement of soil physical properties. Each organic waste has unique properties that should be thoroughly investigated in the soil/water/plant ecosystem.

Some organic amendments are known to mineralize and release available plant nutrients rapidly as a result of microbial attack In some cases this is desirable, particularly on soils that are already in a high state of fertility and productivity. On the other hand, marginal, erodible, sloping, and generally less productive soils would benefit, at least initially, from application of organic materials having a higher degree of microbial stability in soil. Such materials would release their plant nutrients at a relatively slower rate. Farmers in developing countries often have occasion to use both types of materials in their farming operations depending on whether there is a need to release nutrients rapidly, or to improve the productivity of marginal soils. Table 2 lists some organic materials that would be expected to differ considerably in these two properties. Although these are hypothetical values and would have to be verified experimentally, the concept introduced here is the important consideration. A high nutrient availability index (NAI) indicates materials that would release nutrients relatively rapidly, while a high organic stability index (OSI) would be associated with more stable forms of organic matter. Materials with a high NAI value usually would be expected to have a low OSI value, and conversely. Research is needed to develop reliable numerical indexes such as those shown in Table 2. This would allow a realistic basis for predicting the nutrient availability and organic stability of different wastes under different soil, climatic, and cropping conditions.

As noted earlier co-composting can overcome certain chemical, physical or microbiological deficiencies of some organic wastes. For example, wastes such as rice straw that have very high C:N ratios, and which would compost slowly alone, might be combined with a low C:N material such as poultry manure to achieve a more favorable ratio for composting. Research is needed to determine the proper combination of different organic wastes that could be

TABLE 2

Hypothetical nutrient availability indexes (NAI) and organic stability indexes (OSI) for composted and uncomposted organic materials

Product	Nutrient Availability Index[a]	Organic Stability Index[a]
Beef Manure	70	30
Rice Straw	15	85
Sewage Sludge	80	20
Sewage Sludge - woodchip compost	35	65
Refuse compost	25	75
Refuse-pit latrine compost	40	60
Poultry manure - rice straw compost	65	35

[a]Values are hypothetical, but are based mainly on what is known of the C:N ratio of organic materials cited, and the decomposability of the various components (i.e. cellulose, hemicellulose, lignin, sugars, proteins, etc.) that comprise them (Parr & Papendick, 1978).

13

successfully co-composted. The effectiveness of these composts for improving soil productivity should be throughly explored.

It is unlikely that organic fertilizers will totally replace chemical fertilizers in developing countries, nor should that be the goal. There is evidence that higher crop yields are possible when organic wastes are applied in combination with chemical fertilizers than when either one is supplied alone, so that organic amendments may increase the efficiency of chemical fertilizers. Research is needed to evaluate the effect of various combinations of organic amendments and chemical fertilizers on crop yields and fertilizer efficiency. The potential for enriching (i.e spiking) organic wastes and composts with chemical fertilizers or other wastes of a higher plant nutrient content to enhance their fertilizer value should be thoroughly evaluated.

Farmers frequently apply organic wastes (including composts) to their fields at rates that are too low or too high for maximum economic return. When the rate is too low, soil physical properties are not sufficiently improved and the plant nutrient level is inadequate to sustain optimum crop growth and yield. If applied at excessive rates, plant nutrients are not utilized efficiently and contribute to environmental pollution through runoff and leaching. Research is needed to improve the efficient and effective use of organic materials in cropping systems. Such research must consider a number of management factors and how these materials are applied, including: mode or method of application (i.e., surface-applied, plowed-down, disked in or side-dressed); rate, time, and frequency of application; the soil, and the sequence of crops to be grown. A better understanding of the interaction of these factors should provide a more reliable basis for developing more efficient and effective waste application/utilization programs for agriculture.

The beneficial effects of various organic materials on soil productivity are well known. However, for most organic materials it is very difficult to quantify what portion of the crop yield response is due to the organic matter fraction and what is due to the plant nutrient content. Experimental procedures and special data analysis techniques should be thoroughly explored so that the economic value of the organic component in different kinds of organic materials can be accurately and meaningfully estimated. This should be done for a number of different crops, soils, management systems, and climatic situations. Such data could greatly stimulate the use of organic wastes on agricultural land to control soil erosion and nutrient runoff and to improve soil productivity.

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15

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