COMPOST and MULCH — investing in vineyard health

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After harvest, Will Bakx loads trucks with compost and mulch for delivery to vineyards in Sonoma and Napa counties. Bakx, a soil scientist for Sonoma Compost in Petaluma, CA, produces high-quality compost from urban yard trimmings. Many vineyard managers who apply compost and mulch after harvest are finding these products to be useful components of their vineyard floor management program.

While some vineyard managers purchase these soil amendments, others make their own compost from grape pomace. Either way, compost and mulch are products that result from recycling materials that might otherwise be wasted. As many communities collect yard trimmings at the curb to reduce organic materials going to landfills, these materials are being transformed into valuable soil amendments by producers such as Bakx. Growers and researchers alike are discovering the benefits of these recycled soil amendments.

Beneficial microbes in compost may help reduce phylloxera damage

Under the guidance of phylloxera researcher Dr. Jeffrey Granett in the UC Davis Entomology Department, Ph.D. candidate Don Lotter has been monitoring damage caused by phylloxera in organic vineyards for two years. “Indications are that vineyards using compost are doing well if they’ve been applying compost for at least four or five years,” according to Lotter.

Lotter’s research shows significantly less root rot (11.8%) in organically managed phylloxerated vineyards than on phylloxerated roots from conventionally managed vineyards (27.1%). Each of the six organic and seven conventionally farmed vineyards that were monitored have similar sand/silt/clay ratios. All of the vineyards showing favorable results are using compost in combination with winter cover crops.

Phylloxera feeding on the grape roots make the grapevine vulnerable to infection by fungal pathogens, such as Fusarium. However, in the organically managed vineyards, Lotter found a trend toward higher populations of beneficial microorganisms that are antagonists to Fusarium. These beneficial microbes include Trichoderma and Pseudomonas or Pseudomonad bacteria. (Additional information on UC Davis phylloxera research is available at http://entomology.ucdavis.edu/faculty/granett/phypage.htm.)

Compost has long been known for its wealth of microbial activity. Beneficial microbes flourish during the aerobic composting process, where oxygen is made available to the microbes either by turning the heap, thereby increasing the porosity, or by pumping air through a static pile.

There is also a relationship between phylloxera and soil type. According to the University of California Pest Management Guidelines on Grape Phylloxera, “Phylloxera prefers heavy, clay soils, that are commonly found in the cooler grapegrowing regions of the state such as Napa, Sonoma, Lake, Mendocino, and Monterey counties, as well as the Sacramento Delta and the foothills.” Compost is a good soil amendment for improving soil structure and aeration of these heavy soils.

“Compost is an investment in the long term health of the soil and the plants,” asserts Bakx.

Compost builds soils, prepares ground for cover crops

John White of Pina Vineyard Management is a strong advocate of compost. He has been using compost for a number of years and purchases it from several different Napa Valley producers. “We apply compost before planting or within the first year to improve the heavy valley soils and to build soil organic matter,” says White. At an application rate of 10 tons per acre, White is applying more compost than most vineyard managers. However, the higher application rate may be necessary to help loosen heavy soils.

Fetzer Vineyards (Hopland, CA) is a subject of Lotter’s phylloxera study. However, when asked why he uses compost, vineyard manager Tom Piper doesn’t even mention phylloxera damage control. He cites improved soil structure, the addition of potassium, and beneficial microorganisms. In addition, Fetzer sows the seeds for its annual cover crop onto a bed of recently applied compost with good results. Unlike Pina Vineyards, Fetzer makes its own compost on-site.

“We make about 200 tons of compost every year from our pomace,” explains Piper. “We turn it with a front-end loader, so we didn’t need to invest in any special equipment.” Compost is applied at about one ton per acre to established Fetzer vineyards and two tons per acre for new plantings.

Delicato Winery has been compost-
ing grape pomace on-site for more than 15 years. Although Delicato originally invested in large-scale composting equipment, such as a Scarab turner, and sold compost to other growers, the winery now only makes enough for its own use, selling the remaining pomace for animal feed.

“Grape compost makes a great soil amendment,” says Bud Bradley, Delicato’s director of grower relations. “It helps make the soil what I call healthy, improving drainage, and water-holding capacity.” Bradley touts the widely held view that soils high in organic matter are not as attractive to nematodes. Delicato vineyards receive an average of five tons per acre of compost each year over 130 acres. Lab analysis of the compost is a standard procedure, and sold compost to other growers, the winery now only makes

Compost may contribute to healthier vines and increase yields

Andrew Hoxsey of Yount Mill Vineyards is now in his third year of making compost for his organic vineyard with restricted inputs. After experimenting with commercially produced compost, he decided to try making his own custom blend. He now blends 40% pomace and 30% turkey manure with 30% composted yard trimmings from a local commercial compost producer.

Hoxsey is pleased with his blend and finds that vines that were stressed in 1995 and 1996 now appear healthier.

“The primary reason we use compost is to add organic matter and boost microbiological activity,” says Hoxsey. Three to four tons per acre of compost is applied over the 600 acres of Yount Mill vineyards.

Other vineyards have seen improved vine vigor and yield with compost applications. Bob Pestoni of Upper Valley Recycling (St. Helena, CA), producer of Harvest Compost, contracted with Dr. Paul Skinner of Vineyard Investigations to study the effect of his compost on vineyard yields. Skinner compared the effects of compost to a control (no applied soil amendments) in Robert Mondavi Winery’s Tokolon Z block of Cabernet Sauvignon on St. George rootstock.

After three consecutive years, the study at Mondavi found that blocks with compost applied had increased yields of up to 0.9 tons per acre, while the fruit quality remained the same. Application rates for the study ranged from two to eight tons per acre with the 0.9 tons per acre increase in yield occurring in the eight-tons-per-acre treatment.

Cost of the compost at $24 per ton applied at Tokolon was recovered by an increased yield valued at $1,350 per acre. Since the trial ended in 1995, about four tons per acre of compost has been applied annually to 20 acres in Mondavi’s Tokolon vineyard.

In addition to annual applications, Skinner also promotes the use of compost to prepare land for new vineyard plantings. “I typically recommend a pre-plant compost application of five to 20 tons per acre, depending on the results of our “Terrior” soil analysis program. Compost is a good source of trace elements and enhances soil structure,” says Skinner.

Pestoni is in a unique position because, in addition to being a compost producer, he owns Rutherford Grove Winery. When asked what application rate he suggests for compost, Pestoni responds, “You have to know your soil. Work with a soil specialist and get a lab analysis. Then we can talk about application rate.”

Upper Valley Recycling does extensive lab analysis on its Harvest Compost and provides potential customers with the results upon request.

Mulch used for erosion control

While many vineyards use straw or cover crops for erosion control, mulch made from urban yard trimmings can be a cost-effective alternative. Mulch is usually used for erosion control, weed suppression, and water retention. Compost improves soil tilth, adds beneficial microorganisms, and may be used as a slow-release source of nutrients. Mulch consists of yard trimmings that are ground and then screened to a uniform particle size. Unlike compost, mulch does not undergo extensive processing to decompose the material and is, therefore, usually less expensive. It is generally applied as a top dressing and slowly decomposes over time.

Mulch and/or compost effective for vineyard weed control

Clyde Elmore, a UC Cooperative Extension weed advisor, recently spoke at Foothill Grape Day in the Placerville area regarding vineyard floor management. Although he focused on herbicides, Elmore also discussed his research on the use of mulch for weed control. From his trials, Elmore concluded, “Greenwaste wood chips give good weed control. The mulch was persistent in the field and should give long-term weed-control benefits. Because it may last for more than one season, the short-term direct cost is not the best way to evaluate this product.” However, many perennial weeds such as field bindweed are not controlled well with organic mulches. Depending on the coarseness of the mulch, two to six inches of material is needed to control most annual weeds.

At Pina Vineyard Management, White applies compost for weed control in his vineyards. He is perfecting a vine row applicator with the hopes to suppress weeds with compost application right next to the vines. “We find this is the most effective way of applying the compost. The chute will deposit the compost right where we want it and give us a more concentrated application than broadscale spreading.”

Know what you’re getting

Asking questions of compost and mulch producers and reviewing lab analysis results are the only ways to learn exactly what you’re getting.
Common ingredients, or feedstocks, for compost and mulch include yard trimmings (collected at city curbs or transported directly from landscapers), manure, and in grapegrowing regions, grape pomace. Any reputable producer will disclose its feedstock. Producers registered with the California Compost Quality Council (CCQC) are required to disclose feedstock, pH, and a number of other product characteristics.

All large-scale producers of compost are subject to composting regulations promulgated by the California Integrated Waste Management Board. Depending on their composting method, these producers are required to maintain the compost pile at a temperature of at least 131°F for a specified number of days. This "time and temperature" process kills pathogens and weed seeds. In addition, regulated producers must test their end product to ensure that certain heavy metals and pathogens are within acceptable limits.

Producers of mulch, which is ground wood chips made from orchard or tree prunings or yard trimmings, are not subject to the regulations and thus are not required to put the material through the "time and temperature" process. However, some producers will subject the material to this process for a minimum time to kill pathogens and weed seeds, but not long enough to fully decompose the material.

Most producers also obtain product analysis which shows NPK, pH, and other characteristics of interest to growers. Martin Mileck of Cold Creek Compost (Ukiah, CA) sells compost to vineyards as a diverse source of nutrients. "I estimate there's about $60 worth of nutrients in one ton of our compost and it sells for $28 per ton (fob Ukiah, CA), a fraction of that cost," says Mileck. While nitrogen content of compost varies, depending on the feedstock, Mileck's product typically has between 1.5% to 2% nitrogen. Mileck also cites the high potash content (about 2.5%) of his product, which results from the addition of wood ash. Wood ash can also be a good source of other micronutrients.

If producers don't have what you want, ask if they can get it or make it. Material can be screened to specific particle size, small or large. In addition, many producers will make custom blend products upon request. Norm DeLeuze of ZD Wines in Napa Valley wanted a compost higher in nitrogen than the yard-trimming compost normally produced by his supplier for his vineyard in the Carneros district.

Greg Kelly of Napa Garbage Company responded to DeLeuze's needs by adding manure to the feedstock, increasing the nitrogen from 1.59% to 2.19% and increasing the phosphorus from 0.29% to 1.4%, producing a more balanced, higher quality compost. DeLeuze was satisfied, and Kelly is now selling the new product to other grapegrowers in the area.

To locate a supplier near you in California, call the Waste Board at 916/255-2410 to request the "Compost and Mulch Source List." The list is also available on the board's website at: http://www.ciwmb.ca.gov/organics/farming.

Making your own compost

A number of wineries compost their own pomace which solves a waste management issue and produces a valuable end-product. While some wineries use pomace as the only feedstock, a higher-quality compost may result from adding other feedstocks to the mix of organic materials. Yard trimmings, old animal bedding, and manure are good additions to pomace. These additional feedstocks serve as bulking agents and may help to buffer the pH of the pile. Another option to raise soil pH is to add lime.

Those who make their own compost should be familiar with properly using the basic "turned-windrow" technique. The most common composting problem is failure to turn the windrow (pile) frequently. This causes the pile to become anaerobic and encourages undesirable microorganisms and produces unpleasant odors. The windrow should be kept about as moist as a rung-out damp sponge and turned regularly. The more frequently the pile is turned, the faster the compost will decompose. However, less frequent turning saves labor and energy.

"To obtain sufficient pathogen reduction and to kill weed seeds, a minimum of three turnings is required in the 1-2-3 turnover method," advises Bakx, who developed the method. Allow five days or more between turnings. Depending on the composition of the material and the particle size, three turnings will result in compost in five to eight months. Turning six to eight times will produce a finished compost in three to five months.

It's helpful to obtain a compost thermometer and monitor the internal temperature of the pile. The pile should be between 131°F and 150°F for at least 15 days. If the pile exceeds 155°F, turn the pile to dissipate the heat; adding additional water may result in even higher temperatures. Preventing the pile from reaching 160°F helps maintain the desired beneficial microbes and also helps prevent spontaneous combustion from occurring.

While the Waste Board encourages on-farm composting, current compost-
ing regulations may govern agricultural composting in certain situations. On-farm composters who use only agricultural commodities (e.g., grape pomace) as feedstock are not subject to regulatory oversight if they sell or give away no more than 2,500 cubic yards of compost annually. If they are mixing non-agricultural source material such as yard trimmings with pomace, on-farm composters may be subject to nominal requirements.

Check with your local enforcement agency (LEA), usually the county environmental health department, for clarification on any requirements before composting any non-agricultural source materials. LEAs are posted by county along with regulations on the Waste Board’s Web site at www.ciwmb.ca.gov/organics/farming. Look for California Code of Regulations, Title 14, Chapter 3.1.

California growers seriously considering on-farm composting may contact this author for more information and request a copy of the On-Farm Composting Handbook.

A beneficial practice to consider

If your vineyard could benefit from improved soil structure, added beneficial microbes, improved moisture retention, and better erosion control, consider making or purchasing compost and mulch. Compost and mulch can be important long-term investments in the health of your vineyard.

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Introduction

The addition of animal and vegetable waste products and other organic materials to the soil to improve its fertility is an age-old practice. This improvement of soil fertility is brought about by supplying plant nutrients and by improving the physical condition of the soil. The term ‘organic’ is usually taken to imply complex compounds of carbon but in agriculture and horticulture the word ‘organic’ or ‘organics’ are loosely used when referring to materials composed wholly or mainly from animal or vegetable origin. A wide range of these waste products from the farm and from industry are used as soil additives and contain varying amounts of organic matter. Regular additions in appreciable amounts improve the physical characteristics of cultivated soils, such as increasing water holding capacity.

A measure of the content of organic matter (carbonaceous substances) in these materials is given by the percentage of ash-free dry matter. In average farmyard manure this is about 12 per cent and in dry chopped straw, about 80 per cent. To apply significant amounts of organic matter to the soil, farmyard manure, because of its high moisture content needs a considerable weight per hectare (acre), and chopped straw or straw compost, because of their low bulk density, need a considerable volume. Thus, such materials are frequently referred to as ‘bulky organic manures’.

‘Manures’ are now commonly regarded as organic materials which supply appreciable amounts of organic matter to the soil, together with generally small amounts of available plant nutrients; they are applied in large amounts conveniently measured in tonnes per ha (tons per ac). Farmyard manure, deep litter manure, broiler manure, and composts, are examples of these materials.

The term ‘organic fertilizers’ generally refers to fertilizers which contain plant nutrients wholly or partly in organic form, supplying only small amounts of organic matter, and used at rates conveniently measured in kg per hectare (ha) (cwts per acre (ac)). When used for supplying appropriate rates of available plant nutrients, they would not be expected to have any appreciable effect on the physical characteristics of the soil. Dried blood and hoof and horn are examples of these materials.

There is also a small group of organic materials, manufactured for specific purposes, which can be classed as synthetic organic fertilizers; examples being slow release nitrogen fertilizers such as urea-formaldehyde, azamid and isobutylidene diurea.

Manures and fertilizers can be distinguished from other soil amendments in being primarily a source of plant nutrients. Organic materials contain many plant nutrients but their value as fertilizers is mainly determined by their content of nitrogen, phosphorus and potassium and sometimes by their content of nitrogen alone since this is generally the most valuable constituent. Most of these materials have ultimately been derived from animal or vegetable matter and so contain varying amounts of some other plant nutrients such as magnesium, sodium, sulphur and some micro-nutrients; these materials may well be serving an increasingly useful part in supplying additional essential plant nutrients now that such elements as these are being

eliminated from inorganic fertilizers through changes in raw materials and modification of manufacturing processes.

THE VALUE OF ORGANIC MATTER IN THE SOIL

Organic materials when used as bulky organic manures can improve the fertility of soil in several ways by:

1. Supplying plant nutrients;
2. Modifying the physical condition of soils;
3. Providing energy for increasing micro-biological activity; and
4. Protecting crops from temporary gross excesses of mineral salts and toxic substances and from rapid fluctuations in soil reaction by means of their high absorption capacity exerting a ‘buffering’ action.

This complex action of organic material incorporated into the soil when contrasted with the simpler action of inorganic fertilizers has given rise to much controversy about their relative merits in crop production.

When the same amounts of plant nutrients from organic and inorganic sources are compared there is no evidence that the yield response to a particular nutrient is any greater from an organic source than from an inorganic. In most past experiments on this subject the effects of organic materials on crop yield can be fully explained in terms of plant nutrient supply, but in this work levels of nutrients were sub-optimal and it could be expected that where nutrient supply limits crop growth, organic materials would not give higher yields than inorganic materials supplying the same amount of nutrients.

Several widely grown agricultural crops such as cereals and herbage from grassland can be grown satisfactorily over a wide range of soil physical conditions and any improvement in yield from improving these conditions by regular large dressings of organic material would be uneconomic. With maincrop potatoes, quality factors are becoming increasingly important, in particular regular shaped tubers of uniform size free from surface blemishes.

The maintenance of appropriate minimum levels of organic matter in soils assists in obtaining better quality tubers and the use of organic materials may be justified. With these agricultural crops there is usually little economic gain from earlier harvesting but with vegetable crops a horticultural scale earliness and quality are of considerable economic importance and the use of regular heavy dressings of organic materials is usually well worthwhile.

The improvement of physical conditions in soils brought about by regular dressings of organic manures results in earlier and easier working of the soil when cultivating. The supply of plant nutrients is better regulated, often giving a slower release over a period and a better retention of readily leached nutrients over winter. The structure of soils is improved, giving a greater root range, water holding capacity and resistance to adverse effects of heavy farm machinery; there is better cohesion in coarse open sandy soil and greater aggregation in fine particled soil, which assists in regulating drainage and aeration. Soils with a high content of organic matter are darker in colour and this enables more radiant heat energy to be absorbed giving a warmer soil; microbial activity is enhanced by providing more energy in carbonaceous material. The buffering effect against gross excesses of mineral
Effects of Adding Organic Manures to Cultivated Soils

A valuable organic manure like farmyard manure when applied to long established permanent grassland is of value only for its content of plant nutrients. In modern grassland farming this is small especially with regard to nitrogen, and so the manure is wastefully used. Such manures could be much more useful on intensive arable land.

The effect on soil fertility of low rates of bulky organic manures is almost negligible and almost wholly accounted for by the small contribution to plant nutrient supply.

The effect on soil fertility of high rates of bulky organic manures can be considerable and depends among other things upon the nature of the manure and its state of decomposition. In normally fertile soils the ratio of carbon to nitrogen in the organic matter is about 10:1; in freshly produced unrotted organic material such as crop residues and dung this ratio is much wider. When these are added to the soil microbial activity increases resulting in a loss of carbon as carbon dioxide and nitrogen becoming temporarily 'locked-up' in an unavailable form. As rotting proceeds the carbon-nitrogen ratio falls and nitrogen becomes slowly available over a period as it is mineralized. Thus the addition of straw alone and animal residues containing excessive nitrogen before being added to the soil. Large dressings of unrotted organic materials ('long manures') should therefore be applied to the soil in autumn or early winter and of well rotted material ('short manures') in late winter or spring.

In most cases organic manures are worked into the soil by cultivation but some crops make better use of the manure when it is placed; the availability of phosphorus in farmyard manure to swedes has been shown to be greater when the manure is placed just below the seed.

When undisturbed soil high in organic matter is brought under continuous cultivation the level of organic matter falls due to oxidation of the carbonaceous material to carbon dioxide. For many soil types the minimum content reached is too low to provide satisfactory soil physical conditions for all crops. A higher level of organic matter can be maintained by periodic 'resting' of the soil under grass but in many cases this level can be maintained by regular additions of bulky organic manures with continuous cropping of more profitable high value crops. Bulky organic manures such as farmyard manure are applied as fresh material containing about 15 per cent dry matter. Carbonaceous substances in this dry matter, referred to as ash-free dry matter, amount to about 12 per cent of the fresh manure. High rates of application are required, usually between 50 and 125 tonnes per ha (20 and 50 tons per ac) if a useful improvement in physical conditions is to be obtained.

The value of organic materials as fertilizers depends on the total content of plant nutrients and on the availability of those nutrients. Available nutrients are normally taken to be the proportion of the total content of the nutrients that can be used by the first crop following application of the material to the soil. They are measured by comparing yields of the crop when organic material is used with those obtained using inorganic fertilizers and assuming nutrients in the latter to be 100 per cent available.

Some of the crops for which it is appropriate to use organic manures respond very well to nitrogen and much less to phosphorus and potassium. Field experiments with these crops have given reasonable assessments of the availability of nitrogen when the manures were applied in late winter or early spring, and in some cases for other times of application. These are given in the sections dealing with the manures. Little or no information has been obtained about the availability to crops of phosphorus, potassium or other plant nutrients, and experiments would need to be very large and complicated to provide such information. Some crops, notably potatoes, sugar beet and some brassicas respond well to two or all three of the major nutrients, and using soils with generally low levels of these, field experiments have given estimates of the availability of all three nutrients. In this way the fertilizer value of farmyard manure was evaluated, but there is no corresponding body of information for other organic manures. The overall average value for the availability (as defined above) of phosphorus in farmyard manure ranged from 50 to 66 per cent, and that of potassium in farmyard manure ranged from 55 to 95 per cent. Until more precise information is obtained the availability of phosphorus in other organic manures discussed in this Bulletin has been taken as 50 per cent for a single application to soil not treated regularly with the manure in the recent past. The availability of potassium has been taken as 75 per cent, except where almost all the potassium can be readily extracted with water, when an availability of 90 per cent has been taken.

The residual value of single dressings at low rates is very small, but the residual value built up by regular dressings over a long period can be considerable.

Nearly all organic manures are by-products and are non-standard materials. A very wide range of materials from urban areas, from industries, and as waste products from the farm have been used or are in current use as supplies become available in sufficient quantities and at generally low prices. In many instances disposal presents a problem to the producer of the material and it is available to farmers for the cost of transport.

The value of organic fertilizers should be assessed by comparing the cash value of the available plant nutrient content with that from inorganic fertilizer.
Farmyard Manure

The term 'farmyard manure' can be taken to mean the manure, produced from the excreta of any farm animal, mixed with some kind of litter and handled as a 'solid'. It is very commonly confined to describing the manure reduced from the dung and urine of cattle having straw as the litter, and as is what is meant by the material described in this chapter. Excrement from other farm animals such as pigs and poultry is often added to farmyard manure on farms, but most of the total volume of manure produced is derived from ruminant animals, with dung of characteristic fibrous quality. This material is probably the oldest soil amendment known and practical ways of making and storing it, and its value for crop production have been known from very early times. Field experimentation and scientific studies on the use of this manure from about 1850 onwards have explained much of its value but have not so far indicated any better way of utilizing animal waste except improving the soil. Farmyard manure remains a most valuable material in modern farming for maintaining soil fertility in its widest sense.

About 50 million tonnes of farmyard manure are produced annually in England and Wales and this still supplies a substantial part of the plant nutrients applied to the soil for growing crops. The upward trend in fertilizer prices is drawing attention to the need for improvements in methods of storage and application of farmyard manure so as to make better use of its last nutrient content. Specialization in farming enterprises has resulted in areas of predominantly intensive arable land where farmyard manure could be used to advantage and where often little or none is produced, in contrast to predominantly grassland areas where much farmyard manure is produced and used wastefully.

Some of these physiological effects on crop plants can be accounted for by measurable improvements in the physical and biological characteristics of the soil. Soil structure is improved; large clods of dense soil are not so readily produced when cultivations are carried out in wet conditions and crumb-like aggregates of soil particles are not so readily slaked into a slurry. The soil develops more pore space and is able to maintain a better pore size distribution; as a result, permeability to water is improved and available water capacity increased. In an investigation, laboratory tests on dried soil from cereal plots had a bulk density of 1.70 and 32 per cent pore space without farmyard manure treatment and a bulk density of 1.53 and 38 per cent pore space with farmyard manure treatment. Restriction of root growth was significant with bulk densities above 1.60. In other work regular dressings of the manure increased available water capacity of both a sandy loam and a clay loam soil by about one third but the heavier soil required a much longer period of annual applications to bring about the improvement. It was also found that equal amounts of manure gave a larger increase in the available water holding capacity of a sandy soil than a heavy textured soil.

In some of these experiments the plots receiving regular dressings of manure were ready for ploughing earlier in the season and were easier to plough than those not treated. In heavy textured soil types that are prone to structural damage by mismanagement, dressings of manure are not as good a way of restoring good structure as is sowing down to long term grass, but whatever the structure already present in a soil, it is better maintained by the use of manure over years of arable cropping than is soil not so treated. Thus while the plant nutrient content of farmyard manure may give only small increases in yield its use can be justified if it ensures that consistently high yields will be obtained with optimal fertilizer dressings applied over long periods and in poor as well as good seasons.

Biological activity in the soil is increased by treatment with farmyard manure; a measure of this activity is given by the respiration rate. Additions over 30 years increased the rate of evolution of carbon dioxide by two and a half times. Earthworm activity is greatly increased and nodulation of legumes is improved; the population of pathogens which cause plant disease is reduced.

Toxic Effects

Some litter materials contain toxic substances which can persist in the manure after its application to the soil and may damage young crop plants. Examples are residues of the herbicide TBA in cereal straw and wood preservatives such as copper or boron compounds in shavings or sawdust. The only safe way to prevent damage is to avoid using such contaminated litters.
Other Bulky Organic Manures

Bulky organic manures are soil additives which contain relatively large amounts of ash-free dry matter as carbonaceous material. When applied in sufficient quantity they improve soil fertility by supplying a range of plant nutrients, modifying physical characteristics of the soil, and providing a source of energy for biological activity. Other useful effects which have occasionally been observed are attributed to the presence of growth-stimulating and growth-regulating substances. Some contain, or consist wholly of, waste products often with toxic substances present such as the heavy metals zinc, copper and nickel which in excess can adversely affect plant growth. The most valuable bulky organic manure is that from the farmyard. Other commonly used manures are straw, composts made from straw or other plant residues, town waste compost, screened town refuse, sawdust and peat.

All these manures generally contain small proportions of plant nutrients and only a part of the total content of these nutrients is available for plant growth. The process of rotting which many of these materials undergo, invariably increases the proportion of available nutrients. The availability of plant nutrients is discussed on pages 4 and 27. On agricultural land which is in need of bulky organic manures, the levels of plant nutrients needed are usually higher than can be supplied by normal dressings of these manures; it is usual, therefore, to apply inorganic fertilizers to meet the crop requirement making allowance for any appreciable level of available nutrients in the manure. Residual effects of plant nutrients from repeated heavy dressings of the better manures become appreciable and will be reflected in soil analysis, with consequent reduction of optimum fertilizer dressings.

Results from long term experiments using several bulky organic manures annually or biennially on well structured soils show that effects on crop yield can be accounted for in terms of the plant nutrients that the manures supplied. Under these conditions it is likely that bulky organic manures give useful effect on yields from improvement in physical properties of soil in the short term, that is in the first 5 or 6 years. Over the long term (about 20 years) however, increases in yields were found that were not wholly attributable to plant nutrients in recently applied dressings. It was not possible to determine whether this was due to cumulative residual nutrient effects (especially nitrogen) or to improved physical conditions and/or microbial activity in the soil. The manures were invariably tested under sub-optimal levels of plant nutrients and most of the soils used were structurally stable. Farmyard manure was taken as a standard and such materials as sewage sludge, straw, straw compost, and municipal wastes were compared with it in the presence or absence of additional mineral fertilizers on a range of crops.

Predictably there was much evidence to show that the effect of all these manures could be accounted for in terms of their content of available plant nutrients; for instance the relative effect of a particular manure rich in potassium was greater on a crop responsive to potassium than on a crop unresponsive to that element.

On structurally unstable soils improvements in physical conditions have been noted from repeated dressings of manures containing appreciable amounts of organic matter. These improvements are shown by less frequent occurrence of adverse effects from smearing, formation of impenetrable layers, and capping of the soil surface. Such effects are often brought about by untimely cultivations and the use of very heavy machinery which are particularly harmful in the early stages of crop growth.

The value for crop production of the organic matter in these manures depends upon:

- **Soil type.** The effect of single dressings is most transient in light textured soils; a large effect is likely to be seen in the next crop grown (the direct effect) but little effect in subsequent crops (the residual effect). In heavy soils direct effects are smaller but residual effects are more persistent.

- **Rate of application.** Infrequent dressings of manure applying low rates of ash-free dry matter, that is less than 3 tonnes per ha (1.2 tons per ac), are of little or no value in the context of present day yields of most crops. Regular heavy dressings of manure at 12 tonnes per ha (5 tons per ac) of ash-free dry matter increase crop yields on most soil types and over a period, improve the physical characteristics of soils, often leading to earliness in yield and better quality in horticultural crops. With single dressings of bulky organic manure, a larger proportion of the added organic matter is lost from the soil at heavy rates of application than at low rates. Because of this it requires excessively large and frequent dressings to raise the organic matter level in a soil appreciably, such as that obtained when it is sown to grass for ten or more years.

- **Kind of organic matter.** Ash-free dry matter is a measure of all carbonaceous substances in a manure but other means of analysis can distinguish between readily oxidizable substances and those resistant to oxidation. The former are associated with 'active' forms of organic matter and the latter with inert forms. 'Active' organic matter promotes microbial activity in the soil and in particular, the mineralization of nitrogen; it also takes part in chemical processes which bring about the release of fixed phosphorus and non-exchangeable potassium. It is quickly lost from the soil. Inert organic matter consists mainly of fibrous material the effects of which are largely physical such as small increases in the available water holding capacity of soil and it persists for some years. There is evidence to show that cumulative residual effects from long term application are greater from manures containing larger amounts of inert organic matter than from those with more active organic matter. Manures of animal origin generally contain more active organic matter than those of vegetable origin.
Green Manuring

**Green** manuring consists of cultivating a crop and ploughing it in so making use of the nutrients it contains and at the same time adding organic matter to the soil. Where agriculture is based on livestock, green crops are grown almost entirely for fodder, animal manures are used to maintain the supply of organic matter, and fertilizers provide the extra plant nutrients needed.

With modern trends towards intensive arable cropping soil organic matter levels are likely to be reduced. Much can be done to maintain organic matter by ploughing down good leys, and by returning the tops of sugar beet to land. An alternative possibility is green manuring. It is difficult to make a substantial contribution to the soil organic matter by this means because ploughing in an average crop containing 2-5 tonnes per ha (1 ton dry matter per ac) will add about 0·1 per cent to the soil organic matter and of this only a small fraction will ultimately form humus. However, where green manures are grown regularly in a rotation for a number of years soil management can become more flexible, the organic matter level may be increased and soil structure improved.

The first requirement for a green manure is that it should fit in well with the main cropping sequence. The crops chosen must grow quickly, germinate without elaborate preparation of the seedbed and the cost of seed should be low. Since green manuring is almost always a form of catch cropping, time is of primary consideration. The green manure crop has to make the best growth it can at the beginning or end of the growing season; only in exceptional circumstances will it enjoy the full summer. The most favourable conditions for green manuring occur on warm well drained soils in southern and western districts. A well distributed rainfall is also needed as there is then little risk of water shortage either for the germination of the catch crop or the following main crop.

As a rule only catch crops such as mustard, rape, rye and Italian ryegrass are grown. These non-legumes are useful in that they conserve inorganic nitrogen in the soil which would otherwise be lost between harvesting one crop and sowing the next. When legumes such as clovers, vetches and lupins are used they fix extra nitrogen from the air and when ploughed in it becomes available to the following crop. It is possible that green manures may benefit the following crop by extracting nutrients from the subsoil.

The value of green manuring

If the green manure crop is young it decomposes rapidly in the soil; this may result in some slight improvement in soil structure and a rapid release of nutrients. It is important, therefore, that the following crop should be sown as soon as possible after a green manure crop has been ploughed in otherwise there may be a heavy loss of nitrogen. More mature crops will release nitrogen more slowly over a considerable period of the growing season and will also make a greater contribution to the humus content. Green manures also contain small quantities of nutrients other than nitrogen but these are unlikely to have much effect on the following crop when adequate levels of phosphate and potash are applied as fertilizers.

It has been suggested that growing green manures on otherwise fallow land may modify the population of microbes in the soil in a way favourable to the following crop. Many experiments have shown that green manuring is beneficial especially on light sandy soils but in some cases the increased yields could possibly have been obtained more easily by applying extra nitrogen to the following crop. However, in a two year experiment on a light sandy soil, trefoil increased the yield of the following crop of sugar beet above that achieved by applying nitrogen fertilizers at the optimum level. This suggests that green manuring can sometimes increase the yield of a crop in a way that cannot be achieved by fertilizers. It was also noticed that the green manure not only increased the yield of roots but also the percentage of sugar, an action opposite to that of large amounts of nitrogenous fertilizers. In these experiments the green manure plots were ploughed in the spring whereas the fallow plots used for comparison were ploughed in the autumn; the spring ploughing may have benefited the sugar beet.

Green manuring is not always beneficial—in some experiments it has had very little effect upon following crops and occasionally it has reduced yield. This is thought to be due to the green crop transpiring water and depleting the soil reserve of available water that would otherwise benefit the following crop. The gains from the extra nitrogen provided were more than out-weighed by the loss caused by the water used. It is possible that in a dry season green manures may be harmful. In any case, conserving nitrate is unimportant in dry areas where leaching is unlikely. In some cases the newly ploughed soil may be too dry to allow the green crop to decompose and a strawy green manure may lock up nitrogen or the nitrogen provided by the green manure may be leached out before the following crop is ready to assimilate it.

The methods of growing green manures that have been successfully adapted to rotations in this country are as follows:

**Summer sown catch crops**

These are put in after early potatoes, sheep keep or an early harvested corn crop, for ploughing down either in autumn or early the following spring. Mustard, rape, lupins, and Italian ryegrass are used in this way. A good cover crop in July and August has the added advantage of discouraging wheat bulb fly.
Undersown crops

These may be sown under a cereal crop like an ordinary ley mixture with a view to ploughing-under in the first winter or early the following year. Red clover, trefoil and Italian ryegrass, either alone or in a mixture, are used for this purpose. It should be noted, however, that undersown red clover and other crops can cause difficulties and delay in harvesting cereal nurse crops, especially in wet seasons.

Crops taken on bare fallow

When cleaning operations are completed by July the end of the fallow season may be utilized in growing a green manure crop. Mustard either alone or with rape seed is usually grown and ploughed in for the following wheat crop.

Green manure as a main crop

This is only practised as a means of reclaiming very sandy soils as a preliminary to more profitable rotations. Lupins are usually used for this purpose. Care should be taken when growing cruciferous green manures not to contravene the terms of the Beet Eelworm Order* or the sugar factory contract.

The usual seed rates used for green manuring are as follows: mustard can be sown at the rate of 17 kg per ha (15 lb per ac) and that sown in August should be ready for ploughing under in the autumn. Mustard should not be sown on market garden soils infected with club root as the disease may be carried over from one brassica crop to the next.

Rape sown in July at 11 kg per ha (10 lb per ac) broadcast or 6.5 kg (6 lb) drilled can be ploughed under in the autumn or late winter.

Italian ryegrass sown from July to September at the rate of 33-44 kg per ha (30-40 lb per ac) broadcast gives quick growth and the roots and fibre left behind may help to improve soil structure. Only in south-west England is it possible to use very late sowings of Italian ryegrass with good results.

Nitrogenous fertilizers applied to the crop at 70 kg N per ha (50-60 units per ac) will ensure more rapid growth.

Sometimes difficulty is experienced in obtaining a good growth of trefoil. A pH of at least 6.5 is required and where trefoil or lucerne has not been grown recently, inoculation of the seed is advisable prior to sowing.

Green manures will only be worthwhile when they can be grown without altering the planned sequence of harvested crops. Under-sowing a corn crop with green manure would appear to be most beneficial in that undersown crops do not disturb the rotation, but experiments have shown that undersowing with a green manure may affect the yield of the nurse crop. The direct effect measured in past experiments was usually small but with the larger barley yields expected today the effect may be greater. To get a good take of the green manure it may be necessary to use less nitrogen than that needed for the best yield of cereals.

Seaweed

In coastal areas, particularly in the west and in the Isles of Scilly, the Channel Islands and the Western Isles of Scotland, seaweed has been used as a manure for centuries and is available in large quantities merely for the labour of collection especially after storms. It is a valuable bulky organic manure containing the three major plant nutrients and is rich in potassium. Other constituents, such as magnesium, manganese, iron and zinc, are useful in maintaining levels of trace elements. As collected it sometimes contains more common salt (sodium chloride) than most other bulky organic manures which can be beneficial for crops like sugar beet but may be a disadvantage for potatoes unless applied to the land in the previous autumn in time for the salt to be washed out by winter rain. In the fresh state it is free from weed seeds and spores of common fungal diseases.

### Composition

<table>
<thead>
<tr>
<th>Moisture</th>
<th>N</th>
<th>P$_2$O$_5$</th>
<th>K$_2$O</th>
<th>Ash-free dry matter</th>
<th>Salt NaCl</th>
</tr>
</thead>
<tbody>
<tr>
<td>68</td>
<td>0.6</td>
<td>0.3</td>
<td>1.0</td>
<td>16</td>
<td>1.3</td>
</tr>
</tbody>
</table>

The fertilizer value of seaweed is due mainly to its potassium content, there being only small amounts of available nitrogen and phosphorus.

If the weed is left on the beach in heaps exposed to the weather some of the potassium may be washed out, so for the best effect it should be spread and ploughed in soon after collection. Alternatively it may be composted with farmyard manure, straw and vegetable or domestic refuse. Little manurial value is lost if seaweed is dried rapidly and stacked under cover during the summer. In some places it is customary to burn it and to use the ash on the field but in this process the benefits of the organic matter are lost. Commercial dried seaweed meals and liquid preparations containing alginites are also on the market.
Sewage Sludge

The aim of sewage treatment is to separate suspended solid matter and dissolved organic matter as sludge, and produce a liquid effluent which achieves prescribed standards of purity and can be safely discharged into water-courses. Some understanding of sewage processes is necessary to appreciate the difference between the various forms of sludge which are available.

Raw Sludge

Raw sewage sludge is produced by the sedimentation of raw sewage and is a black offensive material with initially about 4 or 5 per cent dry matter. The raw sludge from the sedimentation tanks is further treated, either by the activated sludge process or by biological filtration giving secondary sludges which are generally mixed with the raw sludge to give raw mixed sludges. These usually contain, on a dry weight basis, about two thirds primary and one third secondary sludge.

Digested Sludge

A considerable proportion of raw mixed sludge is treated by anaerobic digestion, in warmed closed tanks, which destroys the offensive smell of the raw materials, decomposes grease and greatly reduces pathogenic organisms present. Since organic matter is lost as carbon dioxide, while nitrogen is unaffected, the nitrogen content of the dry solid increases.

De-watering

Both the digested and raw mixed sludges may be mechanically de-watered and to assist this process chemicals, either lime and ferrous sulphate or aluminium chlorohydrate, may be added. De-watering raises the dry matter content to 15 per cent or more and the air drying in beds will further reduce the moisture content and make the product easier to handle. Alternatively, and this practice is on the increase, liquid digested sludge with 3 to 5 per cent dry matter may be transported in tankers for direct application to the land.

Composition

Some typical analyses of the three kinds of sewage sludge, and an estimate of their available nutrient content is given in the following table:

<table>
<thead>
<tr>
<th>Percentage total nutrients in fresh material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Raw sludge—air dried</td>
</tr>
<tr>
<td>Digested sludge—air dried</td>
</tr>
<tr>
<td>Liquid digested sludge</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Approximate available nutrients in 5 tonnes (tons) of fresh material</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Raw sludge—air dried</td>
</tr>
<tr>
<td>16 (33)</td>
</tr>
<tr>
<td>Digested sludge—air dried</td>
</tr>
<tr>
<td>Liquid digested sludge</td>
</tr>
</tbody>
</table>

one cubic metre weighs one tonne (1000 gallons weighs 44 tons)

Fertilizer Value

Sewage sludges are useful sources of nitrogen and phosphate but contain little or no potash as it is lost in the liquid effluent with some of the nitrogen. There has been a tendency for phosphate contents to increase in recent years, due to the widespread use of synthetic detergents which contain phosphate. The nitrogen content of the dry matter is higher in liquid digested sludge than in other sludges, and the availability of nitrogen is also greater due to the presence of soluble ammonium salts some of which are lost when the sludge is de-watered. Experimental work and advisory experience suggests that 85 per cent of the nitrogen in liquid digested sludge and one-third of that in other sludges is available to crops in the year of application. The nitrogen, especially in digested sludge, is more readily available to plants than that in farmyard manure.

Winter applications, however, especially of liquid digested sludge, may result in considerable loss of nitrogen by leaching. It is also considered that about 50 per cent of the phosphate and 90 per cent of the potash present is immediately available to crops.
**Application**

Solid sewage sludges are bulky to handle and are difficult to spread on the land, especially if too wet. In this condition they may dry in hard lumps difficult to incorporate in the soil. Generally they should be allowed to weather on the soil surface before being harrowed and ploughed in. The organic matter content of sewage sludges is rather higher than that of farmyard manure, but its physical condition is very different so that it does not have the same beneficial effects on the structure of heavy soil. Liquid digested sludge is normally spread on the land from tankers which bring it from the sewage works, although in a few cases it may be pumped through pipelines to rain guns. Care must be taken not to run heavy tankers over the land when it is wet, otherwise compaction on most soils, and smearing on heavy soils may occur with adverse effects on the yield of crops.

**Toxic Elements in Sewage Sludge**

Sewage sludges, even those from sewage containing little or no industrial effluent, contain metals such as zinc and the levels can become dangerous where wastes from industry are discharged into the domestic sewage system. From the point of view of plant growth following the use of sewage sludge, zinc, copper, nickel and possibly cadmium are the metals most likely to give trouble, while in liquid sludges boron could also present problems. In addition to these elements lead is usually present in appreciable amounts and sometimes mercury. Plants grown on soils containing cadmium and mercury could be harmful when eaten by man or animals. Direct contamination of herbage with soils containing lead can harm grazing stock.

In order to give guidance on the safe rates of application for cropping the concept of zinc equivalent has been developed. From experience and experimental work it has been found that nickel is eight times and copper twice as toxic to plants as zinc. A figure for the zinc equivalent of sewage sludge can be obtained by adding together the metal contents in mg per kg after conversion to the equivalent amount of zinc. Thus a sewage with 1,000 mg per kg zinc, 250 mg per kg copper and 50 mg per kg nickel would have a zinc equivalent of

\[
1,000 + (2 \times 250) + (8 \times 50) = 1,000 + 500 + 400 = 1,900 \text{ mg per kg.}
\]

Advisory experience indicates that most agricultural crops can tolerate zinc in the soil up to about 250 mg per litre in the top 15 cms (6 in.). Theoretically this level is reached when 560 kg (500 lb) of zinc equivalent has been added to one hectare (ac) of uncontaminated land that contains only traces of these metals. It does not seem to matter whether heavy metals are added in one or two massive dressings or whether small dressings are added over a period if the final level in the soil does not exceed 250 mg per litre of zinc equivalent. If it is assumed that it would be acceptable to reach this level in the course of a generation, say 30 years, this means that only

\[
\frac{560}{30} = 19 \text{ kg per ha (} \frac{500}{30} = 17 \text{ lb per ac) of zinc equivalent can be added annually.}
\]

As an example of how this calculation works in practice: if a sludge with 3,000 mg per kg zinc equivalent is applied at 25 tonnes per ha (10 tons per ac) it will add 75 kg (67 lb) zinc equivalent, and at this rate per ha (ac) should only be applied once in 4 years.

The harmful effects of metals on plant growth are generally worse in acid soils low in organic matter. The rates of metal additions discussed above assume that the soil has a pH of 6.5, and a normal organic matter content.

Effects of toxicity can be reduced by liming to bring the soil pH above 7.0 or by adding organic manures. Crops vary in their sensitivity to metal contamination of the soil and there is also evidence that some grasses can become adapted so that they can tolerate levels which would normally be damaging, but under the conditions outlined in this chapter even the most sensitive crops should be safe.

**Sewage Effluent**

This is the almost clear liquid left after the solids have settled in the secondary activation process followed by biological and tertiary filtration treatment. It is often discharged into rivers, but as it contains small proportions of soluble nitrogen and potash (10-50 mg per litre) it can be used for irrigation on farms. However, it should not be applied to salad crops because it contains bacteria which may be a hazard to health.

Synthetic detergents have been used in ever-increasing quantities over the past few years and these pass into sewage treatment plants. Part of the detergent remains in the final sludge and part goes through the whole process into the effluent.

The early detergents were based on alkylbenzene sulphonates sometimes with perborates. Sulphonates can cause damage to crops and are resistant to biological degradation. Some sludges may contain up to 2 per cent of their dry matter in this form. The effect of detergent on soils, particularly sandy types, is to cause them to become easily waterlogged at first with a smaller quantity of water than normal and then to lose water more rapidly than a normal soil due to a reduction in the total water holding capacity. Structural breakdown is accelerated, but soils with a fair proportion of clay or organic matter are resistant to these effects.

Recently there has been a change towards detergents more easily degraded biologically so less foam now occurs on activated sewage beds or rivers into which effluent has been discharged. On the other hand the content of perborate in washing powders has been increasing and now is as high as 25 per cent in some products. Sewage effluents contain up to about 7 mg per litre of boron. Excess boron is toxic to plants, the level at which toxicity occurs depending on the species.
The plant nutrient content depends on the kind of weed. The brown types—Laminaria, Fucus and Ascophyllum—are most commonly collected from beaches on to which they have been thrown by tides and storms, or by deliberate harvesting between high and low tide levels.

Laminaria, which grows below the low-water mark, is generally known as 'drift-weed', 'May-weed', 'tangle', 'kelp' or 'oar-weed' and is the seaweed richest in potash; the dry stems contain 10-12 per cent and the dry fronds about 5 per cent. The average nitrogen content of the dried material is about 2 per cent. Laminaria can be harvested only from a boat or collected after it has been washed ashore.

Fucus and Ascophyllum on the other hand flourish between tidal levels and may therefore be harvested by cutting from the rocks at low tide. The former is more plentiful and is familiar under the names of 'bladder-wrack', 'black-wrack' and 'cut-weed'. The potash content of the dried material is 3-4 per cent and the nitrogen about 1 per cent. Ascophyllum, known as 'knotted-wrack', has a similar composition. One green variety, Ulva, known as 'sea-lettuce' or 'green laver' is often washed ashore in large quantities in quiet bays and creeks. It is a better source of nitrogen than the brown varieties as the dried fronds contain up to 4·75 per cent.

The potash and common salt content of seaweed make it a useful manure for sugar beet and mangolds. Other crops which benefit are brassicas, barley, grassland and clover, especially on light sandy soils which are common around some coasts. These soils are deficient in potash and dry out readily. For arable crops the usual rates of application are between 100-125 tonnes per ha (40-50 tons per ac) rotted or composted or 40 tonnes per ha (15 tons per ac) of dried material. Local customs vary in that the manure is sometimes ploughed in immediately after spreading and at other times spread as and when gathered and ploughed in later. Freshly collected seaweed can be spread in spring on grassland so that when growth begins the grass pushes its way through the seaweed causing it to break down quickly.

**Organic Fertilizers**

Organic fertilizers are waste materials of animal or vegetable origin containing nitrogen and occasionally phosphate. They are distinguished from organic manures by their relatively high nutrient content and lack of 'bulk'. When added to the soil the nitrogen in organic materials is converted to inorganic nitrate at a rate which varies with the type of organic fertilizer or with particle size. Experiments indicate that the nitrogen in organic fertilizers is never more effective and often less so than in inorganic fertilizers. The phosphate in organic fertilizers is insoluble and generally less effective than in water soluble inorganic fertilizers.

**Dried blood** (up to 13 per cent N)

Dried blood becomes nitrified in soil more quickly than most of the organic fertilizers and the nitrogen has about 90 per cent of the availability of that in ammonium nitrate. The method of drying influences the quality depending on whether it is by direct heat, steam or vacuum low-temperature. The last process yields a crystalline material of the best quality. Most grades are partly soluble in water.

**Fishmeal** (6-10 per cent N)

Offals from canneries, inedible species and over-large catches when dried and ground have a composition of 6-10 per cent N and 5-9 per cent P₂O₅. The product is used either straight as 'fish guano' or as the basis of a range of compound organic manures.

**Meat and bone meal** (4-12 per cent N)

Waste meat, offals and condemned carcasses when steamed under pressure to remove fat and sterilize possible disease organisms gives, after drying and grinding, meat and bone meal. The grades used as fertilizer contain 5-10 per cent N and 18 per cent P₂O₅.

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**Feathers** (3-13 per cent N)

The large increase in production of broiler poultry has resulted in large quantities of feathers becoming available. Many are burnt as a means of disposal or ground for use as a protein feed for livestock but some are used as a horticultural fertilizer. Small feathers easily decompose in soil but large ones are more persistent. Rates of up to 2·5 tonnes per ha (1 ton per ac) are applied.

**Leather dust** (5-12 per cent N)

Scraps from glove manufacture and the boot and shoe industry have been used in horticulture, but though the nitrogen content may be as high as 10 per cent the availability can vary considerably. Chrome tanning and some other processes may make leather dust almost useless since chromium and other heavy metals are toxic to plants in large amounts.
Rape cake (5 per cent N)
A hundred years ago this was a standard manure produced from the pressing of rape seed for oil. Its historical importance is that it was used in all the classical experiments at Rothamsted and Woburn, and with its high residual value it has given yields of barley comparable with those from a complete compound fertilizer, while for mangolds it has been superior. In the short term it is slightly inferior to ammonium nitrate on an equal nitrogen basis for potatoes, mangolds, kale and Brussels sprouts. Rates of up to 2.25 tonnes per ha (18 cwt per ac) were not uncommon. There are signs of a renewed interest in the growing of rape for seed. This might lead to occasional consignments of rape cake becoming available.

Castor meal (5-6 per cent P₂O₅)
Because it is poisonous to stock, this residue from the manufacture of castor oil is sometimes used in horticulture as an alternative to meat and bone meal.

Shoddy (2-15 per cent N)
Shoddy is wool waste and when pure contains 12-15 per cent N. It often contains a proportion of cotton and dirt which can result in medium grade materials of 5-10 per cent N or low grade materials of 2-5 per cent N. Since the use of synthetic fibres such as nylon became widespread, waste consisting mainly of synthetic fibres is occasionally marketed as shoddy. As most synthetic fibres are very resistant to breakdown in the soil such wastes have almost no fertilizer value. Before purchasing shoddy it is advisable to ensure that its content is mainly wool. True shoddy, containing mainly wool, is a quick acting nitrogenous fertilizer. The physical condition is important; loose friable samples are easier to spread than those that are matted.

Miscellaneous Materials

Particularly in rural areas, where small industries based on locally produced materials are found, quantities of waste products are often offered for a small charge sufficient to cover the labour cost of carting away. The quantities are often too small to be of national interest yet may be of value to agriculture or, even more, to horticulture within a few miles of the source. Examples are leather trimmings from the manufacture of gloves and soft slippers or sheepskin coats; willow stripings; coffee waste; spent hops; feathers and viscera from poultry packing stations; blood from slaughterhouses and carcasses from knackers yards. The materials most frequently offered are briefly described.

Brewery residues (2.5-3.5 per cent N, 1.0 per cent P₂O₅)
Hop residues and malt culms may be used for feeding livestock but low grade, damaged or unwanted consignments are useful as bulky organic manures containing some nitrogen and phosphate. If fairly heavy dressings are applied they will improve the physical state of the soil by the addition of organic matter.

Hops are extracted with water in the process of brewing and the wet residue comprises spent hops, which may be collected from the brewery and used directly on the land. If this is partially dried and fortified with inorganic fertilizers the result is known as 'hop manure'. Extra potash is sometimes added.

Chicory waste and coffee waste (1.0-1.7 per cent N)
Quantities of these and mixtures of the two come from the preparation of quick-brew powdered coffee and of coffee essence concentrates. Their chief value is as a source of organic matter and as a mulch for horticultural crops. The small amount of nitrogen present becomes slowly available.

Cocoa waste (1.4-2.2 per cent N)
The husks of cocoa beans are produced in fair quantities in the manufacture of cocoa and chocolate and are similar in value to coffee and chicory waste.

Malt culms (3.5 per cent N)
These are the rootlets and shoots of barley which have been produced by germination of grain in the malting process and shrivelled by subsequent heating and drying. Only small quantities are likely to be obtainable near to breweries.

Malt fibre (5.2 per cent N, 2.1 per cent P₂O₅, 1.1 per cent K₂O) is similar to malt culms.

Other materials of similar nature are mustard husks (3.3 per cent N), flax savings and cleanings (3.6 per cent P₂O₅, 9.2 per cent K₂O). Dried residues from retting tanks (0.8 per cent N, 0.2 per cent P₂O₅, 0.7 per cent K₂O). Tobacco waste (0.6-0.8 per cent N, 0.1-0.2 per cent P₂O₅) and barley stripings (4.7 per cent N, 1.7 per cent P₂O₅, 2.4 per cent K₂O).