How stubble affects organic matter, plants and animals in the soil

Judy Tisdall

Follow this and additional works at: https://researchlibrary.agric.wa.gov.au/journal_agriculture4

Part of the Natural Resources and Conservation Commons, and the Soil Science Commons

Recommended Citation

Available at: https://researchlibrary.agric.wa.gov.au/journal_agriculture4/vol33/iss1/9

This article is brought to you for free and open access by Research Library. It has been accepted for inclusion in Journal of the Department of Agriculture, Western Australia, Series 4 by an authorized administrator of Research Library. For more information, please contact jennifer.heathcote@agric.wa.gov.au, sandra.papenfus@agric.wa.gov.au, paul.orange@dpird.wa.gov.au.
How stubble affects organic matter, plants and animals in the soil

By Judy Tisdall, Soil Scientist, Institute for Sustainable Agriculture, Tatura, Victoria

Cereal yields have not increased greatly in Australia over the past 30 years and they are still only about half the potential determined by rainfall.

One of the reasons for these low yields is our fragile soils, worsened by traditional systems of tillage and the burning of stubble. These systems reduce the levels of organic matter and biological activity in soil.

Organic matter in soil includes all living plants, animals and microorganisms in the soil, and the organic materials they release. It also includes all the residues of plants and organisms at various stages of decomposition down to humus.

Humus is the dark brown end product of decomposition of organic matter. It is highly degraded organic matter, so is not readily used by microbes and does not provide nutritious food for earthworms.

Organic matter holds the soil together against erosion by wind and water. It keeps the soil soft, permeable and well aerated, and supplies food for plant roots, microorganisms and animals in the soil.

Soils usually become more stable to water after the addition of decomposable organic residues or after the growth of plants. The stable soil aggregates — the groups of particles that make up the soil — do not collapse when wetted quickly by rain or irrigation.

Pastures generally produce more roots and release more organic materials into the soil than do crops, therefore soil under pasture is more stable than soil under crops.

Direct drilled soils have more roots, organic matter and soil organisms and are more stable than tilled soils. Tilled soils are unstable because tillage breaks up the root systems, oxidizes organic matter and decreases the microbial populations. Since crops supply more organic matter than fallow, soil cropped every year is more stable than soil fallowed every second or so years.

NUTRIENTS AND ORGANIC MATTER

Organic matter regulates the supply of nutrients to plants. This is partly because organic matter contains most of the nutrients plants need, and partly because some nutrients become adsorbed by organic matter and are released slowly into the soil.

Most organic matter in soil is able to hold major plant nutrients (see Table 1). Organic matter also forms complexes with micronutrients or trace elements, and these complexes supply readily available trace elements to plants.

Nitrogen

More than 95 per cent of nitrogen in soil is in the organic matter. Plants cannot use this nitrogen until microorganisms have changed it to ammonium or nitrate forms (inorganic
Most of the nitrogen changed by microorganisms comes from organic matter added to the soil during the previous five years. The microorganisms release the nitrogen slowly, so crops can use the nitrogen before it can be leached out of the root zone and lost. For high yields, crops often need extra nitrogen from legumes or fertilizer.

When stubble is burnt, nitrogen is lost from the soil as gas.

On the other hand, the growth of legumes, encouraged by applied superphosphate, increases the level of organic nitrogen in the soil.

The higher the proportion of nitrogen in the organic residues, the more quickly the inorganic nitrogen is released for use by plants. Microorganisms also use some of the available nitrogen, competing with the plant for it. The amount of nitrogen that plants or microorganisms use depends on the ratio of carbon to nitrogen in the organic residues. The higher the ratio, as in undecomposed cereal residues, the more the microorganisms compete with the next crop for nitrogen.

Stubble has a high ratio of carbon to nitrogen. Ploughing stubble into the soil before the next crop can temporarily deprive that crop of nitrogen, because the microorganisms could use more of it, but in practical terms this does not affect crop yield. This lack of available nitrogen, if it occurs, can be avoided by nitrogenous fertilizer placed below the seed or applied later in the season, once the stubble has broken down.

**Phosphorus**

Organic matter may contain 15 to 85 per cent of the total phosphorus in soil. About half of this phosphorus is stable and cannot be released by microorganisms. Microorganisms use much of the inorganic phosphorus derived from organic matter, leaving little for the crop. So crops usually rely on inorganic fertilizers to supply their phosphorus.

Some microorganisms produce small amounts of acids from decomposing organic matter, which may release phosphorus from mineral soil.

**Other nutrients**

Organic matter contains at least 50 to 70 per cent of the sulphur in most soils. When stubble is burnt, organic sulphur is lost as gas.

Organic matter holds potassium, calcium and magnesium in forms that are readily available to plants. It also contains all the trace elements plants need. The availability of these micronutrients depends upon properties of the organic residues and of the soil.

**PLANTS AND ANIMALS WITHIN THE SOIL**

**Mycorrhizas**

A mycorrhiza is an association between a fungus and the root of a plant. The fungus gets its energy (carbon) from the root, and in return, takes up phosphorus and other nutrients for the plant to use. The fungal hyphae or filaments also help to stabilize soil aggregates.

The most common type of mycorrhiza is a vesicular arbuscular or VA mycorrhiza. In a VA mycorrhiza, the fungal hyphae penetrate the tissues inside a root and branch finely within the root cells. (Arbuscular means much branched, like a little tree.) These branches absorb food for the fungus from the cells of the root.
Mycorrhizal fungi can only stabilize soil aggregates when their hyphae infect and colonize the roots, and grow and survive in the soil. Most species of VA mycorrhizal fungi can infect most species of plants, unlike strains of rhizobia which can only infect specific plants. However, as the plant supplies energy to the fungus, some combinations of plant and fungus may produce more hyphae in the soil or more gums than others. Some fungal species also grow further out from the root than do other species.

Mycorrhizas are also important in the root’s uptake of phosphorus. The fungal hyphae ‘extend’ the roots of the plant, to explore a greater volume of soil and increase the uptake of phosphorus. In Queensland, where a long fallow (more than 12 months) had decreased the amount of VA mycorrhizal fungi in soil, wheat crops did not yield well, and were found to be deficient in phosphorus.

We do not know how to encourage these fungi to grow and survive in soil, or to stabilize soil aggregates. However, the soil pH, organic matter, fungicides, pesticides, other organisms and the level of phosphorus in the plant each influence the activity of some VA mycorrhizas.

Long fallow and excessive tillage break up the network of roots and hyphae. This destabilizes soil aggregates, and probably slows the rate at which hyphae can later infect plants and stabilize aggregates.

Roots

Roots also affect soils by producing pores or channels. As roots grow through the soil, they prefer to follow cracks or old channels formed by roots or soil animals. However, once in a channel, the root can expand and widen the channel, and so increase aeration and the growth of future roots. These channels are often highly stable and may remain under direct drilled crops from earlier crops. Tillage destroys many of these channels.

Roots, root hairs and fungal hyphae, especially those of VA mycorrhizas, bind the very fine sand grains into stable, slightly bigger and intact soil aggregates. The hyphae are bound to the soil particles through a mucilaginous mixture of fungal gums and keep the aggregate soft, permeable and well aerated.

When organic residues are added to soil, saprophytic fungae, which live on dead organic matter, also hold the soil aggregates together. However, their hyphae disappear from soil once they have used up all the decomposable residues.

Hyphae of VA mycorrhizas, on the other hand, appear to persist for longer and so are probably more important stabilizers of soil aggregates than are saprophytic hyphae.

Soil animals

Organic residues increase the population of soil animals, some of which mix nutrients with soils, some break down organic matter, and some produce burrows in soil.

The most common soil animals are the microfauna, which are shorter than 0.1 mm, and are hard to see. They are not being studied in Australian soils.

The next group is the mesofauna, which are from 0.1 mm to 100 mm long, and includes small insects, spiders, small millipedes, mites and springtails.

Little is known about the microfauna and mesofauna in our arable soils, although they are probably important in the breakdown of organic residues.

The macrofauna — animals that are easily seen — make up the last group. They include earthworms, woodlice, millipedes, centipedes, snails, ants and termites.

Most work on macrofauna in Australian soils has been done in south-eastern Australia on earthworms. However, other macrofauna may be more numerous and more active in some of the soils of the Western Australian wheatbelt where food and water are scarce.

In Western Australia, Ian Abbott and others from the Western Australian Museum showed that termites, ants and beetles had produced burrows in three virgin soils in the 350 to 450 mm rainfall zone of the wheatbelt. Tillage has almost eliminated these soil animals and their burrows from tilled soils, probably because it had destroyed their food and burrows. We understand little of the activities of these animals in soil, although their beneficial effects may be similar to those of earthworms.
Earthworms

Ian Abbott and Lex Parker, formerly of the University of Western Australia, found four species of earthworms in 122 sites in the Western Australian wheatbelt. They found earthworms in 54 per cent of sites with pasture, in 23 per cent of sites with native vegetation, but in only 18 per cent of tilled sites. Laboratory experiments suggested that earthworm populations at these sites were limited by not enough food rather than low rainfall.

Earthworms can survive on a diet of mineral soil, but they lose weight if they do not have enough high quality organic matter such as partly decomposed animal manure or grass and clover leaves.

Retained stubble is a source of food for earthworms. More earthworms will be found in soils with retained stubble compared with those with burnt stubble. For example, in two sites in south-eastern Australia, there were about twice as many earthworms in direct drilled soil with retained stubble, as in direct drilled soils with burnt stubble, or in traditionally tilled soils (see Rovira et al. 1987; Haines and Uren 1990).

Earthworms can survive in dry soil, but they are not active, and prolonged drought kills them. They are sensitive to poor aeration, so they often abandon poorly drained soil temporarily after rain.

Earthworms and soil structure

Earthworms affect soil structure by burrowing through soil, by mixing organic litter into the soil and by producing casts. Earthworms ingest and mix large amounts of soil and organic matter in their guts and deposit the material as casts. This effect is essential in soil stabilized by organic matter and direct drilled. Their activity also brings about the mixing of fertilizers and pesticides with the soil.

Earthworm casts are aggregates of soil and tend to be more stable than the surrounding soil. They do not slump or slake when wetted, and they prevent impermeable crusts forming on the surface.

Burrows

Earthworms produce their own burrows to live in and to move around soil. In soils where earthworms are very active there is an extensive network of interconnected horizontal and vertical burrows, which are usually continuous to the surface. These burrows are very stable. They may persist for years after the earthworms have left.

Burrows can be one millimetre to more than 10 mm wide, depending on the size of the earthworm. The burrows often increase the percentage of large pores in the soil. These burrows also contribute to infiltration of water, and increase drainage and aeration of the soil.

Further reading


