> *Studies show an integrated approach of applying composts and manures with synthetic nitrogen is a good strategy for building organic matter.*

Carbon cycle

Balancing matters

How does carbon cycling help to build soil organic matter and what role does nitrogen play during the process? *CPM* explores the topic.

By Rob Jones

The role of nitrogen fertiliser in increasing yield and profitability is widely acknowledged. However, a predominant focus on the nutrient's cycle and utilisation may have led to neglecting the importance of preserving soil organic matter reserves.

As researchers further their understanding of soil function and how organic matter is created, will it become easier to balance the two more effectively?

To begin, higher organic matter soils typically have better pore structure leading to increased water holding capacity and reduced nutrient leaching, while providing greater resilience. This doesn't necessarily lead to higher crop yields, especially once soil organic carbon exceeds 2%.

Building organic matter starts with photosynthesis, explains Joel Williams, a soil health educator and consultant from Integrated Soils. "Plants take in carbon dioxide, turn it into sugar and that becomes the building blocks of their bodies. It's how they grow biomass both above and below ground."

Particulate organic matter

When plants die, that biomass is broken down to form organic matter with the roots making a greater contribution, partly through their location in the soil. Microbes use external digestive enzymes to break down plant litter from the highly complex, high lignin-containing carbon compounds into smaller and smaller pieces, explains Joel.

"This is known as particulate organic matter – plant material such as crop residues, dead cover crops and roots in various states of decay – the fraction of carbon that's continually decomposed and cycled."

But this isn't the only type of organic matter. Relatively recent research, driven by the increasing interest in soil organic carbon's role in potentially mitigating climate change, has uncovered that as much as 50% of organic matter is derived from microbial dead bodies rather than it being virtually all decaying plant material.

When the microbial digestion process creates small enough carbon compounds to be ingested by microbes, explains Joel, the carbon becomes of microbial origin and is used to grow microbial ▶

Building organic matter starts with photosynthesis, explains soil health educator and Integrated Soils consultant, Joel Williams.

Benefits of molasses

Liquid carbon-based fertilisers based on sugar cane molasses, such as L-CBF Boost from QLF Agronomy, help to prime the carbon cycle in the soil, according to the firm's US-based vice-president of agronomy, Tim Chitwood.

The molasses acts as a carbon source that provides energy to microbes and helps them to cycle nutrients, he continues. "We're mimicking what Mother Nature wants to do, and that's cycle carbon."

When combined with other management practices such as a more diverse rotation, growing cover crops and reduced tillage, using L-CBF Boost amplifies the effect of making soils more biologically inhabitable, he says.

There are three main times to use a molasses-based product, suggests QLF Agronomy's UK national sales director, David Maxwell. "First, applying it with a starter fertiliser increases microbial loading and helps with rooting and resilience. It'll also help to increase root biomass, allowing the crop to unlock and make more from any residual or newly applied fertiliser," he explains.

"If you're direct drilling, leaving a larger root network will also add to your organic matter over time."

L-CBF Boost, however, is most commonly used in the early spring with fertiliser applications. "That's about improving nutrient use efficiency by spiking the bacteria to consume applied nitrogen and move it from the leaky nitrogen cycle to the more stable carbon cycle," adds David.

The product can also be used with foliar nitrogen applications, which can potentially help to reduce the total nitrogen applied. "Foliar applications are 3-4 times more efficient, and by using them, you reduce the amount of salts (from the urea) you're applying to the soil, producing more of an environment that's better for microbial activity," he concludes.

According to QLF Agronomy's David Maxwell, there are three main times to use a molasses-based product, the first being to apply it with a starter fertiliser.

biomass. Higher carbon-to-nitrogen (C:N) ratio litter such as from cereals, takes longer than low C:N legume cover crops, for example, to reach that point.

Plants also release as much as 30% of the carbon they make during photosynthesis through their roots as exudates. These exudates are also carbon compounds with a lower molecular weight, which can be efficiently ingested by microbial soil life directly without the inclusion of external digestive enzymes.

"When the microbes die, the microbial necromass (a large, dynamic and persistent component of soil organic carbon) has an affinity to stick to soil particles, particularly silts and clays, to form more stable organic matter. This is known as mineral-associated organic matter," says Joel.

Clay soils form more of this type of organic matter than sandy soils, as carbon has more mineral surfaces to bind with in clay soils. However, because there's a finite number of mineral surfaces to adhere to, this type of organic matter will eventually plateau.

In contrast, particulate organic matter doesn't appear to saturate – such as a peat bog where plants grow and die year after year, highlights Joel. "You can build lots of this organic matter but once that environment is disturbed, it's very prone to being lost because it's not chemically attached to soil particles."

Adding legumes, whether in the rotation, as companion crops or in cover crop mixes, helps to prevent nitrogen mining from soil organic matter.

In contrast, mineral association is one of two key mechanisms to stabilise carbon inputs coming into the soil, he says.

"Whereas the second is a physical process, where carbon is trapped within soil aggregates. When soil aggregates – soil particles that are clumped together partly through the glue-like substance released by microbes – any carbon inside gets physically trapped and protected. This can be either particulate organic matter or mineral-associated organic matter."

Practically understanding how the two types are formed can help with management strategies. For example, avoiding tillage means soil aggregates aren't broken up, helping slow down the particulate organic matter carbon cycling.

Whereas maintaining living roots as much as possible through growing cover crops will pump more exudates into the soil, which can be converted more readily into mineral-associated organic matter, continues Joel.

Adding legumes, whether in the rotation, as companion crops or in cover crop mixes, is also helpful, he points out. "Legumes get some 'free' nitrogen from the air to deposit organic nitrogen into the system, which is released through their nitrogen-rich root exudates and helps prevent nitrogen mining from soil organic matter when breaking down high carbon residues."

Priming the carbon cycle, particularly by growing microbial communities, is also

Do N inputs burn or build SOM?

There has been plenty of discussion, and perhaps a little controversy, regarding whether nitrogen inputs burn or build soil organic matter. Joel Williams says that's with good reason, as research suggests the answer appears to be both.

"It's context-dependent, so there's no easy answer," he says. "The evidence from research papers is mixed with plenty showing nitrogen inputs help increase soil organic matter, while others show the reverse."

Nitrogen can stimulate the breakdown of soil organic matter, where nitrogen-enriched microbes require carbon to maintain the carbon-to-nitrogen (C:N) ratio of their bodies, which they find within organic matter.

Where nitrogen is found to increase soil organic matter, it's typically linked to building plant biomass – so the soil receives greater residue inputs to convert into soil organic matter. But too much carbon can result in microbes mining nitrogen from soil organic matter.

The picture is further complicated by research which suggests increased nitrogen fertilisation generally increases above-ground biomass production but not necessarily root biomass. That can be good for boosting yields and indeed most varietal selection has been bred for that type of trait, adds Joel.

However, it's the root biomass and exudates that are more important for building soil organic matter. "This points towards nitrogen fertiliser not being so good for roots," he says.

Joe highlights that one research study suggests applying insufficient nitrogen results in limited biomass production, including root growth. But as nitrogen increases, biomass production is optimised, but only up to a point. "If there's surplus nitrogen, it begins to have a negative effect specifically on root biomass," he comments.

"And it's the roots that build soil organic matter, so the nuance in this discussion is how nitrogen affects that below-ground carbon allocation. The simple answer is, it's another reason to optimise your nitrogen applications."

possible through applying carbon-based inputs such as composts and manures. "There are plenty of studies that show an integrated approach of applying these with synthetic nitrogen is a good strategy for building organic matter," says Joel.

Carbon-based inputs also have a role in helping to optimise nitrogen fertiliser additions. Options such as humic and fulvic acids, and to a lesser extent molasses, act as a carbon sponge binding to nutrients, making nitrogen less likely to leach and helping to optimise inputs (see box).

Where molasses has the advantage over organic acids, is by providing a highly digestible, highly available carbon carbohydrate form of energy to stimulate soil biology, suggests Joel. "In the soil generally, carbon is more limiting, so when we apply some carbon it stimulates their growth."

It also stimulates soil biology to effectively eat nitrogen fertiliser to balance the C:N ratio within their bodies to grow, he adds. "That incorporates the nutrients from that fertiliser into their cells, and it's a way to stabilise the nutrient and help prevent it leaching, creating a slow-release fertiliser," he concludes.■

Strategic focus

Building soil organic matter at Osbaston House Farm is a key part of Will Oliver's management strategy.

Building soil organic matter in his mostly clay/loam soils is a key part of Will Oliver's strategy for Osbaston House Farm. "We're always thinking about soil organic matter," he says.

The 600ha farm makes good use of organic manures from a 200,000-bird broiler unit with litter and digestate applied in spring on wheat, and sewage sludge before grain maize.

Grain maize trash also adds organic matter to soils within the rotation with reduced tillage and direct drilling used when appropriate to avoid soil disturbance. "We've done a lot of mole ploughing this year with the aim of improving drainage. Hopefully that'll help to improve soil health in the long term."

Cover cropping and catch cropping are utilised in a rotation that features winter wheat and winter beans, as well as the grain maize. Will is also making use of L-CBF Boost, having first trialled it on a few tramlines in a maize crop a few seasons ago.

Applied in a mix with the pre-emergence herbicide, pendimethalin, he could see to the line where L-CBF Boost had been used. "I think it's helping to feed the soil biology and hopefully get more out of the organic manures we're using," he explains.

After also seeing a small yield increase in the grain maize, he trialled it in wheat, again applied with a pre-emergence herbicide. "We didn't see much difference at emergence, but there was a yield benefit of around 0.2 t/ha in our tramline trials."

While he believes it's a little early to say whether L-CBF Boost has directly contributed, the combined effect of his management changes is leading to improved organic matter levels in his soils. "We want more resilient soils so they can cope with these freak weather events we seem to be getting," concludes Will.