

Soil Fertility Changes Under Long-Term Direct Seeding

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THE SURFACE RESIDUE LAYER

One of the most profound effects of adopting minimum disturbance direct seeding is the development of a surface residue layer. The surface residue, a.k.a. thatch or duff layer accumulates due to the addition of organic material to the soil surface and lack of incorporation. Without incorporation, decomposition is reduced (Schoenau and Campbell, 1996). Similarities exist between the no-till system and native grasslands. In native grasslands, above ground vegetation develops, matures, dies and forms a layer on the surface of the soil. Nearly thirty years ago, Doran (1980) noted that the no-till ecosystem has similarity to other undisturbed ecosystems such as native grassland, with levels of carbon, nitrogen and water that are higher than tilled land.

The benefits of above ground residues on protection of the soil from wind and water erosion, reducing evaporation and improving soil moisture conditions have been well documented (Dormaar and Carefoot, 1996). Along with benefits, some concerns have also arisen, including lower soil temperatures in early spring, immobilization of fertilizer nutrients placed in the thatch layer and nutrient stratification due to lack of soil mixing. This paper considers the kinds of changes that may occur in the soil after several years of no-till as related to the accumulation of surface residue and its impact on soil fertility and nutrient dynamics.

BUILDING AN EFFECTIVE SURFACE RESIDUE LAYER

Building an effective surface residue layer and a mineral soil beneath with increased organic matter content, aggregation and nutrient supplying power takes time. Advances in direct seeding equipment technology have greatly improved the ability of growers to deal with heavy crop residue. A good crop rotation can also be effective in reducing problems with plugging or cold soil temperatures in spring. Following a high residue cereal crop with a low residue crop like a pulse with a higher nitrogen content that promotes decomposition, will help avoid excessive surface residue. Equipment that shifts residue to the side of the furrow, can also aid in soil warm-up in the seed-row.

The decomposition rate of straw on the soil surface is significantly reduced compared to when the straw is buried (Parr and Papendick, 1978). Factors controlling the release of nutrients from the surface residue layer include the carbon to nitrogen ratio, the amount of nutrient contained in soluble inorganic forms, and environmental conditions that affect microbial activity and leaching, particularly soil moisture content (Schoenau and Campbell, 1996). Carbon tied up in slowly decomposing residue helps no-till soils act as carbon sinks. Slower mineralization of organic nitrogen and greater immobilization of fertilizer N can contribute to reduced N availability and higher N fertilizer requirements in the initial years of no-till in some soils (Nyborg and Malhi, 1989, McConkey et al. 2002). After several years of no-till and by using effective fertilizer placement systems that put the fertilizer N in the mineral soil beneath the zone

of high immobilization in the thatch, availability of N may be unaffected or enhanced. For example, mineralization rates of organic N and S in Oxbow loam soils were higher in the 0-5cm depth of no-till soils compared to conventional till soils (Greer and Schoenau, 1992) and higher in soils that were under no-till for longer periods of time (Table 1). This was attributed to accumulation of easily mineralized organic matter and improved surface moisture conditions that contribute to greater microbial activity in long-term no-till soils. A zone of intense activity is likely present just beneath the surface residue layer. However, within the surface residue, the reduced contact with soil and more intensive drying contributes to a slower decomposition rate, especially with residues of low nitrogen content like cereals and canola (Franzluebbers et al. 1996) and will contribute to accumulation of organic N. In southwestern Saskatchewan, total organic N content of soils under no-till were generally greater than in tilled systems, with 80 to 200 kg/ha more organic N in the 0-7.5cm depth of no-till soils from the Brown soil zone (McConkey et al. 2002). Higher yields and greater residue inputs in more moist environments can also promote increases in total N in the surface soil (Campbell et al. 1996) and therefore an increased amount of substrate available for mineralization.

Table 1. Soil nitrate and phosphate supply rates measured in 2006 using PRS probes in a 2 week incubation of soils collected from short-term (ST) (5yr) and long-term (LT) (25 yr) no-till plots on a Black Chernozem near Indian Head, SK (Schoenau and Lafond, 2007 unpublished data).

STUBBLE TYPE	NO ₃ -N Supply Rate		NH ₄ -N Supply Rate		PO ₄ -P Supply Rate	
	ST	LT	ST	LT	ST	LT
Pea	15.9 a	22.0b	0.10a	0.17b	0.03a	0.06b
Wheat	9.3a	14.1b	0.10a	0.12a	0.05a	0.06a

For a given nutrient ion, means in the same row followed by a different letter are significantly different at p<0.10.

Water management is another important role of the surface residue layer (Lafond et al. 1996). Surface residues greatly reduce evaporative losses and contribute to higher surface soil moisture levels. By reducing raindrop impact and increasing surface roughness, the surface residue layer reduces run-off (Chow et al. 2000). Enhanced infiltration rates under no-till have been attributed to greater pore continuity and macroporosity, which is preserved even in intense rainfall. Old root channels that persist in undisturbed soil also contribute to greater infiltration and reduced runoff (Azooz and Arshad, 1996). Greater infiltration and less retention of water at conditions close to saturation could promote greater leaching under wet field conditions. Still, higher infiltration rates mean less run-off and water redistribution in the landscape, with more of the land area in a conventional till system reported to contribute to run-off compared to a no-till system in a study near Biggar, SK (Elliot and Efetha, 1999).

DISTURBING THE SURFACE RESIDUE LAYER

Some ecological and agronomic concerns have arisen surrounding the accumulation of organic material and nutrients on the soil surface in no-till systems (Crozier et al. 1999). Stratification of nutrients refers to increased concentration of nutrient close to the soil surface and more rapid decrease with depth, as a result of the lack of mixing by tillage. Stratification is more of an issue with immobile nutrients like phosphorus and potassium, as these nutrients tend to be sorbed strongly to the soil solid phase. Stratification of phosphorus near the soil surface in the 0-5cm depth has been reported by several researchers in mature no-till soils (Essington and Howard, 2000; Zibilske et al. 2002). These accumulations of phosphorus at the soil surface can potentially contribute to increases in P in surface run-off (Daverede et al. 2003).

Tillage of no-till soils can alleviate phosphorus stratification (Essington and Howard, 2000; Schoenau et al. 2007). Alleviating P stratification by mixing surface soil where P is concentrated with soil from lower soil depths was reported to result in more uniform root proliferation over the root zone (Drew, 1975). However, a recent study on the effects of imposing a cycle of tillage on long-term no-till soils at three locations in Saskatchewan revealed that while the tillage operation increased the uniformity of soil test phosphorus distribution in the top 15 cm of the soil, there was no apparent effect on supply rates measured in the soil or in concentrations and uptake of P in the crops grown on the soils (Baan, 2007).

Tillage of a no-till soil will stimulate microbial activity and respiration in the period immediately following the tillage operation as evidenced by increased carbon dioxide evolution (Baan, 2007; Quincke et al. 2007). However, tillage effects on available nutrient supply can be variable and appear to be related to the surface straw cover and the degree of incorporation (Baan, 2007). Tillage of long-term no-till soil caused increased N mineralization in a soil from the Brown soil zone under 15 years of no-till fallow-wheat rotation, but reduced the supply rates of nitrate in soils at two sites under continuous cropping in the Black and Gray zones. The difference in behavior was attributed to low amounts of surface residue in the Brown soil zone site while there were large amounts of fresh cereal straw and surface thatch incorporated by the tillage at sites in the Black and Gray zones that would increase microbial immobilization of the nitrate. There was no detectable change in total or particulate organic matter concentration from a single cycle of tillage, and overall most soil properties such as pH and aggregation were relatively unaffected by the tillage cycle. These results agree with findings in Nebraska in which one-time tillage redistributed soil carbon within the profile but did not cause a significant loss of total or labile soil organic carbon (Quincke et al. 2007). It therefore appears that while stratification can be reduced by tillage and that the impact of a tillage cycle on soil organic matter may be limited, it may be of limited agronomic benefit and could potentially expose the soil to erosion.

CONCLUSION

The build-up of a surface residue layer after several years of zero-till can be considered a benefit in soil and water conservation. Placement of fertilizer below the surface residue is beneficial in reducing potential tie up of nutrient via microbial immobilization. Release rates of available nitrogen, phosphorus and sulfur from organic matter turnover appear to increase with time in the zero-till system. While a cycle of tillage can be effective in reducing nutrient stratification at the

surface, the agronomic benefits of this practice appear to be limited. Furthermore, incorporation of a surface residue layer into the soil by tillage may induce nitrogen immobilization and result in reduced nitrogen availability to the following crop.

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