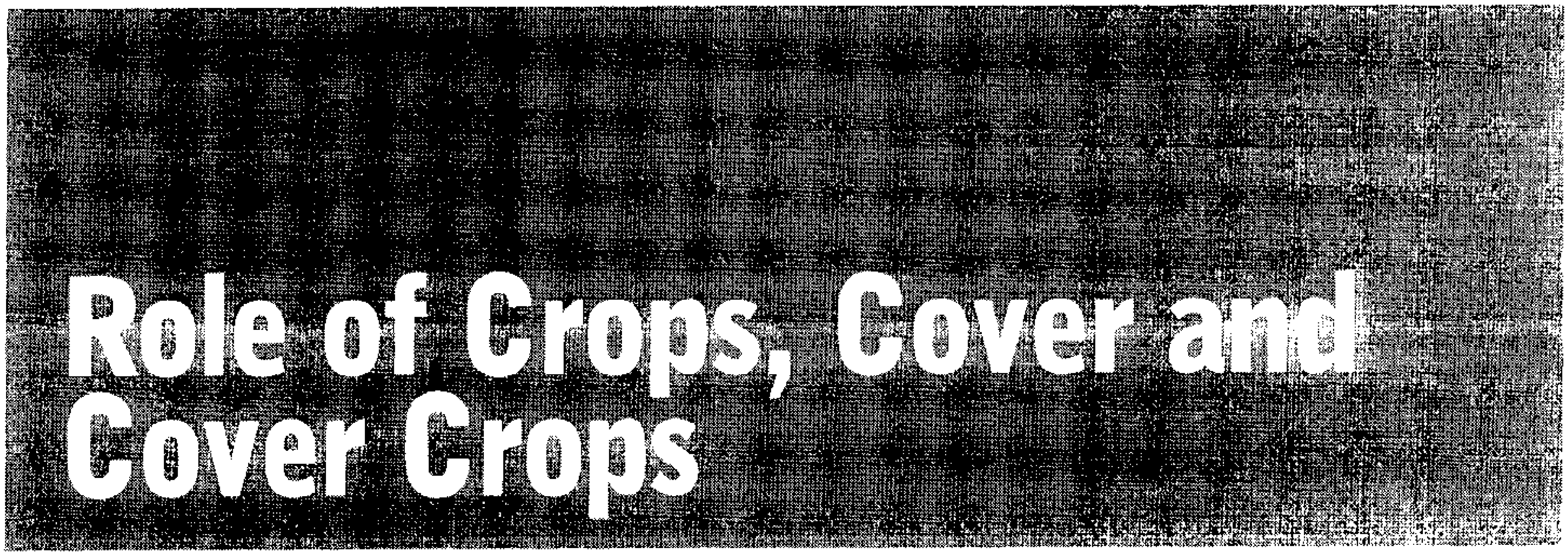


Role of Crops, Cover and Cover Crops

The Synergy Between Soil and Plants

Plants and soils are entwined in shared life; the health of one depends upon the health of the other. In the natural prairie ecosystems these life forms evolved mutually sustaining rhythms surviving the passage of time and ravages of weather. Mimicking these holistic rhythms ensures an enduring future for agriculture.

Martin Entz

"Soils are formed by plants, and plants are critical to keeping the living part of the soil alive," says plant scientist Martin Entz, University of Manitoba, Winnipeg. "It's essential for plants to be a part of any process intended to improve soil health. Healthy soils lead to healthy plants and, in turn, healthy people."

Maintaining this shared cycle of health over the long term is the time-old challenge of agricultural systems across the globe. For the Northern Plains, the challenge is made particularly difficult by a short growing season marked by frequent bouts of hot, dry weather.

Managing moisture

Maintaining sufficient moisture is critical to plant-soil synergy. "Moisture dictates how much biomass plants produce," says Entz. "The volume of biomass is important because from that storehouse of material comes the soil's potential to make organic matter. The carbon in the biomass is the carbon source for the soil, and the amount of root material contributes to this carbon. The soils in the wetter region of the Red River Valley have more carbon than the soils of the drier regions of the Prairies, for instance, because the plants of the Red River Valley have the moisture to produce more biomass."

Thus, on the Northern Plains, the conservation of moisture is an overriding aim of sustainable agriculture, and it is a particular strength of no-till systems. "Because there's no tillage, the loss of moisture through evaporation from the soil surface is reduced," says Entz. "The surface residue conserves the moisture, making it available for plants."

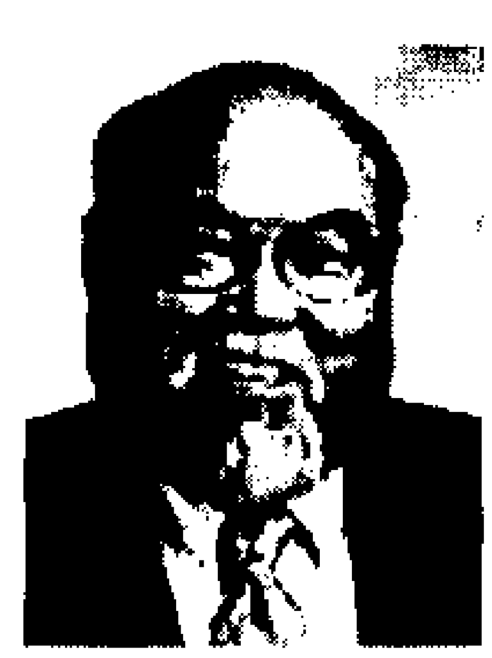
Stubble left standing in fall by many no-till farmers also traps snow, and the snow melt contributes to soil-moisture reserves. This process is critical on the Northern Plains, since "30 percent of our moisture falls as snow," says Entz.

Spring often brings early spells of hot, dry weather. Heat bakes moisture and life from soil not sheltered by residue or living plants. "Where the soil is bare, temperatures in spring can easily exceed 100 degrees Fahrenheit (37 degrees C) in that top half-inch of soil," says Ted Alme, state agronomist for the USDA Natural Resources Conservation Service, Bismarck, North Dakota. "Temperatures in that range will kill soil microbes, and most of the biological activity in the soil then ceases." High heat also causes heat canker and slows, reduces or stops germination of crop seed.

"It's a devastating loss to the total productivity of the soil if we lose the microbes in the upper layer," he says. "A tremendous amount of biological activity occurs in that top inch of soil because much of the organic matter is located there. It's critical to keep the soil biologically active by keeping it covered with residue from the previous crop or by growing a cover crop."

Keeping the soil alive is the catalyst for the ongoing breakdown of decomposing plant residue from previous years' crops. In long-term and stabilized no-till systems this breakdown of residue by microorganisms recycles nutrients, making them available for subsequent years' crops.

Growing diverse plant communities aids residue decomposition because plant diversity above ground stimulates diversity of life below ground. The more diverse the population of soil microorganisms, the more diversified and efficient will be their cycling of residue.



Don Tanaka

"Every crop has a unique set of organisms associated with it, and the organisms gravitate to that crop," says soil scientist Don Tanaka, USDA Agricultural Research Service (ARS) Northern Great Plains Research Laboratory, Mandan, North Dakota. "The best way to develop a diversity of organisms in the soil is to grow a diversity of crops."

Managing rotations

Rotations most efficient in building diverse soil life and most effective in interrupting cycles of weeds, pests and diseases are those comprising crops from five plant families: cooland warm-season grasses, cool- and warm-season broad-leaved crops, and legumes.

Within these families, however, are crops that are either synergistic or antagonistic to a subsequent year's crop. In other words, a previous year's crop can either help or hinder the crop in the following year.

"If you sequence crops appropriately, you can get a synergism creating an exponential response," says Tanaka. "We define synergism as the greater effect of two components than would be expected from summing the effect of each component alone."

"The crops might start out slow, for instance, but all of a sudden they'll just take off," he says. "Flax, for instance, is synergistic with wheat. When you grow wheat behind flax, you get a boost in yield in the wheat that can't be explained by added fertility. The yield increase is not associated with reduced plant disease, either. That certainly accounts for part of the yield increase, but not all of it. The synergy seems to cause a lot of little things to work together to increase yield."

In long-term studies, the Mandan ARS researchers evaluated the synergistic and antagonistic effects of more than 100 sequences of 16 crops under no-till management. One report states, "In a year with about average growing-season precipitation, it became apparent that sunflower, safflower or flax as the previous crop synergizes the seed yield of canola, crambe, dry bean, flax, safflower, spring wheat and barley."

Conversely, canola and crambe had negative effects on subsequent crops. As brassicas, canola and crambe are non-mycorrhizal crops. Growing these crops may negatively impact mycorrhizal fungi in the soil, consequently affecting subsequent mycorrhizal crops.

The Mandan ARS researchers developed a Crop Sequence Calculator to help producers design rotations capitalizing on synergism between crops. The Calculator includes information on 16 crops adapted to regions receiving 18 inches or less of annual precipitation.

The Calculator provides information about the effect of individual crop sequences on seed yield, soil-coverage residue, soil-water use, surface-soil properties and plant diseases. "The Calculator helps farmers develop crop rotations that fit their individual farm and management style," says Tanaka.

Visit www.mandan.ars.usda.gov to order the Crop Sequence Calculator free of charge.

Besides improving health of soil and plants, growing diverse crops also benefits soil moisture, especially when rotations include deep-rooted crops. Decaying roots create pore spaces serving as channels for water to enter the soil profile.

"Roots aerate the soil and improve water infiltration," says Tanaka. "Deep-rooted plants like alfalfa help to get water deeper into the soil profile, where there's a better chance of moisture being retained."

Alfalfa roots will penetrate to depths of 12 feet. By comparison, sunflower roots will penetrate 6 feet; corn and sweet clover, 5 feet; and the roots of peas will penetrate 3 feet into the ground.

The apparent synergistic effects in crop rotation and/or sequencing where crops planted into the residues of the previous crop have lead producers and researchers to examine methods for enhancing these effects. These methods include the addition of perennial crops into an annual crop rotation, cover crops following a cash crop within the same year, or creating a system including annual crops, perennial crops, cover crops, and/or livestock may capitalize upon the synergies between crops and boost yields and soil and water conservation even further or faster than rotation alone. It is also important to note that crop rotation is the foundation to getting these advanced methods to work most appropriately.

Living roots

The symbiotic relationship between plants and soils functions at its best when living roots populate the soil profile. "This is how the prairies were formed, and yet we as scientists did not fully recognize until relatively recently the importance of keeping the soil biologically alive by keeping living plants on the land," says Entz. "Living roots leak carbon all the time and keep the mycorrhizal fungi alive. These fungi cannot live on dead plant material."

The fungi produce a glue-like substance called glomalin, which stabilizes carbon in the soil. "Glomalin is known to be one of the most important factors allowing soil to form aggregates," says Entz.

Adding perennials and cover crops to a rotation of annual crops extends the growing season for living plants. The perennials most closely mirror the native prairie ecosystem. Thus, they are best adapted to the particularly short growing season of the Canadian Prairie and the northern Great Plains of the U.S., and their extensive roots draw water from deep in the soil profile during seasons of drought.

"Perennials put carbon into the soil all day, every day from the end of April through the end of October," says Entz. "They produce a significant amount of glomalin. As additional rewards, farmers can get a boost in grain production as many as seven years following alfalfa, for instance."

But without livestock as part of the enterprise mix on a farm or within a community, the short-term economic rewards often don't warrant including perennials in a rotation. Over the long term, developing enterprise systems for forage-based milk and beef production could build profitability for perennial crops, says Entz.

Perennial grains offer another futuristic possibility for including perennial crops in rotations. "These crops are 10