# Down the Wormhole

## Customizing Biological Methods for Large-Scale Farming


PHOTOS COURTESY OF DAVID YARROW

JR Bollinger in his corn, head-high by 4th of July.

*by DAVID YARROW*

At the end of 2015 I talked to Missouri bootheel farmer David "JR" Bollinger about his experiences growing corn, soybeans and milo using carbon-smart farming principles and practices. In his first year fully committed to biological agriculture, Bollinger cut conventional fertilizers by 50 percent and applied blends of biocarbons, minerals and microbes. Soils, plants and yields are all showing positive results.

Bollinger is the fourth generation to farm on 3,500 acres in the southeast Missouri Delta, with the family's main crops being corn, soybeans, wheat and milo.

"In 2012, I first dabbled in biological farming on a reclaimed coal mine," he said. "A gentleman with microbial products first tickled my brain about dead soil. He challenged me to find an earthworm. I went looking, and … none. I noticed there wasn't much life. The soil looked like moondust, vacant of life."

### DIRT IS INERT, SOIL IS ALIVE

More than mineral dust, soil is created by living organisms. Soil isn't only made by microbes; soil is *made up* of microbes and the living matrix and infrastructure they create to support their invisible communities.

"I sprayed his microbe mix of bacteria, fungi and humate at 1 gallon per acre on 50 acres," said Bollinger. "That year was the big drought with three rains the whole year; 80 percent loss on the 1,000 acres. But 50 acres where I applied microbes actually had a good crop."

He questioned why soils are so lifeless.

"Because of the kind of person I am, I started digging in, and wow! I'm fortunate to live in a time when I can dig as far as I want. Why is this? Why is that? So many different layers of life. I tinkered with mixes under gro-lites in my basement to see what products do. In test pots, I saw effects and benefits. You can say I went down the wormhole."

Bollinger now considers earthworms to be very valuable farming partners.

"When you dig into what earthworms do, they're fascinating. As a kid, I took them for granted as fish bait. Now I see all their benefits – the tunnels they make, their movements in soil, their functions. They're key to good, healthy soil. If you have worms, you have healthy soil."

New research reveals earthworms are farmers, too. They pull plant biomass into their tunnels, not to eat, but as a soft lining for the growth of bacteria and fungi. Later, a worm returns to graze this fuzzy film of mycelium and microbes. Worms farm their tunnels to cultivate microbes, and thus spread them underground. One ton of earthworms per acre are a primary workforce to convert biomass into fertility and growth.

### TEST PLOTS

Urged by positive results and research, Bollinger advocated changes in the family farm's operations. Bollinger, Sr. was skeptical of new products and cautious about spending money on them.

"I started talking to Dad about biological farming," said the younger Bollinger. "We started to use different methods. We started small. We didn't do it all at once. We did test plots for two years. We applied microbes to 1,000 acres of corn and reduced fertilizer on part. We noticed our plants grew bigger and better, and we didn't have to water as much."

Bollinger said after June harvest, they usually burned stubble and planted beans.

"Burning stubble gives away goodies worms and microbes need. So, we did a no-till second crop with microbes and saw more results. We were young at this type of farming. We didn't know what we were doing, but we were

seeing benefits. Every time you see a benefit, human nature is to keep doing that."

### ADDING MORE ACRES

In 2015 Bollinger decided to transition more acres to sustainable farming methods.

"I stuck my head in books, read up on bacteria, fungi, mycorrhizae, cover crops, kelp, fish meal, biochar and humates – the whole smorgasbord. I saw benefits from microbes, so what can I do for microbes? … I dug into what makes their lives better, like conservation tillage. I see it as 'farming microbes' versus applying a chemical. I dug into new products. When we applied biologicals, all of a sudden plants are thriving. A side result is our soil is improving. Now that I had confidence in biological methods, I wanted to apply this on all our acreage."

### DETERMINATION & INGENUITY

On March 28, 2015, I met Bollinger at Missouri University Bradford Research Farm where I was teaching at a biochar symposium sponsored by Phil Blom of Terra Char. The evening before, Bollinger quizzed me all through dinner. The next day, after I taught two hours, he had a steady stream of questions.

He had made his choice and set his course. Bollinger did his homework to use biologicals in large-scale operations. His first corn planting was 1,000 acres. He had to answer his own questions, follow his own strategy, design his own equipment and use his own resources. He knew that no off-the-shelf solutions exist. His burden was to make this work – and convince his father. In his heart and gut, Bollinger knew a biological path is key to 21st century farming. I visited Bollinger on his farm after Thanksgiving to hear about his progress.

First, Bollinger showed me an impressive assembly of equipment, made to operate as a unit to deposit precise, narrow bands of biological nutrients. With extensive equipment knowledge and savvy mechanical expertise, he built apparatuses to perform a miracle on near-lifeless soil: instantly install the foundation of a healthy soil food web. Bollinger's genius isn't just building complicated machinery. Rather, he figured out how to mix nutrients precisely in the root zone with minimum disturbance. Emerging seeds find nutrients and symbiotic fungi all around budding roots.

"These products don't exist on the market," said Bollinger.

We know biochar, trace elements and microbes are potent in soil – individually, but much more so when mixed together. Can carbon-smart, microbe-friendly soil stewardship be integrated into commercial farming? Can this be easy, economical and feasible for large-scale farmers?

"At front, hanging on the tractor, two yellow side-saddle tanks hold liquid nutrients and microbes," said Bollinger. "We inject this as a band 4-inch off-center. We stagger-step fertilizer in bands to chase roots to grow outward. Liquids include anything from fertilizer to fishmeal. We tried different products, all kinds of goodies: humates, humic acid, sea minerals, microbes, fish meal and biochar powder. I wanted to give everything a fair shot in our conventional way and gradually introduce biologicals."

Most of the microbes that Bollinger applied were in liquid form. One lab-brewed blend contains 16 bacteria and nine fungi with support nutrients like humates and trace elements, including free-living nitrogen-cycling bacteria and phosphate-dissolving fungi. The goal is to get them under the surface, in moist, cool soil with nutrients and metabolites, to assure they proliferate.

### FEED SOIL MICROBES, NOT PLANTS

Biochar, however, isn't a fertilizer or nutrient and doesn't break down in soil – maybe 3 percent – but greatly boosts fertilizer efficiency. Char is shelter, not food. Microbes don't eat this super-stable biocarbon; they live in it. Burnt biomass is community infrastructure to house microbes with plumbing for water, thin-film wiring for power and nutrient shopping malls. Biochar also curbs nutrient leaching and outgas.

"Montag is our dry fertilizer cart," said Bollinger. "We get a blend that meets the needs of our soil test. We mix in anything from biochar fines to crab meal, shrimp meal, SEA-90, humates. The Dawn unit does an excellent job mixing fertilizer, char – anything that goes through the hose – and incorporates them into soil."

Farmer JR Bollinger checks out earthworms in his fields.

Bollinger said that with precise strip-till application and biological amendments he had the confidence to cut dry fertilizer use in half.

"We reduced our liquid fertilization as well. We didn't see any lag. If anything, we saw a boost."

Dry ingredients are agitated and sucked by vacuum hose to injectors on Dawn cultivators and land in soil. Biochar and biologicals were supplied by Terra Char, a 3-year-old biocarbon business near Columbia, Missouri. Owner Phil Blom delivered a semi-load of biochar for Bollinger's soils, plus minerals, microbes and metabolite. Blom offered guidance and support throughout the growing season.

### DAWN CULTIVATORS

Behind the tractor ride 16 Dawn cultivators, each with injectors for dry, then liquid amendments.

"I use Dawn because we have sandy ground," said Bollinger. "Its waffle blades are more vertical till, not deep tillage. It moves residue out of the way,

so it's easy to plant through. I don't deep till, like with shanks, since this makes a trench that fertilizer tends to go into and increases leaching."

Bollinger said one side gets dry fertilizer and then, a few inches off center, the liquid band is applied, allowing for precise nutrient placement. Soil between rows isn't disturbed.

"Dawn keeps soil within the unit. Eventually, dirt hits it, flies up where dry and liquid lines come in. Then it hits the lead edge of a disc blade that fills up, then turns it, like mixing potting soil with your hand. Dawn fluffs soil to make a seedbed. Soil warms quicker in spring to speed up planting dates. It's a perfect tool to closely place fertilizers. I love how Dawn handles residue and keeps it confined."

The last part of each Dawn unit are "swirlers" – two rolling wheels with inward-facing fingers that lift and stir soil to mix ingredients and aerate soil in 4-inch slots. The rig's main benefit is that it can concentrate nutrients and inoculants in soil where seeds will germinate, not broadcast wide, but thin, across the field. Bollinger gently injects his microbes in a dark, moist subsurface world, not exposed to hot sun and dry wind. Precision placement and blending assures close proximity of nutrients for fast-acting effects.

### STRIP-TILL

Tillage degrades soil, burns out carbon and disrupts microbes. Why burn fuel tilling if worms pull biomass into their tunnels? Let worms do the work.

"I call this 'strip-till,' or 'conservation till' because we do a percent of tillage," said Bollinger. "Each year, 20 percent of a field is tilled in 6-inch wide strips, to leave a nice mat of residue on 80 percent to suppress weeds. When we irrigate, or get rain, covered soil stays moist longer under thick residue. Residue was gone by end of July. I was fascinated to see how heavy, thick residue disappeared quickly. I call this 'carbon-smart' or 'biological' farming. It's a hybrid – combining both traditional and modern. In my life, traditional became NPK, herbicides, lots of tillage and all."

Strip-till bands are spaced 30 inches apart. Each year, guided by GPS, Bollinger will move his rig over a few inches to inject another band of biochar plus inoculants, minerals and nutrients. In five years, he will deposit this mix all over his field and will need to use very little chemical fertilizer. Meanwhile, Bollinger is assured steady income, larger yields, higher crop quality and improving fertility as soil regenerates.

### SEED STARTER

Bollinger described another biological application at planting: "We also drench with a seed starter. We apply biological nutrients in furrow, right on top of seeds. As soon as a seed kicks out of its tiny nursery sack, I want it in a happy environment. It's another stair-step to optimize germination and seed growth. I only use biological products on top of seed. Later, we sidedress 8 inches off the row – another stair-step. At each stage of growth, we key in nutrients before it needs them, to sit there waiting. We use a lubricant such as talc to help seeds flow and not lodge. This year, we used very fine, 40-micron biochar powder and mycorrhyizal inoculant as lubricants. We get beneficial fungi and biocarbon right by the seed, in direct contact. Spores definitely stick to char particles. How much good it did, I don't know, but it can't hurt. I know our seed germination was off the charts this year."

The seed on the farm is non-GMO.

"We've grown non-GMO corn about 15 years; never got into GMO corn. Our soybeans are non-GMO. We don't believe in GMOs, and getting premiums for non-GMO kept us on the train. Now, later in life, I see the effects GMOs have. Farmers who grow GMOs must use herbicide, and weeds are now becoming resistant. So I'm proud we grow non-GMO crops. To feed grain to cattle, I feel non-GMO is better."

Until nutrients are abundant and soil is fully mature, soil nutrients must be supplemented by seed treatment, foliar feeding, root drenches and sidedressings. The most critical extra feeding is starter food to wake up embryos and stimulate root growth.

Bollinger used a Terra Char formula to blend biochar powder with kelp, humic acid and bacteria. Spores of endo-mycorrhizae initiate symbiosis with infant roots. Fishmeal is amino acid nitrogen for emerging embryo and colonizing microbes. SEA-90 unrefined sea minerals offers complete trace elements with alkaline charge in balanced, fully soluble form. SEA-90 is a fast-acting "igniter" to jumpstart soil biology, which then digests rock into new soil. The same full-spectrum minerals are in other sea products, each packed in different chemistry: kelp (carbon), fishmeal (amino acids), shrimp meal (protein), crab meal (chitin).

### SIGNS OF HEALTHY CORN

"I planted a typical population of 34,000," said Bollinger. "Years past, I planted 28 to 30,000. In strong or weak parts of a field, my planter can change populations. This corn was 33,500 to 34,000. Typically, seed companies tell you to push population up until you get tip back – corn will grow, but not produce complete ears. My corn had full ears with no tip back. Should I increase population more? I don't know, but greater population definitely didn't stress plants."

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The corn came up very uniform with nearly 100 percent germination.

"What was really interesting was the health of plants when they came up. Often corn comes up in its early stage yellow. You see purpling in inclement, wet conditions – phosphorus deficiency. I didn't see any, and we didn't apply in-furrow fertilizer other than pre-planting strip-till. Phosphorus was in dry fertilizer. In the past, we put phosphorus right in furrow. This year all we did was add mycorrhizal fungi, which find and move phosphorus in soil. Did it have an effect that quickly? I don't know, but we didn't have purple corn."

In early June, I received a photo of Bollinger in head-high corn. I couldn't see his face, but I knew he was smiling. His corn was 16 inches taller than his neighbors', with thicker, longer leaves that were distinctly darker green. His corn had more chlorophyll making more sugar to grow faster. Bollinger knew he made the right choice to go carbon-smart and grow biologically.

"The corn, for its early stage, was taller than it should be," he said. "You can see in photos, healthy corn has a glossy, waxy look. See how wide the leaves are. And inner veins all consistent color. Not much striping that shows deficiencies. It's just a healthy plant – as healthy as corn gets."

Early on, the corn had wider, longer leaves.

"You can go in a field and tell if life is going on, or if it's hanging onto life. Times of stress, like going without rain, are hard on people. You know it stresses plants. But this year, our plants weren't stressed the way they should have been. A few fields, some non-irrigated sand, never had a bad day. They held on until it rained."

Bollinger's shaded soil needs no herbicide, like conventional no-till. Yet, three growing cycles are needed to mature soil's full digestive power to rapidly recycle crop biomass.

## CHEAP LABOR

"I was on hands and knees crawling through the crop, looking at soil and plants, at different bugs, different insects, different fungi – lots of life in that soil," said Bollinger. "You can see earthworms. Microbes, you can't see. I expected to see mycorrhizae signs in soil after a test I did last winter with seedlings in pots. I overdosed with spores and saw thick white fungal fuzz like snow on the soil. We're dealing with living organisms, and you've got to treat them right, or they won't treat you right."

Bollinger has learned to think holistically. He knows there are no single-shot solutions. His concept of soil stewardship now embraces the whole community of living organisms that inhabit healthy, fertile soil. Fighting pathogens is secondary strategy, after encouraging roots, enlisting microbes as allies and a complete menu of minerals.

On July 4th, Bollinger sent me a photo of nearly ripe ears. I'm not familiar with southern Midwest corn growth, yet this seemed early. I was told that it was unprecedented.

"End of June, corn tassel starts here," said Bollinger. "Sweet corn is earlier. We start to get sweet corn July 4th. Around the 13th, we usually can sweet corn. We planted late, so I didn't expect such early tassels and ears. I'd say the corn was two weeks early."

On July 16th, Bollinger emailed a photo of three ears.

"Ears were 43 long, majority 16 around, many 18. Typical all over the field. In the past, it might be 12 or 14, a few 16s. But this year, 16 was the norm. Two extra rows on each ear add to overall yield."

Corn ears by July 4th fed my faith that Bollinger's 4-inch strips would work, but photos of roots blew a fuse in my imagination. Thick beards of white roots erupted from the base of stalks. I never saw such dense, fine roots. They knew nutrients were there and saturated the zone with roots to suck up the goodies.

In photos, black grains of biochar are visible. Each absorbs eight times its weight in water, adsorps immense amounts of mineral ions, held loosely, ready for H+ exchange with root or microbe. Biochar's special benefit is to hold anions (nitrogen, phosphorus) as well as cations to keep them near roots.

Bollinger was thrilled by the remarkable roots – and mystified.

"I was scouting for insects the first day I saw roots 6 inches long. Hard to say how long they got, because they twisted and turned, but some grew to 3 feet. This was widespread throughout the field. In fact, the whole 50 acres looked that way – like spaghetti across the field."

They had a wet spring and timely rains at tassel helped.

"Later, we bridged gaps with irrigation. Foliar sprays to put on nutrients help, but aren't a full watering. We used a moisture probe this year to monitor water use. We didn't overwater, but once it got to a certain point, we kept it at that range. Seems like the crop was very efficient with water."

Weed and insect pressure also decreased.

"Residue in middles suppressed weeds. Corn grew so fast, canopy shaded the middles, and weeds didn't grow. Not much bug pressure, either. One zone – a high-sand ridge – a bit more."

Consistently well-nourished plants don't attract pests. If pests do infest, vigorous plants outgrow bug damage. Once during the year, Bollinger sent me a question about an insect pest. I gave him non-toxic remedies to discourage bugs and strengthen plants. He later reported bugs ate the weeds and hardly touched his crop.

## RESOURCES

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## BLENDING BIOCHAR

Estimating biochar application rates was difficult. Field conditions, complex calculations, equipment malfunctions, blending uncertainties, changing recipes and other variables made a precise rate for each field elusive. A minimum of 2 percent biocarbon is needed to sustain strong microbe communities, and Certified Organic requires 4-5 percent carbon. I suggest half as super-stable biochar and humus, another 2.5 percent as digestible carbon, like crop stubble, compost, manure, etc. But 2.5 percent biochar tilled in 6 inches is 8 tons per acre – at $.50 per pound, and $8,000 per acre, and that is too costly for farmers.

Bollinger's genius is to concentrate biochar and nutrients in narrow bands, thus cutting rates to hundreds of pounds per acre, slashing annual costs and spreading expenses over several years.

## FIRST PLACE MILO

"That cornfield produced 235 bushels," said Bollinger. "The 20-year average for that field is 180 bushels. The crop was easy to grow."

But Bollinger's biggest surprise was his grain sorghum crop.

"One sorghum field made 186 bushels in non-irrigated sand. Normal is 100 bushels; most farms were 120, even irrigated. Believe it or not, my field had irrigation on part, but non-irrigated yielded a few extra bushels."

Yields were good enough to win First Place in Missouri for both irrigated and non-irrigated milo. Continuing to talk numbers, I asked about money saved cutting NPK fertilizer 50 percent versus costs for biochar, biologicals and metabolites.

David, Sr. replied, "Yeah, we got some figures. I'll fine-tune fertilizers – exact amounts we cut back. I'd say close to $100 an acre cheaper. Maybe not $100, but way up there." So, 1,000 acres saved near $100,000 just on fertilizers.

Bollinger said their soybeans show signs of increased health and vitality, and they achieved higher yields.

"Stalk is important in soybeans – usually a little pencil-like stalk," he said. "This year, stalks were like tree trunks. We noticed more lateral branches. Typically, we have a single stem and nodes stretched farther apart. This year, nodes were more stacked, with three or four lateral branches. Every soybean plant I pulled up, rhizobia were always vibrant, pink, bigger in size and more of them than typical, especially on poorer ground. On average, in this ground after wheat soybeans get 35 bushels. We ended in 50 to 55. Also, we cut our soybean population way back to the 80,000 to 100,000 range. Many farms plant up to 180,000 per acre."

Bollinger says his journey to more sustainable farming started because a man challenged him to find an earthworm.

"It tickled me yesterday to walk out in a field, stop in a random spot, dig into the soil with two fingers and find an earthworm – then five more. In 2012, I couldn't find a single earthworm."

David Yarrow has taught about and organized sustainable food systems in the northeast United States for more than 30 years. He can be reached at *dyarrow5@ gmail.com*. For more information visit *dyarrow.org*.