

Down the Worm Hole

JR Bollinger's first year success with carbon-smart, biological farming

David Yarrow, April 2016

After Thanksgiving, I interviewed Missouri bootheel farmer JR Bollinger on his 2015 experiences growing corn, soybeans and milo by principles and practices of *Carbon-Smart Farming*. In his first year of full commitment to *Biological Agriculture*, JR cut conventional fertilizers 50% and applied blends of biocarbons, minerals and microbes. After Easter, I was fortunate to enjoy an afternoon with JR learning worm calling.

"I farmed since the day I was born." David "JR" Bollinger spoke quietly, slowly, with careful phrasing. "Worked on the farm my whole life. I'm the 4th generation to farm here in the southeast Missouri Delta. We farm 3,500 acres. Our main crops are corn, soybeans, wheat, and milo."

Search for Life

"In 2012, I first dabbled in biological farming on a reclaimed coal mine. A gentleman with microbial products first tickled my brain about dead soil. He challenged me to find an earthworm on this farm. So, I went looking, and... None. I noticed there wasn't much life. Soil looked like moon dust, vacant of life."

First Principle of Biological Farming Dirt is inert, but Soil is alive

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

JR went, "So, I sprayed his microbe mix of bacteria, fungi and humate at 1 gallon/acre on 50 acres. That year was the big drought: three rains on that farm the whole year; 80% loss on the 1000 acres.

But the 50 acres with his microbes actually had a good crop."

"So, I said, 'Maybe these wee little guys are something.'

"But what really got me was back home in Missouri, the land my family farmed for four generations looked similar. I looked for earthworms in our soil, for signs of life on our farm. Land we farmed was similar to reclaimed mine land."

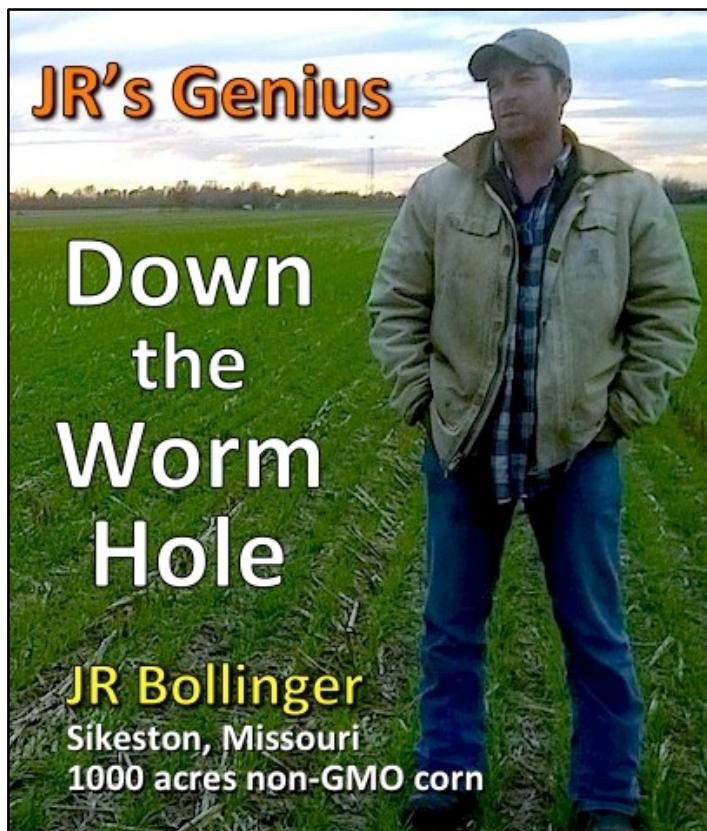
Observant, thoughtful, JR wondered why soils are so lifeless. "Because of the kind of person I am, I started digging in, and wow! I'm fortunate to live in a time when I can dig as far as I want. Why is this? Why is that? So many different layers of life.

"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."

Down the Wormhole

JR's voice softened to begin to speak of his new 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

I see it as 'farming microbes' versus applying a chemical.



benefits. Tunnels they make, movements in soil, functions. They're key to good, healthy soil. If you have worms, you have healthy soil.

"Now that I appreciate earthworms, what can I do to make them happy? Anything I can do for those guys."

New insights reveal earthworms are farmers, too. They pull plant biomass into their tunnels, not to eat, but as soft lining to grow 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

With positive results and research, JR advocated changes in farm operations. David Bollinger Sr.—also a creation of Missouri Delta farming—told me, "I had my first farm when I was 13. My own acre. So farming is pretty much all my life." David Sr. was skeptical of new products, cautious to spend money for them.

JR continued, "I started talking to Dad about biological farming. We started to farm different, use different methods. We started small. We didn't do it all at once. We did test plots two years.

"We applied microbes to 1000 acres of corn, and reduced fertilizer on part. We noticed our plants grew bigger, better. We didn't have to water as much.

"In this county, we burn wheat stubble for a double crop. After June harvest, we



burn stubble and plant beans. But 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 was doing, but we were seeing benefits. Every time you see a benefit, human nature is to keep doing that.”

2015: Complete Commitment

“So, last winter, I stuck my head in books, read up on bacteria, fungi, mycorrhizae, cover crops, kelp, fishmeal, biochar, humates, the whole smorgasboard.

“I saw benefits from microbes, so what can I do for microbes? If they do me a favor, what can I do for them? They need to be fed, too. Anything I can do to make their survival and functions easier. It’s common sense.

“So, I dug into what makes their life 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—boom!—plants are thriving, crops healthy. 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.”

JR didn’t need to know IF biocarbon, microbes and trace minerals work. He saw consistent proof. JR decided put them to work on his farm. Not another tiny, one-year test plot, but full-scale, long-term application to fields and crops. One field, one crop, one year at a time.

First Encounter

March 28, 2015, I met JR at Missouri University Bradford Research Farm to teach at a Biochar Symposium sponsored by Phil Blom of TerraChar. Evening before, JR quizzed me all through dinner. Next day, after I taught two hours, JR had a steady stream of questions in the lobby.

In all my time with JR, he never said much, just kept asking. I saw his intense focus to soak up information. This intelligent young farmer had made his choice, set his course. My words would result in his actions.

Clearly, JR did his homework enough to ask incisive, advanced questions. Clearly, JR set his mind to master and demonstrate this new farming. He chose to step in with both feet to implement better farming. My great joy is to pour knowledge and insight into an inquiring, adventurous mind.

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

JR had to bring these new products and methods together on his farm, in his



Fig. 1: JR Bollinger's custom-built strip-till rig

soil, for his crops, with his equipment—with maximum effect, minimum material, no added cost, and utter efficiency. JR needed equipment to use biologicals in large-scale operations; his first planting is 1000 acres corn.

JR had to answer his own questions, follow his own strategy, design his own equipment, use his own resources. He knew no off-the shelf solutions exist. His burden was to make this work himself—and convince David Sr. In his heart and gut, JR knew a biological path is key to 21st century farming. I knew JR will make this happen on his family farm.

I didn't see JR again until after Thanksgiving for this interview. I did get a series of exciting photos.

JR's Genius

First was an impressive assembly of equipment, made to operate as a unit to deposit precise, narrow bands of biology and nutrients. With extensive equipment knowledge and savvy mechanical expertise, JR built apparatus to perform a miracle on near-lifeless soil: instantly, in one pass, install the foundation of a healthy **Soil Food Web**.

JR's genius isn't just building complicated machinery. Rather, JR designed 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 are on the market.” JR began explaining the rig he built. “I customized and tweaked them to what we want to do.”

“At front, hanging on the tractor, two yellow side-saddle tanks hold liquid nutrients and microbes. We inject this as a band 4-inch off-center. We stagger-step fertilizer in bands to chase roots to grow outward. It’s a unique convenience to apply this extra band of nutrients.

“Liquids had anything from fertilizer to fishmeal—a smorgasboard—different products, all kinds of goodies: humates, humic acid, biochar powder, sea mineral, microbe, fishmeal. I wanted everything to get a fair shot our conventional way and

Fig. 2: Dry fertilizer cart



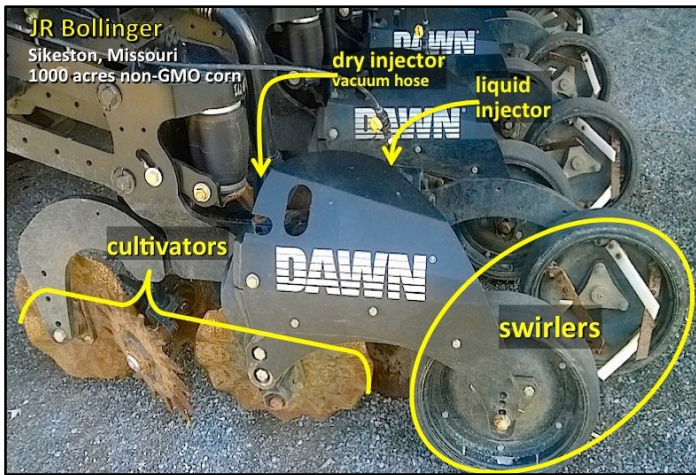


Fig. 3: Dawn strip-till cultivator & injectors

gradually bring in biologicals.

Most microbes JR applied were liquid. One lab-brewed blend has 16 bacteria and nine fungi with support nutrients like humates and trace elements, including free-living nitrogen-cycle 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.

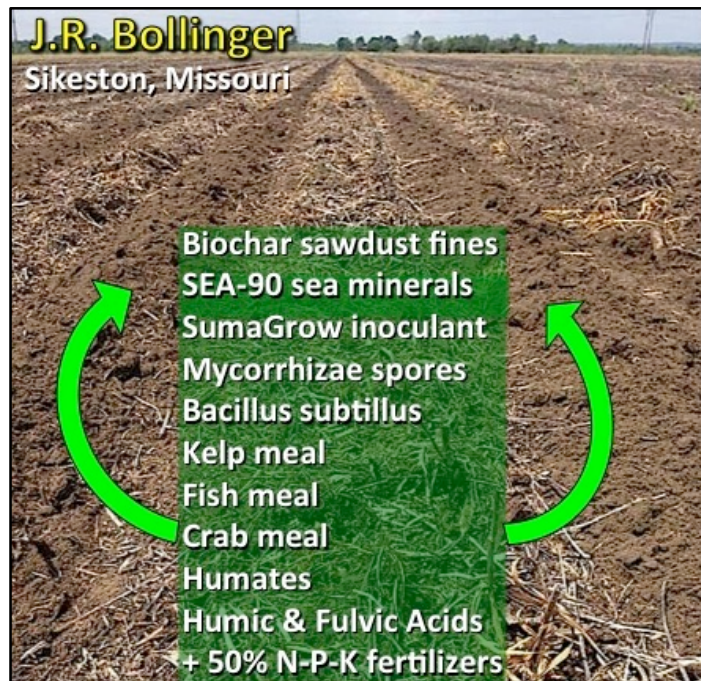
**Biological Farming Maxim:
Feed soil microbes, not plants**

Biochar, however, isn't a fertilizer or nutrient, doesn't break down in soil—maybe 3%—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 outgasing.

Dry Fertilizer Buggy

"Montag is our dry fertilizer cart," said JR. "We get a

Fig. 4: Terrachar'ge recipe tilled into 6-inch-wide strips



blend that meets the needs of our soil test. What's put in the Montag is based off each field's soil test.

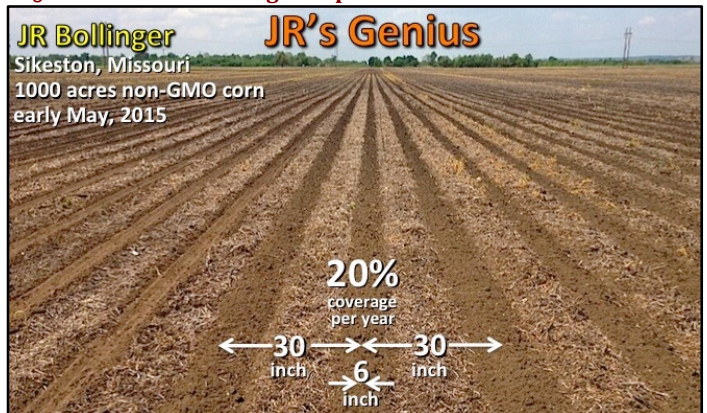
"We mixed in anything from biochar fines to crab meal, shrimp meal, SEA-90, humate. Dawn units do an excellent job to mix fertilizer, char—anything that goes through the hose—and incorporate them into soil."

"The convenience to use chemicals like urea was something we had to do. You can't just go full bore into this. There's too many variables. You got to have some checks.

"With precise strip-till application, and biological amendments, I had confidence to cut dry fertilizer 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 intimately mixed. Biochar and biologicals were supplied by Terra Char, a 3-year-old biocarbon business near Columbia, MO. Owner Phil Blom delivered a semi-load of biochar sawdust fines for JR's soils, plus minerals, microbes and metabolite. Phil was

Fig. 5: 6-inch-wide tillage strips on 30-inch centers



steady guidance and support through the growing season.

Dawn Cultivators

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

JR explained, "I use Dawn 'cause we have sandy ground. Its waffle blades are more vertical till, not deep tillage. It moves residue out of the way, so it's easy to plant through residue. I don't deep till, like with shanks, since this makes a trench fertilizer tends to go into, and increases leaching.

"One side gets dry fertilizer, all mixed. Then, a few inches off center, the liquid band is applied. I get precise nutrient placement this way. Soil between rows isn't disturbed at all, so it's easy on microbes in that zone.

"Dawn keeps soil within the unit. Eventually, dirt hits it, flies up where dry and liquid lines come in. Then 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. A perfect tool to closely place fertilizers. I love how Dawn handles residue, and keeps it confined."

Last in each unit is "swirlers"—wheels with in-facing fingers to stir and mix ingredients, and aerate 4-inch slots.

**Biological Farming Maxim:
Get it in the root zone**

The rig's great benefit is to concentrate nutrients and inoculants in soil where seeds will germinate, not broadcast wide, but thin, across the field. JR gently injects his microbes in a dark, moist sub-surface world, not exposed to hot sun and dry wind. Precision placement and intimate blending assures close proximity of nutrients for fast-acting effects.

Strip-Till

First way farmers degrade soil, burn out carbon and disrupt microbes is tillage. JR now knows tillage is to worms what Katrina was to New Orleans: catastrophic infrastructure degradation. Why burn fuel tilling, if worms pull biomass into their tunnels? Let worms do the work.

JR explained, "I call this 'strip-till', or 'conservation till' because we do a percent of tillage. Each year, 20% of a field is tilled in 6-inch wide strips, to leave a nice mat of residue on 80% to suppress weeds. When we irrigate, or a 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 was concerned that residue, plus new residue, might be trouble next year, when we move tillage over a few inches.

"I also call this "carbon-smart" or "biological" farming. It's a hybrid—combining both traditional and modern. Really, what we do now is truly traditional. In my life, traditional became N-P-K, herbicides, lots of tillage and all."

Strip-till bands are spaced 30 inches apart. Each year, guided by GPS, JR 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



"With precise strip-till application and biological amendments, I had confidence to cut fertilizer in half. We didn't see any lag. If anything, we saw a boost."

field, and use very little chemical fertilizer.

JR's rig spreads labor and cost to boost soil carbon and biology over a few years of incremental applications. Biologicals are integrated with normal farm operation, expenses offset by savings on fertilizers and chemicals. Meanwhile, JR is assured steady income, larger yields, higher crop quality, improving soil fertility as soil. Slowly, JR will wean his farm off chemical dependence.

Seed Starter

JR 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. Another stair-step to optimize germination and seed growth. I only use biological products on top of seed. I'm real cautious.

"Later, we sidedress eight inches off the row—another stair-step. At each growth stage, we key in nutrients before it needs them.

"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 mycorrhizal 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."

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

JR used a TerraChar formula to blend biochar powder with kelp, humic acid and a bacteria. Spores of endomycorrhizae initiate symbiosis with infant roots. Fishmeal is amino acid nitrogen for emerging embryo and colonizing microbes. SEA-90 unrefined sea minerals is 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), fish meal (amino acids), shrimp meal (protein), crab meal (chitin).

JR explained that seed on his family farm is non-GMO, "We've grown non-GMO corn about 15 years; never got into GMO corn. Our soybeans are non-GMO. First, we don't believe in GMOs. And getting premiums for non-GMO kept us on the train. Now, later in life, I see effects GMOs have. Farmers who grow GMOs must use herbicide, now weeds are getting resistant. So I'm proud we grow non-GMO crops."

Signs of Health

"I planted a typical population of 34,000," JR said. "Years past, I planted 28 to 30,000. In strong or weak parts of a



Fig. 6: Strong germination and early growth



Fig. 7: JR Bollinger in his head-high corn first week of June

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 "tipback"—corn will grow, but not produce complete ears. My corn had full ears with no tipback. Should I increase population more? I don't know, but greater population definitely didn't stress plants.

"Corn came up very uniform, germination almost 100%." JR's voice leaned forward to tell exciting news of corn's summer growth. "Real 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 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 effect that quick? I don't know, but we didn't have purple corn."

The Right Choice

Early June, a photo arrived of JR in head-high corn. I couldn't see his face, but I knew he was smiling. His corn was 16 inches taller than neighbors, with thicker, longer leaves, distinct darker green. His corn had more chlorophyll making more sugar to grow faster. JR knew he made the right choice to go carbon-smart and grow biological.

"The corn, for its early stage, was taller than it should be.

Fig. 9: Full ears of corn harvested in mid-July



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. We were just tickled.

"Hard to explain, but I can tell plants were healthier this year. Some say it makes no difference, but I can tell a healthy plant by leaves right off. One thing is thickness of leaves. Early on, this corn had wider leaves, and length a lot longer.

"You can go in a field and tell if life is going on, or if it's hanging on to life. Times of stress, like if it hasn't rained, is hard on your body. 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, set there and waited until it rained.

"Since I started this new farming, when I drive by a field, it's like my plants are smiling. They're happy and healthy. Healthy plants are the best chance of optimum yield.

JR closely observes nature. Our first meeting, I saw intense sentience in his dark eyes. As farmer, JR notes details

Fig. 8: Tight, dense population of healthy corn



of plant physiology and growth. JR's empathy sees plants and bugs as intelligent creatures, not inanimate chemicals. Such open minds learn direct from nature.

JR's inquiring mind discovered crop stubble isn't mere mulch, but habitat and food for tiny life from fungi to earthworms. Digesting debris releases nutrients and energy to **Soil Food Web** microbes. Teeming hordes of invisible creatures swarm over debris, strip out nutrients to recycle as new growth. Decaying debris closes circles of soil nutrient cycles. JR'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

JR went on, "I was on hands and knees crawling through the crop, looking at soil and plants, at different bugs, different insects, growing and going on in there. All different fungi, all kinds of mushrooms. Lots of life in that soil.

"You can see earthworms, but you can't see microbes. 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. You got to treat them right, or they won't treat you right. It's very tricky, especially to combine different species together. The whole living community, all intertwined together..."

*How much space do fungi need to grow?
As mushroom as possible.*

JR has learned to think holistic. He knows there's no single shot solutions. He sees soil is a complete and complex, interactive, living system. JR's concept of soil stewardship now embraces the whole community of living organisms that inhabit healthy, fertile soil. Fight pathogens is secondary strategy, after he encourages roots, enlists microbes as allies, and a complete menu of minerals.

Unaided, our eye sees a few fungi—mostly mushrooms and thick mycelium. Most mycelium is as fine as spider web, and as sticky. Each is a tiny tube with a mouth on one end—invisible plumbing to pump liquid nutrients around in soil.

But we can't see bacteria; they're too tiny—microscopic. Transparent, too. Even if we could see something so small, they're almost invisible. Yet, they digest rock into protoplasm to boost nutrients and water flow to roots. Fungi and "helper" bacteria grow dense networks connected to roots. Their microscopic plumbing in a teaspoon of soil is miles, "all intertwined together..."

On July 4th, JR sent a photo of nearly ripe ears. I'm not familiar with southern Midwest corn growth, yet this seemed early. Someone said, "Unprecedented."

"End of June," said JR, "corn tassel starts here. Sweet corn is earlier. We start to get sweet corn July 4th. Around 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."

July 16th, email brought a photo of three ears. JR said, "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 adds to overall yield."

Corn ears by July 4th fed my faith JR's 4-inch strips would work. But photos of roots blew a fuse in my imagination. Thick beards of white

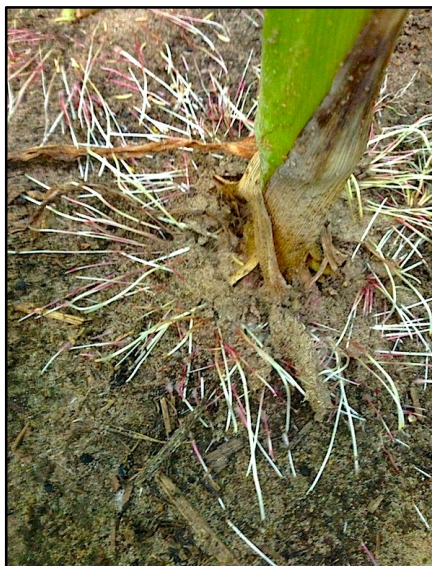


Fig. 10: **White fuzz of fungal mycelium**



Fig. 11: **Full ears mature on July 4th**

Fig. 12: (below) **A profusion of roots**



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 goodies.

In photos, black grains of sawdust biochar are visible. Each absorbs eight times its weight in water, adsorbs 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.

JR was thrilled by the remarkable roots—and mystified, "I was scouting for insects the first day I saw roots six inches long. Hard to say how long they got, 'cause they twisted and turned, but some grew to three foot. This was widespread throughout the field. In fact, the whole 50 acres looked that way—like spaghetti across the field. In close-up photos, I saw fine root hairs. Maybe the white fuzz is mycelium.

"We had a wet spring. 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 over-water, but once it got to a certain point, we kept it at that range. Seems like the crop was very efficient with water.

"Weed pressure this year was down. Residue in middles suppressed weeds. Corn grew so fast, canopy shaded middles quick. Weeds set there and didn't grow. Fast-growing corn really stretched out, leaves were so wide, they shaded ground quick. Harvest photos show not a weed growing.

"Not much bug pressure, either. One zone—a high-sand ridge—a bit more."

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

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.

Minimum 2% biocarbon is needed to

sustain strong microbe communities. Certified Organic requires 4-5% carbon. I suggest half as super-stable biochar and humus, another 2.5% as digestible carbon, like crop stubble, compost, manure, etc. But 2.5% biochar tilled in six inches is 8 tons/acre. At \$.50/pound, \$8000/acre is too costly for farmers.

JR's genius is to concentrate biochar and nutrients in narrow bands, thus cut rates to from tons to hundreds of pounds/acre, slash annual costs, and spread expenses over several years.

Terra Char sawdust fines and 40-micron powder have huge functional surface areas. Minerals mixed in char charges it with nutrient ions. Injecting key microbes adds a Soil Food Web foundation. This cuts quantities of char and fertilizers needed further, while boosting effects. Together, they assure strong response and steady yields at financially feasible expense.

Biochar is inert. Char doesn't react with atoms, but is a substrate to bring other atoms together to react with greater ease, speed and efficiency. Like a catalyst, char is unchanged by a reaction, and stays in soil centuries, delivering services to microbes and roots.

First Place Milo

"That corn field produced 235 bushels," JR was proud. "The 20-year average for that field is 180 bushel. The crop was easy to grow. It was no trouble. Didn't have issues with it. Just watered it, set back and let it do its thing.

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

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

Yield 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 versus costs for biochar, biologicals and metabolites.

David Sr. spoke, "Yeah, we got figures. I'll fine tune fertilizers—exact amount we cut back. I'd say close to \$100 an acre cheaper. Maybe not \$100, but way up there."

So, 1000 acres saved near \$100,000 just on fertilizers. Biological amendments cost less, plus no herbicides or sprays, and a bonus of higher yield. Such economics mean JR can go in his fields to smile with his plants. And this is only his first year with a full biological program. Each year, as soil builds carbon, trace



elements and biology, JR can cut fertilizers more and increase yields.

Soybeans

JR's head shook talking about his #2 crop, "Basically, same story all over again. After long delay due to heavy rains, we planted beans after the 4th. If beans aren't in by July 4th, I risk lots of problems, like frost. They had the worst conditions possible when they came up."

David Sr. commented, "We had 25 inches of rain in July. After 28th, never got another rain for two months."

JR continued, "With heavy rains, several times water rose over bean tops a couple days. Yet, they overcame and bounced back. I was shocked how they kept growing! Yellowing went away fast. I think bacteria got right back in full swing. From that, they just kept on.

"Stalk is important in soybeans—usually a little pencil-like stalk. This year, stalks were like tree trunks. We noticed more lateral branches. Typically, we get a single stem and nodes stretched farther apart. This year, nodes were stacked, with three or four lateral branches, which is like one plant turned into three."

Biochar, fungi and biologicals mostly affect roots we can't see underground. Kansas State Forestry Dept. Nursery in Manhattan grows thousands of pine and cedar seedlings in a greenhouse. Someone gave staff a baggie of mycorrhizae spores, which they applied to a few seedlings. We pulled six out of their cones. Although top growth showed no obvious differences, root growth was 50% greater on treated seedlings, and most had outgrown their containers.

JR agreed, "Every soybean plant I pulled up, Rhizobia were always vibrant, pink, bigger in size, and more of them than typical, especially on poorer ground. It surprised us.

"This soil averages 35 bushels of after-wheat soybeans. We ended in 50 to 55. Quite a difference. Certain areas, they laugh at such soybean yields. But here, that's as good as we find. I'm real pleased with that.

"Also, we cut our population way back to 80 to 100,000. Many farms plant up to 180,000 per acre.

NRCS Cover Crops

"Two years ago I first came on cover crops. This is our first year for multi-species covers. We know our soils are low in organic matter—one thing we want to increase. Cover crops are a good way.

"Cover crops tie everything together—the whole soil ecosystem. Not one thing, but bridge gaps, keep soil life going in drought and winter, suppress weeds, deeper root penetration, keep soil nicely loose. In spring, plants have cover roots as

JR's genius is to concentrate biochar and nutrients in narrow bands, thus cut rates, slash annual costs, and spread expenses over years.

Fig. 13: JR Bollinger calling earthworms



paths to follow. Helps with wind erosion, a major problem here. Without cover, your dirt winds up on a neighbor's farm, his dirt comes on yours."

"Way our farm works, it's hard to do multi-species, since we late-plant beans in fields that will be corn next year. This year we cut beans in November, then air-seeded cover crops when leaves started to yellow, so leaves fell on seed. Looks like a strong population coming.

"In the past, we put a cover in after winter wheat to help with wind erosion, we have such sandy ground. We work ground in spring, and need some foliage for wind. But now we do strip-till and keep all the residue.

Worm Calling

"This all started because a man challenged me to find an earthworm. It tickled me yesterday to walk out in a field, stop in a random spot, dig soil with two fingers, and find an earthworm, then five more. In 2012, I couldn't find an earthworm. Yesterday, at a random spot, we found them.

"That shows me we're going in the right direction. It's a good gauge we are doing well if I see those guys."

March 31, we returned to the cover crop field. JR had a "worm caller"—pointed hardwood stick hammered into sandy soil until firm. He rubbed the top of this embedded stake with a hardwood board with a serrated edge. Stroking vibrated the stake to send low frequency waves through soil.

JR's first "worm caller" was a metal stake and wood rasp in his grandmother's garden. Metal emits higher frequency, and quickly, large worms crawled up out of soil.

Now, JR had trouble calling worms in carbon-poor soil with new cover. He persisted, stroking the stake, carefully fingered through surface litter and soil, and finally found three thin worms.

JR was disappointed to find so few, but two years ago, it had none. I explained his wee worms are teenage—his first crop. By mid-summer, young worms will be adults hatching hundreds of cocoons. By harvest, with food and habitat, next generations will boost populations.

Later, in JR's favorite field growing its first carbon-smart winter wheat, JR probed with a penetrometer to measure soil compaction. The top 12 inches was soft and easy to penetrate, but 16 to 18 inches was still hit a zone of tight soil—a legacy of decades of tillage and tractors. With abundant food and habitat from covers, fungi and worms will loosen this in two years.



Fig. 14: JR smiles to find three worms

"Yeah," senior Bollinger admitted, "as soon as we make it easy to do, I'll be all about it. I'm all about cutting fertilizer back and strip-till, because of erosion and all that."

Over winter, JR enrolled in Dr. Elaine Ingham's Soil Food Web course, and the science of soil microbes, their sizes and services, ways to measure them, and evaluate their effects. Excited by what he learned, JR got a digital microscope for his computer to capture live video of soil microbes.

Dr. Ingham teaches compost tea to culture and deploy microbes on fields, especially weak, deficient soils. To cook compost tea, JR has a 2000-gallon vortex brewer to whirl water to suck in oxygen. This spiral geometry is a key to structure water to boost capacity to carry energy, nutrients and information into soil and cells. When I left, JR was unpacking his new brewer with the joy of a kid at Christmas.

Fig. 15: JR checks compaction in a wheat field



2016

JR couldn't be happier for his farm's future. "We plan next season to use what we learned last year, fix a few gaps, apply things in timely fashion to tweak the system. We'll flex our muscles with what we learned last year. I'm excited."

"For example, I saw bubbles in liquid tubes, and vacuum hoses had trouble starting a row. A percent of mechanical errors, stones in equipment, and all. We have refining and advanced learning ahead before we can go all out."

David Sr. volunteered to gather financial data on savings, "I'll do some fine tuning on fertilizers. I can get you real close, 'cause I don't want to tell somebody something we didn't do, you know what I mean?"

I had to ask, "So, you like what you're seeing so far?"

"Yeah," senior Bollinger admitted, "as soon as we make it easy to do, I'll be all about it. I'm all about cutting fertilizer back and strip-till, because of erosion and all that."

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