Seed Opener Designs: Past & Present

Choices/Trends on Modern Equipment, with Lessons from the Past

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Planting sticks may look primitive, but may do a better job of placing seeds than many of the fancy seeders with wheels and hydraulics.

Many of you are perplexed as to why we at Exapta endorse certain seed opener designs for no-till (NT) and not others. (And many of you wonder if I'm qualified to render judgment at all ☺ but I'll save that topic for another day. Suffice it to say that I've been compelled to spend hundreds of hours digging behind a gamut of opener designs & settings, and I'm highly analytical. Plus, the huge range of climate and soil textures across Kansas—going from native short-grass prairie to a tree-dominated landscape in a mere 300 miles with relatively poor, low-OM soils in an unforgiving climate being typical—has afforded me plenty of diversity of soil conditions to play with. I frequently get out in the field in other parts of the world too.☺) So, here goes:

In the beginning…well, okay, maybe not *that* far back. At the dawn of agriculture, people used sticks to make holes in the soil, drop seeds in, tap them with the stick again, then kick soil back into the hole. Or you would drag the stick (later, a hoe) to make a shallow furrow, then poke the seeds in, and cover. Hence, the hoe opener. Very old technology. But the seed firming and closing was done with care, gently, and was completely separate from the depth-gauging (visually, by a mark on the stick).

Much, much later (in recent centuries), people figured out wheel axles that were durable enough to transport heavier implements around, so that the hoe openers could be ganged together (many openers alongside each other) and built heavier, and eventually added a hopper bin and metering mechanism and a seed tube to drop seeds in behind the hoe opener. Closing and firming was done by dragging loops of chain in dry climates ("dust mulch"), or by a "presser foot" that trailed behind (early 1900s), or by press / packer wheels – one for each row, that became more practical as mechanical bearings improved.

Hoe-drill from USA. Many shank/tyne openers, including air drills, are barely more sophisticated than planting sticks from a functional standpoint.

This was the apex of ag technology at the time, and worked very well in *tilled* seedbeds. That same basic opener design is still used in hoe-drills today, and by air drills that use sweeps, knives, spoons, etc. They are all *shank* (a.k.a. tine / tyne) openers, and drag through the soil to create the furrow, and rely on the loose soil flowing back into the furrow afterwards. Designs have been improved in various ways, including putting each opener on its own linkage, but the principle is very much the same. These shank openers are still relatively simple, low cost, and very good at dealing with somewhat dry, loose soils under tillage.

Light-weight shank opener in Australia with parallel-link and cutting coulter.

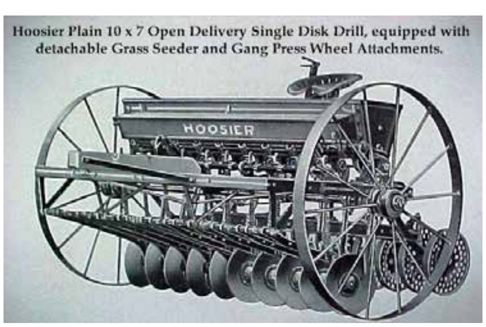
In no-till, when crop rotations lack species diversity, the tillage from shank openers may confer a yield benefit via disruption of pathogenic hyphae. Shanks may also provide a yield advantage (sometimes) in extremely cold climates where soil warming is a factor, although this advantage is exaggerated – disc openers are being adopted rapidly in Alberta & Saskatchewan, for instance. Shanks also create a ridge or berm of loose soil between the rows, which helps cut wind speeds at the soil surface (good for both crops and soil), as well as the furrow trough with some smearing at the bottom, which can be useful in trapping rainfall in *extremely* dry climates (funnels small rains down to the seed, if it's shallowly placed). In wetter climates, however, the seedlings may drown or grow very poorly due to this moisture-collecting effect.

Shank openers have other problems in wetter climates – in mud, they become big goobers and make a huge mess, not to mention pulling really hard. Anything dragging through the soil, such as shanks, will create very bad smearing in damp clayey soils, resulting in a lack of porosity that does not allow sufficient oxygen to get to the seed (anaerobic conditions), and may impede initial rooting if the rain shuts off. For no-till, shank openers are very poor for residue flow (those shanks are a lot like a dump rake for hay), particularly if stalks or pieces of straw are long – to cope, many shank drills are outfitted with cutting coulters ahead of each shank, and/or farmers go to considerable effort and expense to 'size' the residue with the combine during harvest (or mowing afterwards).

While it's very wide and looks sophisticated, it's still just a hoe opener.

For no-till, there are also big problems when the shank (or any opener) is depth-limited by the press or packer wheel, partly because soils are much more likely to be wet under no-till's mulch cover, and also if more down-force is applied to the opener to penetrate the more resilient, structured soils of NT. Some of the 'extra' down-force ends up on the press wheel in softer areas of the field (softer usually being wetter, and more vulnerable to compaction), or else the opener isn't going in at all in the drier or harder spots. Since the press wheel is running exactly over where the seedlings will be trying to emerge, this can be a big problem.

There's also a problem with achieving seed-to-soil contact and closing the furrow in the more structured soils found in no-till (your feet don't sink into NT like they do where the soil structure has been destroyed by tillage). In NT, soil doesn't fall back into the furrow readily after the opener has passed (except in extreme sand without structure). This makes it tough, and sometimes impossible, for the packer wheel to provide adequate, uniform seed-to-soil contact. Furthermore, the depth of the fill material over the seed certainly isn't consistent, and sometimes the furrow remains wide open – particularly in hard soils, or soddy conditions.



An early grain drill with press wheels.

Disc Openers

These became more widely used in the late-1800s and early 1900s in the wetter farmland areas of Europe and the Americas, as metallurgy and mechanical bearings improved. Basically, all that happened was to place one or two blades, sometimes dished outward, where the shank had been (or sometimes the shank was modified into a seed shoe or runner, just behind the disc openers). Listers & other early 'row-crop' (corn) planter units are examples. Despite the additional cost & maintenance, disc openers soon dominated the mechanized ag world, since these were able to continue to

A relic from the past, when planters gauged depth from trailing packer / treader wheels. Despite being one of the earliest planters halfway capable of no-till seeding, the results were pathetic with 50 – 60% emergence, and no consistency in timing of emergence. This one has been modified with serrated furrow-covering discs and sliding 'heave-limiters' alongside the opener blades.

function in muddy conditions, didn't plug so easily with vines & stubble, could be ran at about double the ground speed of shank openers, and with far lower draft. They also push or drag far less soil downslope, which has been proven to cause topsoil loss from hilltops as bad as water or wind erosion.

But for no-till, the packer / press wheel design aspect still had the same problems for depth-gauging (too far rearward of furrow forming and seed drop; excessive packing above the seed), seed firming (inconsistent; packed more at soil surface than at the seed's location), and furrow closing (inconsistent). As far back as the early 1960s, no-till planter & drill manufacturers and engineers were putting aggressive wavy coulters in front of openers with trailing packer-wheels—in essence, adding back some tillage to make the tillage-era openers halfway decent again (e.g., Allis-Chalmers no-till planters from the '60s).

Press-wheel drills have replaced the hoe or knife with rotating disc blades to create the furrow, but still gauge their depth from the trailing packer or press wheel.

Packer / press-wheel drills have the same set of issues—the depth gauging isn't anywhere close to where the furrow is being cut, nor is the packing consistent in undulating soils (the trailing packer is your seed-to-soil contact in these designs). (Alternatively, some "no-till" coulter-cart drills relied on the coulters to set the depth for openers that had feeble springs and wouldn't go deeper than the coulter; the vertical press wheel was used for seed firming, not depth control. This was also a very poor design for no-till in that soil density & moisture determined depth.) But these same basic packer-wheel or press-wheel drill openers are still sold by the millions to no-tillers. Is this all due to lower cost (and lack of awareness of what they're missing out on versus the better opener designs)? Or are many being duped by marketing? —The manufacturers will put heavier springs on the drill openers, or some coulters out in front, slap "No-till" stickers on it, show a few photos of stubble and some vague statements about being "no-till ready," and they sell like mad.

Press-wheel vs. gauge-wheel openers

By the late 1960s, the big new idea was to put the depth-limiting wheel *alongside* the opener blade, and that was a huge step forward – by the 2000s, virtually all planter openers in the USA, Canada, Europe, and the mechanized-farming areas of South America used this design. This depth-gauging wheel, or simply "gauge wheel," is usually mounted flush against the outside of the opener blade, and slightly rearward of the blade, so as to gauge depth exactly where the furrow is being cut, and where the seed tube is dropping seed – for great preciseness of seeding depth regardless of soil variability or bumpiness. The gauge wheel located alongside the opener blade also controls the amount of soil being thrown out of the furrow by the blade, which improves precision of placement still further (no sidewall blowing out and the resulting seed-scatter), and which is usually considered desirable in NT for reducing weed germination. Newer designs from South America place the depth gauge wheel closer to the front to aid in residue cutting, although this makes sidewall blowout considerably worse (if you have trouble cutting residue, put on sharper blades, add more down-force, and/or install a row cleaner). In North America, gauge wheels located too far forward can be found on Case-IH Early Risers, and on the French row unit on Monosems).

Almost all planters worldwide have had gauge wheels alongside the blades for many decades. Brazilian models old & new (2005) shown here.

The gauge-wheel concept is used for a few single-disc drill openers also, namely the Deere 50/60/90-series, Case's defunct SDX & its new Precision 500 (and its predecessor, the Flexi-coil FSO), and a couple others such as the NDF & Daybreak in Australia, and a bunch of near-clones of the Deere

Clones of the John Deere 50/60/90-series gauge-wheel drill openers in Russia & Argentina.

In Australia, the inaugural run of the first Daybreak gauge-wheel opener (left) in 2000, alongside a Flexi-coil Barton (press-wheel). Case-New Holland eventually discontinued the Barton, for good reason; the Daybreak continued to evolve with a 'rolling shield' replacing the seed boot.

Although primitive by our standards, this seeder is depth-limited by an average of the wheel way out in front and the trailing *wheel alongside the row (not over the row). The furrow was partly created by a separate implement. Note that this seeder also has a fertilizer hopper. Other than limiting depth entirely with a gauge wheel exactly alongside the blade(s), this sensing of terrain both ahead of and behind the blade is the only other configuration that makes sense for obtaining the best preciseness of depth (here, it's like a motor grader in that the blade forming the furrow is equidistant between the front & rear wheels sensing the terrain; completely unlike the Borgault 3710 ~~and Morris Razr~~ designs described in the main text).*

50/60/90-series in Argentina, Russia, and Australia by local companies (see photos). On rare occasion, there are double-disc drill openers with true gauge wheels alongside.

As an aside, the original Flexi-coil Barton opener, as well as the more recent Pillar Laser opener, has a rubber wiper wheel alongside the blade, but really it's the trailing packer or press wheel that depth-limits the blade. *Not everything that looks like a gauge wheel actually is.*

There are also hybrids that use a walking beam (walking axle) so that the depth of the cut is limited by an *average* of the wiper wheel and trailing packer wheel – these include the Borgault 3710 and ~~Morris Razr~~. [Edit, Dec 2014: The Morris Razr's walking beam is between the packer and the blade (it has a true gauge wheel)]. Clever, but for the added complexity & cost, they might as well just get it right by using a true gauge wheel and completely independent closing wheel, and a separate in-furrow firming wheel – there wouldn't be any more pivot points / bearings than what they have currently.[1] There really isn't much value in using a trailing wheel to sense the *terrain that's already gone past the other opener components* – i.e., it's of little or no predictive value of what's immediately *ahead* of the opener, nor what the main opener components are *currently* experiencing.[2] So long as firming + closing can float independently of the depth-gauging wheel, there's nothing better than sensing depth exactly where the furrow is being cut and the seed is being dropped.[3]

And, depending on the details, the gauge-wheel designs usually handle mud nearly as well as (or better than) the trailing press-wheel designs. However, one downside is that compaction alongside the row, particularly of the sidewall, can be worse with the gauge-wheel design since the soil is not only being pried outward by the blade, but simultaneously is being held down by the gauge wheel.[4] However, depending on the shape and pressure applied, trailing press-wheels or packer wheels can be badly compacting also (so can the V-type 'pinch' closing wheels of planters when outfitted with smooth wheels and lots of pressure).

[1] Both the Morris Razr and Borgault 3710 already have parallel linkages too, although the Razr's doesn't hold the boot/scraper at a constant angle, so I'm not sure what good it is.
[2] I'm still talking about the Borgault 3710 ~~and Morris Razr~~ averaging design (previous sentence) that uses the trailing press wheel for part of the 'information' as to depth. As for the Morris Razr & AVEC walking beam, the depth is set at the point of seed drop, but the trailing press / closing wheel sets the angle of attack of the opener blades, seed tube, etc. But again, *it's basing this on what is already 'old news' and not predictive of what the front part of the opener is currently experiencing or will experience in the next couple feet.* Indeed, because undulating bumps & depressions don't go up or down for very long (i.e., the small-scale undulations quickly revert to the average slope of the terrain), sensing depth partly or fully from a position rearward of the furrow-forming device is actually predicting incorrectly more often than not – its predictions (for what lies ahead of the opener) are lousy. The exception would be if it was linked to a wheel equally far in *front* of the furrow-forming device; then, you'd have something of a motor grader effect where the ground-cutting apparatus is suspended between wheels far ahead and rearward for precise averaging.
[3] Exception: last sentence of previous footnote.
[4] Alleviating this gauge-wheel compaction has been attempted with Reduced Inner Diameter (RID) gauge tires, and/or by locating the gauge wheel farther forward—although by allowing the sidewall to lift more (partial sidewall blowout), seed placement is less precise since the sidewalls are what guide the seed into position – the lower end of the seed tube is typically a full 2 inches above the bottom of the furrow. Ultimately, this problem may be largely eliminated by the technology of sensing the pressure on each gauge wheel arm, then using automated, fast-acting hydraulic down-force to maintain the pressure on each row continuously on-the-fly. Excess down-force – that is, beyond what's needed to hold the blade at depth, and to keep the sidewall together while the seed drops past – is eliminated. Another option is to mount the gauge wheel so there's a sizeable gap between it and the opener blade—although this also results in the same problems that plague RID gauge tires—only worse.

Cross-slot, a.k.a. Bio-Blade, 2003 model.

One opener that truly blurs the distinction between gauge wheels and press wheels is the Cross-Slot (also marketed under other names). And it blurs the distinction between disc and sliding openers, since the wings for the seed and fertilizer are blunt objects (mini-sweeps) being forced to undercut the soil well apart from the single vertical blade. It's a disc opener, but with things dragging in the soil – creating a lot of smearing in damp clay soils.[5] It was designed for pasture renovation (interseeding) in New Zealand, and handles those conditions well. Its advantages in annual cropping include ability to penetrate extremely hard soils (due to frame weight and hydraulics), and coping with high levels of surface mulch. Downsides include the aforementioned smearing, inability to provide seed-to-soil contact at the seed's location, and excess packing of soil above the seed. They also have extremely high draft, and are expensive / inconvenient to maintain with the wings wearing out frequently.

Opportunities for Precise Seed Environments

A big advantage in relocating the depth-gauging wheel to be alongside the opener blades is that a wide range of more positively engaging (spiked, spoked, or tined) furrow closing wheels or small covering discs could be used to fill the furrow, and with far less pressure deployed on them than a packer / press-wheel. When designed & operated appropriately, these have major advantages in reducing surface crusting, improving emergence (faster, more uniform, and a higher %), and breaking up sidewalls for roots to grow more easily. What is more, the pressure on the closing mechanism is now constant[6] – it isn't merely the leftover pressure after the blades achieved their depth.

Case-IH Early Riser planter opener. Covering discs are suspended from arm that holds the treader wheel (which is capable of going to zero pressure).

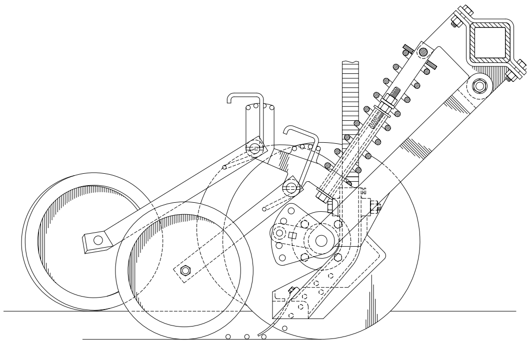
Almost all double-disc planter openers use some sort of firming + closing (or closing + firming) that is entirely on its own independent bracket / linkage with its own pressure settings. The advantages were large and recognized very early. Later, as no-tillers became more aware, those firming and closing functions were often further separated from each other to take full advantage of this design opportunity. By the 1970s, the CIH Early Riser planters had dished-out covering discs to help pull soil back into the furrow. By the '80s & '90s, narrow in-furrow seed-firming devices were becoming more common for both planters and drills, which greatly helped the seed-to-soil contact issue. Already in the 1960s, the first of these appeared on certain models of Buffalo planter (the yellow ones made by Fleitcher in Nebraska) as a true in-furrow firming wheel, albeit on a runner planter, with a separate covering system behind this.

For no-till, for most of these opener designs, we at Exapta strongly recommend that an *in-furrow* seed-firming device be used, either a sliding type such as a Keeton (or Flo-Rite), or a narrow 'seed-lock' wheel. For much of the world's cropland, *in-furrow* seed firming is one of the largest improvements that have come about for no-till seeding. In tougher soils and drier climates, best results obtain from using substantial pressure on these firming devices: 5 to 20 lbs (not ounces!).

Some very cool climates (Canada, Scandinavia) appear to get away with not using an in-furrow seed-firming mechanism—at least most of the time. Still, the advantages are often there, albeit smaller and less noticeable than in warmer and/or drier climates and poorer soils.

[5] There are some other drill openers that also do this, such as the Pillar Laser. A few planter attachments also make this mistake (hanging down below the cut of the blades), such as the Acra V-Slice, other firming points, and the Huckstep fertilizer shoe.

[6] The next step is to vary it in a controlled manner, for instance, by tying it to hydraulic or pneumatic down-force applied to the row unit itself.



JD 50/60/90-series drill opener, showing the seed-lock wheel running in-furrow.

One planter opener design, the Case-IH Early Riser, is solidly in the gauge-wheel category, but has some unique features that don't necessarily lend themselves to Keetons or seed-lock wheels. Primarily this is due to the gauge wheel being located farther forward in relation to the blades, which allow far more sidewall blowout (the Reduced Inner Diameter / indented gauge tires also contribute) – good for reducing compaction, but with the effect that the seeds are in a wide ribbon rather than a well-defined furrow. Since the seeds aren't lined up in a distinct furrow, a relatively narrow firming device (e.g., Keeton or Flo-Rite) only engages some of them, which will make emergence less uniform. This is why we instead recommend Rebounders for Early Riser row units, which don't really do any firming, but do help control seed bounce. (The Early Riser accomplishes seed firming via its wide chevron treader wheel – packing from the surface downward.)

JD 90-series drill opener with aftermarket closing wheel to positively engage & crumble the sidewall. Only because depth-gauging & seed firming are already accomplished does it allow crumbler-style closing wheels

Another instance where Keetons (in their current form) are a relatively poor choice is on the Deere 50/60/90-series gauge-wheel drill openers, because these openers are mounted on a 'swing arm' or radial linkage, such that the opener's body (cast subframe) changes angle significantly during field operation (unlike a parallel-link opener). With the Keeton attached directly to the JD 50/60/90 opener subframe, the pressure on the Keeton varies wildly in field operation, and is often zero when the gauge wheel goes over a very slight hump or bump, or if the entire opener skates out slightly due to lack of down-force, etc. – just a teeny change in the angle of the subframe causes the Keeton pressure to go to zero. Instead, if you really think you want a sliding firmer for these drills, there's one called the Fin that moves independently of the opener subframe, since the Fin replaces the seed-lock wheel on the firming-wheel arm. Thus, the Fin has a much more constant pressure.

Cutting the Furrow

Getting back to the subject of cutting the furrow, there are many designs in the disc-opener category. Almost all single-disc openers run at a slight angle to the direction of travel to create the furrow. Some are also tilted from vertical, either slightly (Deere 50/60/90-series) or dramatically (original Barton). The tilting from vertical has been detrimental to all designs that I've seen in the field. Much better is running the blade at true vertical, such as the (now defunct) Flexi-coil FSO, and its direct descendant, the Case Precision 500 / New Holland 2080 / 2085.

Case-IH P-500 / NH 2080 drill. The lack of an in-furrow seed firming mechanism is a big mistake for no-till (nor does the closing wheel do much in NT).

While single-disc openers are almost entirely reliant on soil cohesion to prevent soil from falling in ahead of the seed, double-discs are far less susceptible to this problem. In general, the double-discs do a nicer job of seed placement so long as the gauge wheel is located appropriately fore/aft to hold the sidewall together, and the gauge wheel has the proper shape and is operated with enough pressure on it to prevent premature sidewall collapse (before the seed comes to rest). It is also important that the seed tube be located as far forward as possible in relation to the double-discs, and that the tube have as vertical of a trajectory as possible (even if this causes seed ricochet internally, with moderately negative effects on spacing of seed-singulation metering).

The most common are double-discs of the same size and no fore/aft offset (e.g., "True-Vee"), but other designs include double-discs of the same size *with* fore/aft offset (e.g., Case-IH Early Riser), double-discs *with* offset *and* different-sized blades (AVEC). All else being equal, the offset double-disc openers cut

Offset (staggered) double-disc opener.

Offset (staggered) double-disc opener.

Another gauge-wheel drill design, by NDF of Australia. Note that the gauge wheel can be slid fore/aft, and the down-force is created by an air bag and not a spring. Nice. While still a swing-arm (radial) linkage, it is better than Deere's by the arm's flatter angle during operation. Still no method for in-furrow seed firming, however.

residue better than having the blades exactly side-by-side, although the offsets cannot go thru as much mud. Offsets do allow a slightly narrower furrow to be formed, but sometimes with a bit more dust and sidewall getting in ahead of the seed.

There are variations of the offset double-disc openers where the trailing blade is: A) smaller; and/or, B) running more straight to the direction of travel. At the extreme, these might be called a single-disc opener with a "rolling boot" (e.g., the current incarnation of the Daybreak). Along this continuum, the trailing blade is doing less work, which results in asymmetrical pressure and far greater wear on the linkage, just like it does for single-disc openers. Along the continuum, the seed placement gradually gets a bit worse. The advantages are less hairpinning of mulch,[7] and—if you eliminate one disc blade and one gauge wheel entirely—the simplicity.

Summarizing:
Disc openers and gauge wheels dominate planter designs globally, for agronomic & economic reasons, which become even more accentuated in no-till. These design features allow far greater tweaking of function (precise seed-to-soil contact, precise depth) to better suit the unique seedbed found in continuous no-till. They allow far more acres to be planted per horsepower per day. Expect to see grain drills moving in this direction also, especially if no-tillers demand it from OEMs. See comparison photos, and note that I see this much performance difference very commonly – and after a farmer finally gets switched from a press-wheel to a gauge-wheel design, I usually hear a comment along the lines of: "I waited far too long."

As to the myriad of choices on firming and closing, the most effective systems really fall into 2 main categories—either keeping the furrow very narrow and well-defined, then doing seed firming in the bottom of the furrow of those carefully aligned seeds, and then closing the furrow by chopping the sidewalls. Or, by allowing a lot of sidewall blowout with the opener blades, then firming all the soil from the surface downward.

How well any of these perform in no-till, especially long-term NT, depends a lot on equipment choices (including aftermarket), as well as adjustments and maintenance. There's a lot of money being left on the table. Choose wisely.

[7] If the first thing you think of when you read this sentence is how awful the JD 50/60/90-series drills are for hair-pinning, keep in mind that almost all of that problem is due to lack of down-stroke in the linkage & big coil spring. If the big coil spring relaxes even a half-inch when the opener goes into a slight depression, it suddenly is providing far less down-force on the opener. (This may soon be solved by Dawn's Rfx-D system: http://new.livestream.com/accounts/9043002/events/3600946 .) Compounding the problem is that the opener blades from JD are very dull even when new, and most people try to run them far too long. Also, the boot hanging out past the opener blade prevents the opener from easily staying at depth and slicing the mulch easily – and this is a big factor if trying to seed deeper, or if blades have lost some diameter. But none of these problems are inherent to single -disc openers, just to that particular design.

*Wheat planted with a so-called no-till drill (actually just the old packer-wheel design with heavier down-pressure springs, but many companies sell these as 'no-till' drills). Note the substantial soil disturbance and stubble being buried. **Stand was 870,000 plants/a.***

*This was taken just a couple hundred feet from the photos to the left. Soil and rotational history were identical. However, this field was planted with a JD 1560, outfitted with 90-series boots, SDX firming wheels, and spoked closing wheels. Extremely low soil disturbance, and all the stubble is retained. **Stand was 1,240,000 plants/a.***

Concord shank - L; JD 1850 - R (same seed lot, same rate, same day; the farmer was well versed in setting shank openers and had been running his Concord for several years, whereas the 1850 was new and unfamiliar to him) North-central KS into sunflower stubble.Yield was ~ 10% less with the Concord.