

Advanced farming systems and new technologies for the maize industry¹

aka What's New in Maize Production in the U.S.

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The lofty title I was assigned for this presentation was rather daunting to me as I began to assemble my thoughts for the task at hand. In my line of work at Purdue University as an Extension maize agronomist, I am frequently consumed by the practical day-to-day agronomic issues that face Indiana maize growers and their supporting agricultural industries. There don't seem to be enough hours in the day to keep up with the latest and greatest advancements / technologies in maize production.

Advancement [ad-vans-muhnt]: The act of moving forward.

The more I thought about this topic, the more I realized that there is a plethora of so-called "advancements" in crop production in today's agriculture compared to the agriculture of 100 years ago. Every farm magazine, newspaper, or Web site you open up contains articles or advertisements about seemingly miraculous new technologies, tools, or crop inputs that promise to dramatically increase crop yield or reduce production costs.

How many truly miraculous advancements in farming practices can you identify that have dramatically moved crop yields forward? Honestly, there have only been a few.

Historical progress in maize yield improvement in the U.S.

From 1866 until the late 1930's, national maize grain yields in the U.S. averaged 1.6 T/ha and showed no evidence of improvement whatsoever during that 70 year period (Fig. 1). The absence of any apparent "advancement" in grain yield over such a long time period is rather amazing considering that maize growers were, in essence, practicing plant breeding (i.e., mass selection) as they selected the best ears from each year's harvest for planting the next season.

During the early years of the 20th century, researchers at several universities (including Purdue) worked on developing a genetic "advancement" that would eventually lead to the first significant and sustained improvement in maize yields..... **hybrid vigor**. As American agriculture slowly recovered from the "Dust Bowl" and economic depression of the 1930's, farmers began to adopt the new genetic technology in the form of double-cross hybrid seed corn that not only exhibited dramatically higher yield potential but also significantly better tolerance to stress compared to the traditional open-pollinated maize varieties. Within only a few years of the increased adoption of this "advanced farming system", the national yield data clearly showed that a "**quantum leap**" shift in maize

¹ Based on presentations made at the 2012 FAR Maize Conference, Hamilton, New Zealand

productivity had occurred and the historical trend for maize grain yield changed from a flat, no improvement “trend” to an annual yield increase of 48 kg/ha/yr (Fig. 1).

Within about 10 years after the end of World War II, the national maize yield data clearly illustrated that a **second significant “quantum leap” shift** in productivity had begun. The rate of annual yield gain more than doubled to approximately 120 kg/ha/yr (Fig. 1). The advanced farming systems and technologies responsible for this amazing shift in maize productivity were a combination of the adoption of further genetic improvements (single-cross hybrids), inorganic nitrogen fertilizers (anhydrous ammonia, urea, etc), chemical pesticides (2,4-D, etc), and agricultural mechanization (tractors and other self-propelled equipment).

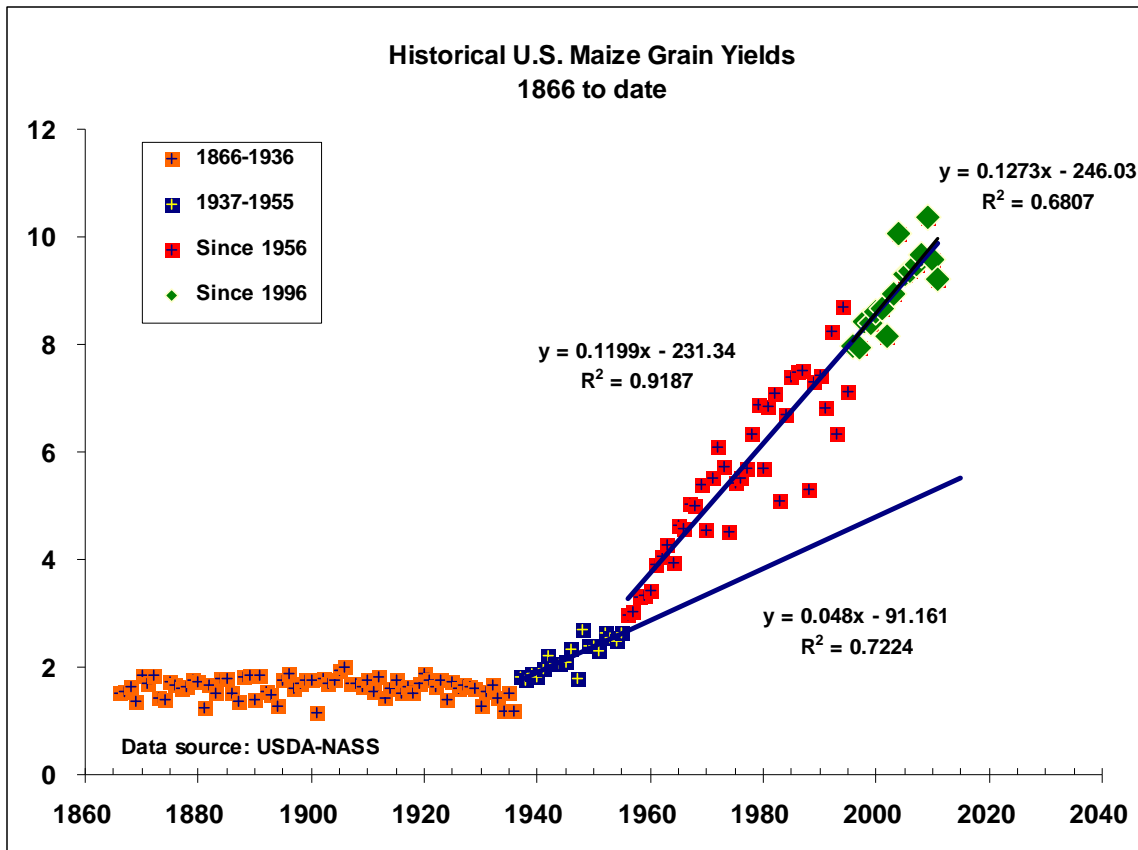


Fig. 1. Historical maize grain yields (metric T/ha) in the U.S. from 1866 to 2011. Data source: USDA-NASS.

For all intents and purposes, the second “quantum leap” shift in the annual rate of maize productivity begun in the mid-1950’s has continued through today; sustained by continued improvements in genetic technology and agronomic management. Proponents of modern biotechnology often proclaim that the advent of transgenic maize traits for insect resistance and herbicide tolerance has ushered in the beginning of a third “quantum leap” shift in American maize productivity. Since the introduction of the first transgenic Bt insect resistance trait in the mid-1990’s, the historical trend lines indeed suggest a minor apparent increase in the rate of annual yield gain (120 vs 127 kg/ha/yr), however I personally believe that there is no clear evidence that this particular “advanced farming

system” has yet initiated a third “quantum leap” shift in our annual rate of maize yield improvement in the U.S. (Fig. 1).

What can you see on the horizon?

The national average maize yield in the U.S. over the past five years (2007-2011) is 9.7 T/ha. The average maize yield for the two largest maize producing states in the U.S. (Iowa and Illinois) for the same 5-year period is 10.7 t/ha. At the current annual rate of yield gain (120 kg/ha/yr), average maize yields will double by the year 2086 unless a third “quantum leap” advancement in farming technologies occurs before then.

So, what technological advancements are clearly viewable on the horizon that will contribute to significant increases in maize productivity in the near future? Frankly, the view of the horizon is fairly muddled.

One would certainly expect that improvements in genetic technologies could lead the list of advancements that could shift the rate of annual yield gain. The most immediate known advancement in genetic technology is that of **increased drought tolerance**.

Both Pioneer Hi-Bred International (DuPont) and Syngenta currently offer a limited number of hybrids that contain improved drought tolerance characteristics developed without the use of transgenic technologies (i.e., non-GMO). Hybrids with these traits (Pioneer AquaMax™, Syngenta Agrisure™ Artesian™) will be targeted towards the more drought-prone areas of the western U.S. Corn Belt (e.g., Kansas, Nebraska, South Dakota). It remains to be seen to what extent these hybrid traits will dramatically improve yields under moderate to severe drought conditions.

The USDA-APHIS regulatory authority recently “deregulated” Monsanto’s “Drought I” branded drought tolerance trait. This transgenic trait involves a bacterial transgene (*Bacillus subtilis*) that codes for a cold shock protein that reportedly confers drought tolerance to the transgenic hybrid. Deregulation by the USDA-APHIS means that Monsanto can proceed with widespread field testing of this trait in 2012 to better determine its utility under drought conditions. Data provided by Monsanto to USDA-APHIS in their application for deregulation suggests that yield improvement under “moderate water deficits” may be as much as half a ton per hectare. No data were apparently provided to document yield improvements under “severe moisture deficits”.

So, will this “advancement” in genetic technologies result in a “quantum leap” in maize productivity at the national level? Time will tell.

Few other significant near-term advancements in genetic technology are evident in the research pipelines of the seed industry. The other “significant” genetic improvement most commonly mentioned for maize is enhanced nitrogen use efficiency, though the true yield impact of the improved trait remains to be seen.

Other new technologies available today?

So, what else is available that could be described as “advanced farming systems” or new technologies for the maize industry?

In recent years, the adoption of various **precision agriculture technologies** by U.S. maize and soybean growers has been increasing dramatically. Among the more

commonly adopted precision farming technologies are those associated with auto-navigation of equipment, auto-control of individual rows or nozzles of application equipment, and variable rate control of application equipment. Interest in data management technologies is also growing as these capabilities become more available and affordable.

The increasing availability and affordability of sub-inch (cm) accuracy in GPS receiver technologies has contributed to growers' interest in **auto-navigation and auto-control technology** in recent years. In particular, adoption of accurate RTK-based GPS receiver technologies is increasing rapidly partly due to the ever increasing availability of RTK networks throughout the countryside. These networks may be subscription-based (e.g., Trimble) or free access via state government department of transportation RTK networks known as continuously operating reference stations (CORS).

The advantages of auto-navigation and individual row control systems lie mainly with their potential for decreasing costs of crop production by virtue of their ability to reduce time and wastage associated with over- and under-laps of field operations (tillage, fertilizer spreading, herbicide applications, headlands or endrows). Some potential for yield increases exists due to fewer skips in weed control and less over-population of headlands (end rows), but these yield improvements will be relatively minor.

I believe it is fair to say that none of today's precision agriculture auto-nav or auto-control technologies represents a "quantum leap" in maize productivity. Rather they offer the potential to reduce production costs through more accurate placement of crop inputs. An intangible, yet meaningful, benefit of auto-nav technologies is the reduction in operator fatigue accompanied with the freedom to monitor equipment more closely.

The opportunity for variable rate (VR) control for application of certain crop inputs, primarily fertilizers and seeds, has been available for some time to U.S. agricultural retailers and increasingly so at the farmer level in recent years. Fertilizer retailers in the U.S. adopted VR application technologies for application of phosphorus and potassium fertilizers plus lime as long ago as the 1990's.

Variable rate application of phosphorus and potassium fertilizers plus lime has proven effective in reducing whole field input costs and improving yields in areas of fields with serious deficiencies for P, K, or soil pH. One of the reasons this VR technology has been effective is that the agronomic data to support the VR decisions can easily be generated from spatially intensive soil sampling data that are then used to develop spatial application maps. In other words, the VR decisions for these inputs are based on a sound understanding of the agronomic relationships between a single variable (spatial soil sample data) and crop response.

While effective, these particular VR technologies do not result in "quantum leap" shifts in the annual rate of maize productivity. At best, VR application of P, K, and lime improve the lower yielding areas of fields identified as deficient for these important nutritional factors.

Variable rate control technology is also available for nitrogen fertilizer applications or seeding rates. Both technologies are becoming increasingly available to farmers and becoming common standard accessories on applicators and planters.

If you create a “prescription” VR application file for use with a VR controller, the applicator or planter will indeed variably apply N rates or seeding rates across a field based on what you told it to do. Therein lies the challenge. The software and hardware will do exactly what you tell it to do. No matter what basis you use to create an application map, the software will generate a pretty color map and “tell” the VR controller what to do.

In contrast to predicting P, K, and lime requirements based simply on soil sample analysis data, there is no similar single criterion for N or seeding rate requirements for maize with which to develop reliable VR application maps. In other words, a lot of factors interact to determine optimal N or seeding rates for given areas of a field.

Variable rate N application for a maize crop, in our experience, is NOT related to spatial yield potential. Rather, VR nitrogen is, at its essence, related to the estimated spatial variability for soil N supply within a given field. However, the estimate of available soil N supply is influenced by a number of factors that influence mineralization, immobilization, denitrification, leaching, and volatilization of N. These include soil organic matter, inherent soil drainage characteristics, adequacy of artificial field drainage, soil temperature, manure application rates & methods & timings, rainfall amounts & timing & frequency, timing of N fertilizer application, method of N fertilizer application, source of N fertilizer, and use of nitrification or urease inhibitors or not. Creating a VR nitrogen application map based on only one or two of these factors will often result in unpredictable levels of error in the true N requirements of the maize crop.

The challenges involved with accurately predicting soil N supply to subsequently estimate variable N application rates have increased the interest in using optical reflectance sensors (e.g., Greenseeker™, Holland Scientific Crop Circle™) to estimate maize N status “on the go” and spatially sidedress apply variable N rates according to the spatial variability in crop canopy reflectance.

Active **optical reflectance sensors** are very sensitive to changes in plant biomass and overall health of a maize crop. Various reflectance indices (e.g., NDVI, chlorophyll index) have been shown to closely correlate with N content of plants or overall N uptake by crops (Fig. 2) and also correlate closely with eventual grain yield (Fig. 3).

The challenge with this technology is that reflectance differences in plant N status due to variable available soil N are not evident until the crop is too tall to sidedress with traditional sidedress row applicators (Fig 2). The physiological reason for this absence of reflectance differences in young maize plants is that maize simply does not begin to take up significant amounts of soil N until about leaf stage V9 (Fig. 4).

Consequently, it is our opinion that optical crop reflectance technologies are best suited for fairly late sidedress N application timings (~ V9 ~ 12) using high-clearance applicators (e.g., Hagie™, Miller™). A late sidedress timing strategy would likely include a “near planting” application of a minimum initial N rate (perhaps 50% - 75% of expected total) followed by a late sidedressing application “controlled” by the optical reflectance data that would determine how much of the remaining 25% - 50% of the expected N was actually needed. In other words, the reflectance sensors would allow maize growers to “fine tune” the application of the final 50+ kg of N fertilizer.

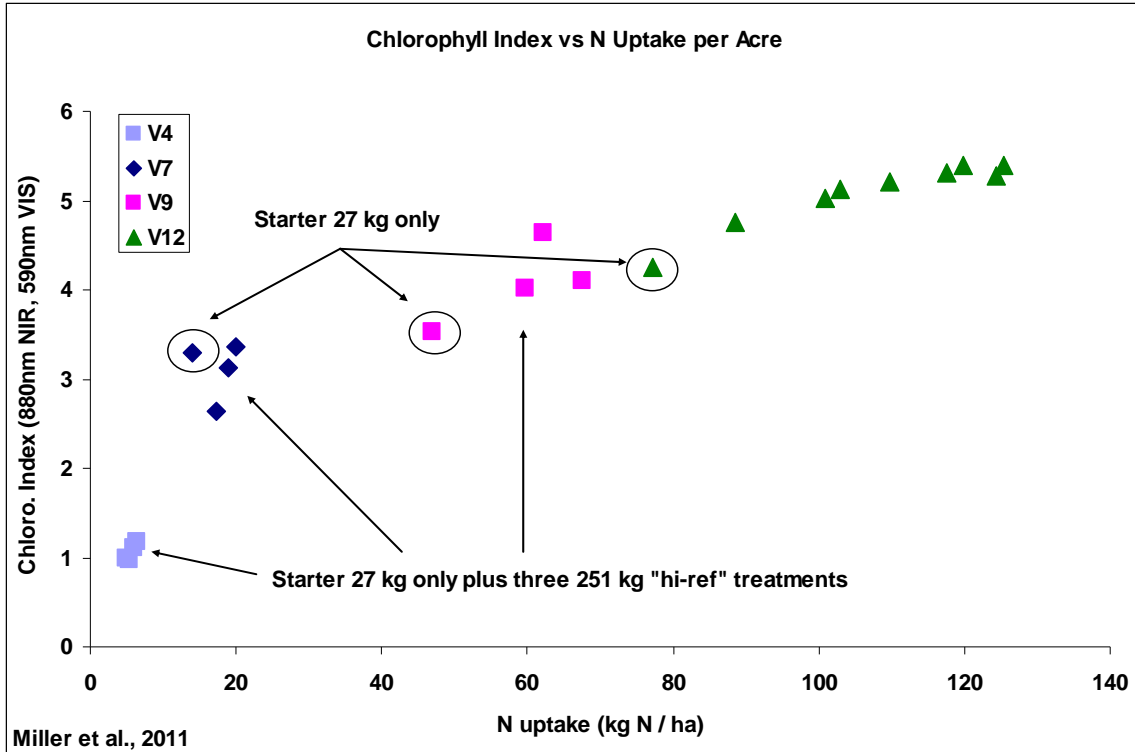


Fig. 2. Optical reflectance (Holland Scientific Crop Circle ACS-210) of a maize canopy relative to nitrogen uptake by the plants as influenced by N timing and rate. Chlorophyll index values calculated as $[Nir880] / [Vis590] - 1$. Purdue Univ.

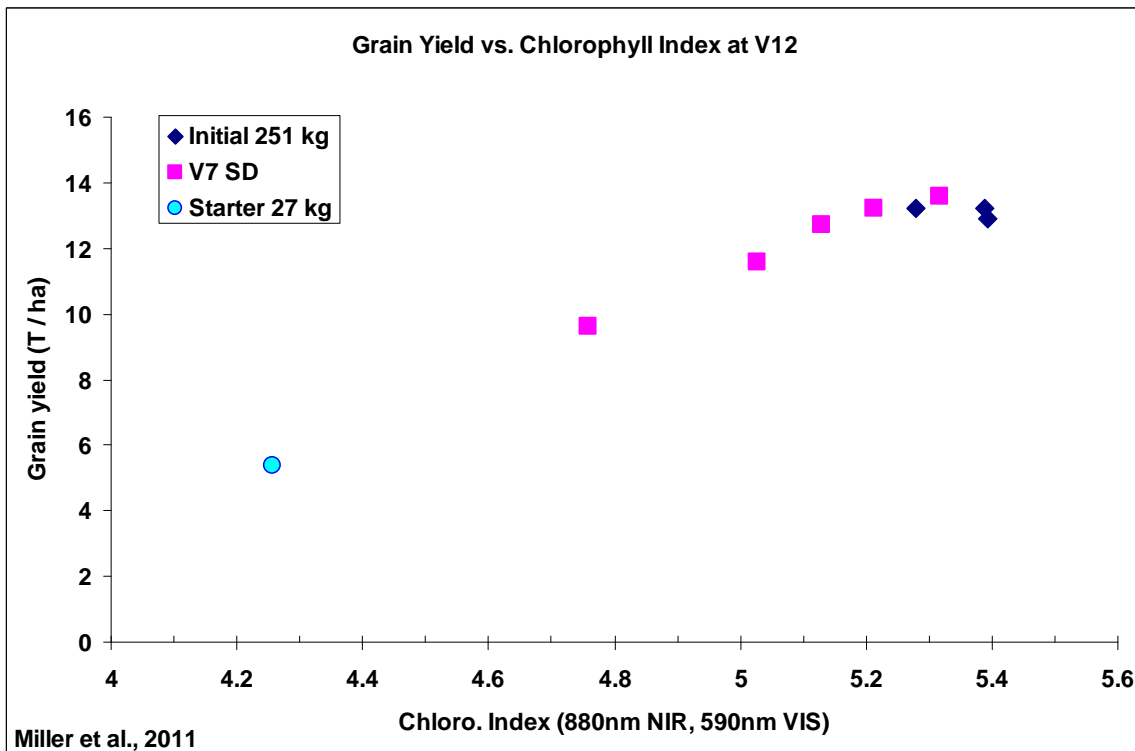


Fig. 3. Maize grain yield relative to optical reflectance (Holland Scientific Crop Circle ACS-210) at leaf stage V7 for a range of N fertilizer application rates. Chlorophyll index values calculated as $[Nir880] / [Vis590] - 1$. Purdue Univ.

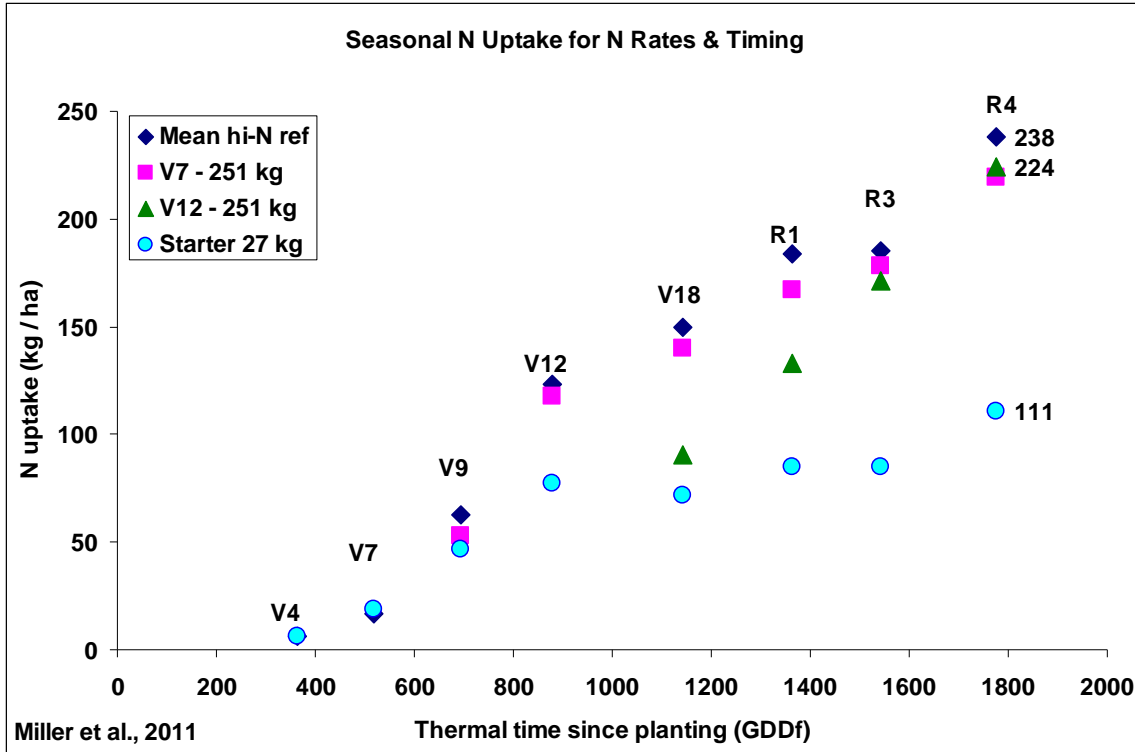


Fig. 4. Seasonal nitrogen uptake by plants (kg/ha) from leaf stage V4 through reproductive stage R4 (dough) as influenced by N fertilizer rate and N application timing. Purdue Univ.

Similarly to VR nitrogen rates, creating **variable rate seeding rate** maps is challenging because there is no single criterion with which to base the “prescription”. There is no single soil factor or other “management zone” that clearly correlates with optimal seeding rates in maize.

Optimal seeding rates for maize are not correlated as strongly with yield potential as one might imagine. In the U.S., it is true that optimal seeding rates are lower for challenging conditions with perennially low maize yields compared to less-challenging conditions with higher maize yields. In all honesty, though, there are probably only two seeding rates necessary for any given field..... a higher rate and a lower rate.

It would appear from previous research that an approximate break point for lower versus higher optimal seeding rates is below or above 8 T/ha. Throughout much of the U.S. Midwest, the lower optimal seeding rate for maize grain yield is about 62,000 seeds per hectare (sph), while the higher optimal seeding rate is no more than about 82,000 sph.

My own field-scale research in Indiana has been conducted primarily on farms with yield levels greater than 8 T/ha, but clearly shows that there is no relationship between [optimal seeding rate] and [yield at optimal seeding rate] for yield levels between about 8 and nearly 14 T/ha (Fig. 5). The range in optimal seeding rates for maize grain yield in 27 field-scale trials in recent years has been primarily between 61,000 to 87,000 sph with an average optimal seeding rate of 74,000 sph.

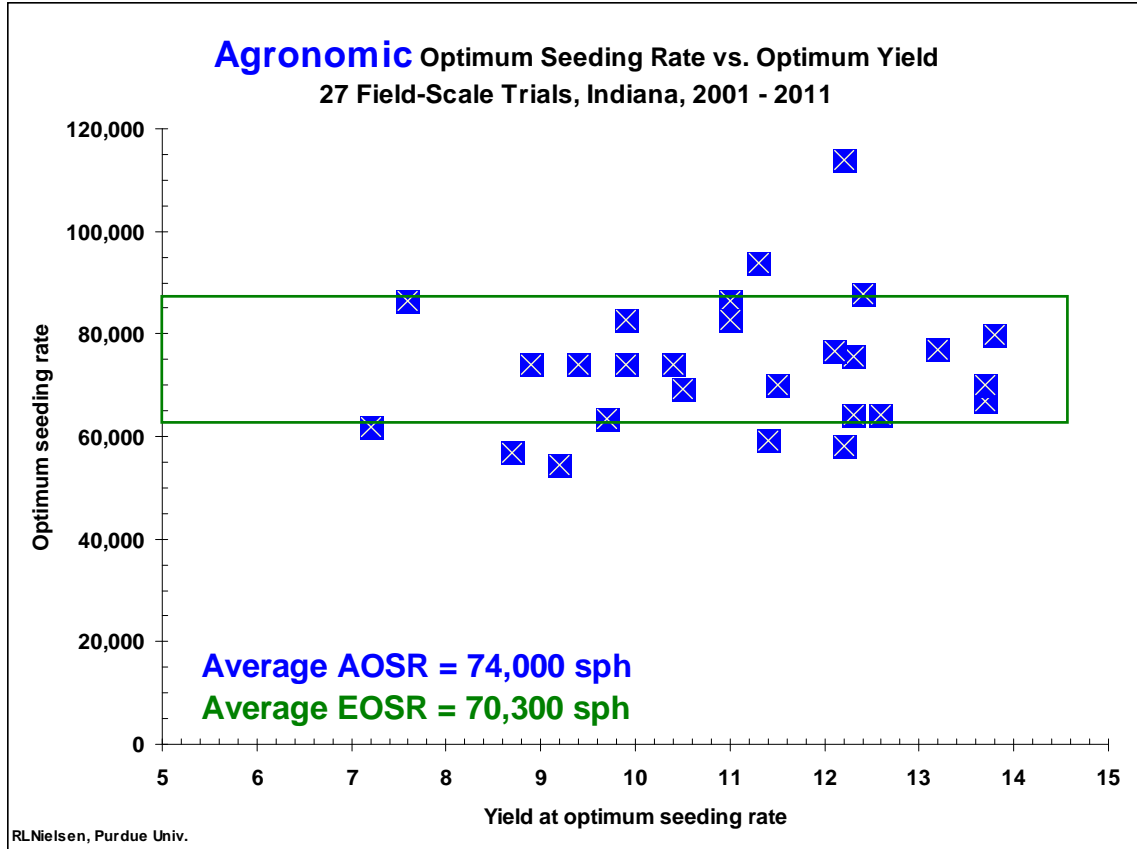


Fig. 5. Optimal maize seeding rate versus yield at optimal seeding rate for 27 individual field-scale trials in Indiana, 2001-2011.

Let me reiterate the challenge of implementing VR strategies for nitrogen fertilizer or seeding rates. There is no single soil factor or other “management zone” that clearly correlates with optimal N fertilizer or seeding rates in maize. Optimal rates for these two crop inputs are related to several or more interrelated factors that often cannot be easily or accurately measured or predicted on a spatial basis.

Data management technologies

True advancements in cab display monitors, controllers, handheld devices, and wireless communication technologies are greatly improving our capabilities to map, monitor, log, and transmit agricultural data from tractor to office to field to other equipment to office to landlord to tenant to contractor to consultant like nothing we have witnessed before. This enhanced ability to manage data electronically and spatially is truly marvelous. Such tools improve our ability to detect spatially consistent areas in fields that deserve our attention and literally allow us to navigate to those areas for diagnosis and corrective measures. Such tools may improve our ability to manage equipment efficiencies and lower our costs of production.

But, honestly, what can we do to improve yields next year?

I will be the first to admit that my curmudgeonly outlook on life colors my opinions about the merits of supposedly miraculous “advancements in farming systems.” Maybe it is history telling me that we have only experienced two major “advancements” in maize

productivity since 1866 (Fig. 1). Maybe it is 30 years of experience as an Extension agronomist and the multitude of supposedly miraculous “advancements in farming systems” that I have seen over the years that have simply not panned out.

The trouble with the way many folks go about the business of improving yields on their farms is that they always look for the “silver bullets” or the “one-size-fits-all” answer to their problems.

They read farm magazine articles that highlight what one guy has done in Timbuktu that supposedly resulted a 1 ton jump in his maize yields and figure that they ought to try the same thing on their farm in the Waikato region of NZ. They listen to the testimonials of someone in the next county over that used Bob’s High Yield Snake Oil & Emolument on his crop and rush over to their local crop input retailer to buy some of the stuff to try on their farm. They take notes on the best management strategies presented at a crops conference by some guy from Purdue University who has never been on their farm and then make plans to adopt those BMPs for next year’s crop.

What I can tell you is that yield improvement in your farming operation in the near future will come about by your investment in hard work and common sense to identify the important yield influencing factors (YIFs) that are specific to your own fields. You need to spend time in your fields throughout the entire growing season; not just at planting and harvest. Once you have successfully identified the YIFs specific to your production fields, then you are better equipped to identify the appropriate agronomic management strategies to alleviate those factors holding back your yield and, perhaps, enhance those factors that promote high yields.

It ain’t rocket science. It is hard work and common sense, coupled with a sound knowledge of agronomic principles.

In addition to agronomic maize resources available to you in New Zealand, recognize that you can easily access maize information from all over the world if you have access to the Internet and the Web. Stay up to date during the growing season by reading Extension newsletters from around the U.S. Midwest. You can find most of them linked at my Chat ‘n Chew Café Web site: <http://www.kingcorn.org/cafe>. Yes, I know this is shameless promotion of my own Web activity, but what can I say?

Spend time perusing two good university Web sites in the U.S. that focus on maize production issues.

Mine at Purdue: <http://www.kingcorn.org/news/archive.html>

Roger Elmore’s at Iowa State Univ: <http://www.agronext.iastate.edu/corn>

So, the secret to improving yields on your farm is simply to sharpen your focus on identifying the yield-influencing factors specific to the fields you farm. Once you have successfully done that, then you are better equipped to identify the appropriate agronomic management strategies to alleviate those factors holding back your yield and, perhaps, enhance those factors that promote high yields.

Pretty simple, eh?

Yield influencing factors (YIFs)

As you pursue the quest of identifying the important yield-limiting factors for your maize operation, remember that you are sifting through a gazillion possible YIFs. The process of identifying the YIFs that are important to your specific fields is not an easy one.

First of all, these YIFs can be either negative or positive in their effects on yield. Pay attention to both.

These YIFs may occur every year in a given field..... or they may not.

These YIFs often interact with other YIFs to influence yield. Think about the compounded effects of heat + drought + soil compaction.

These YIFs often affect different crops differently. For example, most of us do not worry about northern corn leaf blight in alfalfa.

These YIFs often interact with soil type / texture / drainage conditions.

These YIFs almost always interact with weather conditions.

You can focus your search by concentrating on the few components that contribute to grain yield in maize. By and large, these same yield components are primarily responsible for silage yield also.

- Plants per acre (population or “stand”)
- Ears per plant (degree of barrenness)
- Kernels per ear (potential vs. actual)
 - Kernel rows per ear
 - Kernels per row
- Weight per kernel

By focusing on these yield components, it will help you narrow your search to specific periods of the growing season simply because the various yield components are “determined” or “set” at different times of the growing season. The timing of the occurrence of YIFs relative to crop growth stage greatly determines their effect on these yield components because they develop at different times throughout the season (Fig. 6).

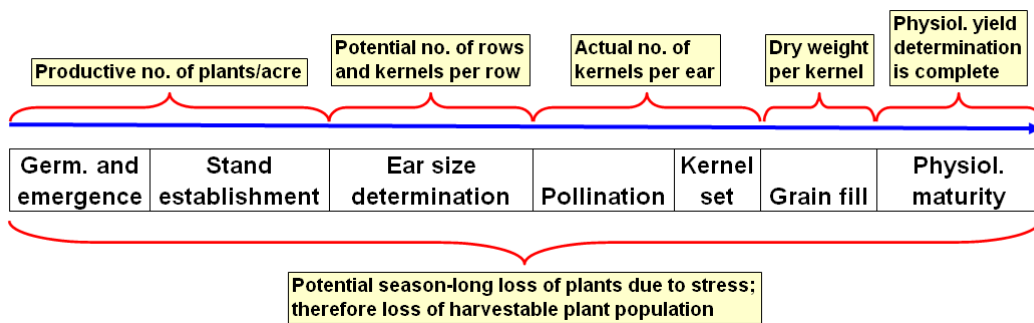


Fig. 6. Timeline of the development of maize yield components.

A few thoughts to get you started...

Even though I hinted earlier in this treatise that you should not blindly believe any “expert” who has never been on your farm, here are a few key factors I can offer for your consideration as you go about the business of identifying the important YIFs for your farm. Because I am “Kiwi-challenged”, these factors will by necessity be influenced by my experiences with growing good corn in Indiana.

The common thread for the first three factors is water management; i.e., striving to avoid periods of excessive or deficit soil moisture levels throughout the growing season. Water management is among THE most prevalent yield influencing factors for maize world wide.

Field drainage

Naturally poorly-drained soils constitute a major perennial challenge to establishing vigorous stands of maize by virtue of their effects on the success and uniformity of rooting and plant development. The adequacy of field drainage (tile or surface) greatly influences whether maize will produce 12 Ton+ yields or nothing (ponded out) or somewhere in between.

By improving tile or surface drainage in a field, you can reduce the risks of ponding or soggy soils, loss of soil nitrate by denitrification, and soil compaction by tillage and other field equipment. Reducing these risks enables more successful root development and stand establishment of the maize crop, which in turn will enable the crop to better tolerate stresses later in the growing season.

Conserve soil moisture & minimize soil erosion

In contrast to flat, poorly drained fields where excess soil moisture throughout the season is a serious limiting factor, water management in maize fields with rolling topography generally consists of strategies to conserve soil moisture and minimize soil erosion. One of the most viable yield improvement strategies for sloped fields is probably no-till or some version of reduced tillage practice (aka non-inversion agronomy). Other strategies include contour farming, alternating crop strips (e.g., strips of maize and alfalfa), construction of terraces or other water control structures, and the planting of fall or winter cover crops.

Supplemental water

Other soils simply require supplemental water (irrigation) when rainfall is inadequate. Obviously, fields with those soils will usually respond to supplemental water provided by above-ground irrigation (center pivots, shotguns, rows) or below-ground supplementation by virtue of pumping water back into tile drains or drainage ditches. Either choice requires informed decision-making relative to irrigation scheduling based on crop demand and soil water availability (Joern & Hess, 2010). Maintenance and proper operation of center pivot irrigation systems is crucial to optimize efficiency in terms of irrigation costs and crop benefit.

Hybrid selection

Most of us spend too little time evaluating the documented performance of potential hybrids for use in our operations. Look at any university hybrid trial that includes “good”

hybrids entered from a range of seed companies and you will easily see a 3 to 6 Ton/ha range in yield between the top and bottom of the trial. Mind you, this spread from high to low occurs in variety trials where supposedly every hybrid entered into the trial is a “good” hybrid. I doubt that seed companies enter “bad” hybrids on purpose.

The key challenge is to identify hybrids that not only have good yield potential, but that also tolerate a wide range of growing conditions (Nielsen, 2010). The best way to accomplish this is to evaluate hybrid performance across a lot of locations. In the U.S., most agricultural universities in the Midwest conduct variety trials at multiple locations around their respective states (e.g., Iowa State Univ, 2011; Devillez, 2011). Availability of public sector hybrid performance trials is limited in New Zealand. If you use seed company trials, be aware that often there are few competitor hybrids included in variety trial results.

Recognize that no hybrid wins every trial in which it is entered. Look for hybrids that consistently yield no less than about 90% of the highest yield in the trial no matter where they are grown. For example, if the top hybrid in a particular trial yielded 14 T/ha, then look for hybrids in the same trial that yield at least 12.6 T/ha (14 x 0.90). That may not sound like much of a challenge, but you will be surprised how few hybrids will meet that goal when evaluated over a lot of locations. Recognize, though, that this strategy works best for variety trials that include 20 or more hybrids.

My opinion for what it is worth: I think New Zealand maize growers would be well-served by the adoption of a uniform set of hybrid trials wherein variety trials within one or more regions of the country would include a common set of commercially available hybrids. Such a uniform hybrid trial system would help growers better identify those hybrids that have superior adaptation to a wide range of growing conditions.

Manage trash in no-till

If you no-till maize on soils that are poorly drained, then you simply must strive to manage surface “trash” to enable drying / warming of surface soils, facilitate effective planter operation, and improve crop emergence / stand establishment. Aim to burn-down (herbicide) winter annual weeds or cover crops before their growth becomes unmanageable. Use row-cleaners on the planter units to remove a narrow band of “trash” from the seed furrow area. Avoid planting “on the wet side” in order to minimize the risk of furrow sidewall compaction or topside compaction.

Avoid soil compaction

If you improve soil drainage, you will also minimize the risk of working or planting fields “on the wet side” and, therefore, the risk of creating soil compaction with tillage or other field operations that can limit root development. Minimize the number of tillage trips, consider strip-till or no-till systems. Remember, though, that no-till or strip-till is not immune to the risk of soil compaction.

Continuous maize or not?

Frankly, continuous maize simply does not yield as well as rotation maize. Numerous long-term rotation trials have documented this across a number of states in the U.S. Midwest. The yield drag is especially likely for no-till maize after maize. Folks who

claim to do well with continuous maize are often fairly aggressive with their management of the stover from the previous crop.

Maize stover delays the drying / warming of the soil and thus delays crop emergence and development. Maize stover (including old root balls) often interferes with planter operation, causing poor / uneven seed depth or seed-2-soil contact and thus causes delayed or uneven crop emergence. Decomposing maize stover immobilizes soil nitrogen early in the season and can retard maize growth and development early in the season until root development reaches a critical mass. Maize stover can intercept soil-applied herbicide and reduce the effectiveness of weed control. Finally, maize stover harbors inoculum of important diseases like northern corn leaf blight.

Any way you look at it, a continuous maize cropping system is fraught with challenges. If you cannot successfully manage these challenges, your yields will suffer.

Starter fertilizer or not?

Starter fertilizer, especially nitrogen, is important for maximizing maize yields in the eastern U.S. Corn Belt. I offer the following explanation and leave it to you to decide whether your situation is similar.

A little background: Young maize plants depend heavily on stored kernel reserves until roughly the V3 stage of development (three leaves with visible leaf collars). At that point, the plants begin to “wean” themselves from dependence on the stored kernel reserves (which are playing out) to dependence on the developing nodal root system. If life up to that point has been hunky-dory (aka favorable), the transition to dependence on the nodal roots will go smoothly and the crop will continue to develop into a vigorous and uniform stand that will tolerate future stresses nicely.

However, if conditions have been challenging during emergence and early stand establishment, then nodal root development has probably been stunted and the young plants will struggle to “wean” themselves from the kernel reserves. Consequently, the plants will appear to “stall out”, their development will become uneven, they will turn light green to yellow, and the resulting stand will not be as vigorous and uniform as you want. Such a stand of maize will likely continue to struggle the remainder of the season.

It is the latter situation wherein a robust 2x2 starter fertilizer program will aid the young plants as they struggle in the transition to dependence on nodal roots. Our experience in the eastern Corn Belt suggests that starter nitrogen is the primary important nutrient and starter N rates should be no less than 20 to 30 lbs actual N per acre (22 to 33 kg N per hectare); perhaps higher than that for no-till continuous maize.

The term “2x2” refers to the placement of a starter fertilizer band 2 inches (5cm) horizontally from the seed furrow and 2 inches (5 cm) below the seed depth. Common sources of 2x2 starter N in the U.S. include liquid 10-34-0, liquid 28-0-0, solid 11-52-0 (MAP), solid 21-0-0-25S (ammonium sulfate), and solid 34-0-0 (ammonium nitrate). Urea (46-0-0) and diammonium phosphate (18-46-0) should be avoided because of risk of free ammonia damage to seed or seedling.

Nitrogen management

Nitrogen management in the eastern U.S. Corn Belt is challenging because of our poorly drained soils, ample and frequent rainfall, and the risk of N loss by either denitrification

or leaching. Consequently, yields are often lower than desired because of inadequate levels of soil N during the growing season, resulting in lower grain income for the grower. Alternatively, growers sometimes apply more N than the crop requires in an effort to mitigate the consequences of excessive N loss on the crop and, thus, incur higher crop production expenses.

Best management practices that target the efficient use of nitrogen fertilizers in maize are well documented (Camberato et al., 2011; Sawyer, 2011) and include avoiding fall N applications, avoiding surface application of urea-based fertilizers without incorporation, and adopting sidedress N application programs where practical. These practices, plus the implementation of a robust starter fertilizer program, will help reduce the loss of soil N and maximize the yield produced per kilogram of N fertilizer applied.

Disease management

Warm, humid conditions during the summer months are conducive for the development of several important foliar fungal maize diseases in New Zealand, including northern corn leaf blight (NCLB) and common rust. Yield losses from these foliar maize diseases can easily decrease maize grain yields by 20% or more.

Best management practices that target efficient management of these important maize diseases are well documented (Anonymous, 2009; Wise; 2010, 2011) and include:

- Hybrid selection for good disease resistance characteristics.
- Avoiding continuous maize cropping systems (NCLB).
- Avoiding no-till cropping systems (NCLB).
- Control of *Oxalis* weed species (alternate host for common rust)
- Responsible use of foliar fungicides

Remember, it ain't rocket science!

It should be obvious at this point that achieving higher, more consistent yields does not require "rocket science". Rather, we're talking about a lot of common sense agronomic principles that work together to minimize the usual crop stresses that occur every year and allow the crop to better tolerate uncontrollable weather stresses. Other agronomic practices not discussed in this presentation include a sound weed control program that focuses on the use of residual herbicides and an attitude that you will aim to kill weeds when they are small.

Make the effort to identify those yield limiting factors that are most important for your specific farming operation. This requires good crop detective skills and a sound understanding of agronomic principles. Together with your crop advisor(s), work toward identifying and implementing good agronomic management practices that target those yield limiting factors.

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