

**Reaching the 300 bu/A Corn Yield Threshold
What Have We Done and What Do We Need To Do?
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Agriculture is faced with the challenge of doubling global food crop production between 2007 and 2050---if not sooner---as growing world population, improving global economies, and new uses for traditional food crops combine to add pressure to current food supplies. While this challenge may seem impossible, history tells us we have done it before. But success in achieving production increases of that magnitude will require a multidisciplinary coordinated program. It will mean concerted efforts to improve resource efficiency and to fine-tune management systems to reduce or eliminate yield-limiting factors, and develop site-specific management systems designed for the soil-climate resources of a given field.

As we look forward, the challenge facing agriculture appears great indeed. The Millennium Project report states that the world will need twice as much food within 30 years. The World Bank predicts a need for 50% more food by 2030. This graph contrasts those rates of yield increase with the historical trend line for maize. It also includes a curve representing continuation of the proportional rate of increase of 1.3% that was experienced in 2007.

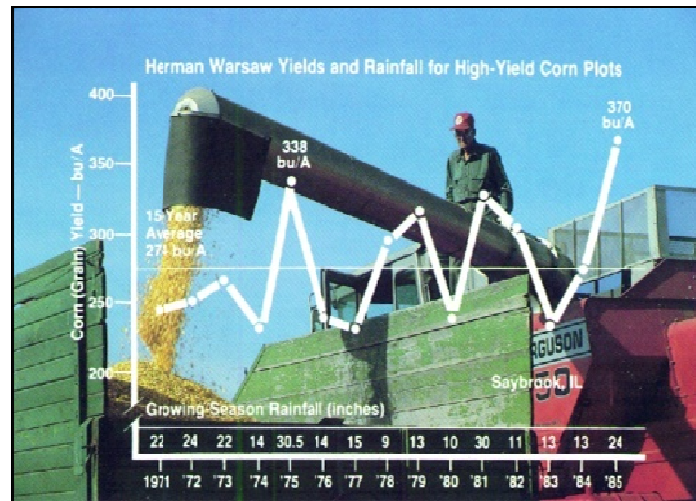
---Dr. Paul Fixen, IPNI. 2010

Dr. Werner Nelson, Potash & Phosphate Institute, was a leading advocate of high-yield management systems. Going to the field with Werner would often mean going to the best corn field and asking the question, *"What's the limiting factor here?"*. His legacy is the countless researchers and field agronomists who were influenced by this approach to improving yields, and who continue to carry Werner's passion for improving yields.



New genetics, from biotechnology and traditional plant breeding, have developed a potential for substantially higher yields. This has been demonstrated in recent years as yields have increased, even under stress situations. Genetics expands the potential yield, but is only part of the story. Concurrent changes in agronomic practices are needed to fully realize that potential. Improved nutrient use efficiency through implementation of best nutrient management practices is also important. Traditional facts and principles of production need to be reviewed and revised under these new hybrids and varieties. Old thresholds for pest management may also come into question under the new genetics. Improved pest management helps to protect the potential yield of the system.

The challenge to increase corn yields was stimulated in 1975 when Herman Warsaw of Saybrook, Illinois, produced a corn yield of 348 bu/A, setting a new world record, which he held until 1985 when he produced 370 bu/A, and new record that was not broken until 1999.



Part of Warsaw's success was from his efforts to build the productive potential of his soil, through increased nutrients in the profile with an aggressive fertilizer application program and improved tilth through careful management of tillage, crop residues, and livestock manure. His soil had a spongy feel under foot. Soil test nutrient profiles from a 1978 sampling are shown in Table 1.

		Sample depth, inches					
		0-3"	3-6"	6-9"	9-12"	12-18"	18-24"
P-1, lb/A	Normal production area	202	134	76	38	28	20
	High yield-lighter subsoil	234	192	58	20	12	8
	High yield-darker subsoil	252	204	108	42	44	36
	Fence row sample	44	26	8	6	6	4
K, lb/A	Normal production area	914	470	346	348	366	400
	High yield-lighter subsoil	740	404	270	232	300	382
	High yield-darker subsoil	1,400	556	412	332	328	320
	Fence row sample	652	452	320	338	284	262
O.M., %	Normal production area	6.6	5.4	5.5	5.4	4.1	3.6
	High yield-lighter subsoil	5.9	5.7	4.9	4.9	3.2	1.4
	High yield-darker subsoil	4.7	4.3	4.0	3.7	4.3	4.3
	Fence row sample	5.8	4.5	4.0	3.3	2.7	2.3
pH	Normal production area	5.5	5.7	5.7	5.6	5.8	5.9
	High yield-lighter subsoil	5.0	5.5	5.8	6.1	6.1	6.6
	High yield-darker subsoil	5.2	5.7	5.6	5.5	5.3	5.4
	Fence row sample	6.0	5.9	6.0	5.8	6.0	6.7

Table 2 shows the soil test results from samples collected in 1985, the year Warsaw produced the 370 bu/A yield. P and K tests are well-above University of Illinois recommendations. Nitrogen applied that year was approximately 485 lb/A, compared to the recommended level of 444 lb/A (based on 1.2 lb N per bushel of expected yield).

TABLE 2. Soil test levels from a field that produced 370 bu/A corn in 1985.

Phosphorus P-1	161 lb/A
Potassium	800 lb/A
Magnesium	871 lb/A
Calcium	4,850 lb/A
Cation exchange capacity	23 meq/100g
Sulfate-S	35 ppm
pH	6.0
Organic matter	5.3%
Zinc (Zn)	Good
Iron (Fe)	Good
Boron (B)	Good
Copper (Cu)	Good

Was his 370 bu/A system profitable? Table 3 shows a partial budget for the production costs on the record-breaking field. The 370 bu/A yield would be \$925 at \$2.50/A; \$1125 at \$3.00/bu. In fact, breakeven price for out-of-pocket costs was \$1.25/bu; \$1.60/bu if land charge is included. Yes, it was a very profitable system.

TABLE 3. Production costs, \$/A, that produced 370 bu/A corn in 1985.

Input category	Cost per acre
Fertilizer	\$201.05
Lime	\$10.42
Herbicide/insecticide	\$39.10
Seed	\$26.72
Field operations, harvesting, and drying	\$186.50
Total out-of-pocket costs	\$463.79
Estimated land cost	\$130.00
Total production costs	\$593.79

The Potash & Phosphate Institute (PPI) organized a series of meetings at the Warsaw farm, bringing together leading researchers from across the country, and later sponsored a series of high yield projects through the newly-formed Foundation for Agronomic Research (FAR). PPI/FAR staff met annually with the researchers to visit one of the sites and share experiences and results. This series helped guide numerous researchers, younger and older, to shift their thinking and their research programs toward defining high-yield management systems. Several of the researchers eventually achieved over 300 bu/A yields on their high-yield plots.

One of those projects, initiated at Purdue University in 1978, was an attempt to duplicate the high-yield management approach used by leading farmers, like Herman Warsaw. Drs. Harold Reetz, Kim Pollizotto, and Dave Mengel, designed a series of comparisons on a 20 acre site at the Purdue Agronomy Farm. By 1981, the third year of the study, corn yields

had increased from 155 bu/A to 185 bu/A, and soybean yields had increased from 55 bu/A to 85 bu/A. High fertility, deep chisel plowing, high population, and genetic selections for high yields were the main factors in increasing the yields.



Drs. Kim Polizotto, Dave Mengel, and Harold Reetz evaluate corn plants from the Purdue site for their PPI/FAR-funded High Yield Production System project.

During the 1980s, interest in high-yield research declined, and the leaders of these projects moved on to different research agendas or different jobs, or retired, and the PPI/FAR high-yield production studies were terminated. 30 years later, we are finding interest in high-yield management systems is growing once again, and a new group of researchers is beginning to reinstate such studies.

High-yield systems for the next decade must be finely-tuned management systems. As yields increase, the need to measure and manage for the variability in the crop field also increases. More components of the system must be adapted to the specific variability of the field. Site-specific management becomes more essential. This was the basis for the development of IPNI's InfoAg Conference series. New technologies and new management tools make it possible to respond to the within-field variability more directly than ever before. Finely-tuned systems take advantage of all the resources available.

What is the maximum potential yield for corn? Based on the physiology of the corn crop, some researchers have estimated that the maximum potential, given perfect weather for the entire growing season, is just over 600 bu/A. Dr. Richard Johnson, former agronomist

for John Deere & Company, estimated the theoretical maximum yield for Midwest corn to be about 490 bu/A.¹ The following assumptions were used in that estimate:

- 120- to 130-day growing season; 90 days of full canopy cover.
- Daily solar energy input of 20 billion calories per acre.
- This leads to 625 lb/A of dry matter produced per day (allowing for 1/3 of carbon dioxide to be re-released in respiration).
- 25% of dry matter used in root production; 55% of remaining above-ground dry matter goes to produce grain.
- A corn crop producing 625 lb/A/day of dry matter would yield 490 bu/A of #2 corn.
- Areas with higher solar radiation would have increased yield potential.

Obviously these are crude estimates, but they illustrate that potential yield is considerably above current levels of 150-160 bu/A national average.

Further elaboration on the physiological aspects of high corn yields was provided by Dr. Richard Hageman, University of Illinois plant nutrition specialist. After studying the mineral nutrition characteristics of the corn hybrid (FS 854) used by Herman Warsaw, he concluded:

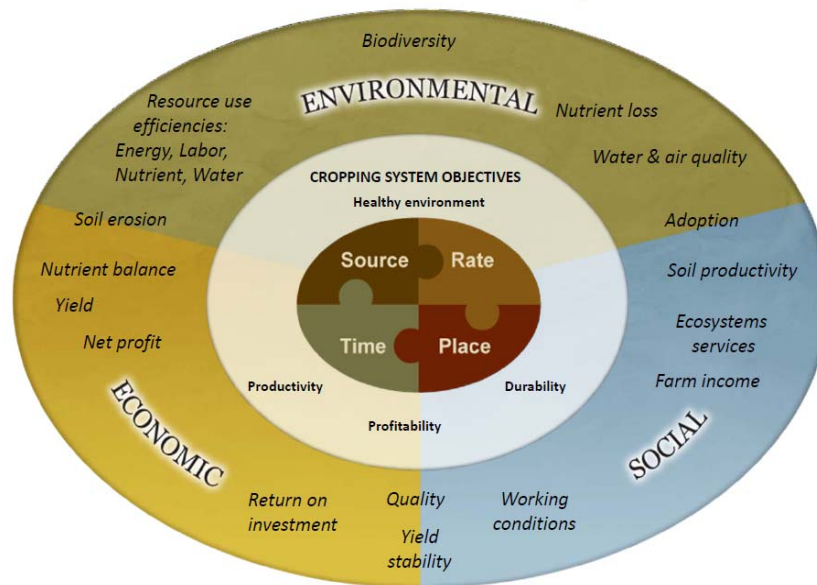
- The high soil test K level in Warsaw's field helped maintain the plant growth regulator activity that keeps N uptake and utilization functioning at full capacity two weeks longer at the end of the growing season.
- With lower K levels, the N uptake system begins to decline, and the photosynthetic enzyme, RuPD carboxylase (the primary N storage compound in corn leaves), begins to be broken down to supply the N needs of the developing grain.
- This deterioration of the photosynthetic mechanism of lower leaves leads to less sugar supply to the roots, further decreasing the ability to absorb water and nutrients.
- Warsaw's high soil K levels kept lower leaves healthy about 2 weeks longer, leading to increased yield potential.

Successfully increasing corn yields for any given site depends upon identifying yield-limiting factors and then systematically eliminating them one-at-a-time through implementation of better management practices.

Nutrient management is obviously a major part of a crop management system. The fertilizer industry has adopted a global framework of nutrient best management practices. The framework is called the "**4 Rs**" of nutrient management: ***Right Source; Right Rate; Right Place; Right Time***. The puzzle pieces in the center of the diagram illustrate the interlocking relationship among the practices, and the items listed around the diagram are

¹ ***Better Crops with Plant Food***, Winter 1981-82, p. 3-7.

some of the key performance indicators to be measured and monitored to ensure the management system meets the environmental, economic, and social goals of the farmer and society.



The Global Framework for nutrient best management practices adopted world-wide by the fertilizer industry to help explain the relationships among cropping systems objectives and the various performance indicators of improved nutrient management.

It was 14 years before Herman Warsaw's yield was eclipsed. Iowa farmer, Francis Childs, was the official winner of the 1999 National Corn Growers Association Non-Irrigated Corn Yield Contest with a yield of 393.7 bu/A.



A few things stand out about Francis Child's corn production system:

- **His final plant stand was 44,000 plants per acre.** One of the most important things you can do is insure uniform seed placement, depth and good seed-to-soil contact, to obtain a uniform seedling emergence. Non-uniform plants will do nothing but compete against one another all season long.
- **He planted his test area at 2 mph.** The rest of his farm was at 4 mph. Even though we have improved planters today, we still should not plant faster than 5 miles per hour.
- **He used a modified “mini-moldboard” plow** that plows 13-14 inches deep and leaves at least 30 percent residue on top. A healthy, high organic matter soil will maintain it’s structure longer following sub-soiling and will improve nutrient availability, drainage during wet times and moisture retention during dry times. It is important to realize that increasing organic matter in our soils goes hand-in-hand with profitable farming. It takes time to build it but it can be done with good manure management, crop residue management and high fertility.
- **Fertility is an area that must not be compromised.** Childs, like Warsaw, had high soil test levels, and increased soil tilth from his tillage and residue management systems.

While the Childs actual yield has become a controversial point, those who visited the field saw a well-managed, high-yield crop, providing further insight into the process of eliminating the barriers to high yields.

Numerous other farmers have now topped the 300bu/A mark. Many consistently produce 200 bu/A farm averages. Scientists and crop advisers need to set their sites higher and work to achieve even higher yields. If the predictions of 300 bu/A U.S. average corn yields are to be accomplished, some of the top producers must reach yield levels above 400 bu/A. It is a formidable challenge. It will require a collaborative, multi-disciplinary approach. What do we need to do in the future to continue on the quest for maximum corn yields? The secret is in paying attention to details, working to identify limiting factors, and using site-specific management improvements to systematically eliminate the barriers to increasing yield. The pressures to grow more corn will continue, as will the economic pressures to improve efficiency, and environmental pressures to do all of this with less impact on our natural resources. We need to expand production system research to learn how to combine the new genetics, new management practices, and new technology tools to build the best site-specific management systems for each corn field. We need to take advantage of the tools available that can easily help turn each field into a research site by collecting and analyzing data from farmers’ fields. We need to rebuild the passion for increasing yields among farmers and their advisers...to challenge them to set higher goals for yield, efficiency, environment, and sustainability.