Low Tech Efficiency Improvements

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'Getting the most for the least' is a mantra that could apply to many things: buying a car, selling stocks, choosing a spouse, practically everything. Crop production is no exception. Whether you have a lot of money to spend, or a little, you want to get the best return for your money spent on production. Optimizing the balance of expenditures in years with low cash flow often requires looking at low cost tools.

Despite the sophisticated nature of the industry, low tech efficiency improvements can be a part of any size of operation. Agriculture is a science that still involves a lot of predictions, therefore low-cost options to assist making these predictions are often the best option.

Predicting input requirements is a big challenge. Even with the best information, many factors aren't controllable. Climate—the biggest factor affecting crop production—isn't controllable. However, farmers are seasoned guessers and have many tools available to make the most use of the information that is available. Returns are maximized when these predictions closely match the requirements. Tools can be utilized to assist with these predictions. Opportunities to maximize returns also exist from greater utilization of the inputs and lowering the cost of the inputs required.

Inputs can be lumped into two categories: those that establish yield potential—crop factors, soil factors, climate factors; and those that maintain yield potential—weed, insect, and disease control. All variables must work together or yield will be limited. Most inputs are managed very efficiently. However, opportunities are still present for increasing efficiency in soil and nutrient management. Nutrient management is one of the most costly parts of crop production and—next to climate—has the greatest impact on crop production.

1. Soil Test

A basic message, but one worth repeating. A soil test is the single best method to prevent under or over-expenditure on fertilizer. Compared to fertilizer, soil testing is very cheap. For about $0.20 to $2.00 an acre a soil test will indicate which nutrients should be applied and how much of them should be applied. The soil solution is constantly cycling nutrients. Utilizing the available nutrients will decrease the fertilizer requirements. Nutrients in the soil are nutrients that don't have to be applied as fertilizer.

All local soil testing facilities provide excellent testing techniques and provide recommendations based on local growing conditions. Personal preference will determine what testing procedure, recommendation philosophy and level of service is best for your operation.

2. Measure stored soil moisture

Available moisture—unlike fertilizer—cannot be controlled; however, it can be managed. Stored soil moisture will affect yield targets and therefore nutrient requirements. Stored spring soil moisture is something like fuel in the tank. It won't be enough to get you to the end of the season, but if you know how much you have you'll have an idea as to how far you can go. If you start out with a full tank, chances of meeting your yield target are greater. Stored soil moisture plus expected in-season precipitation can be use to create yield targets and determine nutrient requirements. Knowing your spring soil moisture will increase the accuracy of soil test labs nutrient recommendations.

A soil moisture probe will quickly and easily estimate stored soil moisture. A soil moisture probe can be made by welding a 1.9 cm (¾ in.) steel ball on one end of a 1.1 metre (3.5 ft.) long 1.27 cm (½ in.) rod and welding a handle on the other end.

Select a representative area of the field. Avoid saline areas, potholes, and other problem areas. Depression areas, slopes, and knolls can be measured separately for site specific crop planning.

Push the probe into the ground in a single motion. It will stop penetrating when it hits dry soil. A rock or frozen ground (in the spring) will also stop the probe. Always push and pull the probe using your knees while keeping your back straight.

Each field should be sampled separately, because rainfall amounts can vary over short distances, crops and varieties differ in water use, crops mature at different times because of seeding date and differing days to maturity, etc.

Sample a minimum of 15 to 20 sites per field and record the average depth of moist soil. More sampling will be required for site specific management. Spring sampling may require more sites within a field because of increased variability caused by snow trapping, snow drifting, water runoff, moisture migration within the soil and variations in ground frost, etc.

Soil texture and average depth of moist soil are used to calculate the plant available water, see Table 1.

Table 1. Plant available water stored per foot (305 mm) of moist soil for various soil textures

Soil Texture	Inches of soil water per foot (305 mm) of moist soil
Sand	0.75 in. (19 mm)
Loamy sand	1.00 in. (25 mm)
Sandy loam	1.25 in. (32 mm)
Loam	1.50 in. (38 mm)
Clay loam	1.75 in. (44 mm)
Clay	2.00 in. (51 mm)

Table 2. Yield equations for wheat, barley and canola by soil zone.

Soil zone	Wheat (CWRS)	Barley	Canola
Dry Brown	Y=(WU - 2.5) x 3.5	Y=(WU - 2.5) x 5.3	Y=(WU - 2.5) x 2.0
Brown	Y=(WU - 2.25) x 3.75	Y=(WU - 2.25) x 5.7	Y=(WU - 2.25) x 2.5
Dark Brown	Y=(WU - 2.0) x 4.0	Y=(WU - 2.0) x 6.0	Y=(WU - 2.0) x 3.0
Thin Black	Y=(WU - 1.75) x 4.25	Y=(WU - 1.75) x 6.4	Y=(WU - 1.75) x 3.3
Thick/Gray Black	Y=(WU - 1.5) x 4.5	Y=(WU - 1.5) x 6.7	Y=(WU - 1.5) x 3.6
Gray	Y=(WU - 1.25) x 4.75	Y=(WU - 1.25) x 7.2	Y=(WU - 1.25) x 4.0

Y = yield in bushels per acre. (The equations in this table are based on pre-1990 varieties)
WU = water use; inches of plant available stored soil water plus inches of growing season precipitation.

-Table 2 is adapted from "Criteria for Targeting Yields in Saskatchewan" Soils and Crops Workshop, 1991. R.E. Karamanos and J.L.Henry, Department of Soil Science,University of Saskatchewan.

Table 3. Estimated yield calculation

Example (wheat in the dark brown soil zone)			My field
Depth of spring soil moisture	A	3 ft.	
Soil texture		Loam	
Plant available water stored /foot (Table 1)	B	1.5"	
Inches of stored water	A x B = C	4.5"	
Expected growing season rain	D	7"	
Water Use	WU = C+D	11.5"	
Yield equation for wheat in the Dark Brown Soil zone (Table 2)		(WU - 2) x 4	
Estimated yield calculation bushels/acre (11.5 - 2) x 4 =		38	

3. Reduce Reliance on Fossil Fuels
Farm land is a huge solar energy collector. Crops collect solar energy and make the energy available for further utilization as food, feed or fuel. Despite capturing huge amounts of energy, agricultural products aren't tied to the price of oil. Until alternative energy sources such as biodiesel and ethanol production develop, agricultural producers are still heavily reliant on fossil fuels for fuel, fertilizer, chemicals and transportation amongst many others. Reducing your fossil fuel requirements is an effective way of controlling costs.

a. Fuel

Fuel and time savings are one of the major contributing factors for the adoption of direct seeding. Fuel and labour costs are dramatically cut by reducing the number of operations required for seed establishment. With good residue management and seed establishment, one low-disturbance pass can produce similar or better yields than multiple passes with higher disturbance seeding systems.

Equipment required for low disturbance one-pass seeding equipment is abundant and used equipment can be relatively inexpensive. When it isn't economical to purchase a good one-pass low disturbance seeding systems, retrofitting existing seeding equipment can be a cost-effective alternative. Many aftermarket retrofitting options are available.

One-pass seeding requires good seed placement without sacrificing seed-bed quality through fertilizer application. Good seed establishment is always the number one priority. A separate fertilizer application is preferable to poor seed placement or exceeding the safe amount of fertilizer that can be applied with the seed.

Heavy harrowing is a straw management tool that has limited benefit. Heavy harrows are effective at distributing straw, not chaff. Evaluate the benefits of upgrading your straw chopper as a straw dispersal alternative. Flax straw is always difficult to manage. Heavy crop residue can be managed with a good straw chopper and keeping the stubble height as tall as possible.

b. Fertilizer

Natural gas is the major component of commercial nitrogen (N) fertilizer. Natural gas is converted to ammonia and ammonia is further processed into urea. Maintaining crop yield and quality requires proper plant nutrition. Crops require nutrients, but source of the nutrients doesn't have to come from commercial fertilizer. Decreasing your reliance on commercial fertilizer requires increasing fertilizer use efficiency and providing alternative sources of nitrogen.

1. Fertilizer Use Efficiency

Fertilizer placement and the time of application are the main mechanisms of increasing fertilizer use efficiency. Banding fertilizer at the time of seeding provides the highest fertilizer use efficiency. Nutrient uptake is increased and losses are minimized with banding.

Placement

Phosphorus (P) and potassium (K) are less mobile in the soil solution than N. Therefore, uptake of these nutrients is mostly dependent on root interception. Broadcasting P and K or banding away from the seed will delay root interception and limit uptake in the year of application. Banding close to the seed row increases early season access to the nutrients and increases uptake of the applied fertilizer.

Nitrogen should always be banded, preferably soil banded. Nitrogen is mobile in the soil solution. It moves with moisture, and will access the roots through capillary action even when banded away from the seed.

Broadcasting nitrogen is not a good idea. If adequate rainfall occurs after application, surface broadcasted nitrogen can work. However, this is a very risky procedure and can result in very low utilization of the applied nitrogen. Nitrogen is susceptible to gaseous losses when exposed to the air. Broadcasted N is very susceptible to volatilization (gaseous loss) when soils are warm, moist and there is a wind at the soil surface. If broadcasting N is the only option, i.e. - winter wheat, nitrification inhibitors will increase the critical period required for rainfall, however, a significant rain is still required to leach the nitrogen into the soil solution.

Liquid dribble banding is a fast and effective method of meeting N requirements. Dribble banding concentrates the nitrogen on the soil surface and decreases the susceptibility of volatilization losses. However, it still requires moisture to enter the soil solution. Without moisture, the N can be stranded at the surface.

Time of Nitrogen Application

When logistics and management considerations don't favour spring application of nitrogen, fall or post-emergent application of N can still be effective placement options. Losses of N are minimized when fall application occurs after soil temperature drops below 10 degrees C (50 F). Nitrification inhibitors can reduce or eliminate N losses from fall to spring. Fall applied N is as effective as spring applied N in areas where soils are not susceptible to becoming saturated.

2. Alternative nutrient sources

Nutrients required for crop production must be either present in the soil or supplemented in a plant available form prior to crop production. Commercial fertilizer is one source for plant available nutrients. However, the cost of commercial fertilizer is closely related to fossil fuels. Commercial nitrogen is processed from natural gas. Natural gas is the largest component of all nitrogen fertilizers. Phosphorus and Potassium are mined nutrients, but require fossil fuels for extraction, processing and transportation. Utilizing other sources of nutrients such as manure or biological organisms to 'fix' nitrogen will offset the costs associated with applying commercial fertilizer.

Nutrients used in crop production are retained in the plant biomass. The nutrients in the crop biomass are either returned to the field or exported in the grain and straw removed. Grain production creates a net removal of nutrients. Manure addition can offset the net removal of nutrients. Manure and bedding used in livestock production is a significant source of nutrients. If livestock manure is available, it is an excellent source of nutrients for crop production.

Table 4. Average nutrient analysis of manures

Type of manure	Number of samples	Total N	Phosphate P_2O_5	Potassium K_2O	Sulphur S
LIQUID		Lb./1000 gallons			
Hog	76	30	9	10	4
Dairy	18	23	6	20	4
SOLID		Lb./ton			
Hog	3	18	9	22	6
Poultry	2	18	26	16	6
Beef	33	13	4	12	3
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There is a considerable range in the amount of nutrients found in manure. Manure analysis is the only reliable method of determining how much nutrients are available for utilization. Of the nutrients present in manure, only a portion is available for immediate uptake. Nutrients in liquid manure have a higher percent available in plant available form. Solid manure requires additional time to breakdown into a plant available form, but application will increase overall soil fertility levels over time.
Nitrogen is a plentiful nutrient. The air we breathe is 78% N gas. Plants cannot utilize the N in this gaseous form unless they have a symbiotic relationship with a bacteria called rhizobia. When the rhizobia is present in the soil, soon after legume seeds germinate, rhizobia enter the root through root hairs and multiply rapidly causing the root cells to swell creating root nodules.

All leguminous crops have this association. Utilizing these crops—either in the form of annual pulse crops or perennial forage crops—will add N to the soil and decrease N requirements for subsequent crops. Legumes vary in their ability to fix N. (Table 5) Benefits of legume crops go beyond N. Non-nitrogen benefits include increasing soil organic matter and physical structure, and stimulating biological activity. Non-N benefits can exceed the N benefits.

Table 5. Nitrogen Fixation in Inoculated Legumes Grown Under Irrigation in Southern Alberta

Legume	Plant-N Derived from Atmosphere* (%)	N Fixed Symbiotically (lb/A)
Alfalfa	80	267
Sweetclover	90	223
Fababean	90	267
Field pea	80	178
Lentil	80	134
Soybean	50	134
Chickpea	70	108
Dry bean	50	62

**Determined by 15N isotope techniques.*
Source: adapted from R.J. Rennie, formerly at Agriculture Canada Research Station, Lethbridge, Alberta

In addition to type of legume grown, the amount of N retained for subsequent crop use will vary based on quantity of plant material returned to the soil, and soil and climatic conditions. The underlying message is constant; a legume crop grown in rotation will generate a N credit. Nitrogen may not be available the first year after production, but it will become available over time.

Annual grain legumes (pulse crops) generally have smaller and shorter-lived effects on soil quality than perennial forage legumes. As the major portion of plant nitrogen accumulates in the seed at maturity, most of the fixed nitrogen is removed from the soil with the harvest of the grain of the pulse crop. However, during the growth of grain legumes, considerable amounts of nitrogen are leaked from roots into the soil. Also, the residues from these crops have a higher nitrogen content than cereal straw and they break down more readily, releasing nitrogen into the soil.

Forage legumes are much more effective in improving soil quality because of their large and deep root system, longer growth period and greater capacity for nitrogen fixation. In the wetter areas of the province, biennial and perennial forage legumes can produce large quantities of organic matter and nitrogen in the second year after underseeding in cereals (Table 6). For maximum soils improvement, forage legumes should be managed as green manure with the entire growth being turned under prior to full bloom.

Table 6. Yield of Dry Matter and Nitrogen from Tops and Roots of Sweetclover, Alfalfa and Red Clover in the Second Year on a Degraded Black Loam at White Fox, Saskatchewan

Growth Stage and Date of Sampling	Legume	Dry Matter (lb/A)			Nitrogen in Plant (lb/A)		
		Tops	Roots	Total	Tops	Roots	Total
Early Bud (June 15)	Sweetclover	2029	552	2581	59	9	68
	Alfalfa	2029	828	2857	59	14	73
	Red Clover	1629	641	2270	44	12	55
Full Bloom (July 15)	Sweetclover	4299	810	5109	74	10	84
	Alfalfa	3293	1388	4681	63	27	90
	Red clover	3017	908	3925	55	17	72

Source: K.E. Bowren et al., Can. J. Plant Sci., Volume 49:61-68 (1969)

When top growth is harvested for hay or silage and only the stubble is turned under, less than one-third of the legume dry matter and nitrogen is retained by the soil. However, even when legumes are used for hay or silage, the beneficial effects on soil quality and following crops may be substantial.

Summary

Building soil resources and optimizing inputs can be done with minimal cost or risk. Utilizing resources that are available and finding other, lower cost alternatives may help increase production efficiency and reduce input costs.

Input costs can be lowered by using manure and legume crops. Greater utilization of the commercial fertilizer applied is done through proper placement and timing. Banding fertilizer close to the time it is required will ensure maximum utilization of the fertilizer and fertilizer dollar.

Estimating crop production and nutrient requirements is facilitated by soil testing and soil moisture measurements. These are quick and easy tools to increase your accuracy of estimating yield potential and determining the economic yield target.

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