Introduction

Field crops are produced in Ontario under diverse soil and climatic conditions. The goal is sustainable crop production using proven techniques that include: scouting and pest management, soil and fertility management, tillage, variety selection, planting and harvesting practices. These techniques also take into consideration the responsible use of natural resources. These, combined with in-field trials, help producers determine which practices warrant adoption. Good agronomic practices are essential for helping Ontario farmers produce food, fibre and fuel. Successful crop production is dependent upon many inter-related management practices. A little good luck and good weather helps too.

Publication 811, the *Agronomy Guide for Field Crops* is designed to be a technical resource for field crop production. This third edition replaces the 2009 edition. It has been updated with current Ontario research and production guidelines as approved by the Ontario Soil Management Research and Services Committee (OSMRSC), which is represented by researchers, industry, producers and extension staff.

Some information used in the *Agronomy Guide for Field Crops* originates from other sources, including the University of Guelph, the Ontario Soil and Crop Improvement Association (OSCIA), the Innovative Farmers Association of Ontario (IFAO), seed companies, the United States Department of Agriculture (USDA), U.S. universities and other research institutions. Data presented in this publication — both new and old — represents the most relevant and current knowledge available.

The *Agronomy Guide for Field Crops* is available in its entirety, on the OMAFRA website. Additional or updated information on many of the topics discussed throughout this guide can often be found on the crops pages of the OMAFRA website at ontario.ca/crops or at fieldcropnews.com.

This publication does not provide information regarding specific pesticide products for the control of insects, diseases or weeds. For pesticide product information, see OMAFRA Publication 812, *Field Crop Protection Guide* and Publication 75, *Guide to Weed Control.*

Integrated Cropping Systems

Sustainable Crop Production

Publication 811, the *Agronomy Guide for Field Crops* is organized by crop and by discipline. Each chapter has detailed information that is current, Ontario specific and promotes sustainable crop production. Crop production is not just about one crop or one specific discipline (e.g., pest management). Crop production requires an integrated approach that looks at all aspects of the farm and production practices, with an eye to maintaining or improving the land.

Sustainable crop production can be defined as *"developing and utilizing crop production systems that meet the need of present producers without compromising the ability of future generations of producers to do the same"* (adapted definition from Dr. G. Brundtland — Director-General of the World Health Organization).

There are three segments to sustainable crop production: economic, social and environmental.

Economic sustainability focuses on:

- profit/loss of operation
- supply and demand — product marketability
- operation capacity and long-term availability of resources (e.g., soil)
- maintaining a viable business for the future

Social sustainability focuses on:

- succession planning for the next generation
- ability to engage with and support the community (e.g., rural/urban)
- maintaining a viable business/family life balance

Environmental sustainability focuses on:

- ensuring continued resources to sustain crop production activities
- ability to communicate the use of sustainable, traceable production practices to the public
- maintaining soil health and decreasing negative impact of crop inputs on the environment (e.g., nutrient/pest management)

Sustainability = Systems Thinking

Sustainable crop production requires an integrated systems approach. Every field has unique and site-specific characteristics that influence management, inputs and profitability. Integrated crop management takes all aspects of crop production into consideration, including:

- soil management — texture and tillage requirements
- crop rotation
- crop fertility
- nutrient (waste) management
- water management
- crop protection
- wildlife management
- site management
- scouting and record-keeping
- labour/equipment management
- energy consumption
- economic analysis (e.g., determining thresholds for action, cost of production, return on investment)

The *Agronomy Guide for Field Crops* covers many aspects of the sustainable crop production considerations listed above. Chapter 1, *Corn* discusses the aspects of tillage, while soil management, crop rotations and improving soil health is explored in Chapter 8, *Managing for Healthy Soils.* Scouting and record keeping are covered in Chapter 10, *Field Scouting,* while crop fertility and nutrient management are discussed in Chapter 9, *Soil Fertility and Nutrient Use.* Crop protection issues are covered in detail in Chapter 13, *Weed Control,* Chapter 14, *IPM and Protecting Natural Enemies and Pollinators,* Chapter 15, *Insects and Pests of Field Crops* and Chapter 16, *Diseases of Field Crops.*

The paragraphs below summarize how the aspects listed above integrate into the production of Ontario field crops.

It Starts With a Healthy Soil

Soil health is often described as the soil's capacity to support crop growth, without becoming degraded or otherwise harming the environment. Physical, chemical and biological indicators are measured to determine a soil's health. Physical indicators include aggregate stability, available water holding capacity, soil structure and soil compaction. Soil nutrient levels and soil pH are chemical indicators. Biological indicators include soil organic matter, microbial respiration and soil life populations.

In simple terms a healthy soil will:

- have good soil structure, minimal compaction and resist crusting
- have good drainage, water movement and water-holding capacity
- have nutrient levels, pH and organic matter (OM) in the optimal range
- be resistant to wind, water or tillage erosion
- encourage seedling emergence and root growth
- produce uniform crop growth
- have an abundance of earthworms
- have a fresh, earthy odour
- readily decompose residue

Most of the characteristics of a healthy soil have a direct or indirect link to other aspects of integrated crop management. More information on healthy soils can be found in Chapter 8, *Managing for Healthy Soils.*

Crop Rotation

Crop rotation is an integral part of the crop production system. A well-planned crop rotation will:

- increase yields
- aid in maintaining or improving soil structure and organic matter levels
- protect against soil erosion
- improve soil resilience against weather extremes
- provide residual nitrogen from legumes in the rotation
- help to disrupt insect and disease cycles
- reduce weed pressure
- spread out workload

The basic rule of crop rotation is that a crop should never follow itself. Continuous cropping of any crop will increase the buildup of diseases and insects specific to that crop and will potentially result in heavier infestations and reduced yields. The more often the same crop type has been grown in the same field, the greater the potential risk.

The greatest benefit from crop rotation comes when crops, including cover crops, grown in sequence are from different families; monocots (grasses) and dicots (broadleaves). The fibrous root systems of cereal and forage crops (including red clover) are excellent for building soil structure. The advantage of including wheat in the rotation often goes beyond the wheat year. Table Intro–1, *Management considerations for various crop rotations* provides an example of response to a crop following various crops in a rotation. More information about crop rotations can be found in Chapter 8, *Managing for Healthy Soils.*

Table Intro–1. Management considerations for various crop rotations

	Previous Crop					
Crop	**Corn**	**Soybeans**	**Cereals**	**Forages**	**Edible Beans**	**Canola**
Corn	• high residue volume to manage • yield depression • less herbicide rotation/weed control options • corn rootworm slugs (in short term no-till)	• greater herbicide rotation/weed control options • increased European chafer risk (light-textured soils)	• high residue in no-till system – if straw wasn't removed could keep soils cooler • greater herbicide rotation/weed control options • greater cover crop options	• increased wireworm risk in grassy sod	• no issues	• reduced mycorrhizae = less P uptake • potential reduced crop growth
Soybeans	• high residue volume to manage • greater herbicide rotation/weed control options • slugs (short term no-till)	• yield depression • low residue return – declining soil organic matter • less herbicide rotation/weed control options • increased risk of soybean root diseases, white mould, soybean cyst nematode,	• herbicide rotation options • slugs could be issue (over-winter cover)	• increased wireworm risk	• increased risk of white mould • soil degradation	• increased risk of white mould • potential reduced crop growth
Winter Cereals	• increased Fusarium head blight risk	• planting date issues depending on length of season bean variety	• increased risk of seedling, root and leaf diseases • reduced herbicide rotation/options	• increased risk of wireworm feeding	• earlier harvest makes timely planting easier	• may cause a slight reduction in growth
Spring Cereals	• high residue can affect seedbed preparation	• no issues	• increased risk of seedling, root and leaf diseases	• increased risk of wireworm	• no issues	• no issues
Forages	• high residue can affect seedbed preparation	• limited weed control options • potential for herbicide carryover	• limited weed control options	• autotoxicity if re-seeded too soon • limited weed control options	• no issues	• no issues
Dry Edible Beans	• no issues	• increased risk of root rots, white mould	• slugs may cause damage in no-till	• slugs in no-till • reduced herbicide options	• soil degradation • increased risk of root rots and white mould • yield depression	• white mould • may cause a slight decrease in growth
Canola	• slugs may cause damage in no-till • harvest is too late for planting winter canola • potential for herbicide carryover	• increased risk of root rots, white mould	• no issues	• slugs may reduce stand	• increased risk of white mould	• yield depression • increased risk of root rots and white mould • decreased soil structure

Rotation Economics

The success of a crop is generally evaluated on economic yield, where inputs and fixed costs are subtracted from gross profit. Most of the time the crop is evaluated on a per year basis and includes market demand as part of the decision making process as to which crop to grow. A more sustainable approach to crop economics would look at economic yield by rotation. This would combine inputs and fixed costs for all the crops within a crop rotation, divided by the gross profit of all the crops within that rotation. This would allow a longer-term evaluation of all the crops and could often reflect benefits beyond the actual crop harvested, such as pest management, herbicide rotation opportunities or soil building practices. As shown below under *Economic Justification for Including Wheat in a Corn-Soybean Rotation,* Dr. B. Deen, University of Guelph, demonstrates the potential yield benefit from adding wheat into a corn-soybean rotation.

Economic Justification for Including Wheat in a Corn-Soybean Rotation

Example: Adding Wheat into a Corn-Soybean Rotation[1]

- 2%–6% increase in corn yield
  6.5 bu/acre @ $4.50/bu = $29.25
- 9%–14% increase in soybean yield
  5 bu/acre @ $12.00/bu = $60.00
- reduction in rotational nitrogen requirement
  26.4 lb/acre @ $0.60/lb = $15.84
- other advantages
  - tillage reduction
  - yield stability
  - opportunity to sell straw
  - potential reduction in compaction
  - improved soil structure
  - spread-out workload

Conservative estimate = $10.00

Total additional profit to wheat is approximately $115.00/acre

Benefits of diversifying a crop rotation include:

- increased subsequent corn yield (average 4%)
- increased subsequent soybean yield (average 11%)
- opportunity for addition of cover crops
- opportunity for manure application
- opportunity for wheat straw sales
- spread workload over growing season

When profitability is assessed on a full rotation basis, often the economies of scale have resulted in accepting a lower profit per acre.

[1]Source: Dr. B. Deen, University of Guelph. Metric is not provided as the example is for illustrative purposes only.

Integrating Cover Crops into the Rotation

Resilient crop yields can be maximized by improving soil health, which is enhanced through the use of cover crops. Long-term advocates have found that adding cover crops to their rotation adds a critical amount of additional carbon to the soil.

Cover crops should be considered as part of the overall crop rotation and especially on soils with lower organic matter, or on fields with short rotations and little return of crop residue or manure. Cover crops can help to ensure appropriate ground cover over the non-growing season to help protect the soil. It is important to know the goal or expected benefit from a cover crop. The section *Matching Cover Crop Choices to Function,* looks at the various reasons for including cover crops in a rotation and the potential cover crops that best meet those goals. See Chapter 8, *Managing for Healthy Soils* for more information about cover crops.

Matching Cover Crop Choices to Function

Cover Crop Function	Best Choices for Cover Crops
• nitrogen production	• legumes — red clover and other clovers, alfalfa, peas, vetch
• nitrogen scavenging	• fall uptake — oilseed radish and other brassicas, oats, barley • winter/spring uptake — cereal rye, winter wheat
• weed suppression	• fast growing/shading plants — oilseed radish and other brassicas, winter rye, buckwheat
• soil structure building	• fibrous root systems from oats, barley, rye, wheat, triticale, ryegrass or clovers
• compaction reduction	• most cover crops roots will assist in reducing compaction • moderate compaction — radish • more severe compaction requires strong, dense tap roots that grow over time — alfalfa, sweet clover
• biomass return to soil	• fall seeded — spring cereals, oilseed radish • summer-seeded — millets, sorghum, sudangrass, sorghum-sudangrass
• erosion protection, (wind, water)	• most cover crops once well established — winter rye, winter wheat, ryegrass (well-established), spring cereals seeded early
• emergency forage	• fall — oats, barley, wheat, rye, forage brassicas • summer — millet, sorghum, sudangrass, sorghum-sudangrass, see Table 3–2 for more annual forage options
• nematode suppression	• cutlass mustard, sudans/sorghums (Sordan 79, Trudan 8) pearl millet (CFPM 101), marigold (Crackerjack, Creole), oilseed radish (Adagio, Colonel) **Not all cover crops have the ability to suppress nematode populations; some can act as hosts. Cover crop activity is variety- and nematode-specific.**

Tillage and Residue Management

Reasons for Tillage

There are many reasons to perform tillage for crop production in addition to increasing soil dry-down. Soil is also tilled for reasons, including:

- weed control
- wireworm and grub suppression
- soil levelling to improve seedbed uniformity
- incorporation of crop residues
- incorporation of fertilizer and manure
- seedbed preparation

The advent of herbicides greatly reduced the need for tillage to control weeds (except in organic systems) and the development of equipment to plant into crop residues ensures that crops can be planted successfully with little or no tillage. Generally, performing primary tillage operations in the spring will leave the soil less prone to erosion than tillage in the fall. It is best to use the least amount of tillage necessary to achieve the goal. This will help to keep the soil in place and prevent movement into water courses.

Considering all parts of the system will improve the success of any tillage system. For example:

- Spreading residue and chaff evenly at harvest will improve tillage and planting operations.
- A diverse crop rotation can reduce insect and disease issues and can increase the potential success with reduced tillage.
- Adapting the planter or drill for specific soil texture and/or crop residue type, over and above the addition of coulters or residue wheels, will improve seed placement.

A number of different tillage systems are used in Ontario. These are summarized below. Additional information can be found in the tillage section of Chapter 1, *Corn.*

Conventional Tillage

Conventional tillage in Ontario generally consists of fall mouldboard or chisel plowing followed in spring by secondary tillage, usually with a field cultivator or tandem disc. Most plowing is targeted to an operating depth of 15 cm (6 in.), since plowing deeper often results in unwanted mixing of subsoil into the seedbed. The more uniform and level a field is left after fall plowing, the greater the opportunities to reduce secondary tillage costs and improve planter or drill performance. One disadvantage is that the lack of surface residue in conventional tillage exposes fields to greater erosion risks from water and wind. On complex slopes, tillage can be responsible for causing large quantities of topsoil to move to lower slope positions (tillage erosion).

Fall Mulch Tillage

The chisel plow, disc-ripper and discs (either tandem or offset) are the most widely adopted fall primary tillage tools in Ontario. These tools usually leave more residue on the soil surface while leaving the surface level in the fall, so that single-pass planting (no secondary tillage) becomes a viable option in the spring.

Vertical Tillage

Vertical tillage is used to reduce any pushing or smearing action that may be caused by tillage tools. Many vertical tillage tools are designed to size residue into more manageable pieces and distribute crop residue, while causing some soil fracturing and mixing of soil with residue at the surface. A number of tillage tools embrace the concept of "vertical" tillage, but use shallow concavity discs, low profile sweeps and extensive harrows to provide some additional soil disturbance — all the while attempting to remain true to the idea of tillage without significant inversion and soil smearing.

Spring Mulch Tillage

The best practice for reducing erosion and input costs is to eliminate fall tillage. Producers working on fine-textured soils, where crop residues are high following corn, wheat or other crops, may be apprehensive about leaving soils untouched in the fall. Following soybeans or dry edible beans, there is little justification for doing fall tillage on most fields in Ontario. Considerations following other crops include risk of soil erosion, availability of equipment to handle spring residue and field drainage. Producer experience with spring mulch tillage systems has shown that working undisturbed soils in the spring obtained better results when using high-clearance tines, narrow teeth and/or when packers or rollers were used in conjunction with the field cultivator.

Fall Strip-Tillage

Performing fall tillage, confined to narrow zones that correspond to next year's corn rows, has received considerable attention in the past few years. The strips of soil are loosened, cleared of residue and often elevated, while leaving the rest of the field covered with protective crop residue. The following spring, the strips are drier, less dense and more suited to "no-till" planting.

Strip-tillage systems also provide an opportunity to band fertilizers that must be broadcast in a no-till system. Applying fertilizer using the strip-tillage system may also replace the need to apply banded starter fertilizers through the planter. Fall banding of phosphorus and potassium in strip-tillage systems, with adequate fertility levels, can produce higher yields than when similar rates of fertilizer are broadcast in no-till systems.

Spring Strip-Tillage

Spring strip-tillage offers an opportunity to prepare fine, residue-free seedbeds in which a planter can operate. Most spring strip-tillage operations are restricted to the lighter textured soils but in some cases medium textured soils that are well drained are suitable for this one pass tillage option. The spring strip-tillage operation usually precedes the planter by no more than 6–12 hours in order to prevent the seed zone from drying out excessively. Producers have also used spring strip-tillage as a technique for applying all or part of a corn crop's nitrogen (N), phosphorus (P) and potassium (K) requirements.

From a soil conservation perspective, spring strip-tillage also offers the advantage of eliminating the presence of fall strips that can potentially funnel water and be susceptible to erosion, especially if implemented up and down the slope.

Deep Tillage

Increasing axle loads of farm machinery, and the general concern that soils have become more compacted, have increased the use of deep tillage systems. The main reason offered for deep tillage is that elimination of compacted sub-soil layers and/or tillage pans will promote rapid and deep root growth and improve drainage. However, in Ontario, subsoils loosened using deep tillage are often easily re-compacted by wheel traffic. Moreover, it is possible that deep-tilled soils receiving wheel traffic end up with poorer drainage because deep tillage destroyed the natural pores created by worms or previous crop roots. Deep tillage into dry soils combined with deep rooted crops (alfalfa, sweet clover) offer the best opportunity for repairing compacted soils.

No-Till Systems

In no-till systems, tillage is not used to prepare a seedbed. Minimal soil loosening in a narrow band immediately ahead of the seed opener is performed by planter-mounted coulters and/or residue clearing devices. Successful no-till crop production is partially dependent on effective use of alternative production practices and field management strategies that deal with yield-limiting factors that otherwise would have been corrected with tillage.

For successful no-till production it is important to:

- have good soil drainage and water infiltration
- maintain a multi-crop crop rotation
- incorporate residue management to maintain some soil cover all year
- incorporate weed control strategies without use of tillage
- manage diseases and insects
- start with adequate soil fertility levels and consider fertilizer placement
- minimize soil compaction

Field Scouting and Integrated Pest Management

Integrated Pest Management (IPM) is an approach to weed, insect and disease management that uses all available control strategies to manage pest populations, keeping them below economic thresholds. This results in a cropping system that is more resilient to failures since it does not exclusively rely on the use of pesticides to control pests. For example, integrated weed management strategies include field scouting, tillage and nutrient management practices, crop rotations and cover crops.

Ongoing monitoring of fields and crops, throughout the growing season and beyond, allows a farmer to observe issues and apply remediation in a timely manner to minimize any negative economic impact, while improving field operation efficiencies. Some problems cannot be addressed when observed, but the information can still be recorded for future use.

While traditionally field scouting has been solely associated with pest monitoring and management, it has many other benefits, including:

- pre-planting field walks that identify drainage issues
- post-planting field walks to look at equipment performance (planters delivering desired population, depth, placement across the entire unit)
- nutrient management (specific areas with nutrient deficiency symptoms)
- crop variety selection (evaluation of in-field comparisons of variety performance)
- scouting as part of soil sampling, which allows observation of field conditions (erosion, drainage) outside the cropping window

Additional information about field scouting can be found in Chapter 10, *Field Scouting.*

Record Keeping

New tools are available to increase the value of scouting and to assist in record keeping. With the adoption of smartphones and tablets, a large number of apps are available to assist with scouting. Selected apps should address all the information parameters of interest and integrate with other software/hardware systems on the farm. An app that isolates data on a phone or tablet offers little value. Many of the crop and whole farm management systems have developed field apps that integrate with their main programs. Many of these also take advantage of Global Positioning Systems (GPS) capabilities to better identify the location where problems/issues are discovered. Figure Intro–1, *An example of an Ontario scouting and record keeping smartphone app,* is a collection of screen shots from *Pest Manager,* an app developed to aid Ontario producers in identifying pests while scouting. *Pest Manager* provides instant management options, with the ability to map the locations where the pest was found for record keeping purposes.

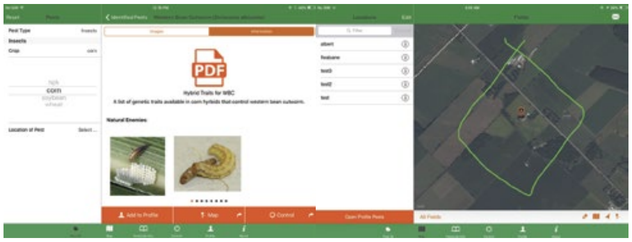

Figure Intro–1. An example of an Ontario scouting and record keeping smartphone app.

The *Pest Manager* app is an excellent example of a scouting and record keeping tool for pest management. The app includes diseases, weeds, and insects of soybean, corn and cereal crops. Users can map areas of fields where pests are identified. This tool can help in the identification of each pest (insect, weed, disease) and provides detailed information on their life cycle, impact, action thresholds and management strategies, including biological, cultural and chemical control options. Information provided within this app is only valid for Ontario. When using pesticides, always be sure to read and follow the labels and warnings. This app is free to download and is available for iOS, Android and the BlackBerry BB10 operating systems.

A Systems Approach to Managing Crop Nutrients

How nutrients are managed for crop production will depend on many other components of the whole farm operation. The 4R concept of nutrient management — the right nutrient sources, at the right rate, at the right time and in the right place — is being implemented world-wide by industry, researchers, government agencies, producers and their advisors. 4R nutrient stewardship is an approach that is essential to the development of sustainable agriculture. Its application can have positive impacts on increasing food production in an economically viable manner, while preserving the environment.

4R stewardship or nutrient management is a systems approach that considers the following components:

1. **Inventory of nutrients on the farm**
   This includes organic (manure), inorganic, the nutrients needed by the crop and those already in the soil.

2. **Characteristics of field and farm**
   Nutrients are managed according to land base availability, production goals, proximity to water resources, farmstead layout, equipment availability and safety concerns.

3. **Site conditions when nutrients are applied**
   Crop requirements and baseline fertility levels from regular soil testing are used to determine best application rates. At the time of application, field conditions are assessed to determine the best nutrient source and the best option for nutrient placement. Where manure or other organic amendments are applied, special consideration is given to odour, potential nutrient loss and maintaining adequate separation distance from sensitive areas.

4. **Residual nutrients from previous crops**
   Where legumes are used in rotation, or where manure or other organic amendments are applied regularly, credit is given to available nutrients and is subtracted from commercial fertilizer needs.

5. **Nutrient use efficiency**
   Nutrient use efficiency ensures that the nutrients are available when the crop requires them, resulting in reduced nutrient loss and sustained soil fertility.

6. **Production vs. profit**
   Because maximum yield will not always give the most profitable yield, crop production practices should always strive for maximum economic yield.

7. **Other farm management considerations**
   Nutrient management is part of a comprehensive crop production system that includes soil and water management, crop rotation, variety selection, planting techniques, tillage systems and pest management. How nutrients are managed will depend on these other components of the whole farm operation, including some of the social aspects such as family needs and outside-farm interests. For additional information see Chapter 9, *Soil Fertility and Nutrient Use.*