The Future of Plant Protection

Mary Ruth McDonald[1], Bruce D. Gossen[2], Clarence Swanton[1], Cynthia Scott Dupree[3]

[1]Dept. of Plant Agriculture, Univ. of Guelph, Canada

[2]Agriculture and Agri-Food Canada, Saskatoon, Saskatchewan, Canada

[3]School of Environmental Sciences, Univ. Guelph, Canada

Niels Bohr (1885-1962)

"Prediction is very difficult, especially if it is about the future"

Back to the Future day- Oct 21, 2015

Doc Brown is seen holding a tablet in Back to the Future II

iPad - yes

Marty McFly rides a hoverboard in Back to the Future II

Hoover skate board - No

What hasn't changed in the past 40-50 years?

- Crop losses as a result of insects, diseases and weeds
- Introduction of new insects, diseases and weeds increasing as international transportation increases
  - Emerald ash borer, *Tuta absoluta*
- Resistance to crop protection materials and host resistance: if a strong selection pressure is applied to a population, they will evolve
  - Weeds, insects and pathogens

What hasn't changed in the past 40-50 years?

Plant pathology:

Many diseases that were a problem then are still very difficult to control

Fusarium on maize

- Fusarium head blight on wheat and maize
- Clubroot of Brassica crops,
- other soil borne pathogens= Fusarium, Verticillium
- Bacterial diseases – fire blight
- Phytoplasmas – Huonglongbing/citrus greening
- Viral diseases

Colorado potato beetle

We are still using some old fungicides, such as mancozeb and chlorothalonil

What has changed?

Agricultural equipment is getting bigger and bigger

58 **Briefing** Brazilian agriculture — The Economist August 28th 2010

The miracle of the cerrado

risen from barely 15m tonnes to over 60m
Brazil accounts for about a third of worl

Replacing persistent chemicals with reduced-risk products, biopesticides and biocontrols:

The organophosphate insecticide, chlorpyrifos (Lorsban), is still used to protect onions from onion maggots- in us for at least 40 years

BUT, it is being replaced by seed treatments, such as Entrust (spinosad) that is approved for organic use.

More and better integrated pest management programs and move to integrated crop management

- **Example Pro_Plant**

- **Developed in Germany for cereal crops, then potatoes**
- **Monitoring of environment, diseases, crop growth stage, cultivar resistance, nitrogen status of plant.**

- **Develop infection probabilities**
- **Recommends specific fungicides for specific diseases, and spray timing**

Detection and Diagnostics

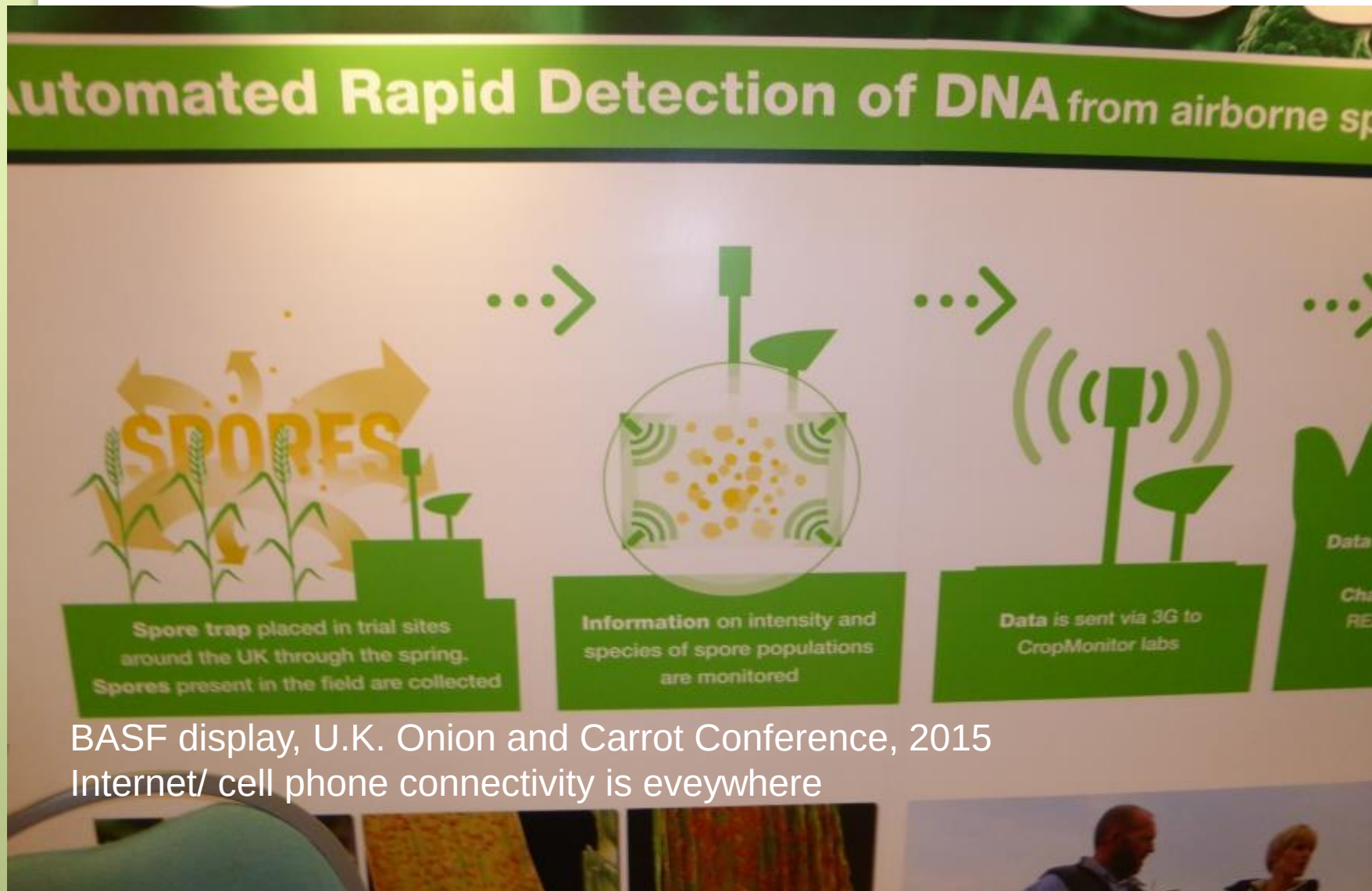
- DNA technologies for rapid detection of invasive insects, fungi and bacteria and weed seeds/pollen in the air with improved molecular detection and identification
- Sequencing and Barcode of Life – Will develop to on site identification
  - ELISA (enzyme-linked immunosorbent assay),
  - PCR (polymerase chain reaction)

  LAMP (loop mediated isothermal amplification
- Detection at points of entry into a county also on a regional and field scale.

The future is now: remote counting of insects and diseases within traps

Remote pest management with automated traps- Semios
Pheromones are used to attract the insect pests and their acitivity is recorded using cameras and other sensors and the data is sent back to headquarters. Insect activity can be used to trigger pheromone release for mating disruption

The future is now: remote counting of insects and plant pathogens in traps



BASF display, U.K. Onion and Carrot Conference, 2015
Internet/ cell phone connectivity is eveywhere

Ten years ago, I thought that the future of plant protection revolved around more and better reduced risk pesticides and improvements in Integrated Pest Management

Now there are so many more options

What has also improved? Precision Agriculture

- **Site or plant specific fertilizer application, emphasis on nitrogen**
- **Site specific application of herbicides**
- **“Scouting” using drones (early stages) mostly to detect nitrogen deficiency and soil moisture**

Drones will also be used for spraying crops, in addition to monitoring

Other approaches to plant protection

- Products that induce resistance (still have to spray something)
- Better understanding and use o **mycorrhizae**- crop specific, seed treatments
- Endophytes – (remember: some produce dangerous mycotoxins)
- Rhizospere “microbiome”

Bacillus subtilis

Other approaches to plant protection

- RNAi =gene silencing with small pieces of double stranded RNA that prevent gene expression (prevent transcription, translation or replication of the target gene.
- Potential to control insects, nematodes, viruses, fungi
- Very specific
- Expression in plant, chemical formulation or expression in bacteria

Colorado potato beetle

What will change- general

- Much better weather forecasting
- Driverless vehicles and farm equipment =
  robots and more drones for scouting and crop protection
- Better batteries (Tesla) which means local use of solar energy on a 24 hour basis
- Machine learning (autonomous and semi-autonomous) in computers

In the Future

- More effective biocontrols and use of biocontrols, because there will be much better weather forecasting
- Enhancement of habitat for natural biocontrols- nurse crops, hedgerows
- “Push-pull” strategies with trap crops, attractants and repellants

Plant breeding

Marker assisted selection – Faster breeding for better resistance to insects and diseases (stacked genes, partial resistance)

CRISPR/Cas9- genome editing and rapid introduction of traits

Isolines- to allow for 3 or 4 resistance genes in a single field?

Plant breeding

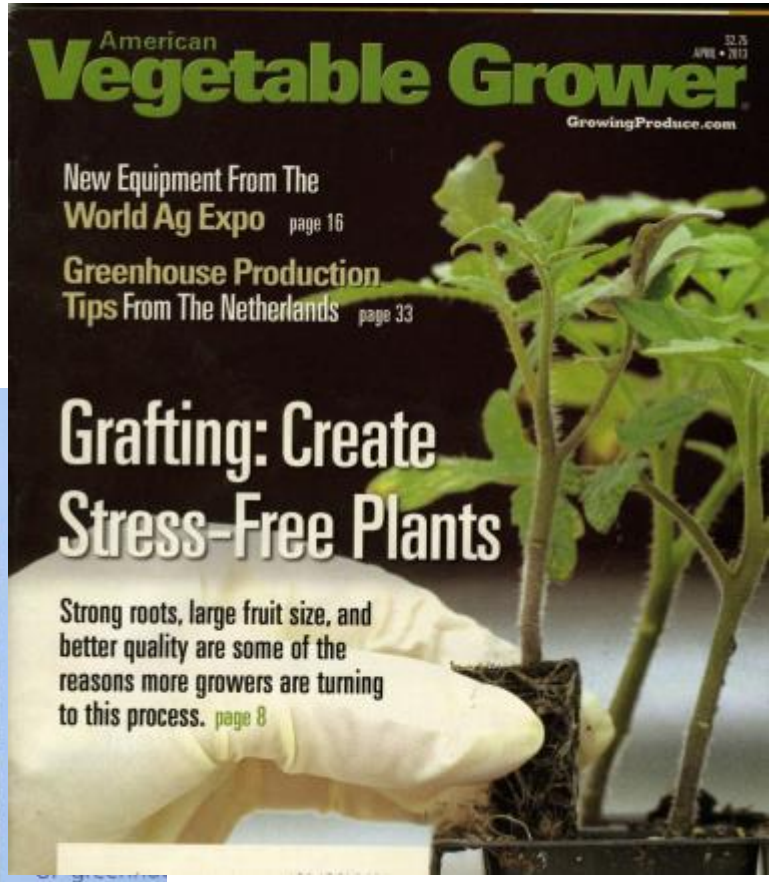
Pathogens and insects can be tested for **virulence genes** – then use a resistant cultivar ie downy mildew on spinach or lettuce (many pathotypes)

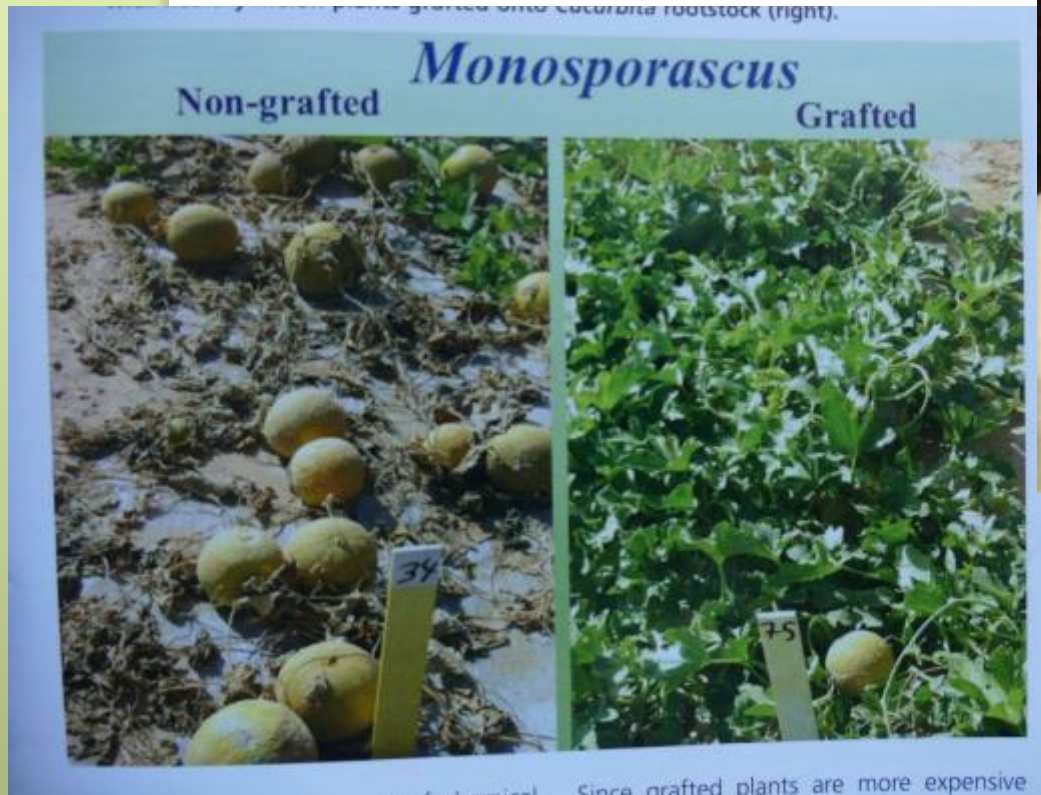
Breed crops to better ability to resist weed competition

–Early emergence?

- Rapid development of canopy?
- Less reactive to competition from nearby weeds

The future: A return to physical and cultural controls
Grafting





Effective for several soil borne diseases: Fusarium

The future is happening now
Machine thinning and weeding

Blue River Technology Takes In Another $10M For Its Agriculture Opti... http://techcrunch.com/2014/03/19/blue-river-technology

Blue River Technology, which uses robotics and computer vision to optimize agriculture by, for instance, determining which lettuces to thin out of a row and which to keep, has closed a $10 million Series A-1 funding round, led by Data Collective Venture Capital — topping up a $3.1 million Series A it raised back in 2012.

Eric Schmidt's Innovation Endeavors also joined the round as a new investor, while existing

The future is now: Machine learning

Robots to monitor greenhouse tomatoes and harvest tomatoes

Medhat Musa and Patrick Wspanialy at the University of Guelph

The computer can detect leaves, as distinct from fruit or stems

More challenging is detecting powdery mildew and other symptoms of disease on leaves

To come:

Chemical detectors - a “nose” to detect the chemical signature of plant pathogens and insect pests at points of entry, on imported food and other plant materials.

Also in the field, to detect the chemical signals that plants emit when under attack from insect herbivores and other stresses

Visions for the future: small is beautiful

- Small, self propelled equipment – planters, harvesters, monitors and sprayers will be highly efficient and can work day and night.
- Spacing can vary, plants can be seeded and harvested as needed, and at optimum timing.
- Monitoring can be site specific to an individual plant or leaf
- If sprays need to be applied, they can be applied to very small, specific areas- or the whole field.

soybean.jpg (JPEG Image, 270 × 203 pixels)

Vision for the future

Greater biodiversity

Smaller farm equipment will allow for intercropping, strip cropping and hedgerows – with benefits for soil health, enhancement of natural enemies

- Better recommendations for crop rotations and companion planting

Visions for the future: smal is beautiful

"Crop Defender" robots will continuously monitor the crop:

- 3 cameras- true colour, infrared and multispectrum, including a camera with microscope capabilities.
- Sensor "noses" for volatiles
- On-board computer capable of machine learning, GPS and communication software
- Solar powered with good batteries so can work night and day

iRobot Roomba® 980- Overview

Now cleans an entire level of your home

iAdapt® 2.0 Navigation

Uses a high-efficiency cleaning pattern and a full suite of sensors to

map and adapt to real world clutter and

furniture for thorough coverage.

Visual Localization

Expands the Roomba 980's coverage to an entire level of your home by using iRobot's proprietary vSLAM® technology to create visual landmarks in its map so it doesn't lose track of where it is or

Recharge & Resume

Runs continuously for up to two hours[1] then automatically recharges and resumes cleaning to complete the entire job.

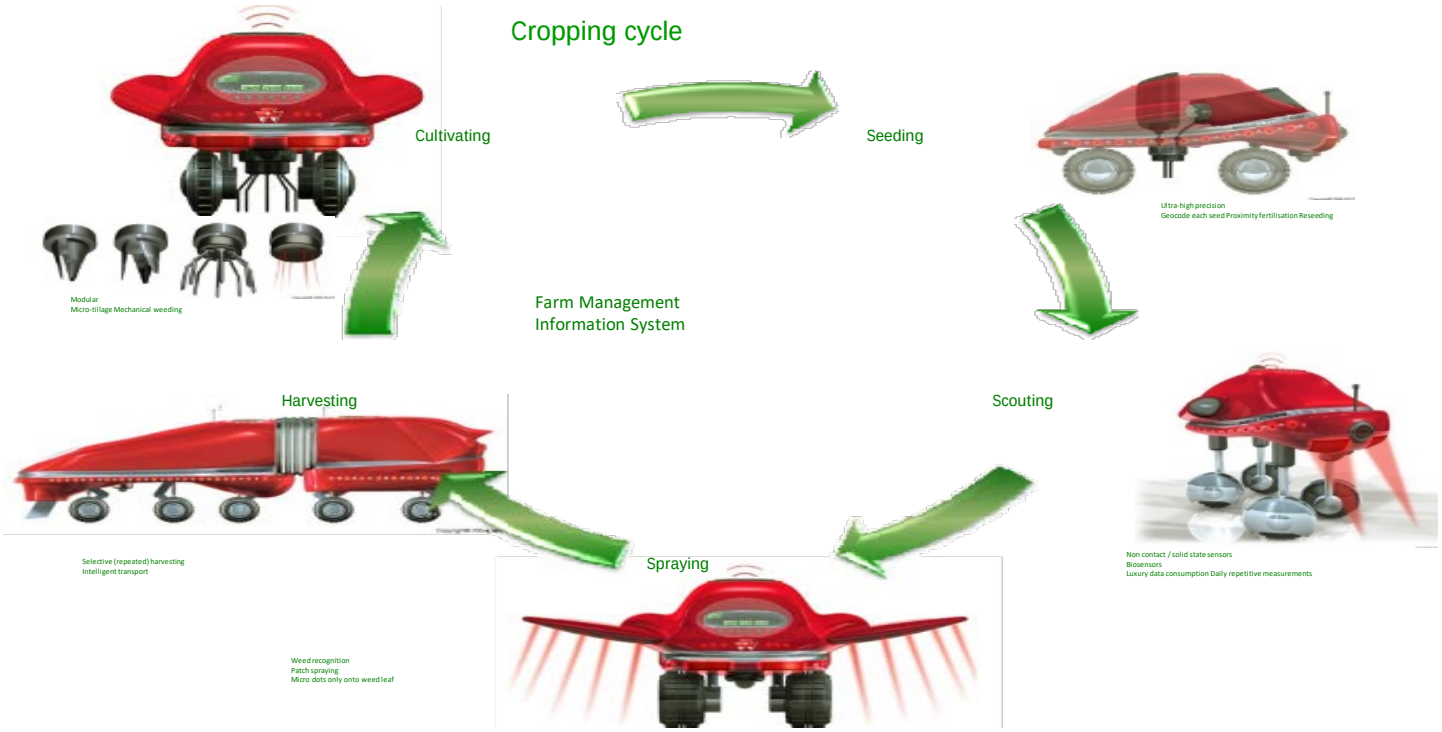
Visions for the future: Precision Ag

The ultimate precision ag and IPM: physical controls

The robots can identify weeds and pull them out, identify insect pests and squash them, or aspirate them into a fan that macerates them.

Small portions of infected leaves can be excised, leaves can be pruned to increase air movement or to remove susceptible tissue

Octocopters can create air movement to dry dew from leaves in order to prevent germination and infection by fungi or bacteria.



Prof Simon Blackmore – The Future of Farming

Small UAV's (drones) can apply sprays and do other crop monitoring tasks

Visions for the future: Precision Ag

Plant specific application of macro or micronutrients, water, or products to increase host resistance

Biocontrols can be applied in small quantities at the right site- on or near an insect pest, or on the susceptible portion of a leaf.

Pheromones, repellants or attractants (hedgerows)

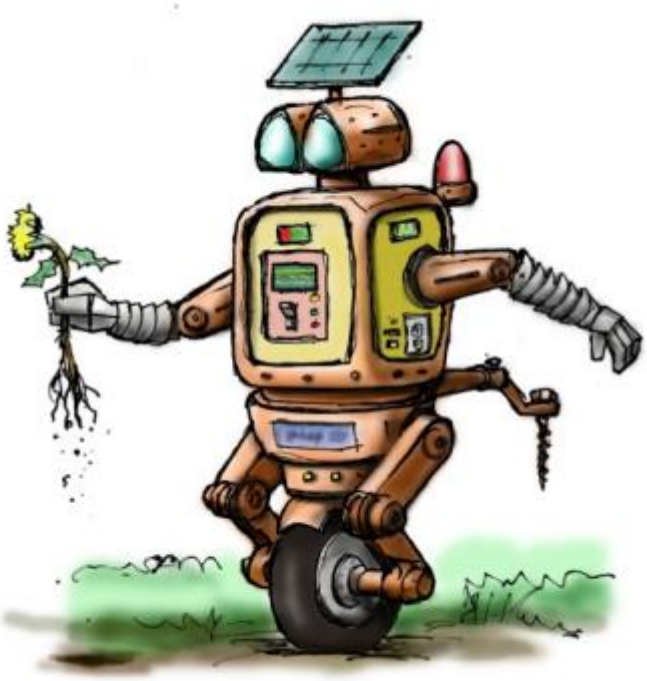
Reduced risk pesticides, applied as needed, where needed

This unmanned airplane is a prototype of one that Greg Krehn, a researcher at Fresno State, is working to develop in order to give commercial farmers an eagle eye view of their crops. These types of aircraft, which are 9 to 15 feet long, could be instrumental in helping farmers monitor their fields for broken irrigation lines and other problems. Photo courtesy Greg Krehn, Fresno State

What human resources will be needed?

- More engineers, specialists in robotics and computer programmers
- Professionals in the various crop protection disciplines will still be needed:
  - There can be too much data for a grower to absorb and use effectively.
  - The technology will not always deliver the correct result. There will still be a need for specialists who can go to the field and ‘ground truth’ the results
  - The biology of insects, diseases and weeds will keep changing

Questions and Comments?



References

Prof. Medhat Mussa and Patrick Wisplany, Univ. of Guelph, Canada
Prof. Simon Blackmore, Harper Adams Univ. U.K.

Bortesi, L and R.Fischer. 2014. The CRISPR/Cas9 system for plant genome editing and beyond. Biotechnology Advances 33:41-52
Copping, L.G. 2014. Biopesitides: Making integrated pest management work for farmers and growers. Outlooks on Pest Management-June 2014 DOI 10.1564/v25_jun_02
Frewin, A. C. Scott-Dupree and R. Hanner. 2013. DNA barcoding for plant protection: applications and summary of available data for arthropod pests. CAB Reviews 8:No. 018.
Moussa, W.K., C.R. Shearer, V. Lemay-Rios, T. Zhou, and M.N.Raizada. 2015. Bacterial endophytes from wild mailze suppress Fusarium graminearum in modern maize and inhibit mycotoxin accumulation. Front. Plant Sci. http://dx.doi.org/10.3389/fpls.2015.00805
Palli, S.R. 2014. RNAinterference in Colorado potato bettle; steps toward development of dsRNA as a commercial insecticide. www.sciencedirect.com 6:1-8

Integrated Pest Management

- Crop rotation
- Sanitation
- Site selection
- Timing of planting and harvesting
- Cultural controls such as tillage
- Encouraging natural biocontrols/beneficial insects
- Treatment thresholds
- Pesticides are a last resort, but much of IPM focuses on optimizing pesticide use

Interrelationships

- Soybean aphids – imported pest (China)
- Pumpkin viruses increase as soybean aphids increase

- Asian multicoloured ladybird beetle – imported as a bio control for aphids (but not soybean aphid), increase as aphid populations increase and are out- competing native ladybird beetles

- Wine production in Ontario – when aphid populations drop, ladybird beetles more to vineyards, when pressed with wine grapes, cause off-flavours in the wine.

What has changed?

- ❑ Equipment keeps getting larger and larger – more efficient use of human inputs
- ❑ Replacing persistent chemicals with reduced-risk products, biopesticides and biocontrols
- ❑ More and better integrated pest management programs and move to integrated crop management (includes plant mineral nutrition and other crop factors)
- Better monitoring methods, spore traps, pheromone traps. Pest ID with DNA sequencing ie The Barcode of Life
- Identification of genes for resistance to pesticides

- ❑ The internet and connectivity!

Future of plant protection- What is needed?

- Better and more effective biological controls
- Much better controls for bacteria, phytoplasmas and viruses
  - Bacteria phages? Induced resistance?
- More reduced-risk crop protection materials- most derived from naturally occurring substances ie thymol or products based on naturally-occurring substances (strobilurins, spinosad)
- Products that stimulate host plant resistance

What has improved?

Integrated pest management methods

information about thresholds, monitoring methods, life cycles

Less persistent pesticides- reduced risk products, mostly based on naturally-occurring chemicals, such as the strobilurin fungicides

More biological controls – but much more improvement is needed

Molecular methods

- Pest ID with DNA sequencing ie The Barcode of Life
- Identification of genes for resistance to pesticides