Part 3: Understanding How to Benefit Crop Production

Farmers are tasked with feeding a rising population while using a smaller workforce. As farmers are increasing efficiency within agricultural operations, meeting the needs of consumers and following federal and state regulations, they are constantly evaluating the costs that are necessary to grow crops effectively. Agriculture has seen many changes in the last several decades and the practices that are being implemented by farmers have come under increased scrutiny. One of these practices is using additives in the fields to increase crop yields. These practices take the form of soil amendments and pesticides. These decisions increase the input costs of the operation, while the margins for the outputs (market value) are becoming smaller. Each field and crop rotation requires a prescription for how to best manage the land and the yield.

Section A: Soil Amendments

Soil amendments are usually done before the crop has been planted. They take the form of manure, gypsum, or lime and can also include fertilizers.

Gypsum:

The use of ***GYPSUM*** (calcium sulfate) is a 200-year old practice that was too expensive to use in all applications. This changed with the Clean Air Act in the 90s, and it has now become a cost effective solution to help increase the physical nature of soil.[1] The benefits included are:

1. Provides calcium and sulfur for plant nutrition.
2. Improves acid soils and treats aluminum toxicity.
3. Improves soil structure.
4. Improves water infiltration.
5. Helps reduce runoff and erosion.

Lime:

Agricultural ***LIME*** (calcium carbonate) is made from pulverized limestone and is used to neutralize acids in the soil, enabling microorganisms to break down organic materials. Lime improves soil quality in a variety of ways:[2]

1. Increases the pH of acidic soils.
2. Provides a source of calcium for plants.
3. Improves uptake of essential plant nutrients.
4. Improves water penetration for acidic soils .

FERTILIZER: An additive that is used to enhance the growth of plants by putting the right nutrients in the soil when the plant needs them most.

FGD GYPSUM: Flue gas desulfurization (FGD) gypsum is produced at some coal-fired power plants as a by-product of pollution control measures.

LIME: A white caustic alkaline substance that is made up of calcium oxide. It is used on soil to reduce acidity and improve fertility by increasing oxygen levels.

PESTICIDE: Chemical that is used to kill, or repel pests.

SOIL CONDITIONERS: A product that is added to soil to increase the physical qualities of the soil, which increases the flow of nutrients to the plants.

[1] The Role Of Gypsum In Agriculture: 5 Key Benefits You Should Know. CropLife. Retrieved 15 March 2015 from, http://www.croplife.com/crop-inputs/micronutrients/the-role-of-gypsum-in-agriculture-5-key-benefits-you-should-know/

[2] Lime - Source of calcium for plants, increases the pH of acidic soils, improves water penatration and nutrient uptake. AGRA Marketing GRP. Retrieved 28 March 2015, from http://agramarketing.com/page/lime1.html

Fertilizers:

Application of fertilizer can happen at any point in the year, depending on the needs of the crops that are in the field. ***FERTILIZER*** is an additive that is put on the field to supplement the nutrients that are in the ground. At times, it is applied just after harvest. Sometimes, it is put on before planting or at the time of planting. Fertilizer can also be applied as side-dress after the crop has started to grow. Decisions on when to apply fertilizers are dependent on monies that are available for the farm operation, yield goals, logistics of equipment, and the need of the plants. Fertilizer ranges from synthetic products to manure, with the goal of increasing the nutrients, predominantly N, P, or K, within the soil.

Reading Questions

1. Why has the application of additives come under scrutiny by the general public?

2. Where does the gypsum that is being used now come from?

3. Carbon and sulfur are both essential nutrients that are necessary for plant growth. Where do they come from naturally?

4. When are fertilizers applied to a field?

5. Why would farmers choose to amend their soil?

6. What should farmers consider as they consider amending their soil?

Section B: Pesticides

Pesticides have evolved with the understanding of plant genetics and genetically modified organisms, and the federal laws that govern the use and application of pesticides have, too. The first law was passed in 1910 and now it has morphed into the *Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)*. ***PESTICIDES*** are chemicals that are used to reduce the effect of pests in the fields. These pests can be insects, weeds, fungi, bacteria and/or viruses. To choose correctly farmers need to know why the crop is not performing the way it is expected.

Each pesticide can pose a different level of risk to non-target insects, people, pets and the environment. When a farmer applies a pesticide to a field, consideration of drift is important. **Drift** is the amount of a product that does not reach the desired target. Factors that affect drift are wind speed, the droplet size of the liquid being applied, and the speed of the tractor pulling the spreader. In the past, these factors have been difficult to manage, but now that precision agriculture is part of many operations, the drift effect is being reduced.

Overview of FIFRA

The first pesticide control law was enacted in 1910. This law was primarily aimed at protecting consumers from ineffective products and deceptive labeling. When the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) was first passed in 1947, it established procedures for registering pesticides with the U.S. Department of Agriculture and established labeling provisions. The law was still, however, primarily concerned with the efficacy of pesticides and did not regulate pesticide use.

FIFRA was essentially rewritten in 1972 when it was amended by the Federal Environmental Pesticide Control Act (FEPCA). The law has been amended numerous times since 1972, including some significant amendments in the form of the Food Quality Protection Act (FQPA) of 1996. In its current form, FIFRA mandates that EPA regulate the use and sale of pesticides to protect human health and preserve the environment.

Since the FEPCA amendments, EPA is specifically authorized to: (1) strengthen the registration process by shifting the burden of proof to the chemical manufacturer, (2) enforce compliance against banned and unregistered products, and (3) promulgate the regulatory framework missing from the original law.

FIFRA provides EPA with the authority to oversee the sale and use of pesticides. However, because FIFRA does not fully preempt state/tribal or local law, each state/tribe and local government may also regulate pesticide use.

Source: U.S Environmental Protection Agency. "Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)". Retrieved 01 April 2015.

Precision Agriculture is also known as ***Site-Specific Crop Management (SSCM)***. This is a process by which a farmer uses technology to scale down the size of a management area. Instead of looking at the field as a whole, the farmer looks at groupings of plants. This process improves the efficacy of the treatment and also the bottom line for the farmer.

Insecticides:

The goal of the farmer is to protect the plant by keeping insects from destroying leaves, stems or roots of a crop. Several options must be considered in order to have an integrated pest management program and to avoid resistance in the insects.

Consideration of the different Modes of Actions (MoA) is necessary. MoA are classified into broad groups that are broken into sub-groups that represent distinct chemical classes that are different enough in chemical structure, or mode of interaction with the target protein, or bind differently with the target.[3]

Disorientation of the insect can be achieved as insecticides modulate the chordotonal organs. (These organs are used to detect the position of the body antennae.) This is one way in which the nerve and muscles are affected. There are also **agonists,** which are chemicals that bind to a receptor prompting the receptor to produce a biological response. Where there is an agonist, there may also be an **antagonist,** which blocks the action from occurring and thus a lack of the biological response.

One way in which growth is inhibited is by reducing the biosynthesis of chitin. **Chitin** is the principal component of arthropod exoskeletons. Another way is the inhibition of acetyl CoA carboxylase which inhibits fatty acid synthesis.

Insecticides that affect respiration interfere with the ability of mitochondrial ATP synthase (the energy transport for the cell) and electron transport across membranes, cutting down the amount of energy an organism can access.

Another insecticide directly affects the midgut, the portion of the embryo from which the intestine develops. These insecticides act as microbial disruptors within the insect causing damage to their intestines.

MoA	Group	Mode of Action (Specific)
Nerve & Muscle	1	Acetylcholinesterase (AChE) inhibitors
Nerve & Muscle	2	GABA-gated chloride channel antagonists
Nerve & Muscle	3	Sodium channel modulators
Nerve & Muscle	4	Nicotinic acetylcholine receptor (nAChR) agonists
Nerve & Muscle	5	Nicotinic acetylcholine receptor (nAChR) allosteric activators
Nerve & Muscle	6	Chloride channel activators
Growth	7	Juvenile hormone mimics
Unknown	8	Miscellaneous non-specific (multi-site) inhibitors
Nerve & Muscle	9	Modulators of Chordotonal Organs
Growth	10	Mite growth inhibitors
Midgut	11	Microbial disruptors of insect midgut membranes
Respiration	12	Inhibitors of mitochondrial ATP synthase
Respiration	13	Uncouplers of oxidative phosphorylation via disruption of the proton gradient
Nerve & Muscle	14	Nicotinic acetylcholine receptor (nAChR) channel blockers
Growth	15	Inhibitors of chitin biosynthesis, type 0
Growth	16	Inhibitors of chitin biosynthesis, type 1
Growth	17	Moulting disruptor, Dipteran
Growth	18	Ecdysone receptor agonists
Nerve & Muscle	19	Octopamine receptor agonists
Respiration	20	Mitochondrial complex III electron transport inhibitors
Respiration	21	Mitochondrial complex I electron transport inhibitors
Nerve & Muscle	22	Voltage-dependent sodium channel blockers
Growth	23	Inhibitors of acetyl CoA carboxylase
Respiration	24	Mitochondrial complex IV electron transport inhibitors
Respiration	25	Mitochondrial complex II electron transport inhibitors
Nerve & Muscle	28	Ryanodine receptor modulators
Unknown	UN	Compounds of unknown or uncertain MoA

Modes of Action retrieved online at http://www.irac-online.org/modes-of-action/ April 2015.

[3] Procedure for allocation of new insecticidal materials to the MoA classification. Insecticide Resitance Action Committee. Retrieved 15 April 2015, from http://www.irac-online.org/documents/new-actives-for-moa-classification-procedure/?ext=pdf.

Herbicides:

Herbicides are the most common chemical application that a farmer will apply to the fields. These are used to reduce the amount of weeds that may out compete the desired plant. This may require three trips through the fields.

Herbicides are classified in three categories. The initial is by the weed/plant that is being treated. Structure and function of various weeds may be the same, which allows for the same herbicide to be used on multiple plants.

The second is the timing in which it is applied. It can be preplant incorporated (PPI) meaning that it is placed in the soil either as the crop is planted, or before the planting. It can be done premergence, indicating that the weed has not started to grow. Or it can be applied after the weed has been established. In this last application, the herbicide might be effective on contact or for systematic absorption.

The third way in which herbicides are classified are by the Mode of Action (MOA) and Site of Action (SOA). This is indicated in the table to the right.

Resistance to herbicides can occur. It is necessary for the farmer to keep this in mind. Not only is it necessary to implement a thoughtful crop rotation but it is also important to vary herbicides for effective weed management.

Group	Mode of Action
1	**ACC-ase Inhibitors (ACC):** blocks the activity of the Acetyl-CoA Carboxylase enzyme
2	**ALS Inhibitors:** Acetolactate synthase is an enzyme involved in the synthesis of several amino acids
3	**Microtubule Assembly Inhibitors:** Interfere with the organization of microtubules which are part of cell division and cell wall structure.
4	**Synthetic Auxins:** Interfere with plant growth by disrupting hormone balance and protein synthesis.
5	**Photosynthesis Inhibitors Binding Site A (PS2-A)**: Disrupt photosynthesis by blocking electron transfer in Photosystem II. (Different binding characteristics)
6	**Photosynthesis Inhibitors Binding Site A (PS2-B):** Disrupt photosynthesis by blocking electron transfer in Photosystem II. (Different binding characteristics)
7	**Photosynthesis Inhibitors Binding Site A (PS2-C):** Disrupt photosynthesis by blocking electron transfer in Photosystem II. (Different binding characteristics)
8	**Lipid Synthesis Inhibitors:** Multiple sites of action that inhibit lipid synthesis.
9	**EPSP Inhibitors:** Inhibits amino acid synthesis but in a different site and enzyme from the ALS-inhibitors
10	**Glutamate Synthetase:** Inhibits glutamine synthetase, a key enzyme in incorporating ammonium into amino acids.
13	**Carotenoid Biosynthesis Inhibitors:** Inhibits the synthesis of carotenoids, which protects chlorophyll from photo-oxidation.
14	**PPO Inhibitors:** Inhibit protoporphyrinogen causing the generation of singlet oxygen which is highly reactive and disrupts membranes, resulting in degeneration of plant tissue
15	**Cell Division Inhibitors:** Inhibit proper cell division.
19	**Auxin Transport Inhibitors:** Inhibit the flow of natural and synthetic Auxins, which are necessary for proper plant growth.
22	**Photosystem I Inhibitors:** Intercept electrons moving through Photosystem I, passing them to other compounds forming hydrogen peroxide, which disrupts cellular integrity.
27/28	**4-HPPD Inhibitors:** Inhibits the enzyme 4-HPPD which is involved in the synthesis of carotenoids.

Summarized from *Bulletin 789: Weed Control Guide for Ohio and Indiana.* The Ohio State University Extension and the Purdue Extension, Purdue University. pp 12-13

Fungicides:

A fungicide is a specific type of pesticide that controls fungal disease by specifically inhibiting or killing the fungus causing the disease. Diseases are a major source of crop and plant damage that can be caused by a number of plant pathogenic (disease-causing) organisms. Fungi are the number one cause of crop loss worldwide.[4]

As with the other pesticides that can be used, there are specific Modes of Action that are leveraged by the farmers. (Listed to the right) Each one of these has specific effects on the fungus that has infiltrated the crops. It is necessary for farmers to understand the risk and the resistance that is possible with each application.

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A: NUCLEIC ACID SYNTHESIS
B: MITOSIS AND CELL DIVISION
C: RESPIRATION
D: AMINO ACIDS AND PROTEIN SYNTHESIS
E: SIGNAL TRANSDUCTION
F: LIPID SYNTEHSIS AND MEMBRANE INTEGRITY
G: STEROL BIOSYNTHESIS IN MEMBRANES
H: CELL WALL BIOSYNTHESIS
I: MELANIN SYNTHESIS IN CELL WALLS
P: HOST PLANT DEFENSE INDUCTION
UNKNOWN MODE OF ACTION
MULTI-SITE CONTACT ACTIVITY

Retrieved from http://www.frac.info/docs/default-source/publications/frac-code-list/frac-code-list-2015-finalC2AD7AA36764.pdf?sfvrsn=4 15 April 2015

The most important thing that farmers can do is to create an integrated pest management practice that includes soil amendments, crop rotation, and diversity of pesticide applications (chemical, physical and biological). It is paramount for farmers to be able to identify the root cause of problems that they are seeing in the field and to understanding if these are biotic or abiotic symptoms. Timing of the action is also important. If the timing of the application is incorrect, it becomes money thrown away.

[4] What are Fungicides. The American Phytopathological Society. Retrieved 15 May 2015, from https://www.apsnet.org/edcenter/intropp/topics/Pages/fungicides.aspx

Reading Questions

1. Why have there been so many changes in the laws that govern pesticides?

2. What should be considered when applying a pesticide?

3. What are the primary modes of action when using insecticides?

4. Why would farmers want to apply a herbicide to their field?

5. When do farmers apply herbicides?

6. Do you see similarities in the MoA of fungicides as you do in herbicides and insecticides?

7. How can farmers decrease the likelihood of resistance from pesticides?