

KENTUCKY CERTIFIED CROP ADVISOR TRAINING MANUAL 2001-2002 VERSION



**Performance Objectives and General
Responses for the Kentucky Exam**

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INTRODUCTION

The International Certified Crop Adviser (ICCA) program is coordinated by the American Society of Agronomy. State or regional boards administer the CCA program in each state or region, respectively. The Kentucky CCA (KyCCA) Board is responsible for developing state-specific performance objectives and the Kentucky CCA exam. Performance objectives outline the knowledge base and skills that the KyCCA Board believes all Certified Crop Advisers practicing in Kentucky should possess. They are shown in bold font in the text below. Performance objectives, thus, are useful in determining areas of expertise that may be covered in the state exam. In addition, the performance objectives serve as an outline for continuing education once an applicant becomes a CCA.

This training manual is divided into four modules: (1) Nutrient Management; (2) Soil and Water Management; (3) Integrated Pest Management; and (4) Cropping Systems Management. Each module is further divided into competency areas and specific performance objectives within each competency area. Modules are updated, periodically, to keep the KyCCA program in step with changing trends and technology. Sample examination questions (**not** drawn from the KyCCA exam) are included for each of the four modules.

The main rationale for having a state-specific CCA performance objectives, continuing education, and exam is to address practices and situations that are not covered by the ICCA performance objectives and exam. This KyCCA Training Manual addresses the most important non-horticultural crops grown in Kentucky. These include: corn for grain and silage, forage grasses, forage legumes, soybean, tobacco, and small grains.

This material was compiled by Larry J. Grabau, Department of Agronomy, University of Kentucky, based on lectures delivered by the following UK faculty members during the first on-campus UK CCA training course in the spring of 1999: Kenneth Wells, John Grove, William Thom, Jim Thompson, Thomas Mueller, William Witt, Dennis TeKrony, Morris Bitzer, Robert Pearce, and Jimmy Henning (all of the Department of Agronomy); Lee Townsend and Monte Johnson (both of the Department of Entomology); and Donald Hershman and William Nesmith (both of the Department of Plant Pathology). The continuing input of each of these professionals to this training manual is gratefully acknowledged. As this is a first edition, careful readers are likely to encounter portions that need to be clarified, corrected, or otherwise improved. It is important that the training manual be continually updated and improved. Please send such suggestions to Wilbur Frye (wfrye@ca.uky.edu).

PART I: NUTRIENT MANAGEMENT

COMPETENCY AREA 1. Basics of soil fertility

1. Distinguish between elements essential for plant growth (listed below) and non-essential elements.

Carbon	Sulfur	Phosphorus	Iron
Hydrogen	Boron	Potassium	Manganese
Oxygen	Chlorine	Calcium	Molybdenum
Nitrogen	Copper	Magnesium	Zinc

These 16 elements are essential for the growth of all plants. On a practical level, this means that such elements are irreplaceable in their functional or structural roles. For example, carbon makes up a significant part of cellulose, the structural material in plant cell walls; nitrogen is an important constituent of all amino acids, which make up the proteins that carry out the cells enzymatic functions; and potassium is absolutely necessary to activate many of those enzymes.

Carbon, hydrogen and oxygen are present in the largest amounts. Carbon is fixed from carbon dioxide in the atmosphere; hydrogen and oxygen come primarily from the water drawn in through the plant's root system. Nitrogen, phosphorus, and potassium are referred to as "macronutrients" because they are required in relatively large amounts—most of the fertilizers sold around the world include one or more of these three elements. Leguminous plants (like soybean, red clover, and alfalfa) can acquire their N from N₂ gas through a symbiotic association with various soil bacteria. "Secondary" nutrients are calcium, magnesium, and sulfur. Plants require them in somewhat smaller amounts than the macronutrients. The other seven elements listed above are called "micronutrients" because they are required in relatively small amounts. For example, leguminous plants require small amounts of molybdenum to fix atmospheric nitrogen gas. In addition, nickel is required by some plants to allow certain enzymes to function.

2. Understand the ionic form in which essential elements are taken up by plants from the soil. Carbon comes into the plant as CO_2 , and is fixed by photosynthesis into organic (carbon-containing) compounds. Hydrogen and oxygen enter through the root system as H_2O . While nitrogen enters the plant root nodules as N_2 gas in leguminous plants like alfalfa and soybean, all of the other 12 essential elements enter the plant in the soil solution (water with dissolved nutrients) taken up by the root system. Nitrogen is taken up as the anion (negatively charged ion) nitrate (NO_3^-) or as the cation (positively charged ion) ammonium (NH_4^+). Phosphorus is absorbed mainly as primary orthophosphate (H_2PO_4^-), but can also be taken up as secondary orthophosphate (HPO_4^{2-}). Potassium is taken up as only as the monovalent cation K^+ . Calcium (Ca^{2+}) and magnesium (Mg^{2+}) are both taken up as divalent cations. Sulfur comes in only as SO_4^{2-} . Plants take up iron as mostly as ferrous ion (Fe^{2+}), but some is taken up as ferric ion (Fe^{3+}). Manganese (Mn^{2+}), copper (Cu^{2+}), and zinc (Zn^{2+}) come into plants in the divalent form. The remaining three elements are all taken up by plants primarily as anions: chlorine as chloride (Cl^-), molybdenum as molybdate (MoO_4^{2-}), and boron as borate (H_2BO_3^-) or as boric acid (H_3BO_3).

3. Define cation exchange capacity (CEC) and understand its units of measure.

Cation exchange capacity measures the amount of cations that can be held by a given weight of soil. The expression is in terms of moles of positive charge per unit mass of a soil. Since negatively charged soil particles naturally attract cations, the CEC of a soil will be directly related to the amount of negative charges present on its particles. The primary sources of negative charges in a soil are clay minerals and organic matter. The traditional unit for measuring CEC is as milliequivalents per 100 grams of soil (meq/100 g soil). Numerically, meq/100 g soil comes out the same as the more current unit used for CEC (centimole of charge per kg of soil [$\text{cmol}(-)\text{kg}^{-1}$ soil]).

4. Recognize the soil properties which affect CEC and the relationship of CEC to the following: (a) mobility of nutrients in the soil, and (b) plant availability of nutrients.

As stated above, soil organic matter level and clay content (along with the particular clay mineral present) will affect CEC. Per unit weight, organic matter has a greater charge density than clay, but most soils have much more clay than organic matter. In addition, some clay minerals carry far more negative charges than do other clay minerals. Mobility of nutrients is strongly affected by CEC. For example, cations are much less likely to be leached (moved downward with water) than are anions, since the CEC attracts cations toward the surfaces of soil particles. However, a high CEC is also good for plants, because as plants take up a particular cation, additional quantities of that same cation are released into the soil solution to maintain equilibrium between the soil solution and the CEC.

5. Understand the principles of the mineralization process and recognize the nutrients N, P, S, and B and their forms involved in that process.

To “mineralize” means to move from an organic form to an inorganic one. In this context, that means that nutrients contained soil organic material can be released (via the process of mineralization) as inorganic forms. Then, those inorganic forms are taken up by plants from the soil solution. In general, warmer soil temperatures and aerobic conditions favor mineralization. Most mineralization is accomplished by soil microbial enzymes.

For N, the primary organic forms present in soil are proteins and nucleic acids (DNA, deoxyribonucleic acid; and RNA, ribonucleic acid). Once these organic forms are decomposed by soil microbes, NH_4^+ is released. Sulfur is also found in proteins; in a soil system, it is generally mineralized to SO_4^{2-} . Phosphorus can be found in organic form as phospholipids and nucleic acids, and is mineralized to H_2PO_4^- or HPO_4^{2-} . Organic boron is generally released as boric acid (H_3BO_3).

6. Understand nutrient movement in soil and water and the effects of the following soil, nutrient, and climatic properties on movement: a) cation exchange capacity, b) soil texture, structure, and bulk density, c) soil pH, d) drainage (both surface and subsurface), e) nutrient form (cation vs. anion), f) rate of nutrient application, g) time of nutrient application, h) precipitation (both amount and distribution), i) irrigation, j) soil slope and crop residue cover, and k) season.

Water in soil is referred to as “soil solution,” since all such water contains dissolved nutrients, particularly in the forms of cations and anions. Thus, any time that water moves in the soil, nutrients are also moving. For example, earthworm channels can act as macropores, allowing rapid infiltration of incoming rainfall. However, those same macropores can therefore allow rapid downward movement of nutrients as well. Micropore water flow is much slower, but can also be quite important. Both crop producers and citizens share concerns about the loss of nutrients from soil systems. Crop producers are concerned, since nutrients lost to the soil will no longer be available to the plants they are attempting to cultivate. On the other hand, citizens are concerned about the appearance of such nutrients as contaminants in both ground and surface water. Thus, the nutrient movement of interest is anything that takes nutrients out of the rooting zone of plants. Leaching moves nutrients below the rooting zone, and runoff moves them off the surface away from the field. In both cases, crop producers may sustain an economic loss, since their soil is less fertile. In addition, those nutrients end up in groundwater (if leached) or in surface water (if moved by runoff); in both cases, the nutrients may now be undesirable contaminants of water. This is a particular concern with nitrate in groundwater and phosphates in surface water.

A high CEC helps slow cation leaching, since the cations are adsorbed to organic matter and clays. Soils with a greater number of macropores will be subject to greater leaching losses, since water will move more readily through such soils. (Of course, such soils will suffer less runoff, since more of the incoming rainfall enters the soil.) Platy soil structure, and soils with low macroporosity and/or high bulk densities (which impede gravitational flow of water) will cut down on leaching losses, but increase surface runoff. Soil pH can affect the amount of certain nutrients in soil solution; the more of a nutrient in solution, the more likely it will leach. Nutrients have different reactions to pH levels.

Easy surface drainage makes runoff nutrient losses more likely (but reduces leaching). Well-drained soils (referring here to internal drainage) are more likely to suffer leaching, but will generally have less of a runoff problem. In most Kentucky soils, the presence of a respectable CEC level (10 to 15 meq/100 g soil) improves the retention of cations important for plant nutrition. Higher rates of nutrient application, especially if they are made at a time when the crop is not rapidly taking up the nutrient, make leaching losses more likely. If heavy rainfall occurs at a time when plants are small, then runoff losses are likely to be great, except for soils under no-till management. Irrigation needs to be carefully managed, so that neither runoff nor leaching are aggravated. Steeper soils are more subject to runoff losses; leaving crop residues on the surface can reduce runoff (but may increase leaching). Natural losses of nitrogen to leaching will be greater in the spring season, as mineralization and nitrification processes are beginning, plant growth is generally modest, and incoming rainfall exceeds evapotranspiration.

7. Identify advantages and disadvantages of broadcast and banded fertilizer applications and determine the effect of the following on each method of application: a) tillage system, and b) soil test level.

Broadcast fertilizer is generally cheaper to apply, since it can be applied with fast-moving trucks or tractor-drawn spreaders. Banding will be advantageous on soils with low soil test levels, especially for nutrients like P and K (which are less mobile in soils than is N). Tillage system does not have a large effect on the response to banding.

Note: to get AGR-1 (Lime and Fertilizer Recommendations) on-line, go to <http://www.ca.uky.edu/agc/pubs/agr/agr1/agr1.htm>.

8. Interpret the management of, and determine the nutrients available from, materials other than fertilizers, including the following: a) manures, b) legumes, c) sludges, and d) by-products.

It is essential that a crop producer know the nutrient content of the material being applied. This is especially true for manures, sludges, and various by-products. With manure, animal species will also have an important influence on nutrient availability. Manure can provide N, P, and K, as well as most secondary nutrients, but not in the ratio often required by plants. In many cases, incorporating or injecting the manures or sludges may help make more of the nutrients available to plants. The primary nutritional contribution of legumes will be in the addition of nitrogen to the soil system, via their symbiotic fixation of N_2 gas from the atmosphere. This depends on just which legume you are raising, and whether the plant material is being removed as a crop or left in (or on) the soil as a cover crop.

It is also important to be more vigilant regarding soil nutrient availability. Growers should soil test more often when non-fertilizer nutrient sources are utilized. In the case of manures, current practice in animal feeding rations includes apparently excessive mineral supplementation. If growers continuously fertilize their soils with manure from such operations, remarkable buildups of nutrients such as phosphorus, copper, and zinc can occur.

9. Calculate fertilizer product needs based on nutrient rate recommendations and fertilizer analyses.

Both nutrient rate recommendations and fertilizer analyses in Kentucky are given in terms of N, P_2O_5 , and K_2O . The practical question here is if you can take a nutrient rate recommendation and give a crop producer an amount (and related pricing information) for the field. Probably the best way to handle this is to convert the fertilizer analysis to a “per ton” basis. For example, diammonium phosphate (DAP) has a fertilizer analysis of 18-46-0. To get to a per ton basis, multiply the analysis values by 20. Hence, DAP has 360 pounds of N and 920 pounds of P_2O_5 per ton. If the main question is how much DAP do I need to provide 60 pounds of P_2O_5 per acre to my 40 acre field, you would multiply 60 pounds P_2O_5 per acre by 40 acres to get 2400 pounds P_2O_5 needed. Then, divide that result by 920 pounds P_2O_5 per ton, and you get 2.6 tons of DAP.

Note: to be smooth with these sorts of calculations, you need to practice a lot. It is also important to use the factor/label method to make sure that you don't end up multiplying when you should be dividing or dividing when you should be multiplying.

COMPETENCY AREA 2. Soil pH and Liming

10. Define soil pH and interpret each of the following: a) pH scale, b) effect of soil pH on availability of plant nutrients, c) effect of soil pH on plant toxicity of elements in the soil, d) effect of soil pH on soil microorganisms, e) effect of fertilizer materials on soil pH, and f) suggested soil pH ranges for crop production.

Soil pH is the negative logarithm of the hydrogen ion concentration. A pH of 7.0 is referred to as a “neutral” pH, pH values above 7.0 are considered alkaline, and pH values below 7.0 are acidic. Since the scale is logarithmic, a change in pH of one unit reflects a ten-fold change in hydrogen ion concentration.

Plant nutrients react differently to changing pH levels. Iron, manganese, and zinc become more available as pH falls below 7.0, while calcium and molybdenum become more available as pH rises above 7.0. In general, the best pH for good general nutrient availability is around 6.5. The major toxic elements of interest in soils are aluminum and manganese. As pH falls below 5.0, aluminum concentrations in the soil solution rise dramatically, becoming toxic to plant roots. A more common pH-related toxicity is the influence of manganese on burley tobacco at pH levels below 5.5. Since the application of acid-forming nitrogen fertilizers (like urea and ammonium nitrate and other fertilizer salts) to tobacco fields can often cause solution pH levels to drop by a full pH unit, farmers are encouraged to lime their tobacco fields to a soil pH level of 6.6 (see AGR-1 at <http://www.ca.uky.edu/agc/pubs/agr/agr1/agr1.htm>). In general, most soil bacteria prefer a pH near neutral. However, soil fungi dominate microbial activity as soil pH falls below 6.0.

11. Understand the difference between soil pH and buffer pH and what each measures.

Soil pH (often referred to as “water pH”) simply measures the hydrogen ion concentration in soil solution. Buffer pH measures the ability of a soil to replenish the hydrogen ion concentration in soil solution. Buffer pH provides a more realistic estimate of the amount of lime that will be required to change soil pH to a desired level because it measures hydrogen in soil solution as well as the amount held on cation exchange sites. A soil with a lower buffer pH level will require more lime to raise its soil pH to the desired level.

12. Distinguish between liming practices and determine the effect of each of the following factors on limestone application rates: a) soil organic matter, clay content, texture, and cation exchange capacity, b) liming material and quality, c) depth and uniformity of incorporation, and d) cropping system.

The key point to good liming practices is regular testing of soil and buffer pH. Failing to apply needed lime can result in both poor nutrient availability and increased mineral toxicity. Applying lime when it is not needed wastes producer dollars, and can cause problems with elevated pH levels (for example, poor activity of certain herbicides, zinc deficiency in corn, or manganese deficiency in soybean).

Ideally, liming materials should be finely ground, pure, applied well in advance of the pH-sensitive crop to be planted, and thoroughly incorporated into the soil.

High organic matter and clay levels generally mean that a soil will be more strongly buffered and require more lime to correct low pH. Conversely, sandy soils tend not to be strongly buffered. A high CEC level coupled with a low soil pH will mean that a good deal of the sites on the cation exchange complex are occupied by hydrogen and aluminum ions; this combination will increase the lime requirement of the soil. Most liming materials are simply ground limestone; for example, dolomite [$\text{CaMg}(\text{CO}_3)_2$] or calcite (CaCO_3). These materials are effective in correcting low pH problems. Burned lime (CaO) is very caustic and hard to handle, but it reacts rapidly with the soil. Slaked lime [$\text{Ca}(\text{OH})_2$] is also somewhat difficult to handle, but does produce quick results.

Quality of a liming material is related to its composition, purity and the fineness to which it is ground. The CCE (calcium carbonate equivalent) expresses the purity of a liming material. Neutralizing capacity is related to both fineness and purity of a liming material.

The reaction of a liming material with a soil will be more rapid if the material is thoroughly incorporated into the soil. The main impact of cropping system is regarding the application of acid-forming nitrogen fertilizers. For Kentucky cropping systems including tobacco and corn, soil pH will have to be more closely monitored. On the other hand, legumes like alfalfa and soybean are more sensitive to low pH, because their nitrogen fixation is inhibited by pH values below 6.0.

Please see “When to Apply Lime and Fertilizer” by Kenneth Wells at <http://www.ca.uky.edu/agc/pubs/agr/agr5/agr5.htm>.

COMPETENCY AREA 3. Nitrogen

13. Understand the role of nitrogen in plants, including the following: a) essential functions, and b) mobility.

Essential functions of nitrogen in plants include its key role as part of the structure of both proteins and chlorophyll. If nitrogen is limited, less chlorophyll can be made by plants, and so photosynthetic rates decline. Proteins also require nitrogen; some proteins are for storage purposes (for example, in seeds), and other proteins have important roles as enzymes responsible for catalyzing specific biochemical reactions.

Nitrogen is quite mobile within plants. If nitrogen supplies are limited, plants will often translocate nitrogen compounds from older tissues to younger tissues. Also, grain plants usually move a good deal of the nitrogen from their leaves to their seeds as maturity approaches.

14. Recognize and interpret nitrogen deficiency symptoms in the following crops: a) tobacco, b) corn, c) small grains, and d) forage grasses.

Tobacco will show yellowing and eventually browning of lower leaves if it is deficient in nitrogen. Of course, since a nitrogen deficiency would cause such a serious economic problem for Kentucky growers, they apply large quantities of N fertilizers, and such deficiencies are rarely observed.

Corn shows similar symptoms; such deficiencies can occur when wet spring conditions prevent the application of nitrogen fertilizers on a timely basis.

Wheat has similar yellowing symptoms, and can show these symptoms whenever conditions prevent timely applications of needed nitrogen fertilizers.

Forage grasses likewise have a tendency toward yellowing of lower leaves with nitrogen deficiency.

All of the cereals tend to show yellowing near leaf midribs before leaf edges begin to yellow. For all of the above crops, nitrogen can be applied to the soil to help the plants recover. However, if a grower allows nitrogen deficiency to become visible, yield potential of the crop has most likely been diminished.

15. Understand the nitrogen cycle in soils and know the mechanisms and the nitrogen forms involved in each of the following processes: a) mineralization, b) nitrification, and c) immobilization. In addition, know the mechanisms and nitrogen forms involved in the following nitrogen loss pathways: a) leaching, b) denitrification, c) volatilization from soils, d) volatilization from plants, e) crop removal, f) soil erosion. Finally, understand the ideas behind the use of both nitrification and urease inhibitors.

It would be a good idea to pull out a soil science text to look over the nitrogen cycle in a graphical representation; that would help you see the relationships among the following processes. You should also refer to “Nitrogen in Kentucky Soils” at <http://www.ca.uky.edu/agc/pubs/agr/agr43/agr43.htm>.

Mineralization is the conversion of organic nitrogen (proteins and nucleic acids) to inorganic nitrogen in the form of ammonium (NH_4^+). This process is accomplished by various soil microbes.

Nitrification is the conversion of NH_4^+ to nitrite (NO_2^-) by *Nitrosomonas* bacteria and then of nitrite to nitrate (NO_3^-) by *Nitrobacter* bacteria.

Immobilization refers to the incorporation of inorganic forms of nitrogen (NH_4^+ and NO_3^-) into organic material, generally in the form of plant and microbial tissue.

Leaching refers to the loss of NO_3^- carried by water to a depth in the soil profile below the normal rooting zone of crop plants.

Denitrification is the conversion of NO_3^- to nitrogen-containing gases. In this process, nitrate is used as an electron acceptor by a wide range of anaerobic bacteria. Hence, nitrate is more likely to be lost this way when the soil is quite wet.

Volatilization losses of nitrogen primarily occur directly from the soil. A high soil pH shifts the equilibrium between NH_4^+ and NH_3 towards NH_3 . Some of this gaseous NH_3 may be lost to the atmosphere as the soil dries. If urea is applied to the soil, especially when the soil is warm, moist, and covered with residue, large nitrogen losses as ammonia can occur. Urease is an extra-cellular soil enzyme that catalyzes that transformation.

Crop removal, as opposed to other modes of nitrogen loss, is the main objective of crop producers. Higher crop yields means that more nitrogen is sold from the field as part of the plant product produced. Much of the crop removal will be as proteins (in both seeds and leaves) and chlorophyll (in leaves, especially in tobacco and forage crops).

Soil erosion will primarily remove soil organic matter and soil particles. Hence, this process will remove organic nitrogen as well as ammonium held on cation exchange sites in soil particles.

The idea behind both nitrification and urease inhibitors is to slow down specific nitrogen loss processes. In the case of nitrification inhibitors (for example, nitrapyrin), both *Nitrosomonas* and *Nitrobacter* are inhibited. As a result, more of the N remains as ammonium and less is converted to nitrate. Nitrate, of course, is subject to far more losses than is ammonium. Under Kentucky conditions, we do not often see a positive corn yield response to the use of nitrification inhibitors. In the case of the urease inhibitors (for example, NBPT), the idea is to slow down volatilization of NH_3 from urea fertilizers. This idea is quite effective, but the cost must be evaluated against the benefits.

16. Determine the relative plant availability of nitrogen from the following organic sources and interpret the effect of the C/N ratio on nitrogen availability: a) legume crops, b) non-legume crops, c) manures, d) sludges, and e) by-products.

In general terms, the wider (or higher) the C:N ratio, the lower the nitrogen availability to plants. That happens because when a high carbon substrate is added to the soil, soil microbes multiply on this new source of energy. However, if the substrate has relatively little nitrogen, the microbes will scavenge whatever N is available in the soil solution to support their growth. Often, they are “better” at doing this than are plant roots. As a result, the addition of such materials to a soil will often aggravate nitrogen deficiency symptoms of plants. Residues of legume crops, which fix their own nitrogen from the atmosphere, are generally higher in nitrogen levels than are non-legume crops. Manures vary in nitrogen content, but tend to be higher than are plant residues. By-products are quite variable in their nitrogen content.

17. Understand nitrogen uptake and nitrogen use efficiency by crops as influenced by: a) soil properties, b) rate of nitrogen fertilization, c) environmental conditions, and d) availability of other nutrients.

The efficiency of N fertilizer use by crops is directly related to the balance of nitrogen transformations (discussed in objective 15 above) as influenced by prevailing environmental conditions. For example, if a soil has a fragipan, internal drainage will be somewhat restricted. Under low evaporative demand conditions in the spring, that soil will tend to be wet, providing denitrifying bacteria with everything they need to denitrify fertilizer N. Also, a soil with a very high sand content will be subject to leaching losses, due to its lack of micropores. As environmental conditions and soil properties promote nitrogen losses, both nitrogen uptake and fertilizer use efficiency fall.

Higher nitrogen rates generally reduce the efficiency of N fertilizer use, since relatively less of the N can be put to use by the crop and relatively more of the N is lost to the environment.

If other nutrients are not available in adequate levels to support crop growth, then those nutrients will eventually become more limiting than is nitrogen. For example, forages growing on a low P site will be less responsive to added nitrogen fertilizer than would be forages growing on a high P site. The reduced response contributes to lower N use efficiency.

18. Recognize how cropping systems affect the rate of nitrogen fertilization.

Crop rotations including forage legumes will generally require lower amounts of nitrogen fertilization on the subsequent grain crop. For example, a Kentucky farmer planting corn after 3 years of alfalfa would need less applied nitrogen than would a Kentucky farmer planting corn after corn or corn after soybean.

Since no-till methods generally increase corn yield in Kentucky (due to better moisture conservation), no-till corn needs about 25 pounds more N per acre than does conventionally tilled corn. In addition, no-till corn may be subject to greater N losses to immobilization, leaching, and denitrification, so may need more N to satisfy the crop's needs.

19. Recognize the analysis, physical form, and handling precautions of each of the following nitrogen fertilizer materials and understand their effect on soil pH and nitrogen availability: a) anhydrous ammonia, b) urea, c) ammonium nitrate, d) UAN solutions, and e) ammonium sulfate.

Anhydrous ammonia (NH_3) is 82% N, is transported as a liquid under high pressure (released into the soil as a gas, so it must be injected), and quickly injures persons directly exposed to it.

Urea [$\text{CO}(\text{NH}_2)_2$] is 46% N, is applied to the soil as prilled fertilizer, and can be subject to substantial N volatilization losses, especially under warm, moist, high residue conditions. Such losses are related to the presence of the enzyme urease in soils (both within soil microbes and free in soil solution). Of course, any fertilizer containing NH_4^+ is subject to volatilization under high soil pH conditions.

Ammonium nitrate, NH_4NO_3 , (34% N) is applied to the soil as granular fertilizer, and it can be subject to caking in humid climates, since it is hygroscopic.

UAN solutions are varying liquid mixtures of urea and ammonium nitrate, contain between 28 and 32% N, and are commonly used to treat winter wheat with nitrogen in February and March. If conditions get too cold, these materials can “salt out,” forming precipitates in storage tanks.

Ammonium sulfate, $(\text{NH}_4)_2\text{SO}_4$, (21% N) is a highly hygroscopic, granular material and is often used when crop producers are trying to correct a sulfur deficiency along with applying some nitrogen.

Since all of these five N sources include some ammonia or ammonium, they will lower soil pH. Since ammonium nitrate and UAN solutions both contain some nitrates, they will lower soil pH to a lesser extent than the other three N sources. Nitrogen availability of these sources to crops is primarily affected by their relative N losses. If anhydrous ammonia is fall applied, a producer can expect some N losses over the winter. If urea is applied to warm, moist soils with high residue levels, a substantial amount of volatilization can be expected.

1. Distinguish between the advantages and disadvantages of each of the following nitrogen fertilizer materials in different soils, cropping systems, and tillage systems: a) anhydrous ammonia b) urea, c) ammonium nitrate, d) UAN solutions, and e) ammonium sulfate.

Anhydrous ammonia is generally favored because it has the highest available N content, resulting in lower shipping costs. Since it must be injected into the soil, this N form works better on soils that will quickly seal over the application slit. Sandy soils are somewhat more subject to ammonia losses with this N form. Since this material must be applied between rows, it is not used in forage crops. In a similar way, very little tobacco is treated with anhydrous ammonia, since the application equipment is less likely to be available in primary tobacco growing regions. Tillage is not a concern with this material.

Urea is a concentrated N source, which is advantageous, but it is subject to volatilization losses, making it less suitable for surface application to pastures or no-till cropping systems. It can be used with corn or tobacco.

Ammonium nitrate is quite easy to handle, but can “salt” burn corn or wheat plants when applied topdress to these crops. It is extensively used with tobacco and often with forage crops. Tillage is not a major issue for this N form.

UAN solutions are most often used with winter wheat, combined with streamer bars, which minimize leaf burn of the wheat, and help ensure a more uniform nitrogen application. Tillage is not a major factor for wheat, because temperatures are cool at the time of application. UAN should be injected into the soil when used in no-till corn production.

Ammonium sulfate is a solid, not extensively used in Kentucky cropping systems. If a grower has clear evidence of sulfur deficiencies, this N material would be a good choice.

COMPETENCY AREA 4. Phosphorus

2. Understand the role of phosphorus in plants, including the following: a) essential functions, and b) mobility.

Phosphorus is involved in photosynthesis (as part of phosphates attached to sugars), energy transfer (as part of adenosine tri-phosphate, ATP, a high energy molecule), and as part of nucleic acids. Phosphorus is quite mobile in plants, although not as mobile as is nitrogen.

3. Recognize and interpret phosphorus deficiency symptoms in the following crops: a) tobacco, b) corn, c) soybean, d) small grains, e) alfalfa, f) red clover, and g) forage grasses.

Note: If you are diagnosing P deficiency and fertilizer needs visually, you are likely to suffer substantial yield losses. It would be much more desirable to do soil tests and fertilize for a given crop based on established soil test recommendations.

Tobacco plants deficient in P will show flecks of yellowing on their leaves, dark green leaves, and severe plant stunting.

Corn plants deficient in P will show reddish purple coloring in their lower stems. Note: some corn hybrids have natural levels of the pigment that produces the purple coloring, but they will also show this trait to a greater extent with P deficiency.

Other plants will generally show stunting and dark green color when subjected to P deficiencies. Some will, like corn, show some purple color when P is limiting growth.

4. Recognize how each of the following factors affect phosphorus fertilization: a) soil properties, b) cropping systems, c) availability of soil phosphorus, d) soil test level, e) crop grown, and f) environmental concerns.

Soil properties that affect P fertilization rates are those that affect P retention and fixation. Important factors are related to both the quality and quantity of the surface area in the soil. With regard to quantity, the more clay present in the soil, the more surface area will be present, and that will force farmers to apply more P to get soil solution P up to desirable test levels. In addition, the type of clay is also important. Phosphorus retention is greatest on amorphous clays, followed by oxides, 1:1 type clays, and 2:1 type clays, in that order.

Soil pH also has a large effect on P availability. At a pH of 6.5, the best compromise between P precipitates with iron and aluminum and calcium is achieved. That is, at lower pH values, P is precipitated with Fe and Al; at higher pH values, P is precipitated with Ca.

The best example of a cropping system impact on P fertilization is that both P and K for our winter wheat/double crop soybean rotation are typically applied prior to wheat planting in the fall. The P recommendation is set in accordance with the wheat need for P; meanwhile, the K recommendation matches the soybean need for K.

Ideally, fertilizer P would only be applied as indicated by soil test recommendations. Unfortunately, some producers apply additional P even though their soil test recommends that no P be added. While such P is not likely to be lost from the soil, since P is relatively immobile in soils, it is a serious economic disadvantage to growers, especially when grain prices are low.

Clearly, some crops are more responsive to P availability than are others. Corn and wheat are especially responsive, while soybean and alfalfa are less responsive.

The major environmental concern with phosphorus is runoff of P containing soil, fertilizer, or manures into surface waters. That P becomes an environmental contaminant, and can lead to excessive algal growth and ultimately to eutrophication of surface water. No-till agriculture, and careful manure applications, can help minimize problems with P runoff.

5. Recognize how each of the following factors affect soil retention and fixation of phosphorus: a) soil clay, b) soil pH, and c) soil texture.

See answer to objective 23 above.

6. Recognize the analysis, physical form, handling precautions and phosphorus availability of each of the following fertilizer phosphorus materials: a) diammonium phosphate, b) monoammonium phosphate, c) triple superphosphate, d) ordinary superphosphate, and e) ammonium polyphosphate.

Diammonium phosphate (DAP) contains 18% N and 46% P_2O_5 . This P fertilizer is a solid.

Monoammonium phosphate (MAP) contains 10 to 12% N and 48 to 55% P_2O_5 . This P fertilizer is a solid.

Triple superphosphate (TSP) is a calcium phosphate that contains 46% P_2O_5 . This P fertilizer is a solid.

Ordinary superphosphate (SSP) is a mixture of calcium phosphate and calcium sulfate (gypsum) that contains about 20% P_2O_5 and 12% S. This P fertilizer is a solid.

Ammonium polyphosphates (APP) are liquid products made from the reaction between ammonia and superphosphoric acid; their common analyses are 10-34-0 and 11-37-0.

These materials are each relatively safe to handle (especially in comparison with N fertilizers). All are considerably more available to plants than is rock phosphate, which is the primary source of fertilizer P accepted for use by certified organic growers.

26. Distinguish between the advantages and disadvantages of each of the following phosphorus fertilizer materials in different soils, cropping systems, and placement in different tillage systems: a) diammonium phosphate, b) monoammonium phosphate, c) triple superphosphate, d) ordinary superphosphate, and e) ammonium polyphosphate.

Diammonium phosphate: Gives high pH when dissolved, so favored on more acid soils. Favored on crops with some early nitrogen requirement, but not favored for seed placement. Is favored for band placement to the side and below the seed.

Monoammonium phosphate: Gives low pH when dissolved, so favored on more alkaline soils. Favored on crops with less of an early N requirement, and is favored for seed placement as well as band placement. Can be used in all tillage systems.

Triple superphosphate: Gives low pH when dissolved, so favored on more alkaline soils. Favored on legume crops with no early N requirement and for applications to make up for P removal in perennial crops like alfalfa where no additional N is needed. Can be used in all tillage systems.

Ordinary superphosphate: Same as triple superphosphate, except that it is a mixture with gypsum. Not quite as readily available. Otherwise, same in all ways as triple superphosphate.

Ammonium polyphosphate: This material is available in several N:P₂O₅ ratios, but all are only as liquids. Used primarily in fertigation, weed and feed, and seed-placed applications. Not often used simply as broadcast P fertilizer because of greater P fixation. Probably would be better in no-till because of surface application without incorporation would limit fixation. Not usually used with legumes.

27. Understand the use of soil tests for phosphorus and interpretation of soil test values.

The most common soil test for phosphorus is the Bray I. In Kentucky, the Mehlich III extraction is now standard practice. Soil test levels can be expressed in terms of parts per million; however, they are often broken into the following categories: very low, low, medium, high, and very high. The probability of a yield response to added P falls as the initial soil test level for P rises. For example, it would be very unlikely that a producer who applied fertilizer P to a “high” testing soil would see any yield response.

It is important to use the appropriate calibration for the crop of interest. Some crops (for example, corn and wheat) respond to higher levels of P availability than others (for example, soybean and alfalfa). Producers need to be sure to do a good job of taking soil samples because of random variation in the field. Soil test values are not absolute measures of plant available soil P; rather, they are relative indices of the soil's ability to supply P.

COMPETENCY AREA 5. Potassium

28. Understand the role of potassium in plants, including the following: a) essential functions, and b) mobility.

Essential functions of K in plants include: protein synthesis, carbohydrate metabolism, ionic balance, and disease resistance. Perhaps the most important role is that potassium is required to activate a large number of plant enzymes, all of which are essential to plant function. Potassium is quite mobile in plants; as a result, its deficiency symptoms tend to show up first in older tissues.

29. Recognize and interpret potassium deficiency symptoms in the following crops: tobacco, corn, soybean, small grains, alfalfa, red clover, and forage grasses.

In general, potassium deficiency appears as yellow/brown discoloration starting at the edges of leaves. In cereal grasses (like corn), this deficiency will first begin to appear near the tips of leaves. Specific examples of K deficiency symptoms include: “shothole” problems with tobacco leaves, lodging of corn plants (due to weakened stems), and white flecking near leaf margins of both alfalfa and red clover.

30. Recognize how each of the following factors affect soil retention of potassium: a) CEC and b) soil texture.

As CEC rises, more potassium can be held on the cation exchange complex. Soils with relatively high levels of clay will tend to retain larger amounts of potassium. Of course, CEC and clay content of soils are related factors.

31. Recognize how each of the following factors affect potassium fertilization: a) soil properties, b) availability of soil potassium, c) soil test level, d) cropping system, e) tillage system, and f) crop grown.

The main soil properties affecting how K fertilizers are managed include soil texture and clay type. Some leaching of K can occur in sandy or organic soils; however, relatively few of these soils are found in Kentucky. Clay mineral is more important; K can be bonded in exchangeable, internal, and planar positions. Potassium in the planar position is relatively more available. So, clay minerals with relatively more K binding sites in the planar position will have higher K availability.

Availability of soil K and soil test levels of K will be discussed in item 33.

Potassium for double crop soybean is often applied prior to planting winter wheat, since soybean is more responsive to added K than is wheat, and since K is not subject to substantial losses from the soil system. Farmers planting corn into cool soils have seen some benefits to banding K; however, the benefit of banding K under Kentucky conditions has been minimal.

Tillage system seems to have little influence on crop response to added potassium. While most important Kentucky crops are quite responsive to added K on soils with soil test K values in medium or lower ranges, that response does depend on crop. Soybean, alfalfa, and corn are especially responsive to added K.

32. Recognize the analysis, physical form, handling precautions, potassium availability, and relationship to chloride in soils of each of the following potassium fertilizer materials: a) potassium chloride, b) potassium sulfate, and c) potassium nitrate.

Potassium chloride (0-0-60), also referred to as “muriate of potash,” is solid and is quite soluble. For Kentucky tobacco growers, KCl is a poor potassium source, since tobacco plants will readily take up the added chloride. Tobacco leaves with a high Cl concentration have dramatically lower quality. Except for tobacco, KCl is the most popular K source, primarily because of its relatively high K₂O analysis.

Potassium sulfate (K₂SO₄; 0-0-50) also provides about 17% sulfur. However, its main role in Kentucky agriculture is as a K source for tobacco fields. Like KCl, potassium sulfate is quite soluble and, therefore, quite available.

Potassium nitrate, KNO₃, (13-0-44) provides some nitrogen, in addition to being a substantial source of potassium. It is a soluble solid, and quite available to plants. This material receives only limited use in Kentucky crop production due to its higher relative price.

Since the salt index is high for all of the above K sources, these fertilizer materials cannot be applied in close proximity to crop seeds except in small amounts. Each of these solid materials is relatively safe to handle; eye protection and layered clothing are a good idea, however, since the salty dust can burn both eyes and damp skin surfaces.

33. Understand the use of soil tests for potassium and interpretation of soil test values.

Ammonium acetate extraction of potassium is most often used to measure soil K availability; however, Kentucky uses the Mehlich III procedure. As with phosphorus, potassium soil test levels are often reported as very low, low, medium, high, and very high. Soils with test values at high and very high for potassium are not likely to show a significant yield response to added potassium fertilizers.

COMPETENCY AREA 6. Secondary and micronutrients

34. Identify plant deficiency symptoms of each of the following secondary and micronutrients in tobacco, corn, soybean, alfalfa, red clover, and small grains and recognize soil properties and nutrient interactions affecting their availability to plants: a) magnesium, b) sulfur, c) zinc, d) iron, e) boron, f) manganese, and g) molybdenum.

Plant deficiency symptoms for magnesium are rarely observed in Kentucky. Typically, older leaves will show yellow discoloration between veins; then as the deficiency symptoms worsen, reddish-purple coloring will begin to appear at the outer leaf edges.

Sulfur deficiency is rarely observed in Kentucky soils. For tobacco, the use of potassium sulfate eliminates any risk of S deficiency. With other crops, native soil levels of S, supplemented by S contained in rainfall, is nearly always adequate for crop growth. Deficiency symptoms would include leaves turning yellow, starting from the youngest leaves first.

Zinc deficiency is sometimes seen with corn in Kentucky soils with high soil pH and high levels of available phosphorus. Symptoms include broad white to yellow bands along the leaves on each side of the leaf midrib. In addition, plants may be stunted due to shortened internodes. Since Zn is more available as pH falls below 7.0, its deficiency symptoms are more likely to show up in fields with pH levels at or above 7.0.

Iron deficiency causes leaves to be yellowish colored, starting from the interveinal area. In soybean, iron deficiency is much more likely with pH levels over 7.0. However, this problem is relatively rare in Kentucky.

Boron can cause yellowing of leaves near the terminal growing points, and the growing points themselves can turn white or light brown as they die. The only current application of B to Kentucky crops is on alfalfa; however, rates must be kept low, since some other crops can be injured by excessive levels of soil B.

Manganese can be deficient in soybean on high organic matter, high pH soils. Leaves will show interveinal chlorosis that appears yellowish-gray to reddish-gray with veins remaining green.

Molybdenum is involved in nitrogen fixation, so is important for crops like alfalfa and soybean which fix atmospheric nitrogen. This is a key reason why alfalfa and soybean growers need to keep their soil pH above 6.0, since Mo availability drops rapidly with pH values below 6.0. Young leaves wilt and die back along their margins. Older leaves will turn yellow in these plants because N supply may be inadequate. Molybdenum is also important in crops such as tobacco as part of the enzyme system that converts nitrate to amino acids. Deficient tobacco plants will show leaf mottling with bending and twisting of the leaf lamina at mid-stalk leaf positions. The small necrotic areas in the leaf will enlarge until the entire leaf is withered.

35. Identify plant toxicity symptoms of each of the following elements in tobacco, corn, soybean, alfalfa, red clover, and small grains and recognize soil properties and nutrient interactions affecting their availability to plants: a) aluminum, b) manganese, and c) boron.

Aluminum toxicity is evidenced primarily by poor root growth, which of course, results in poor shoot growth. Leaves of cereal grasses may show a combination of gray, purple, or tan lesions between veins.

Manganese toxicity is an important issue for burley tobacco growers in Kentucky. Soil pH levels below 5.5 can result in very high levels of available soil Mn, and tobacco plants will have dramatic interveinal chlorosis, resulting in low yields and poor quality. This toxicity costs Kentucky tobacco growers more money than any other nutrient problem.

Boron toxicity can result with excessive B applications—many plants will simply die if too much soil B is available.

36. Distinguish between methods of correcting secondary and micronutrient deficiencies or toxicities as well as the advantages and disadvantages of each of the following practices: a) foliar application, b) soil application, and c) adjusting soil pH.

Foliar applications of liquid fertilizers are intended to rapidly correct deficiency symptoms, and can help to some extent for iron and manganese deficiencies in soybean, and perhaps in a few other cases. In general, soil applications are more likely to result in a positive response (in the long run) than are foliar applications. However, sometimes growers are unable to apply fertilizers to the soil once they discover the nutrient deficiency.

A far more important strategy to correct both nutrient deficiencies is to manage the soil pH carefully. For example, molybdenum deficiency in alfalfa and manganese toxicity in tobacco are both much less likely if soil pH is near 6.8 at the start of the growing season.

COMPETENCY AREA 7. Soil and plant sampling analysis

37. Understand University of Kentucky recommended soil sampling and handling procedures and the effect of the following factors on soil test results and interpretations: a) time of sampling, b) depth of sampling, c) frequency of sampling, and d) sampling density (number per acre).

Soil samples can be taken at any time during the year; however, for crop farmers, sampling is much easier when the crop is not in the field. In general, sooner is better than later, especially if you are concerned about soil pH. Since many growers sample in February and March, fall sampling will often result in quicker turn-around of soil samples.

In tilled fields, sampling depth should be 6 to 8 inches; in no-till fields (and pastures), sampling should be 3 to 4 inches deep.

Sampling every year would be ideal; however, sampling every two to four years in the crop rotation can work, provided careful records are kept, and management practices are employed to anticipate problems. In the case of a high value crop like burley tobacco, which is subject to a serious manganese toxicity problem if soil pH falls below 5.5, annual soil testing is highly recommended.

A random sample of 10 to 30 separate cores should be taken to represent field sizes up to 20 acres. Producers need to have a clear idea of how their fields vary, and to sample areas of their fields which are dramatically different (say eroded hillsides) separately. Of course, the assumption here is that the grower has the ability and time to spatially manage soil fertility according to changing soil test results.

38. Understand the underlying principles of each of the following philosophies of soil test interpretation and recommendations for fertilization: a) sufficiency, b) buildup and maintenance, and c) basic cation saturation ratio.

A good reference here is “Soil Testing: What it is and what it does” found at:
<http://www.ca.uky.edu/agc/pubs/agr/agr57/agr57.htm>.

The sufficiency philosophy recommends nutrients to be applied according to the needs of the current crop. The focus is on keeping soil fertility just high enough to meet the needs of a grower’s crop. As a result, this approach may often call for lower rates of nutrient application.

The buildup and maintenance approach attempts to push soil test levels up to the high or very high level for P and K, and then apply fertility each season according to the amounts removed by the crop being grown. It is clear that this philosophy requires higher rates of fertilization; however, it is not clear that the cost of the additional fertilizer applied will be returned to the grower in added crop yields.

The basic cation saturation ratio philosophy attempts to adjust the quantity of the monovalent and divalent cations adsorbed on the soil's cation exchange complex. Such adjustments have been found to be poorly related to crop growth responses.

39. Interpret laboratory test reports and the soil and plant test results they contain: a) degree of nutrient deficiency and adequacy, b) expected crop response to applied nutrients, c) units of measure and conversion between different units, and d) reliability.

Growers are encouraged to take soil and plant samples at the same time; this will often make interpretation of the results much easier. Provided sampling of the calibrated plant part is done at the calibrated growth stage (see objective 40), tissue concentrations associated with nutritional sufficiency have been established for most important Kentucky crops. If plant nutrient levels are below the critical value for that nutrient in that crop, producers can expect a response to additions of the deficient nutrient. Of course, the amount of the response will depend on just how deficient the plant was in the first place, the method of application, and any other environmental factors which may be affecting nutrient uptake. At concentrations, above the critical level for a nutrient, no yield response can be expected.

For macronutrients and secondary nutrients, plant tissue sample results are generally reported as a percentage of plant dry matter (for example, 4.1% N). Micronutrient values are generally reported in parts per million parts of plant dry matter (for example, 4.1 ppm Zn).

The biggest issue to remember is that tissue nutrient concentrations may not reflect soil nutrient availability. Drought, compaction, excessive wetness, and soil acidity are only a few of the reasons that plants may not contain the nutrients available in the soil.

40. Identify the plant parts to sample and the time to sample (calibrated plant growth stage) when determining the nutrient status of the following crops by plant analysis: a) tobacco, b) corn, c) soybean, d) alfalfa, e) red clover, f) small grains, and g) forage grasses.

Tobacco should be sampled before bloom, and the uppermost fully developed leaf should be taken.

Corn should be sampled when 50% of plants have their silks just beginning to emerge. The ear leaves should be sampled.

Legumes (soybean, alfalfa, and red clover) should be sampled when 10% of the plants have blooms. The uppermost mature leaves of soybean should be sampled. In the case of both alfalfa and red clover, the upper one-third of the plant should be collected.

Wheat (and barley) should be sampled when 25% of the plants have headed; the flag leaf is the plant part to collect.

For forage grasses, collect the upper 6 inches of the plant at the time that it would be harvested for optimum forage quality.

Nutrient Management

Sample questions for Kentucky Certified Crop Advisor exam.

- ___ 1. If a tobacco field is diagnosed with manganese toxicity symptoms, the best thing a farmer can do is: a) apply foliar manganese. b) disk up his plants and wait until next year. c) apply extra nitrogen fertilizer to help the plants out-grow this toxicity. d) be sure to correct the soil pH before planting his tobacco next year.
- ___ 2. Which of the following crops would be most likely to respond to potassium applications? a) tobacco b) soybean c) corn d) alfalfa.
- ___ 3. How does CEC influence plant availability of a nutrient present in the soil solution as a cation? a) It has no effect at all. b) As CEC increases, plant availability declines. c) As CEC increases, plant availability improved. d) CEC only affects cation availability to legumes growing in the soil, but does not affect availability to other kinds of plants.
- ___ 4. A soil has poor P availability. How will this affect the observed response to added nitrogen fertilizers? a) Not at all, since these two nutrients are independent. b) Since few plants need large quantities of P, it will have an effect only for those plants. c) Nitrogen response will be limited by the inadequate P supplies. d) Actually, nitrogen response is even more obvious when P is limited.
- ___ 5. In scientific language, cation exchange capacity (CEC) is expressed in milliequivalents/100 g soil. If a farmer's soil test says that her soil has 142 ppm of potassium, how many pounds/acre of potassium does her soil have? a) can't calculate pounds/acre from ppm b) 284 pounds/acre c) 71 pounds/acre d) 142 pounds/acre e) 568 pounds/acre.
- ___ 6. For no-till corn, why is a slightly higher rate of N fertilizer recommended? a) because N losses to immobilization and denitrification are higher in no-till systems. b) because yields tend to be lower in no-till systems, and the extra N helps get around that problem. c) because organic matter breaks down rapidly under no-till, and extra N helps replenish this critical organic reserve. d) because the fertilizer associations want to sell more nitrogen fertilizer.
- ___ 7. Which element can be taken up by plants as either an anion or a cation? a) nitrogen b) sulfur c) calcium d) manganese e) chlorine.
- ___ 8. The form in which nitrogen exists at the start of its mineralization process is: a) as amino acids b) as part of soil organic matter c) as ammonium d) as nitrate.
- ___ 9. Which of the following elements is NOT essential for plant growth? a) copper b) iron c) molybdenum d) silicon e) potassium.
- ___ 10. At which stage should you take samples for plant analysis of corn? a) early vegetative b) late vegetative c) one-half of plants beginning to silk d) at complete maturity.
- ___ 11. Aluminum toxicity is most likely to be a problem when: a) farmers apply too much of this essential plant nutrient. b) soil pH is very low. c) inadequate amounts of nitrogen have been supplied to the plants. d) a liming material with high aluminum levels was used to correct low pH conditions.

- ___ 12. For which agricultural chemical phase would layers of clothing be advised? a) liquid b) solid c) gas d) all three phases require this protection.
- ___ 13. Potassium can be fixed on soil clays in three different positions: edge, internal, and para. Which position is most likely to be released to soil solution? a) edge b) internal c) para d) none of these are ever released to soil solution.
- ___ 14. Which type of clay mineral would have the highest P retention? a) amorphous clays b) oxides c) 1:1 clays d) 2:1 clays.
- ___ 15. You see tobacco plants that are dark green, severely stunted, and have yellow flecks in lower leaves. What is the likely culprit? a) blue mold b) excess nitrogen c) inadequate soil phosphorus d) residual herbicide from a previous corn crop.
- ___ 16. Which of the following nitrogen forms would cause the largest drop in soil pH? a) anhydrous ammonia b) ammonium nitrate c) ammonium sulfate d) calcium nitrate.
- ___ 17. What factors cause ammonium in the soil to be mineralized to nitrate? a) Cool soils are essential for this process to occur. b) A pair of soil bacteria is responsible for this reaction. c) Wet soil conditions greatly enhance this process. d) This process is actually driven by exudates from plant root systems.
- ___ 18. The scenario under which banded starter fertilizer is most likely to benefit corn is: a) no-till, early planted, low soil test b) no-till, late planted, high soil test c) conventional till, early planted, low soil test d) conventional till, late planted, high soil test.
- ___ 19. The most common uptake form of potassium is as: a) K^{++} b) K^+ c) K^- d) K^- .
- ___ 20. What is the main reason for doing plant analysis? a) to decide how much fertilizer to apply next year. b) to see if the folks you hired to spread fertilizer put on as much as you paid them to apply. c) to accurately diagnose nutrient deficiencies. d) to identify disease and insect pathogens present in your fields.
- ___ 21. Which of the following statements are true about sulfur in Kentucky soils? a) Our soils receive about 10 to 15 pounds/acre of S in rainfall every year. b) Soil tests for sulfur have become quite accurate. c) Sulfur is primarily taken up as a divalent cation. d) all of the above.
- ___ 22. What potassium form must tobacco growers avoid? a) potassium sulfate b) potassium nitrate c) potassium chloride d) potassium borate.
- ___ 23. If you are deciding how much P and K to apply to winter wheat, and you plan to double crop soybean the following summer, how should you decide how much P and K to apply? a) Use the P recommendation for wheat, but use the K recommendation for soybean. b) Use the K recommendation for wheat, but use the P recommendation for soybean. c) Use both P and K recommendations for wheat, since wheat requires higher levels of both nutrients. d) Use both P and K recommendations for soybean, since soybean requires higher levels of both nutrients.
- ___ 24. How does soil pH affect P availability? a) P is most available to plants at a pH of about 6.5. b) As soil pH falls below 6.0, P availability increases. c) Fortunately, P availability is entirely unrelated to soil pH. d) As soil pH increases above 7.0, P availability goes up dramatically.

- ___ 25. The bad thing about using urea as a nitrogen source for no-till corn is: a) it can't possibly provide enough N. b) it burns corn leaves severely. c) it is subject to significant losses through the process of volatilization. d) it lowers soil pH much more than does anhydrous ammonia. e) it is generally the most expensive per unit of N provided.
- ___ 26. What is the key advantage of anhydrous ammonia over other forms of nitrogen? a) It is the safest compound for applicators. b) It is the most available to plants. c) Since it has the highest analysis, it is often the least costly form of nitrogen. d) It is well known to prevent nitrate leaching.
- ___ 27. Of the three macronutrients, which is most mobile within crop plants? a) nitrogen b) phosphorus c) potassium d) all of them are similarly mobile.
- ___ 28. How many tons of ammonium nitrate (34-0-0) would be required to deliver 300 pounds of N per acre to 40 acres of tobacco? a) 5.3 b) 11.8 c) 17.6 d) 22.5 e) 31.4.
- ___ 29. Besides C, H, and O, which of the following are essential elements required in the largest amounts? a) copper, cobalt, and cesium b) nitrogen, phosphorus, and potassium c) zinc, chlorine, and boron d) calcium, magnesium, and manganese e) iron, zirconium, and rubidium.
- ___ 30. If you are getting a soil sample for a soil test, how deep should you take your samples? a) 3 inches, b) 6 inches, c) 9 inches, d) 12 inches, e) 15 inches.
- ___ 31. Soil solution levels of calcium are dependent on: a) soil pH b) how much clay is present in the soil c) what type of clay is present in the soil d) all of the above.
- ___ 32. Roles of potassium in plants include: a) a key component of all plant membranes b) a structural unit in plant proteins c) an important factor in helping balance negative charges in transported nutrients d) part of ATP.
- ___ 33. A fertilizer with an analysis of 0-46-0 would be: a) diammonium phosphate b) muriate of potash c) ammonium polyphosphate d) triple superphosphate e) urea.
- ___ 34. If you are concerned about a deficiency of a relatively immobile plant nutrient, in what part of the plant should you look first? a) the roots b) the lower stem c) older, more mature leaves d) newly emerging leaves and buds.
- ___ 35. Nitrogen use efficiency by cereal crops is: a) reduced if N application rates are excessive. b) reduced if soils are consistently water-logged. c) reduced if other nutrients are in short supply. d) all of the above.
- ___ 36. If your corn was nitrogen deficient, what symptoms should you be able to see? a) wilting of all leaves due to poor control of stomates b) yellowing of lower leaves c) purple color appearing on the lower stem d) interveinal chlorosis on upper leaves.
- ___ 37. Keeping pH up close to 7.0 so that molybdenum is reasonably available is most important for which plant? a) tobacco b) corn c) tall fescue d) alfalfa e) lespedeza.
- ___ 38. When pH changes from 7.0 to 6.0, how much has the hydrogen ion concentration changed? a) It has increased by 14%. b) It has increased 10 fold. c) It has decreased 10 fold. d) It hasn't changed at all, since pH and hydrogen ion concentration are unrelated.

- ___ 39. How many pounds/acre of diammonium phosphate (18-46-0) should be applied to achieve a desired P_2O_5 application rate of 40 pounds/acre? a) 45 b) 90 c) 135 d) 180 e) 225.
- ___ 40. The plant part to sample for plant nutrient analysis of tobacco is: a) the lower stem b) floral structures just before topping c) the uppermost fully developed leaf d) the primary root.
- ___ 41. If a farmer's soil tests very high for potassium, she should: a) apply 60 pounds of K per acre b) not apply any K at all c) only apply K if it were cheaper than usual d) apply a complete fertilizer to take advantage of the extra K.
- ___ 42. Alfalfa plants with white flecks near the edge of its leaflets are most likely to be deficient in: a) phosphorus b) chlorine c) nitrogen d) potassium e) boron.
- ___ 43. Which of the following can affect optimal P fertilization rates? a) environmental concerns b) initial soil test level c) cropping system utilized d) soil textural class e) all of the above.
- ___ 44. When tobacco transplants are set in relatively cool soils in the spring, which nutrient deficiency may show up temporarily, even if soil nutrient levels are high? a) calcium b) phosphorus c) potassium d) manganese e) nitrogen.
- ___ 45. Which sort of organic residues would provide the best nitrogen availability to a subsequent crop? a) legume crop residues b) poultry manure c) non-legume crop residues d) straw.
- ___ 46. Denitrification would be highest under which set of conditions? a) no-till management, wet season, poorly drained soil b) no-till management, dry season, well drained soil c) conventional tillage, wet season, poorly drained soil d) conventional tillage, dry season, well drained soil.
- ___ 47. Phosphorus is most available to plants at a pH of _____. a) 4.5 b) 5.5 c) 6.5 d) 7.5 e) 8.5.
- ___ 48. Just what does "buffer pH" mean? a) the ability of a soil to replenish H^+ in the soil solution b) the same thing as water pH c) the pH of a soil after recommended nutrients have been added d) the titration response of a weak acid like acetic acid.
- ___ 49. Under which condition would you expect nutrients to move most quickly to ground water? a) The nutrient is a cation. b) All of the nutrient is applied when the plants are very small. c) Rainfall is lighter than normal. d) The soil is a clay loam.
- ___ 50. The tendency of some plants to take up nutrients in excess of their own requirements is known as: a) luxury consumption b) poverty adjustment c) critical confinement d) nutrient scavenging.

Key for Kentucky CCA Practice Exam Nutrient Management

1. D	11. B	21. A	31. D	41. B
2. D	12. B	22. C	32. C	42. D
3. C	13. C	23. A	33. D	43. E
4. C	14. A	24. A	34. D	44. B
5. B	15. C	25. C	35. D	45. A
6. A	16. A	26. C	36. B	46. A
7. A	17. B	27. A	37. D	47. C
8. B	18. A	28. C	38. B	48. A
9. D	19. B	29. B	39. B	49. B
10. C	20. C	30. B	40. C	50. A

PART II: SOIL AND WATER MANAGEMENT

COMPETENCY AREA 1. Soils and landscapes

1. Recognize that soil surveys provide a soil resource inventory for each county: a) natural drainage classes, b) soil depth, c) soil slope, d) parent materials, and e) influence of natural vegetation.

Natural soil drainage classes are: excessive, somewhat excessive, well, moderately well, somewhat poorly, poorly, and very poorly. Most Kentucky crops are produced on land that falls into the well, moderately well, and somewhat poorly drainage classes.

Each soil survey also provides measurements of the depth of major soil horizons. This is of particular interest in predicting the water holding capacity of soils, and thus their ability to provide water to growing crops during dry periods.

Each soil series with some degree of slope has a letter attached to its symbol; for example, an MaB soil series would be a Maury silt loam, 2 to 6 percent slopes. Letter assignment to a given range of slopes depends on the particular soil series of interest. The importance of slope is that it influences directly the potential for water erosion of topsoil because it influences the partitioning of rain water between infiltration and runoff.

Primary parent materials in Kentucky are bedrock, alluvium, colluvium, and loess. Bedrock is limestone, sandstone, shale, or siltstone. These parent materials give rise to soils that are silty (loess or alluvium), sandy (sandstone), or clayey (shale or limestone). Of course, these broad textural classes have large influences on the properties of the resulting soils. Another example of the importance of parent material is that the geology of the central Bluegrass provides soils with very high native levels of phosphorus.

Natural vegetation has a large impact on the depth and amount of soil organic matter. For example, prairie soils, with perennial grasses as their dominant vegetation, will have deeper topsoil with higher organic matter contents, and are referred to as Mollisols. In contrast, deciduous forest soils have thinner topsoils with lower organic matter content and a more highly structured subsoil, and are called Alfisols or Ultisols. In both cases, the native vegetation, along with long-term climatic conditions, has a considerable influence on soil development.

2. Understand the relationships among the following: a) soil series, b) soil type (consociation), and c) soil map unit.

A soil series is a group of soils that have very similar profiles. However, soil phases describe differences within a particular soil series. Those differences can include the texture of the surface layer, the texture of underlying layers, slope, stoniness, salinity, wetness, and erosion. From the example given in the answer to objective 1 (see above), “Maury silt loam” is the soil series, and MaB is a phase of that soil series with the difference from other phases being its slope.

Soil types or consociations are a mapping unit consisting of at least 50% of a primary soil series along with a closely related soil series.

A soil mapping unit is a unique natural arrangement, and includes a typical pattern of soil series within its boundaries. Soil mapping units can be consociations (see above), complexes, associations, or undifferentiated soil groups. Complexes and associations are mapping units of dissimilar soil series. In the case of a complex, the components cannot be separately mapped on a scale of 1:24,000. In the case of associations, the component soil series can be separately mapped on that scale.

3. Recognize general management considerations associated with different soil parent materials (loess, limestone, shale, sandstone, colluvium, alluvium, etc.): a) texture, b) bulk density, c) water relationships, d) landscape shape and position, and e) erosion potential (both water and wind).

Loess materials are high in silt content, because they are wind-transported materials deposited on the surface of previously existing soils or parent materials. Typically, loess depths are highest near the downwind side of ancient river beds. Soil fertility is generally greater for soils that have a thicker loess layer. Bulk density is relatively low. Loess can occupy a multitude of landscape positions, but may have been eroded away from shoulder slope areas. Such soils are generally subject to water and wind erosion, due to their high silt content.

Because shale parent material produces a high clay soil, it tends to have a higher bulk density and to hold a good deal of water (although much of that water may not be available to plants). Shale can be found in a variety of landscape positions.

Sandstones give rise to sandy soils. Such soils have low bulk densities, and hold relatively little water (since pore sizes tend to be too large to hold water against the force of gravity). Landscape positions vary. Erosion with wind can be a problem in dry climates; however, this rarely occurs under Kentucky’s humid climatic conditions.

Colluvium is parent material which has been moved down a slope by the force of gravity. These soils are of minor significance for crop production, and are of limited extent in Kentucky. Bulk density of these materials is relatively high; however, water holding capacity can be limiting in stony areas. Most colluvial soils are found in relatively steep areas, and are therefore readily subject to water (but not wind) erosion.

COMPETENCY AREA 2. Soils properties

4. Define soil structure and determine its relationship to each of the following: a) crop growth and production, b) tillage and cropping system, c) soil organisms, and d) soil drainage.

Soil texture refers to the percentages of sand, silt, and clay in a soil. Sand particles are between 0.05 and 2.0 mm in diameter, silt particles are between 0.002 and 0.05 mm in diameter, and clay particles are less than 0.002 mm in diameter. The relative amounts of each size classification strongly affect the soil properties. Groupings of soils with similar percentages of soil particles are referred to as soil textural classes. For example, a “silt loam” soil is one of the 13 soil textural classes.

Soil texture affects: a soil’s ability to absorb cations and contaminants (clay>sand); nutrient holding capacity (clay>sand); organic matter level (clay>sand); porosity (clay>sand); water holding capacity (clay>sand); infiltration and permeability (sand>clay); resistance to erosion (sand and clay both > silt); compactability (clay>sand); and ease of cultivation and management (loamy and silt loam soil textural classes are best).

Soil structure refers to the way that sand, silt, and clay particles are arranged into secondary aggregates. Examples of soil structural units are granular, platy, columnar, and blocky. Good soil structure includes a reasonable number of macropores (to allow for water drainage through and air movement into the soil profile) and of micropores (to store water for plant growth). For example, a granular soil would drain excess water more easily than would a fragipan soil (a structure with horizontal layers restrictive of water movement downward).

A good soil structure provides: better drainage, greater stability, improved aeration, better root distribution, easier tillage, and improved resistance to erosion. In addition, such soils provide a better environment in which soil organisms (including earthworms) can thrive.

5. Define soil organic matter and determine its relationship to each of the following: a) soil color, b) soil structure, c) nutrient supply, and d) soil erosion.

Soil organic matter consists of living biomass (plant roots, bacteria, earthworms), residues (primarily of plant roots and shoots), and humus (the more stable carbon-based materials which are no longer identifiable as plant residues).

Greater amounts of organic matter will give soils a darker color; for example, Histosols (organic soils) are quite black in color. High levels of organic matter generally benefit soil structure, because structural units are more stable with the inclusion of humus. In addition, highly organic soils tend to support greater populations of microbes, and microbial exudates can help hold soil aggregates together. Because organic matter contains some nutrients (especially N, P, and S), and can provide some negatively-charged binding sites for soil cations (like K^+ , Ca^{2+} , and Mg^{2+}), organic matter is highly beneficial to a soil's ability to supply nutrients to plants. Higher levels of organic matter generally reduce a soil's susceptibility to water erosion, primarily because the structural aggregates are better able to resist the detaching force of rainfall. However, Histosols can be subject to wind erosion (since the soil particles are so light). Please note that Histosols are not an important contributor to agriculture in Kentucky.

6. Recognize the effects of plant cover, plant residue, soil fertility level, and tillage system on water infiltration, soil erosion, soil temperature, and soil moisture.

Anytime rain falls, the water has to go someplace. If we fight soil erosion by having plants growing year round or by leaving lots of plant residue on the soil surface, we will see lower amounts of runoff. Thus, more of the water is infiltrating into the soil.

Plant cover will generally improve water infiltration, and reduce soil erosion and soil moisture (because plant roots extract water from the soil). Plant cover's impact on soil temperature will depend mostly on how moist and how dark the soils are naturally.

Plant residues will act in a similar way to plant cover with respect to water infiltration and soil erosion, with the exception that they will generally reduce soil temperature by reflecting more of the incoming sunlight, since their color is generally lighter than that of soils. As a result, soil moisture will tend to be higher under plant residue. (This is a key reason why no-till corn often produces higher yields than conventionally tilled corn. The prior crop residues help keep water in the soil so that corn roots can access it during dry periods.)

A more fertile soil will improve both plant growth and increase the amount of plant residues left for subsequent crops. So, its influences will be good for both water infiltration and soil erosion, and will be a "compromise" between the impacts of living plants and plant residues for soil moisture and soil temperature.

Tillage differences are easiest to see if you compare the extreme examples of moldboard plowing (relatively uncommon in Kentucky) and no-tillage to each other. Of course, moldboard plowing leaves the soil bare and unprotected. Rainfall quickly compacts the surface layers, and thus reduces infiltration and increases runoff (and, of course, erosion). Bare soils will be more subject to temperature extremes; that is, hotter in the summer and cooler in the winter. Soil moisture will be lost by evaporation (as sunlight warms the bare soils). In addition, plowing breaks down the natural soil structure that would help reduce erosion.

7. Relate properties such as soil texture and soil moisture to potential development of soil compaction.

Soils with greater amounts of clay will be more subject to soil compaction. This is especially a problem if soils are wet. Farmers must be careful not to till or work on high clay soils under wet conditions. Of course, our humid temperate climate generally results in wet soil conditions in both the spring and the fall, so growers may not always be able to avoid compacting soils while conducting time-sensitive field operations.

COMPETENCY AREA 3. Soil erosion

8. Relate erosion control practices to air and water quality.

Air quality, as affected by wind erosion, continues to be a significant issue in parts of the western US. Wind blown soil particles can cause health hazards to people, and can also become a significant safety risk to drivers. Of course, wind erosion is not a serious problem in Kentucky.

Water quality is a much bigger issue in our state. Surface waters can suffer eutrophication due to the transport of significant quantities of N and P through water erosion. In addition, the sediment itself can fill in drainage ditches (resulting in costly removable work) and can eventually reduce the capacity of constructed water reservoirs.

Of far greater economic significance, however, is the damage water erosion does to soil quality. Because erosion removes organic matter and clay particles preferentially, it does substantial damage to the soil's fertility. Eroded soils will have reduced water holding capacity, lower CEC, less biological activity, and a reduced ability to supply plant nutrients. Eroded soils are more likely to suffer surface crusting; this will make for even more erosion because of decreased infiltration and increased runoff. Finally, gullies can impede mechanized field operations.

9. Recognize the influence of tillage practices common in Kentucky on erosion, soil structure, soil organic matter, compaction, crop productivity, and water quality.

Of approximately 3.8 million acres of cropland used in 1998 in Kentucky, 70% was in either no-till or mulch till (greater than 30% of plant residues remaining on the surface). Ten percent was under reduced till (15 to 30% of residues remaining), while 19% was under intensive tillage (less than 15% of residues remaining). [Note: see ctic website (<http://www.ctic.purdue.edu/CTIC/CTIC.html>) for annual updates of tillage information for any state; however, you must pay a membership fee to get this information.]

The more of the previous crop's residues are left on the surface, the lower the soil erosion will be. Conversely, as tillage intensity increases, problems with compromised soil structure will increase. In addition, because tillage buries residues and aerates the soil, it speeds up the breakdown of both plant residues and previously existing soil humus, thereby lowering soil organic matter. Compaction is greater with the higher number of passes with heavy equipment under conventional tillage. However, there has been some evidence of soil compaction developing in long-term no-till sites. Crop productivity for summer annuals (corn and soybean) has been higher under no-till methods, primarily because more soil moisture is conserved for plant use during dry periods. Productivity of winter wheat has been generally lower with no-till methods, partly due to problems with stand establishment in the fall, but also partly due to cooler, wetter soils in the late winter months when wheat is going through green-up.

No-till will cut down drastically on the amount of sediment reaching surface waters. Because more water will infiltrate a no-till soil, there is some potential for greater leaching of both nitrate and agricultural pesticides to groundwater.

10. Recognize the components of an approved conservation plan and its relationship to crop management decisions.

Farmers who benefit from the Food Security Act (for example, through the Conservation Reserve Program) are required to file a conservation plan with the Farm Service Agency through the Natural Resource Conservation Service (NRCS). This is a technical plan, and may be a bit difficult to translate into field management practices. Other farmers are required to develop a conservation plan based on Best Management Practices (BMPs); this plan is also worked out with the NRCS, but is much more useful for field management. On the state level, Kentucky's Agricultural Water Act has begun requiring farmers to develop a water quality plan based on the use of BMPs.

In general, such plans show individual fields with their slopes, and describe management practices which will be employed to minimize erosion or to improve water quality.

11. Identify and understand the following erosion control practices recommended for use in Kentucky: a) conservation tillage, b) residue management, c) contouring, d) terracing, e) grass waterways, f) crop rotation, g) vegetative filter strips, and h) strip cropping.

Conservation tillage is defined as any tillage system which leaves a minimum of 30% of the previous crop residue on the soil surface. This could be no-till, ridge till (tillage only of slightly elevated ridges just before planting), strip till (in row tillage only, just before planting), mulch till (entire field is tilled, but a less “aggressive” tillage tool is used in order to leave behind more residue), and reduced till (any other system which leaves behind the desired level of residue).

Plant residues can be managed in various ways: buried, left alone, cut up with a bush-hog, for example. As an erosion control practice, the idea is to leave as much of the residue on the surface as possible.

Contouring means that row crops (like corn, soybean, and tobacco) are planted across the slope as much as possible. This practice can slow down both tillage and planting, because field shapes will have to be irregular in most areas (to accommodate irregular slopes). However, contouring, especially when combined with strip cropping (see below), has been shown to sharply reduce erosion (by reducing both runoff volume and velocity).

Terracing is especially useful in cropped areas with long slopes. The idea is to shorten the slopes by installing some sort of ridges across the contours of the field. Terraces can be cropped; in steeper areas, the downhill side of the terrace will often be kept covered with grass. Unfortunately, terraces are quite expensive to install, and the NRCS has stopped providing as much support to build these structures. The key advantage of terracing over contour strip cropping is that terraces allow the grower to plant large fields to a single crop. In some areas of the country, terraces can also help conserve moisture, by slowing runoff and thereby increasing the opportunity for infiltration.

Grass waterways slow down the movement of water in water channels, and protect those channels from the severe erosion which could otherwise develop. The favored grass in our state is tall fescue, simply because it persists so well. Producers must take good care of grass waterways (avoid spraying grass herbicides, raise up tillage equipment) in order to maintain their protective value against erosion.

Crop rotation is simply a recurring sequence of two or more crops on a farmer’s land. Rotations which include solid-seeded or broadcast crops (like wheat, alfalfa, tall fescue, and red clover) will have lower erosion, primarily because the soil is protected from raindrop impact over a greater portion of each year. In addition, such rotations will typically do a better job of maintaining soil organic matter levels; as we know, organic matter can help maintain the stability of soil aggregates against rainfall.

Vegetative filter strips are often installed in riparian areas. The intent is to reduce the flow rate of runoff water, and to allow sediments to fall out before the water reaches the stream. In addition, such filter strips can also help to keep surface runoff of fertilizers and pesticides lower; that is clearly an advantage.

Strip cropping includes alternating strips of row crops and forage (or wheat) crops to cut down on water and/or wind erosion. In the less rolling, western parts of the US, such strips are typically parallel, and are sized to match a farmer's equipment. In more hilly areas, strip cropping is often done on the contour; this practice is then referred to as contour strip cropping.

12. Recognize practices used to control excess soil water: a) surface drainage, and b) subsurface drainage.

Surface drainage is used to help move water off fields which tend to accumulate ponded water during rainfall events. In Kentucky, this most often consists of shallow channels cut into fields immediately before or after spring planting of corn or soybean. Of course, such channels have to be cut again every season. In addition, if internal drainage is a serious problem, surface drainage will do relatively little to aerate the root environment. In areas of the state with large numbers of sinkholes (for example, Simpson, Logan, Todd, and Christian Counties), surface drainage is of only modest value.

Subsurface drainage requires the installation of perforated plastic tubing, usually about 3 or 4 feet deep. This system can lower the water table to provide better aeration of the root zone. Of course, there must be a lower place to which the water can be drained. In some cases, this has involved digging out (and then maintaining) ditches around field sites. In certain parts of the state (for example, Daviess County), subsurface drainage is widespread. Of course, it is quite expensive to install, but can provide large benefits to growers in such areas.

13. Recognize properties that affect potential erosion: a) texture, b) organic matter, c) surface cover (rock and plant), d) % slope, e) length of slope, f) permeability, and g) structure.

Silty soils are most sensitive to erosion, because these particles are relatively small. While clays are still smaller, they provide some stabilization to soil aggregates. Sticky clays cut down on the detachment step of erosion. Sandy soils allow for easy water infiltration, thus minimizing both runoff and erosion. Sand particles are larger in size, therefore heavier and harder to move downslope than are smaller soil particles.

Organic matter provides a higher degree of aggregate stability, increases infiltration, and thus reduces runoff and erosion. In very high organic matter soils (for example, Histosols), small aggregate size can help promote erosion due to wind or water. However, we do not have any significant acreage of Histosols in Kentucky.

As noted in the answer to objective 11 above, plant and plant residue cover help increase infiltration and reduce runoff. Rocks on the surface could actually increase erosion through more rapid water velocities.

Steeper, longer slopes make for greater water erosion, because the runoff water can attain a greater velocity before it reaches the bottom of the slope.

More permeable soils (soils which allow water to move more rapidly downward through their profile) are subject to less runoff; therefore, erosion is a smaller problem.

Stable soil structural aggregates (due to the presence of high levels of organic matter or reasonable levels of non-swelling clays) are more resistant to the detachment force of raindrop impact.

14. Relate soil erosion to Food Security Act.

Since the 1985 Farm Bill (the Food Security Act of 1985), the federal government has been supporting the Conservation Reserve Program (CRP). The goals of this program were (and are) to reduce soil erosion, improve water quality, cut down on surplus grain production, enhance wildlife and fish habitat, reduce the sediment load on streams, and to provide some additional income to farmers.

Under the CRP, farmers receive federal payments to remove highly erodible lands (HEL) from row crop production. Such CRP land must be planted to a more protective type of vegetation (for example, forage grasses).

In addition, farmers are encouraged to participate in the Environmental Quality Incentives Program (EQIP), which pays up to 75% of the costs for installing new erosion control mechanisms.

COMPETENCY AREA 4. Tillage

15. Recognize how each of the following factors influence the selection and use of tillage systems: a) crop rotation/field history, b) field design, c) soil properties, d) crop productivity potential, and e) costs.

Crop rotation can both help and hinder the use of no-till systems. Summer annual crops like corn and soybean often produce higher yields with no-till management; however, in Kentucky, winter wheat has generally produced lower yields under no-till. In addition, some crops leave behind relatively little residue (for example, soybean), so soils would be better protected if soybean were rotated with crops like corn and wheat.

If a field has a history of erosion in the past, it would be a good idea to at least use conservation tillage in the more sensitive areas of the field.

The primary question about field design is if erosion is an important enough concern to warrant contour planting. While management is easier with straight rows, if such rows leave long slopes unbroken by crop rows, they will aggravate soil erosion problems.

The erodability of a soil is measured by a factor called “K”. Greater K values make for greater erosion. High K values are related to: high silt content, expansive clays, surface crusting, and impervious or poorly permeable soil layers. Low K values are related to high soil organic matter, nonexpansive clays, and strong granular soil structure. In general terms, K is lower for soils with good water infiltration capacities and strong soil structure. If a soil has a high K value, it should be managed to keep as much residue on the surface for as much of the year as possible. If a farm has a conservation plan, soil K values will have to be considered before BMPs can be developed.

Crop productivity is an important question. If the soil is poorly drained, no-till may not work very well, since this practice can aggravate wet soil conditions. On the other hand, many Kentucky sites run short of water in July and August, and no-till can help conserve some soil water for those months with high evaporative demand.

On-farm costs for fuel, equipment, and labor generally drop for no-till management. On the other hand, more N fertilizer, more seed, and more herbicides are often required for no-till. For summer annual crops, enhanced yields with no-till often make this a clearly beneficial economic choice. For wheat, a grower must be convinced that saving her topsoil is of sufficient long-term economic benefit that she can withstand the short-term losses in wheat yield.

16. Identify tillage implements used for each of the following systems: a) conventional tillage, b) reduced tillage, and c) no-till.

The moldboard plow turns over the soil and incorporates a very high percentage of crop residues. Some Kentucky tillage systems (for example, chisel plowing following by a couple of diskings) can also bring crop residues into the “conventional” level (under 15% of crop residues left on the surface).

The chisel plow, a popular reduced tillage implement in Kentucky, goes a bit deeper than the moldboard (about 12 inches vs. 6 inches), and left a good deal more of the residue on the surface (because it is not designed to invert the soil).

Disks have sharp, rolling concaves, and do a substantial amount of cutting and residue burying. Set at a less aggressive angle, disks can leave enough surface residue to fall into the category of reduced tillage.

Although not commonly used in Kentucky, sweep cultivators use V shaped blades to undercut previous crop stubble, thus fitting into the stubble mulch category of reduced tillage.

No-till systems do, in fact, accomplish some tillage during the planting operation. Various no-till planters are on the market for corn and soybean, as are several drills for wheat and double crop soybean. This equipment is much more effective at placing the seed at a uniform depth through substantial crop residue than was the equipment available just a few years ago.

17. Identify advantages, disadvantages, and limitations of each of the following tillage systems: a) conventional, b) reduced, and c) no-till.

Conventional tillage allows more uniform seeding, and can allow for earlier planting in some soil systems. In the case of winter wheat, conventional tillage appears to result in a yield advantage.

On the other hand, conventional tillage can promote erosion, especially on sloping areas with high K values; can compact soils just below the depth of annual tillage, resulting in poor root growth; and can progressively degrade the soil's fertility, by loss of organic matter and loss of fertile topsoil.

No-till (and to a lesser extent, reduced tillage) cuts down on fuel, labor, and equipment costs; can improve yield of corn and soybean on drought-prone soils; can improve organic matter content, aggregate stability, water holding capacity, and biological activity in soils; and reduce erosion.

On the other hand, no-tillage can increase the use of herbicides (with both economic and environmental costs); can increase the need for nitrogen fertilizers through greater losses to denitrification (especially on wet soils) and leaching (especially on well drained soils); and more careful management of soil fertility may be necessary to make sure that roots have optimal access to added soil fertility.

18. Describe the influence of tillage systems and tillage implements on each of the following: a) soil disturbance, b) crop residue remaining on the soil surface, c) incorporation of fertilizers, lime, and pesticides, and d) compaction.

As tillage intensity increases, the soil is relatively more disturbed. That disturbance has been shown to be harmful to topsoil structure, and may reduce populations of beneficial earthworms.

Likewise, increasing tillage intensity will cut down on the amount of crop residues left on the soil surface, but will make incorporation of fertilizers, lime, and pesticides easier. No-till farmers may have to be more timely in their application of lime. In addition, no-till farmers much recognize that some herbicides are not suitable for use in a no-till system, since their volatility and/or activity require incorporation into the soil.

While some compaction can be measured in continuous no-till systems, compaction is a far greater concern under conventional tillage. Farmers need to carefully monitor their soils for compacted layers, then take appropriate remedial action (for example, para-plowing, only as needed).

COMPETENCY AREA 5. Residue cover

19. Recognize how each of the following factors affect soil residue cover: a) cropping rotation, b) crop yield, c) harvesting methods, d) weather, e) tillage system, and f) fertilizer and manure methods.

Crops in a rotation which produce high grain yields also tend to leave behind greater amounts of plant residues. For example, corn > sorghum > wheat > soybean for typical residue levels. So, rotations which include a high residue crop may benefit from that crop for more than a single cropping season. In a similar way, a higher yield level of a given crop in a good year (say 200 bu/A corn vs. 125 bu/A corn) will leave behind a good deal more crop residue.

The most important differences here in harvesting method relate to how much of the plant is removed from the field. Corn cut for silage leaves virtually no residue in the field, while corn cut for grain leaves a lot of residue in the field. Likewise, if a wheat grower bales off his straw, that will leave far less residue on the surface. Other mechanical designs are of less importance; for example, using a stripper header vs. a conventional grain platform will affect how much of the plant is still standing, but will have relatively little impact on how much plant residue is left out in the field.

Growing seasons which cut crop yield will, of course, reduce plant residues. An additional weather influence is the conditions which follow harvest of a previous crop. For example, if the weather is cool and dry after corn is harvested, then most of the corn residue will remain on the soil surface when a farmer goes out to plant winter wheat. On the other hand, warm, wet conditions can speed up the decomposition of plant residues, since soil microbes are favored by those conditions.

It should go without saying that less intensive tillage practices leave more of the previous crop residue on the soil surface. However, sometimes growers do not consider the significant influence of tillage speed on the incorporation of plant residues. The faster a tillage implement is pulled through the field, the less residue remains on the surface. It would be more efficient to more closely match the size of the tillage equipment to the tractor pulling it, reducing the temptation to shift to the next higher gear.

Maintaining sufficient levels of soil fertility will improve crop growth, resulting in better protection of the soil both during and after the growing season (assuming that fall tillage is not practiced). Most growers with access to manures are encouraged to inject or incorporate them into to soil (to reduce fertility losses, and in the case of swine manure, to reduce odor). Therefore, such manures are not going to have a significant benefit on surface residue cover.

20. Know how to measure soil residue cover.

The preferred measurement technique is called the “line-transect” method. You put knots in a rope at regular intervals, then walk out into a representative area of your field (avoid end rows, weedy or wet spots, or otherwise atypical areas). Stretch your rope diagonally across the rows, then count the number of knots which fall directly over crop residue. If you use a 100 foot rope, and put knots every foot, then the number of knots falling directly on top of crop residue will provide a good, direct estimate of the percentage level of soil cover. You should repeat this process in at least three different areas of your field.

With appropriate practice, a person can get pretty good at estimating soil cover simply by careful, visual observation.

Soil and Water Management

Sample questions for Kentucky Certified Crop Advisor exam.

- ___ 1. How does tillage affect soil residue cover? a) Faster speeds cover more residue. b) Deeper tillage covers more residue. c) More passes across the field cover more residue. d) all of the above.
- ___ 2. Which of the following factors give rise to high “K” values? a) a high silt content b) high organic matter levels c) granular structure d) freedom from surface crusting.
- ___ 3. A Kentucky crop which leaves behind a large amount of crop residue is: a) soybean b) tobacco c) corn d) wheat e) alfalfa.
- ___ 4. An eroded soil will suffer in which of the following way(s)? a) reduced ability to supply plant nutrients b) more subject to surface crusting c) reduced water holding capacity d) reduced biological activity e) all of the above.
- ___ 5. Which grass would be most suitable to plant in grass waterways in Kentucky fields? a) bermudagrass b) Kentucky bluegrass c) reed canarygrass d) tall fescue.
- ___ 6. Which step of the process of water erosion of soils is inhibited by plant cover on the soil surface? a) detachment b) transport c) sedimentation d) none of the above.
- ___ 7. In which of the following way(s) does a high level of soil organic matter affect a soil’s properties? a) it makes the topsoil color darker b) enhances aggregation c) increases water holding capacity d) helps replenish soil N, P, and S e) all of the above.
- ___ 8. Soil in this landscape position is most likely to suffer erosion: a) bottom b) first terrace c) toe slope d) side slope e) ridgetop.
- ___ 9. A soil consociation is best defined as: a) an area covered by at least 50% of a single soil taxon b) a shortened way of saying a soil conservation association c) a group of closely related soil orders d) a group of soil series best managed by conservation tillage.
- ___ 10. If you are using the line-transect method to estimate percent residue cover, you should: a) Choose an area close to the field entrance. b) Sample from a minimum of 10 different sites in the field. c) Sample diagonally across crop rows. d) Count as you drag the rope or measuring tape across the field.
- ___ 11. This nutrient is more available to plants in a no-till field if it is surface applied: a) nitrogen b) phosphorus c) potassium d) sulfur.
- ___ 12. Which are advantages of no-till crop and soil management? a) lower use of herbicides b) faster warmup of soils in the spring c) better moisture retention d) lower use of nitrogen fertilizers.
- ___ 13. The Food Security Act set up the Conservation Reserve program. What was this program intended to accomplish? a) reduce food prices in the US b) provide more exportable grain surpluses for hungry nations overseas c) drive poor farm managers out of business d) improve water quality by reducing soil erosion.

- ___ 14. Which scenario will result in the greatest amount of topsoil erosion? a) heavy rain on a dry, conventionally tilled field b) heavy rain on an already wet, conventionally tilled field c) heavy rain on a dry, no-till field d) heavy rain on an already wet, no-till field.
- ___ 15. What nutrients in eroded soils are likely to cause lakes to go through eutrophication? a) N and P b) P and K c) Al and Fe d) Ca and Mg e) Cl and Mo.
- ___ 16. No-till management reduces erosion primarily by reducing: a) detachment b) transport c) deposition d) saltation.
- ___ 17. Soil structure is defined as: a) the percentages of sand, silt, and clay in a soil b) the way that textural units are arranged into aggregates c) the depth to which crop roots can penetrate the subsoil d) the amount of resistance of the soil as measured by a penetrometer.
- ___ 18. How does soil texture influence the development of soil compaction? a) Clay soils are more likely to suffer compaction than are sandy soils. b) Sandy soils are quite subject to compaction when dry. c) It is basically impossible to compact a silt loam soil. d) The amount of water present in a soil is far more important than its textural class.
- ___ 19. The soil drainage class which is easiest to manage for crop production would be: a) somewhat poorly b) excessive c) well d) moderately well.
- ___ 20. Which of the following crops would usually leave behind the greatest amount of residue? a) soybean b) wheat c) tobacco d) corn e) sorghum.
- ___ 21. Disadvantages of no-till agriculture include: a) less water available to the crop b) increased usage of herbicides c) more frequent insect outbreaks d) excessive release of mineralized nitrogen, burning young crop plants.
- ___ 22. Which of the following tillage implements would leave the least amount of crop residue on the soil surface? a) chisel plow b) moldboard plow c) disk d) sweep cultivator.
- ___ 23. In order to be classified as conservation tillage, a tillage practice must leave ___ % of the previous crop residue on the soil surface. a) 30 b) 50 c) 70 d) 90.
- ___ 24. Farm conservation plans must show: a) yield histories for each field b) best management practices (BMPs) to be used for each field c) amount of soil erosion expected per year on each field d) rates of water infiltration for each soil series included.
- ___ 25. How extensively does the use of no-till methods reduce soil erosion? a) not at all b) slightly c) moderately d) dramatically.
- ___ 26. Which of the following soils is most likely to have an erosion problem? a) a soil in a light rainfall zone b) relatively flat regions c) a soil cropped using contour strip cropping d) a soil with long, sloping fields.
- ___ 27. Plant residues, allowed to remain on top of the soil, provide which of the following benefits? a) reduced moisture retention b) reduced soil erosion c) warmer soil temperatures d) all of the above.

- ___ 28. Why is good soil structure important? a) It keeps water from draining away from the site. b) It makes tillage easier. c) It cuts down on the number of macropores in the soil. d) all of the above.
- ___ 29. If the natural geology of an area is limestone, what soil of soil textural class might you expect to see in that area? a) sandy soils b) clayey soils c) silty soils d) parent material has little to do with the textural class of the resulting soil.
- ___ 30. How does high soil fertility influence the amount of crop residues? a) makes crop residues break down rapidly b) enhances crop growth, thereby increasing the amount of residues c) encourages weed growth, thereby increasing residues d) has essentially no impact on crop residues.

Key for Kentucky CCA Practice Exam Soil and Water Management

1. D	11. B	21. B
2. A	12. C	22. B
3. C	13. D	23. A
4. E	14. B	24. B
5. D	15. A	25. D
6. A	16. A	26. D
7. E	17. B	27. B
8. D	18. A	28. B
9. A	19. C	29. C
10. C	20. D	30. B

PART III: INTEGRATED PEST MANAGEMENT (IPM)

COMPETENCY AREA 1. IPM concepts (strategies to address pest problems)

1. Describe the general concepts of IPM and how these concepts apply to making economically and environmentally sound pest management recommendations.

Integrated pest management is the use of all available tactics in a program to manage (not eradicate) pest populations in order to minimize economic damage, environmental side effects, and human exposure (both during application and as residues on foods).

Recognizing that we are dealing with a dynamic biological system when trying to grow crops is helpful; therefore, trying to “wipe out” a pest is not only expensive, it is very unlikely to succeed.

In addition, IPM may cut production costs by reducing inputs of fuel, fertilizers, and pesticides. This may happen because IPM focuses on using only the inputs required to produce a good crop. Much more work is done with scouting to make sure that the grower knows if she needs to apply an input.

Further, the potential for exposing both humans and the natural environment to unnecessary pesticides and fertility applications is reduced by judicious use of these materials.

Another way of looking at IPM is as a consultant’s toolbox which includes cultural, chemical, and natural tactics to achieve economic, ecological, and social goals. Integrated pest management relies on natural pest mortality factors (like weather and natural enemies), resistant or tolerant crop varieties), careful choice of planting dates, and application of pesticides only on an “as-needed” basis.

2. Distinguish between economic injury level, economic threshold, and treatment guidelines; recognize how they are used in decision-making for pest control.

Economic injury level is the lowest pest population density that will cause economic damage. In other words, the number of pests per plant (or per unit area) at which the cost of controlling the pest equals the value of the crop yield that would be lost if no pest control measures were taken.

Economic threshold is the pest density at which management intervention must be taken to prevent the pest from reaching the economic injury level. The point here is that you have to be aware of what the pest population is doing (multiplying, declining, stable) in order to know when to take steps to keep it from reaching the economic injury level.

Treatment guidelines are any of a series of general guides or information used to aid in making control decision, but which have not yet been refined into an economic threshold.

In essence, these are like “best guess” economic thresholds, based on long experience of crop managers and advisors, in the absence of hard data which conclusively shows what the economic threshold for that pest in that crop would be.

Both economic thresholds and treatment guidelines are tools which provide a rational method of using field-generated information (like pest counts, plant stages, and damage assessments) combined with research knowledge about the crop-pest interaction to keep the pest from reaching the economic injury level. In addition, these tools also help prevent the unnecessary use of pesticides, which can often result from making pest management decisions on a calendar basis or without careful field scouting.

3. Recognize, in general terms, how environmental and cultural factors influence pest populations.

Pests are directly affected by major environmental influences like temperature, humidity, soil moisture, and air movement (for example, weed germination date, insect reproduction rates, and movement of fungal spores). In general, most pests develop and multiply more rapidly under warmer temperatures and higher humidity. Key examples of environmental influences are that johnsongrass seed begins germinating at a soil temperature of 60 F; alfalfa weevils become active above 48 F; and leaf rust spores are often blown in wind rainstorms moving from the Gulf Coast states.

Key cultural practices which can influence pest populations include tillage, planting date of the crop, and crop density. In general terms, such practices modify the local environment in which the pest lives. For example, no-tillage methods may decrease soil temperature and increase soil moisture. Such cultural practices can make a given pest more or less of a problem. For example, some perennial weeds are more likely to become yield-limiting under no-till methods than if tillage is regularly practiced.

Often, adjustments in planting date are the most important cultural tool in controlling pests. For example, winter wheat planted before the Hessian fly free date (will range from October 10 to 20, depending on the average first fall killing freeze in a given part of the state) is more likely to be affected by barley yellow dwarf virus than is later planted wheat, since the aphids which transmit this disease are much more active before the first hard frost.

4. Recognize the importance of using correct pest monitoring procedures based on behavior and/or biology of the pest.

The location of pests within a field may vary by the nature of the pest. For example, common stalk borers and grasshoppers in conventionally tilled crop fields are often found near field edges or grass waterways, while in no-tillage fields they may be found near clumps of grassy weeds. Spider mites in soybean fields may only be found in droughty areas; while soybean cyst nematodes may be spread within fields in the direction of tillage operations. Under such variable pest densities, a careful sampling scheme must be arranged. Sampling only areas likely to show pests may over-estimate overall pest pressure, while sampling the field randomly may entirely miss serious pest problems in small areas within the field. Of course, good knowledge about pest habits will help a consultant to design a sampling procedure which provides reasonably useful data.

5. Describe methods for sampling and submitting plant, soil, and pest materials for analysis and diagnosis.

Best sampling for unequivocal identification of a given pest species requires careful attention to detail. Be sure to take several specimens of the pest, and get different sizes of the pest if they can be found. Try not to damage the sample. For weeds, that means that the sample should be kept from drying out too rapidly (actually digging up a weed and putting it in a pot can be helpful if the sample has to be stored or transported for identification). For soft-bodied insects, putting the sample in rubbing alcohol is a good strategy.

Be sure to make detailed observations about the severity of the infestation, what crop symptoms you observed, what crop variety is being affected, and the history and distribution of the pest in this particular field. If a consultant is unsure about the identification of a particular pest, a sample can be taken to the county extension office. In addition, digital images of the pest can be e-mailed to state specialists, who can then often e-mail back with an accurate pest identification.

Further information can be obtained in the following list of related references.

References:

- Entfact 001 and Insect Diagnosis form (do we have a web address for this?)
- PPA-9 and Plant Disease Diagnostic form
- Weed Identification Form
- AGR-16 Taking Soil Test Samples

<http://www.ca.uky.edu/agc/pubs/agr/agr16/agr16.htm>

6. Recognize the necessity for correct pest identification in making pest management decisions; describe the consequences if pest management decisions are based on incorrect pest identification.

Any given pest management tactic will not effectively take care of all pest types. Examples of that truth follow.

In Kentucky, we now have insects, weeds, and diseases which are resistant to the common control tactics (for example, triazine-resistant pigweed and metalaxyl insensitive blue mold). In addition, any given herbicide will not provide excellent control of all weed species. In some cases, even closely related weed species are not controlled equally well by a given herbicide.

Broadcast sprays of the appropriate insecticides can result in adequate control of both armyworms in small grains or green cloverworm in soybean, but cannot provide control of either European corn borer or fall armyworm in corn.

Crop rotation is recommended for take-all of wheat (since this disease is caused by a soil-borne fungus), but will not help at all with barley yellow dwarf virus of wheat (since this disease is transmitted by several species of flying aphids which can move in from some distance away).

If pests are incorrectly identified, farmers may be given an incorrect treatment recommendation. If that happens, the following bad outcomes may result: crop damage due to the lack of pest control; use of unnecessary control measures which waste time, fuel, and pesticides; and unwarranted exposure of both people and the environment to pesticides. In addition, such mistaken treatments could actually increase the rate at which certain pests develop pesticide resistance.

Pheromones are one of several types of chemicals that insects use for communication among themselves. For example, Japanese beetles give off pheromones while feeding which signal other nearby Japanese beetles that a food source is available. Specially designed traps can be baited with such pheromones to help attract and then capture such insects. By regularly counting the number of insects trapped, a crop manager can determine when control measures are warranted.

A degree day is a measure of the speed of insect development. Each insect has a specific base temperature at which it becomes active, and its activity is enhanced as temperatures increase above that base temperature. Degree day models are mathematical formulas which can take temperature information (daily highs and lows) and predict insect activity over time. Such models may be used in conjunction with pheromone traps; for example, once a trap has shown that a particular insect is moving into a crop, then a grower can begin the “clock” on the degree day models.

It is worth noting here that pheromone traps have not been extensively used with field crops in Kentucky. However, degree day models have been quite helpful with control of alfalfa weevil in alfalfa and black cutworm in corn.

7. Describe the importance of the following components of an IPM program: a) assessment of past, present and potential pest problems, b) development of management plan, c) selection of a scouting process, d) implementation of a plan, and e) evaluation and record-keeping

Assessment of past, present and potential pest problems gives a grower or consultant a good idea of what pests are likely to require monitoring and perhaps control measures. For example, if a soybean grower has never tested her fields for soybean cyst nematode (SCN) consultant would be wise to suggest that be done as soon as possible.

Development of management plan implies that the grower is ready to apply the appropriate cultural and chemical interventions on a timely basis. In addition, a clear knowledge of likely pest problems may allow for the use of genetic interventions; that is, the use of resistant or tolerant crop varieties. In the above example, the soybean grower would be wise to make use of SCN-resistant soybean varieties as part of a carefully planned crop rotation.

Selection of a scouting process suggests that a grower or consultant have a plan (and a person) ready to check fields regularly for the expected pest problems. For example, if a grower has chosen to rely exclusively on post-emergence herbicides for weed control, then he must have someone out in his fields checking for weed species and weed pressures a few days before the optimal treatment timing. In addition, growers need to be sure that they have access to the appropriate crop protection chemicals on a timely basis.

Implementation of a plan simply means carrying out the established plan. A key factor here is that a person is available to do the required scouting carefully. Drive-by or field margin scouting can result in inappropriate (and often unnecessary) pesticide applications.

Evaluation and record-keeping help a farmer know which interventions made him money at the end of the season. For example, an extra post-emergence herbicide application to clean up a few escaping weeds may not have been economically justified.

8. Describe how to integrate pest management tactics (e.g., crop rotation, tillage, etc.) for managing the following difficult-to-control pests:

johnsongrass: This weed is a creeping perennial, greatly despised by Kentucky grain crop producers. With the advent of effective post-emergence herbicides in both corn and soybean, johnsongrass has become much easier to control; in fact, it no longer ranks in the top five of the “worst weeds in Kentucky” list. Herbicides like Assure in soybean and Beacon and Accent in corn, when properly applied, can greatly assist in the control of rhizome and seedling johnsongrass. Soil-applied herbicides do relatively little to slow down either rhizome or seedling johnsongrass. One real problem for corn growers is that most herbicides which are effective in controlling johnsongrass should be applied to the field before the corn reaches 20 inches of height. However, at that stage of crop growth, some seedling johnsongrass is still emerging, since rhizome johnsongrass can start growing with 50 F soil temperatures but seedling johnsongrass does not reach its germination optimum until the soil temperature hits 75 F. So, some farmers are waiting to apply herbicides like Accent until most of the seedling johnsongrass is growing; and that means that their corn is suffering some crop injury. One partial solution here is to plant corn in johnsongrass infested fields last; that would mean that the seedling johnsongrass would emerge when the corn plants were somewhat smaller and less sensitive to herbicide injury. Crop rotation and tillage are of little value in controlling this weedy pest. The long dormancy in johnsongrass seeds (up to 18 years in UK studies) does mean that Kentucky farmers will continue to battle this weed well into the future.

triazine resistant smooth pigweed: Triazine herbicides include atrazine, simazine, and cyanazine. Of these three, atrazine is by far the most important, having been a cheap and effective way to control many broadleaf weeds in corn crops for several decades. In fields where atrazine was used continuously for a number of years, strong selection pressure was inadvertently applied for an increase in the previously rare number of triazine-resistant smooth pigweed plants. Over time, this type of plants has become more numerous, forcing growers to search for alternative control methods. Most of the known fields with significant populations of triazine resistant smooth pigweed are found around Lake Cumberland or in Hardin and Union counties.

The simplistic response to this resistant weed species is to stop using atrazine, replacing it with other herbicides. However, the cheap control that atrazine provides for other broadleaf weeds may mean that growers will need to continue using atrazine, but supplement it with a herbicide effective against triazine resistant smooth pigweed.

Crop rotation, coupled with rotation of herbicide classes, is a wise strategy to reduce the likelihood that such herbicide resistant weed populations will build up.

Eastern black nightshade: This weed pest is not very competitive with soybean for plant growth resources (like water and nutrients), but it is economically important because it interferes with soybean harvest. For that reason, it has been declared a noxious weed species, and certified seed inspectors could reject an entire field if they observed just one Eastern black nightshade plant. Soft, ripening berries can contain up to 100 seeds each; these berries can be smashed during the harvest process, effectively “gluing” Eastern black nightshade seeds to soybean seeds. Alternatively, hard green Eastern black nightshade berries are about the same size and weight as soybean seed, and so can be “recognized” as soybean seed by combines. Either way, viable Eastern black nightshade seed can contaminate the soybean seed lot.

The most effective control of this weed is to make sure that you are using a soybean seed source which is free of Eastern black nightshade seed. Once you have identified Eastern black nightshade in your soybean field, there are a number of herbicides which do an effective job of controlling this pest (see AGR-6, “Chemical Control of Weeds in Kentucky Farm Crops”; available on the web at <http://www.ca.uky.edu/agc/pubs/agr/agr6/agr6.htm>).

European corn borer (Ecb): This pest causes damage in two successive generations in Kentucky. First generation larvae, feeding on stem tissue in corn, interfere with water and nutrient movement. Second generation larvae can weaken stem tissue, and can cause harvest loss due to lower stem breakage.

For control measures, crop rotation is used, but has relatively little benefit, since the adult moths can fly in from other areas. The concept behind using tillage is to bury the larvae; however, just a few survivors can rebuild the population. The important development recently is the release of genetically engineered corn hybrids referred to as “Bt corn.” Such hybrids have had a gene which codes for the natural toxin from the bacteria *Bacillus thuringiensis*. This toxin is present in the tissues of the corn plant, so that when first or second generation larvae begin feeding on the corn plants, they quickly die. The US EPA is concerned about the possibility of Bt resistant Ecb strains developing, so they will review the agreement with corn seed companies as of April 2001. If current resistance management plans are not successful in preventing the development of Bt resistant Ecb, more aggressive resistance management plans will be implemented (including, perhaps the elimination of Bt corn). Late planted corn can be subject to greater damage from Ecb, since the plants can be at just the right stage for the adults coming from the first generation in nearby, early-planted fields to come in and lay eggs for the second generation of larvae. Thus, it might be especially important to harvest late-planted corn early, since it can be subject to Ecb-related harvest losses. Lady bugs can help as a natural enemy, as can early season rain events. Insecticides have not been widely employed, in part because of the difficulty of scouting for the pest and then applying a systemic insecticide to try to control it.

soybean cyst nematode (SCN): The first step is to sample your fields to find out what, if any, level of SCN infestation is present. Ideally, this sample should be taken in the fall, so that management decisions (for example, purchasing seed of an SCN-resistant soybean variety) can be made on a timely basis. If a substantial amount of SCN is present, varieties to races 3 and 14 should be grown. Crop rotation is also a key element in an IPM approach to SCN management. Planting a nonhost crop (like corn, alfalfa or forage grasses) will help. UK recommends a 4 year crop rotation involving: year one, nonhost crop; year two, resistant soybean variety; year three, nonhost crop; and year four, SCN- susceptible soybean variety (providing SCN counts have fallen below the economic injury level). In addition, practices like optimizing soil fertility, controlling weeds, and controlling diseases and insects will lessen the impact of SCN on susceptible soybean varieties. Nematicides are biologically effective but not very cost effective, and should only be implemented as a last resort.

corn stalk and ear rots: No good resistance is available to the pathogens (primarily *Fusarium* sp.) which cause these problems. Growers can help their cause to some extent by selecting corn hybrids which have strong stalks, and therefore will be less subject to lodging even if attacked by stalk rots. Growers can also help their cause here by not applying too much nitrogen or planting too thick of a plant population. Both of those decisions will help improve stalk strength and reduce the impact of any stalk rot which may be present. In the case of ear rot, if growers pick hybrids with ears that point downward at maturity, that will help lessen ear rot by reducing the entry of moisture through the tips of the husks.

black shank of tobacco: Over the history of tobacco production in Kentucky, this soil-borne disease has caused significant economic loss to growers. Four key steps to help control black shank are the four “R’s”: 1) real good sanitation, 2) rotation to nonhost crops, 3) resistant varieties, and 4) metalaxyl (trade name: Ridomil). Good sanitation means preventing, as much as possible, the spread of this pathogen. Since black shank resting spores can be transported through infested soil, infested water, or infested plant material, there are a lot of things to be careful about. Infested transplants are particularly problematic, since they can be transported long distances and thus spread the disease to distant fields. Of course, black shank can also be spread in soil on equipment or by livestock or wildlife. Rotation helps reduce the number of black shank spores in the soil, so that the next time tobacco is planted, the disease will not be as severe. Resistant varieties can be either: 1) L8 hybrids which have resistance only to race 0, or 2) general (or horizontal) resistance to both races 0 and 1. L8 hybrids have immunity to race 0, but are totally susceptible to race 1. Horizontal resistance helps against low to moderate black shank levels, but doesn’t help much if the black shank level is high. Metalaxyl must be used in conjunction with resistant varieties in fields with black shank present. If disease is present, metalaxyl applications should be made as preplant or preplant plus cultivation. Waiting until disease symptoms appear to apply metalaxyl will generally result in poor disease control.

barley yellow dwarf virus (BYDV): This viral pathogen is transmitted by several species of aphids. The key management practice is to delay planting winter wheat until after the first hard frost, since crop emergence will coincide with greatly reduced aphid activity. Unfortunately, aphids can be active right through the winter in a mild year, so delayed planting may be of limited value in some years. Fall BYDV infection often results in small circles of stunted plants; spring infection generally does not cause much stunting, but can cause yellowing and purpling of leaves. Either infection timing can substantially reduce yields but greatest yield reductions generally occur with fall or early winter infections. Aphid prevalence is largely influenced by summer weather, through the condition of their alternate hosts; that is, if a summer is especially dry, grass plants will not be growing as much, and aphid numbers will decline.

If a grower chooses to attempt to control BYDV with an insecticide, the application must be timed according to a field-based estimate of aphid numbers. Some growers apply an insecticide (for example, Warrior) with fall and/or spring applications of herbicides. Wheat variety selection is of only limited value in the reduction of BYDV-related yield losses.

alfalfa weevil: Alfalfa weevil larvae attack the upper leaves and stems of alfalfa plants in the spring. Of course, that means the larvae are attacking the most nutritious part of the plant, so they are not only reducing yields, they are also reducing forage quality. Weevil numbers tend to build up as an alfalfa stand ages. Weather has a big impact on larval development and alfalfa damage. Freezing weather can kill off many larvae, so control decisions need to be based on actual larval counts, rather than merely on the presence of feeding injury. Weevil Check, a variety with good resistance to alfalfa weevil, can be utilized. Some natural enemies exist. A well-timed insecticide application may be beneficial; however, if plants are approaching an appropriate harvest stage, a grower can save the insecticide and application costs by simply harvesting the crop; that process itself will destroy many of the larvae.

9. Recognize the benefits of developing a list of major weed species and a weed map for each field.

A weed map and a list of major weed species are good parts of an overall weed management plan. Such a plan for each field should include:

- 1) crops to be grown,
- 2) tillage practices to be employed,
- 3) with which equipment and by whom with the herbicide be applied (make sure that you have access to equipment, herbicides, and operating personnel on a timely basis, whether you are applying the herbicides yourself or whether you are having a crop service company handle this operation on your behalf),
- 4) the top 5 or 6 weeds with which you expect to be dealing, based on a carefully taken field history,

- 5) a plan to control the key weed species, with two or three reasonable options (in case herbicides are unavailable or applications cannot be made at the optimal crop/weed growth stages), and
- 6) evaluation of the weed control practices utilized.

Of course, fields should be scouted before herbicides are applied, since environmental conditions can strongly influence which weed or weeds predominate in a given field in a given season.

10. Describe the use of pheromone trapping and day degree predictions of insect activity for insects like European corn borer and black cutworm.

Most insects develop more rapidly as temperatures increase above a species specific minimum. European corn borer becomes active at 50 F; alfalfa weevil at 48 F, and black cutworm at 45 F. To calculate degree days, use the following formula:

$$[(T_{\max} + T_{\min})/2] - T_{\text{base}} = \text{degree days}$$

Where T_{\max} = maximum daily temperature,
 T_{\min} = minimum daily temperature, and
 T_{base} = base growth temperature for the insect of interest.

Such degree day information is summed over a period of time, and growers or crop consultants then will know when they should scout for the insect likely to be present. For example, degree days for European corn borer are counted starting as of January 1 each year. You can get up to the day information of degree day accumulation for European corn borers from the UK Agricultural Weather Center's website [<http://www.agwx.ca.uky.edu>]. Black cutworm degree days are counted once the first moths are observed in the spring. Once 300 degree days are accumulated, scouting for black cutworm needs to begin. Interestingly, since corn's base temperature is 50 F (5 degrees higher than that of black cutworm), this insect can be a growing problem while corn is basically standing still, unable to grow past the potential for damage by black cutworm.

Pheromone traps contain compounds used naturally by insects to attract mates (most often this compound is released by insect females to attract males). Pheromone traps thus attract males with the compound specific to the species of interest. The traps are constructed so that once the insect enters, it is unable to escape.

COMPETENCY AREA 2. Pest characteristics

I. Weed pests

11. The following are examples of weed species that are grouped according to life cycle. Describe the life cycle and recognize key identifying characteristics during early and late growth stages for these and other major problem weed species.

Note: The Weed Science Society of America has an extensive photo gallery of important weedy species on their website (<http://ext.agn.uiuc.edu/wssa/index.html>). Ohio State Bulletin 827 also (<http://ohioline.ag.ohio-state.edu/b827/>) provides good information on identifying most of the weed species listed below. Of course, the only way to get really good at weed identification is to work in the field with live samples! You could also buy a CD-ROM version from the University of Illinois; check out the details at <http://www.aces.uiuc.edu/~vo-ag/newnew.htm>. Or you can get free pictures and descriptions for some weeds species from Purdue at <http://www.agry.purdue.edu/ext/corn/cgg6.htm>.

ANNUALS:

Warm season: Another way of describing these weeds is to say they are “summer annuals”; that is, they germinate in the spring and complete their growth before frost that fall.

Grasses:

Giant foxtail

Large crabgrass

Fall panicum

Shattercane

Broadleaf signalgrass

Broadleaf:

Cocklebur

Morningglories

Giant ragweed

Common ragweed

Velvetleaf

Eastern black nightshade

Smooth pigweed

Common lambsquarters,

Prickly sida

Cool season: Such weeds are also called “winter annuals” since they emerge in the fall, then flower and produce seeds in the spring. These weeds are problematic in winter wheat, since their growth cycle matches that of winter wheat.

“

Grasses:

Italian ryegrass

Cheat

Broadleaf:

Common chickweed

Henbit

BIENNIALS: Such plants grow vegetatively for one growing season, then reproduce and die during their second growing season.

Musk thistle

PERENNIALS:

Warm season:

Johnsongrass

Yellow nutsedge

Honeyvine milkweed

Bigroot morningglory

Cool season:

Wild garlic

Curly dock

12. Describe the types of reproduction methods of weeds and why it is important to know them when designing a weed management program.

Most weedy plants reproduce primarily by seed, hence one goal of a weed management program is to prevent weeds from “going to seed”, since any seed produced will be a problem in coming seasons. Some weedy plants reproduce by rhizomes (johnsongrass is a good example; rhizomes are underground stem tissue with nodes from which new shoots can arise). Other weeds can re-grow from underground carbohydrate storage, pokeweed is an especially good example of this feature. Wild garlic can regrow from underground bulbs or from aboveground bulbets. Knowledge of the reproductive strategy of a given weedy species allows growers to tailor their weed control strategy to the primary weeds with which they are dealing. For example, growers trying to deal with johnsongrass will want to prevent it from going to seed (to keep from building up the johnsongrass seedbank in the soil), but will also have to think about how to control rhizome johnsongrass already present in the field.

13. Recognize the importance of the following factors affecting weed-crop competition in corn, soybeans, small grains, forages, and tobacco:

row spacing: In general, wider rows mean that more sunlight will “evade” interception by the crop canopy; thus, light energy will be more abundant for weed seedlings trying to make a go of life in the crop field.

crop population: Higher plant densities generally result in quicker canopy closure, thus impeding the growth of most weed seedlings in the low light conditions below the crop canopy.

weed density: Higher weed densities will give the weed a competitive advantage over the crop, just as higher crop populations (see above) give the crop a competitive advantage over the weed. However, one must not carry the crop population idea too far; in dry seasons, excessive crop population can hurt yields since too much of the available soil water is used up during vegetative growth of the crop.

duration of competition: In general, the longer a weed competes with a crop, the greater its impact on that crop. Of course, some weeds are more competitive than others even though they are present for the same length of time. Most weeds need to be controlled within 3 weeks of crop emergence; any longer durations will usually impact yield in a negative way.

weed distribution: Weed distribution within a field is never uniform. If a grower can get a good handle on the areas in which a weed is a significant problem, she may be able to apply treatments only to that portion of her field, thereby saving a significant amount on both herbicide and application costs. Some preliminary work has been done on weed recognition technology, which would allow growers to selectively apply specific herbicides only when susceptible weeds were detected. In Kansas, good results have been achieved with a weed recognition system based on plant color. That system is workable since the detection is comparing green weeds versus senesced wheat plants.

II. Insects and mites

14. Identify important insect pests of forages, corn, soybeans, tobacco, and small grain; describe their life cycles, and recognize characteristic damage they cause.

Key crop pests in Kentucky are those which are present every year, are capable of causing significant crop damage, and are somehow responsive to management decisions.

Alfalfa weevil adults lay eggs in the stem, and larvae consume upper leaves of the first cutting, reducing both yield and quality. This pest only has one generation per year, during the summer, adults go through an “aestivation” period, something like a summer hibernation. Both eggs and adults can overwinter in alfalfa fields, thus this pest tends to become more prevalent as an alfalfa stand ages. Tolerant alfalfa varieties generally “outgrow” the feeding injury of the larvae.

Potato leaf hopper, another important pest of alfalfa, lays its eggs in leaf veins and stems. Both the nymphs and adults are sap feeders, so a scout will not be able to see “munching” injury on leaves. This pest moves in from the south each year, and tends to attack the second and third cuttings. Several generations can develop each growing season. Alfalfa varieties with some resistance are pubescent (hairy) types which make movement and feeding by nymphs difficult.

Black cutworm of corn is a migratory pest which comes in from the gulf coast states. This pest damages crops like corn, tobacco, and tomato by cutting off plants near the soil surface. Since it likes to lay its eggs in chickweed, henbit, and yellow rocket weedy plants, black cutworm can be a bigger problem in settings which allow these weeds to grow. For example, no-till corn fields, in which the weeds are killed at or just after corn planting, can result in a large number of active cutworms which are quite hungry since their primary food source (the weeds) is now dead, so the only green “food” around is the emerging corn plants.

European corn borer is discussed above (in question #8). Southwestern corn borer can also be a problem in Kentucky. Most insecticides must be applied while both of these borers are still in the leaf whorl (so that the insecticide can get to the larvae).

Western corn rootworm overwinters as eggs laid in the soil. The May hatched insects feed on the root systems. These rootworms have always been a much bigger problem in continuous corn fields. However, some variants have now been observed (in the northern regions of Illinois, Indiana, and Ohio) which can multiply on soybean as a rotational crop. In addition, the South Dakota variant of the Northern corn rootworm (a related species) has some eggs which hatch in the second, third, fourth, or even fifth year after they are laid. Hence, crop rotation is no longer an effective practice to control corn rootworms in all areas.

Soybean has relatively few important pests (since it is an introduced crop in this hemisphere) , and is also quite tolerant of leaf-feeding injury. A few general feeders which can attack soybean are: Japanese beetle, green cloverworm, and corn earworm (sometimes referred to as “podworm” because it can attack soybean pods). Control decisions for such pests are made based on the extent of leaf feeding injury.

Flea beetle of tobacco overwinters as adults. Larvae damage new transplants by eating small, rounded holes in their leaves. Generally, tobacco can outgrow the damage by this pest.

Tobacco aphids overwinter, it is thought, on weedy species. They accumulate on small leaf buds, and can cause damage directly by feeding on plant sap or indirectly by transmitting viral diseases. Most of the damage happens from 4 weeks after transplanting until topping. This insect produces several generations of all-female offspring each year, so has a huge reproductive potential. Chemical resistance can easily develop, so growers attacking these aphids with pesticides should rotate chemical classes.

Wheat can be attacked by aphids; their primary damage is through vectoring BYDV (see question #8 for a discussion of this problem). Economic damage from other insect pests (for example, cereal leaf beetle or fall armyworm) rarely occurs.

15. Describe how insect biology and behavior affect management practices and decisions.

Key factors here include overwintering site, feeding site, sucking vs. chewing mouthparts, number of generations per growing season, and insect life cycle.

Some pests overwinter in or near the field; for example, European corn borer, Southwestern corn borer, and alfalfa weevil. Others (like black cutworm, fall armyworm, and potato leafhopper) fly in each season. Managers can generally do more to cut down on levels of pests that overwinter in their fields than they can for pests which fly in each year.

Insects which feed on plant roots will usually need to be treated with a preventative insecticide (for example, the corn rootworms). Those which feed on leaves (for example, alfalfa weevil larvae) will be most responsive, of course, to foliar sprays. Those which start their feeding in corn whorls will have to be treated before they move down into the stems (for example, the corn borers). Since insects with sucking mouthparts (like tobacco aphids) will not get a very high dose of contact sprays, they must be controlled with systemic insecticides. On the other hand, voracious leaf feeders (like Japanese beetles) can be controlled with contact insecticides. A pest with only one generation per year (like alfalfa weevil) is much easier to manage than a pest with several generations per year (like tobacco aphids). For insect species which go through a complete metamorphosis, it is important to time management interventions to attack the pest during its most susceptible life stage (for example, treating alfalfa weevil as larvae, rather than attempting to kill adults).

16. Describe how plant growth stage affects severity of insect damage to plants.

Seed maggots and cutworms can kill seedlings, but are not a problem for larger plants. In general, the vegetative stage of plants is more tolerant of insect injury, while the reproductive stage is more sensitive (for example, it takes a large amount of vegetative leaf injury to justify treatment of soybean, but a relatively small number of stinkbugs can hurt yields by feeding directly on developing seeds). Pollen shed can attract a number of insects (for example, European corn borer moths or corn rootworm beetles). If, for example, corn plants are shedding pollen just as first generation European corn borer moths are emerging, such plants can attract a large number of moths and thus be subject to substantial feeding by the second generation of this pest.

III. Disease pests

17. Describe how pathogen characteristics affect management strategies for important diseases of corn, forages, soybeans, small grains, and tobacco in Kentucky.

The key principle here is that thorough knowledge of a pathogen's characteristics can allow us to identify (and attack) the weakest link in their life cycle. The following general concepts are important to know.

We must know (or find out) whether the pathogen is a fungus, virus, bacterium, or a nematode. That will greatly help in making control decisions.

The specific source of the pathogen must be determined. Knowing whether a pathogen is soil-borne, foliar, or seed-borne is quite helpful. For example, since black shank of tobacco is soil-borne, a grower with infested soils knows from the start that she has to do something to control this pathogen. On the other hand, blue mold of tobacco moves in the air or on transplants, and does not overwinter outdoors in Kentucky. Growers must be aware of the potential for blue mold infection (presence in nearby production areas, weather, etc.) and take appropriate measures to protect their crop. (Note: the use of "clean" transplants will help reduce the spread of both of these diseases.)

The host range (that is, which plants a pathogen can infect) helps determine if a crop rotation could assist in pathogen control. For example, gray leaf spot of corn has a very narrow host range; hence it is relatively easy to control by using rotations. On the other hand, pests with a wide host range are not as easy to control using crop rotations.

It is also important to know the survival mechanism(s) of the pathogen. First, we need to know just what is the dormancy structure, then we need to know where to look for it. For example, take-all fungus of wheat is found in the soil, and its effects can be minimized by rotating away from wheat. On the other hand, soybean cyst nematode persists many years in the soil, so rotating away from soybean will not ever eliminate this pest. Some pathogens persist in crop residue; for example, the *Fusarium* fungus which causes stalk rot in corn also causes head scab of wheat. Some wheat growers have blamed no-till wheat production after corn for high levels of head scab. However, the *Fusarium* fungus is pretty much ubiquitous (check out a dictionary; you should know that word), and the development of head scab is much more dependent on having moist conditions at wheat flowering than on the amount of corn residue present. Some pests (like *Rhizoctonia* which causes seedlings to damp-off) are present both in the soil and in crop residues).

Where possible, it is good to know about alternate hosts (generally weedy plants). For example, the fungus which causes stem rust of wheat uses the plant barberry as an obligate part of its life cycle. More significantly for Kentucky, johnsongrass harbors two corn viruses [MCDV, maize chlorotic dwarf virus and MDMV, maize dwarf mosaic virus) which can be vectored to nearby corn plants by leaf hoppers and aphids, respectively.

It is also key to know if the pathogen can survive in Kentucky, since our cold winter temperatures (okay, you can chuckle if you are from a colder climate!) can greatly reduce populations of many pathogens. Blue-mold cannot survive in Kentucky (except for inside a heated greenhouse). Likewise, leaf rust of wheat must be blown in from the south. So, by monitoring the development of leaf rust in Louisiana, Texas, Arkansas, and Tennessee, we can have a pretty good idea when (or if) leaf rust inoculum will be arriving in our state.

Survival in insect vectors is also important, especially for viral diseases like BYDV of wheat. In such cases, predicting disease development and planning for control interventions becomes much more complicated.

One should also get a handle on the pathogen's epidemiology, starting with the primary source of inoculum (the original source of the pathogen infection). For example, bacteria may be transmitted by insects or by raindrop splash. On the other hand, since nematodes are soil-borne, most of their transmission is done through any activity that moves soil. Secondly, we need to know the lifespan of the inoculum. For head scab, ascospores are active in warm, rainy weather; on the other hand, soybean cyst nematodes can persist in their hardened cysts in the soil for many years. It is also important to know if an organism is monocyclic (one generation per growing season) or polycyclic (more than one generation per growing season). Polycyclic organisms are more likely to develop pesticide resistance, since they can go through several genetic recombinations each season. The number of generations drives both the speed and the extent of a disease outbreak. For example, infection of soybean with the stem canker fungus occurs early in the season, but is not expressed until the soybean plants enter reproductive development. So, a stem canker infection is not going to get any worse late in the season. On the other hand, both blue mold of tobacco and leaf rust of wheat often continue to reinfect and multiply throughout the growing season.

Finally, some highly variable pathogens (like soybean cyst nematode and the fungus that causes black shank of tobacco) have many different races, greatly complicating the use of resistant crop varieties.

18. Describe how environment, host plant characteristics, and pathogen interact for the following disease groupings:

a) wind/rain dispersed fungal diseases: Blue mold of tobacco and leaf rust of wheat are good examples here. In both cases, movement of the pathogen into the field is generally by wind and rain (of course, a blue mold outbreak can be started by transporting and using contaminated transplants). The fungal spores are deposited in the field with the rainfall. If the host plant is present and weather conditions are favorable, disease development is likely. In the case of leaf rust, 6 hours of continuous leaf wetness is required for infection to occur.

b) insect transmitted viral diseases: Barley yellow dwarf virus (BYDV) of wheat is vectored (transmitted) by several species of aphids. Wheat is susceptible to BYDV throughout its life cycle, so infection depends mostly on the environment and the pathogen. If summer growing conditions for the aphid's summer grass hosts (for example, tall fescue) is good, aphid numbers are likely to be high. It is not clear what factors determine the percentage of aphids which carry the virus. If a hard fall freeze occurs before wheat plants emerge, aphid activity will be lower, and BYDV infection will probably be reduced. If winter weather is mild, there is a good chance that aphids will be active throughout the winter and early spring, and infection could occur at those times.

c) bacterial diseases: Transmission of bacteria tends to be more localized than transmission of fungi. Between fields, bacteria can move on infested plant material (for example, transplants). Within fields, transmission can occur by “raindrop splash”; that is, falling rain washes some bacterial ooze off of the surface of an infected leaf. Later raindrops can impact the soil where that ooze had been deposited, then splash up onto leaves of nearby plants, thereby infecting those plants.

d) soil-borne fungal diseases: Black shank of tobacco develops more rapidly under warm and wet environmental conditions. This disease has two distinct races (0 and 1); tobacco varieties may be strongly resistant to race 0 or moderately resistant to both races. The presence of the black shank pathogen in a soil depends on how carefully sanitation practices have been followed (see objective #20 below).

e) diseases caused by nematodes: Soybean cyst nematode can develop on soybean roots of susceptible soybean varieties. Varieties with resistance to races 1, 3, and 14 are available for sale in Kentucky; overuse of resistant varieties may impose strong selection pressure for a shift in the SCN population to other races. Nematode injury can be worse if plants suffer from other stresses (for example, drought or sudden death syndrome of soybean).

19. Describe how the following types of diseases affect plant health and productivity:

a) root rots: Root rots affect the ability of diseased plants to take up water and nutrients, and also decrease the plant roots’ ability to store carbohydrates. Severe root rots can cause plant death, sometimes within just a few days. Lower levels of root rot can slow down plant growth (due to problems with water and nutrient uptake) and can render plants more susceptible to infection by other pathogens, and in the case of perennial crops, to winter injury.

b) stem rots: Stem rots impact plants in a similar manner as do root rots. Uptake of water and nutrients can moderately (or severely) influence plant growth.

c) leaf spots: Leaf spots directly reduce leaf area involved in photosynthesis. While some infected plants may die, most plants will survive but grow more slowly and be less productive.

d) shoot blights: Like leaf spots, shoot blights can sharply (or moderately) reduce functional leaf area and thereby hurt photosynthesis.

e) fruit rots: Fruit rots are a serious problem for fruit growers because these pathogens directly attack the marketable portion of the plants. So yield is reduced. However, quality of the harvested fruit may be impacted by low levels of pathogens in those fruit.

f) vascular wilts: Vascular wilts impede the functioning of the vascular tissue of plants (that is, the xylem and phloem). So, the impacts on the plant can be similar to those of stem rots. However, external symptoms may be less apparent for vascular wilts than for stem rots.

g) viruses: Viral pathogens take over the reproductive machinery of the plant cells in order to reproduce their own genetic material. Affected plants will often be distorted, discolored, and unproductive.

h) nematode root feeding: If many nematodes are feeding on plant roots, the impact on the plant may be similar to that of root rots. However, nematode-infested plants rarely die. Instead, such plants have reduced vigor and productivity, as well as greater susceptibility to other stresses.

COMPETENCY AREA 3. Pest management tactics

Non-pesticide pest management tactics

Prevention:

20. Describe methods to prevent introducing such pests as tobacco black shank and eastern black nightshade into non-infested fields.

In general, the **black shank fungus** can move in infested water, on infested plants, or in infested soil. Key practices to minimize one or more of those forms of spread include:

- 1) Make sure the transplants you use were grown in black shank-free soil.
- 2) Make sure that any equipment used in your tobacco fields (whether your own equipment or custom equipment) is cleaned and treated with chlorox before entering your fields.
- 3) Destroy tobacco stalks and barn trash from infested plants (instead of spreading it on clean fields or nearby pastures).
- 4) Be sure that transplant or irrigation water does not contain black shank organisms.
- 5) Prevent livestock from entering clean soil sites from nearby infested sites.

Under Kentucky seed law, **Eastern black nightshade** is considered a noxious weed seed in soybean seed. That means that zero tolerance for Eastern black nightshade is the policy of Kentucky seed law, and therefore, that growers using certified seed should not run any significant risk of bringing seeds of this weed into their fields. However, if a grower buys seed from a neighbor, or uses seed from an infested field to plant soybean in another field on their farm, the potential for spread is real. If farmers choose to clean and plant seed from their own farms, they should scrupulously avoid areas with Eastern black nightshade plants.

Genetic:

21. Describe advantages and disadvantages for herbicide-tolerant crops on pest management.

Two different examples of herbicide-tolerance will be discussed here: 1) Roundup Ready (RR) soybean and corn, and 2) sulfonylurea tolerant soybean (STS).

The advantages of RR soybean and corn are obvious. Most important weed species are easily controlled with a single application of Roundup; Roundup is relatively inexpensive; and scouting may not need to be as intense in a field to be treated with Roundup. Disadvantages of these genetically modified organisms (GMOs) are less obvious. It may be difficult to get an applicator into your field on a timely basis (since so many acres are being treated at about the same time); Roundup is still more expensive than atrazine for use in corn; some yield lag has been detected for RR soybean varieties and RR corn hybrids; some weed species are not well controlled by Roundup or may require higher (thus more expensive) Roundup rates for control; using both RR corn and RR soybean in an ongoing crop rotation may result in significant shifts in weed species populations toward those species less susceptible to Roundup; and some countries are uneasy about purchasing grain from our GMO crops.

The advantages of STS are straightforward: such soybean can be treated with a potent range of herbicides from this ALS inhibitor herbicide class, resulting in more effective weed control, and, since STS is not a GMO, some growers have been able to contract soybean for up to a 30 cent per bushel premium to the European market. Disadvantages of this technology are: many weed species are not susceptible to these herbicides; and development of resistant weed populations is enhanced by the relatively long persistence of this herbicide class in the soil, along with the tendency to utilize ALS inhibitors in rotated corn crops as well as on these soybean varieties.

22. Explain the use and limitations of pest-resistant varieties in insect and disease management.

Insect resistant crop varieties are clearly possible to develop. Classic examples include crops like tobacco (nicotine), the milkweeds (cardiac glycosides), and neem (several compounds) which include their own natural insecticides. Since most work on developing pest-resistant varieties has focused on disease resistance, relatively less progress has been made in the development of insect resistant varieties. A big factor in making insect resistant varieties a low priority has been the availability and low cost of many different insecticides. In addition, “yield drag” has been a problem; this simply means that insect-resistant varieties may have a lower yield potential than the susceptible varieties when both are grown under light insect pressure.

Disease resistant crop varieties should be used whenever possible. This strategy is a low cost, environmentally sound approach to disease management. In addition, this is a carefully planned, pro-active step which growers can take, rather than a reactive approach, which often leaves the grower with little choice but to apply a pesticide to try to slow down an already present disease pathogen. However, the use of disease resistant crop varieties does have a number of limitations, including: 1) Disease resistance packages are not available for most crop/pathogen pairs. 2) Even if we have resistant varieties, that resistance is not durable. Pathogens adapt, through shifts in their populations, to many resistant varieties, and we then say that the variety “lost” its resistance (even though the variety is still the same). 3) Often, disease resistance genes may be closely linked to other genes with poor agronomic traits. That results in poor yield of such varieties under low disease pressure, hardly encouraging growers to adopt the variety. 4) Many times, the resistance available is only partial; that is, resistant varieties are affected by a pathogen to a lesser degree than are susceptible varieties. 5) From a practical standpoint, the variety a grower needs may not be locally available.

Mechanical:

23. Recognize the role that the following mechanical methods of weed control play in overall management of weeds in Kentucky’s crops:

tillage practices:

primary tillage: Primary tillage, defined here as moldboard or chisel plowing, can help control weeds in certain situations. For example, moldboard plowing would remove most of a tall fescue stand for a grower wishing to switch to corn. In addition, some perennial species are partially controlled by primary tillage. However, there are relatively few situations in which primary tillage itself is a significant aid in weed control. In fact, such tillage operations can bring up a fresh supply of buried weed seed or transport and spread other plant parts which weeds use to propagate themselves (for example, johnsongrass rhizomes). The main aid of primary tillage in weed control is that it enables growers to use secondary tillage implements.

secondary tillage: Implements like a field cultivator can be used after weed seedling emergence to remove large numbers of seedlings. Of course, the grower must be prepared to wait to plant the crop until after weed emergence.

selective cultivation: Tobacco farmers in Kentucky, not blessed with the wide array of herbicides available for weed control in corn and soybean, have long utilized cultivators to remove weeds between the rows of growing tobacco plants. This practice allows for weed removal in a standing crop; however, it is generally not used in corn or soybean to a great extent. Cultivation is less effective in weed control than are herbicides, so where herbicides are available, most growers use them.

hand weeding: This practice is not extensively used with Kentucky field crops. Instead, hand weeding is more often employed by growers with high value crops (like vegetables) or by organic growers. Some farmers have used hoes or “chemical hoes” (spot sprays of herbicides) to eliminate individual weeds in their fields. This may be advantageous if a grower is trying to cut down on weed seed availability for the coming seasons.

mowing: In the Bluegrass region (and elsewhere also), mowing is often used to control weeds in pastures. Such a practice does not kill weeds, but may provide a competitive advantage to grass plants (which are adapted to grazing and mowing scenarios). Some control of thistles in pastures is obtained in this way.

Cultural:

24. Describe how the following are used to manage pests:

field history: The pests which have been problematic in the past are most likely to be problems in the future. In the case of weeds, knowing that certain species have consistently be troublesome may help the grower to decide to use a pre-plant or pre-emergence herbicide to get control measures underway earlier. In some cases, such a step can save money when compared to post-emergence treatments.

cropping sequence: Some pests are much worse in certain crops; growing such a crop continuously in an infested field would be asking for trouble. On the other hand, rotating crops can cut down on pest buildups and reduce the likelihood that a grower has to intervene with pesticides. For example, most corn rootworms are less problematic for corn following soybean than for corn following corn. In other cases, a crop rotation can help bring down the population of an existing pest; for example, switching away from soybean in a field infested with soybean cyst nematode can reduce the nematode population.

variety selection: Variety selection will generally not do much to help control weeds, unless you are talking about herbicide tolerant varieties (like Roundup Ready soybean). However, many crop varieties are available with some level of disease resistance, and some are available with insect resistance (for example, Weevilcheck alfalfa).

seed/plant source: In the case of Eastern black nightshade, using certified seed will help prevent introduction of this weed. In the case of blue mold of tobacco, using clean transplants can help prevent introduction of this disease.

tillage system: In a long-term no-till situation, perennial weeds tend to build up to fill the ecological niche left open. In conventional tillage, most (but not all) of the weed problems tend to be annual species. Tillage can help control some insect and disease pests; however, most such examples tend to be for crops not grown in Kentucky (for example, boll weevil of cotton).

residue management: The most significant change in residue management is from conventional to no-tillage methods (or vice versa). Hence, see tillage system above for pertinent comments.

planting date and method: Planting dates can be effectively used to manage some pests. For example, early planted corn will generally have less trouble with European corn borer. Likewise, wheat planted after the first fall freeze will generally have less barley yellow dwarf virus.

plant population: In grain crops, plant populations have been pushed progressively higher over time. However, overly thick plant populations can cut down on air circulation within the crop canopy, and can help fungal pathogens proliferate. This is a problem for blue mold of tobacco, gray leaf spot of corn, and leaf rust of wheat. So growers may be wise to cut back slightly on planting rates, or be prepared to apply fungicides to slow down fungal pathogens. In general, the recommendation is to target optimal stands for best crop yield, but to avoid the excessive planting rates which will promote stress and produce a favorable environment for development of some plant pathogens.

soil/plant fertility: In general, anything done to enhance plant growth will help plants withstand the stresses brought on by pests. For example, by applying potassium fertilizer to a K-deficient field, a grower can help her soybean crop close canopy sooner and thereby reduce weed competition. However, there can be too much of a good thing; for example, too much nitrogen fertilizer for a wheat crop may cause lodging and even could reduce grain yields.

water management: Relatively little of Kentucky's field crop acreage is irrigated. However, for those farmers, some things can help. For example, irrigating in the morning (rather than the evening) can not only get more of the water into the soil (because evaporative loss is lower), it can also reduce problems with some diseases (because the plant leaves dry off quicker during the day than at night).

pest interactions: Sudden death syndrome of soybean can be a greater problem in fields already suffering from soybean cyst nematode pressure. So, if a grower can take steps which reduce problems with one pest, he can sometimes cut down on problems with other pests at the same time.

timeliness of harvest: Early harvest of corn infested with second generation European corn borers can reduce grain lost to lodged plants. In some cases, early harvest of alfalfa may be the best method to control a hungry population of alfalfa weevil larvae.

Biological:

25. Recognize the following beneficial insects or biological control agents: a) lady beetles in corn, b) spiders in soybeans, c) syrphidfly in wheat, and d) thistlehead weevil.

Beneficials and biologicals generally have long, slender bodies with long legs; large eyes; sharp mouthparts or beaks; the capability to move quickly; grasping front legs; and are found around groups of plant feeding insects. Growers need to give these natural organisms their best chance to help the grower control insect pests. Generally, such organisms are of less value on leaf or high value crops, since even small levels of pest damage can be costly.

26. Describe the role of naturally occurring pathogens, predators, and parasites on insect populations.

Predator species (for example, spiders) often kill many different prey. While that helps the spiders survive, it minimizes the chances that spiders will play a central role in controlling any one insect pest. Unfortunately, the effect of pathogens, predators, and parasites on plant pests is relatively slow. So, the short-term benefits may be hard to see, but the long term benefits in keeping a pest infestation from going out of control are more apparent. Within a season, the benefit is often delayed, since the pathogen, predator, or parasite must have a minimum pest level in order to thrive themselves. Pathogens can, in unusual circumstances, provide substantial pest control. However, managing to produce this result is quite difficult.

II. Pesticide pest management tactics

27. Recognize how the following factors influence crop injury caused by pesticides in Kentucky:

crop/variatal sensitivity: Most of the sensitivity responses important in Kentucky crops are with herbicides. For example, each corn herbicide has a defined window of time in which it can be applied without significantly injuring corn. For example, Accent and Beacon should be applied before corn reaches 20 inches in height. Refer to the table “Timing of Herbicides Relative to Corn Growth Stages” on page 39 of the 1999 version of Chemical Control of Weeds in Kentucky Farm Crops (<http://www.ca.uky.edu/agc/pubs/agr/agr6/agr6.htm>). In addition, some new crop/herbicide packages must be carefully managed. For example, a soybean grower must be careful to not apply Roundup to her fields which were not planted with Roundup Ready soybean varieties.

weather: Most pre-emergent herbicides are more effective in weed control with a rainfall event to help move the herbicide into the topsoil. However, sometimes the herbicide may be moved into the level at which the crop was planted; this may increase the potential for crop injury. For example, alachlor injury of soybean may be greater if the germinating seedlings are exposed to higher levels of alachlor.

persistence: Persistent herbicides are more effective in weed control; however, such herbicides may have the potential to cause greater crop injury simply because they stick around longer in the soil. This can be an issue in rotational crops; for example, Scepter applied to a soybean crop can cause injury in a following corn crop, particularly if rainfall and temperature conditions (cool and dry) favor pesticide persistence in the soil.

rate and formulation: A low volatility formulation of 2,4-D is less likely to cause injury of nearby tobacco crops than is a normal volatility formulation. (However, this choice will NOT eliminate your chances of injuring nearby tobacco.) Higher rates of a compound mean that both crop exposure and pesticide persistence will be greater, making crop injury more likely.

method of application: Some herbicides are more likely to cause crop injury when soil applied; others are more likely to cause crop injury when applied to crop leaves. For example, Roundup applied before the crop is planted will not injure the crop, but could wipe out an entire field planted to a non-Roundup Ready variety. In addition, some adjuvants/additives (see question # 29 below) can make a herbicide “hotter” against certain weeds, but may also increase the potential for crop injury.

incompatibilities of pesticides: In some cases, applying two herbicides together can make crop injury more likely. For example, applying Assure II and Blazer at the same time can cause severe soybean injury. Refer to the table “Postemergence Tank Mixtures Labeled for Soybeans” on page 88 of the 1999 version of Chemical Control of Weeds in Kentucky Field Crops (<http://www.ca.uky.edu/agc/pubs/agr/agr6/agr6.htm>).

28. Describe how the following factors affect pesticide selection and use in Kentucky:

effectiveness against pest: Some pests are poorly controlled by a given pesticide, while others may be well controlled by the same pesticide. For example, while Harmony Extra does a good job controlling wild garlic but provides no control of annual ryegrass, Hoelon does a good job of controlling annual ryegrass but provides no control of wild garlic. Thus, a grower must be certain about the identity of his pest, and must have good information about pesticide effectiveness.

chemical and physical properties of pesticide: Pesticide chemistry is important to know if you are making repeated pesticide applications against a single crop pest. This will help you to reduce the chances of a shift in the pest population toward resistance to a single pesticide or pesticide chemistry. Physical properties can also be important; for example, Sevin will photo-degrade on leaf surfaces, and may need to be applied again even if a rainfall event has not washed off the Sevin.

toxicity: All other factors equal, a grower would usually favor to use a less toxic pesticide. This reduces both applicator and environmental hazards.

environmental hazard: Widely used herbicides, like atrazine, have turned up in ground and surface waters. As a result, significant regulations have been placed on such herbicides. For example, corn growers in sandy areas must cut down on atrazine rates, and must avoid atrazine all together near riparian zones.

persistence: More persistent herbicides are generally favored, because they “hold off” weeds for a longer period of time. However, such herbicides can cause problems with rotational crops. In a similar way, Tilt fungicide was only recently labeled for application to wheat through the heading stage (Feekes’ 10.5). In the past, regulators were concerned that Tilt residues would show up in wheat grain, and so prohibited Tilt applications after boot stage (Feekes’ 8).

potential for pest resistance: In a way, Bt corn hybrids come equipped with their own “natural” pesticide. Overuse of this pesticide (or any other pesticide) can result in development of pesticide resistant pest populations. So, a grower may rotate pesticide chemistries, even if it means using a less effective pesticide, simply to delay the development of pest resistance.

method of pesticide application: Some pesticides can only be applied in a preventative mode; that is, they must be applied before the pest appears in order to do any good. Others can be applied after the pest “arrives” in the field. It is important to know which pesticides can be used in which way.

field pest history: For pests which are primarily resident in individual fields (weeds, for example), a thorough knowledge of past weed pressures can help the grower in choosing herbicides. For example, if a corn grower knows that cocklebur, lambs quarter, and common ragweed have been big problems in the past, she may choose to apply atrazine to her soil (rather than waiting for these weeds to emerge).

pest identity: See the answer to question #6 in this section. A mistake in identifying a pest can cause all kinds of bad outcomes. Accurate pest ID will help a grower may an informed decision on what, if any, intervention to make in a pest outbreak.

incidence and severity of pest: Some wheat growers will treat their fields with Warrior to control aphids (which may spread barley yellow dwarf virus) if even one aphid is observed. A more logical approach to pest management is based on a whole-field look at pest presence and pest pressure. Of course, this requires careful scouting. In some cases, treatment with a pesticide may be confined to only a small portion of a field. For example, a wheat field with annual ryegrass along one side could just be treated in that area with Hoelon.

pest stage of development: Some pests will do little damage after reaching a certain point in their development. For example, once chickweed has flowered, there may be little benefit to spraying a wheat field to control the chickweed. Other pests are more difficult to control at certain stages in their lives. For example, once European corn borer larvae have burrowed into the stems of corn plants, pesticide treatments will have little benefit because this pest's exposure to the pesticide will be so low.

crop growth stage: Sometimes, a farmer is wise to simply go ahead and harvest the crop, rather than applying a pesticide. In certain situations, this is the recommended strategy for dealing with alfalfa weevils in alfalfa. In other cases, one herbicide may be effective against a given weed, but the grower may need to use a different herbicide to reduce the risk of crop injury.

weather-pest interactions: Sometimes, the weather can make pest pressure worse; for example, by bringing in spores of blue mold of tobacco or leaf rust of wheat. In other cases, the weather can help control diseases. For example, as temperatures warm up, wheat may grow out of a powdery mildew infestation. A spring freeze can sometimes kill off alfalfa weevil larvae without injuring the alfalfa.

pesticide availability and label restrictions: Maintaining careful, detailed field histories will help a grower keep from getting caught without a pesticide effective against a given pest. However, some pests are less predictable than others (for example, blue mold is less predictable than is black shank of tobacco). In such cases, growers or even chemical distributors may not have the best pesticide for a given pest available at the time it is needed. In that case, a grower may have to make do with what is available. In other cases, a crop label may prohibit use of the pesticide at the current crop growth stage. State and federal agencies sometimes permit emergency use of pesticides "off" the standard label, provided the risk of crop loss is severe.

economics: This is the single main reason why atrazine has been so popular for use on corn. It still provides solid control of many broadleaf weeds, and does so at very low cost to farmers. All other factors being equal, most farmers will wisely choose to control pests with the least expensive alternative. Of course, growers must justify any pesticide treatment primarily on economic grounds; if the treatment will not pay for itself in increased crop yield and/or quality, the treatment should generally not be made. Often, growers will "cheat" on pesticide rates in an effort to get reasonably good pest control at a lower cost.

public concerns: Public concerns about environmental impacts of pesticide applications have certainly been growing. As a result, increasing regulatory pressure has been placed on growers to force them to be more environmentally responsible. Water quality concerns have played a leading role in this area; by October of 2001, every farmer with 10 or more acres of land will have to have a water quality plan in place (see answer to question #45 below).

soil characteristics (for soil applications): Not only do soil characteristics affect herbicide effectiveness, they also influence the potential for herbicide leaching. For example, coarse textured soils are more likely to show herbicide leaching. In addition, soils with higher levels of organic matter will often bind a higher percentage of a herbicide, thus requiring that higher herbicide rates be applied.

29. Describe the role of the following adjuvants/additives in pesticide applications:

surfactants: Surfactants are any material which favors or improves the emulsifying, dispersing, spreading, wetting or other surface modifying properties of herbicide solutions. Surfactants improve absorption of herbicides by weed leaves, and thereby improve herbicide effectiveness.

oil concentrates: Oil concentrates are a blend of non-phytotoxic crop oils, surfactants, and emulsifiers; they work in a similar way to improve herbicide absorption.

fertilizer additives: Urea ammonium nitrate (UAN) solutions are sometimes applied with herbicides to enhance their effectiveness.

drift control agents: Such treatments are designed to help keep the pesticide from drifting to other nearby fields.

defoamers: Defoamers reduce foam buildup in the sprayer tank, making pesticide applications more uniform and tank clean-up easier.

30. Recognize how the following factors affect spray delivery and spray coverage:

spray pressure: Higher spray pressure will result in a greater volume of solution applied to the field, and will also enhance coverage of plants with pesticide.

application speed: Faster ground speed will reduce both volume of spray per unit area and coverage of soil and/or plants with pesticide.

nozzle type: Nozzles of the 80 series produce an 80 degree spray pattern, while those of the 110 series produce a 110 degree spray pattern. Within each series, a range of orifice sizes are available, so that a grower can adjust spray volume as desired for any particular application.

nozzle spacing: Spacings are typically either 20 or 30 inches. Of course, the same nozzle type will deliver 50% more spray solution per unit area if the nozzles are moved from 30 to 20 inch spacings.

nozzle height: Ideally, the nozzle height above the soil or crop canopy (whichever is the target) should be set to result in a 30% overlap of the spray pattern of adjacent nozzles. For example, if you are using an 80 series tip and 20 inch nozzle spacings, the spray height should be about 18 inches. Details on nozzle types are shown on page 8 of the current version of the Chemical Control of Weeds in Kentucky Field Crops (<http://www.ca.uky.edu/agc/pubs/agr/agr6/agr6.htm>).

31. Define the following types of pesticide interactions when two or more pesticides are used:

additive: Additive interactions simply means that each pesticide continues to do the same job it would do when applied alone. Pest control is neither enhanced nor harmed by mixing the pesticides. Applying them together is advantageous simply because that saves the cost of two trips across the field.

synergistic: In this case, performance of the pesticides in tandem is clearly enhanced by mixing the pesticides. So, a simultaneous application of both pesticides will both improve pest control and save application costs.

antagonistic: In this case, pest control activity is harmed by mixing the two pesticides. So, growers will want to avoid this scenario if at all possible.

32. Describe methods to reduce risk or manage pesticide-resistant pests.

An important example of an integrated approach to manage an already resistant pest is for triazine resistant smooth pigweed (see response to question #8 above). In a similar way, an important example of resistance management (an effort to delay or prevent development of pest resistance) is the judicious use of Bt corn hybrids to control European corn borer (see also response to question #8 above).

In general, growers should use crop rotation combined with “chemical rotation” (using different pesticide classes against a given pest) to delay pesticide-resistance.

33. Identify general plant symptoms (weed and crop) caused by the following herbicide mode of action groups and identify the herbicides in each group:

contact herbicides: Such herbicides kill tissue with which they make direct contact. Hence, they are applied directly to weeds (rather than to the soil) and are not translocated. Diquat and paraquat are two good examples from the Photosystem I inhibitor class (see below) and acifluorfen, fomesafen, and lactofen are good examples from the PPO inhibitor subclass of the Enzymatic inhibitors class (see also below).

growth regulators: Growth regulators include phenoxy acids (2,4-D; dichlorprop; and 2,4-DB), benzoic acids (like dicamba) and pyridines (like picloram). These herbicides disrupt plant growth, primarily affecting dicot plants (but they can injure corn and wheat if applied at the wrong growth stage). Dicots will show darker than normal leaves, malformed leaves, and twisted stems. Monocots (like corn and wheat) will show onion-leafing (whatever that is!), brittle stalks, malformed brace roots (in corn), curved stems, and misshapen heads or ears. Generally, leaf symptoms appear within 48 hours of foliar applications of growth regulators.

photosynthetic inhibitors: Photosynthetic inhibitors include those which affect photosystem I (diquat and paraquat), those which affect photosystem II, site A (the triazine family, including atrazine; also, the triazinones including metribuzin), and those which affect photosystem II, site B (including the s-phenylureas like diuron and linuron; uracils like bromacil; nitriles like bromoxynil; benzothiadiazoles like bentazon; amides like propanil; phenyl-pyridazine like pyridate; and phenylcarbamates like desmedipham). [Note: for a current listing of herbicide trade names based on their active ingredients, see the current version of Chemical Control of Weeds in Kentucky Farm Crops (web address).]

Photosystem I inhibitors are contact herbicides which result in rapid leaf chlorosis and necrosis. They are not translocated within the plant. Symptoms produced by Photosystem II, site A inhibitors depend on the site of plant uptake. If such herbicides are taken up by plant roots, older leaves will be the first to show interveinal chlorosis, and the weeds may take weeks to die. If such herbicides are taken up by plant leaves, both treated and younger leaves will show interveinal chlorosis first, and weeds will die within a few days. Symptoms produced by inhibitors of Photosystem II, site B are like those of site A; the main difference is that these herbicides attack electron transport at a different site than do site A inhibitors.

pigment inhibitors: These herbicides blocks the formation of carotene in chloroplasts; as a result, only new leaves will show the bleaching characteristic of this herbicide class. They include the triazoles (like amitrole), the pyridazinones (like norflurazon), and the isoxazolidinones (like clomazone).

meristematic inhibitors:

root: The dinitroanilines (like pendimethalin, trifluralin) are applied to the soil (since they impact roots!) and generally must be incorporated into the soil (because they are poorly soluble in water and are subject to photodegradation). They severely inhibit root development; as a result, shoots will be stunted. Root inhibition will be obvious within 7 to 10 days for most plants. Grass shoots will turn red to purple; meanwhile, broadleaf shoots will become brittle, but not until 6 to 8 weeks after emergence.

shoot: Amides (like acetachlor, alachlor, and metolachlor) cause grasses to leaf out before completing emergence. Corn can be protected from such injury by the inclusion of a safener in the formulation of acetachlor or metolachlor.

Carbamates (like chloropropham) inhibit mitosis and are effective on small seedlings. Carbamothioates (like butylate and EPTC) are volatile, and so must be incorporated into the soil immediately upon application. Leaf malformation and twisting appear within the first week after emergence. Grasses show “buggy-whipping” symptoms at 12 to 24 inch heights. When butylate and EPTC are applied to corn fields, a safener is added to the formulation to protect the corn plants.

Sulfonylcarbamates (like asulam) inhibit mitosis of grass weeds.

enzyme pathway inhibitors: All such herbicides block plant metabolism at a specific enzymatic target. Classes include: 1) acetyl CoA carboxylase (ACCase) inhibitors (like flumazifop-P, quizalofop-P, and sethoxydim); 2) acetolactate synthase (ALS) inhibitors [sulfonylureas (like chlorimuron, nicosulfuron, rimsulfuron, thifensulfuron, and tribenuron); imidazolinones (like imazaquin and imazethapyr); sulfonamides (like flumetsulam); pyrimidinylthiobenzoates (like pyriproxyfen)]; 3) 5-enolpyruvylshikimate-3-phosphate (EPSP synthase inhibitors (like glyphosate and sulfosate), 4) a glutamine synthetase inhibitor (glufosinate), and 5) protoporphyrinogen oxidase (PPO) inhibitors like (acifluorfen, fomesafen, and lactofen).

ACCase inhibitors control grasses (except annual ryegrass). Symptoms develop slowly, but start with chlorosis and purpling of newly emerging leaves.

ALS inhibitors cause a range of symptoms, depending on the target weed species. Soil treatments may result in stunting, purpling of new leaves, and the “bottle brush” syndrome of roots (proliferation of small roots). Leaf treatments may cause stunting, shortened internodes, and chlorosis of new leaves.

EPSP synthase inhibitors produce chlorosis, necrosis, and death, usually within 2 or 3 weeks after treatment. These herbicides are nonselective and are only applied post-emergence.

Glufosinate causes chlorosis within 3 to 7 days after treatment, due to a buildup of ammonia in plant tissues.

The PPO inhibitors will produce leaf necrosis within 48 hours after treatment, and generally do produce some injury on treated soybean plants (leaf puckering, reddish color, chlorosis). These herbicides have contact activity only.

34. Define the role that the following factors may play in influencing the persistence of soil-residual herbicides and the potential for rotational crop injury from soil-residual herbicides:

soil moisture: In wetter soils, both leaching and biological degradation of herbicides will be enhanced. So, dry soil conditions are more likely to result in carryover injury to sensitive rotational crops.

soil temperature: Warmer soils enhance biological degradation of herbicides. So, cool soil conditions would generally result in greater potential for carryover injury.

soil pH: Both triazines and sulfonylureas persist longer in soils with an alkaline pH. Thus, carryover injury is more likely in soils with a pH above 7.0. On the other hand, clomazone (an isoxazolidinone, can persist longer with pH levels at or below 5.9.

soil microbes: Microbial activity is favored by warm, moist conditions; this scenario leads to faster herbicide breakdown and lower potential injury to rotational crops.

application rate & timing: Of course, higher application rates will increase the likelihood of carryover, since injury to rotational crops is dependent on the concentration of the herbicide in the soil, and a higher starting point for herbicide concentration would make it more likely that the threshold level for crop injury would still be in the soil when the next crop was planted. If a residual herbicide is applied later than normal (say corn is planted in June after a wet spring), then carryover injury is more likely.

crop/variety tolerance: Some crops are more sensitive to residual herbicides than others. For example, oats are very sensitive to residual atrazine. In addition, some varieties within a crop are more likely to suffer rotational injury; consult with your seed and chemical dealer to be sure that your combination is not a problem. For example, some wheat and barley varieties do not tolerate Sencor (metribuzin) very well. Since this herbicide is the best choice for control of *Bromus* species (like cheat and downy brome), growers facing substantial pressure from these weeds should be careful to avoid Sencor-sensitive wheat and barley varieties.

35. Recognize the role that persistence plays in weed control and in the potential carryover problems for specific herbicides belonging to the following herbicide families:

In general, while persistence is good for longer lasting weed control, it can be a problem if significant levels of residual herbicide are still in the soil when growers are ready to plant the next crop in the rotation.

amides: Dual II and Dual II Magnum (metolachlor), Harness (acetochlor), and Micro-Tech (alachlor) are all amides. Sometimes, grassy weed control can be less than expected due to wet, warm conditions, which speed up herbicide degradation. However, these herbicides vary in their potential impacts on rotational crops. The Dual formulations call for a 4.5 month delay post-treatment for small grains, 4 months for alfalfa, and 9 months for clover. Soybean may be injured by Harness in the year following treatment of corn with this herbicide; this will depend on the weather conditions experienced after Harness treatment. Micro-Tech does not include any warnings or restriction on rotational crops.

dinitroanilines: Prowl, Squadron, and Steel (all of which contain pendimethalin) and Treflan and Tri-Scept (all of which contain trifluralin) are common dinitroaniline herbicides. Prowl is used on corn and tobacco, while Treflan is used on soybean. Both of these herbicide's active ingredients must be incorporated into the soil, and this has contributed to their decline in importance (as farmers move toward greater adoption of no-till methods). Pendimethalin requires a 4 month delay for planting small grains. Trifluralin requires a 12 month delay for planting grain sorghum, oats, and forage grasses. If trifluralin is applied at its "high end" labeled rate (3 pints/A), sensitive crops may not be planted until the second season following application.

imidazolinones: Pursuit (imazethapyr), Scepter (imazaquin), Raptor (imazamox), Lightning (imazethapyr plus imazapyr), Squadron and Tri-Scept (both of which include imazaquin), and Steel (which includes both imazaquin and imazethapyr) are all in this herbicide class. The potential for rotational injury with imidazolinones is substantial, as you can see from the following list of restrictions.

Lightning is only used on corn hybrids which have genetic resistance or tolerance to its active ingredients. Wait four months to plant wheat or rye; 9 months to plant soybean; 9.5 months to plant alfalfa, barley, or tobacco; 18 months to plant popcorn, sorghum, sweet corn or oats; and 40 months to plant forage grasses.

Pursuit is used on soybean. It requires a planting delay of 4 months for alfalfa, rye and wheat; 8.5 months for non-IMI corn; 9.5 months for barley and tobacco; 18 months for sorghum and oats; and 40 months, along with a successful bioassay, for other crops.

Raptor, used on soybean, requires a planting delay of 3 months for wheat, 4 months for barley or rye, and 9 months for corn, grain sorghum, or tobacco.

Scepter (and other herbicides containing imazaquin) are used to control weeds in soybean fields. Rotational restrictions include a delay in planting of 3 months for wheat; 9.5 months for corn or tobacco; and 11 months for barley or grain sorghum. If rainfall from 2 weeks prior to Scepter application through November 15 is less than 15 inches, do not plant corn the following spring [unless you are using imidazolinone resistant/tolerant (IMI) corn hybrids].

isoxazolidinones: Command (clomazone) is used on soybean and tobacco. Corn and grain sorghum require a 9 month planting delay; wheat requires 12 months; and other crops require 16 months. With dry conditions after Command application and/or pH levels below 5.9, clomazone can persist even longer in soils.

sulfonylureas: These herbicides have become extremely important in weed control in Kentucky field crops. Unfortunately, the potential for injury to rotational crops is substantial.

Harmony Extra (thifensulfuron and tribenuron) is used in wheat. Accent (nicosulfuron), Accent Gold and Basis Gold (which contain both nicosulfuron and rimsulfuron), Beacon (primisulfuron), Exceed and Spirit (both of which contain prosulfuron and primisulfuron), and Permit (halosulfuron) are used on corn. Permit can also be used on grain sorghum. Classic (chlorimuron), Canopy and Canopy XL (which contain chlorimuron), and Pinnacle (thifensulfuron) are used on soybean. In addition, Synchrony STS (contains both chlorimuron and thifensulfuron) is used only on STS soybean varieties.

The only restriction on the Harmony label is to avoid planting rotational crops within 60 days of herbicide application. Since much of the state's wheat acreage is treated with Harmony in the fall, this is generally not an issue. However, if Harmony were applied in the spring, and then the wheat crop was abandoned for whatever reason, rotational crop injury could occur.

Accent requires a delay on planting soybean for 15 days (not months); wheat, barley or rye for 4 months; and alfalfa, rye, or grain sorghum for 10 months.

The restrictions for Accent Gold are longer than for Accent. For wheat, barley, and rye, wait 4 months; for alfalfa and soybean, wait 10.5 months; and for grain sorghum, wait 12 months. Other crops (like tobacco and forage grasses) require a 26 month waiting period as well as a successful bioassay.

Basis Gold, which includes atrazine as well as a pair of sulfonylureas, permits soybean, small grains, and grain sorghum to be planted 10 months after application. Other crops require an 18 month delay. If Basis Gold is applied after July 1, only corn or grain sorghum may be planted the following season.

Beacon requires a 3 month delay in planting for wheat, barley and rye, and an 8 month delay for alfalfa, grain sorghum, soybean or tobacco. Other crops require an 18 month delay.

The label for both Exceed and Spirit depends on soil pH at the time of herbicide application. If the soil pH is below 7.8 (most Kentucky fields would fall below this mark), a 3 month delay is required for wheat, barley and rye; a 10 month delay for soybean, grain sorghum, forage grasses and tobacco; and an 18 month delay for alfalfa or any of the clovers. If soil pH is above 7.8, sensitive broadleaf crops will require more time to pass for safe planting. Further, if conditions are cool and dry after herbicide application, any fields rotated to soybean the following season may need to be planted to STS soybean varieties.

Permit requires a planting delay of 1 month for corn (yes, that's right); 2 months for grain sorghum, wheat, barley, or forage grasses; and 9 months for soybean or alfalfa.

Canopy and Canopy XL persistence is affected by the rates applied. If the soil pH is 7.0 or less and the rate is less than 10 ounces per acre (Canopy) or 6.4 ounces per acre (Canopy XL), the following planting delays apply: wheat and barley, 4 months; alfalfa, tobacco, grain sorghum, and corn, 10 months; other crops, 18 months. [Note: Canopy XL requires a 12 month delay for alfalfa.]

Classic requires a planting delay of 3 months for wheat or barley; 8 months for imidazolinone resistant (IR) corn hybrids; 9 months for non-IR corn hybrids, grain sorghum, or tobacco; and 12 months for alfalfa or clovers.

Pinnacle permits any crop to be planted once 45 days pass after its application.

Synchrony STS may only be used on STS soybean varieties. Rotational restrictions are: 3 months for wheat, barley, tall fescue and ryegrass; 9 months for tobacco, sorghum and corn; and 12 months for alfalfa and clovers.

triazines:

The most important triazine herbicide is Aatrex (atrazine) used on corn, followed by Sencor and Lexone (metribuzin), which are primarily used on wheat and soybean and Canopy (which includes metribuzin) and is used on soybean. Note that atrazine itself is also sold under several other brand names besides Aatrex. In addition, several other corn herbicides also include atrazine as a key ingredient in their formulations: Basis Gold, Bicep II, Bicep II Magnum, Bullet, FieldMaster, Fultime, Guardsman, Harness Xtra, LeadOff, and Marksman.

The atrazine label says not to plant small grains or small-seeded legumes or grasses in the year of application or in the following year. Only corn, grain sorghum, or soybean should be planted in the spring of the year following atrazine application. [Note: many Kentucky growers regularly plant wheat or barley in the fall following corn which was treated with atrazine. So, this planting precaution appears to be overly long in that particular case.]

36. Describe the benefits and limitations of the following methods of herbicide application and the potential use of these methods in different tillage systems in Kentucky:

early preplant: Under this system, a grower must have a good idea of what weeds are likely to be a problem in her crop. In general, an early preplant application needs to be made two or three weeks ahead of planting in order to accomplish the desired effect of burning down existing weeds (as well as applying a residual herbicide). If early season crop growth is slowed by adverse environmental conditions (too cold, too wet, too dry), followup weed control measures may be necessary.

preplant incorporated: Some herbicides cannot be used unless they are incorporated (for example, Treflan and Prowl). Other herbicides are more effective with at least a shallow incorporation (for example, Scepter). Thus, this application method allows some additional herbicide choices to be considered for growers' weed control programs. The biggest disadvantage to this system is that it requires tillage. Besides being an extra production cost, tillage can also leave the soil more susceptible to erosion, and may hurt yield of summer annual crops like corn and soybean (especially in dry seasons).

preemergence: Such applications can follow the planting operation, and may give a grower a little flexibility on when the herbicide might be applied. (Of course, herbicide application could be delayed by rainy weather, and could leave a grower trying to decide which postemergence herbicides to apply.) A real problem here is that sometimes rains do not come after herbicide application; this can leave the herbicide only on the soil surface and may result in relatively poorer weed control, especially of less-sensitive weed species.

postemergence broadcast: The biggest advantage of this system is that a grower knows (or should know) exactly what weeds he is trying to control, since the herbicide is applied to growing weeds. There should be no guesswork as to what weeds are likely to be a problem for this year's crop in this field. A disadvantage here is that growers really need to get out within a week of planting their crop to see what weeds are out there, and some growers simply have not allocated people to that task on a timely basis. A sharp grower can make (or save) some money by carefully picking the herbicides needed to control existing weeds on a field-by-field basis. Another potential problem here is that the grower may wait too long to apply the herbicide, and since larger weeds are generally harder to control, inadequate weed control may result.

With the advent of Roundup Ready soybean (and Roundup Ready corn, to a lesser extent), this post-emergent herbicide/seed package has lessened (but not eliminated) the need for scouting of soybean fields.

postemergence directed:

This system is intended to attack weeds in crops which have passed the safe time window for an “over-the-top” application of a given herbicide. By minimizing the contact the herbicide makes with crop leaves, a grower can “get away with” a later than normally appropriate application of a herbicide. This system may provide some assistance in the control of johnsongrass or vines in corn fields, for example. A serious limitation with this system is that if weeds are allowed to compete with the crop for this long, they may have already caused some yield loss. In addition, even with the directed application, there is still a good chance for some level of crop injury to be caused by the directed spray.

37. Recognize the potential effect that stage of growth of plants and environmental factors have on weed control and herbicide injury to crops in Kentucky.

In general, smaller weeds are more easily controlled with any given herbicide. In contrast, the general rule for crops is that the larger the crop plant is at the time of herbicide application, the more likely it is that crop injury will result. An excellent example of the timing of herbicides to minimize crop injury was discussed for corn in response to question #27 (above).

If crop plants are already under a stress (for example, water stress, disease pressure, or insect attack), herbicide injury may be worse than it would be for non-stressed crop plants. Unfortunately, weedy plants often respond in the opposite fashion. For example, if weeds are suffering from water stress when a herbicide is applied, weed control will often be less effective than for non-stressed weeds.

Of course, some pre-emergent herbicides will be less effective if rains do not come within a few days of their application, since those rains are needed to move the active ingredient down into the soil where weeds seeds are germinating.

Some growers believe that air temperatures play an important role in herbicide effectiveness. The general rule is that if the weeds are actively growing at the time the herbicide is applied, then it will be able to provide the expected level of weed control. For example, if Harmony Extra is applied on a cool December day to control wild garlic in wheat, garlic control is likely to still be good. Of course, air temperature on the day of application will have little to do with the efficacy of soil-applied herbicides. For post-emergent herbicides applied to summer annual crops, some will clearly benefit from warmer temperatures, since weeds are more likely to be growing rapidly (assuming that soil water supplies are adequate).

38. Describe modes of action of the major insecticide groups.

Nerve poisons include: chlorinated hydrocarbons, organophosphates, carbamates, synthetic pyrethroids, and chloronicotinyls. Organophosphates and carbamates block the activity of a specific enzyme active at the synapse gap of the nerve. Synthetic pyrethroids and chlorinated hydrocarbons work on the axon itself (by preventing the correction of a charge imbalance in the axon). Chloronicotinyls inhibit post-synaptic reception. If you are not up-to-speed on neural function, don't worry too much. The key point here is that you must know to which group your "regular" pesticides belong, so that you can rotate to a different type of nerve poison, rather than within a class. Rotating to another insecticide of the same class would not delay the development of insect resistance. Also, you should be aware that all of the nerve poisons can also be quite dangerous to people, since our nerves work basically the same way as do insect nerves.

Insect growth regulators interfere with specific steps in the metamorphosis of insects. For example, some can "freeze" insects in their immature stage (this would not be so great for most Kentucky field crops!). Biological insecticides can help significantly. For example, the Bt toxin can reduce some larval infestations and the venom from some scorpions and spiders can be used against certain insects.

39. List the benefits and disadvantages (efficacy, economic, environmental) when using fungicides in the following categories:

a) contact vs. locally systemic vs. systemic

Contact fungicides are applied to the plant's surface. They must be applied before the infection occurs. Examples of active ingredients of contact fungicides include: mancozeb, maneb, chlorothalonil, ferbam, captan, and thiram. Locally systemic fungicides do penetrate the plant's tissues but move only to a limited extent within the plant. Systemic fungicides are absorbed by the plant, then translocated throughout its tissues. Systemics can be applied after an infection occurs and still have a beneficial impact. Examples of active ingredients of systemic fungicides include: benomyl, metalaxyl, triadimefon, and thiophanate methyl.

In general, contact fungicides are less efficacious than either systemic fungicide class, primarily because they must be applied before disease symptoms appear. Cost-wise, the systemics tend to cost more. Environmental impacts of all three classes are modest; contacts are washed off plant leaves by rainfall at some point and thus can get into the soil and surface and groundwater, but systemic fungicides tend to persist for a longer time.

b) protective vs. curative

Protective (or protectant) fungicides have to be applied before the infection occurs because they are contact fungicides, and must remain on the soil surface to have an effect on disease development. Curative fungicides (either systemic or locally systemic) can slow down or stop an existing infection; such fungicides can be applied after disease symptoms appear. See part a) for information on the efficacy, economics, and environmental impacts of these fungicide classes.

c) seed vs. soil vs. foliar applied

Seed treatments can be either contact (captan, thiram) or systemic (metalaxyl). Contact seed treatments protect the seedling from soil fungi during and shortly after emergence. Systemic fungicides are absorbed by the developing seedling, and can help reduce incidence of seedling diseases.

Soil applications of fungicides can be as either fumigants [dichloropropene, methyl bromide (being phased out due to environmental problems), chloropicrin, and dazomet] or as nonfumigant fungicides (metalazyl, thiophanate methyl, and PCNB) or as nonfumigant nematicides (carbofuran, ethoprop, and aldicarb).

Foliar fungicides are applied to plant leaves to protect them from fungal pathogens, and can be either protectant or systemic (see above).

Seed treatments are quite effective for most seedling diseases, as are soil fumigants. Foliar fungicides are much more effective for fungal diseases which attack leaf tissue. Cost of seed treatments are generally low, since a separate application trip is not required. Soil fumigants can be quite expensive, and are usually used only on high value crops grown on relatively small areas. Cost-wise, foliar fungicides would fall between the other two classes. Environmental impacts of seed treatments are generally modest, since application rates are relatively low. Similarly, foliar fungicides generally have little environmental impact. On the other hand, some soil treatments are environmentally problematic. For example, the fumigant methyl bromide is being phased out because it has been shown to be responsible for some of the destruction of protective ozone in the upper atmosphere. In addition, some nonfumigants can be moved easily to the groundwater (aldicarb has been an example of this problem).

d) broad spectrum vs. narrow spectrum.

Broad spectrum fungicides kill a wide array of fungal pathogens, while narrow spectrum fungicides take care of only one (or a few) fungi. Of course, a grower should know which fungal pathogen she is targeting before she sprays a fungicide. Once this is known, a grower can pick the specific fungicide most effective against that particular problem. The chosen fungicide could be either broad or narrow spectrum. In general, growers prefer broad spectrum fungicides because they can offer some level of control of secondary pathogens. For example, a wheat grower may choose to apply Tilt for leaf rust control of wheat, knowing that he is also gaining some control of glume blotch as well. Cost-wise, these two classes do not differ too much, and environmental impacts are generally modest.

40. Describe how fungicides differ from bactericides, nematocides, and soil fumigants.

Fungicides are used to control plant diseases caused by fungi. They come in many different types (see question #39 above), but most are relatively nontoxic to humans.

Bactericides are used to kill bacteria. Such compounds only have protectant activity; thus, they must be applied before the bacterial infection occurs if they are to do any good. Streptomycin is an example of a bactericide.

Nematicides are used to help control nematodes. These compounds are usually quite toxic to humans, so must be used with extreme care. Such compounds may be either fumigants or nonfumigants. Temik (aldicarb) is an example of a nematicide.

Soil fumigants are applied to the soil as either liquids or as granules and turn to a gas in the soil. Often the soil area is covered to keep more of the gas in the soil to help with its intended function. Some fumigants are quite toxic to people.

41. List the factors that affect the activity of soil fumigants.

Soil which are moist and friable (loose) with temperatures between 50 and 75 F will provide the best results in terms of reducing numbers of fungal spores and nematodes. If a soil is too wet, the gas will not diffuse readily, since gases diffuse much more rapidly into air than into water. If a soil is too dry, much of the gas will quickly escape from the soil. In a similar way, fumigant gas will diffuse too slowly in cold soils and too rapidly in warm soils. A compacted soil will impeded diffusion of the gas.

COMPETENCY AREA 4. Safety/regulatory aspects

42. Describe how misuse of pesticides can affect:

a) non-target organisms: Pesticides may contact nontarget organisms even if pesticide applications are done according to the label restrictions. However, misuse of a pesticide can greatly enhance the chances of impacts on non-target organisms. For example, applying a pesticide on a windy day can aggravate its spread away from the intended site. In a similar way, applying a nonlabelled pesticide to an aquatic area could result in an extensive fish kill.

b) ground and surface water: Pesticides vary dramatically in their leaching potential (see IP-41 at <http://www.ca.uky.edu/agc/pubs/ip/ip41/ip41.htm>). If an easily leached pesticide is applied to a soil in higher rates than the label permits, groundwater contamination is likely. Strict adherence to label requirements will help protect groundwater. Surface water contamination can occur when a heavy rainfall event occurs soon after a pesticide is applied. For that very reason, farmers are to be discouraged from making pesticide applications just prior to expected heavy rainfall events.

c) food safety: Pesticide application later than the label permits can result in plant products which carry pesticide residues in excess of the “safe” levels established by regulatory agencies. In a similar way, excess applications of pesticides can also result in pesticide residues on food products.

43. Describe how information on pesticide labels is used to determine proper pesticide use rates.

“Understanding Pesticide Labels and Labeling” (ID-100) at <http://www.ca.uky.edu/agc/pubs/id/id100/id100.htm> has details on the 17 categories of information included in pesticide labels listed below.

1. brand name, common name, and chemical name
2. active ingredients
3. inert ingredients
4. hazards to humans and domestic animals
5. environmental hazards
6. physical and chemical hazards
7. directions for use
8. reentry statement
9. category of applicator
10. storage and disposal directions
11. statement of use classification (general or restricted use)
12. signal words (Danger, Warning, Caution)
13. symbol (skull and crossbones used to indicate poisonous nature of a pesticide)
14. statement of practical treatment
15. name and address of manufacturer

16. registration and establishment numbers
17. net contents of container.

Pesticide use rates are determined by the percentage active ingredient (see item #2 above) and by the directions for use (see item #7 above). The directions for use will include information on which pests the pesticide controls, what rates should be utilized for particular pests at particular growth stages, and with which crops the pesticide may be safely used.

44. Explain Kentucky and Federal pesticide recordkeeping requirements.

Whenever Restricted Use Pesticides (RUP) are applied, federal law requires that the applicator, within 30 days of the application (and preferably right away), record the following information: product name, EPA registration number, total amount of pesticide applied, location of the field, crop being treated, total number of acres treated, name and RUP certification number of the person supervising the application, and date of application.

The state of Kentucky requires that pesticide applicators keep such records for 3 years, and make the records available to the state at their request.

45. Describe the requirements and best management practices (BMP's) under the Kentucky Agricultural Water Quality Authority.

The Kentucky Water Quality Act was passed by the 1994 General Assembly. It requires any farmer with at least 10 acres of land to develop and implement a water quality plan for her land by October of 2001. The goals of the Water Quality Authority are to: 1) identify water pollution problems, 2) evaluate current BMPs, and 3) suggest new BMPs and other initiatives to improve water quality in the Commonwealth. The full text of all of the BMPs is not yet available on the web, but you can find a full description of two of the newest Livestock BMPs at <http://www.ca.uky.edu/enri/news/marapr99.pdf>. In addition, you can find a description of the Water Quality Act and a list of its board members at <http://www.nr.state.ky.us/nrepc/dnr/Conserve/doc2.htm#KAWQA>.

Category	BMP
Pesticide & Fertilizer	#8 Mixing, Loading, & Handling of Pesticides and Fertilizer and their Containers
	#9 Excess Pesticide Disposal
	#10 Pesticide & Fertilizer Container Disposal
Crops	#1 Conservation Cropping Sequence
	#2 Conservation Cover
	#3 Conservation Tillage and Crop Residue Use
	#4 Contour Farming
	#5 Nutrient Management

- #6 Filter Strip
- #7 Grasses and Legumes in Rotation
- #8 Mulching
- #9 Pasture & Hayland Planting and Management
- #10 Stripcropping
- #11 Critical Area Planting and Treatment
- #12 Pest Management, Including Cultural Control
- #13 Cover Crop
- #14 Waste Utilization
- #15 Grassed Waterway

Livestock

- #1 Planned Grazing Systems
- #2 Proper Grazing Area
- #3 Riparian Area Protection
- #4 Limiting Access to Streams by Fencing with Alternative Water Systems or Limited Access Points
- #5 Waste Management Systems
- #6 Waste Storage Ponds
- #7 Waste Storage Structures: Holding Tanks
- #8 Waste Treatment Lagoons
- #9 Sediment or Solids Separation Basins
- #10 Waste Storage Structures: Stack Pads
- #11 Nutrient Management
- #12 Equine or Poultry Waste Feed
- #13 Filter Strips
- #14 Feeding and Heavy Use Area Management
- #15 Dead Animal Disposal
- #16 Milking Center Wastewater Treatment
- #17 Poultry Facility Siting and Land Application of On-Farm Generated Waste By-Products

In general, each BMP includes: 1) a description and definition of the BMP, 2) specific regulatory requirements, 3) AWQA (Agricultural Water Quality Act) minimum requirements, 4) design information, 5) practice maintenance, 6) technical assistance, 7) cost share assistance (if available), 8) recommendations [this is the most practical part], and 9) a list of references.

For example, the recommendations for Pesticide & Fertilizer BMP #10 (Pesticide & Fertilizer Container Disposal) are as follows: “Participate in a rinse and return program. Use biodegradable or returnable containers whenever possible. Puncture recyclable containers to prevent reuse.”

If a grower wants to work on his water quality plan, his local cooperative extension agent for agriculture will have access to the full text of each BMP, and also has a “Producer Workbook” is designed to help growers develop their plan. Some agricultural extension agents have further simplified the Producer Workbook.

46. Identify the rules regarding pesticide use, storage, and distribution in Kentucky Pesticide and Application Act.

This Act was passed in 1996 by the Kentucky Legislature; its provisions are administered by the Kentucky Department of Agriculture (KDA). The KDA has published a printed summary of the Act; that booklet is titled: “Kentucky Fertilizer and Pesticides Storage, Pesticide Use, and Application Act of 1996.” Rules established by this Act are as follows:

- 1) No person shall discard or store any pesticide or pesticide containers in such a manner as to cause injury to humans, vegetation, crops, livestock, wildlife, pollinating insects or to pollute any waterway in a way harmful to any wildlife therein.
- 2) No person shall use any registered pesticide in a manner not in accordance with its label.
- 3) No person shall purchase, use or supervise the use of, a restricted use pesticide unless such person be licensed in a classification which permits such purchase, use or supervision of use.
- 4) No person shall distribute a restricted use pesticide to a person who is not licensed as a restricted use pesticide dealer or applicator as prescribed in this chapter.

47. Describe the importance of re-entry and preharvest intervals following a pesticide application.

Re-entry intervals are established to minimize worker risk of exposure to pesticides. Risk of exposure is especially high when plant leaves are still wet with the pesticide solution. Posting of warning signs is required in many cases to advise workers of the appropriate re-entry interval. The appropriate re-entry interval will be listed on the pesticide label.

Preharvest intervals are developed to minimize consumer risk to pesticide residues on food items. Some pesticides are more persistent; while this helps extend their useful “life” in terms of pest control, it also means that growers must be more careful about applying such a pesticide too close to harvest time. This interval will also be listed on the pesticide label.

48. Recognize the responsibilities of and the assistance available through the following State and Federal Agricultural agencies:

University of Kentucky: The University of Kentucky annually updates AGR-6 (Chemical Control of Weeds in Kentucky Farm Crops; available on the web at <http://www.ca.uky.edu/agc/pubs/agr/agr6/agr6.htm>). This publication provides information about herbicide efficacy, rates, and safety procedures, and is an excellent resource for any weed manager. In addition, the University of Kentucky offers courses preparing pesticide workers to take certification exams for various levels of pesticide treatment applications. A schedule for such training courses is available on the web at <http://www.uky.edu/Agriculture/PAT/welcome.htm>.

Kentucky Department of Agriculture: The Kentucky Department of Agriculture, through the Division of Pesticides under the Office for Environmental Outreach, regulates the licensing, labeling, and use of pesticides throughout the state. The division has regulatory control over the pest control and lawn care industries as well as commercial and private applicators. To assist farmers in keeping the land free of outdated and unwanted pesticides and containers, this division operates the Rinse and Return Program and the Pesticides Collection Program. The Kentucky Department of Agriculture can be found on the web at <http://www.kyagr.com>.

Kentucky Cabinet for Natural Resources and Environmental Protection

The focus of the KCNREP is to provide a safe, clean environment in the Commonwealth, while working with business and industry to help ensure adequate jobs and a strong economy. As part of this charge, the KCNREP publishes “Land, Air and Water” which provides new updates on its programs and progress; the Cabinet’s web home is at:

<http://www.nr.state.ky.us/nrhome.htm>.

The Division of Water is most closely concerned with pesticide safety; its specific mission is to manage, protect, and enhance the water resources of the Commonwealth for present and future generations through voluntary, regulatory, and educational programs. The Division of Water is concerned with the quality of both surface and groundwater.

The Division of Conservation administers the Kentucky Agriculture Water Quality Act discussed in detail in response to objective #45 above.

Farm Services Agency

This federal agency (at <http://www.fsa.usda.gov/>) administers the Conservation Reserve Enhancement Program (CREP), an updated version of the CRP. In addition, this agency deals with acreage reduction programs for crops and provides loans to farmers.

Natural Resources Conservation Service

This federal agency, accessible on the web at <http://www.nrcs.usda.gov/>, deals with pesticides indirectly through its Conservation Reserve Program (CRP), Wetlands Reserve Program (WRP), Environmental Quality Incentives Program (EQIP), and Wildlife Habitat Incentives Program (WHIP), among other agency programs. As you can see, the NRCS has broadened its goals from its former position as the Soil Conservation Service (SCS).

Environmental Protection Agency

The EPA's primary role with pesticides, in cooperation with the Food and Drug Administration (FDA), is to provide Americans with a safe food supply. The EPA is responsible for regulating pesticide sales nationwide; that is, vendors must go through an extensive (and expensive) set of tests in order to be able to market a new pesticide for use in the US. You can find the EPA on the web at <http://www.epa.gov>.

COMPETENCY AREA 5. Pesticide stewardship

49. Discuss how the following factors may affect spray drift and spray volatilization:

[Spray drift is simply the movement of spray droplets away from the intended target (crop, weeds, or soil). Meanwhile, spray volatilization means that a high vapor pesticide is converted to a gas, which can then be easily blown away from its intended target.]

spray volume: Low spray volumes generally mean smaller droplets, and therefore, greater likelihood that drift will occur.

weather conditions: Higher wind speeds can increase drift. Warmer temperatures can increase volatilization.

pesticide formulation: [to be added]

additives (drift control agents): Obviously, such additives can help reduce spray drift. However, they cannot overcome high wind conditions, and so pesticide applicators still need to carefully manage their sprays.

nozzle height: As the nozzles are raised higher above the crop canopy or the soil surface, the likelihood of off-site drift increases.

droplet size: Smaller droplets are more likely to drift.

pressure: High pressure makes for smaller droplets, which are more subject to drift.

50. Recognize how the following factors may affect movement of pesticides in soil or into surface or groundwater:

cation exchange capacity (CEC): If a pesticide is attracted to the negative charges on soil clay or organic matter, it is less subject to leaching losses, since the CEC will temporarily remove some of the pesticide from the soil solution.

depth of water table: If a water table is shallow, the chances that pesticides will move into groundwater (through leaching) are enhanced.

erosion: Runoff increases the movement of both dissolved and adsorbed pesticides to surface waters.

leaching: For any pesticide which is soil active, the implication is that the pesticide is present in the soil solution, and thus is subject to losses to groundwater through leaching.

Coarse textured soils are more prone to leaching losses.

pesticide adsorption to soil: If a pesticide is adsorbed to the soil, leaching losses will naturally be quite unlikely. The primary loss mechanism for such a pesticide would be through erosion of soil particles off of the site.

pesticide application rate and timing: Since higher pesticide rates increase the concentration of any soil active pesticide in the soil solution, higher rates would increase the likelihood of leaching losses. Pesticide applications are generally applied when pest pressure calls for an application; however, this may coincide with timing that can result in increased leaching or runoff losses. For example, pre-plant herbicides are, of course, applied before the crop is planted or weeds begin to grow. Since the plants will not soon begin to take up large amounts of water, that timing is more likely to result in greater leaching losses (and perhaps greater runoff losses as well).

pesticide degradation and persistence: Pesticides which are biologically- (by microbes) or photo-degraded (by sunlight) are less persistent in the field, and therefore are less likely to leave the site either by leaching or runoff. Unfortunately, such pesticides are also less likely to provide protection from the target pests.

precipitation and runoff: Higher rainfall makes for greater potential for both leaching and runoff.

soil pH: Some pesticides are pH-sensitive, and will have different soil solution concentrations as pH changes.

soil texture: Coarse textured soils are more subject to leaching losses of pesticides; on the other hand, fine textured soils are more subject to pesticide losses in runoff.

plant residue at surface: Plant residues will reduce runoff (that's why no-till agriculture is so highly regarded for use on Kentucky's sloping fields). However, this can increase the potential for leaching, since any water which does not leave the field by runoff can contribute to water movement downward through the soil. So, leaving plant residues on the soil surface can reduce pesticide movement to surface water, but may actually increase pesticide movement to groundwater.

crop/weed canopy: Assuming that we are here considering a post-emergence pesticide (which is intentionally applied on crop and weed leaves), an increase in the percentage of the soil covered by a leaf canopy will mean that more of the pesticide lands on plant leaves. Therefore, less of the pesticide reaches the soil. Since the plant leaves are the target in this particular case, any fraction of pesticide reaching the soil is not contributing to pest control; that fraction of the pesticide is also subject to losses by either runoff or leaching.

51. Describe reporting and cleanup procedures when pesticide spills occur.

If you have a pesticide spill, first call 911 and provide specific information on the location of the spill, any injuries which have occurred, and the amount and type of pesticide which has been spilled. Second, you should call 800-928-2380 to reach the Kentucky Environmental Response Team. They will want to know similar information, to help assist in the cleanup.

52. Define the following terms:

point source pollution: Such pollutants enter the environment from a single source. What this means is that identification of the source of pollution is relatively easy; that may mean that mitigation of the pollution is less complex than for nonpoint sources.

nonpoint source pollution: Such pollutant sources enter the environment from a poorly defined area. For example, nitrates or pesticides in groundwater can be attributed to agricultural activities, yet it is difficult to identify a specific farm which is causing the problem. Hence, mitigation of such a pollutant is more difficult. One regulatory approach is to sharply restrict use of pesticides which reach groundwater. This may unfairly penalize careful crop managers.

maximum contaminant level: This refers to the highest level of a contaminant that is allowed in drinking water. Of course, such MCLs can be changed over time as societal attitudes and scientific accuracy changes.

parts per million and parts per billion: These two measures, like parts per trillion and parts per quadrillion, can be expressed on a weight/weight or volume/volume basis, so can be a bit confusing. It is actually preferable to use the units measured (for example, mg/L, rather than ppm).

Integrated Pest Management

Sample questions for Kentucky Certified Crop Advisor exam.

- ___ 1. On what part of the alfalfa plant should you look for alfalfa weevil larvae? a) lower stems b) in the crown roots c) on the youngest leaves and buds d) on older leaves near the base of the plant.
- ___ 2. Tillage is a good example of which type of weed control practice? a) herbicidal b) mechanical c) biological d) cultural e) preventive.
- ___ 3. Weeds are plants growing where we don't want them. Which of the following are characteristic of weedy plants? a) dormant seeds b) abundant seed production c) competitive with crop plants d) excellent spreading ability e) all of the above.
- ___ 4. Which of the following herbicides work via ALS inhibition? a) Harmony Extra in wheat b) Accent in corn c) Scepter in soybean d) Pursuit in soybean and Pursuit-tolerant corn e) all of the above are ALS inhibitors.
- ___ 5. To get maximum yields, weeds should be controlled in soybean and corn by the ___ week after planting. a) second b) fourth c) sixth d) eighth.
- ___ 6. Under cool soil conditions, soil applied herbicides will persist ___ as compared to warm soil conditions. a) forever b) somewhat longer c) the same length of time d) somewhat shorter e) not at all.
- ___ 7. Which herbicide family is likely to persist the longest in the field, making its weed control better, but its chances of injuring rotational crops greater? a) triazines b) sulfonylureas c) imidazolinones d) dinitroanilines e) amides.
- ___ 8. The two states which lead the way for the rest of the nation on more aggressive control of pesticide use are: a) Kentucky and Tennessee b) Iowa and Illinois c) California and Florida d) Oklahoma and Texas e) Oregon and Washington.
- ___ 9. What is the most important factor which keeps farmers from over-applying herbicides? a) concern about exposure to themselves or their families b) worry that they will be caught by the EPA c) agreements they've signed with chemical companies d) the cost of the herbicide itself.
- ___ 10. Degree days for black cutworms use what temperature (F) as the baseline for black cutworm activity? a) 32 b) 40 c) 45 d) 50.
- ___ 11. What damage do tobacco aphids inflict on tobacco? a) They spread viral diseases. b) They cause plants to turn yellow prematurely. c) They extract sap from the plant, depriving it of energy for growth. d) They chew holes in leaves.
- ___ 12. Under what circumstance(s) can pathogens, predators, and parasites help with plant pest management? a) when your crop is severely infested with pests b) when environmental conditions are just right c) when your first choice of pesticides fails to wipe out the pest d) when the pest has been newly introduced to the area.

- ___ 13. Witt says we should start developing weed management plans in November for summer annual crops. Just what should our weed management plan include? a) 2 or 3 control options b) mechanism to evaluate effectiveness of the plan c) identify the most important 5 or 6 weeds to control d) choose a set of tillage practices e) all of the above.
- ___ 14. Triazine resistance is becoming a serious problem with: a) johnsongrass b) morningglory c) pigweed d) cocklebur e) crabgrass.
- ___ 15. Why is cocklebur no longer such a serious concern for Kentucky soybean growers? a) It has developed herbicide resistance. b) The new classes of herbicides are incredibly effective against cocklebur. c) With more acres managed without tillage, far fewer cocklebur seed are able to germinate. d) Japanese beetles are especially fond of cocklebur, and have greatly reduced their populations.
- ___ 16. The mode of action of the herbicide atrazine is: a) meristematic inhibition b) photosynthetic inhibition c) burndown d) pigment inhibition e) growth regulation.
- ___ 17. If a farmer has decided to use a pre-plant incorporated herbicide, she has obviously concluded: a) that she is going to get rid of all her johnsongrass. b) that she is going to have a substantial number of weeds to deal with, and may as well get after them from the start. c) that her crop would benefit from the use of no-tillage practices. d) that no post-emergence herbicides are available for her crop.
- ___ 18. Pesticide storage rules include: a) "Keep pesticides away from food and feed." b) "Herbicides should be kept under lock and key." c) "You should keep a fire extinguisher handy." d) "Avoid mixing leftover pesticides." e) all of the above.
- ___ 19. Pesticide drift will be greater if: a) droplet size is large b) low spray pressures are used c) nozzles are kept close to the plant canopy d) winds are high during application e) all of the above.
- ___ 20. An effective IPM program must include: a) evaluation of past practices b) an appropriate scouting process c) assessment of likely pest problems d) development of a flexible management plan e) all of the above.
- ___ 21. Insects which feed on ___ are probably the hardest ones to manage. a) roots b) leaves c) whorl d) seeds.
- ___ 22. Beneficial insects are likely to have: a) small eyes b) grasping front legs c) short hind legs d) sucking mouthparts e) all of the above.
- ___ 23. The best time to apply post-emergence herbicides is: a) within one week after planting the crop b) 3 or 4 days before the crop closes its canopy c) about the time that the crop starts reproductive growth d) one week before crop harvest.
- ___ 24. Why is it important to control Eastern black nightshade in soybean fields? a) because we don't have any good herbicides to use in rotational corn b) because this weed is incredibly competitive with soybean c) the berries can stain soybean seeds an undesirable purple color d) insects are attracted to this weed, then begin to feed on neighboring soybean plants.
- ___ 25. Rhizome johnsongrass is best controlled by: a) application of soil active herbicides b) use of appropriate post-emergence herbicides c) intensive grazing d) spring tillage e) burning in the fall.

- ___ 26. A farmer mixes two incompatible herbicides, and as a result, both work poorly. What term describes the relationship between these herbicides? a) substitutionary b) antagonistic c) reflexive d) synergistic e) additive.
- ___ 27. The stage at which nearly all weeds are most successfully controlled by the use of herbicides is: a) germination b) seedling c) vegetative d) flowering e) seed development.
- ___ 28. Pesticide misuse can: a) result in pesticide residues left on food commodities. b) contaminate groundwater through leaching. c) injure crop plants. d) harm non-target organisms. e) all of the above.
- ___ 29. When would heavy rainfall be most likely to move substantial amounts of soil-applied herbicides to ground or surface waters? a) just before herbicide application b) just after herbicide application c) just before the crop closes its canopy d) late in the season, when weeds are no longer growing e) after harvest of the crop.
- ___ 30. What can happen if a crop manager incorrectly identifies a crop pest? a) Money could be wasted on an unnecessary herbicide. b) Other pests may be enabled to attack the crop. c) Inappropriate management decisions may be made. d) Someone might be hurt during treatment for the pest. e) all of the above are possible bad outcomes.
- ___ 31. Which of the following insecticides are nerve poisons? a) organophosphates b) carbamates c) chlorinated hydrocarbons d) cholinergic agonists e) all of the above.
- ___ 32. Why can't pest resistant varieties be developed to eliminate the need for pesticides? a) Chemical companies, which now own most seed companies, will not allow this work to proceed. b) In the absence of the pest, resistant varieties are often lower yielding than nonresistant varieties. c) Farmers much prefer to spend their money on pesticides instead of on better crop varieties. d) We just are not yet very good at predicting which pests will be troublesome in a particular season.
- ___ 33. Assume you have applied a soil-active herbicide to your crop field. How soon after planting should you be out there scouting for weeds? a) the next day b) after one week c) after two weeks d) after three weeks.
- ___ 34. Optimal soil temperature (F) for germination of johnsongrass is: a) 45 b) 55 c) 65 d) 75.
- ___ 35. Which of the following important Kentucky weeds is a biennial? a) johnsongrass b) Musk thistle c) henbit d) wild garlic e) broadleaf signalgrass.
- ___ 36. Why are some herbicide applications done under low volume arrangements (10 gallons/acre or less)? a) to minimize the potential for leaching to groundwater b) to save time and fuel in hauling water to the field c) to improve the coverage of the weeds with herbicide d) to make sure that a few weeds survive to produce seeds for next year's crop.
- ___ 37. The Kentucky weed most likely to be controlled by mowing is: a) shattercane b) Italian ryegrass c) common lambsquarters d) Musk thistle e) yellow nutsedge.
- ___ 38. A "Material Safety Data Sheet" must include: a) clear identification of the material's nature b) emergency telephone numbers c) fire and explosion hazards d) recommended first aid procedures e) all of the above.

- ___ 39. An example of point source pollution would be: a) a farmer applying double rates of herbicide to his corn fields. b) a custom sprayer applying Roundup to non-Roundup Ready crops. c) a farmer allowing mixed herbicide solution to back siphon into her well. d) spraying leftover herbicide solution on cropland.
- ___ 40. General concepts of IPM include: a) minimizing environmental harm b) providing a high quality food supply c) using a variety of complementary tactics d) protecting field workers e) all of the above.
- ___ 41. The northern corn rootworm: a) feeds on corn stems b) hatches in August c) hatches a varying number of years after its eggs are initially laid d) will not respond to any current insecticide.
- ___ 42. In general, plants are most tolerant of insect injury during: a) seedling stage b) vegetative stage c) flowering stage d) seed filling stage.
- ___ 43. After corn reaches ___ inches in height, growers should be very cautious about applying herbicides. a) 10 b) 20 c) 30 d) 40.
- ___ 44. From this list, which weed is least competitive with soybean? a) cocklebur b) giant foxtail c) velvetleaf d) giant ragweed.
- ___ 45. What advantage do herbicide tolerant crops provide? a) improved weed control b) simplicity of weed management c) reduced likelihood of crop injury d) reduced seed expenses e) consistently higher yields.
- ___ 46. The purpose of adding a surfactant to a herbicide tank is: a) to reduce the potential for crop injury b) to increase absorption of the active ingredient by weeds c) to keep the herbicide solution from sloshing around so much d) to mark the edges of the spray boom pattern.
- ___ 47. Most farmers will refer to a pesticide by its ____ name. a) street b) brand c) common d) organic.
- ___ 48. A pesticide with an LD50 of 0 to 50 mg active ingredient per kilogram of test animal would be labeled with ____ signs. a) "Caution" b) "Toxic" c) "Warning" d) "Danger."
- ___ 49. Why is it so important to know the life cycles of plant pathogens? a) It helps us find the best time to control them. b) It guarantees that our pesticides will be effective. c) It allows us to properly time the release of beneficial insects. d) It allows us to control all pests without resorting to pesticide applications.
- ___ 50. What is the key cultural control measure for barley yellow dwarf virus (BYDV)? a) bringing in a biological control agent b) spraying Warrior in the fall c) planting your wheat after the first hard freeze d) using resistant varieties.
- ___ 51. In order for a plant disease to develop, which of the following must be conducive to disease development? a) The host plant must be present and susceptible. b) Environmental conditions must be appropriate. c) The pathogen must be present. d) all of the above.
- ___ 52. Where does blue mold of tobacco overwinter? a) on tobacco stubs in Kentucky fields. b) on wild tobacco in Texas. c) in frequently used tobacco beds. d) all of the above.

- ___ 53. Good strategy(ies) to help reduce stalk rots of corn include: a) plant only disease resistant corn hybrids b) increase plant population c) make sure you have applied a little extra nitrogen d) choose hybrids with strong stalks.
- ___ 54. A control program for black shank of tobacco should include: a) rotation away from tobacco b) timely application of Ridomil c) selection of a resistant tobacco variety d) excellent sanitation practices e) all of the above.
- ___ 55. Which of the following plant pathogens would be easiest to control? a) those with a narrow host range b) those with a wide host range c) those which overwinter on residue d) those which are spread by insects.
- ___ 56. For tobacco bed fumigation to be most effective, you should: a) treat the site without tillage b) thoroughly soak the site with water before fumigating c) treat only when soil temperatures are below 40 F d) treat fall and keep the site covered until you plant in the spring.
- ___ 57. Resistant crop varieties are a great idea, but do have some limitations. Which of the following accurately describe the limitations of resistant crop varieties? a) The right variety may not be locally available. b) The right variety may not be good in all of the other factors which combine to produce top-notch yields. c) A resistant variety can lose its resistance as the pathogen goes through population shifts. d) all of the above.
- ___ 58. What is the status of blue mold resistance in currently used burley tobacco varieties? a) no resistant varieties are available b) the most popular variety, TN 90 has some resistance c) a newly released variety is almost entirely resistant to this pest d) genetic engineers have just successfully inserted chrysanthemum genes for blue mold resistance into tobacco plants.
- ___ 59. A good example of a monocyclic disease is: a) blue mold of tobacco b) leaf rust of wheat c) stem canker of soybean d) all of the above.
- ___ 60. Which of the following help determine the economic threshold for a crop pest? a) control cost b) potential crop yield c) crop value d) potential loss to the pest.

Key for Kentucky CCA Practice Exam Integrated Pest Management

1. C	11. C	21. D	31. E	41. C	51. D
2. B	12. B	22. B	32. B	42. B	52. B
3. E	13. E	23. B	33. D	43. B	53. D
4. E	14. C	24. C	34. D	44. B	54. E
5. B	15. C	25. B	35. B	45. B	55. A
6. B	16. B	26. B	36. B	46. B	56. D
7. B	17. B	27. B	37. D	47. B	57. D
8. C	18. E	28. E	38. E	48. D	58. B
9. D	19. D	29. B	39. C	49. A	59. C
10. C	20. E	30. E	40. E	50. C	60. E

PART IV. CROPPING SYSTEMS MANAGEMENT

COMPETENCY AREA 1. Crop establishment

1. Define the optimum seeding periods, and recognize the consequences of seeding too early or too late for the agronomically important annual and perennial crops.

Wheat (for grain) should be planted in early to mid October. Ideally, a killing freeze would have occurred prior to wheat emergence. If wheat is planted too early, the likelihood of barley yellow dwarf virus developing is greater (because more of the aphids which transmit this virus are likely to be alive and active). Very early planting can also allow some wheat varieties to advance too far in their development and leave them more susceptible to winter injury. Later planting will often result in slower fall development, and can reduce yield potential. In addition, growers who plan to plant late (say November 1), may find themselves not getting the crop planted at all (if the weather turns sour).

Corn should be planted when the soil temperature reaches 50 F (usually sometime around mid April). Planting earlier can result in poor stands, which can force a grower to replant or hurt yield potential (neither of which are desirable outcomes). Planting after May 10 (May 15 in Eastern Kentucky) can be expected to reduce yield potential by 1% per day of delay. Some growers (especially in the Simpson County area) will often plant corn in March; their logic is that early planting helps “make” their crop before the often-stressful days of August arrive.

Soybean should be planted when the soil temperature reaches 60 F (usually around late April into early May). Many growers who manage both corn and full-season soybean simply start planting soybean after they finish getting their corn fields planted. Long-term data from the University of Kentucky show that planting soybean after June 10 cuts yield by 1.5% per day of delay. This is apparently because the plants must move into reproductive development before they are able to grow a sufficiently large photosynthetic “factory.” Of course, much of the state’s double crop soybean are planted after that date; the point here is that farmers planting soybean after wheat need to get the soybean planted as soon as possible. (Some growers, especially in Logan County, have used barley instead of wheat; this allows them to generally get their double crop soybean planted before June 10.)

2. Describe the physical and environmental factors that influence germination and emergence of crops.

Poor field emergence can result from cool soil temperatures. Since crop plants require certain temperatures to actively grow (for example, corn needs 50 F), planting seed into cool soils will cause delayed emergence and greater opportunity for soil pathogens to do their “dirty work.” If soils are too wet (often associated with cool spring temperature conditions), the seed may not be able to get enough oxygen to carry out the respiration required to convert seed storage compounds into energy for germination and emergence. In some soils, surface crusting can be a major factor for crops like soybean with an epigeal emergence pattern (because the large cotyledons must be pushed up through the soil surface before the plant can grow). Surface crusting can result from excess surface tillage combined with forceful rainfall prior to crop emergence. Of course, planting too deep or too shallow can also cause serious problems (see answer to question #4 below).

3. Recognize recommended seeding depths of crops and describe adjustments to the seeding depth according to the following factors:

The best results for corn appear to have come with planting between 1.5 and 2.0 inches. More shallow planting can put the seed into dry soil, and hinder germination. Planting deeper can both delay the time of and decrease the extent of eventual emergence. Some growers plant deeper “to get a deeper root system” to help their crop be more tolerant of dry conditions. Unfortunately, the persistent root system of corn originates from a node about 1 inch below the soil (not at the depth to which the seed is planted).

Soybean should generally be planted between $\frac{3}{4}$ and 1.5 inches deep. Since soybean seeds must imbibe a substantial amount of water to germinate (50% of their original dry weight), shallow planting is not a good idea. Planting too deep will make the already difficult task of emerging from the soil even more difficult.

Wheat should be planted no less than $\frac{3}{4}$ inches deep and no more than 2 inches deep. Planting too shallow is especially an issue of concern for no-till management. If the seed is not getting $\frac{3}{4}$ inches into the soil, winter survival may be in doubt (due to heaving of poorly rooted seedlings). A grower may plant a bit deeper than $\frac{3}{4}$ inches to get to soil moisture; however, planting more than 2 inches deep is unlikely to result in better stands.

Of course, no planter or drill puts every seed at exactly the intended depth. In the case of soybean, a grower should not be nervous if an occasional seed winds up on the soil surface. If a planter or drill is set deeper to make sure every seed is covered, a good percentage of the seed is probably going to be planted too deep.

soil conditions (texture, temperature, moisture & level of tillage): If soils tend to crust (some in Daviess County are prone to this), a grower may want to plant a shade more shallow. If soils are cool and moist, growers would be wise to stay on the shallow end of a crop's favorable planting depth "zone" in order to help their crop escape seedling diseases. Under no-till management, a grower needs to be sure that her seed is actually getting into the soil (versus just sitting on the surface residue). Under conventional management, surface soils are more exposed to evaporation, and farmers may want to plant a shade deeper to make sure that their seeds have enough moisture to germinate and emerge.

weather outlook: The weather outlook has to be considered along with the current soil conditions. For example, if the surface soil is quite dry, but rainfall looks likely, a grower may want to plant at the shallow end of her crop's planting depth zone. On the other hand, if the surface soil is drying, there is a reasonable amount of moisture at the lower end of a crop's planting depth zone, but rainfall does not look likely, the grower may be ahead to plant a shade deeper.

seed size: Large-seeded crops are generally planted deeper than small-seeded crops (because the large seeds need to absorb more water and the small seeds can't emerge from deeper depths). So, it would seem reasonable to plant a large-seeded variety of a given crop deeper than a small-seeded variety of the same crop. However, in grower practice, this is not very important. For example, soil moisture conditions and tillage practices are far more important in determining optimal seeding depth of wheat than is the seed size of the variety to be planted. If a grower got into a variety with dramatically larger seed size from her traditional varieties (for example, tofu soybean), perhaps she would need to plant a little deeper in a drying soil (to make sure that her soybean seed could imbibe enough water).

4. Recognize crop responses to planting too deep or too shallow.

If crop seed is planted too deep, the seedling may run out of energy before it can reach the soil surface. This can be a serious problem for small-seeded plants (like tall fescue, alfalfa, and tobacco), but can also be a problem for large-seeded plants (like soybean). If crop seed is planted too shallow, the main problem is that seeds cannot imbibe enough water to be able to trigger their germination processes. In addition, birds are more likely to find and consume seed planted too close to the soil surface.

5. Describe crop responses to planting patterns (broadcast, row width, plant spacing, etc.) and plant population (seeding rate).

In general, seeding rate is easier and less costly to change than is row width. For most planting equipment, seeding rate requires only that the grower make an adjustment on his planter (and pay for the additional seed). However, changing row width generally means that a grower must buy (or lease) a new piece of planting equipment. Thus, it is often easier to economically justify bumping up planting rate than squeezing down row spacing.

Most Kentucky corn is now planted in 30 inch rows, at planting rates approaching 30,000 kernels per acre. Some recent work has been done on 20 inch rows (due to grower interest in this system). In the northern US (for example, Minnesota), 20 inch rows can be justified economically. However, yield increases have been modest with 20 inch rows in Kentucky. Our longer growing season gives our corn more time to cover the row middles of 30 inch row corn. In addition, gray leaf spot (a fungal disease) has actually been worse in 20 inch rows in Kentucky (due to the reduction in air movement in the tighter canopy). Growers will want to bump up their seeding rate slightly for no-till methods, a little more for silage, and more yet for irrigated corn for grain. Two relatively new technologies may be quite important for corn planting rates. Variable seeding rate equipment, some of which allows growers to adjust seeding rate from the cab of their tractor on-the-fly, may help growers plant a bit lighter in shallow soils (say on eroded hillsides) and a bit heavier on field areas with thicker topsoil. Corn hybrids with Bt toxin, a generally engineered trait which provides protection against European corn borer, are quite costly. So, growers may want to cut their seeding rates slightly (while being a bit more careful about consistent planting depth) in order to save some money on seed.

Soybean is generally planted in 30 inch rows (for the full season crop) and in either 15 inch rows (with a corn/soybean planter) or in 7 or 7.5 inch rows (with a wheat/soybean drill). Most of the fields planted to 15 inch or narrower rows are in double crop soybean. Soybean planting rates generally run between 120,000 and 180,000 seeds/A. Soybean emergence is a bit less reliable than is corn emergence. Fortunately, soybean is a bit better at filling in the gaps created by lower than expected stands than is corn. If soybean stands are a bit too low, excessively low podding may result, as well as a delay in canopy closure. If soybean stands are too high, lodging may be severe, and soybean plants may compete with each other for water and light. If a grower suspects that rainfall will be low in a particular growing season, or if his soils tend to be drought-prone, he may want to aim at the lower end of the seeding rate range. For full-season soybean, there may be some advantage to consider planting in 15 to 20 inch rows (15's would fit well for growers with 30 inch row corn planters, since soybean splitters can be added on to the same planter). For double crop soybean, 7 inch rows have a clear yield advantage over wider row spacings.

Wheat should be planted to get around 35 seeds/square foot (1.5 million seeds per acre), with a 10% increase suggested for no-till management. While wheat tillers extensively under Kentucky conditions, poor initial stand establishment can sharply reduce yield potential. Most of the crop is planted in 7 inch rows. Some Virginia data has shown a slight yield increase with 4 inch rows. However, such narrow row spacings would be a huge problem for reduced- or no-tillage fields.

Corn growers have long been accustomed to planting a certain number of seeds per acre. However, many soybean and wheat growers have instead planted by weight (say, 1 bushel per acre). Unfortunately, soybean and wheat seed both vary substantially in size (due to both varietal characteristics and seed growing conditions). As a result, growers planting by weight could be dramatically under-seeding or over-seeding their fields. It is clearly worth the trouble to use seed size (it is often on the seed tag) to help calculate a more precise seeding rate. While corn and soybean planters generally place pretty much the number of seed per acre that they are “asked” to place, drills are much less cooperative. It is not unusual for one unit of a given drill to be dropping twice as much seed as the adjacent unit. So, it is usually worth the trouble to check seeding rates for each unit on a drill (even with a new piece of equipment).

Tobacco growers have been moving toward lower plant populations by increasing the spacing between plants within the row. Between row spacing of 38 to 42 inches combined with in-row spacings of 16 to 18 inches used to be common. This resulted in populations of 8,300 to 10,300 plants per acre. Now many growers have moved to in-row spacings of 22 to 24 inches, resulting in populations of 6,500 to 7,500 plants per acre. This shift has occurred primarily in response to labor shortages. Growers can produce more pounds of cured leaf with less labor lower plant populations due to the individual tobacco plant’s ability to compensate for fewer plants per acre. Yield per acre decreases slightly at lower plant populations, but the labor savings more than offset the yield decline. At lower populations larger leaves and larger stalks are produced. The shift to lower populations also aids in the control of foliar diseases by improving sunlight penetration and air-flow through the canopy.

6. Recognize the effect of seed quality on crop establishment and describe ways to compensate for poor seed quality.

The value of seed is related both to the amount and quality of its product. However, a terrific variety can become terrible if it fails to germinate and produce plants. In a sense, the seed is a nifty delivery system for improved crop genetic packages. Seed is tested by various official seed testing laboratories, which use standardized, repeatable methods to assess seed quality. In Kentucky, this work is done by the Division of Regulatory Services in the University of Kentucky College of Agriculture. Growers get seed quality information on the seed tag of seed they purchase (unless they buy the seed from a neighbor; in that case it is “let the buyer beware”).

Seed quality includes physiological, genetic, physical, pathological, and mechanical purity aspects. Under **physiological** aspects, quality is primarily expressed as the capability of a seed lot to germinate and emerge from the soil. Physiological seed vigor can be related to the maturity of the seed lot when it was harvested, as well as to the moisture level under which the seed lot was stored between its harvest and subsequent planting. Ideally, seed is kept from overly warm conditions, as well as from overly cold conditions. The age of the seed lot is important too; as seeds age, they lose some of their vigor. So, a grower should be wary about buying seed which has been “held over” from a previous growing season. Growers should check the label for percent germination and the date the seed lot was tested. Some companies also provide an assessment of seed vigor; for example, a cold test of corn hybrids. The big question about **genetics** is this: Is the seed from the variety which it is supposed to be? For certified seed, a grower can be confident that the seed production field was carefully inspected for any off-type plants. Buying from a reputable commercial or certified dealer will eliminate most problems here. **Physical** condition of the seed is largely influenced by how gently it was handled at harvest time. If the seed was too dry at harvest, lots of cracked and split seed will be found in the seed lot. The best thing here is to be careful about how you harvest seed to be used for seeding your next crop. Seedborne diseases can cause problems for plants which are grown from them. This **pathological** problem can arise during seed production or during seed storage. Some relief may be obtained by treating the seed with fungicides before planting. *Phomopsis* (the fungus which causes pod and stem blight) is an example of a problem which can arise during seed production and which responds positively to seed treatment. **Mechanical purity** reflects how much of the seed lot is made up of other crop or weed seed or inert matter (rather than the intended seed). Growers can avoid seed lots with low crop purity, or they could adjust seeding rates (see PLS calculation below) accordingly.

7. Determine pure live seed (PLS) from seed tag information.

Among other information (kind and variety of seed, lot identification, inert matter, crop seed, weed seed, hard seed, date tested, origin, amount of noxious weed seed present, and the name and address of the seed vendor), the seed tag is also required to show pure seed (in %) and germination (also in %). Simply multiply pure seed by germination (as fractions), and then convert the result to a percentage; this will be PLS. For example, if pure seed is 94% and germination is 90%, PLS is 85% (rounded to nearest whole percentage).

8. Recognize the recommended seeding rates for crops to achieve optimum plant populations.

Plant populations were discussed above (see answer to question #5). Under optimal planting conditions, a grower can simply calculate pure live seed from the information on the seed tag, and use that as the basis to set her planting rate. If seed bed conditions are stressful (for example, cool and wet, or no-till residue), seeding rates will need to be adjusted upward accordingly. Since seed is relatively expensive, the grower needs to carefully evaluate, based on his own experience, just how much to increase seeding rates.

A generalization could be that a stressful soil should call for 10% more seed and that no-till planting methods should also call for 10% more seed.

9. Calculate plant populations and identify factors involved in a replanting decision.

The idea here is that a grower has had some problems establishing a stand in her fields, and that she wants to know if she should replant any or all of those fields.

Replanting is rarely done for winter wheat; by the time a grower knows what sort of stand he's obtained, it is usually too late to replant (adjustments in nitrogen management may help, however).

For corn, a uniform stand is quite important. However, since yield potential falls 1% with each day that passes after May 10, a replanting decision must be made carefully. First, a grower needs to have a very good idea of what stands are needed to optimize corn yield. For example, if a grower concludes that she must have 28,000 corn plants per acre for optimal yield, then she has a basis for deciding whether or not to replant. In general, a 10% reduction in stands will not justify replanting. A 20% reduction in stands might call for replanting, as long as this determination is made in April, when there is still time to get a new planting done before yield potential begins to decline. A 30% or greater reduction in yield will probably call for replanting, as long as replanting can be done early. If a corn crop is damaged later in the season (say, by a hail storm in late May or early June) replanting may not be justified, even if stand reductions are substantial. Sometimes a grower may wish to replant with another crop (say soybean); however, herbicide used to treat the failed corn crop (for example, atrazine) may preclude replanting with that other crop.

For soybean, a uniform stand is important, though not as critical as for corn. Yield potential of soybean falls 1.5% with each day that passes after June 10, so a manager must weigh that yield decline against the potential benefits of replanting. In general, poor stand establishment is more often a problem for soybean than for corn. Good information on replanting decisions for both corn and soybean are shown in Ohio State's Bulletin 827 (<http://ohioline.ag.ohio-state.edu/b827/>).

Stand counts for any of these grain crops should be done of representative areas of the field (avoid especially good or bad areas), and should be repeated several times in each field (to make sure the results are repeatable). A suitable length of row should be marked (might be 100 feet for corn, 20 feet for soybean, or 3 feet for wheat), live plants counted, and then a “plants/unit area” calculation made based on the row spacing in that field. For example, if you counted 103 corn plants in 100 feet of rows that were 30 inches (2.5 feet) apart, you would have 103 corn plants per 250 square feet. If you divide 250 square feet into 43560 square feet, you will get the corresponding number of plants on a per acre basis (it turns out to be 18,000). If the field needed 30,000 corn plants to achieve its yield potential, stands would be short by 40%. Early in the season, this would almost certainly be poor enough of a stand to justify replanting.

10. Recognize desirable crop variety characteristics for Kentucky.

For any given crop, the most important variety characteristic is its ability to produce large amounts of the desired plant product (grain, forage, sugar, leaf, fiber). Marketable quality and consistency of that plant product is also quite important (for example, endophyte-free tall fescue can result in better performance of grazing animals). Growers also are concerned with the variety’s ability to germinate and emerge; in other words, to get a good, uniform stand rapidly established. Disease resistance can be quite important (for example, leaf rust tolerance of wheat varieties or soybean cyst nematode resistant soybean varieties.). Insect resistance, where it is available, can also be helpful (for example, Bt corn hybrids). Lodging resistance can be quite important for corn, soybean, or wheat. A grower (or consultant employed by him) should know his fields well enough to choose varieties appropriate to each field situation. Finally, herbicide tolerant crop varieties (like Roundup Ready soybean) may give growers an appealing alternative to weed control, especially in fields which have difficult-to-control weed populations.

11. Describe the management of the following tobacco transplant production systems: a) conventional plant beds, b) direct seeded float systems, and c) plug and transfer float systems.

a) conventional plant beds: Site selection for the plant bed is quite important. The soil should be well-drained (to keep transplant roots healthy) as well as south-facing (to provide warmer soils for the transplants). Windbreaks on both the north and west sides would be helpful, but the location should receive as much sun as possible. A convenient clean water source is important. It would be nice if the bed were close to the field (to save time); however, being too close could potentially cause some disease problems.

Fumigation is now done primarily with Vapam (since methyl bromide is being phased out). As noted in the section on fumigation effectiveness (see response to competency area 3, question 41 in the IPM section), soil temperature at the time of fumigation should be at least 50 F, soil should have a moderate amount of water, and surface clods should be broken up. Many times, fall fumigation will be more effective than spring fumigation, because soil conditions are generally more favorable for effective fumigation in the fall.

Use no more than 50 pounds of 10-10-10 fertilizer per 100 square yards of plant bed, as higher amounts can cause salt damage to transplants. Salt damage can be recognized by wilted, yellowed plants and the formation of grayish-white crystals on the soil surface. Salt problems can be minimized by watering deeply after fertilization. Try not to overwork the plant beds with tillage, since soil compaction can cause some problems with tobacco root development.

Seeding is done as early as possible in the spring; usually in late February or anytime in March. For a 1200 square foot bed, 2 teaspoons are seeded (in a mixture of fine sand to help spread the tiny seeds uniformly). Ridomil is applied to the soil (to help control fungal pathogens during seedling establishment), a straw layer is applied (to keep the bed cover from sticking to the plants), and a bed cover is fastened over the bed (to keep the soil warm and moist).

If conditions become dry, water thoroughly every 4 or 5 days, and keep the bed cover on (to slow down evaporative losses). Small plants are subject to cold injury, especially with the large temperature fluctuations which often occur in April. Plants should be clipped (upper leaves removed) two or 3 times to improve uniformity and to increase the number of useable plants from a given area of bed. However, the bud must not be cut, since that would severely hurt yield.

b) direct seeded float systems: This system has dramatically increased in popularity over the past several years. Its main attraction is the production of consistently sized seedlings coupled with a shift in labor requirements. With the float system, more labor is needed at seeding time and much less labor is needed for plant pulling at transplanting time. This shift allows a grower to get tobacco transplanted more quickly during the busy spring growing season.

Sanitation of the float system is critical to its success, because the environment in a float system is very conducive to the development and spread of diseases, and there are few if any labeled rescue treatments. With the float system, an increase in the long distance transport of tobacco transplants has been observed. This increases concern about the potential for the spread of diseases such as blue mold.

Cost per transplant is higher in the float system than for conventional plants, but the higher cost is often offset by the added convenience, uniformity, and quality of float plants. Direct seeding may be done in greenhouses or in outside float beds. Outside float beds have lower cost but higher risk of plant loss.

Trays should be uniformly filled with soilless media. Most of the media used today are packaged pre-moistened, so the producer does not need to add water prior to tray filling. Avoid compacting media in the trays. Trays with compacted media are heavy, tend to have excessive algal growth and often produce stunted, yellowed plants with a higher incidence of spiral roots than in non-compacted trays. Fertilizers used in the float system should contain little or no urea, as it has been shown to result in toxic levels of nitrite in the float system. Add fertilizer at the rate of 75 to 100 ppm N in float water. Higher concentrations of fertilizer promote lush growth making plants more susceptible to bacterial rots such as black leg, while lower rates may predispose plants to other diseases like target spot.

Clipping of float plants promotes uniformity and results in a stockier plant. Clipping should be done when the foliage is dry and care should be taken that clippings are not allowed to fall back into the canopy where they may increase the potential for disease. Clipping equipment should be sanitized before and after each use to avoid spreading disease organisms.

Float plants tend to be more susceptible to chilling injury than are bed plants. Symptoms of chilling injury include yellowing of the bud, and leaf cupping that appears 3 to 4 days after the chilling event. Plants often outgrow these symptoms, but the lasting effect of chilling injury is the induction of lateral buds that may become ground suckers in the field. Wide temperature fluctuations in greenhouses or float beds are thought to increase the incidence of chilling injury.

c) plug and transfer float systems: Direct seeded float systems require careful management and attention to detail during germination. For small growers or part-time growers, the plug and transfer system offers an alternative. In this system, the grower purchases small seedlings from a greenhouse operator and then transfers (plugs) the small seedlings into finishing trays. The same principles for fertilization, clipping, etc. used in the direct seeded system can be applied to the plug and transfer system.

COMPETENCY AREA 2. Growth & development

12. Recognize the optimum temperatures for crops and describe the effect of temperature extremes on growth and development.

Optimal crop growth temperatures are as follows:

<u>Crop</u>	<u>Optimal temperature range (F)</u>
Alfalfa	64 to 77
Bermudagrass	80 to 90
Corn	77 to 88
Johnsongrass	75 to 88
Soybean	65 to 84
Tall fescue	62 to 78
Tobacco	65 to 82
Wheat	62 to 73

Okay, johnsongrass is not generally used as a crop in Kentucky (even though it was originally introduced as a warm season forage grass). In any case, the plants which are adapted to warmer temperatures (here, bermudagrass, corn, and johnsongrass) are plants with the C4 photosynthetic pathway, while the rest of the plants listed possess the C3 photosynthetic pathway. As temperatures rise up into the 80s, C3 plants suffer from photorespiration, and that slows down their assimilation of carbon dioxide from the atmosphere. Even C4 plants cannot tolerate temperatures in the 90s well. All plants will eventually suffer from high temperature stress, even if soil moisture supplies are adequate. For example, on a hot afternoon you can often see soybean leaflets folded over upside down. That is an attempt by this plant to conserve moisture, and can happen even if the soil has plenty of water. In general, plants close stomates when temperatures are so high that they cannot bring up water fast enough to cool themselves. That causes leaf temperatures to rise (which is damaging in itself) and shuts down photosynthesis until the stomates can be re-opened.

On the cool side, of course freezing temperatures can kill most of these plants. Winter wheat and alfalfa can tolerate much colder temperatures than any of the other crops listed. Above freezing, but below the optimal range for crop growth and development, crops grow more slowly, since like many biological organisms, their activity is tied to increasing temperature. For example, if soils remain in the low 50 degree range after corn planting, corn seedlings will grow very slowly, and remain subject to attack by diseases or insects for a much longer period of time. Few of our crop plants show chilling injury; that refers to membrane disruption by plants like tomatoes and bananas which occurs will cool temperatures which remain above the freezing point.

Occasionally, we will get sub-freezing temperatures during March and April; this can cause severe problems for wheat. A sharp freeze (say 20 F) after wheat has started jointing (see response to question #20 below) can kill developing heads, since they are now above the soil line. Freezing temperatures while wheat is flowering (usually early May) can cause severe yield reductions by killing potential kernels before their growth can start.

With the small grains, rye is most winterhardy, followed by triticale, then wheat, then barley, and finally oats. Wheat is the primary small grain produced in Kentucky (usually around 500,000 acres), but it can suffer substantial winter injury in some growing seasons.

13. Describe how the water and nutrient needs of crops change during growth and development.

For each of the crops discussed, more detail on specific growth stages is shown in the response to question #20 (below).

For **tobacco**, excess water is harmful during the lag phase, since it slows root growth and can aggravate disease problems. During the exponential growth phase, water is quite important; however, tobacco can deal with short-term water deficits without serious adverse impacts. During the last growth phase (maturation), excess rain can actually cause some regrowth of suckers, detracting from the focus on thickening leaf tissue.

Tobacco is known to need 200 pounds N, 35 pounds P_2O_5 , and 240 pounds K_2O per acre to produce a top-notch crop. Many tobacco growers apply as much as 350 pounds of N per acre; while some N losses are unavoidable, this application rate is probably too high, and could delay leaf senescence in some seasons. Lower, older leaves would yellow if too little soil N were available. Most burley tobacco fields are very high (above 80 pounds P_2O_5 per acre) in soil phosphorus. This is related to the very high initial levels of soil P, coupled with annual applications of complete fertilizers (like 5-10-15). If P were in low supply, you would see “metallic” leaf spotting of younger leaves. Sometimes, with cool spring conditions combined with low soil pH (below 6.0), temporary P deficiencies may be observed even on high testing P_2O_5 sites. The occurrence of very high testing K soils is less than that for P. Potassium is very important for high leaf quality. A K deficiency can initially be seen as yellowing starting at the leaf tips; those leaves eventually will necrose.

Because the most rapid nutrient uptake for tobacco occurs during its exponential growth phase, sidedressing is sometimes used to place fertilizer near the plant roots just before the period of maximal uptake.

For grain crops, a relatively large percentage of their nutrients are taken up prior to the onset of vegetative growth. For example, corn has taken up about 60% of its total N needs by the time of silking. Similar responses are also generally observed for both P and K. Crops which a lot of K (for example, alfalfa) will need a substantial K replacement (for alfalfa, this may mean K fertilization just after alfalfa harvest during the growing season).

Water needs of grain crops are generally tied to the size of the plants. Larger plants tend to withdraw more water from the soil; what's more, since air temperatures are usually higher by the time the plants get large, evaporative demand is higher during that time period. Other times during plant growth can also be quite stressful for crop plants. For example, a water deficit during tasseling and silking of corn can result in barren ears and poor yield (even if later rains are excellent). In contrast, heavy May and June rains can actually harm our wheat crop by raising the pressure of fungal pathogens on the crop.

As annual plants near maturity, their metabolism slows down, and both nutrient and water uptake taper off. For example, low rainfall after topping of tobacco will not generally be a big problem, since the plants can usually find enough soil moisture to complete their growth.

14. Relate the growing degree day concept (GDD) to crop development, recognize its use in production systems and calculate growing degree days for crop development.

In Kentucky, growing degree days are most often utilized with corn, since its development is clearly tied to temperature. Development of other crops is also moderated by temperatures; however, some crops are triggered to flower by daylength (really by nightlength, but it comes out to be the same difference in nature). For example, soybean plants flower primarily based on daylength.

For corn, the minimum temperature for growth is 50 F, while the maximum temperature for growth is 86 F. To calculate corn GDD, you average each day's maximum and minimum temperature, then subtract the base temperature for growth (50 F) from the result. For example, if the daily high was 82 F and the low was 60 F, the daily average would come out to 71 F, and your corn would accumulate 21 GDDs that day. To follow the development of a specific corn hybrid, you simply add up the GDDs for each day from the time it emerges until you reach its current stage. Note: if the daily high is above 86 F, you set it at 86 before calculating the daily average. Otherwise, if the high was 110, the GDD calculation would suggest that a ton of GDDs were accumulated on a day when corn would be pretty much shut down for most of the day.

The value of GDDs lies in picking corn hybrids which will mature around the time that the grower wishes to have them mature. The alternative (days to maturity) depends on what the temperatures are in a given year, and so can be off significantly if temperatures are hotter (or cooler) than normal.

15. Identify the growth stages during which crops are most susceptible to environmental stress. Most plants are pretty susceptible to stress during their initial establishment; for example, if it is hot and dry when you try to plant alfalfa in August, you will probably not get much of a stand.

As stated above, corn plants are quite sensitive to water and temperature stress during tasseling and silking. Soybean plants are especially sensitive to these stresses during their seed development phase. Winter wheat can be hammered by severe cold at almost any time over its winter and spring growth. Alfalfa can be hurt by a sharp freeze late in the fall if it has invested a lot of its root carbohydrates in re-growing from a late season cutting. Tall fescue handles mid-summer temperature stress by shutting down during that time of year. While this is not so great for grazing cattle, it helps tall fescue survive for very long periods of time. If tobacco is set too early, cool temperatures can diminish stands and force growers to re-set part of their crop.

16. Identify characteristics which indicate mechanical damage to agronomic crops from causes such as:

hail: Fortunately, hailstorms are much less common in Kentucky than they are further to our west. In addition, wherever hailstorms occur, they tend to be localized, rather than widespread. The most obvious result of hail is shredding of leaves. In plants with less sturdy stems (for example, wheat and soybean), stem breakage can also be evident. For wheat, an untimely hail event could also damage head tissue.

frost: Frost preferentially injures highly hydrated tissues. So, leaves are more vulnerable than are stems. If you don't actually see the frost on the leaves, you may have to wait a few hours to see if the leaf tissues become soft and lose their turgidity. Some tissues are even more sensitive to freezing injury than are leaves. For example, developing winter wheat heads above the soil line may be killed by a moderate freezing event. To check for this injury, a grower (or crop consultant) will need to split the lower stem and evaluate the condition of the developing head. Sometimes, you may have to wait a couple of days to see if the heads are turning brown and dying.

flooding: Flooding harms plants by depriving their roots of the oxygen they require to conduct respiration. If the water gets up over a low lying field for just a few hours, most plants will survive. However, flooding which lasts for 24 hours or longer can cause plants to yellow and wilt (symptoms which could be confused with drought symptoms). However, it should not be too difficult to determine if the damage is due to flooding or drought, simply by checking around for evidence of recent water flow. Plants in wet prone areas will often grow slowly and exhibit N deficiency symptoms (due to poor root growth in saturated soils).

drought: The most obvious symptoms here will be stunted plants with leaves that have lost their turgidity. Usually, you can also pick up on the drought by checking out the soil (unless a recent rain has occurred).

wind: Unless the wind was from a tornado, wind events will generally lodge plants in a single primary direction. Larger plants are generally more likely to be blown over by high winds, especially if a strong rainfall event accompanied the wind storm. Strong winds could also break off the tops of mature corn plants.

humans: The best way to see if people have harmed crop plants is to check for footprints. Probably the most frequent crop damage inflicted by people is through stealing of sweet corn ears. You can usually tell if that damage is by raccoons, since raccoons tend to break over more of the plants and do nearly all of their eating right there in the field. People tend to simply strip the ears off the stalks. Other damage could be inflicted by people driving around in a crop field; that too should be pretty obvious.

wildlife: Deer can cause recontamination of fumigated tobacco plant beds (by punching holes in the bed covers with their hooves). Now that float systems are getting more of the tobacco plant raising business, damage to soybean crops may be more significant. Deer will tend to browse along the margins of a soybean field, eating the top leaves of the plants. Unless a deer population is heavy, or the fields are small and isolated, the damage tends to be light.

17. Recognize climatic, plant, and management factors which influence plant survival and recovery after injury.

Injured plants are subject to secondary invasion by pathogens (especially bacteria and fungi). If weather conditions favor these pathogens (moist and cool, or moist and warm), then more plants may be lost to the pathogens than were lost to the initial mechanical injury.

Plant size and stage of development also play a role here. For example, if a hailstorm hit a grower's corn field just after silking, no new leaves could re-grow to replace those damaged in the storm, since the plant has already made its physiological switch from vegetative to reproductive growth. Lodged corn plants which are still growing vertically will have the opportunity to right themselves (by growing stem tissue more rapidly on the side closer to the soil). If winter wheat plants are injured before they complete tillering, additional tillers can be started to replace those injured.

If winter wheat is injured by a spring freeze after jointing, there is some evidence that an additional application of N may stimulate some late tillering and help the plants recover from this injury. Producers who are aware of recurring problems (frost, flooding, or drought, for example) can choose to plant varieties or hybrids which are less sensitive to those injuries. Sometimes, a producer will not take time to look carefully at a damaged field, and destroy the crop prematurely, even though it may have been able to recover nicely from the injury (for example, an early season hailstorm on corn or soybean).

18. Determine crop damage levels which may justify replanting and identify factors that affect replant decisions.

This is truly a judgment call. In the case of corn or soybean, a decision to replant a crop has to weigh losses due to late planting (after May 10 for corn or after June 10 for soybean) against the losses likely to be incurred due to the early season damage. Since you usually have to wait a few days to decide how severe the damage is, and since it often would take a few more days to get into the field and replant (the soil could be too wet too work, for example), those additional delays tend to favor leaving the damaged stand to grow (rather than re-planting).

Additional detail on a replanting decision can be found in the response to question #9 above.

19. List advantages and limitations of monoculture versus crop rotation. With tobacco, monoculture is undesirable, primarily because it greatly increases the chances of disease problems. Tobacco monoculture also results in soil degradation due to the intensive tillage generally practiced for this crop. For both alfalfa and tall fescue, monoculture is just fine, since these are relatively persistent perennials. (Don't try to re-plant alfalfa directly back into an alfalfa field, however. This plant has some auto-allelopathy factors which impedes the growth of alfalfa seedlings.) In the case of wheat, monoculture can result in increasing problems with the take-all fungus.

Most of the US work on rotations has investigated the benefits of rotating corn and soybean with one another, compared to continuous corn or continuous soybean. That work has shown the following advantages for a corn/soybean rotation: 1) about a 10% increase in yield of either corn or soybean, 2) reduced pest pressure (for example, better weed control or lower disease or insect pressure), 3) improved soil quality (perhaps through an improvement in soil organic matter levels, and 4) an N contribution from soybean to a subsequent corn crop. However, some mystery remains here, since the yield benefit to rotations often persists even when pests are controlled and extra N is applied. Further, rotations may have some other economic advantages; for example, through reduced pressure to plant or harvest a single crop in a narrow time frame, a grower can get by with smaller equipment and fewer workers.

Rotational limitations are generally less significant than are rotational advantages. There are some pests for which short-term rotations provide little benefit (for example, soybean cyst nematode). In addition, population shifts of other pests have allowed them to adapt to this two-year rotation system (for example, some corn rootworms). Some rotations may require the purchase of additional equipment, or may aggravate time and labor pressures from other crops. One concern about rotating Roundup Ready corn with Roundup Ready soybean is that this system provides a strong selection for weed species or biotypes which can survive treatment with this herbicide. In some environments, soybean can worsen problems with water erosion, since it tends to leave relatively little residue cover on the soil surface. In the case of Kentucky, our common corn, winter wheat, double crop soybean rotation is less susceptible to soil erosion during the winter following soybean because the wheat residue is usually still present.

20. For the following crops, identify stages of crop development:

tobacco: Tobacco plants go through three major stages in their growth (once they have been transplanted to the field). The first is the “lag” phase; during this time (25 to 30 days) the shoot is growing slowly, but the root system is rapidly establishing itself. The second is the “exponential” growth phase; during this time period up to 3 or 4 leaves are added per week, and rapid leaf expansion and nutrient uptake is occurring. This stage takes about 35 to 40 days. Once the plants are topped, the maturation begins. Growth slows down, and leaves are no longer added. However, leaves are becoming thicker. Little nutrient uptake occurs. Senescence (leaf yellowing) is desirable, and harvest usually takes place at 85 to 90 days after transplanting (or 3 to 4 weeks after topping). Both 1995 and 1998 were relatively poor years for growing burley tobacco in Kentucky; wet springs were followed by dry summers. This resulted in poor leaf body, low quality, and low yields. A dry spring followed by a moist summer would improve both quality and yield.

small grains: Barley growth stages are quite similar to those presented here for wheat. This description was developed by Large (1954), but is referred to as the Feekes’ scale. More detail, along with pictures are available on the web from the UK publication (Wheat Management in Kentucky) at <http://www.ca.uky.edu/agc/pubs/id/id125/02.htm> or from Ohio State’s Bulletin 827 at http://ohioline.ag.ohio-state.edu/b827/b827_92.html. Stages F1 through F10 are vegetative; stages F10.1 through F11.4 are reproductive. The vegetative stages are further subdivided into tillering (F1 through F5) and stem extension or jointing (F6 through F10). Stages are as follows: F1, seedling emergence; F2, tillering starts; F3, tillers fully formed; F4, leaf sheaths strengthening; F5, pseudo-stem strongly erected; F6, first node above soil surface; F7, second node above soil surface; F8, flag leaf tip emerges from the whorl; F9, flag leaf ligule emerges from the whorl; F10, boot stage (head swollen within top of stem); F10.1 through F10.5, heading; F10.5.1 through F10.5.5, flowering; F11.1 through F11.4, kernel ripening.

corn: Corn goes through a series of V-x (for vegetative growth) stages, followed by 6 R-x (for reproductive growth) stages. Check out Iowa State’s Special Report 48 (1992) by Ritchie et al (available on the web at <http://www.ag.iastate.edu/departments/agronomy/corngrows.html#how>) for more details.

The VE stage is emergence (when the spike is visible above the soil surface). Subsequent V stages correspond to the number of leaf collars present; for example, the V8 stage is reached when the 8th leaf collar has come out of the whorl. The last V stage is VT; this refers to the complete emergence of tassels from the whorl. Reproductive stages are as follows: R1, 50% silking; R2, kernels in blister stage; R3, kernels in milk stage; R4, kernels in dough stage; R5, kernels in full dent stage; and R6, black layer visible at the base of the kernel indicates that physiological maturity has been reached.

soybean: Like corn, soybean's growth stage descriptions are a series of V (for vegetative) and R (for reproductive) stages. Fehr and Caviness crafted this description; their work is available on the web at <http://www.agron.iastate.edu/soybean/soybean.html>.

The vegetative stages are as follows: VE, for emergence of cotyledons; VC, for unrolled unifoliate leaves; V1, unifoliate leaves fully developed; V2, first trifoliate leaf fully developed; and a series of further Vn stages, when n is the number of nodes which have fully developed leaves (counted the unifoliate, but not the cotyledonary node).

Reproductive stages are as follows: R1, beginning bloom; R2, full bloom; R3, beginning pod; R4, full pod; R5, beginning seed; R6, full seed; and R7, physiological maturity.

forage legumes: Forage legumes (like alfalfa and red clover) are generally a bit slow in establishment, since they start from relatively small seeds. Once forage legumes are established, the main differences among them are related to their life cycle. Alfalfa is a perennial, so it grows back after each cutting, and if carefully managed, can be productively grown for 3 or 4 years. Red clover stands will generally last only two years, and then must be re-seeded. Lespedeza is an annual forage legume; unfortunately, that means it must be re-seeded each season or be managed to re-seed itself.

21. Recognize a crop's response to different tillage systems.

Tobacco fields are often tilled excessively. This can cause tillage pans, and these compacted layers can inhibit root growth. This may hurt both nutrient and water uptake, especially during the exponential phase of growth. In-row subsoiling has given a solid benefit (2800 vs. 2300 pounds per acre, averaged across 7 tests). This was apparently due to the relief of tillage pans. Before recommending that sub-soiling be done, first a compaction problem must be verified; this can be done with a soil penetrometer.

Many growers insist that tobacco must be cultivated, even if there are very few surviving weeds to remove. Unfortunately, cultivation can aggravate problems with soil erosion. The biggest advantage of no-till tobacco is that it allows limited-land farms the opportunity to rotate their tobacco fields. Often small farms have little level land, and without no-till, they are stuck continuously growing tobacco on the same field (not such a good practice from the plant disease standpoint). The new herbicide Spartan (sulfentrazone) has helped facilitate no-till methods.

In general, both corn and soybean have responded positively to reduced tillage and no-tillage systems. These summer annual crops have benefited from the soil moisture retained by the previous crop residue remaining on the soil surface. In somewhat dry seasons, this can result in a substantial yield advantage for reduced till and no-tillage systems (compared to conventional tillage).

Recent work with no-till wheat has generally shown about a 4 or 5 bushel decrease in grain yield compared to conventionally tilled wheat. Since most Kentucky wheat follows corn in the rotation, stand establishment has been impeded somewhat by the presence of a heavy residue layer from the corn crop. Winter injury can be a greater problem for no-till wheat, primarily because attaining the right planting depth for no-till wheat can be difficult, and wheat planted too shallow can be injured by heaving (due to freeze-thaw cycles). No-till wheat may start off a bit slower in the early spring (February), and may require slightly more nitrogen at that time of year. In spite of these difficulties, no-till wheat may still be economically competitive with conventionally tilled wheat, due to the reduction in tillage expenses and in topsoil erosion.

22. Describe the endophyte and its effect on the growth and development and stress tolerance of tall fescue. Much of Kentucky's tall fescue pasture is infested with the endophytic ("within plant") fungus. This fungus lives in the seed, develops with the plant, and ends up in the seed of the next generation. More than 80% of the "old" pastures are infested to some extent; many have infection levels approaching 90% of the plants. This fungus is **only** spread through seed. That means that if a grower can establish an endophyte-free field, he can pretty much count on the field staying that way.

In general, endophyte-infected tall fescue plants are more stress tolerant than are endophyte-free tall fescue plants. The endophyte produces some protection against insect feeding. In addition, since the endophyte slows down grazing animals, endophyte-infected plants are less likely to be heavily grazed than are endophyte-free plants. In addition, endophyte-infected plants also tend to be more drought-tolerant than endophyte-free plants.

23. Describe the effect of topping practices and sucker control on burley tobacco yield and quality.

Without topping, tobacco plants would concentrate their energy on seed production. However, when tobacco plants are topped, suckers will soon grow from the leaf axils. Before maleic hydrazide (MH) was released in 1973 as a sucker control agent, suckers were removed by hand every few days. However, chemical methods of sucker control have improved leaf yield significantly, because they shut down suckers before the suckers have consumed quite so much energy.

Topping (when 10 to 25% of plants have one open flower) requires less labor, improves root growth, produces a heavier bodied leaf, results in leaves which cure darker in color, and helps reduce aphid pressure (since aphids reside primarily on the youngest tissue, and it is that very tissue which is removed by topping. Once a field gets into full flower, its physiology has already dramatically shifted toward seed production, as the top (versus the leaves) has become the primary energy sink of the plant.

Topping at 20 to 22 leaves saves labor at the stripping phase. Most burley tobacco varieties will achieve their yield potential with 20 to 22 leaves; however, since the tobacco companies want more tip leaves, growers may need to top higher in the future.

Sucker control agents include Prime⁺ and Butralin (both are locally systemic); MH (systemic); and fatty alcohols (which burn lateral buds but have no residual sucker control activity). The recommended practice now is to use Prime⁺ along with MH. This results in better, longer lasting sucker control, and can allow for lower MH rates which reduces the amount of MH residue on the leaves (which had been an issue for some European markets). A high volume (40 to 60 gallons/acre) is used; the point is to get the sucker control solution to flow down the stem and to come into contact with the buds in each leaf axil.

24. Identify best management practices for double crop soybeans.

Since soybean yields begin to decline when this crop is planted after June 10, planting as soon as possible after wheat harvest is critical. Some growers choose to plant barley instead of wheat, partly because barley can be harvested about 10 days earlier and double crop soybean planting can be done by or soon after June 10. Planting some of a grower's wheat acreage to earlier maturing wheat varieties can help get him started planting soybean sooner. Stripper headers allow for more rapid wheat harvest, since only the kernels are taken through the combine; this technology can also help get double crop soybean planted sooner. Of course, no-till methods should be used, since this practice helps get the soybean planted sooner and conserves valuable moisture for later in the soybean season. Choice of a variety which will consistently mature before frost is important. Row spacings below 20 inches are advantageous; most growers now use either 7 or 15 inch row equipment to plant double crop soybean. Generally, planting rates are 10 to 20% higher (to ensure a good stand and to help compensate for the shortened growing season). If surface moisture is inadequate for germination and emergence, most experts will recommend waiting to plant until a reasonable rainfall event has occurred. Most growers are using a burndown herbicide to control existing weeds; a number of growers are using a post-emergence treatment with Roundup (over Roundup Ready soybean, of course) to control existing as well as emerging weeds. Most growers will apply their P and K fertility before planting winter wheat in the preceding fall, and apply P according to wheat's needs and K according to soybean's needs.

25. Compare and contrast forage legumes for:

ease of establishment: Establishment is relatively easy for most forage legumes.

persistence: In general, alfalfa stands can be expected to last up to 4 or 5 years, if carefully managed (good fertility, good weevil control, opportunity to store root carbohydrates each fall). Red clover stands rarely last more than two or three years. White clover can be relatively persistent, since its prostrate growth habit protects it from grazing cattle. Of course, annual lespedeza must be re-seeded each season or managed to re-seed itself.

yield: Alfalfa can produce the best yields in this category (between 5 and 10 tons/A). Red clover runs between 2 and 5 tons/A, and annual lespedeza produces 1 to 3 tons/A. White clover productivity is not often measured directly (since it is usually harvested by grazing animals). However, it produces around 1 or 2 tons/A.

seasonality of growth: All of these forage legumes are of the C3 photosynthetic type. However, they are less likely to go dormant during the hottest part of the summer than are C3 forage grasses, especially if moisture is available. So, their productivity tends to be highest during the cooler months of May and June, but they can continue growing through July and August.

rooting depth: Alfalfa will root as deep as the soil profile allows it to go (up to 30 feet in some locations). In contrast, the clovers (both red and white) and annual lespedeza will usually only root in the top 2 or 3 feet of the soil.

management requirements: AGR-18 (Grain & Forage Crop Guide for Kentucky, written by M.J. Bitzer, J.C. Henning, G.D. Lacefield, and J.H. Herbek) provides a detailed listing of management practices for nearly all of the forage crops discussed. That publication is especially valuable for showing the appropriate planting rates, depths, and dates for each of the important forage crops.

Forage legumes have high protein content, in part, because they can fix nitrogen directly from the atmosphere. This is good for livestock nutrition, and saves the producer the expense of purchasing nitrogen fertilizer. However, nitrogen fixation is impeded by soil pH levels below 6.0, so careful liming is required. (Annual lespedeza is more tolerant of acid and infertile soils than are the other forage legumes.)

Bloat can be a serious problem for growers who graze or green-chop forage legumes. White clover is especially bad for bloat; but both red clover and alfalfa can also cause problems (annual lespedeza will not cause animals to bloat). Bloat potential can be minimized by making sure that animals are not hungry when they first are given access to the legume.

Recommended seeding rates are as follows: alfalfa, 12 to 20 pounds/A; red clover, 8 to 12 pounds/A; white or Ladino clover, 1 to 3 pounds/A; and annual lespedeza, 20 to 25 pounds/A.

growth & identification characteristics: Alfalfa has serrated tips on its leaves (a similar plant, sweet clover, also has serrated leaves, but the serrations go all the way around each leaf). Red clover has a characteristic “water mark” (light gray in color) which goes across its broad leaflets. In addition, red clover leaves (except a few newer varieties) have leaflets covered with tiny hairs. White clover can be identified by its prostrate (“along the ground”) growth habit.

26. Compare and contrast forage grasses for:

ease of establishment: In general, cool season forage grasses are not difficult to establish. Kentucky bluegrass is a bit slow, and may require more attention than tall fescue, timothy, or orchardgrass. In general, native warm season grasses are very difficult to establish, since they have light, fluffy seed (requiring a special drill), tend to have a high incidence of dormant seed, and are notorious for low seedling vigor. In fact, it may take 24 months before a grower can recognize these plants as dominating the area into which they were sown. Bermudagrass has to be established from “sprigs” (stolons); that means “seeding” has to be handled in a very different way. The old world bluestems have small, low vigor seeds. In contrast to both native and introduced perennial warm season forage grasses, the annual warm season forage grasses are generally quite easy to establish.

persistence: Tall fescue is king in this category; these plants can persist for decades in Kentucky. Kentucky bluegrass is also quite persistent. Timothy generally must be re-seeded after 4 to 5 years (however, since timothy is often seeded with alfalfa, that’s about the time that the alfalfa will need to be re-seeded anyway). Orchardgrass can get “clumpy” after 3 years or so. The native warm season perennials can be quite persistent, provided they are well-established and carefully managed. Introduced warm season perennials are generally quite persistent. Of course, introduced warm season annuals do not persist beyond their first season, and must be re-planted each time a producer wants to have some of this type of forage.

yield: Yields are seasonal (see “seasonality of growth” below). For growers who graze their animals (especially beef producers), a balance of spring, summer, fall, and stockpiled winter grazing is ideal. Tall fescue and orchardgrass produce reasonable yields (2 to 4 tons/A). Since timothy is a “one-cut” per year crop, its yields are somewhat lower (1 to 3 tons/A). Kentucky bluegrass is notorious for its low yields (1 to 3 tons/A). Native warm season perennials produce reasonably good yields, but must not be closely grazed (3 to 5 tons/A). Both types of introduced warm season forage grasses (annuals and perennials) can produce 2 to 5 tons/A; sorghum-Sudangrass likewise produces 2 to 5 tons/A.

seasonality of growth: Cool season grasses will have their primary flush of growth in the spring (April through June), and a secondary growth flush in the fall (September through November). During the summer, such grasses grow slowly (if at all) due to their C3 photosynthetic pathway. Tall fescue is by far the leading cool season forage grass in Kentucky, followed by bluegrass, orchardgrass, and timothy. Warm season grasses do most of their growing from June through September, since they have the C4 photosynthetic pathway. Some warm season grasses are native to Kentucky; examples are switchgrass, big bluestem, Indiangrass, Eastern gama grass, side oats grama, and little bluestem. Other warm season grasses have been introduced to Kentucky. Perennial warm season grasses include bermudagrass and the old world bluestems. Annual warm season grasses include Sudangrass, sorghum-Sudangrass hybrids, forage sorghums, pearl millets, and foxtail millets.

rooting depth: In general, rooting depth of forage grasses reflects their shoot heights. So, Kentucky bluegrass may only root in the top 6 to 12 inches of the soil, but tall fescue may be able to extract water and nutrients to a depth of 3 feet or so. Of course, very tall forage plants (like sorghum-Sudangrass) will grow roots only as deep as the soil's features allow; this may still be no deeper than 3 or 4 feet into most Kentucky soils.

management requirements: **Cool season perennials** require that producers with grazing animals plan for an alternate source of summer forage for their cattle. In addition, timely applications of spring and fall nitrogen can help to advance growth of these plants during their primary and secondary growth periods. In the case of tall fescue, a number of beef producers use a practice called "stockpiling" in which they make an early fall N application to a pasture, then keep cattle off until December. This provides winter forage without the expense of machine harvest and storage. Of course, tall fescue infested with the endophyte can require special management (see response to question #29 below).

It would also be good to know the seeding rates of the following cool season forage grasses: both tall fescue and orchardgrass, 10-15 pounds/A; timothy, 3 to 6 pounds/A; and Kentucky bluegrass, around 10 to 15 pounds/A.

Native warm season perennials require a great deal of care during the difficult establishment phase. Once the pasture is established, producers must be careful not to overgraze it, especially in the fall (when these plants need to establish root carbohydrate reserves for the next growing season).

Introduced warm season perennials also require a good deal of care at the time of establishment. Warm season annuals are generally used as a source of emergency summer forage. With the Sudangrass, forage sorghum, and sorghum-Sudangrass hybrids, growers must be careful about prussic acid poisoning and nitrate poisoning. Both of these problems tend to be worse whenever plants are small or stressed (by drought or frost) prior to harvest or grazing.

growth & identification characteristics: Tall fescue plants are coarse (compared to other grasses) and have a corduroy (“corrugated”) leaf appearance. Kentucky bluegrass has a characteristic “boat-shaped” leaf tip. Orchardgrass leaves have a soft-green to almost gray color, and the bottoms of their stems are flat. Switchgrass is tall and coarse with large leaves. Eastern gamagrass will be most growthy during the summer. Old world bluestems like to grow during the summer, and have a leaf color similar to orchardgrass. Even a professional can’t tell between Sudangrass, forage sorghum, and sorghum-Sudangrass hybrids.

COMPETENCY AREA 3. Harvest

27. Describe harvest schedules for optimum crop quality and yield. For **tobacco**, the best match of yield and quality will usually come at 3 to 4 weeks after topping. This allows for increases in leaf dry matter to occur, and generally results in a more appealing leaf color and a more desirable chemical profile of the harvested leaf. Optimal curing conditions allow the leaves to “cure” rather than merely dry down. Ideally, leaf tissue would come in and then back out of “case” each day during curing; this means controlling barn door opening. Interestingly, some of the new, low cost outdoor curing structures have actually resulted in better curing conditions than the traditional 3 rail (and relatively more expensive) tobacco barns.

Forage legumes will produce best yield per cutting if they are allowed to grow into their reproductive stages. However, quality will decline if harvest is delayed that long. The best compromise between quality and yield is to harvest at the bud to early flower stages of growth. For **forage grasses**, the time at which their physiology switches from vegetative to reproductive growth is also the best compromise of yield and quality. In some cases, tradition demands later harvest; for example, horse farmers like to see the full head of timothy plants, and that means grower who want to sell to this market must let their timothy grow well into its reproductive stages.

For grain crops, harvest timing is dependent on a balance between the gain (from reduced drying expenses) and losses (crop lodging and/or reduced yield potential of double crop soybean). So, for **wheat**, the over-riding concern is to get the wheat crop off the field as quickly as possible to get double crop soybean planted. In the case of **corn**, harvest generally does not begin until grain moisture falls below 20%. Further delays after that point may save additional drying costs, but can also result in reduced yield due to increasing stalk breakage (for example, if second generation European corn borer damage was substantial). **Soybean** harvest is generally completed after corn is harvested and wheat is planted. Unfortunately, that can mean that soybean harvest gets strung out into the short, damp, and cloudy days of November. Such a delay can harm soybean grain quality, both due to the growth of pathogens (like *Phomopsis*) and greater field weathering and mechanical damage to the seed during harvest. This is a much greater concern for growers attempting to produce certified seed (rather than grain).

28. Describe the effect of grazing system on forage growth, quality, persistence and subsequent animal performance. The two most important grazing systems are continuous stocking and rotational stocking. Under continuous stocking, animals are allowed to have access to the entire pasture over a long period of time. Under rotational stocking, fences are arranged so that cattle can be systematically allowed to graze only in certain parts of the pasture (meanwhile, the other parts of the pasture are in various stages of recovery from grazing).

Continuous grazing may hurt forage longevity, especially if a pasture is overstocked. In addition, since cattle preferentially graze forage plants which they find more palatable, continuous grazing will generally give an advantage to less palatable species (over the long haul). If this occurs, nutritional quality of the subsequent forage crops will be lower. Again, if stocking rates are too high, especially during a season in which the forage is not growing actively (early spring for a warm season grass or mid-summer for a cool season grass), forage growth can be adversely impacted. Animals grazing an unproductive or unpalatable pasture will grow more slowly.

Rotational grazing requires a greater investment, both financially (to construct and maintain fencing) and managerially (to decide when to move cattle to the next paddock). However, as is the case with even more complex grazing systems, this additional investment is generally rewarded with higher forage yields, better quality (since animals graze off grasses more uniformly in each paddock), better forage persistence (since the plants have the opportunity to recover from grazing pressure), and better animal performance. The real issue here might be whether beef market prices are high enough for the above benefits to translate into a financial reward for the producer.

An excellent reference on grazing systems (and on forages in general) is the book “Southern Forages” by D.M. Ball, C.S. Hoveland, and G.D. Lacefield (published by the Potash and Phosphate Institute and the Foundation for Agronomic Research in Atlanta, GA; phone number 404-634-4274).

29. Describe the effect of the endophyte of tall fescue on the performance of beef and dairy cattle and horses. When livestock consume “dirty” tall fescue (infested with the endophyte), blood flow is restricted to their extremities. This makes it harder for the animals to dissipate excess body heat. As a result, they spend less time grazing, and more time standing in the shade or in the water. This has all sorts of bad results for the animals. For beef cattle, rate of growth declines, primarily because the animals eat so much less forage. For dairy cattle, the decline in forage intake can dramatically depress milk production. With horses, reproduction is impaired; often mares will abort their foals. (Reproductive efficiency can also be reduced for both beef and dairy cattle.)

If a grower suspects that the endophyte is present, a test can give her a good idea of just how serious the problem is. Renovation with legumes is a good first step, since this allows the animals to get a greater part of their forage from a source without any of the toxins present in endophyte-infected tall fescue. A grower can also manage infected tall fescue in such a way as to keep it leafy (by timely N applications, for example). For dairy cattle and horses, infected tall fescue should be avoided during the most stressful times (hot summer for dairy cattle; last 60 days of gestation for horses). The most expensive alternative is to replace the dirty tall fescue with “clean” (endophyte-free) tall fescue. This option will most likely be attractive to dairy and horse farmers.

Several clean tall fescue varieties are available. However, they are generally not as tolerant of abusive grazing practices or drought stress as are dirty varieties. However, some clean varieties have performed well under abusive grazing; for example, “Cattle Club” had better stands after 2 years of abusive grazing than did dirty Kentucky 31.

30. List the factors at harvest (timing, method of harvest, losses) that influence crop quality and yield.

Tobacco is discussed above in the response to question #27.

Forage legumes and **forage grasses** are also discussed in question #27 above.

Corn, soybean, and wheat are also discussed in question #27 above.

Cropping Systems Management

Sample questions for Kentucky Certified Crop Advisor exam.

- ___ 1. Cold tests are often used to measure the vigor of ___ seed. a) tobacco b) corn c) wheat d) soybean e) tall fescue.
- ___ 2. In general, tobacco growers can expect their crop to be ready to harvest ___ days after transplanting. a) 45 to 55 b) 65 to 75 c) 85 to 95 d) 105 to 115.
- ___ 3. The best balance between tobacco yield and market quality is achieved by harvesting ___ weeks after topping. a) one to two b) three to four c) five to six d) seven to eight e) nine to ten.
- ___ 4. The best curing conditions for burley tobacco are: a) damp, dry cycles daily b) continuously damp c) continuously dry d) below freezing temperatures e) warm, humid days.
- ___ 5. Of the following list, the forage legume with the least persistence is: a) alfalfa b) annual lespedeza c) kura clover d) red clover e) white clover.
- ___ 6. Which of the following forage grasses would produce the most forage for mid summer grazing? a) tall fescue b) switchgrass c) bluegrass d) orchardgrass e) timothy.
- ___ 7. The most common maturity group for Kentucky soybean is: a) II b) III c) IV d) V e) VI.
- ___ 8. The maximum temperature (F) for corn to grow is: a) 56 b) 66 c) 76 d) 86 e) 96.
- ___ 9. The main thing a tobacco grower can do to minimize the likelihood of problems with manganese toxicity is: a) apply manganese only at recommended amounts b) keep initial soil pH around 6.5 c) avoid buying plugs grown out-of-state d) avoid soils with high Mn test levels.
- ___ 10. Seed lot quality is influenced by which of the following factors: a) mechanical purity b) seed moisture at harvest c) longevity d) seedborne diseases e) all of the above.
- ___ 11. Seed tags must include: a) the variety name b) date the seed lot was tested c) percent pure seed d) address of the vendor e) all of the above.
- ___ 12. In float beds, the entity most likely to inhibit root growth is: a) magnesium b) sucrose c) nitrite d) low pH e) low temperatures.
- ___ 13. For optimal tobacco sucker control, use: a) one application of fatty alcohols b) a coarse spray of 50 gallons per acre of maleic hydrazide combined with Prime⁺ c) butralyn applied one week before topping d) hand removal of suckers is still your best bet.
- ___ 14. Key advantages of tall fescue include: a) consistently high forage quality b) tolerant of abusive management c) excellent productivity in mid-summer d) all of the above.

- ___ 15. For best forage quality, harvest forage grasses at ____ stage of development. a) early vegetative b) late vegetative c) boot to early heading d) late seed development e) senescence.
- ___ 16. The main impact of the tall fescue endophyte on grazing animals is: a) enhanced disease tolerance b) increased insect tolerance c) poor blood flow to their extremities d) reduced rate of weight gain e) more time spent sleeping.
- ___ 17. The optimal soil temperature (F) for planting soybean is: a) 45 b) 55 c) 65 d) 75 e) 85.
- ___ 18. During the development of a corn plant, the most important stage for it to have adequate water supplies is: a) early vegetative b) late vegetative c) around silking time d) during kernel development e) during field drying.
- ___ 19. Tobacco plants in the field are showing leaves with yellowing starting from the tips of leaves. What is most likely the problem? a) too much nitrogen b) too little water c) a blue mold infestation d) an extensive aphid attack e) too little potassium.
- ___ 20. Currently, about ____ % of the soybean acreage in Kentucky is planted to varieties developed by private companies. a) 15 b) 35 c) 55 d) 75.
- ___ 21. The most stressful seedbed environment would be: a) cold and dry b) cold and wet c) warm and dry d) warm and wet.
- ___ 22. Conventional tobacco beds should be: a) well drained b) on a north-facing slope c) close to your home for easy monitoring d) low in phosphorus e) all of the above.
- ___ 23. The best stage at which to top tobacco plants is when: a) they have 10 leaves. b) 10 to 25% of the plants have one open flower c) at least 75% of plants have one open flower d) all flowers are fully open e) one week after all flowers are fully opened.
- ___ 24. The best thing a dairy farmer can do if her tall fescue is heavily infected with the endophytic fungus is: a) make sure her cows have plenty of water b) interseed red clover in her pastures every other year c) replace her pasture with an endophyte-free fescue variety d) switch over to raising horses.
- ___ 25. The endophytic fungus infection level which would make tall fescue most stress tolerant would be ____ %. a) 10 b) 30 c) 50 d) 70 e) 90.
- ___ 26. In pounds per acre, about how much tall fescue seed should be planted? a) 5 to 10 b) 15 to 20 c) 25 to 30 d) 35 to 40 e) 45 to 50.
- ___ 27. A soybean crop has reached its physiological maturity when: a) seeds are touching each other within the pods b) leaves begin to turn yellow c) one pod of mature color is visible on an average plant d) seeds are dry enough for harvest to begin.
- ___ 28. Soybean plants are most susceptible to environmental stresses during what phase of their growth? a) early vegetative b) late vegetative c) early flowering d) early in seed development e) as they reach physiological maturity.
- ___ 29. UK recommends that burley tobacco farmers apply from 150 to 300 pounds of N per acre, depending on the previous crop. Most Kentucky burley farmers apply about ____ pounds of N per acre. a) 150 b) 350 c) 550 d) 750 e) 950.

- ___ 30. Most Kentucky corn is: a) open pollinated varieties b) synthetic varieties c) single cross hybrids d) double cross hybrids e) clonal varieties.
- ___ 31. In order to complete the process of germination, soybean seeds must take up ___ % of their dry weight in water. a) 10 b) 30 c) 50 d) 70 e) 90.
- ___ 32. In a corn field with 20 inch rows, you find that the average plants are 12 inches apart within the row. How many plants per acre do you have? a) 26,000 b) 28,000 c) 30,000 d) 32,000 e) 34,000.
- ___ 33. The new herbicide labeled for weed control in tobacco is: a) Scepter b) Roundup c) Spartan d) Prowl e) Atrazine.
- ___ 34. A key disadvantage of timothy as a hay crop is: a) the great difficulty involved in getting it established. b) the lack of a local market. c) that it only produces one cutting per year. d) that it must be re-seeded each season.
- ___ 35. The best stage for the harvest of alfalfa is: a) late vegetative b) early bloom c) late bloom d) mid seed fill e) senescence.
- ___ 36. The situation under which bloat problems are most likely is: a) hungry cattle feeding on pure white clover stands b) feeding cows baled red clover c) grazing annual lespedeza mixed with tall fescue d) grazing alfalfa mixed with orchardgrass.
- ___ 37. The most rapid nutrient uptake by corn occurs: a) within the first 25 days after planting b) during the weeks just before tasseling and silking c) during the weeks just after tasseling and silking d) within the last 25 days of the crop's growth when kernels are developing.
- ___ 38. You observe that most of the plants in a soybean field are "Y" shaped. What is the most likely cause? a) excessive nitrogen fertilizer b) application of the wrong herbicide c) early season hail damage d) this is simply a characteristic growth pattern of some varieties e) insect feeding.
- ___ 39. A great tobacco season would include: a) dry spring, wetter summer b) cool spring, hot summer c) wet spring, drier summer d) hot spring, cool summer.
- ___ 40. For most Kentucky crops, the genetic delivery system is: a) stem cuttings b) sprigs c) rhizome pieces d) seeds e) transplants.
- ___ 41. How does seed size affect the optimal seeding depth? Larger seeds should be planted: a) on the soil surface b) about 0.25 inches deep c) 1 to 1.5 inches deep d) at least three inches deep.
- ___ 42. If you have a seed lot with poor seed quality, what can you do to help get a better stand? a) make sure you have a good seedbed b) treat the seed with fungicides c) avoid early planting in cool soils d) make sure to plant at a uniform depth, on the shallow end of that crop's range e) all of the above.
- ___ 43. How can excessive tillage harm tobacco plants? a) makes them grow roots too deep, wasting energy b) can cause soil compaction, thereby restricting rooting volume c) makes them more subject to blue mold and black shank diseases d) only causes indirect harm by enhancing soil erosion.

- ___ 44. In general, warm season grasses: a) like temperatures in the 75 to 85 F range. b) have higher crude protein and digestibility than do cool season grasses. c) are inexpensive to establish. d) are not especially responsive to applications of nitrogen fertilizers.
- ___ 45. Benefits of annual lespedeza include: a) will grow on infertile soils b) does not cause bloat c) provides mid-summer grazing d) can re-seed itself if carefully managed e) all of the above.
- ___ 46. The most important factor controlling the rate of development of grain crops is: a) daylength b) soil moisture c) temperature d) insect pressure e) soil fertility.
- ___ 47. On May 22, the high temperature is 78; the low temperature is 62. How many growing degree days (GDD) were accumulated for corn that day? a) not any, because corn wouldn't be planted yet b) 20 GDD c) 30 GDD d) 40 GDD.
- ___ 48. Before corn plants reach this height, they are likely to recover from hail damage, since their growing point will have been protected under the soil. a) 6 inches b) 12 inches c) 18 inches d) 24 inches e) 30 inches.
- ___ 49. If you cut apart corn plants at or after this growth stage, you will be able to find developing tassels and ears. a) V6 b) V12 c) V18 d) R1 e) R4.
- ___ 50. The most effective disinfectant for equipment used in float culture of tobacco plants is: a) steam b) methyl bromide with chloropicrin c) quaternary ammonium chloride salts d) chlorine bleach.
- ___ 51. If wheat seed is planted too deep, what is the most likely consequence? a) few plants will come up b) coleoptiles will simply elongate until they reach the light c) this will result in deeper root systems, a major advantage in dry seasons d) most plants will still come up, but spread out over a longer period of time.
- ___ 52. The most appropriate row spacing for corn in Kentucky appears to be: a) 10 inches b) 20 inches c) 30 inches d) 40 inches e) 50 inches.
- ___ 53. Most rapid tobacco leaf growth occurs during the _____ phase of tobacco development. a) seedling b) transplant shock c) exponential d) flowering e) post-flowering.
- ___ 54. In general, what are the benefits of forage legumes? a) provide excellent mid-summer grazing b) contain high levels of protein and energy c) do not require applications of nitrogen fertilizers d) produce excellent forage yields e) all of the above.
- ___ 55. The key disadvantage of red clover is: a) must be re-seeded every 2 or 3 years b) is very susceptible to leaf diseases c) when interseeded with tall fescue, can cause severe bloat problems d) very tricky to get established.
- ___ 56. The most winterhardy small grain is: a) oats b) wheat c) triticale d) rye e) barley.
- ___ 57. Planting wheat too early can increase problems with: a) barley yellow dwarf virus infection b) spring freeze damage c) Hessian fly attack d) all of the above.

- ___ 58. You are told that a soybean field is at growth stage R2. What are the plants doing at this time? a) just beginning to emerge b) they have two fully developed trifoliate leaves c) just beginning to flower d) at full flower stage e) just beginning to ripen.
- ___ 59. The optimal date for planting double crop soybean in Kentucky would be: a) May 10 to 15 b) May 25 to 30 c) June 10 to 15 d) June 25 to 30 e) July 10 to 15.
- ___ 60. Companies and public institutions develop new crop varieties; what characteristic(s) are they trying to improve? a) crop quality b) biological efficiency c) yield d) resistance to production hazards like disease e) all of the above.

Key for Kentucky CCA Practice Exam Cropping Systems Management

1. B	11. E	21. B	31. C	41. C	51. A
2. C	12. C	22. A	32. A	42. E	52. C
3. B	13. B	23. B	33. C	43. B	53. C
4. A	14. B	24. C	34. C	44. A	54. E
5. B	15. C	25. E	35. B	45. E	55. A
6. B	16. C	26. B	36. A	46. C	56. D
7. C	17. C	27. C	37. B	47. B	57. D
8. D	18. C	28. C	38. C	48. B	58. D
9. B	19. E	29. B	39. A	49. A	59. C
10. E	20. D	30. C	40. D	50. E	60. E

APPENDIX

COMMON WEEDS IN KENTUCKY'S CROPS

COMMON NAME	SCIENTIFIC NAME	LIFE CYCLE*
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CORN

Grasses & Grass-like Plants (Monocots)

broadleaf signalgrass	<i>Brachiaria platyphylla</i>	A
crabgrass, large	<i>Digitaria sanguinalis</i>	A
foxtail, giant	<i>Setaria faberi</i>	A
johnsongrass	<i>Sorghum halepense</i>	P
fall panicum	<i>Panicum dichotomiflorum</i>	A
ryegrass, Italian	<i>Lolium multiflorum</i>	A
shattercane	<i>Sorghum bicolor</i>	A

Broadleaf Plants (Dicots)

burcucumber	<i>Sicyos angulatus</i>	A
cocklebur, common	<i>Xanthium strumarium</i>	A
milkweed, honeyvine	<i>Ampelamus ambidus</i>	P
morningglory, bigroot (wild sweet potato)	<i>Ipomoea pandurata</i>	P
morningglory, ivyleaf	<i>Ipomoea hederacea</i>	A
pigweed, smooth	<i>Amaranthus hybridus</i>	A
pokeweed, common	<i>Phytolacca americana</i>	P
ragweed, giant (horseweed)	<i>Ambrosia trifida</i>	A
trumpet creeper	<i>Campsis radicans</i>	P

SOYBEANS

Grasses & Grass-like Plants (Monocots)

broadleaf signalgrass	<i>Brachiaria platyphylla</i>	A
crabgrass, large	<i>Digitaria sanguinalis</i>	A
foxtail, giant	<i>Setaria faberi</i>	A
johnsongrass	<i>Sorghum halepense</i>	P
fall panicum	<i>Panicum dichotomiflorum</i>	A
shattercane	<i>Sorghum bicolor</i>	A

Broadleaf Plants (Dicots)

burcucumber	<i>Sicyos angulatus</i>	A
cocklebur, common	<i>Xanthium strumarium</i>	A
copperleaf, hophornbeam	<i>Acalypha ostryifolia</i>	A
lambsquarters, common	<i>Chenopodium album</i>	A
mare's tail (horseweed)	<i>Conyza canadensis</i>	A
morningglory, ivyleaf	<i>Ipomoea hederacea</i>	A
nightshade, eastern black	<i>Solanum ptycanthum</i>	A
pigweed, smooth	<i>Amaranthus hybridus</i>	A
pokeweed, common	<i>Phytolacca americana</i>	P
ragweed, giant (horseweed)	<i>Ambrosia trifida</i>	A
sicklepod	<i>Cassia obtusifolia</i>	A
sida, prickly (teaweed)	<i>Sida spinosa</i>	A
trumpet creeper	<i>Campsis radicans</i>	P

COMMON NAME	SCIENTIFIC NAME	LIFE CYCLE*
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TOBACCO

Grasses & Grass-like Plants (Monocots)

crabgrass, large	<i>Digitaria sanguinalis</i>	A
foxtail, giant	<i>Setaria faberi</i>	A
johnsongrass	<i>Sorghum halepense</i>	P
nutsedge, yellow	<i>Cyperus esculentus</i>	P

Broadleaf Plants (Dicots)

galinsoga, hairy	<i>Galinsoga ciliata</i>	A
horsenettle	<i>Solanum carolinense</i>	P
jimsonweed	<i>Datura stramonium</i>	A
lambsquarters, common	<i>Chenopodium album</i>	A
milkweed, honeyvine	<i>Ampelamus albidus</i>	P
morningglory, ivyleaf	<i>Ipomoea hederacea</i>	A
pigweed, smooth	<i>Amranthus hybridus</i>	A
ragweed, common	<i>Ambrosia artemisiifolia</i>	A
sida, prickly (teaweed)	<i>Sida spinosa</i>	A

WHEAT

Grasses & Grass-like Plants (Monocots)

cheat	<i>Bromus secalinus</i>	A
chess, hairy	<i>Bromus commutatus</i>	A
ryegrass, Italian	<i>Lolium multiflorum</i>	A
garlic, wild	<i>Allium vineale</i>	P

Broadleaf Plants (Dicots)

bittercress, hairy	<i>Cardamine hirsuta</i>	A
chickweed, common	<i>Stellaria media</i>	A
cornflower (bachelor's-button)	<i>Centaurea cyanus</i>	A
deadnettle, purple	<i>Lamium purpureum</i>	A
dock, curly	<i>Rumex crispus</i>	P
fleabane, Philadelphia	<i>Erigeron philadelphicus</i>	P
henbit	<i>Lamium amplexicaule</i>	A
pennycress, field	<i>Thlaspi arvense</i>	A
pepperweed, field	<i>Lepidium campestre</i>	A
shepherd's-purse	<i>Capsella bursa-pastoris</i>	A
speedwell, ivyleaf	<i>Veronica hederifolia</i>	A
thistle, musk (nodding thistle)	<i>Carduus nutans</i>	B

COMMON NAME	SCIENTIFIC NAME	LIFE CYCLE*
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ALFALFA

Grasses & Grass-like Plants (Monocots)

crabgrass, large	<i>Digitaria sanguinalis</i>	A
foxtail, giant	<i>Setaria faberi</i>	A
fescue, tall	<i>Festuca arundinacea</i>	P
johnsongrass	<i>Sorghum halepense</i>	P
nutsedge, yellow	<i>Cyperus esculentus</i>	P

Broadleaf Plants (Dicots)

chickweed, common	<i>Stellaria media</i>	A
dandelion	<i>Taraxacum officinale</i>	P
deadnettle, purple	<i>Lamium purpureum</i>	A
dock, curly	<i>Rumex crispus</i>	P
fleabane, Philadelphia	<i>Erigeron philadelphicus</i>	B
henbit	<i>Lamium amplexicaule</i>	A
horsenettle	<i>Solanum carolinense</i>	P
mustard, wild	<i>Brassica kaber</i>	A
pigweed, spiny (spiny amaranth)	<i>Amaranthus spinosus</i>	A
plantain, broadleaf	<i>Plantago major</i>	P
thistle, musk (nodding thistle)	<i>Carduus nutans</i>	B

PASTURES

Grasses & Grass-like Plants (Monocots)

broomsedge	<i>Andropogon virginicus</i>	P
crabgrass, large	<i>Digitaria sanguinalis</i>	A
foxtail, yellow	<i>Setaria glauca</i>	A
nimblewill	<i>Muhlenbergia schreberi</i>	P
purpletop (grease grass)	<i>Tridens flavus</i>	P

Broadleaf Plants (Dicots)

blackberry spp.	<i>Rubus</i> spp.	P
buckbrush	<i>Symphoricarpos orbiculatus</i>	P
buttercup spp.	<i>Ranunculus</i> spp.	A/B/P
dock, broadleaf	<i>Rumex obtusifolius</i>	P
ironweed, tall	<i>Vernonia altissima</i>	P
pigweed spiny (spiny amaranth)	<i>Amranthus spinosa</i>	A
ragweed, common	<i>Ambrosia artemisiifolia</i>	A
ragweed, lanceleaf	<i>Ambrosia bidentata</i>	A
redcedar, eastern	<i>Juniperus virginiana</i>	P
rose, multiflora	<i>Rosa multiflora</i>	P
sumpweed, rough	<i>Iva ciliata</i>	A
thistle, musk (nodding thistle)	<i>Carduus nutans</i>	B

* A = annual, B = biennial, P = Perennial

COMMON INSECTS IN KENTUCKY'S CROPS

COMMON NAME	SCIENTIFIC NAME	LIFE CYCLE*
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CORN

Moth / Caterpillar (Lepidoptera)

Armyworm	<i>Pseudaletia unipuncta</i>	C
Black cutworm	<i>Agrotis ipsilon</i>	C
Corn earworm	<i>Helicoverpa zea</i>	C
Common stalk borer	<i>Papaipema nebris</i>	C
European corn borer	<i>Ostrinia nubilalis</i>	C
Fall armyworm	<i>Spodoptera frugiperda</i>	C
Southwestern corn borer	<i>Diatraea grandiosella</i>	C

Beetle / grub or wireworm (Coleoptera)

Western corn rootworm	<i>Diabrotica virgifera virgifera</i>	C
Northern corn rootworm	<i>Diabrotica barberi</i>	C
Southern corn rootworm	<i>Diabrotica undecimpunctata howardi</i>	C
Japanese beetle	<i>Popillia japonica</i>	C
Wireworm	Several - in family Elateridae	C
White grub	Several - in family Scarabidae	C

Fly / maggot (Diptera)

Seed corn maggot	<i>Delia platura</i>	C
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Aphids (Homoptera)

Corn leaf aphid	<i>Rhopalosiphum maidis</i>	G
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Bugs (Hemiptera)

Green stink bug	<i>Acrosternum hilare</i>	G
Brown stink bug	<i>Euschistus servus</i>	G

FORAGES

Moth / Caterpillar (Lepidoptera)

Armyworm	<i>Pseudaletia unipuncta</i>	C
Fall armyworm	<i>Spodoptera frugiperda</i>	C

Beetle / grub or wireworm (Coleoptera)

Alfalfa weevil	<i>Hyper postica</i>	C
Blister beetles	Several - <i>Epicauta</i> sp.	C
Clover root curculio	<i>Sitona hispidulus</i>	C

Grasshopper (Orthoptera)

Redlegged grasshopper	<i>Melanoplus femurrubrum</i>	G
Two-striped grasshopper	<i>Melanoplus bivittatus</i>	G
Differential grasshopper	<i>Melanoplus differentialis</i>	G

Plant bugs and aphids (Homoptera)

Potato leafhopper

Empoasca fabae

G

COMMON NAME	SCIENTIFIC NAME	LIFE CYCLE*
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SMALL GRAINS**Moth / Caterpillar (Lepidoptera)**

Armyworm

Pseudaletia unipuncta

C

Fall armyworm

Spodoptera frugiperda

C

Beetle / grub or wireworm (Coleoptera)

Cereal leaf beetle

Oulema melanopus

C

Fly / maggot (Diptera)

Hessian fly

Mayetiola destructor

C

Grasshopper (Orthoptera)

Redlegged grasshopper

Melanoplus femurrubrum

G

Two-striped grasshopper

Melanoplus bivittatus

G

Differential grasshopper

Melanoplus differentialis

G

Plant bugs and aphids (Homoptera)

Bird cherry-oat aphid

Rhopalosiphum padi

G

English grain aphid

Sitobion avenae

G

Corn leaf aphid

Rhopalosiphum maidis

G

SOYBEAN**Moth / Caterpillar (Lepidoptera)**

Black cutworm

Agrotis ipsilon

C

Fall armyworm

Spodoptera frugiperda

C

Soybean podworm

Helicoverpa zea

C

Green cloverworm

Plathypena scabra

C

Beetle / grub or wireworm (Coleoptera)

Bean leafbeetle

Cerotoma trifureata

C

Japanese beetle

Popillia japonica

C

Mexican bean beetle

Epilachna varivestis

C

Fly / maggot (Diptera)

Seed corn maggot

Delia platura

C

Grasshopper (Orthoptera)

Redlegged grasshopper

Melanoplus femurrubrum

G

Two-striped grasshopper

Melanoplus bivittatus

G

Differential grasshopper

Melanoplus differentialis

G

Plant bugs and aphids (Homoptera)

Three-cornered alfalfa-hopper

Spissistilus festinus

G

Stinkbugs (Hemiptera)

Green stink bug	<i>Acrosternum hilare</i>	G
Brown stink bug	<i>Euschistus servus</i>	G

COMMON NAME	SCIENTIFIC NAME	LIFE* CYCLE
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TOBACCO

Moth / Caterpillar (Lepidoptera)

Black cutworm	<i>Agrotis ipsilon</i>	C
Tobacco budworm	<i>Helicoverpa virescens</i>	C
Tobacco hornworm	<i>Manduca sexta</i>	C

Beetle / grub or wireworm (Coleoptera)

Tobacco flea beetle	<i>Epitrix hirtipennis</i>	C
Wireworms	Several in family <i>Elateridae</i>	C

Grasshopper (Orthoptera)

Redlegged grasshopper	<i>Melanoplus femurrubrum</i>	G
Two-striped grasshopper	<i>Melanoplus bivittatus</i>	G
Differential grasshopper	<i>Melanoplus differentialis</i>	G

Aphids (Homoptera)

Tobacco aphid	<i>Myzus nicotianae</i>	G
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Bugs (Hemiptera)

Green stink bug	<i>Acrosternum hilare</i>	G
Brown stink bug	<i>Euschistus servus</i>	G

NATURAL ENEMIES

Beetle / grub (Coleoptera)

Multicolored Asia Lady Beetle	<i>Harmonia axyridis</i>	C
Convergent Lady Beetle	<i>Hippodamia convergens</i>	C
Seven-spotted Lady Beetle	<i>Coccinella septempunctata</i>	C
Pink Lady Beetle	<i>Coleomegilla maculata</i>	C

Fly / maggot (Diptera)

Syrphid flies	Several in the family Syrphidae	C
Tachinid flies	Several in the family Tachinidae	C

Bugs (Hemimoptera)

Big-eyed bug	Several - <i>Geocoris</i> sp.	G
Damsel bug	Several in family Nabidae	G

Spiders (Araneida)

Several

Lacewing (Neuroptera)

Green lacewing	<i>Chrysoperda carnea</i>	C
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*Life Cycles -

C = Complete life cycle consists of: egg, larva (like caterpillar, wireworm, grub or maggot) pupa and adult

G = Gradual life cycle consists of: egg, juvenile, adult (except aphids born live, no egg)

COMMON DISEASES IN KENTUCKY'S CROPS

COMMON NAME	SCIENTIFIC NAME	TYPE OF PATHOGEN
ALFALFA		
Anthracnose	<i>Colletotrichum trifolii</i>	Fungus
Aphanomyces root rot	<i>Aphanomyces euteiches</i>	Fungus
Crown rot complex	Various	Bacteria and fungi
Lepto leaf spot	<i>Leptosphaerulina briosiana</i>	Fungus
Phytophthora root rot	<i>Phytophthora megasperma</i>	Fungus
Sclerotinia crown and stem rot	<i>Sclerotinia trifoliorum</i>	Fungus
Spring black stem and leaf spot	<i>Phoma medicaginis</i>	Fungus
Web blight	<i>Rhizoctonia solani</i>	Fungus

BARLEY		
Barley yellow dwarf	<i>Barley yellow dwarf virus</i>	Virus
Head scab	<i>Fusarium graminearum (Gibberella zeae)</i>	Fungus
Leaf rust	<i>Puccinia hordei</i>	Fungus
Loose smut	<i>Ustilago tritici</i>	Fungus
Net blotch	<i>Helminthosporium teres</i>	Fungus
Scald	<i>Rhynchosporium secalis</i>	Fungus
Leaf and glume blotch	<i>Stagonospora nodorum</i>	Fungus

CORN		
Anthracnose leaf blight, top dieback and stalk rot	<i>Colletotrichum graminicola</i>	Fungus
Charcoal stalk rot	<i>Macrophomina phaseoli</i>	Fungus
Common rust	<i>Puccinia sorghi</i>	Fungus
Common smut	<i>Ustilago maydis</i>	Fungus
Fusarium stalk and ear rot	<i>Fusarium moniliforme</i>	Fungus
Gibberella stalk and ear rot	<i>Gibberella zeae</i>	Fungus
Gray leaf spot	<i>Cercospora zeae-maydis</i>	Fungus
Northern corn leaf blight	<i>Exserohilum turcicum</i>	Fungus
Pythium seed and seedling blight	<i>Pythium</i> spp.	Fungus
Southern leaf blight	<i>Bipolaris maydis</i>	Fungus
Southern rust	<i>Puccinia polysora</i>	Fungus
Stenocarpella (Diplodia) stalk and ear rot	<i>Stenocarpella maydis</i>	Fungus
Virus complex	<i>Maize chlorotic dwarf virus</i> <i>Maize dwarf mosaic virus</i>	Viruses

COMMON NAME	SCIENTIFIC NAME	TYPE OF PATHOGEN
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SOYBEAN		
Anthracnose	<i>Colletotrichum dermatum</i> var. <i>truncata</i>	Fungus
Bacterial blight	<i>Pseudomonas glycinea</i>	
Bean pod mottle	<i>Bean pod mottle virus</i>	Bacterium
Brown spot	<i>Septoria glycines</i>	Virus
Cercospora leaf blight (purple seed stain)	<i>Cercospora kikuchii</i>	Fungus
Charcoal rot	<i>Macrophomina phaseolina</i>	Fungus
Downy mildew	<i>Peronospora manshurica</i>	Fungus
Phytophthora root and stem rot	<i>Phytophthora sojae</i>	Fungus
Pod and stem blight	<i>Diaporthe phaseolorum</i> var. <i>sojae</i> (<i>Phomopsis</i> spp.)	Fungus
Rhizoctonia stem rot	<i>Rhizoctonia solani</i>	
Seed and seedling blights	Various	Fungus
Soybean cyst nematode	<i>Heterodera glycines</i>	Fungi
Soybean mosaic	<i>Soybean mosaic virus</i>	Nematode
Stem canker	<i>Diaporthe phaseolorum</i> var. <i>caulivora</i>	Virus
Sudden death syndrome	<i>Fusarium solani</i> f.sp. <i>glycines</i>	Fungus
		Fungus
TOBACCO		
Alfalfa mosaic	<i>Alfalfa mosaic virus</i>	Virus
Anthracnose	<i>Colletotrichum gloesporioides</i>	Fungus
Bacterial (angular) leaf spot	<i>Pseudomonas syringae</i> p.v. <i>angulata</i> and <i>P.syringae</i> p.v. <i>tabaci</i>	Bacteria
Black leg/hollow stalk	<i>Erwinia carotovora</i>	Bacterium
Black root rot	<i>Thielaviopsis basicola</i>	Fungus
Black shank (Phytophthora root rot)	<i>Phytophthora parasitica</i> var. <i>nicotiana</i> <i>Peronospora tabacina</i>	Fungus
Blue mold (downy mildew)	<i>Botrytis</i> spp.	Fungus
Botrytis blight	<i>Orobanche ramosa</i>	Fungi
Broomrape	<i>Pratylenchus</i> spp.	Parasitic higher plant
Brown root rot (lesion nematode)	<i>Alternaria alternata</i>	Nematodes
Brown spot	<i>Sclerotinia sclerotiorum</i>	Fungus
Collar rot	<i>Cuscuta pentagonia</i>	Fungus
Dodder	<i>Cercospora apii</i> f.sp. <i>nicotianae</i>	Parasitic higher plant
Frogeye leaf spot	<i>Fusarium oxysporum</i> f.sp. <i>nicotianae</i>	Fungus
Fusarium wilt	<i>Tobacco vein mottling virus</i>	Fungus
Poty-virus complex	<i>Tobacco etch virus</i> <i>Potato virus Y</i> <i>Meloidogyne</i> spp.	Viruses
Root knot nematodes	Various	Nematodes
Root rot complex	Various	Bacteria and fungi
Seedling root and stem rots	<i>Rhizoctonia solani</i>	Bacteria and fungi
Soreshin	<i>Sclerotium rolfsii</i>	Fungus
Southern stem blight	<i>Thanatephorus cucumeris</i>	Fungus
Target spot	<i>Tobacco ring spot virus</i>	Fungus
Tobacco ring spot	<i>Tobacco streak virus</i>	Virus
Tobacco streak	<i>Glomus</i> spp.	Virus
Tobacco stunt	<i>Tomato spotted wilt virus</i>	Fungi

Tomato spotted wilt		Virus
COMMON NAME	SCIENTIFIC NAME	TYPE OF PATHOGEN
WHEAT		
Barley yellow dwarf	<i>Barley yellow dwarf virus</i>	Virus
Black chaff (bacterial streak)	<i>Xanthomonas campestris</i> p.v. <i>translucens</i>	Bacterium
Head scab (head blight)	<i>Fusarium graminearum</i> (<i>Gibberella</i> <i>zeae</i>)	Fungus
Leaf rust	<i>Puccinia recondita</i> f.sp. <i>tritici</i>	Fungus
Loose smut	<i>Ustilago tritici</i>	Fungus
Powdery mildew	<i>Erysiphe graminis</i> f.sp. <i>tritici</i>	Fungus
Seed and seedling blights	<i>Fusarium</i> spp. and <i>Pythium</i> spp.	Fungi
Septoria tritici leaf blotch	<i>Septoria tritici</i>	Fungus
Soil-borne wheat mosaic	<i>Soil-borne wheat mosaic virus</i>	Virus
Stagonospora nodorum leaf and glume blotch	<i>Stagonospora nodorum</i>	Fungus
Take-all	<i>Gaeumannomyces graminis</i> var. <i>tritici</i>	Fungus
Tan spot	<i>Pyrenophora tritici-repentis</i>	Fungus
Wheat spindle streak mosaic	<i>Wheat spindle streak mosaic virus</i>	Virus