VI. Remedial Management Tactics

A. Arthropod management and insecticides

Most insecticides used to control arthropod pests in a soybean IPM program should be applied after careful assessment of the level of pest infestation and estimation of the injury, if the pest is a foliage-feeding species (Table 3). Scouting provides the information needed to arrive at decisions about treatment application, product selection, and timing. Organosynthetic insecticides generally have provided an effective and economical means of suppression of soybean arthropod pests. Applications of pesticides by aircraft or tractor-mounted sprayers are recommended only to control pest infestations that are likely to reach the EIL. Applying insecticides only when necessary and at recommended minimum effective rates provides adequate control, and generally is not detrimental to natural enemies.

Chemical control remains the only consistently effective tactic for the remedial control of mid- or late-season outbreaks of arthropod pests. Advances in the new-generation pyrethroid insecticides, insect growth regulators, and genetically altered bacteria *(Bacillus thuringiensis)* generally have increased the efficacy on most target pests.

Soybean IPM programs throughout the United States promote the integration of chemical control with other tactics and production practices to lessen the dependence on insecticides. This integrated approach has reduced insecticide usage, resulting in less environmental contamination and prolonging the effective life of these pesticides by retarding development of resistant populations (Todd *et al.* 1994).

Insecticide resistance, however, has been reported for soybean looper, *Pseudoplusia includens* (Plates 38, 39), populations in certain areas of the Southeastern United States. This pest has become tolerant of methomyl and newer pyrethroid insecticides. Resistance levels are reportedly higher in areas where soybean is grown near cotton fields. More costly alternative insecticides and insecticide combinations now are necessary to achieve acceptable soybean looper control. No other major soybean arthropod pest has shown signs of resistance. Insecticide use on soybean has remained, in general, low relative to other row crops, thus reducing the potential for resistance development.

When an insecticide is needed, selective compounds should be chosen, as they are more compatible with biological controls. One method of increasing selectivity of certain organo-synthetic insecticides has been to reduce dosages to the minimum effective rates for the target species. High levels of selectivity are achieved with the use of microbial insecticides, many of which are available as commercial formulations (Table 18).

The effect of pesticides on natural enemies of arthropod pests has been rated according to the potential impact each has on survival and reproduction of those natural enemies (Table 13).

B. Weed control

The integrated management of weeds combines cultural, mechanical, and chemical control methods.

1. Cultural methods

Cultural control makes the crop more competitive with the weed. Crop rotation, good soil fertility, and using vigorous, adapted crop seeds increase the competitive ability of soybean. Narrow rows help soybean compete with weeds. Mechanical weed control is difficult in narrow row soybean fields.

2. Preplant and preemergence herbicides

Soybean herbicides may be applied as a preplant application to the soil surface or incorporated into the soil. A preemergence herbicide can be applied as seeds are being planted or immediately after planting. A postemergence application is best applied when weeds are young and most susceptible to herbicides.
a. Early preplant herbicides not incorporated Early preplant application of herbicides is used in no-tillage soybean fields to minimize existing vegetation and to reduce the need for a "knockdown" herbicide. Most broadleaf herbicides used in early preplant application have both foliar and soil activity, so they may control small annual weeds, especially if a nonionic surfactant (NIS) or crop oil concentrate (COC) is added to the spray mix. However, if weeds are more than one to two inches tall, paraquat (a restricted—use herbicide in the U.S.), glyphosate, sulfosate or 2,4-D should be added to the spray mix within label guidelines, b. Soil-applied "grass" herbicides Trifluralin, ethalfluralin, and clomazone are soil-applied "grass" herbicides that require mechanical incorporation, whereas metolachlor, dimethenamid, alachlor, and pendimethalin can be

used preplant-incorporated or preemergence, clo-mazone is used only for PPI unless microencapulat-ed. Incorporation improves herbicide performance if rainfall is limited.

c. Soil-applied "broadleaf herbicides Flumetsulam + metolachlor, flumetsulan + triflu-ralin, metribuzin + chlorimuron, clomazone, linu-son, imazethapyr, imazaquin, and metribuzin are soil-applied herbicides used for broadleaf weed control in soybean. Linuron should not be incorporated, and clomazone should be incorporated unless applied early preplant or the 3ME formulation is used. The others can be used preplant-incorporated or preemergence after planting soybeans.

Timely rainfall or incorporation is needed for uniform herbicide placement in the soil. Incorporation may improve control of deep—germinating, large—seeded weeds, especially when soil moisture is limited. Accurate and uniform application and incorporation are essential to minimize potential soybean injury. Except for clomazone, these herbicides are photosynthetic or meristematic inhibitors (Tables 16 & 17).

3. Postemergence herbicides

Postemergence (foliar) herbicides are more effective when used in a planned program, so that application is timely and not just an emergency or rescue treatment. Foliar treatments allow the user to identify the problem weed species and choose the most effective herbicide.

Rates and timing for foliar treatments are based on weed size. Early application, when weeds are young, may allow the use of lower herbicide rates. Treatment of oversized weeds may suppress growth only temporarily, allowing regrowth. Cultivation 7 to 14 days after application but before regrowth can often improve weed control. However, cultivation during or within 7 days of a foliar application may cause erratic weed control.

Crop oil concentrate (COC) or nonionic surfactant (NIS) is usually added to the spray mix to improve postemergence effectiveness. The base for a COC can be either petroleum or vegetable oil. Dash ® HC is a special adjuvant for use with sethoxydim. Fertilizer adjuvants, such as 28-0-0 (urea-ammonium nitrate) or ammonium sulfate, may be specified on the label to increase control of certain weed species, such as velvetleaf. Rainfall soon after application can cause poor weed control. Warm temperatures and high relative humidity greatly increase foliar herbicide activity. Weeds growing under drouthy conditions are more difficult to control.

Postemergence herbicides for soybean are either translocated (systemic) or contact in action (Tables 16 & 17). Translocated herbicides do not require complete spray coverage because they move to growing points (meristems) after foliar penetration. Their action is slow, and symptoms may not appear for a week after applications.

4. Weed resistance to herbicides

One of the disadvantages of chemical weed control is weeds can become resistant to herbicides. There are triazine-resistant pigweed, lambsquar-ters, and kochia, as well as acetolactate synthase (ALS)-resistant waterhemp and cocklebur. The imidazolinone, sulfonylurea, and sulfonamide herbicides all have the same mode of action, they inhibit the ALS enzyme. These herbicides have become quite popular because they have good environmental and economic profiles.

Certain management strategies will help deter the development of herbicide-resistant weeds: a. Scout fields regularly to identify resistant weeds. Monitor changes in weed populations to restrict the spread of herbicide—resistant weeds, b. Rotate herbicides with different modes of action. Do not make more than two consecutive applications of herbicides (whether within the same year or between years) with the same mode of action against the same weed. Instead, include other effective management strategies for weed control. This is critical when using herbicide-resistant crops.

c. Use multiple modes of action (tank-mix, premix, or sequential) that will effectively control potentially resistant weeds.
d. Where practical, use rotary hoeing and cultivation to control weed escapes. If necessary, use hand weeding to minimize the spread of herbicide—resistant weeds.
e. Be aware that resistant weeds can spread from total vegetation control programs used along highway, railroad, or utility right-of-way areas near farms.

5. Conservation tillage and weed control

Conservation tillage allows crop production while reducing soil erosion. Minimum or reduced tillage refers to any tillage system that leaves crop residue on the soil surface. This includes primary tillage with chisel plows or disks and the use of field cultivators, disks, or combination tools for secondary tillage. Mulch tillage is reduced tillage that leaves at least 30% of the soil surface covered with plant residue.

Ridge tillage and zero tillage are conservation tillage systems with no major tillage prior to planting. In ridge tillage, conditions often are ideal for banding preemergence herbicides because cultivation is a part of the system. "No-till" is actually "slot-tillage" for planting with no overall primary tillage. No-tillage planting conserves moisture, soil, and fuel. It also allows timely planting of soybeans or sorghum after winter wheat harvest (double cropping).

If tillage before planting is eliminated, undesirable existing vegetation must be controlled with herbicides either before, at, or after planting. The elimination or reduction of preplant tillage and row cultivation puts a greater reliance on chemical weed control. Greater emphasis may be placed on preplant or postplant soil-applied herbicides that are not incorporated or on foliar-applied herbicides.

Where primary tillage is minimized, soil residual herbicides applied several weeks before planting may reduce the need for a "knockdown" herbicide. However, early preplant application may require additional preemergence or postemergence herbicides or cultivation for satisfactory weed control after planting.

Soybean stubble often is ideal for minimum-tillage production systems. Primary tillage is rarely needed, and the crop residue should not interfere with herbicide distribution. Early preplant application of preemergence herbicides or the use of postemergence herbicides often can provide adequate weed control.

Table 18. Organisms used as microbial insecticides potentially useful in soybean IPM[1]

Pathogen	Host range	Uses/comments
Bacteria		
Bacillus thuringiensis var. kurstaki	Larvae of butterflies and moths Deactivated by direct sunlight, or on overcast days	Active by ingestion against foliage-feeding caterpillars. Better applied in the evening
Bacillus thuringiensis var. tenebrionis	Beetles, adults and larvae	Active by ingestion against larvae and adult beetles
Fungi		High moisture requirements
Beauveria bassiana	Soil-dwelling arthropods	
Metarhizium anisopliae	Foliage-feeding arthropods	
Nomuraea rileyi	Moth larvae	
Protozoa		Active if ingested. Recommended for treatment in large areas. Slow acting
Nosema locustae	Grasshoppers	
Viruses		Highly specific
Helicoverpa NPV	Helicoverpa larvae	Highly specific
Baculovirus anticarsia	Anticarsia gemmatalis larvae	
Entomogenous nematodes		Requires high moisture to be effective
Steinernema spp.	Larvae of soil-dwelling arthropods	
Heterorhabditis heliothidis	Larvae of soil-swelling and stem-boring arthropods	

[1] After: Falcon, 1985, and Weinzierl & Henn, 1989