II. Principles of Integrated Pest Management

Integrated pest management (1PM) is a concept applied originally to arthropod management. The concept has evolved to include production practices that involve management strategies for the control of crop pathogens and weeds, in addition to arthropods.

The optimal combination of the 1PM tactics best suited for a given production system form the 1PM strategy of choice for that system. The strategy should include all stages of the production system: cultivar selection, soil sampling, use of superior quality seeds, soil preparation, nutrient management, planting dates, row spacing, seeding rates, water management, scouting, monitoring and the use of pesticides that will keep all pests (pathogens, arthropod pests, and weeds) below an economic injury level. When 1PM is incorporated within the entire agroecosystem of a region, it reaches the highest levels of integration, and growers then should reap the maximum benefit from its adoption (Kogan, 1988).

To produce a soybean crop that yields economically anywhere in the world, farmers must control pathogens, arthropod pests, and weeds. Most soy bean pathogens have been managed by planting resistant or tolerant cultivars, crop rotation, and the use of pathogen-free seeds, but fungicides as a seed treatment or foliar application and the use of nematicides can be part of the plant pathologists' arsenal against soybean pathogens. Arthropod pest control in the 1940's and 1950's relied heavily on organosynthetic insecticides and, when these materials were too expensive, farmers accepted their losses. For weed management in large farming operations, there has been nearly total reliance on pre-and postemergence herbicides, although cultural methods, such as crop rotation and tillage, are part of a comprehensive weed management pro gram. Hand-weeding still is a common practice by small farm operators. Current soybean production in many parts of the world has adopted 1PM principles to avoid or reduce pest-induced crop losses, but pesticides remain the foundation for most pest management programs.

Concerns about farm worker safety, environmental contamination, and problems with pest resistance and outbreaks of secondary pests, which result from reliance on pesticides, have contributed to the acceptance of 1PM as the approach of choice in crop protection. 1PM is based on the active participation of the grower in the decisions leading the selection and on use of pest management practices that maintain pest impacts below economic levels and have the least detrimental effects on the environment and society. A diagram showing the components of a basic 1PM program is presented (Fig. 2).

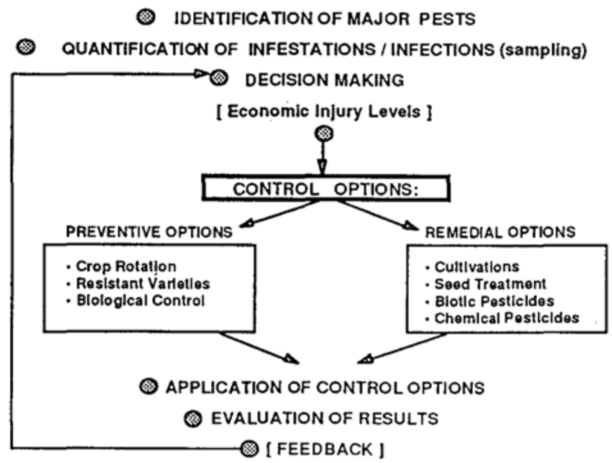


Figure 2. Components of a basic integrated pest management program (1PM) program for an annual field crop (Developed by M. Kogan).

A. Pest identification

The first step in an 1PM program is the correct identification of the pest or pests that are observed in greatest abundance or cause the most observed symptoms. Pest identification is essential because its name provides a key to all the information about its biology; its potential economic impact, and the recommended management methods. This manual contains a pictorial description of many important soybean pests but is not a complete catalog. Species with a similar appearance or which cause similar symptoms may be difficult to distinguish and may require quite different control methods. In general, soybean growers should request the assistance of qualified personnel for pest identification. To obtain such assistance, it is important to collect pest samples or plant parts that show signs or symptoms and that preserve the color and shape of the specimen.

1. Diseases

For practical 1PM purposes, soybean disease identification relies mainly on signs and symptoms. Sometimes these symptoms help to determine the probable cause of the disease. Symptoms may appear anywhere on or in the plant. Soybean growers need to recognize the symptoms before contacting extension personnel or specialists. The grower should make sure that symptomatic plant parts are not due to poor agronomic practices, lack or excess of moisture, mineral deficiencies or toxicities, or injury resulting from vertebrate (e.g. birds, moles, rats, etc.), or arthropod (e.g., insects and mites) pests.

To find the cause of a disease, first read available soybean disease publications such as this one or use a personal computer with a diagnostic program (Michalski et al., 1983). If in doubt, contact local extension personnel or a crop consultant. If these people are unable to help, send the specimen to a specialist for diagnosis and control recommendations, remembering that most soybean diseases should be prevented rather than mitigated after the damage has been done. Most current—year disease monitoring is therefore, directed at identifying the most important soybean diseases in the region and following preventative measures as directed by soy bean pathologists.

A specimen should arrive in good condition in order for the specialist to make an accurate identification. The entire plant, with the roots, stems, and leaves, should be included. A plant should be select ed that is still alive and shows typical symptoms of all other similarly abnormal plants. If the plants are small, several samples showing different stages of the disease may be included. Plant materials of this kind are best shipped in sealed plastic freezer bags or other moisture proof containers. Do not add water. These bags then are placed into a box, mail ing tube, or other sturdy container. The roots should be wrapped separately in paper or a bag to prevent the soil from getting on other parts of the plant. Large specimens can be cut into sections and placed in plastic bags.

Occasionally, cultures and specimens of bacteria and/or fungi need to be sent elsewhere for identification or kept for reference. Keep the following in mind:

a. The specimen should provide sufficient material (e.g., leaves, stems, roots) for proper examination.
b. Substrates with delicate fungal structures should be secured within a suitable container before mailing.
c. Always keep a representative portion of all collections sent for identification.
d. Fungi should be in a good state of sporulation.
e. Dry specimens should be sent as if they were herbarium specimens of flowering plants, i.e., press plant material flat while drying and wash stems and roots free of soil and remove excess moisture.
f. Reference fungal cultures should be grown on any suitable agar substrate (e.g., potato-dextrose agar, cornmeal agar, etc.) in either plastic culture plates or small test tubes (l00xl5mm). The cultures must arrive unbroken, free from mites, and not overgrown with contaminants.
g. Dried specimens should be placed in ungummed, good-quality paper envelopes (about 15x10 cm). Larger portions of partially dried stem or roots should be wrapped separately in newspaper. Place fresh leaf material showing virus symptoms between cotton-wool pads in a plastic envelope left open at one end for aeration. Then place the material in a wooden or strong cardboard box.
h. Before mailing specimens or cultures, each container should be adequately labeled with an adhesive label or waterproof ink. Wrap each separately and pack with cotton-wool or poly styrene granules within a wooden, metal, or strong cardboard box. The wrapped parcel, if it contains a plant-pathogenic organism, will need a special customs declaration and should have an international "Perishable Biological Substance" label. Strict international rules govern the mailing of pathogenic material. If in doubt, consult a copy of the International Postal Regulations and contact appropriate state and/or federal plant quarantine officials well in advance of mailing.
i. Bacterial cultures and specimens are handled much like fungi, except infected material should be sent by air mail as soon after collection as pos sible. Grow cultures on a storage agar medium containing 2% precipitated calcium carbonate in suspension that will maintain an acceptable pH so the bacteria will remain in good condition.

2. Arthropods

Insects and mites should be collected without squashing them or losing body parts. Always carry a plastic tube when surveying fields (an empty photographic film tube will do). A lOX hand lens also is helpful. Soft-bodied insects, such as aphids and caterpillars, are best preserved in vials containing 70% alcohol. Hard-bodied insects, such as beetles, true bugs (Hemiptera), and grasshoppers, can be kept in a box between layers of tissue paper.

Most specialists require mounted specimens for proper identification. Various methods are used depending on size, color fastness, body rigidity, and sturdiness of body appendages. A description of these techniques is found in the book "How to Know the Insects" (Jaques, 1947).

3. Weeds

Most taxonomic guides are based on floral characteristics, but seedling weed identification is based on vegetative characteristics. Dicot seedling identification is based on cotyledon shape plus leaf characteristics, such as arrangement (alternate, opposite or whorled), leaf margin, and leaf shape. Grass seedling identification is based on type of ligule (hairy or membranous) and auricles, plus leaf and sheath characteristics.

Mature weed specimens submitted for identification should be carefully arranged in a flat position and pressed between heavy paper or cardboard. If available, include flowers, fruits, and seeds. Submit grass or broadleaf seedlings as fresh samples. Wrap the roots and soil (not the foliage) in a moist paper towel. Tie a plastic bag around the base of the sample, then wrap the entire sample in a dry newspaper or paper towels. Place in a crush—proof container marked “Plant Sample—Perishable”. Keep samples refrigerated until mailed. Mail samples “First Class” and try to avoid a weekend layover in the post office.

Once the pathogen, arthropod, or weed is identified the next step is to gather as much information as possible about it. This manual provides general information about groups of pests that cause similar damage to soybean and are managed similarly. References to more detailed publications and sources of information to complete and expand what is provided here are listed in the References section.

B. Principles of sampling

Surveillance of pests in soybean fields allows the detection of early symptoms of diseases and the status of insect and weed populations. Monitoring and surveillance are a fundamental part of any 1PM program because treatment decisions and planning are based on current and historical records of pest incidence and severity of pest problems. Each type of pest requires specific sampling methods, but in general, growers should scout their fields regularly to observe disease symptoms, arthropod activity, or weeds that have escaped herbicides or mechanical weeding. Decisions for the appropriate and timely management of major pests may require a more systematic sampling approach.

1. Disease and nematode monitoring

In order to monitor disease symptoms on soy beans, a grower should carry out the following:

a. Determine the distribution of the disease in the area and if diseased areas are spotty or have a general distribution in the field.

b. Record the number or area of diseased plants involved.

c. Examine an entire plant carefully. Dig up a typically diseased plant with a shovel or spade. Examine the roots for abnormal growth or decay. Look at the foliage. Notice the size, shape, color, and general appearance of leaf spots or other patterns. Study the stems for cankers or lesions. Determine their size, shape, color, and texture.

For the correct diagnosis of plant parasitic nematodes, it is necessary to use a laboratory analysis of root and soil tissue. For best results, samples should be taken with a special soil sample tube, trowel, or a narrow—blade shovel. Samples should be taken at 5 to 30 cm depth and contain as many roots as possible. Each sample to be analyzed consists of 0.5 to 1.0 liter of soil taken from a larger sample composed of 10 or more subsamples (soil cores or borings). The subsamples are mixed in a clean pail or plastic bag. The number of subsamples needed depends on the size of the area in the field:

- Small area (<0.1 hectare) = at least 10 subsamples
- Medium area (0.1 to 0.5 hectare) = at least 25 subsamples
- Large area (0.5 to 2.0 hectare) = at least 50 subsamples

No sample should represent more than 2 ha, and samples should be from an area of uniform soil type, tillage systems, previous crop, or other factors that affect nematode populations.

Nematodes will be killed if the subsamples are allowed to heat or dry. It is important that the nematodes be alive when they arrive in the laboratory for analysis. Therefore, processing should follow sample collection very closely. If delays are necessary samples should be stored at 100 to 15°C.

2. Arthropod monitoring

Because there is such a diversity of arthropod pests in soybean fields, it is difficult to recommend a sampling procedure that is equally effective for all species. Arthropod pests are very mobile and invade soybean fields at different stages in the crop’s growth cycle. Depending on the region, soy bean fields should be visited at least once after emergence to determine possible problems with early season arthropod pests, such as cutworm, bean flies, or seed flies. During the season, fields should be scouted two or three times, and more often if infestations are detected. Soybean is most vulnerable to foliage feeding arthropods during the period after pod-set to pod-fill (growth stages R3 to R5). Foliage feeding arthropods should be sampled carefully during this period. Finally, pod and seed attacking arthropods should be monitored between growth stages R5 to R7.

Various methods are recommended for sampling insect populations. Up to the four-leaf stage (V4), visual observation is the most reliable method. The method consists of measuring a 1 meter length of row and then carefully examining leaflets and stems for damage or presence of arthropods. After plants are more than 30 cm tall, the most versatile sampling method is based on the use of a ground cloth (Figs. 3 and 4). To sample with a ground cloth, the surveyor should randomly select a spot in the field and carefully approach the spot to avoid disturbing the arthropods. At the spot, the surveyor can kneel down and unroll the ground cloth between two adjacent rows, until the rods touch the base of the plants. With both hands stretched out, the surveyor should vigorously shake the plants along the length of the cloth. The arthropods that fall onto the cloth then can be identified and counted.

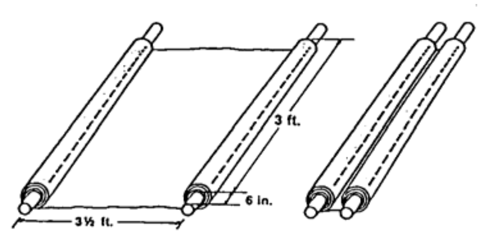


Figure 3. Ground cloth construction. Use two, 1.25 m lengths of 2.5 cm dowel and a piece of white canvas 10 m by at least 1.5 m. Roll the narrower side of the canvas once around each stick and fasten with heavy- duty staples. Leave 15 cm handles at both ends of the sticks (From Kogan & Kuhlman, 1982).

Figure 4. Sampling procedure. (A) Keep the cloth rolled up while slowly approaching the sampling site. Walk along the row space next to the chosen site to avoid disturbing the arthropods. (B) Carefully move up to face the site. Place the cloth, still rolled, between the two rows. Quickly unroll the cloth and hold the rods in place with your knees. (C) Shake the plants from each row over the cloth. Release the plants and quickly look for caterpillars or beetles clinging to fallen leaves (From Kogan & Kuhlman, 1982)

The ground cloth cannot be used efficiently if the rows are too narrow or if plants are badly lodged. For narrow rows, the sweep net method is best (Figs. 5 and 6). Sampling with a sweep net requires training and should be done in a consistent way so the information obtained is readily comparable. The sweep net is swung back and forth, keeping the upper border of the hoop at the top of the plant canopy. Each swing of the net counts as one sweep, and a sample usually consists of 20 sweeps.

The optimal number of samples for 1PM decisions varies with the arthropod and location, but, as a rule, at least five samples should be taken per field. Thus, it is recommended five sets of 1 meter lengths of row for direct observations, five beat samples for the beat cloth; and five sets of 20 sweeps each for the sweep net. Depending on the shape of the field, the five samples should be taken following an M—shaped pattern, if the field is rectangular or square; or an elliptical pattern, if the field is narrow and elongated (Fig. 7). These same sampling pat terns also may apply to pathogens and weeds.

3. Weed monitoring

Weeds are less transitory than pathogens or arthropods and usually do not multiply as rapidly within the same season. There is also a critical period when soybean is most sensitive to weed com petition, so scouting for weeds should be concentrated during stand establishment. Factors, such as moisture, temperature, and type and time of seedbed preparation, will affect weed seed germination and renewed growth from perennials and thus, determine which weeds will be predominant during the season. In general, if a weed species was pre sent one year, it is almost certain that the same species will be present in the same field the following year, if crops with similar characteristics are grown using similar cropping practices. Weed surveys and the drawing of weed—occurrence maps from one season may help predict the likely weed problems in the next. Mapping weed infestations can be helpful. Some global positioning systems (GPS) allow weed infestations to be noted on base maps during harvest, which provides a record of

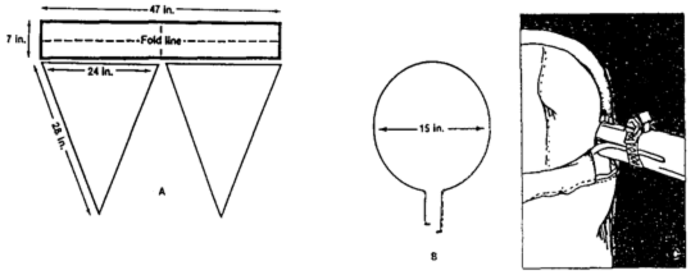


Figure 5. Sweep net construction. Use white canvas or muslin cloth for the net and number 6- to 8-gauge wire for the hoop; and a light weight but strong wood handle. (A) For making the net, sew two triangles of the cloth together by the sides, then fold and sew a bond of cloth around the top of the net. A gap of about 5.0 cm should be left between the ends for inserting the hoop (C). Allow about 1 .5 to 2.0 cm for all of the seams. Form a hoop from the wire as shown (B), making one stem shorter that the other. On opposite sides of the handle, make grooves for the stems (C). Thread the hoop through the band of the net, press the stems of the hoop into the grooves on the handle and fasten securely with a hose clamp (From Kogan & Kuhlman, 1982).

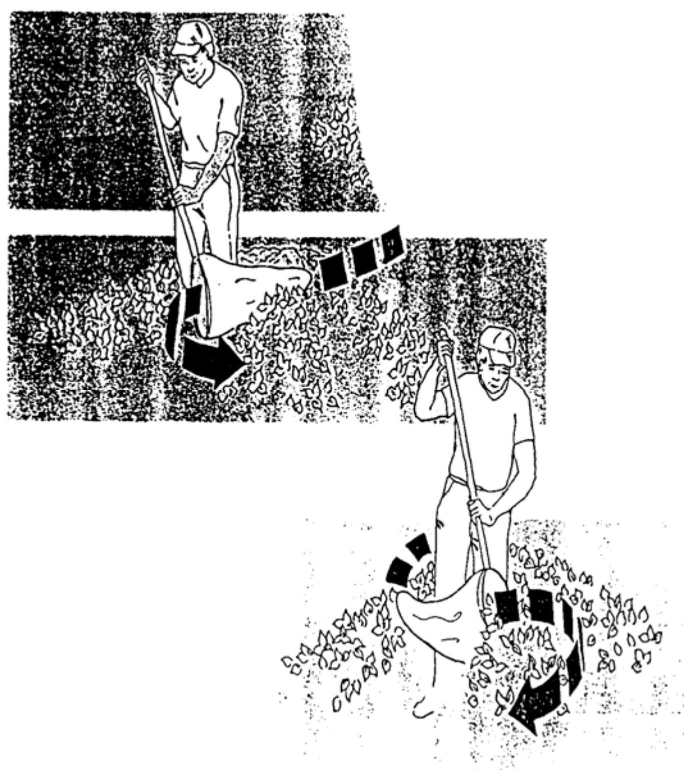


Figure 6. Using a sweep net. While walking along a row, swing the net from side to side with a pendulum-like motion, the first sweep in the row and the second between plants (From Kogan & Kuhlman, 1982).

infested areas for the next season. Although detailed weed mapping may not be possible, it is recommended that weeds be observed in connection with scouting for diseases or arthropods or observed during other operations, such as cultivation and harvest. Records should be kept of areas in a field with a greater incidence of weeds. The methods for quantifying weeds need not be complicated. In general, it is enough to use some type of subjective evaluation model with a three- or four-division scale, such as “scattered”, “light”, “moderate”, and “severe”. For a more precise assessment, the number of weeds per unit area may be recorded.

Weed monitoring for foliar-applied herbicide use is based on identifying and quantifying weeds during the early stages of soybean growth. Postemergence herbicides generally should be applied about two to four weeks after planting, so monitoring should be scheduled to provide timely information. The areas should be scouted again about two weeks after application to verify control and determine the need for further treatment.

C. Decision making

A successful program for the control of pathogens, arthropods, and weeds must take into account the economic realities of the producer, that person’s acquired experiences and preconceptions, and the societal characteristics in which the person operates. The attitude of the producer/farmer to soybean pests and their management generally is determined by: (i) control measures that prevent

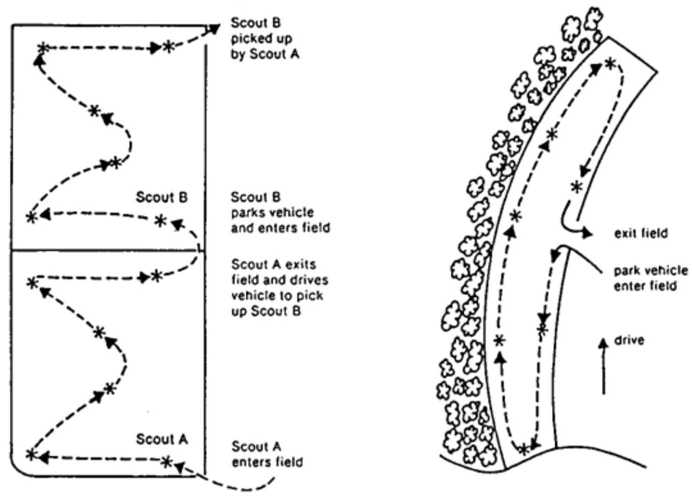


Figure 7. Depending on the shape of a field, arthropod sampling with a sweep net may be taken in a M—shaped or elliptical pattern (From Kogan & Kuhlman, 1982).

damage at the lowest possible cost; (ii) actions that produce the desirable immediate effect, with long—term detrimental effects being of lesser concern; and (iii) willingness to absorb a reasonable cost by preventively applying a pesticide rather than risk losing some yield to pests.

It is necessary to consider all possible interactions and consequences of any control measure. Crop protection specialists, therefore, must develop a system that maximizes the chance for economic management of pests with minimum risk to the farmer. It is also the responsibility of the researcher to investigate any undesirable as well as desirable effects of management measures since these may later translate into economic losses. It is essential to understand that any pest control pro gram will be successful only if results provide an economic advantage for the producer and society.

The following are some operational definitions for the concepts commonly used in 1PM decision making:

1. Economic injury level (EIL)

The EIL is one at which a pest population is capable of producing an amount of damage that, if prevented, could offset the cost of treatment necessary to suppress the population, i.e., that point at which the cost of the management action equals the benefits resulting from that effort. The establishment of EILs is a preliminary and essential phase in the development of any 1PM program. EILs pro vide an objective criterion for decisions as whether or not to apply a control measure for reducing the risk of crop loss from a pest problem. EILs express the relationship between the value of the portion of the yield expected to be saved from pest attack and the cost of the treatment applied to prevent a yield loss due to the attack. For example, if it costs $30 per hectare to apply a pesticide, the value of the crop threatened by the target pest must be worth at least $30 to justify the treatment cost.

2. Economic threshold (ET)

The ET is a level, just below the EIL, at which one should apply a pesticide to keep an increasing pest population from reaching the EIL. ET is the practical measure that provides a safety margin for delayed kill by a pesticide or a lag between the time the field is scouted and management procedures are undertaken.

3. Pest status

The relationship between the amount of crop loss to the cost of preventing this loss largely determines the status of an arthropod species, a weed, or plant pathogen. Pests thus fall into three categories. (i) Key or major pests are those that are persistent, occurring perennially and dominate management practices. In the absence of control, these pests cause severe economic losses (e.g., the soybean pod borer, Leguminivora glycinivorellae (Matsumura) in the Orient (Plates 50, 51); cocklebur (Xanthium strumarium L.)(Plates 128, 129), a serious weed in the Midwest USA; or the soybean cyst nematode (Heterodera glycines Ichinohe)(Plate 95) in many parts of the world). (ii) Occasional pests are those whose status fluctuates; populations usually are under adequate biological and environmental control, which may, however, be disrupted occasionally (e.g., the green cloverworm, Plant hypena scabra (F)(Plates 40, 41, 79); frogeye leaf spot (Cercospora sojina Hara), a fungal disease; and black nightshade (Solanum spp.) (Plates 123, 124), which varies with locality. (iii) Arthropod pests and seed pathogens that cause no significant damage under prevalent conditions, but whose populations might be stimulated by control procedures directed at controlling key or occasional pests (e.g., outbreaks of loopers, Plusiinae (Plates 38, 39), in certain areas of Brazil following treatment against the velvetbean caterpillar, Anticarsia gemmatalis Hubner)(Plates 36, 37); and a weed example is prickly lettuce (Lactuca serriola L.) that is a problem in no-tillage soybeans.

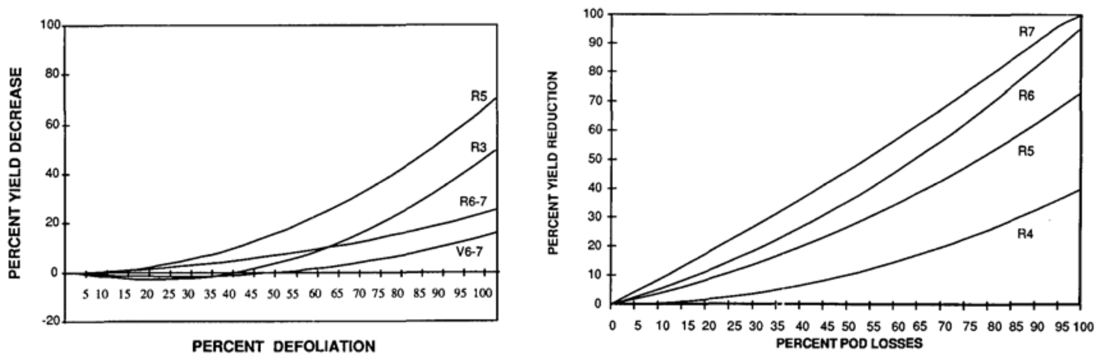


Figure 8. Economic injury levels for arthropods fluctuates with plant growth stage. 8A — Relationship between level of defoliation at various stages of plant growth and yield reduction. 8B — Relationship between pod losses (shedding, destruction or abortion) and expected yield reduction depending on growth stage of the crop (Based on Kogon & Turnipseed, 1980).

D. Economic injury levels (EILs)

1. EILs for diseases

Determining the EILs for soybean diseases is complicated because of the diversity of causal agents. Also a pathogen may be destructive one sea son and difficult or impossible to find the next. Many pathogens initiate an epidemic only under specific environmental conditions. The incidence and severity of any one soybean disease also depends on the degree of compatibility between the host and pathogen and on the influence of the environment on this association. The extent of yield loss depends on the pathogen or the conditions involved. One or more diseases generally can be found in fields wherever soybean is grown.

All soybean plant parts are susceptible to pathogens that reduce the quality and quantity of seed yield. In many diseases, a latent period lapses between infection and symptom expression (Sinclair, 1991b). Arthropods are vectors for some pathogens, and are necessary for transmission of many soybean viruses and mycoplasma-like agents. Feeding by arthropods and nematodes may predispose soybean to infection from root-infecting or wilt-inducing agents and seed-decay organisms by providing wounds for pathogen entry. Depending on the pathogen involved, disease incidence may or may not have a relationship to disease severity or yield loss. Disease severity usually is expressed as a proportion or percentage of a plant (or plant part) destroyed by the pathogen. Using methods similar to those of entomologists, the relationship between leaf area reduction by foliar pathogens and yield loss is used. Yield loss is measured at harvest or near harvest but can be studied throughout the season and expressed by measuring the area under a disease process curve.

Other methods used to determine EILs include the use of isogenic lines, fungicide spray treatments under controlled field conditions, field surveys quantified using mathematical models, aerial surveys by remote sensing, and comparing pathogen-infected and pathogen-free plants under controlled field conditions. Crop loss assessment caused by seedborne pathogens must be conducted only for a particular cultivar and under a well defined set of production conditions. Losses due to soilborne fungi that produce infectious propagules require a considerable amount of epidemiological data for any single pathogen.

2. EILs for arthropods

A useful method for practical determination of EILs for arthropod pests that feed on soybean leaves is based on a model that uses the known relationship between leaf area reduction and yield loss at key stages of crop development (Kogan, 1976; Ruesink, 1975). The information necessary to use this method includes: (i) the leaf area of soy bean plants at a given growth stage; (ii) the amount of leaf area damaged by an arthropod; (iii) the relationship between percent foliage loss and yield loss; (iv) the expected yield in the absence of injury; (v) the market value of soybean; and (vi) the cost of chemical treatment to mitigate the pest. The EIL fluctuates with plant growth stage because of the relationship between amount of foliage destroyed and yield reduction (Fig. 8A), or pod losses caused by arthropod pest feeding that results in pod shed ding or pod or seed abortion (Fig. 8B). EILs for some important defoliators and pod-feeding

Table 1. Economic injury levels (EILs) for selected foliage— and pod—feeding arthropods on soybean at growth stages R3 to R5. Values based on average recommendations for the major soybean growing regions of the USA, which may differ for different growing regions of the world.

Pest complex	Representative species	Economic injury level
Foliage-feeding arthropods at growth stages R3 to R5		
Lepidopterous	*Anticarsia gemmatalis*	20-25 larvae (>1.2cm)/row m + 15% defoliation
	Epinotia aporema	30% of growing tips attacked[1]
	Helicoverpa zea	8-10 larvae/m row
	Plathypena scabra	25-30 larvae (>1cm)/row m + 15% defoliation
	Pseudoplusia	20-25 larvae (>1.2cm)/row m + 15% defoliation
Coleopterous[2]	*Cerotoma spp.*	20 beetles/row m + 15% defoliation
	Epilachna varivestis	15-20 adults + larvae (<0.5 cm)/ row m + 15% defoliation
Pod feeding arthropods at growth stages R5 to R7		
Coleopterous	*Cerotoma spp.*	20-25 beetles/row m + 8-12% pod injury
Hemipterous	*Various species*[3]	2-3 large buds/row m
Lepidopterous	*Helicoverpa zea*	2-3 larvae (>1.5)/m row
	Tortricid & Pyralid spp.[4]	EILS not defined

1 EIL defined for conditions in southern Brazil.
2 Coleopterous species that could also follow these EILs are: Aulacophora sp. (Plate 4), Colaspis brunnea (Plate 5), Diabrotica spp. (Plate 6), and various species of Meloidae (Plates 15, 16).
3 Acrosternum hi/are (Plates 22, 23), and Nezara viridula (Plates 24, 25),
4 servus (Plate 28), and other Euschistus spp. (Plate 29).
4 Includes: Leguminivora g/ycinivore/la (Plates 50, 51), Matsumuraeses phaseo/i, and Etie//a zinckene/la.

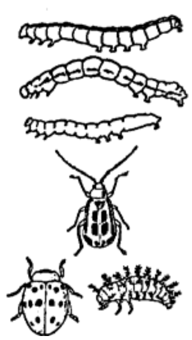
arthropods are summarized (Table 1). Large-scale use of ETs similar to those shown in Table 1 permitted an arthropod pest management program for soy bean in Brazil to reduce the number of insecticidal sprays during one growing season by 50 to 75% (Kogan et al., 1977; Oliveira et al., 1980).

3. EILs for weeds

As long as decisions to use preplant or preemergence herbicides are made preemptively, economic decisions must be based on the history of weed infestations and severity. With effective postemergence herbicides for soybean, a criterion similar to the EIL was proposed by weed scientists based on the "competitive index" (CI) of weeds (Coble, 1985). The CI considers that: (i) several weed species occur in a field at the same time; and (ii) different weed species compete differently with soybean, therefore the relationship of weed population to yield reduction is different for each species. The CI is derived from competition experiments.

The most prevalent weed is not necessarily the most competitive one. The determination of EILs for weeds depends on limiting resources such as

Table 2: Decision chart for control of defoliating pests of soybean after full—bloom and before seed maturation (R1 to R5).[1]

			Number of insects per foot of row[2]		
Insect		Velvetbean caterpillar, soybean looper or	<8	8 to 12	>12
		green cloverworm, or	<16	16 to 24	>24
		Bean leaf beetle or Mexican bean beetle	<12	12 to 18	>18
Defoliation (%)		0 to 20%	Sample at regular intervals (10 to 12 days)	Sample at closer intervals (3 to 5 days)	Spray (preventive): low probability of loss
		20 to 30%	Sample at closer intervals (3 to 5 days)	Spray (correct time)	Spray (overdue); probability of minor loss
		>30%	Sample at closer intervals; probability of loss but populations in decline	Spray (overdue) probability of loss	Spray (much overdue) probability of major loss

[1] To use this table, first sample the field to determine the pest population level and the percent defoliation. Then, match the insect population level and percent defoliation columns to arrive at the proper decision.
[2] If more than one species occur simultaneously, adjust the number of insects per foot of row in proportion to the relative population of each species.

light, moisture, or nutrients. The degree of injury increases if a weed grows over and shades the crop or if soil moisture is limiting. Competition studies indicate that differences year by year can be greater than 50%, with larger yield reductions in a dry year than a wet one.

Thresholds based on weed mixtures are needed since a single species is rarely the problem. Coble (1985) proposed a relative weed ranking or CI, with the most competitive weed, cocklebur, ranked as 10 and other species assigned a proportional CI. Weeds were identified and counted and the “competitive load” determined. Rather than use a CI, listing weeds by percent yield reduction per plant per unit area would make calculations simpler. The CI is a multiple of the percent yield reduction, i.e., cockle bur (Plates 128, 129) had a CI of 10, but each plant per ten steps (approximately 8 meters) of row decreases yield by 5%.

Factors affecting the ET are the yield goal, commodity price, cost of treatment and efficacy of the treatment, and yield potential. The action threshold is the weed population at which a grower decides to institute control. The action threshold is usually lower than the ET because of efforts to maximize yield rather than profit.

4. Practical use of EILs

EILs have been most useful for medium—size soy bean farms with 1 to 100 hectares (van Schoonoven & Kogan, 1983). Under these conditions, scouting can be efficiently and economically performed, and control decisions can be reached in a timely way. For example, a decision chart can be established based on scouting data for various soybean foliage-feeding anthropods in Illinois (Table 2). Such charts are being used in soybean 1PM programs in the Argentina, Brazil, and the U. S. (Kogan & Kuhlman, 1982).

For subsistence farmers or very large operations, the use of E for decision making may not be as applicable. Subsistence farmers seldom use chemicals in pest control and may resort to labor intensive procedures. Under large farming operations, the assessment of infected plants or infestations of arthropods and weeds over extensive areas often is impractical. Nonetheless, information on E is still fundamental for the development of 1PM programs for such production systems. Schoonoven and Kogan (1983) suggested that EIL information can be forwarded to pro grams breeding more tolerant cultivars adaptable to subsistence farming. For large operations, forecasting, modeling, and eventually remote sensing will lead to control strategies that take advantage of the most advanced technological achievements. Decisions still will be made on the basis of cost/benefit analyses using the E concept. Regardless of farming unit size, the EIL assessment by experimental means and dynamic simulation models is the heart of a sound IPM program.