are not compatible with soil texture, an improper depth of incorporation can bring a higher concentration in the upper layers of the soil or a high dilution of the product, which results in a loss of effectiveness. Another factor that can contribute to this is a poor soil preparation.

Basic studies are needed on the interaction between herbicides and soil in tropical conditions, and on the residual effects on soils, plants, animal and atmosphere.

PEST CONTROL

Soybeans in tropical conditions have serious entomological problems. There are about 28 native species of insects that attack soybeans. Leaf-feeding insects such as *Anticarsia gemmatalis* and *Plusia oo*, and pod-feeding insects such as *Nezara viridula*, *Piezodorus guildini* and *Euchistos heros* have a great economic importance in Brazil due to the damage that they induce.

Chemical pest control has been used, sometimes in excess. There is no worry about environment pollution and its consequences. An urgent need exists to decrease chemical control of pests in soybeans, and to fulfill this need, studies on breeding for pest resistance, insect population fluctuations, and residual effects are necessary.

OTHER PRACTICES

Proper harvest machinery and conditions have to be established to prevent harvest losses and mechanical seed injury. The application of Paraquat as a defoliant has produced some good results, in spite of the high amount of residues in the seeds (15).

REFERENCES

1. Leng, E.L., in "Nutritional Improvement of Food Legumes by Breeding," edited by M. Milner, PAG. UN, New York, NY, 1973, p. 101.
2. Lam-Sánchez, A., Archivos Latinoamericanos de Nutricion 27:77 (1977).
3. Mondardo, A., EMBRAPA Circular Técnica 2:7 (1979).
4. Rufino, R.L., A. Mondardo, G.S. de Farias, C. Castro Fº, M.J. Vieira, J.C. Henklain, B. Kemper and R. Derpsh, in "II Encontro nacional de pesquisa sobre conservação de solo," Passo Fundo, RGS, Abril 1978.
5. Hinson, K., and E.E. Hartwig, in "Soybean Production in the Tropics," FAO Plant Production and Protection Paper 4, 1977, p. 92.
6. Vedoato, R.A., N.G. Fernandes and A. Lam-Sánchez, in "Jornada Cientifica da Faculdade de Ciencias Medicas e Biologicas de Botucatu," Botucatu, SP., December 1973.
7. Lam-Sánchez, A., and K. Yuyama, Cientifica 7:225 (1979).
8. Lam-Sánchez, A., and J.E. Velloso, Ibid. 2:137 (1974).
9. Cordeiro, D.S., G.S. Sfredo, C.M. Borket, J.R. Sarruge, J.B. Palhano and R.J. Campos, EMBRAPA, Circular Técnica 2:19 (1979).
10. Gonzales-Erico, E., E.J. Kamprath, G.E. Naderman and W.V. Soares, Soil Sci. Soc. Am. J. 43:1155 (1979).
11. Ruschel, A.P., A.R. Suhet, R. Vianni and D.L. Almeida, in "XIV Congreso Brasileiro de Ciencia de Solo," Santa Maria, RS, 1974.
12. Guimaraes, J.A.P., C.S. Sediyama, T. Sediyama, R.F. Novais, J.M. Braga and S.S. Brandão, Experientae 21:101 (1976).
13. Maggione, C.S., and A. Lam-Sánchez, Cientifica 4:107 (1976).
14. Forster, R., and A. Alves, A. Granja, 326:1 (1975).
15. Durigan, J.C., and N.M. Carvalho, in "XIII Congresso Brasileiro de Herbicidas e Ervas Daninhas," Ilheus, BA, July 1980.

Soybean Pest Management

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ABSTRACT

The rapidly growing world population and rising cost of fossil fuel has caused the increase in importance of soybeans as a source of high protein food and quality vegetable oil. The area planted with soybeans is not likely to increase greatly because of geographic adaptation and environmental limitations. Any large increase in the quantity of soybeans, therefore, must come from increases in yield per unit area, that is, increased production efficiency. Part of this can be accomplished by improved pest management systems that use cultural, mechanical, biological, ecological, and chemical methods to reduce the 30% loss caused by insects, weeds, and diseases. Pest control strategies are discussed.

INTRODUCTION

A few introductory remarks should make it evident that soybean pest management is an essential part of soybean production. It took the people of the world from the beginning of time until 1830 to reach a population of one billion. In the last 150 years the population has doubled twice and it is expected to double again, from 4 to 8 billion, in the next 40-50 years. The amount of food produced in the world will have to double during this same period just to keep up with the world population. We barely produce enough food and fiber to feed and clothe the people of the world now. Poor distribution and economic inequalities have resulted in two-thirds of the people not having enough food, particularly food with adequate protein. As the world population rapidly increases, there is no way to feed the people without making all nations as self sufficient as possible. People who feel that it will be easy to feed our children and grandchildren do not understand the magnitude of the problem. One of the primary

TABLE I

Major Weeds Infesting Soybean Fields in the United States

Common name	Scientific name
Barnyardgrass	*Echinochoa crus-galli*
Bindweed, field	*Convolvulus arvensis*
Cocklebur, common	*Xanthium pensylvanicum*
Crabgrass	Digitaria spp.
Crotalaria	Crotalaria spp.
Foxtail, giant	*Setaria faberi*
Foxtail, green	*S. verdis*
Foxtail, yellow	*S. lutescens*
Goosegrass	*Elusine indica*
Jimsonweed	*Datura stramonium*
Johnsongrass	*Sorghum halepense*
Lambsquarters, common	*Cheopodium album*
Milkweed, common	*Asclepias syriaca*
Milkweed, honeyvine	*Ampelamus albidus*
Morningglory, annual	Ipomoea spp.
Morningglory, bigroot	*Ipomoea pandurata*
Mustard, wild	*Brassica kaber* var. *pinnatifida*
Nutsedge, purple	*Cyperus rotundus*
Nutsedge, yellow	*C. esculentus*
Panicum, Texas	*Panicum texanum*
Pigweed	Amaranthus spp.
Pusley, Florida	*Richardia scabra*
Quackgrass	*Agropyron repens*
Ragweed, common	*Ambrosia artemistifolia*
Ragweed, giant	*A. trifida*
Redvine	*Brunnichia cirrhose*
Sandbur	Cenchrus spp.
Sesbania, hemp	*Sesbania exaltata*
Shattercane	*Sorghum bicolor*
Sicklepod	*Cassia obtusifolia*
Sida, prickly	*Sida spinosa*
Signalgrass, broadleaf	*Brachiaria platyphylla*
Smartweed	Polygonum spp.
Thistle, Canada	*Cirsium arvense*
Trumpetcreeper	*Campsis radicans*
Velvetleaf	*Abutilon theophrasti*

purposes of this conference is to recognize this problem and to assess the role of soybeans in the solution of the problem as it relates to Central and South America.

As the cost of fossil fuel increases, soybeans become a more important source of protein and vegetable oil. One calorie of fossil fuel will grow 4 calories of corn, 3 1/2 calories of soybeans, and about 2 1/2 calories of grains such as barley, wheat, oats or rye. A calorie of fossil fuel will grow a little over a calorie's worth of potatoes, but it will not grow quite a calorie of beef. Vegetables produce about 1/4 calorie for each calorie of fuel. Eggs, lamb, chicken, turkey, milk and pork are not efficient in using fossil fuel. Thus, it would appear that soybeans have a decided advantage over other sources of protein, and farmers will grow more soybeans and fewer vegetables as fuel costs go up.

There is still some room for expansion of soybeans in Brazil, Argentina, Mexico and Australia. I do not anticipate any great increase in soybean production in other parts of the world, with the possible exception of China, because of crop priorities, geographic adaptation and environmental limitations. If the quantity of soybeans is to be increased, as it must be, it will have to come from an increase in yield per unit area. In other words, we must produce more kilos per hectare. This can be accomplished partly by reducing the loss caused by insects, weeds and diseases, which will require improved pest management systems utilizing cultural, chemical and biological methods.

Using the best current pest management technology in soybean production, losses in yield and quality caused by all pests are estimated at 20-30% of the potential production (1). Of the total loss caused by all pests, about 50% is due to weeds. The other 50% is about equally divided

TABLE II

Major Insects of Soybeans in the United States

Common name	Scientific name
Armyworm	Spodotera spp.
Bean leaf beetle	*Ceratoma trifurcata*
Blister beetle	*Epicauta pestifera*
Clover root curculio	*Sitoma hispidula*
Corn earworm	*Heliothis zea*
Differential grasshopper	*Melanoplus differentialis*
Garden symphylan	*Scutigerella immaculata*
Garden webworm	*Lexestege rantalis*
Grape colaspis	*Colaspis brunnea*
Green cloverworm	*Plathypena scabra*
Green stink bug	*Acrosternum hilare*
Japanese beetle	*Popillia japonica*
Mexican bean beetle	*Epilachna varivestis*
Potato leafhopper	*Empoasca fabae*
Redlegged grasshopper	*Melanoplus femurrubrum*
Seed corn maggot	*Hylemyl platura*
Soybean looper	*Pseudoplusia includens*
Tarnish plant bug	*Lygus lineolaris*
Thistle caterpillar	*Vanessa cardui*
Thrips	*Sericothrips variabilis*
Twospotted spider mite	*Tetranycus urticae*
Velvetbean caterpillar	*Anticarsia gemmatalis*
White grubs	*Phyllophaga rugosa*
Wireworm	*Liminius dubitans*

between insects and diseases, including nematodes. Because our primary concern is with Central and South America, we should be aware that weeds, insects and diseases are generally a more serious problem of plants in the tropic and subtropic regions of the world than they are in the temperate zone. Not only are the warm moist conditions favorable for the proliferation of these pests, but the growing season is longer and many of the pests survive the mild winters even though they may have a dormant or semi-dormant period.

WEEDS

Weed control in soybeans is essential to success. Weeds compete with soybeans for moisture, light and nutrients. The competition for light is of greatest importance in soybeans, which, because of their short height, are often overtopped by weeds (2). More than 40 plant species infest soybean fields in the United States (Table I) (2). Foxtail, pigweed, velvetleaf, cocklebur, smartweed, morningglory, ragweed, nutsedge, Jimsonweed, crabgrass, sicklepod and Johnsongrass are the most troublesome (1-3).

INSECTS

The soybean is subject to attack by insects that feed on roots, stems, pods and foliage. Soybeans in certain growth stages can tolerate considerable foliar feeding by insects with minimal yield loss. Defoliation during and after bloom, however, is the common type of insect damage and contributes most to yield loss (4). Insects that may cause significant damage to soybeans are listed in Table II. Of these, the Mexican bean beetle, green stink bug, bean leaf beetle, green clover worm, wireworms and armyworms are the most destructive insect pests of soybeans.

DISEASES

Bacteria, fungi, nematodes and viruses cause a large number of soybean diseases. They attack the roots, stems, leaves, pods and seeds. The bacterial leafspots, brown spot, downy mildew and purple seed stain are the most prevalent diseases. Phytophthora and Rhizoctonia root rots, pod and

TABLE III

Major Soybean Diseases in the United States

Common name	Causal organism
Bacterial diseases	
Bacterial blight	*Pseudomonas glycinea*
Bacterial pustule	*Xanthomonas phaseoli* var. *sojensis*
Wildfire	*Pseudomonas tabaci*
Fungus diseases	
Anthracnose	*Colletotrichum dematium* var. *truncata*
Brown spot	*Septoria glycines*
Brown stem rot	*Cephalosporium gregatum*
Charcoal rot	*Macrophomina phaseoli*
Downy mildew	*Peronospora mansburica*
Frogeye leafspot	*Cercospora sojina*
Fusarium root rot	*Fusarium orthoceras*
Mycoleptidscus root rot	*Mycoleptodiscus terrestis*
Phyllosticta leafspot	*Phyllosticta sojaecola*
Phytophthora root rot	*Phytophthora megasperm f.* sp. *glycinea*
Pod and stem blight	*Diaporthe phaseolorum* var. *sojae*
Powdery mildew	*Microsphaera diffusa*
Purple seed stain	*Cercospora kikuchii*
Pythium root rot	Pythium spp.
Rhizoctonia root rot	*Rhizoctonia solani*
Sclerotinia stem rot	*Sclerotinia sclerotiorum*
Sclerotium blight	*Sclerotium rolfsii*
Stem canker	*Diaporthe phaseolorum* var. *caulivora*
Target spot	*Corynespora cassiicola*
Thielaviopsis root rot	*Thielaviopsis basicola*
Nematode diseases	
Cyst nematode	*Heterodera glycines*
Lance nematode	*Hoplolaimus columbus*
Reniform nematode	*Rotylenchulus reiniformis*
Root-knot nematode	Meloidogyne spp.
Root lesion nematode	Pratylenchus spp.
Sting nematode	*Belonalaimus gracilis*
Virus diseases	
Bean pod mottle	Bean pod mottle
Bud blight	Tobacco ringspot
Soybean mosaic	Soybean mosaic
Yellow mosaic	Bean yellow mosaic

stem blight, mosaic and cyst nematode are the most destructive diseases. Few of the soybean diseases develop in epidemic proportions, but their cumulative affect results in significant loss of yield. The cyst nematode, Phytophthora root rot, stem canker and bud blight have at times threatened production in certain regions of the United States. Soybean diseases of economic importance are listed in Table III (5,6).

WEED CONTROL

Weed control in soybeans is based on a combination of cultural, mechanical and chemical treatments. Cultural and mechanical weed control were the only methods available until recently. Cultural weed control practices emphasized seedbed preparation, weed-free seed, fertilizer placement and timing, narrower rows, crop rotation and field sanitation. Fast-moving, shallow cultivators, rotary hoes, blade, sweep, and rolling cultivators, and the use of oil and gas burners for flame weed killing are some of the improvements in mechanical weed control (1,7,8).

The development of selective herbicides greatly changed weed control practices. The first experiments with selective chemical methods of weed control in soybeans were in 1948 (9). Now, over 80% of the soybeans grown in the United States are treated with a herbicide at a cost of about $400 million. There are now nearly 100 individual herbicides or herbicide mixtures registered for weed control in soybeans. This array provides soybean growers with a choice of chemicals for their particular weed problems. The relative effectiveness of the most widely used herbicides on the more common weed pests is presented in Table IV.

INSECT CONTROL

Cultural practices have limited use in controlling insect pests of soybeans. Appropriate rotations may reduce numbers of and damage from clover root curculio or grape colaspis. Delayed planting may speed germination and emergence, and reduce damage from soil insects. Use of early maturing varieties decrease the chance of late-season damage from corn earworm (4).

The use of insecticides to control insect pests of soybeans has increased greatly in the past few years. The primary chemicals used include Sevin, Malathion, Disyston, Guthion, Toxophene and Methyl parathion. The decision to control insects should be based on insect population, stage of development of the insect and crop, an estimate of the existing damage, and potential crop yield. Broad spectrum chemicals are often applied when unnecessary, and frequently at unnecessarily high rates. Some of the insecticides give residual kill of predators and parasites, while affording only initial effectiveness against certain pest species. Recent research indicates that lower rates of certain insecticides give adequate pest control and allow survival of beneficial species (10).

Several predators and parasites attack species of insects that are soybean pests. Most of these are nabids, geocorids and spiders. The fungus, *Spicari rileyi*, and the bacterium, *Bacillus thuringiensis*, cause fatal diseases to green cloverworms, soybean loopers, cornearworms and velvetbean caterpillars (4).

Genetic resistance offers the greatest potential for effective control of soybean insect pests. High levels of resistance to the Mexican bean beetle have been found in certain plant introductions (11). Some lines with excellent resistance to the Mexican bean beetle also have some degree of resistance to the bean leaf beetle, the green cloverworm and the striped blister beetle (10).

DISEASE CONTROL

Control or preventive tactics for soybean diseases are cultural practices, pesticides and biological control. Cultural practices include rotation, tillage, drainage, fertility and planting date. Rotation is very effective in controlling some diseases such as brown stem rot and cyst nematode. One, two, or three years of corn, cotton, or milo is an excellent rotation for cyst nematode control (12). Three to four years between crops of soybeans greatly reduces the incidence of brown stem rot. Most nematodes have short life spans and do not persist for long without food from a host plant. At least one year between soybean crops reduces the incidence of most foliage diseases that overwinter on plant debris.

Many disease-producing organisms can live from one year to the next on soybean stems, leaves and pods. Plowing, preferably in the fall, covers the diseased debris and causes it to deteriorate more rapidly, thus reducing inoculum for subsequent crops. The reduced tillage practices that are being advocated to conserve soil, water, and energy frequently result in weak seedlings because of difficulty in their emergence. Such seedlings are more susceptible to disease. The soil remains wet longer following rain with minimum tillage, and Phytophthora root rot has been more severe with this type of tillage compared to conventional tillage.

Drainage is important in reducing some of the root rots, particularly those caused by Pythium and Phytophthora. Tile drainage and anything that will prevent soil compaction, including deep tillage, is helpful.

Good soil fertility produces strong plants that have a better chance of remaining healthy or at least product a

TABLE IV

Relative Effectiveness of Herbicides for Soybeans

	Foxtail	Barnyard grass	Crabgrass	Fall panicum	Nutsedge	Pigweed	Lambs-quarter	Jimsonweed	Ragweed	Velvetleaf	Smartweed	Morning glory	Cocklebur	Soybean tolerance
Preplant incorporated														
Basalin & Lexone or Sencor	G	G	G	G	N	G	G	F-G	G	F-G	G	N	P-F	F
Basalin	G	G	G	G	N	G	F-G	P	P	N	P-F	—	N	F-G
Dual & Lexone or Sencor	G	F-G	G	G	F-G	G	G	F-G	G	F-G	G	F	P-F	F
Lasso	G	G	G	G	F-G	G	F	P	P	N	P	N	N	G
Lasso & Lexone or Sencor	G	F-G	G	G	F-G	G	G	F-G	G	F-G	G	F	P-F	F
Prowl	G	G	G	G	—	G	F-G	P	P	P	N	P	—	F-G
Prowl & Lexone or Sencor	G	G	G	G	—	G	G	F-G	G	F-G	G	P	P-F	F
Tolban	F-G	F-G	F-G	F-G	N	G	F-G	P	P	N	P-F	—	N	F-G
Tolban & Lexone or Sencor	G	G	G	G	N	G	G	F-G	G	F-G	G	P	P-F	F
Treflan	G	G	G	G	N	G	F-G	P	P	N	P-F	P	N	F-G
Treflan & Amiben	G	G	G	G	N	G	G	F	G	F	F	N	P-F	F-G
Treflan & Furloe	G	G	G	G	N	G	F-G	P	P	N	G	N	N	F-G
Treflan & Lexone or Sencor	G	G	G	G	N	G	G	F-G	G	F-G	G	F	P-F	F
Vernam	G	G	G	G	F	G	F	N	P	F-G	N	P	P	F
Preemergence														
Amiben	G	G	G	F	N	G	G	F	G	F	F-G	N	P-F	F-G
Bexton or Ramrod	G	F	G	F	P	G	F	N	P	N	P	N	N	G
Dual	G	G	G	G	P-F	G	P	P	P	N	P	N	N	F-G
Dual & Lexone or Sencor	G	G	G	F-G	F	G	G	F-G	G	F-G	G	P	P-F	F
Dual & Lorox	G	G	G	F-G	P-F	G	G	P-F	F-G	F-G	G	P	P-F	F-G
Furloe (CIPC)	F	F	F	F	N	P	N	P	N	N	G	F	N	G
Lasso	G	G	G	G	P-F	G	F	P	P	N	P	N	N	G
Lasso & Maloran	G	G	G	F-G	P-F	G	G	P-F	F-G	F-G	G	P	P-F	G
Lasso & Lorox	G	G	G	F-G	P-F	G	G	P-F	F-G	F-G	G	P	P-F	G
Lasso & Lexone or Sencor	G	G	G	F-G	P-F	G	G	F-G	G	F-G	G	P	P-F	F
Delayed preemergence and cracking														
Dual & Dyanap	F-G	F-G	F-G	F-G	—	G	G	G	G	F	F-G	F-G	F	F
Dyanap	P	P	P	P	N	G	G	G	G	F	F-G	F-G	G	F
Lasso & Dyanap	F-G	F-G	F-G	F-G	P	G	G	G	G	F	F-G	F-G	G	F
Lasso & Premerge	F-G	F-G	F-G	F-G	P	G	G	G	G	F	F-G	F-G	F	F
Premerge, Sinox, Unico Diniro	P	P	P	P	N	G	G	G	G	F	F-G	F-G	F	F
Early postemergence														
Basagran	N	N	N	N	F-G	P	P	G	G	G	G	F	G	G
Dyanap	P	P	P	P	N	G	G	G	G	F	F-G	F-G	G	F-G

G = good, F = fair, P = poor, N = none.
Adapted from Purdue Agr. Ext. Bul. ID-1, 1980.

near normal yield even though infected with one or more disease-producing microorganisms. Both potassium and phosphorous deficiency result in poor seed development and quality.

Soybeans should not be planted until the soil is warm enough for rapid germination and emergence. With adequate moisture this will result in maximum emergence of strong, fat-growing seedlings. Early planting often results in poor stands and the seed may ripen during warm temperature, which is unfavorable both physiologically and pathologically.

Chemical pesticides have not been widely used to control soybean diseases because of the high cost of material and application in relation to the value of the soybeans that might be saved. Pesticides may be applied as seed, soil or foliage treatments.

Treating soybean seed with a seed protectant usually results in a higher percentage of emergence than occurs with nontreated seeds, but the yield is seldom any different unless the final stand from the nontreated seed is below the optimum stand for the maximum yield. The poorer the seed quality, the greater the differences in emergence from treated and nontreated seed. Soybean seed produced in the southern United States is generally lower in quality than that produced under the cooler conditions in the north. For that reason, more of the seed planted in the south is treated with a chemical seed protectant.

Nematicides are the most effective and reliable means of controlling a wide variety of nematodes. Suitable methods have been devised for applying highly effective nematicides and soil fumigants; however, only a few chemicals have been approved for use to control nematodes of soybeans. Nematicides have not been used extensively to control nematodes of soybeans mainly because of the high cost of the material and application.

The systemic fungicide Benomyl applied as a foliage spray at the proper time has improved soybean seed quality by reducing the incidence of pod and stem blight and purple seed stain. Although the cost of the material and application is high, it is justified in seed fields in those years when conditions are favorable for seed infection by the pod and stem blight fungus. Benomyl as a foliage spray has been reported to increase seed yield in the southern United States, probably by preventing premature defoliation. Limited tests indicate that the chemical fungicide Ridomil, when broadcast and incorporated into the soil, will control Phytopthora root rot of soybean fairly well—but the cost is prohibitive.

Host plant resistance is the most promising means of controlling soybean diseases. There is excellent resistance to root-knot and cyst nematodes, bacterial pustule, wildfire, downy and powdery mildew, frogeye leafspot, target spot, purple seed stain, Phytophthora root rot and mosaic. Some soybean strains have low susceptibility to brown spot, stem canker, brown stem rot, Pythium root rot and bud blight. Disease resistance is complicated by the existence of pathogen variability or physiologic races; however, resistance where available is the best control for most soybean diseases.

TREND IN SOYBEAN PEST MANAGEMENT

The current and future trends in soybean production will dictate to a large degree the future trends in pest management. All indications are that farms on which soybeans are produced will increase in size. The increase in farm size will be accompanied by an increase in the size of farm equipment, particularly planters and machinery to apply herbicides. Along with the larger equipment, the trend will be toward reduced tillage and narrower rows to conserve water, soil, and mainly, energy. Reduced tillage and narrow rows will intensify the use of new effective herbicides (13). Reduced tillage practices will increase the insect and disease problems. In general, the major insect problems appear to be greater in minimum tillage, especially armyworms and stalk borers. Good insect control is often difficult to obtain with insecticides because of the heavy, undecomposed crop refuse from the previous season. The crop residue also provides a substrate upon which many of the soybean disease organisms can overwinter saprophytically. The trend towards reduced tillage and narrow rows suggests that control of diseases and insects of soybeans will become more dependent upon chemical and biological methods.

FUTURE PEST CONTROL STRATEGIES

Weeds. Continuous improvement in chemical weed control can be expected. The most eminent changes will be herbicides with controlled-release, which will improve both efficiency and safety; new herbicides and herbicide mixtures with greater selectivity and less persistence; and improved herbicide application equipment and methods of application. In the future we can expect a better understanding of penetration, translocation, sites and mechanisms of action, metabolism in plants and soils, and the behavior, fate, and effects of herbicides in plants, soils and the environment. Allelopathy, phytotoxicity, seed dormancy breakers or germination stimulators, and plant ecology are biological methods of weed control which may play a part in the future.

Insects. The emphasis in insect control will focus on the optimal use of all available methods for pest suppression (13). Chemical pesticides probably will continue to be the primary protection tool for insect management. There needs to be improvement in definition and identification of economic thresholds, proper targeting of pesticides in the application process, determination of effective minimal application rates, selectivity and degradation of pesticides, timing of application with relation to parasitosis and predators, and pesticide interactions.

Improvements are rapidly taking place in biological insect control technology. Resistance is available for the Mexican bean beetle and the green cloverworm, and sources of resistance or tolerance to other insects are being found. Better understanding of the nature of insect resistance in soybeans is needed. Alternative biological methods include pheromones (attractants), mating inhibitors, juvenile inhibitors, parasites and predators. The use of pathogens such as bacteria, fungi and viruses as control agents holds great potential. A large number of parasites and predators have been identified from various insect species.

Diseases. Disease resistance will continue to be the primary method of controlling soybean diseases, possibly along with an increase in the use of chemical protectants. New sources of resistance to many diseases are being found continually. Efforts are being made to increase the genetic diversity of soybeans to reduce the vulnerability of soybean cultivars to disease. Basic research now in progress will provide information about the value of different types of resistance, the biochemical nature of resistance, and the effect of selection pressure on pathogen variability, which will enhance soybean disease control with resistant cultivars.

The use of systemic fungicides as a seed or foliage treatment probably will increase for those diseases for which resistance is unattainable. Ultrasonic or radiation treatment of soil and crop debris is a new and novel method of biological disease control, that may be applicable to soybeans. It is aimed at the eradication of the disease-producing agent or changing the genetics or physiology of the pest.

Integrated pest management. Integrated pest management is a popular concept at the present. It implies a unification of insect, disease and weed control. To some people this means a solution to all our pest problems. To others it is a safeguard to protect the environment from excessive use of pesticides and other pest control practices, so that one practice does not disturb the balance of nature and create another problem. It has been shown, for example, that benomyl used as a foliar fungicide to control disease also kills beneficial insects that normally feed on soybean insect pests.

Carboflurin, a soil insecticide commonly used to control insects and nematodes in corn, increases the damage from Phytophthora root rot in soybeans. Likewise, continual use of certain classes of herbicides has increased the presence of Rhizoctonia root rot. Then there is the more direct cummulative effective of metabuzin on soybeans following corn with atrazine the previous year. To prevent these problems, it is necessary to use a concerted approach in applying the current technology in dealing with pests and pest complexes.

I believe we are in the position at the present that pests should not threaten soybean production. How much we reduce the loss caused by soybean pests will depend upon how well we use the pest management technology we now have and how well we keep abreast of future problems. I would like to emphasize that when introducing a crop into a new area, you must have adapted cultivars that can compete with other local crops in demand and production costs. Much of the basic information and basic production technology is transferable, but the success or failure of the program will depend on local production practices. These are practices in production, including pest management, that must be developed at the local level through applied research to meet the local needs. One must be willing and prepared to meet this challenge of applied research.

REFERENCES

1. Shaw, W.C., L.M. Wax, C.G. McWhorter, C.C. Dowler and R.N. Anderson, paper presented to the Nat. Soybean Crop Imp. Council, p. 50-63 (1979).
2. Wax, L.M., in "Soybean: Improvement, Production, and Uses," edited by B.E. Caldwell, Am. Soc. Agron, 1973, p. 417-457.
3. Purdue Agr. Exp. Sta. Ext. Bul. ID-1, W. Lafayette, IN, p. 55 (1980).
4. Turnipseed, S.G., in "Soybeans: Improvement, Production and Uses," edited by B.E. Caldwell, Am. Soc. Agron, 1973, p. 545-572.
5. Compendium of Soybean Diseases, edited by J.B. Sinclair and M.C. Shurtleff, St. Paul, MN, 1975, p. 69.
6. Athow, K.L., B.W. Kennedy, H. Tachibana, J.M. Dunleavy and J.M. Good, in "Soybeans: Improvement, Production, and Uses," edited by B.E. Caldwell, Am. Soc. Agron., 1973, p. 459-543.
7. Shaw, W.C., Proc. NE Weed Science Society 30:18 (1976).
8. Timmons, F.L., Weed Sci. 18:294 (1970).
9. Shaw, W.C., Res. Rpt. NC Weed Cont. Conf. 5:Sec VII, Abstr. No. 13, (1948).
10. Turnipseed, S.G., J. Econ. Entomol. 65:224 (1972).
11. Van Duyn, J.W., S.G. Turnipseed and J.D. Maxwell, Crop Sci. 12:561 (1972).
12. Hadden, C.H., J.M. Epps and C.J. Southards, Tenn. Agric. Ext. Publ. 637 (1972).
13. Pest Control, Vol. II, National Academy of Science, Washington DC, 1975, p. 169.

Improving the Quality of the Soybean

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ABSTRACT

Soybeans, once a relatively minor farm commodity, have become the world's most abundant source of vegetable protein and oil. This growth in popularity, much of which has occurred in the last 20 years, has been made possible partly by genetic improvements that have successfully adapted soybeans to a wide variety of environmental conditions. To date, however, soybean breeders have concentrated their research efforts on increasing the quantity rather than the quality of soybeans. This paper summarizes genetic research currently underway to improve the quality of soybeans and/or soybean products. It also examines research efforts to improve the soybean's fatty acid composition, change the amino acid profile and reduce antinutritional factors.

INTRODUCTION

The growth of soybean production is remarkable. Research has played a major role in making this crop the premier of oilseed protein and the dominant vegetable oil, and thus indispensable to our agricultural economy. Research has been responsible for improved soybean yields, for cultural practices that reduce production cost, and for developing a better understanding of plant physiological functions. Today, we know much about soybean production; however, research to improve the quality of the soybean has been limited. This paper will discuss research designed to modify the soybean by maximizing its usefulness and minimizing its shortcomings.

The ideal soybean would be: (a) High in protein. The amino acid profile should compliment cereal grains in meeting nutritional requirements. (b) High in oil. The oil should contain low levels of fatty acids, which cause stability problems. (c) Low in undigestable carbohydrates. (d) Low in antinutritional factors.