APPENDIX A

Areas Needing Additional Study

Perhaps the major benefit of this project will be in identifying areas needing additional study. Here are some of the questions identified by participants:

1. What are indicators of soil health and plant health (other than absence of insect pests and disease)? Would we measure the balance of fungi and bacteria in the soil? The amount and form of nitrogen in the plant tissues?
2. How can the principles of no-till or minimum tillage, which clearly have benefits in building soil organic matter, be adapted to the needs of organic farmers and other farmers who want to reduce the use of herbicides?
3. What specific elements (plants or practices) are most effective in providing supplemental food of nectar and pollen and habitat for useful natural enemies of insect pests?
4. How can products of research be made available to farmers more rapidly? Two examples are the "Zea-later" device for applying oil to the corn ear for control of corn earworm and the "TIC" lure (made from a mixture of three naturally-occurring chemicals), which doubles the trap catch of striped cucumber beetles. Many additional examples could be drawn from the realm of biological control, where the possibilities of using natural enemies in augmentative or inoculative releases have been demonstrated, but the natural enemy is not commercially available.
5. What are the possibilities of using weeds or other plants commonly found in the Northeast (or plants farmers could grow) as sources of insect repellents or as herbal treatments to produce healthy crop plants and domestic animals?
6. How can weather and the seasonal phenology of insects and their natural enemies be put together in a form more useful to farmers? What kinds of records of weather and seasonal phenomena are farmers already keeping? How are they using that information to time their actions in the field?
7. We need monitoring methods for natural enemies in relation to pest populations so we can predict when the pest population can be left alone because biological control is working well.
8. For potato leafhoppers: Could an early warning system be established to alert northern growers to unusually high numbers and/or favorable weather for migration of leafhoppers as they move into the Northeast each year?
9. For crucifer flea beetles *(Phyllotreta cruciferae):* Are they a significant pest in Eurasia, where they originated? What natural enemies are present in other parts of the world that could be brought here as biological control agents? What techniques are farmers using against them in other parts of the world?
10. For tarnished plant bug: Does the level of parasitism in alfalfa result in declining populations across the Northeast? Does it result in lower abundance of these insects and their damage in vegetable, berry, and fruit crops? What can be done to increase the effect of these parasites? Is there some way to provide host reservoirs and overwintering sites for the parasites without increasing the population of tarnished plant bug?
11. For Mexican bean beetles: An artificial diet for raising Mexican bean beetle would decrease the cost of production of the parasite *Pediobius foveolatus.* We also need information on the timing of release of these parasites and release rates necessary to get control of Mexican bean beetle earlier in the season in snap beans.

APPENDIX B

Sources of Commercially Available Biological Control Agents

This is only a small selection of the suppliers of beneficial organisms. For more complete listings, see Hunter (1997) or the annual *Directory of Least-Toxic Pest Control Products* in the *IPM Practitioner,* both of which are listed under "Resources for General Information," page 72. Also, please note that both availability of particular organisms and information about particular companies change frequently, so check current lists to keep up-to-date.

Selected sources of some biological control agents

Biological control agent	Sources
Anaphes iole (Parasitoid of tarnished plant bug — but *not* the one introduced by Bill Day; his is not available commercially)	Rincon Vitova Insectaries, Inc.; IPM Laboratories, Inc.; The Green Spot, Ltd.
Pediobius foveolatus (Parasitoid of Mexican bean beetle and squash beetle)	Maryland Department of Agriculture; New Jersey Department of Agriculture; Rocky Mountain Insectary; The Green Spot, Ltd.; ARBICO; Rincon Vitova Insectaries, Inc.
Trichogramma ostriniae (Parasitoid of European corn borer eggs)	Beneficial Insectary (large supplies of *Trichogramma*, but supply of *T. ostriniae* is currently limited)
Insect-attacking nematodes (*Steinernema carpocapsae, Heterorhabditis bacteriophora,* other species)	These are available from several sources, including IPM Laboratories, Inc. and The Green Spot, Ltd. as well as BioLogic, which specializes in these nematodes. Be aware that each species has specific ecological, environmental, and host species requirements and make sure the species you are using is appropriate for the pest to be controlled.
Parasites and predators used for biological control in the greenhouse (as listed by Cass Peterson): *Aphidoletes aphidimyza, Aphidius colemani*, and lady beetles for aphids; *Neoseiulus cucumeris* for thrips; *Encarsia formosa* for whitefly; and *Hypoaspis miles* for fungus gnat and shorefly	There are many suppliers of beneficial organisms whose primary business is to supply these natural enemies for use in the greenhouse. IPM Laboratories, Inc. and The Green Spot, Ltd. list all of these organisms for sale.

Contact Information

ARBICO
P.O. Box 4247 CRB
Tucson, AZ 85738
800-827-2847

Beneficial Insectary
14751 Oak Run Road
Oak Run, CA 96069
800-477-3715
(Note: If you want *T. ostriniae,* let them know dates and amounts needed well in advance.)

BioLogic
P.O. Box 177
Willow Hill, PA 17271
717-349-2789

The Green Spot, Ltd.
93 Priest Road
Nottingham, NH 03290
603-942-8925

IPM Laboratories, Inc.
P.O. Box 300
Locke, NY 13092-0300
315-497-2063

Maryland Department of Agriculture
Plant Protection Section
50 Harry S. Truman Parkway
Annapolis, MD 21401
410-841-5927

New Jersey Department of Agriculture
Division of Plant Industry
Bureau of Biological Pest Control, P.O. Box 330
Trenton, NJ 08625-0330
609-530-4192

Rincon Vitova Insectaries, Inc.
P.O. Box 1555
Ventura, CA 93002
800-248-2847

Rocky Mountain Insectary
P.O. Box 152
Palisade, CO 81526

Glossary

AI Active ingredient (in a pesticide).

Allelopathy Suppression of one or more plant species by another, due to phytotoxic compounds released by the other plant as it lives or decomposes.

Amino acids The smaller chemical compounds, made from carbon, nitrogen, and hydrogen (and for some amino acids, sulfur) from which proteins are assembled.

Apiaceae Family of plants including carrot, dill, fennel, cilantro, and other cultivated plants and weeds (formerly known as the Umbelliferae)

Aster yellows A disease caused by a mycoplasma-like organism that affects many vegetables, ornamentals, and weeds. The disease is transmitted by a leafhopper vector. Symptoms vary with different hosts but typically include yellowing of the plant, abnormal production of shoots, or reduction in quality and quantity of yield.

Augmentative biological control The periodic release of captured or artificially produced natural enemies to supplement those that occur naturally.

Bacteria One-celled microorganisms that reproduce by division and differ from other microorganisms in their lack of a distinct nucleus and other cell structures.

Barriers Obstructions, such as plant collars or row covers, placed to prevent insects from being to able to attack crop plants.

Biodynamic farming A system of farming developed in Europe in the 1920s following lectures on agriculture by the Austrian anthroposophist Rudolf Steiner. Biodynamic farming parallels organic farming in many ways but places greater emphasis on the integration of animals to create a closed nutrient cycle, the effect of crop planting dates in relation to the calendar, and awareness of spiritual forces in nature. A unique feature of this system is the use of eight specific preparations derived from cow manure, silica, and herbal extracts to treat compost piles, soils, and crops.

Biological control The use of organisms, such as predators, parasitoids, and pathogens, to control pest species.

Bivoltine Having two broods or generations per season.

Blind cultivation Killing weeds with cultivation just before crop plants emerge.

Botanical insecticides Insecticides derived from plant materials. Examples include rotenone, pyrethrum, and extracts of neem.

Braconid wasps Small parasitoid wasps belonging to the family Braconidae (of which there are over 1,700 species in North America). They are distinguished from other families in the order Hymenoptera by characteristics of wing venation, antennae, and other structures.

Brassicaceae, brassicas Family of plants including cabbage and its relatives, mustards, turnips, canola, rape, arugula, and many weeds (formerly known as the Cruciferae).

Brix level Measurement using a refractometer to monitor sugar content in plant tissue sap.

Bt The bacterium, *Bacillus thuringiensis,* or proteins derived from it.

Bumper crop An unusually large yield.

Caterpillar The immature stage (larva) of butterfly, sawfly, or moth.

Classical biological control The importation of foreign natural enemies to control previously introduced, or native, pests.

Companion planting Interplanting different crop species in combinations intended to provide benefits such as deterrence of insect pests.

Compost Organic material broken down by microorganisms to a relatively stable intermediate stage.

Conservation tillage General term for many reduced tillage practices that leave some crop residue on the soil surface to reduce erosion.

Cover crop A crop used to protect soil from erosion as well as to build soil organic matter, control weeds, provide nitrogen, or for additional purposes. Common examples are rye, oats, vetch, and clovers.

Cucurbitaceae Family of plants including squash, cucumbers, and melons.

Cucurbitacins Chemical compounds produced by plants in the family Cucurbitaceae which are bitter to humans and feeding deterrents to most insects, but are attractive to cucumber beetles and related species.

Cultural control Pest management practices that rely upon manipulation of the cropping environment (e.g. , cultivation of weeds harboring insect pests).

Cytokinin One of a group of plant hormones that regulate cell division.

Degree-days The number of degrees above the threshold temperature occurring each 24-hour period. A simple way of calculating degree-days for a threshold of 50°F is:

1. (Maximum temperature + minimum temperature) ÷ 2 = mean temperature
2. Mean temperature – threshold temperature (50°F or 10°C) = daily degree-days
3. Sum of daily degree-days = accumulated degree-days

Essential oil Concentrated extract of plant chemicals, often produced by steam distillation.

FIFRA Federal Insecticide, Fungicide, and Rodenticide Act. The Federal legislation regulating the registration, labelling, and use of pesticides.

French intensive beds A system of growing vegetables and other plants in permanent beds, with the soil deeply dug, so that there is more room for roots and plants can be grown at a higher density.

Generalist A pest or natural enemy that can utilize a wide range of species as host or prey.

Genotype The genes in an organism distinguishing it from others of the same species.

Green manure A crop grown to build fertility and suppress weeds. Green manures are turned in before they mature.

Heliothis monitor trap A trap baited with pheromones used to monitor various moth species, including corn earworm (formerly in the genus *Heliothis*, now *Helicoverpa*).

Honeydew The sweet liquid excretion of sap-feeding insects such as aphids, leafhoppers, and whiteflies. An important alternate food for many predatory and parasitic insects.

Inoculative release The release of relatively small numbers of natural enemies that are expected to colonize, reproduce, and spread naturally throughout an area to suppress pest populations.

Instar The stage of an insect's life between successive molts; for example, the first instar is between hatching from the egg and the first molt. Most insects pass through three to six instars.

Integrated Pest Management (IPM) An approach to the management of pests in which all available control options, including physical , chemical, and biological controls, are evaluated and integrated into a unified program. Seeks to minimize disruption of natural mortality factors.

Inundative release The release of relatively large numbers of natural enemies to suppress pest populations, without the expectation that the natural enemies will colonize and spread throughout the area.

IPM threshold The pest density at which a control tactic must be implemented to avoid economic loss. Also called economic or action threshold.

Larva, larvae (pl.) The immature stage between the egg and pupa of insects having complete metamorphosis, where the immature differs radically from the adult (e.g., caterpillars, grubs).

Living mulch An understory of vegetation that helps reduce soil erosion and adds organic matter to the soil, but which does not compete heavily with the crop for water and nutrients.

Low-input Refers to reduced use of off-farm resources (such as synthetic fertilizer and pesticides) and increased reliance on naturally occurring resources and on-farm nutrients.

Microbial insecticides Insecticides derived from materials produced by microscopic organisms or the microscopic organisms themselves, applied in large numbers in order to kill insects.

Mid-whorl stage of corn When the corn plant has seven to ten leaves, and the emerging tassel cannot yet be seen or felt within the whorl.

Mummy The exoskeleton of a parasitized insect that has hardened to form a case around the larva or pupa of the parasitoid.

Mycorrhiza, mycorrhizae (pl.) A symbiotic association of a fungus with the roots of a plant.

Native (insect) Of local origin, not intentionally or accidentally introduced.

Natural enemies Living organisms found in nature that kill insects, weaken them, or reduce their reproductive potential.

Nectar The sugary liquid secreted by many flowers.

Nematode Nonsegmented, microscopic, wormlike animals free-living in soil or water, parasitic in insects, plants, and animals.

NIR (near infrared reflectance) spectroscopy A method of chemical analysis using the measurement of reflectance and absorption in a specific region of the electromagnetic spectrum (near infrared) to deduce the chemical characteristics of complex materials.

No-till Planting a new crop directly into the residues of the old crop without tilling.

Nymph An immature insect, usually with undeveloped wings, that does not have a pupal stage. Most nymphs resemble the form of the adult stage, although markings and coloration may differ considerably.

Organic As an agricultural term, it usually refers to a method of farming or gardening without the use of synthetic pesticides or fertilizers. As a general biological term, it refers to something derived from plants and animals.

Organic matter The fraction of the soil that includes plant and animal remains, residues, or their waste products in various stages of decomposition.

Overwinter A period of rest or hibernation by which insects survive the winter.

Oviposition The laying or depositing of eggs.

Parasite An organism that lives and feeds on another organism for at least part of its life cycle. Usually, only one host organism is required for the complete development of the parasite. Most insect parasites are technically "parasitoids," that is, parasites that eventually kill their hosts. The contributors to this book have used both words.

Parasitoid An animal that feeds in or on another living animal, consuming all or most of its tissues and eventually killing it.

Pathogen An organism capable of causing disease in other organisms.

Pest Any organism (weed, disease, insect, mite, vertebrate, etc.) that interferes with human activity or causes injury, loss, or irritation to a crop, stored product, animal, or people.

Pesticide A substance used to kill pests.

Pest-resistant crops Crops that possess attributes that minimize damage by pests.

pH, soil A measure of the concentration of hydrogen ions in the soil solution and a primary factor in optimum plant growth. When pH is maintained at the optimal level for a given crop, plant nutrients are at a maximum availability and toxic elements are at reduced availability. On a scale of 1 to 14, a pH of 7.0 is neutral, lower numbers indicate acidity, and higher numbers indicate alkalinity.

Pheromone A chemical produced for communication among the members of a species. The most well-known examples are sex pheromones, used by one sex to attract the other for mating, but there are other types, such as aggregation or alarm pheromones.

Phloem Food-conducting tissue in plants.

Photoperiod The period between sunrise and sunset at different times of year.

Plant-positive Emphasizing the creation of optimum conditions for plant health.

Predator An animal that feeds on another live animal. A predator usually needs to feed on more than one host to complete its development.

Pupa, pupae (pl.) An inactive stage of an insect, between larva and adult, in which adult features develop.

Pupate To transform to a pupa.

Recalcitrant organic matter Organic matter that has become chemically and biologically stable and breaks down extremely slowly, if at all, under natural soil conditions.

Sampling, Scouting Estimating the density of organisms (pests or natural enemies) or damage by examining a defined portion of the crop.

Soil microflora Microscopic organisms in soil other than soil animals. Includes bacteria and fungi.

Solanaceae Family of plants including potatoes, eggplants, peppers, and other cultivated plants and weeds.

Strain A subgroup within a species that differs in a particular characteristic from other members of the same species.

Strip-tillage Tilling strips 12–24 inches in width in order to create a seedbed for planting row crops, while leaving strips of residue from the previous crop on the soil surface to act as a mulch and prevent erosion.

Sustainable Regarding agricultural systems, as defined by The American Society of Agronomy: "A sustainable agriculture is one that, over the long term, (1) enhances environmental quality and the resource base on which agriculture depends; (2) provides for basic human food and fiber needs; (3) is economically viable; and (4) enhances the quality of life for farmers and society as a whole."

Synthetic Produced artificially, or man-made, rather than occurring naturally.

Tassel stage of corn The stage where tassels (male flowers) are fully emerged from the whorl and the "arms" of the tassel have opened.

Trap crop A small area of a crop used to divert pests from a larger area of the same or another crop. The pests, once diverted to the trap crop, may be treated with an insecticide or killed by other methods.

Univoltine Having only one brood or generation per season.

Vector An organism capable of carrying and transmitting a pathogen from one host to another.

Volatiles Chemicals released by plants or insects into the air.

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Potato Leafhopper

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Other Publications from NRAES

Below are a few of the publications available from NRAES (Natural Resource, Agriculture, and Engineering Service). Contact NRAES for current prices and shipping and handling or for a free catalog (see contact information on the inside back cover).

Facilities for Roadside Markets. NRAES–52 • 1992 • 32 pages • This publication is for those considering a roadside market or looking to improve a current one. Three chapters cover site considerations, market layout, and market structure and facilities.

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Field Guide to On-Farm Composting. NRAES–114 • 1999 • 128 pages • This book helps in day-to-day compost system management. Topics discussed in the book include operations and equipment; raw materials and recipe making; process control and evaluation; site considerations, environmental management, and safety; composting livestock and poultry mortalities; and compost utilization on the farm.

Implementing Pheromone Technology in the Northeast. NRAES–83 • 1996 • 65 pages • This publication includes nine papers that discuss current pheromone technology, including the types of pheromone traps and lures, pheromone-mediated mating disruption, and commercial applications.

IPM Field Corn Pocket Guide. IPM–1 • 1999 • 280 pages • This compact guide discusses scouting and managing insect pests, beneficial insects, corn plant diseases, and vertebrate pests, grass weeds, and broadleaf weeds. Also covered are plant and soil health and fertility and postharvest storage. Includes over 80 line drawings, 18 color plates, over 40 tables, and 5 fold-out reference charts.

On-Farm Composting Handbook. NRAES–54 • 1992 • 186 pages • This book contains everything you ever wanted to know about composting on the farm—benefits and drawbacks, raw materials, composting methods, and management. It is so comprehensive that it is used as a college textbook.

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Sustainable Vegetable Production from Start-Up to Market. NRAES–104 • 1999 • 280 pages • This book introduces the full range of processes for moderate-scale vegetable production using ecological practices that minimize synthetic inputs and maximize stewardship of resources. Chapters address these topics: practical implications of sustainability; getting started; business management; marketing; soil fertility; composting; crop rotation; cover crops; tillage equipment and field preparation; seeds and transplants; irrigation and spraying systems; harvest and postharvest handling; season extension; integrated pest management; and environmentally friendly strategies for managing insects, diseases, weeds, and wildlife.