Pesticides, Plant Introductions and Organic Gardening: Ethical Issues facing Horticulture

Abstract

This paper is a discussion of impacts arising from use of pesticides, introduction of new plants for horticulture and the increasing interests in 'organic' gardening. Consideration of these practices in a broad context of benefits and harm allows us to begin addressing commercial and public perceptions from an ethical perspective. Past experience with all forms of herbicides, insecticides, fungicides and biological control agents points to a need for a greater effort to learn from the past. Introduction of new cultivated material cannot be fully predicted to be free of invasive risks. The increasing complexity and generally low level treatment of human and industrial waste makes it increasingly difficult to assume that 'natural' soils are as pristine as we may like to think in moving towards 'organic' gardening practices. Biomagnification of toxic materials in soil by food plants may compromise their perceived safety of such 'organic' production.

Introduction

The beautiful and productive garden is the horticulturist's dream. With such high ideals, it is hard to accept that horticulture, particularly at the level of the amateur gardener, may have serious negative environmental impact. Much horticultural research and practice is devoted to production of the desired 'crops' at the expense of other members of the garden ecosystem. Recently there has been increased interest in reducing human impact on the horticultural environment, particularly with respect to use of pesticides, the introduction of "new" ornamentals and the practice of organic gardening.

These practices all have beneficial aspects, but there are also risks of harm and thus we find ourselves in a variety of dilemmas. If we accept that ethical analysis can move us to "doing the right thing" when faced with finding a balance between beneficial and harmful outcomes (dilemmas), it is reasonable to use this approach in consideration of pesticide use, organic gardening practices and the introduction of new plants.

Use of chemical and biological pest controls benefit the grower with some form of improved crop quality, new plant introductions expand both commercial and aesthetic opportunities, and organic gardening practices

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provide some frame from which we can develop more sustainable horticulture. However, these benefits may be countered by risks of harm. Pesticide use may cause direct or indirect damage to non-targets, plants in a new environment may outgrow their new neighbours, and the quality presumed in organic gardening practices may be compromised by unpredicted accumulation of harmful substances in what may have been previously assumed to be safe soils. Some harms may be justified or not from one perspective or another. In this paper, I take the position that all parties deserve consideration but that we must beware of the view that a justifiable harm, often couched in tangible, short-term economic terms, can override harms for which justification is less tangible, for example long-term, poorly defined environmental impact.

Underestimated Impacts of Horticulture

Examples of major conflicts in large-scale environmental conservation, such as in commercial forestry, monocrop agriculture, and even depletion and damage to oceanic resources provide some lessons for horticulture. Successful large scale practices and preferences, such as the simplification of pest control and limitation of germplasm supply to the economically most viable varieties, have had impacts on smaller scale (e.g. gardening) practices as the commercial interests have sought to expand theirs (Scott, 1999).

Over the centuries and especially in the last century, the expansion of intensive farming practices has changed the balance between human needs and sustainability. There has been an international assault on plant and animal diseases using pesticides and an accelerated depletion of soil nutrients by the use of chemical fertilizers. Commercial horticulture and the amateur gardener have both benefited from the the use of pesticides and fertilizers. However, public and commercial perceptions that the scale of horticulture is not large enough to be a threat to the environment may be misdirected, as a drive past the intense horticultural operation in British Columbia's lower Fraser Valley or the bulb fields of the Netherlands clearly does not support this view. It is ironic that large-scale conservation efforts in major industrial countries have been much less active in dealing with destruction of natural landscapes and ecosystems that are closer to urban areas.

Hobby and commercial gardening and the provision of horticultural services are two of the fastest growing land use sectors in the North American economy. The public demand for supplies and resources to cultivate picture-perfect urban gardens has been met by gardening and landscape companies, who in turn have increased demand for chemicals that can raise productivity and supplied pest control practices that cause rapid decrease in pest damage. While an individual urban garden may be quite small (200-500m^2 in Vancouver), it is no longer possible for the hobby gardener to claim a trivial environmental impact, because the total city-wide impact of gardening is substantial; as much as 45% of a single family home lot area may be devoted to this activity. The hobby gardener can no longer redirect criticism to the presumed 'axis of evil', identified as the multi-national agro-chemical companies, because a substantial component of urban water run-off, carrying residual fertilizers and pesticides with it, is not subject to significant sewage treatment.

The dilemma for commercial horticulture is also cause for concern. Modern greenhouse technology allows production of fresh 'out of season' food and ornamental crops. The public's demand for visually attractive flowers, fruit and vegetables forces small and large-scale growers to market cosmetically perfect produce. The emerging harm is that producers are forced to rely on pesticides, fertilizers and protectants to ensure that their commodities meet public expectations.

The public and perhaps gardeners in particular are seemingly obsessed with novelty. In addition to the pest free garden, there is a call for new plants to grow and new or unfamiliar foods to eat. The searches for the truly blue rose or the black tulip are fuelled both by novelty and commercial opportunity. Kiwifruit (*Actinidia deliciosa*), once the purview of the specialist fruit farmer, is increasingly common in urban gardens. Individual needs can be met by introduction of new material through garden club seed exchanges or local plant sales, but commercially new material introductions involve import of new or exotic material followed by mass production and some level of marketing effort. The presumption has long been that individual introductions are harmless and that commercial material is screened and approved. The increasing awareness of invasive species and well-documented studies of their impact show the fallacy of these assumptions.

Increasing concerns about the rapid changes in worldwide gardening practices point to three very broad issues (control of unwanted or harmful agents, new plant introductions, and organic gardening) that face hobby and commercial horticulturists. Major opportunities for ethical leadership by the botanical garden community include: research into alternative pest control and the impact of currently preferred methods; development and application of rigorous assessment for potentially invasive plants; and provision of independent research data on persistent soil contaminants.

Control of Unwanted or Harmful Agents by Pesticides

I use the term 'pesticide' to refer to all forms of chemical or biological agents that are used to control unwanted agents. Thus, herbicides, insecticides, fungicides etc., are referred to separately as sub-sets of 'pesticides'

Herbicides

Gardeners and nursery operators have a long-term need for weed control. The mechanisms of synthetic herbicide actions on plants have usually been investigated, if not fully understood before the products have received regulatory approval. However, until recently few concerns had been voiced about impact on non-target plants, on soil organisms, and on animals in the food web. One of the first commercially available synthetic herbicides, the auxin analogue 2,4 dichlorophenoxyacetic acid (2,4-D), persists in plant tissue. This property allows time for it to cause its herbicidal effect, but also means that it may persist in soil where it can enter the food chain and exert unsuspected effects. It has been reported that it has neurotoxic effects on animals and sprayed plants that are normally distasteful are rendered attractive to grazers (Carson, 1962). Increasingly, regulatory approvals for the newer generation of herbicides, such as glyphosate and urea herbicides, require manufacturers to identify both the active principle and the solvents and wetting agents that are essential parts of the product formulation. Concerns that wetting agents and other solvent components may persist long enough to have toxic effects on soil and aquatic organisms have led some government regulators to require manufacturers to make clear statements that such products are not recommended for use close to streams, rivers and ponds (SA Occupational Health, Safety and Welfare Regulations.1995)

In April 2003, the city of Halifax, Nova Scotia implemented a by-law passed in 2000 (Halifax HRM, 2000) acting on a June 2001 ruling by the Supreme Court of Canada that allowed municipalities to restrict pesticide use and became the first major Canadian city to ban the cosmetic use of pesticides, although several smaller municipalities had already acted. It is well documented that after heavy rains pesticide seepage into ground water raises contaminant levels above allowable limits for drinking water and far above those that are documented to cause environmental damage.

The recent US report that low levels of atrazine, a widely used herbicide, were linked to feminization of male frogs (Hayes et al., 2002) provides an example of the need to avoid use of persistent pesticides in sensitive environments, such as water side gardens. Although this report is controversial, this study shows the need for greater precaution in approving and regulating herbicide use, especially when, as in this case, the ecologically harmful concentrations are much lower than levels approved for human drinking water (0.001 ppb and 3 ppb respectively). More than 40 years ago, Rachel Carson (1962) argued that knowledge of long-term bioaccumulation and biomagnification of organic residues was essential to finding ethically acceptable solutions on continued use of pesticides that have long-standing regulatory approval.

Ecologists and gardeners have long known that some plants seem to have their own herbicides that act to inhibit the growth of others in their immediate vicinity (allellopathy). *Juglans nigra* (black walnut) is a well known example. Recently, Jorge Vivanco and collaborators at Colorado State University (Bais et al. 2002) have established that catechin, a secondary plant metabolite found in *Centaurea maculosa* (spotted knapweed), acts as a natural herbicide by killing seedlings that germinate near the weed's root system. This and other observations suggest that it may be possible to develop a much more environmentally sensitive approach to herbicide use based on natural models. However, the same precautionary approach is needed because such herbicidal molecules are by definition toxic and concentrations that provide commercially acceptable impact may, if they are much higher than the natural levels, create unpredicted environmental and/or human health complications.

Insecticides

The insects are arguably the most numerous group of animal pests and probably the best known because some of them transmit human diseases, such as malaria and west nile virus. From the horticulturist's perspective their damage is to consume products; in some cases, a different life cycle stage may attack a different part of a plant. However the dilemma of insect pest control lies in the fact that an enormous number of plants rely on insects to ensure pollination. Hence, if we target the pest we may risk damaging a closely related species that is benign or even has a beneficial role. An attack on a pest stage (such as a caterpillar) may have a collaterally damaging effect if the adult stage is an important pollinator. Such is the case with butterflies, moths and many flies when the insect seeks nutrient nectar from the flower and incidentally pollinates before, during or after feeding. The adult female may not feed, but she must find the correct plant to lay eggs. So if the species has a pest stage, the specificity of egg laying provides the emergent young stage with a food supply and contributes to undesired crop damage.

Perhaps the most notorious case of environmental and biological damage comes from the use of DDT (Carson, 1962). The pressure to eradicate malaria was enormously more powerful than what, at the time, was perceived as an irrelevant concern that misuse of the pesticide would lead to genetically resistant strains of mosquito or other unpredicted problems. The passage of this compound up the food chain and the damage that it causes as it proceeds seemingly without any degradative metabolism has been extensively documented. It is now banned worldwide, but enforcement is often not actively pursued. Although it is an insecticide, DDT has been extensively documented to harm plants. Damage was particularly extensive when the pesticide was applied by aerial spraying. However, the most extensive damage was due to the loss of pollinators upon which a very substantial amount of horticulture depends. The temptation to spray a legal insecticide is considerable particularly during the various summer insect infestations that kill lawn grass (*Tipula paludosa*, European crane fly), potato vines (*Leptinotarsa decemliniata*, Colorado potato beetle) or cole crop leaves (*Pieris rapae*, cabbage white butterfly). The experience with DDT provides a model to remind us for the need for precaution in decisions to use both synthetic and natural insecticide preparations.

The introduction of new insecticides has resulted in a rapid increase in resistance, with many species now resisting several classes of insecticide (Denholm et al. 2002). The use of non-specific insecticides against a target pest often leaves residue or contacts non-target species, such as bees, beetles and flies, which are not pests. Their deaths reduce the pollinator populations and hence the gardener produces fewer fruit and flowers. Residual pesticide poses the same threat as residual herbicide. Predatory or carrion eaters provide biomagnification, circumstances that were so dramatically documented by Carson, more than 40 years ago.

A slightly different issue arises from the use of nematocides, pesticides that target nematodes, also known as roundworms. The issue here is that nematode pests are largely soil organisms, so that an effective nematocide must be stable in the soil long enough for the nematodes to encounter the poison. This leads us to ask how biodegradable should such pesticides be, and if they are persistent, is there opportunity for food chain accumulation such as occurred with DDT, or will they kill everything as occurs with use of the soil fumigant methyl bromide?

As with herbicides, Nature has developed several effective pesticides and deterrents. Citrus oils are available as insecticidal soap. Neem oil from *Azadirachta indica* is reported to contain effective insect anti-feedant chemicals. Many gardeners use a form of companion planting by rotating *Tagetes* sp. (marigold) to reduce nematode populations with the nematode susceptible crop. In spite of the need for natural insecticides, the level of research is surprisingly low. However, the requirement for much greater environmental consideration by pest control industries must surely lead to a much stronger research effort, especially to look for and follow up clues provided by natural pest protection.

If insect control has made a major contribution to the fundamentals of plant protection it is in the area of biological control.

Fungicides

In reporting his revolutionary discovery of the antibiotic, penicillin, Sir Alexander Fleming is reputed to have warned the medical profession that misuse of the drug would inevitably lead to the evolution of drug resistance in microbes. Some decades earlier, plant pathologists had begun to report on the ability of pathogens to "fight back". However, it took the rapid emergence of resistance to DDT in the 1940's and the now worldwide observation of antibiotic resistant bacteria as Fleming predicted, combined with the discoveries of the structure and fundamental importance of DNA to attract major research attention to one of the basic realities of host-parasite relations.

The ‘battle’ between the plant breeder and the fungus has gone on for more than a century, but we now understand that it may take a fungus between 5 and 7 years to break a newly introduced host plant resistance. Plant protection against fungi has perhaps been slightly more multi-faceted than human and animal protection against microbial opportunism. There are many commercial fungicides providing effective protection, but it is surprising to me that some of the oldest remedies are still widely used and effective. Bordeaux mixture, a combination of copper sulphate and hydrated lime was first introduced in 1878 and its continued use probably lies in no small part to the non-specific toxic effects of high copper concentrations that can accumulate in the fungus and inhibit initial infection. The second strategy is to use antitranspirants, a group of waxes, silicones and other plastic polymers used on food crops and other ornamental plants to decrease loss of water through stomata (Olkowski et al. 1991), that act by denying access to fungal spore germ tubes when they develop on a leaf surface.

As with most pesticides, timing of application is most effective when it coincides with the sensitive stages of the pest life cycle. Issues of residue have not received a great deal of attention, indeed environmental impact of fungicides appears to be a relatively poorly researched problem. This is surprising to me because a very large number of plants form mutual or symbiotic relationships with fungi and other soil microbes. Hence if substantial amounts of a non degradable fungicide are applied to a crop or to a garden, it is possible that it will kill both the pest and at least some non-target soil fungi. The increasing recognition of the role of mycorrhizal fungi in the healthy lives of many species (some researchers believe that all plants will eventually be found to have some form of interdependence with soil microbes) shows that there is much research required to identify and understand pest-specific fungicides.

The existence of natural fungicides has been implied from simple observations that certain groups of plants seem less prone to fungal disease. The emergence of antibiotic resistant bacteria has led to renewed efforts to identify anti-fungal, anti-bacterial and anti-viral compounds in plants (Anani et al., 2000). In spite of substantial investment by research funding agencies and the pharmaceutical companies, there have been very few compounds whose anti-microbial activity in the test tube has proved to be useful in clinical settings. The complex life histories of many fungi provide an interesting opportunity for their control without fungicidal interventions. This strategy is to remove the obligate secondary host without which the fungus cannot complete its life cycle. The life history of *Puccinia graminis*, the causal agent of wheat rust, can be interrupted by removal of a number of *Berberis* spp., which are its secondary hosts. The same principle has been applied to controlling pear trellis rust (*Gymnosporangium fuscum*), a recent arrival in SW British Columbia, by removal of its secondary host, *Juniperus* spp. This is made difficult for hobby and commercial orchardists because junipers are widely favored for public landscape plantings and municipal parks departments and homeowners seem unaware of the potential problem (BC Ministry of Agriculture and Food, 1998)

Pesticides and the Genetic Engineer

Stated benefits for the development of genetically engineered (GE) herbicide- and pest-resistant crops include claims that such products will lead to massive reduction of chemical control agents, avoid health hazards and enhance environmental protection (McHughen, 2000). The very rapid progress in genetic engineering research and development has been very strongly encouraged by government without proper provision of resources for regulatory agencies to assess impact. Governments in North America have been persuaded by a very powerful industrial lobby that genetically engineered organisms are "substantially equivalent" to organisms that have been produced by the long-standing practices of plant and animal breeders. The academic research community has preferred this interpretation in part because it removes the need for new regulations and controls and thus ensures faster, unimpeded development of engineered organisms as research tools. These factors have contributed at least in part to public distrust of this new science, which in turn has led to a polarization of views that has set researchers against a public that is asking questions but is receiving often patronizing and seriously biased answers.

The arguments in favour of GE herbicide resistant crops are fairly straightforward (see for example, Rissler and Mellon 1996). Weeds are a serious problem for all plant growers. What better solution than to develop plants that are resistant to one or several herbicides by changing the DNA composition of the crop plant? Benefits for the farmer should include improved crop productivity and financial well-being, and give the public access to a safe and 'better' product. Soon after the first releases, researchers working outside government and industry began to raise questions of environmental impact, especially in the medium or long term, and also to study much more closely the claims for product safety. Careful analysis of documents submitted to meet regulatory requirements for environmental impact showed over-emphasis on very short-term effects (Barrett, 1999). Unfortunately, there is an increasing body of evidence, published in peer reviewed journal papers, that some of the experimental and observational studies submitted for regulatory approval do not meet acceptable standards of scientific rigor (Marvier, 2002). Herbicide-resistant weeds have been known for almost a century (Gunsolus, 2002) and hybridization between wild weeds and their GE herbicide resistant, "substantially equivalent" forms is widely documented.

The advent of genetic engineering using the insecticidal protein from *Bacillus thuringiensis* (Bt) has certainly had considerable positive impact on insect control in major agricultural crops. However, there are reports of damage to pollinators and other non-target species. One horticulturally relevant, but extremely controversial report by Ewan and Pusztai (1999), claimed that potato engineered to protect against Colorado beetle using an insecticidal protein caused digestive tract inflammation in some of his test rats. While the research was widely criticized because of methodological inadequacies, it raises the important ethical issue of whether or not anecdotal research reports of harm should be made public. Gardeners may gain substantial benefits from growing GE crops, but there must be full disclosure, even of preliminary information, especially when there is potential for harm. Precaution dictates that an observation of apparent harm arising from any control method must be explained by reexamination to confirm or find error.

Towards an Overall Strategy to Control Unwanted or Harmful Agents

Integrated Pest Management (IPM) has emerged in the last 30 years as a scientific, economical and environmentally responsible approach to control the horticulturist's unwanted or harmful agents. The decision that an agent is "unwanted" is being challenged and greater emphasis is being placed on the reality or otherwise of "harm". Control using natural biological predators of the pest seems to be a truly "green" approach to the problem, and many cases are well documented (see for example Woo et al. 2002). However, before embarking on a biological control programme, it is important to understand the complexity of a system, which is not currently controlled naturally, as is the case when a pest has arrived in a previously unoccupied region without its natural predator. The pest may not be recognized until it reaches population levels that disrupt the ecosystem. Such is the case in the emergence of *Lythrum salicaria* (purple loosestrife) from a garden introduction to a continent-wide invasive in North America. There are now active attempts at biological control using the European native beetles, *Galerucella calmariensis* and *G. pusilla* (Woo et al., 2002). Small IPM projects may be suitable for the small gardener, for example the use of *Adalia punctata* (convergent ladybird beetle) to control aphids and related species.

The existence of natural microbe biocontrol in the rhizosphere has been known for decades. Fernando et al. (2003) presented a preliminary report of volatile antifungal compounds that are produced by rhizosphere and soil bacteria and have 100% inhibitory effects on, for example, *Sclerotinia sclerotiorum* strains that attack canola. Opportunities to develop microbe-based biological pest control have emerged with relatively recent discoveries of microbe-microbe parasitism. High resolution microscopy and DNA analysis have proved to be essential tools in this research, and have been very important in the discovery and development useful microbial fungicides. Taylor et al. (2003) investigated the potential of *Stachybotrys elegans*, a destructive mycoparasite for biocontrol of the black scurf of potato, *Rhizoctonia solani*. These studies suggest the potential for a more effective approach to control of fungal disease than current reliance on chemical sprays, which are persistent problems for agriculturists and gardeners alike.

A logical development for plant pathologists is to adopt some of the strategies that have driven GE efforts to protect plants against herbicides and insect pests. Knapp et al. (2001) have established that a protein gene product in an African frog is toxic to *Phytophthora cinnamomi*, the causal agent of rhododendron root rot. Their strategy is to genetically engineer the gene into the rhododendron and create a stable, but fungus resistant strain. As with all such work, the idea and the first results are a very long way from an approved product that can be released into commercial production, but this and other strategies show that there are new ways by which horticulturists may be able to gain a little more control of pest organisms. However, there is no evidence that the pests will not fight back with new tools for better pathogen action!

Plant Introductions

Many horticulturists are drawn to the prospect of growing a previously uncultivated plant or to develop such plants for others to grow, but developing new material remains a long and risky business. Observations of natural diversity in field or nursery, followed by germplasm collection start the processes that will establish the stability of the desired character's genetic control. Seed collection is preferred, because it is relatively non-destructive, but natural diversity makes it unlikely that seed from an attractive specimen will show consistent expression of the desired trait. Direct transplantation, especially of endangered species, from the wild is no longer considered acceptable because, even in expert hands, the survival rates are very low. Clonal transfer may be the only option for woody species.

Movement of plants across international borders is now strictly regulated for both quarantine and conservation reasons. Several regional, national and international agreements exist that regulate whole plant and seed collection and transfer across ecological and political boundaries. The Convention for Biodiversity (CBD) provides a clear framework to direct international transfers of germplasm that recognizes the rights of signatory states to regulate the transfer of the genetic resources. Rare and endangered species are regulated with greater or lesser effect by national laws. The announcement of the establishment of the Genetic Resources Policy Initiative (GRPI, 2003) points out that the political morass surrounding germplasm collections, exchange, conservation and research is undermining critical agricultural research. The isolation and unique flora of Australasia has led both the Australian and New Zealand governments to establish quarantine laws and to upgrade them consistently. Richardson (2002) quotes from an article posted on the Australian Quarantine and Inspection Service website. "Imagine surfing the Internet and coming across a great site that offers to mail you the seeds of an exotic plant that would look just fabulous in your garden. You place your order without realizing that you might have taken the first step in the destruction of Australia's native flora and fauna". Such a case applies equally well to North America. Gone are the days when enthusiastic gardeners can carry home "just a few seeds" from an overseas trip. Invasive exotics occur throughout the world. While many moved in ships' ballast, many also arrived in their new habitat in the suitcase of the horticultural traveler. Although many introductions have remained in cultivation and indeed do not survive long without attention, others have deservedly earned the title of invasive, obnoxious weeds. The case of *Lythrum salicaria* provides a North American example of what may be called an environmental time bomb. It spread in the United States soon after its introduction in ships' ballast in 1843 (Woo et al, 2002), although there are reports from Ontario suggesting that it was introduced for horticulture and did not begin its migration to western Canada until approximately 50 years ago (Ducks Unlimited, 1993). These events seem to have been stimulated by changed levels of environmental disturbance, particularly ditching along highways, increased fertilizer run-off from intensive animal husbandry and other farming activities. Its visual attractiveness led to development of several, self sterile ornamental varieties (e.g., Morden Pink, Morden Gleam and Morden Rose), which outcrossed with wild populations and produced long-lasting viable seed.

Almost every regional flora now includes species that are described as 'garden escapes' and we have come realize that some may become serious threats to the native flora. In southwestern British Columbia, we have several escapees, including *Ulex europaeus* (gorse), *Cytisus scoparius* (Scotch broom), *Rubus armeniacus* (blackberry), and *Buddleja davidii* (butterfly bush) to name a few. The mowing and expansion of roadside margins have also created new opportunities for native plants to escape from their normal balanced ecosystem, to become weeds and even to become invasive. What better place to test for unpredicted effects than botanical gardens?

While targeted herbicide application can help on a local level, and the small gardener may be able to eliminate and unwanted plant by diligent weeding, the larger scale control has tested the ingenuity of scientists. The dilemma is unresolved. We seek new and interesting plants for our gardens so must ensure that such introductions have minimum and benign effects on their new environments.

Organic Gardening

For those who grew up in the first half of the 20th century, before the population boom led to the massive and increased demand for food, the discovery of 'organic' agriculture seems ironic. However, since Rachel Carson (Carson, 1962), we recognize that there are serious issues arising from the emergence and current dominance of high-intensity agriculture and horticulture. So-called chemical fertilizers and pesticides have become in many ways essential to achieve the required production, but the worldwide results are decreased soil quality and nutrient depletion (Cohen, 1997).

The increased use of the term "organic gardening" has become synonymous with 'natural' practices, which in turn have become equated with "healthy" practices, which in turn is equated with "safe" and "good". Chemical fertilizers, which usually contain the same chemical constituents found in a healthy soil, and pesticides, which rarely rely on naturally occurring agents, are forbidden and may lead to personal expulsion from an organic gardening club or removal of a certification of organic production.

The widely presumed goals of organic gardening are indeed laudable, but dilemmas arise because human and agricultural societies no longer produce fully recyclable waste. Composted biological waste is increasingly becoming contaminated by the accidental inclusion of residual pharmaceuticals, fossil fuels waste products and other farm and domestic wastes. Once perceived as a truly natural resource, ground water is often polluted by seepage that enters aquifers, which serve regions that may be tens if not hundreds of kilometres distant from the original source. The result of ecological magnification is that nowadays there are high and even dangerous levels of toxic metals, including those that were only present in unpolluted soils at the levels needed to meet plant nutrient requirements (e.g. copper, iron, manganese, molybdenum, nickel, zinc). There is little public awareness of the changing reality of "organic" production. Acid rain produced from acidic gaseous pollutants lowers soil pH by solubilizing aluminum complexes that are potentially toxic to both plants and animals.

The commercial food and ornamental industries recognize major and economically rewarding targets for 'organic' produce. However, modern economies have added many new chemicals to the environment and what our predecessors perceived as natural soils are becoming increasingly polluted with substances which may accumulate in the soil and eventually enter the food chain that leads to the human dinner table. In short, if we are to practice 'organic' gardening, we must understand and take some action to correct the weaknesses in our assumptions that "organic" = healthy = safe = good.

Conclusion

Horticultural realities are changing. Herbicides and pesticides may be persistent and achieve results far beyond the desired or the predicted. Plants taken out of their native environment may take unforeseen opportunities to cause major environmental change. The solution of returning to Nature's way may not be as feasible as we anticipate. Clearly, both large and small-scale horticulturists must learn to be much more questioning and cautious. Society will be well advised to demand caution from professional agriculturists, horticulturists as well as government regulators. If we address the questions, avoid the understandable bias of promoting what is good for our business, and strive to provide much more rigorous prediction and testing, especially for long-term effects of new products and ideas, we should be able to move towards real sustainability in our food and ornamental production.

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